133 Molesworth Street
PO Box 5013
Wellington 6140
New Zealand
T+64 4 496 2000

5 April 2022

[redacted]

By email: [redacted]
Ref: H202203766

Tēnā koe [redacted]

Response to your request for official information

Thank you for your request under the Official Information Act 1982 (the Act) transferred from Taumata Arowai to the Ministry of Health (the Ministry) on 10 March 2022 for:

> *"the statistics and information on the public health impact of poor drinking water on NZ communities for the past 5 years."*

You can find a significant amount of information publicly available on the websites below.

Annual drinking water quality reports:

- www.health.govt.nz/publications?f%5B0%5D=im_field_category%3A39&f%5B1%5D=im_field_category%3A81#find-by-region.

Environmental Health Indicators:

- www.ehinz.ac.nz/indicators/water/.
- www.ehinz.ac.nz/indicators/water/drinking-water-quality/water-borne-diseases-related-to-drinking-water/.

Two additional documents have been identified within scope of your request. These are itemised in Appendix 1 to this letter, and copies of the documents are enclosed. Appendix 1 also outlines the grounds under the Act which I have decided to withhold information. Where information is withheld, this is noted in the document itself. I have considered the countervailing public interest in release in making this decision and consider that it does not outweigh the need to withhold at this time.

I trust this information fulfils your request. Under section 28(3) of the Act, you have the right to ask the Ombudsman to review any decisions made under this request. The Ombudsman may be contacted by email at: info@ombudsman.parliament.nz or by calling 0800 802 602.

Please note that this response, with your personal details removed, may be published on the Ministry website at: www.health.govt.nz/about-ministry/information-releases/responses-official-information-act-requests.

Nāku noa, nā

D Woodley

Deborah Woodley
Deputy Director-General
Population Health and Prevention

Appendix 1: List of documents for release

#	Date	Title	Decision on release
1	27 June 2019	Capability of Drinking-Water Suppliers in New Zealand.	Released with some information withheld under section 9(2)(a) of the Act to protect the privacy of natural persons.
2	N/A	Re-Assessment of the Risks of Protozoa in New Zealand's Natural Waters.	

Document 1

Beca

Capability of Drinking-Water Suppliers in New Zealand

Review to Aid in the Development of New Regulatory Framework for Drinking-Water

Prepared for Ministry of Health
Prepared by Beca Limited

27 June 2019

Creative people together transforming our world

Contents

Revision History

Revision Nº	Prepared By	Description	Date
A	s 9(2)(a) [redacted]	For Ministry review	13 February 2019
B		Updated following Ministry comment	25 February 2019
C		Updated to reflect Stage 2 findings	14 May 2019
D		Updated to include additional costing information	27 June 2019

Document Acceptance

Action	Name	Signed	Date
Prepared by	s 9(2)(a) [redacted]		27 June 2019
Reviewed by			27 June 2019
Approved by			27 June 2019
on behalf of	Beca Limited		

Executive Summary

The Ministry of Health (the Ministry) commissioned Beca Ltd (Beca) to a carry out a qualitative systematic review of current drinking-water suppliers' capability as part of the Drinking Water Programme. This piece of work will aid in the development of the new regulatory framework for drinking-water. The Ministry are interested in reviewing the capability of self-suppliers as well as networked suppliers.

The three key research questions identified by the Ministry are:

1. What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?

2. What is the relative capability of current drinking water suppliers to provide demonstrably safe drinking water? Where are the gaps?

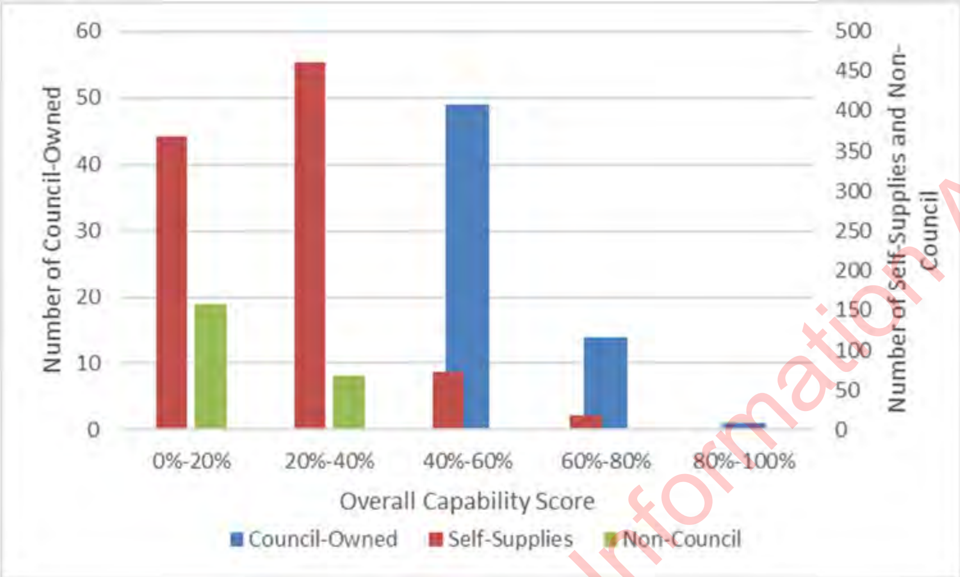
3. What is the capability of suppliers in areas of high tourist use to cope with tourist-driven peaks in demand?

To answer these questions, a literature review of a number of publicly available resources was carried out with the aim of answering the three questions. This literature review led into the development of the capability category framework and capability measures shown in the table below.

No.	Capability	Sub-Capability
1	**Governance**	
1.1		Governance
2	**Management**	
2.1		Management Capability
2.2		Future Planning
2.3		Organisational Culture
2.4		Staff Training
3	**Financial Capability**	
3.1		Financial Management
3.2		Procurement Capability
4	**Technical Capability**	
4.1		Water Supply Technical Capability
4.2		Range of Technical Capability
5	**Systems**	
5.1		Risk and Compliance
5.2		Asset Management
5.3		Quality

A very high-level categorisation of New Zealand's council-controlled drinking-water suppliers (65 in number) was carried out using judgement calls based on the Beca team's existing knowledge of the suppliers and the data available in the National Performance Review (Water New Zealand, 2017). This assessment is aimed at providing the Ministry with an early indication of the existing capability range. It does not identify individual supplier's scores. As the Beca team involved has not worked with every New Zealand supplier, and does not have a complete knowledge of each organisation, further work to confirm this categorisation is recommended.

A rating for each council-controlled drinking-water supplier was identified and then the capability weighting was applied. This resulted in a total score from 0 – 100% for each supply with 100% being the highest possible level of capability. The graph below summarises the results. This shows that most council suppliers have an overall score of 40-60% with some achieving higher percentages. A rough assessment of the number of self-supplies and non-council supplies in each category was also carried out. As the figure shows, there are a much greater number of self-supplies and non-council supplies than council-owned supplies, and they are likely to have lower capability.



To answer key question number 3, an analysis of tourist numbers and the capability of the supplier for each destination was carried out. Tourism New Zealand and Statistics New Zealand data were used to compile a list of 52 towns with high levels of tourism. There is no record of town drinking-water supplies for ten of these towns and so it is likely that consumers use self supplies for which there is no list. The costing database established for the 2018 DIA report titled *Cost Estimates for Upgrading Water Treatment Plants to Meet Potential Changes to the New Zealand Drinking Water Standards* was used to estimate the cost of upgrading the known supplies to meet the DWSNZ. A summary of the results is shown in the table below. An assessment of the capability of the suppliers for high tourism drinking-water supplies showed that they had similar capability to other suppliers but a lower rate of DWSNZ compliance. This may be related to the relatively low permanent population that provides funding.

As shown in the figure above, non-council and self-supplies are likely to have a much lower capability than council-owned supplies. For this reason, the Ministry was interested in understanding what it would cost to upgrade these supplies to meet the DWSNZ, to transfer ownership of non-council networked supplies to councils and to outsource operations and maintenance of specified self-supplies. The table below shows the costs associated with bringing supplies up to the DWSNZ.

Rural supplies are also of particular interest to the Ministry. A list of 81 rural supplies was compiled and only 6-9% of these are fully compliant. Many of these schemes were built in the 50s, 60s and 70s with partial funding from the Ministry of Works. Treatment was generally limited at the time and many have not been upgraded with adequate treatment to provide reliable compliance. The costing database for the 2018 DIA study was also used to estimate the cost of upgrading these rural supplies. The results are shown in the table below.

For supplies serving areas of high tourism and rural supplies, it is likely that an additional $1 to $2 million would be required per small plant which means that the total costs could be significantly higher, as shown in the table. However, this is unlikely to cover all of the required costs for the upgrade. For non-council networked supplies and self-supplies, a similar additional capital allowance has been included as per the 2019 DIA study to allow for greenfield type developments for a more representative value of the true cost.

Parameter	Estimate of Probable Capital Cost using 2019 DIA Study (±30%)	Estimate of Probable Capital Cost including allowance for small supplies or greenfield type site developments (±30%)
Supplies serving areas of high tourism	$64 million	$81 – 98 million
Non-council networked supplies serving > 500 people	$5 million	$98 million
Non-council networked supplies serving 25 - 500 people	$47 million	$210 million
Non-council networked supplies serving < 25 people**	$32 – $210 million	$50 – 300 million
Specified self-supplies	$81 – 150 million	$130 – 200 million
Self-supplies**	$856 – $1,360 million	N/A
Rural supplies	$25 million*	$85 – 150 million

*using 2018 DIA Cost Database.

**these estimates are likely to be accurate to +30% rather than ±30%

If the Ministry would like to gain a better understanding of the cost of compliance, then the it is recommended that a pilot study is carried out. This could include assessment of the actual requirements (drinking-water upgrades and any enabling works) for a selection of water supplies in varying capacity and condition categories. These assessments could be used to improve the cost estimates of these schemes, and then used to benchmark the estimates completed to date.

1 Introduction

1.1 Background

In August 2016 the town of Havelock North had an outbreak of gastroenteritis because of contamination in their drinking-water supply. This outbreak resulted in a two-stage government inquiry into the cause of the outbreak and the lessons to be learned from it. Stage 2 of this inquiry included four recommendations relating to the establishment of a drinking water regulator.

The Ministry of Health (the Ministry) commissioned Beca Ltd (Beca) to a carry out a qualitative systematic review of current drinking-water suppliers' capability as part of the Drinking Water Programme. This piece of work will aid in the development of the new regulatory framework for drinking-water. The Ministry are interested in reviewing the capability of self-suppliers as well as networked suppliers.

The three key research questions identified by the Ministry are:

1. What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?

2. What is the relative capability of current drinking water suppliers to provide demonstrably safe drinking water? Where are the gaps?

3. What is the capability of suppliers in areas of high tourist use to cope with tourist-driven peaks in demand?

1.2 Scope

The purpose of this report is to answer the three key questions based on previously published literature. This work has been broken down into two stages, both of which are summarised in this report.

The scope of Beca's commission for Stage 1 included:

- A literature review to assist in answering the three key questions
- Compiling measures of capability that best capture the Ministry's broad definition of capability, and that can be extracted from the material reviewed to give the widest possible coverage of suppliers
- Development of capability categories that the capability measures feed into using a weighted attribute method
- A very high-level categorisation of New Zealand's drinking-water supplies into the categories of capability
- A very high-level assessment of the capability of water suppliers serving the most popular tourist areas.

The scope of Beca's commission for Stage 2 included four topics:

- Further investigation into the capability of water suppliers servicing the most popular tourist areas
- Non-Council supplies' shortcomings and the cost of upgrade
- Rural Supplies' shortcomings and the cost of upgrade
- Areas of weakness and improvements for all supply types

2 Methodology

2.1 Overview

This study consists of a literature review to answer the three key questions, the development of capability categories and measures, and a high level categorisation of New Zealand's drinking-water supplies into these categories.

The literature review to help inform what good capability in drinking-water suppliers looks like (i.e. to answer key question 1) drew on the following resources:

- *Managing the Supply of and Demand for Drinking Water* by Controller and Auditor-General
- *Local Government: Results of the 2016/17 Audits* by Controller and Auditor-General
- *Asset Management and Long-Term Planning: Learning from Audit Findings 2015 to 2017* by Audit NZ
- Havelock North Inquiry reports (Stages 1 and 2)
- *Three Waters Asset Management Maturity in New Zealand* by Castalia
- *Three Waters Review* by MartinJenkins
- *Cost Estimates for Upgrading Water Treatment Plant to Meet Potential Changes to DWSNZ* by Beca
- *National Performance Review 2016-2017* by Water New Zealand
- *Annual Report on Drinking-Water Quality 2016-2017* by The Ministry of Health
- *Building a Strong Local Government for New Zealand* by Local Government New Zealand
- *Non-Financial Performance Measures Rules 2013* by Department of Internal Affairs

A brief description of these resources aims, methodologies and their main findings are given in Section 2.2 to 2.12.

Note that inclusion of Consumer New Zealand reviews of Local Government performance was also included in the proposal, however no applicable reports were found on their website. Regardless, the Local Government New Zealand resource covers a survey of consumers.

2.2 Managing the Supply of and Demand for Drinking Water by Controller and Auditor-General

This report summarised an audit of three district councils (Horowhenua District Council, Kāpiti Coast District Council, and Manawatu Dist ict Council) and one city council (Palmerston North City Council) that aimed to gain a better understanding of the challenges faced in supplying drinking water to their communities. The focus of the audit was on reliable and sustainable drinking water rather than the quality of the water. It was found that some things had been done well and that other aspects could be improved.

All four counc ls audited noted challenges in their industry including funding constraints. As there is no national framework requiring a certain level of service for the supply of drinking-water, councils are responding in the way that they consider to be "prudent and responsible". One council that was audited was using a demand reduction framework to supply drinking-water while others were using more traditional supply management approaches.

All four councils had planned how they will respond to increasing demand for water from a growing population. They also all have planned to renew assets and improve network resilience to seismic events and drought.

The report concluded that each council has different priorities and that those councils best equipped to respond to future challenges in the supply of and demand for drinking-water are those that have "a broad range of objectives for providing drinking water and a greater balance between supply and demand management tools." It was found that there has been less emphasis on leak reduction and water conservation when water supplies are considered plentiful and that although this may be satisfactory in the short/medium term, there is a risk that it may limit councils' ability to plan in the future. A lack of future planning may mean that more reactive solutions are required and these can come at a higher operational and renewal cost.

Table 2-1: Managing the Supply of and Demand for Drinking Water by Controller and Auditor-General Key Question 1 Response

No.	Key Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• Need to have a broad range of objectives for providing drinking water and a greater balance between supply and demand management tools • Planning for future requirements is required to make sure that more cost effective solutions are applied rather than requiring councils to react quickly

2.3 Local Government: Results of the 2016/17 Audits by Controller and Auditor-General

The Controller and Auditor-General carries out an annual audit of local government and reports the findings. The 2016/17 audit covers financial results and trends, timeliness of annual reporting, an update on issues identified in the previous audit report, issues with rates, severance payment and remuneration disclosures, local authorities (members' interests) Act 1968, and the Controller and Auditor-General's work in local government. The opening statement in the audit is that "some of our findings are recurring, which is of concern."

Of these concerns, the ones with relevance to drinking-water supply are:

- An apparent lack of investment to ensure ongoing delivery of services
- Relevant and reliable asset information is a challenge and this affects the ability for elected members to make good decisions about when to spend money on assets
- Both the revenue and debt of local authorities is increasing which requires forward planning to make sure that the debt can be serviced
- The earthquake related issues seen in the 2016-2017 period serve as a reminder as to how dramatic, disruptive and expensive these events can be and that local authorities need to plan for and try to mitigate the risks associated with natural disaster

Table 2-2: Local Government: Results of the 2016/17 Audits by Controller and Auditor-General Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• Suppliers should have the ability to manage budget commitments and to invest in assets • Need for relevant and reliable asset information, and the ability to communicate this at a governance level • Suppliers should be able to respond well to emergency situations • Investment in governance arrangements, and operational and risk assessment plans, must occur

2.4 Asset Management and Long-Term Planning: Learning from Audit Findings 2015 to 2017 by Audit NZ

This audit was carried out to provide public sector organisations that manage significant infrastructure with a resource. It aims to foster further improvement of asset management in the public sector by sharing views and examples. The report is of particular relevance to asset managers and those responsible for asset-related decisions including governance.

The report states that "good asset management makes an essential contribution to the governance and management of a public entity's business, and is an integral part of an organisation's wider service and financial planning process."

Figure 2-1 summarises recent asset management risk ratings and shows the differences between organisation types. This demonstrates that management approach needs to match the complexity and the importance of the task and that the local government sector has a relatively high inherent risk. In this context, inherent risk is most significantly influenced by the value of the assets and the criticality of them. It is worth noting that there are a number of self-supplies throughout New Zealand that are run by health and tertiary organisations. Because water supply is not core business for these organisations, these organisations may not have the asset management systems and long term planning in place for their water supplies that would be seen in good local government practice.

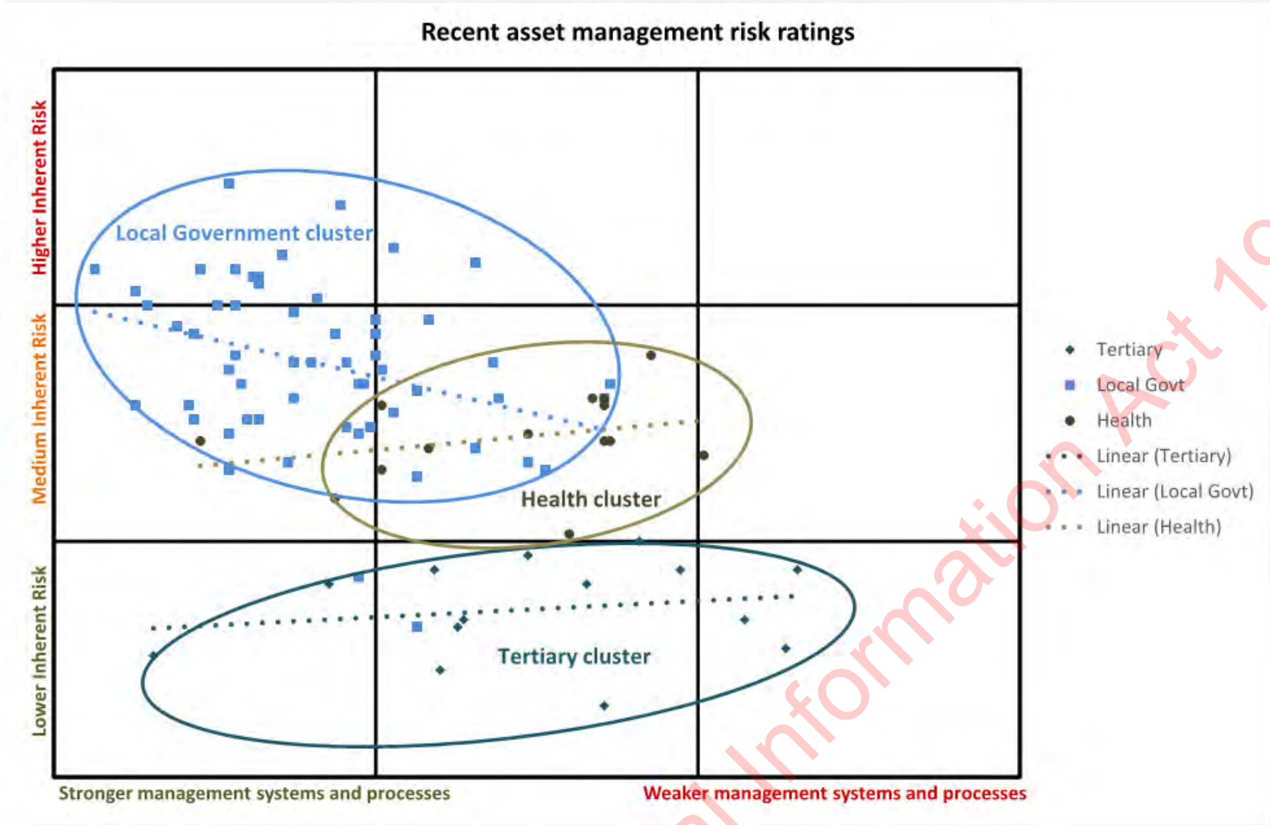


Figure 2-1: Comparison of Inherent and Management-Related Risk for different Organisation Types (Audit NZ, 2017)

Figure 2-2 summarises recent asset management risk ratings showing the difference between councils of different sizes. Generally, city councils face the highest levels of inherent risk and regional councils have lower. It is interesting to note the large variability within each council cluster.

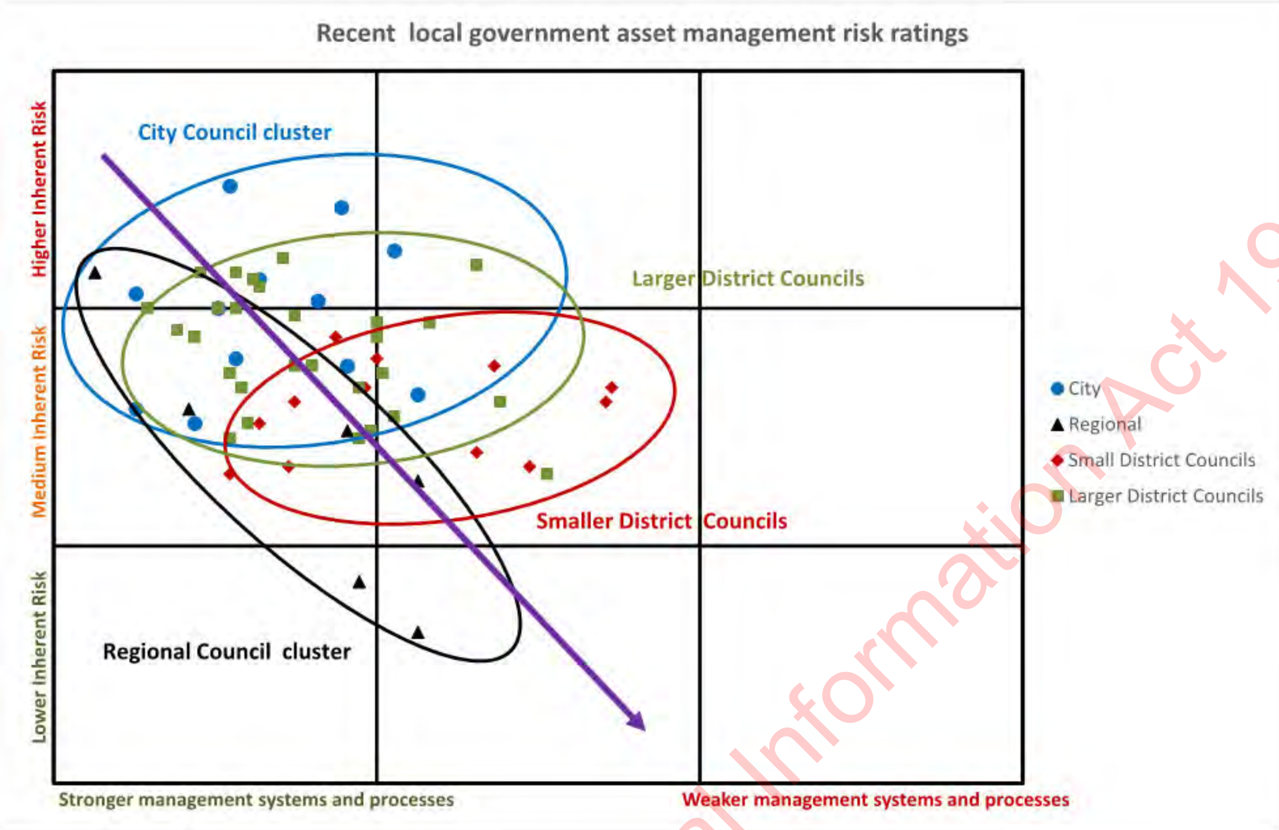


Figure 2-2: Comparison of Inherent and Management-Related Risks for Councils of different Sizes (Audit NZ, 2017)

The report offered eight key messages for asset managers:

- Learn from others i.e. read and learn from the findings of the report
- Asset management systems should be informed by risk and there is greater scope for organisations to learn from each other on how best to do this
- Planning should be based on strategic and operational factors and should be based on reliable asset information and good quality analysis
- Infrastructure Strategies and strategic asset management plans have resulted in a rapid improvement in the way that planning is documented
- Co-ordination within different discipline of a single organisation, and between neighbouring entities, offers a potential solution for overcoming a storage of expertise
- Good quality data s required for effective planning as it allows for informed analysis of risk and facilitates forecasting
- Smaller entities have added challenges and might see improvements by ensuring policies are clear, governing bodies are well informed, learning from peer reviews and maintaining data with a more structured approach
- Asset management planning is more than a box ticking exercise, it is important to produce concise, consistent and timely documents

Table 2-3: Asset Management and Long-Term Planning: Learning from Audit Findings 2015 to 2017 by Audit NZ Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• Good capability includes learning from others and working with other organisations • Working with other organisations and departments also offers a potential solution to skills shortages • Planning should be based on strategic and operational factors, reliable asset information, and good quality analysis • The International Standard ISO 55000 and International Infrastructure Management Manual (IIMM) are recommended for guidance

2.5 Havelock North Inquiry Reports (Stages 1 and 2)

The August 2016 drinking-water contamination report in Havelock North resulted in a government inquiry that was split into two stages. The Stage 1 Inquiry (Government Inquiry into Havelock North Drinking Water, May 2017) addressed matters relating to the campylobacteriosis outbreak in August 2016, while the Stage 2 Inquiry (Government Inquiry into Havelock North Drinking Water, December 2017) was focused on systemic issues, lessons to be learned and recommendations for future improvements.

The structure of the Stage 1 Inquiry document includes an overview of the events and issues preceding the outbreak, and the outbreak events and response. The aim of the Inquiry was to "inquire into how the Havelock North water supply system became contaminated, how this was subsequently addressed, how local and central government agencies responded to the public health outbreak that occurred as a result of the contamination and how to reduce the risk of outbreaks of this nature recurring."

The Inquiry included public hearings to allow evidence on potentially contentious matters to be called and tested. Independent expert advice was also drawn on. The stage of the Inquiry did not make recommendations, however the information gathered was used to inform Stage 2 of the Inquiry.

The Inquiry refers to an Independent Capacity and Capability Review that was commissioned by Hastings District Council. This document has not been able to be located on the Inquiry website, however it may provide some valuable insights into best practice for capacity and capability.

Also, of significance is the submissions supporting the concept of dedicated drinking-water suppliers. The Inquiry stated that these submissions referred to economies of scale, focused attention on a single service reducing expenditure conflicts and increased accountability. This results in benefits to water suppliers capabilities such as the ability to attract and retain qualified staff, greater access to expert advice, more rigorous risk management systems, quality assurance, the ability to secure long term funding and to carry out planning.

It was also found that larger suppliers have the resources to plan proactively and strategically rather than just being reactive. They also have the ability to provide staff with training, have good quality assurance measures, greater access to technical resources, and have more sophisticated risk management programmes including buffers against emergencies, breakdowns and staffing issues. Also of significance is the ability to apply adequate resources to small and remote communities because of cost-sharing.

The Inquiry noted that a lack of accountability underlies the current poor compliance with the Drinking-Water Standards New Zealand 2005 (revised 2008) (DWSNZ). Accountability in a limited liability company is likely to be more direct, transparent and effective. It was concluded that political accountability by elected councillors is ineffective.

The key feature of the Stage 2 document was a list of 51 recommendations to substantially improve the safety of drink-water in Havelock-North and throughout New Zealand to prevent a future outbreak of waterborne illness. The Stage 2 Inquiry identified that the problems identified during the Stage 1 Inquiry specifically related to Havelock North were also identified in other parts of New Zealand.

Table 2-4: Havelock North Inquiry Reports (Stages 1 and 2) Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• Good capability includes the ability to attract and retain qualified staff, access to expert advice, rigorous risk management systems, quality assurance, the ability to secure long term funding and to carry out planning • Suppliers should plan rather than being purely reactive, provide training and have more sophisticated risk management programmes • Managers should be held accountable, there should be transparency and traceability

2.6 Three Waters Asset Management Maturity in NZ by Castalia

This review was commissioned by The Department of Internal Affairs (DIA) to investigate the current asset management practices in three waters local councils and other water service providers. The review included development of a framework and evaluation of service providers against the framework through use of research and interviews. The aim was to answer two key questions:

- "How well is asset management (AM) of three waters services performance in New Zealand, and what is the variation across the country?
- How does this compare with the quality of AM in other infrastructure fields?"

Service providers were assessed through interviews of asset managers, engineers and environmental managers, reviews of publicly available asset management plans and further interviews with representatives from relevant organisations such as Engineering New Zealand, Water New Zealand, the Institute of Public Works Engineering Australasia, Local Government New Zealand and the Office of the Auditor General.

The review considered the difference between the size/scale of three waters service providers. It was found that service providers with more advanced asset management systems were large and urban and that these organisations have big specialist teams made up of formally qualified engineers. Larger teams allows there to be economies of scale in terms of asset management system improvement and larger organisations are also more likely to be able to attract talent. It was also found that larger organisation are able to look beyond the immediate challenges and issue and can do strategic planning including research into new technology and advancing innovation practices.

This study did find that asset management in the three waters sector is less mature than other infrastructure sectors including New Zealand's energy sector and roading sector and the water sectors in Australia and

Scotland. Reasons for this included greater scale, higher level of regulation, greater public visibility and funding incentives.

Table 2-5: Three Waters Asset Management Maturity in NZ by Castalia Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• Elected member and executive team make strategic trade-offs that are informed from the asset management team • Other council departments consider 3 waters assets in day-to-day decision making • There is asset management framework, policy, strategy and plans • Good understanding of level of service, future demand forecasts, critical assets, life-cycles • Use of sophisticated analytical techniques, mature asset management plans and effective asset management team structures • Confidence in service delivery models

2.7 Three Waters Review by MartinJenkins

Martin, Jenkins & Associates Limited (MartinJenkins) prepared a report for the DIA titled "Three Waters Review" (2017). This review investigated long-term improvements to three waters with a focus on financial incentives, asset management practices, and compliance and monitoring. The aim was to "provide an evidence-based assessment of the current practices, and identify good practices and potential opportunities for systemic improvements." This study did not consider self-suppliers however the results will be of relevance to them.

This review included a desktop analysis of available reports, development of a governance framework to establish what good governance should look like, face-to-face interviews of elected members and senior officials within a cross-section of councils and council-controlled organisations and a workshop with Zone 2 Local Government New Zealand members.

A key feature of this piece of work was the development of, and measurement against, a governance framework. This is summarised in Figure 2-3. This framework was the basis for the face-to-face interview questions and was used to assess the adequacy of governance. Note that the characteristics of good governance defined in this framework have also been used in the capability framework defined in Section 4.1.

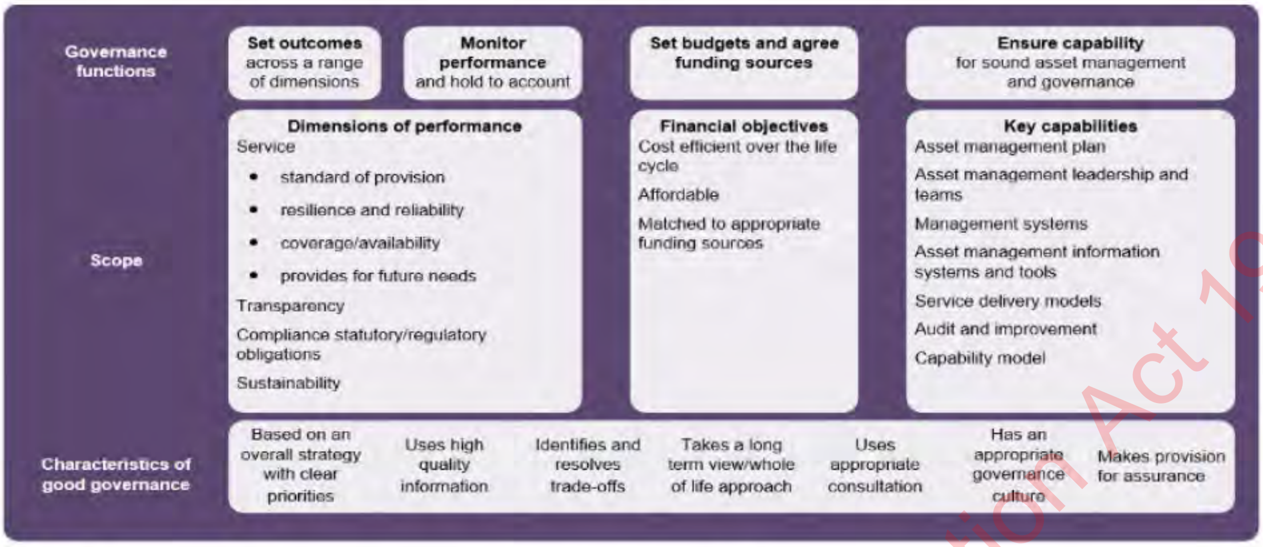


Figure 2-3: Governance Framework as developed by MartinJenkins (2017)

This review considered three different governance structures:

- **"Council elected member governance:** In most of the country, councils manage water services directly, using the elected member governance model.
- **Asset-owning council-controlled organisation:** In Auckland a council-controlled organisation, Watercare, wholly owns Auckland's potable and wastewater assets for a single (Auckland) council.
- **Asset-managing council-controlled organisation:** In the Wellington region a council-controlled organisation, Wellington Water, manages but does not own the three waters assets of multiple councils."

MartinJenkins stated that "the governance implications for these types vary in nature but not significance." This study included further comparison of the three different governance structures however this has not been summarised here as it is not closely related to the overall objective of aiding in the development of the new regulatory framework. The study concluded that council-controlled organisation models with scale provide the opportunity for a substantial improvement in the performance of water asset governance.

In general, the study found that elected members did not have a consistently clear and comprehensive understanding of 'good' water asset management and 'good' governance of water assets. The study found that this understanding has increased as a result of the Havelock North contamination but that there is inadequate assurance that this will continue where systemic changes have not been made. Councillors are elected based on their ability to represent the community rather than their governance skills. Council controlled organisations can provide a benefit as governance can be provided by council appointment officials.

Table 2-6: Three Waters Review by MartinJenkins Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• Good governance skills and expertise based on the framework developed (Figure 2-3) • Good governance also includes clear roles and responsibilities, periodic review of the effectiveness, governance workload planning, effective meetings of governance and provides assurance including drawing on third-party advice as required

2.8 Cost Estimates for Upgrading Water Treatment Plant to Meet Potential Changes to DWSNZ" by Beca

Beca prepared a high-level cost estimate for the DIA for implementing two of the recommendations of the Havelock North Stage 2 Inquiry as summarised in Section 2.4. These recommendations were:

- Removal of the "all practicable steps" clauses in the Health Act, making compliance with the drinking water standards mandatory (Scenario 1)
- Abolition of the secure groundwater classification system (Scenario 2)

The estimates were intended to give an indication of the likely increase in capital and operational cost to water suppliers for the purposes of informing the Ministers around potential DWSNZ changes.

This analysis included all networked supplies – both council owned and non-council owned but excluded self-supplies. The analysis only included upgrades associated with the two recommendations above and did not include allowances for other upgrades that may be required such as capacity upgrades.

When this cost estimate was completed there were nearly 800 register networked water treatment plants in New Zealand, so it was not practical to prepare an individual estimate for each. Instead water treatment plants were categorised based on their size, compliance status and source water quality. For each category a set of existing treatment processes, and corresponding required upgrades to meet the drinking water standards, was assumed. A model was then developed to provide a cost estimate for a particular treatment process to be generated based on the population served by a water treatment plant. The outputs from the cost model for each treatment component for a particular size of water treatment plant (medium, small etc.) were amalgamated to generate capital and operating cost estimates for each water treatment plant category. Larger water treatment plants were considered on an individual basis.

Compliance data was provided by ESR so that compliance for each supply could be assessed yes/no against bacterial, protozoal and chemical standards.

Table 2-7: Cost Estimates for Upgrading Water Treatment Plant to Meet Potential Changes to DWSNZ" by Beca Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• No applicable information identified, cost estimates provide some insight into the relative capability of current drinking water suppliers

2.9 National Performance Review by Water New Zealand

Each year Water New Zealand (Water NZ) carries out a National Performance Review (NPR) of organisations providing three waters services across New Zealand. The aim of the NPR is to identify where challenges and opportunities exist as a starting point for improving service delivery with a focus on the core elements shown in Figure 2-4. This can assist water managers in identifying opportunities for improvement, provide a transparent snapshot of the industry's performance and reduce the number of requests for information that councils receive. Note that drinking-water quality issues are excluded from this review as they are included in the Ministry's Annual Report on Drinking Water Quality.

Figure 2-4: Core Elements of Three Waters Services (Water New Zealand, 2017)

At the time of writing, the 2016/17 report was the most recent and so has been reviewed. There were 44 voluntary participants in the review. The report is split into two volumes; Volume 1 contains a snapshot of the current status of the sector and Volume 2 provides comparative performance information for each of the participants.

Information is gathered by asking participants to manually enter data into a spreadsheet and to provide a confidence level rating for each data item. The report and associated data were peer reviewed by AECOM which involved a second interview of four councils.

A number of key themes relating to water supply, wastewater and stormwater were identified. The four that relate to drinking-water are:

- "The absence of clear guidance is creating inconsistencies in the management of asset condition assessments and climate change management"
  - Assessment of pipelines and above ground assets is common place however the method varies
  - Climate change considerations are generally included in planning documents but detailed projections for future climate conditions are rare and inconsistent when available
- "Actual capital expenditu e trails budgeted expenditure, with participants spending a median of 76% of their budgeted capital
  - A lack of internal resources has been found to be the main barrier in preventing the delivery of programmed capital expenditure
- "The regulatory regime for 3 Waters services could be sharpened"
  - The discussion around this mostly related to wastewater and stormwater but is of relevance to drinking water as well
- There is an ongoing need to improve sector data"
  - The large variation in customer data between organisations suggests that there is a need to improve data collection

Table 2-8: National Performance Review by Water New Zealand Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• High quality data to inform decisions and planning • Consistent and appropriate planning techniques are required • Understanding and implementation of the core elements of three waters (Figure 2-4) • There is a training budget allocated and training development plan for each staff member

2.10 Annual Report on Drinking-Water Quality 2016-2017 by The Ministry of Health

The Ministry prepare an annual review of drinking-water quality for all registered networked drinking-water supplies that served populations of more than 100 people. The report covers compliance with the DWSNZ and the supplies progress towards meeting the requirements of the Health Act 1956, as amended in 2007 (the Act). The report reviewed covered information from 2016 to 2017.

The information used in this report is gathered from Drinking Water Assessors (DWAs), questionnaires that sought data relating to water supply quality, monitoring and management. Two questionnaires were used; the first gather information from registered networked drinking-water supplies serving populations of more than 100 people on the microbiological and chemical quality of the drinking-water, while the second sought information relating to the management of the supplies. The Water Information New Zealand (WINZ) database was also used. Data quality assurance was carried out through the use of integrity checks, peer reviewing and duplicate analyses. The DWAs and water suppliers also reviewed drafts of the zone-level data before publication.

Among other things, the annual review reports back on the compliance with bacteriological, protozoal and chemical standards stated in the DWSNZ. Non-compliance with one of these standards may be due to a lack of treatment, measurement of a sample exceeding the maximum acceptable value for a particular determinand or inadequate sampling. Inadequate sampling may be because of the sampling frequency, the method used or because of ineffective, delayed or unreported remedial action following a transgression.

During the 2016-2017 period, it was found that 81.1 % of New Zealanders received drinking-water that met the bacteriological, protozoal and chemical standards stated in the DWSNZ. This was a small increase (1.1%) from the previous report (2015 to 2016). Compliance with the bacteriological and chemical standards was reasonably high (96.2% and 97.2%, respectively), while compliance with the protozoal standards was lower (83.1%). It is of interest to note that compliance with bacteriological and protozoal standards actually decreased from the previous report (1.4% and 1.2%, respectively). A greater proportion of large suppliers achieved compliance with the DWSNZ than small suppliers.

The majority (97.8%) of the population served from supplies serving more than 500 people, receives water from a water supplier that has at least started to implement a Water Safety Plan.

Table 2-9: Annual Report on Drinking-Water Quality 2016-2017 by The Ministry Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• No capability-specific information identified, but level of non-compliance gives broad indication of levels of capability in industry

2.11 Building a Strong Local Government for New Zealand by Local Government New Zealand

The Building a Strong Local Government for New Zealand report summarises the inaugural study, of what is expected to become an annual study, by Local Government New Zealand. Almost 3,000 citizens and businesses were surveyed in mid-2014 to produce this report. Questions were about the local government sector rather than the individuals specific council. The aim was to understand New Zealanders' perceptions of local government so that focus areas for improvement could be identified.

Six key focus areas were identified:

- "Governance, leadership and strategy
- Financial decision-making and transparency
- Asset management and infrastructure
- Engaging with business
- Communicating and engaging with the public
- Building stronger relationships with central government."

One of the key findings was that the public wants there to be stronger leadership and performance than what is currently perceived. They also believed that communication with the public is a key priority.

A few key and relevant survey results are:

- The majority of the public has a low awareness of the wide range of services that local government offers and the services tend to be under valued
- Local government plays a role in developing the prosperity and wealth in NZ, however there is more than can be done
- Local government performance factors such as financial management and community leadership are viewed as current weaknesses, although local engagement is generally working.

Table 2-10: Building a Strong Local Government for New Zealand by Local Government New Zealand Key Question 1 Response

No.	Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• The six key focus areas identify good capability • The reputation of local government is key and this is often down to managing finances, making prompt and appropriate decisions and delivering value for money • An understanding that economic growth requires investment and spending rather than simply trying to avoid immediate rate increases • Working with communities to solve local issues

2.12 Non-Financial Performance Measures Rules 2013 by DIA

DIA requires local government to report on a list of five Non-Financial Performance Measures relating to water supply. Additional performance measures are included for wastewater and stormwater. The purpose of this is to provide the public with non-financial performance measures to compare level of service.

A document stating the rules for the performance measures was available, but the results of this reporting were not published on DIA's website at the time of writing.

Some councils publish their performance measure results on their website. Wellington Water is one example. This allows customers to see a clear list of where performance measures are met and where there is a need for improvement.

Table 2-11: Non-Financial Performance Measures Rules 2013 by DIA Key Question 1 Response

No.	Key Question	Inputs to Capability from this Source
1	What does good capability look like in a drinking water supplier? What are the skills, knowledge and behaviours needed?	• Measures of good performance include: compliance with DWSNZ for bacteria and protozoa, low percentage of real water loss from the network, low call-out times, low number of customer complaints and demand management.

3 Good Capability

3.1 Introduction

The resources listed in Section 2 were reviewed with a focus on investigating what good capability in a drinking-water supplier looks like and what the current capability is. The follow sections describe the key findings.

It is important to note that assessing and measuring good capability is more complicated than just measuring compliance with the DWSNZ. Compliance with the DWSNZ is an outcome of good capability for water suppliers.

3.2 Governance

High quality governance is a key indicator of good capability of a drinking-water supplier (Local Government New Zealand, 2015). Those in governance roles require a range of skills and experience including commercial, financial, regulatory, engineering, public policy, Iwi interests and project management (MartinJenkins, 2017). They must understand risks and the required mitigation, budgets and community consultation.

As stated in Section 2.7, the Three Waters Review (MartinJenkins, 2017) developed a governance framework. Table 3-1 shows the aspects of governance identified and summarises examples to illustrate good practice. This framework can also be applied to self-supplies even though they were not considered in the Three Waters Review.

Table 3-1: Aspects of governance and examples to illustrate good practice (MartinJenkins, 2017)

Aspects of Governance	Examples of Good Practice
Based on an overall strategy with clear priorities	Use of Long Term Plans and Infrastructure Strategies or other appropriate plans Budget for asset renewals
Uses high-quality information	Able to articulate levels of confidence in information with examples Robust asset management information systems Reporting is received at an appropriate frequency
Identifies and resolves trade-offs	Options and issues are presented to and considered by those in governance Good understanding of trade off and the associated risks
Takes a long-term view / whole-of-life approach	Use of asset management plans to consider the whole life of the asset, not just the next 10 years as is included in the Long Term Plan
Uses appropriate consultation	Appropriate information available for the public and engagement/feedback is encouraged
Has an appropriate governance culture	Clear communication and a good working relationship between governance and management
Makes provision for assurance	Independent reviews of asset management arrangements

Governance for council run drinking-water suppliers is generally provided by elected members, rather than appointed directors, which means that a broad range of perspectives and skill sets may not be captured. Councillors are elected based on their ability to represent the community, rather than governance skills. They do not always have a good understanding of water asset management (MartinJenkins, 2017). The Local Government New Zealand survey (2015) showed that the public believe that more can be done to improve the leadership of mayors and councillors and to develop strategies for developing the prosperity and wellbeing of communities.

In the wake of Havelock North, there has been an increase in the understanding of good governance however there is a fear that the governance level may revert back if Havelock North is forgotten. One mitigation to this is the appointment of an external chair to council Audit and Risk committee to provide some of the necessary expertise. There has been a recent increase in these appointments which is promising. Council controlled organisations have the benefit of being potentially able to receive good governance from council appointed officials (MartinJenkins, 2017).

3.3 Management

3.3.1 Management Capability

One of the key features of management capability is that those in positions of seniority are held accountable and understand their responsibilities. Management should be transparent and traceable, and there should be clear targets and clear levels of responsibility (Government Inquiry into Havelock North Drinking Water, December 2017).

Organisational factors such as complacency or inadequate resourcing are the responsibility of managers to rectify. The Stage 2 Inquiry (December 2017) stated that waterborne disease outbreaks and altered chemical composition often arise following some change in circumstance which could have been brought on by these factors. Managers must be able to recognise when expert advice is required from outside of the team and they need to be able to clearly communicate risk and resourcing requirements to those in governance roles.

As stated in Section 3.2, elected members provide governance in council run drinking-water supplies. This means that management capability is often affected by the drivers at a governance level. The Havelock North Stage 1 Inquiry found that mid-level managers were not adequately supervising tasks delegated. This led to unacceptable delays in the preparation of a Water Safety Plan and this is fundamental in reducing risk. The Inquiry stated that “management and governance fell well short of the standards required for a public drinking water supplier.” The Inquiry also found that a lack of accountability underlies the current poor compliance with the DWSNZ (Government Inquiry into Havelock North Drinking Water, May 2017).

One of the four key challenges identified in the Controller and Audit-General report was staff capability and capacity. It is a manager’s responsibility to hire, retain and train suitable staff. The main issues identified were related to succession planning and recruiting and retaining staff. The councils included in the audit expressed concerns with retiring senior engineers and stated that the existing role may need to be divided into multiple roles thus resulting in an increased cost. Many councils are doing their part to attract new staff to be trained on the job however it is not clear whether enough is being done to account for the aging workforce (Controller and Auditor-General, 2018). It was also found that a lack of resources has meant that programmed capital expenditure is not being fully spent (Water New Zealand, 2017)

3.3.2 Future Planning

Planning for the future is an important capability as it allows budgets to be set aside, consultation to be carried out and initial planning and investigations to be completed. Under the Local Government Act 2002, councils are required to prepare Annual Plans, Long Term Plans and Thirty Year Infrastructure Plans. They are also required to consult with the community before finalising these documents. Therefore, our understanding is that all council run water supplies have at least these plans in place for the future.

However, the level of reliability surrounding these plans may differ. Plans may simply be based on best guesses from asset managers, or they could be informed by a robust analysis of existing assets, possible changes affecting assets, improvements in level of service and customer feedback. Consideration should be given to the effects of climate change, reduced water availability compared to demand (Controller and Auditor-General, 2018) and other possible changes even if they are not in the immediate future.

Infrastructure investment should be planned in advance rather than constructed in response to the need to solve a problem quickly. If solutions are reactive, then there is a risk that water suppliers put in place solutions that address short-term concerns in a way that may not meet long term interests. These solutions may be more expensive in terms of capital and operational costs, and they may limit what can be done in the future. Scenario planning is required to deal with the uncertainties in planning assumptions and to communicate these to the public (Controller and Audit-General, 2018).

New legislation has introduced mandatory requirements for planning, including for asset management and reporting and these plans have resulted in rapid improvement in the way that planning is documented (Audit NZ, 2017). Councils included in the Controller and Audit-General report stated that funding was easier to obtain for compliance activities rather than discretionary activities. Elected members have an incentive to keep rates low and this often drives a tendency to minimise spending. However, because many drinking-water assets can last longer than 30 years, infrastructure strategies only produced to the minimum required level may not show when assets are theoretically due for renewal (Controller and Auditor-General, 2018).

Of the four councils audited in as part of the *Managing the Supply of and Demand for Drinking Water* report (Controller and Auditor-General, 2018), all had planned how they will respond to increasing demand, renew assets and improve network resilience to seismic events and drought. However, it was also noted that water supply is plentiful in many parts of New Zealand and so there has been less emphasis on leak reduction and water conservation.

Unless there is limited access to water, there are weak incentives for councils to prioritise water efficiency or water conservation (Controller and Auditor-General, 2018). Activities such as leak detection and repair, increasing pipe renewals, and reducing water pressures to reduce the risk of burst pipes require significant capital investment which is not available due to other funding priorities. The effects of this are likely to become more apparent as we see the effects of climate change. Kāpiti Coast District Council is an exception to this. In the late 1990s and early 2000s, the council exceeded its assigned water take and received abatement notices. In response, the council prepared a comprehensive water strategy of investigations, research, and intermediary measures to optimise the supply. This took 15 years which shows that councils need to be planning for changes even if they seem to be a long time away (Controller and Auditor-General, 2018).

We consider that it is likely that many non-council networked supplies and self-supplies do not have plans in place for the futu e of their water supplies. Most of these supplies belong to small organisations and small businesses Even those that are part of a larger umbrella sector, like schools and health providers, are unlikely to have comprehensive future plans. Future planning of assets is typically not part of their normal business operations, and they are unlikely to have an appropriate understanding of best practice in the water industry.

3.3.3 Organisational Culture

An organisation's culture reflects its values, all the way from its governance through its management and into its staff and contractors. This includes things like its understanding of standard of care, the level of collaboration between departments and related organisations, and the importance of health and safety.

The importance of applying a very high standard of care was one of the overarching findings of the Stage 2 Inquiry (Government Inquiry into Havelock North Drinking Water, December 2017). The risks to public health from unsafe drinking-water justify the application of the highest standard of care. A contamination outbreak can cause sickness and suffering as well as substantial financial consequences and disruptions to schools, hospitals and other workplaces/facilities. Very high standards of care are seen for providers of services that can make people sick or injure or kill them (for example, surgeons, pilots or operators of dangerous machinery and food processing equipment) and the same should be seen in the supply of drinking-water. The Inquiry found that there is a "widespread systemic failure among water suppliers to meet the high standards required for the supply of safe drinking water to the public." The Stage 2 Inquiry stated that there should be a sense of curiosity and concern regarding transgressions but instead Hastings District Council had a culture of explaining results away (Government Inquiry into Havelock North Drinking Water, May 2017).

Collaborative working between organisations is also a key component of organisational culture. The regulatory framework for drinking-water supply in New Zealand consists of three principal components. The environment (i.e. water source) falls under the responsibility of the Ministry for the Environment and the Regional Council. The drinking-water supplier (e.g. a council or a self-supply) has responsibilities under the Health Act and the Local Government Act. The public health system also has responsibilities under the Health Act and the Ministry of Health contracts many of these responsibilities to the relevant District Health Board. If this multi-organisational system is functioning well, then proper consideration is given to the protection of the water source, the operation of the water supplies including appropriate treatment and adequate monitoring for contaminants (Government Inquiry into Havelock North Drinking Water, May 2017). This collaborative working can be measured by quantifying the systems and processes for information sharing, liaison and co-operation between organisations. Interactions between organisations should be maximised and there should be mutual support.

Collaborative working within an organisation is also important. For example, the team responsible for water supply should regularly interact with finance, strategic policy, audit, legal and compliance (Castalia Limited, 2017). It is important that the asset management team spends time effectively communicating risks and responsibilities to senior executives and elected members.

The Havelock North Stage 1 Inquiry found that there was a lack of collaboration and liaison between the Regional and the District Council and went as far as to say that the relationship was "dysfunctional". It commented that the "strained nature of this relationship, together with an absence of regular and meaningful cooperation, resulted in a number of missed opportunities that may have prevented the outbreak (Government Inquiry into Havelock North Drinking Water, May 2017)." Following the Havelock North outbreak, the Regional Council filed criminal prosecution against the District Council alleging breaches of the Resource Management Act 1991 which further illustrated the strained relationship.

Following the Havelock North contamination, a joint working group was established to allow cooperation of key agencies. Representatives from the District Health Board, the District Council and the Regional Council were included. The Inquiry found that this group worked effectively and competently (Government Inquiry into Havelock North Drinking Water, May 2017). Mandated collaboration is recommendation 31 of the Stage 2 Inquiry

The health and safety culture of an organisation also feeds into their overarching organisational culture. Health and safety culture includes systems and procedures that an organisation has in place, as well as the willingness to abide by them. It is interesting to note that there are large variations between the number of near miss reports and loss time injuries at councils included in the National Performance Review (Water New Zealand, 2017). This may reflect differences in the relative safety of workplaces, but it may also reflect differences in the culture of reporting near misses and injuries.

3.3.4 Staff Training

There currently is no licensing or mandatory qualification for drinking-water suppliers and their staff. There are voluntary training courses available which many drinking-water suppliers require their staff to attend. This means that although staff may currently have the required skills, there is no way of establishing or monitoring skills and competence levels.

The National Performance Review found that 78% of study participants had formal training and development plans in place for their three waters staff, and of those that provided budget values, the mean allowance was $1,797 per staff member per year (Water New Zealand, 2017). This review did not measure the relevance and value of the training.

The Stage 2 Inquiry stated that water treatment plants are becoming more complicated and although they function most of the time, when they fail a competent person is required to troubleshoot, solve the issue and mitigate the risk to the public.

Training should also include learning from past events. The 1998 contamination event at Havelock North was not included in the District Council's training materials or in their Water Safety Plans (WSPs) and was not known to the Water Services Manager and the Water Supply Manager. This meant that important knowledge and lessons from this previous event were lost and this contributed to the 2016 outbreak.

Most service providers do not have "mature quality management systems and p ocesses" and in small service providers there is a particularly strong reliance on the knowledge and historical understanding of a few long-standing staff members. Consideration of succession planning is not always apparent (Castalia Limited, 2017). At Havelock North, it was found that some managers and officials at the District Council seemed to have little or no knowledge of protozoa and the risks associated with these pathogens (Government Inquiry into Havelock North Drinking Water, May 2017).

Recommendations 22 – 24 of the Havelock North Stage 2 Inquiry were in relation to the establishment of a potentially mandatory licensing and qualification system for drinking-water suppliers and their staff. It stated that the standards for this licensing system should be high and in line with the risks associated with supply drinking-water to the public (Government Inquiry into Havelock North Drinking Water, December 2017).

3.4 Financial Capability

3.4.1 Financial Management

The ability to manage financials is a key competency for a drinking-water supplier. Many water-suppliers (especially those with a relatively small number of consumers spread out across a large area) face severe affordability issues and are concerned about increased regulation increasing this burden (MartinJenkins, 2017). This means that extensive rigor around financial management is required.

Advanced decision-making techniques, such as predictive renewal modelling, should be used to develop long term capital investment programmes. Water suppliers must understand future demand forecasts, critical assets and intended level of service. They should have sophisticated capital investment strategies (Castalia Limited, 2017).

Note that the financial management capability discussed in this section only covers the capability of the water supply organisation. It does not include a number of other constraints that can affect a water supplier's ability to deliver safe water such as: the ability to raise finance, debt limits imposed by others and the community's willingness to pay.

One of the key components of financial management is budget setting. When budgets are set too low, then upgrades and required maintenance becomes difficult and less than optimal compromises are often made. Past asset funding decisions (including a lack of funding for asset depreciation) can affect current budget considerations. Most, but not all, of the councils interviewed in the Three Waters Review seemed aware of these considerations and had plans in place to address them (MartinJenkins, 2017). The Auditor-General and the Productivity Commission have raised concerns over the investment in the three water sector (Castalia Limited, 2017).

One of the findings of the local government audit (Controller and Audit-General, 2018), was that there is an apparent lack of investment to ensure ongoing delivery of services. It was also found that both the revenue and debt of local authorities is increasing which requires forwarding planning to make sure that the debt can be serviced.

Financial management by Councils is viewed by the public as weaknesses (Local Government New Zealand, 2015)

3.4.2 Procurement Capability

In our view, procurement is a key capability as it relates to an organisation's ability to source the products and services that they need at an appropriate price and level of risk. Water supply procurement practices in New Zealand vary in sophistication and mean that the desired procurement outcome is not always achieved.

One of the four key challenges identified in the Controller and Audit-General report was under-delivery of planned capital spending. The councils included in the report stated that this was due to a number of factors including inefficient procurement practices, poor or overly optimistic planning, inefficient procurement practices, staff vacancies, lack of capability and capacity, limited interest from private firms in competing for work, and weak management and governance accountability (Controller and Auditor-General, 2018).

3.5 Technical Capability

3.5.1 Water Supply Technical Capability

Water supply technical capability is a key requirement for drinking-water suppliers. Suppliers must understand the day-today requirements of their own supplies as well as keeping up with technologies and advancements in the industry. The Stage 2 Inquiry stated that the supply of drinking-water is an increasingly complex and demanding operation and that it requires many different skills. It is vital that operators have the skills required for day-to-day operations as well as for mitigating equipment malfunctions and more serious emergencies including natural disasters (Government Inquiry into Havelock North Drinking Water, December 2017).

Many suppliers outsource the operations and maintenance of their assets and this is considered appropriate as long as asset information and technical knowledge is fed back to the asset owner, as it is critical that the asset owner knows and understands their assets and is in control.

Many smaller drinking-water suppliers have lower technical capabilities as their staff are often spread across a variety of fields. This is reflected in reduced DWSNZ compliance, but is also a reflection of the pressures on affordability for smaller rating bases. Over the 2016-2017 monitoring period, compliance by population reduces from 88.8% for large supplies to 25.0% for small supplies (Ministry of Health, 2018).

3.5.2 Range of Competencies

Drinking water suppliers require a range of competencies on top of their water supply technical knowledge. Staff must be competent in commercial, financial, regulatory, engineering, public policy, Iwi interests and project management. Licensing (including governance, finance, backup, management, insurance, training and competence of key staff) was recommended as part of the Stage 2 Inquiry (Government Inquiry into Havelock North Drinking Water, December 2017).

The ability to communicate with the community is a key competency of a drinking-water supplier that is often overlooked. Consumers should be consulted on the level of service strategy and this strategy should be central to decision making (Castalia Limited, 2017). The Three Waters Asset Management Maturity in New Zealand study found that small and medium service providers often saw little value in community engagement on level of service strategy as they felt that regulations dictated the requirements and the community expectations were clear. Larger service providers were more likely to refine their understanding of the community's level of service requirements. The Three Waters Review noted a significant difference in the amount of public information available on various council websites (MartinJenkins, 2017).

A national survey of 4,557 respondents found some evidence to suggested that the public is dissatisfied with the current approaches to water management. 50% of respondents did not feel that local and national government agencies work together to make the right decisions for New Zealand's water resources. 44% of respondents felt that councils do not adequately plan for future water needs (Controller and Auditor-General 2018). These results may reflect a lack of community engagement.

One of the four key challenges identified in the Controller and Auditor-General report was working with Iwi. Some of the four councils considered in the report are working closely with Iwi while others are still in the early stages of building a relationship (Controller and Auditor-General, 2018).

3.6 Systems

3.6.1 Risk and Compliance

Drinking-water suppliers have a duty to carry out competent risk assessments regarding the source and supply of drinking-water (Government Inquiry into Havelock North Drinking Water, May 2017). These risk assessments must include health risks associated with the drinking-water supply, critical control points in the supply and the risk mitigation measures. There should be a formal risk management policy in place and risk should be integrated into decision making. Risk should be quantified and risk mitigation measures should be evaluated (Castalia Limited, 2017).

WSPs are required under the Health Act and are a way of reviewing the whole water supply chain from raw water through to the consumer. This review process includes an assessment of possible causes and risks of contamination as well as mitigation measures. The plan should also state what remedial action needs to be taken should a contamination event occur. Most (97.8% when excluding supplies serving less than 500 people) water supplies have WSPs (Ministry of Health, 2018).

It is important that the exercise of writing and updating a WSP is more than a box ticking exercise. Before the Havelock North contamination event, Hastings District Council was found to have no system for acquiring the knowledge needed to safely make an assessment of the relevant risks to the consumer. The Inquiry found that the risk assessments included in the WSPs were "inadequate and not based on any meaningful process." Hastings District Council also did not integrate risks from the WSP into the Council risk register (Government Inquiry into Havelock North Drinking Water, May 2017).

Drinking-water suppliers must have appropriate emergency procedures in place and they must follow them if an event occurs. This requirement is reflected in Recommendations 40 and 41 of the Stage 2 Inquiry as they relate to amending the Health Act to require water suppliers to have effective emergency response plans (Government Inquiry into Havelock North Drinking Water, December 2017). The local government audit (Controller and Audit-General, 2018) highlighted the fact that natural disasters (such as the earthquake related issues seen in 2016/17) can be dramatic, disruptive and expensive. This shows the importance of plann ng for and trying to mitigate the risks associated with natural disaster.

Hastings District Council did not have a comprehensive contingency plan for a water contamination event and the Inquiry found that the effects of this permeated the response to the outbreak (Government Inquiry into Havelock North Drinking Water, May 2017). The National Performance Review found that 78% of water suppliers that participated had emergency management plans in place, however the nature and extent of the plans varied significantly (Water New Zealand, 2017).

Thorough investigation into past events and issues is a key step towards minimising risk. The Havelock North Stage 1 Inquiry listed a number of past events and issues at Hastings District Council that related to the 2016 outbreak and had the potential to instigate preventative change. A significant event was the 1998 water contamination outbreak which was remarkably similar to the 2016 event. The Inquiry estimated that in the 1998 event that 80 people contracted campylobacteriosis as a result of contaminated bore water. An investigation at the time concluded that the source was likely heavy rainfall causing flooding of water contaminated with sheep faeces to enter the drain adjacent to the bore and infiltrate the supply. The investigation noted that there was doubt that the aquifer was confined and that maintaining a non-chlorinated supply requires a higher level of hygienic operation and greater control and monitoring of the system. The findings included identifying issues with loose gland seals, leaking bore chambers, an inoperable sump pump and the potential for surface water to enter the bore made it obvious that an effective inspection and maintenance programme was required (Government Inquiry into Havelock North Drinking Water, May 2017). This previous event and the resulting investigation provided substantial insight into the public health risks and the possible risk mitigation measures. The District Council did follow some of the recommendations of the investigation however others were not carried out, for example pressure grouting around the casing, and maintenance in the following years was inadequate.

The Havelock North Stage 1 Inquiry also noted a number of other events and issues that were raised which should have provided the District Council with insight into how to reduce the likelihood of future events. These events included; a complaint from a Health Protection Officer about the proximity of the bore to a sheep paddock, backflow from a stagnant water tank entering the public supply and resulting in a high E. coli reading in 2013, an October 2015 contamination event that the Inquiry found was not responded to with the level of care and concern required, high E. coli readings in December 2015 which were investigated at a very slow rate and a series of E. coli transgressions recorded from 2007 onwards that were responded to in varying ways. The Inquiry found that these events and issues, including the 1998 contamination, were missed opportunities for the Regional and District Councils to learn from past events and improve water safety. Formal debriefs should occur after incidents and forensic root cause analysis should be carried out to investigate significant faults (Castalia Limited, 2017).

3.6.2 Asset Management

A water supplier with good capability in asset management will have high quality condition information that supports risk management, lifecycle decision making and financial reporting. Relevant and reliable asset information is a challenge, and this effects the ability for elected members to make good decisions about when to spend money on assets (Controller and Audit-General, 2018). The quality of asset management programmes can be measured by ISO9001 certification and audits that demonstrate satisfaction with QMS (Castalia Limited, 2017).

The Three Waters Asset Management Maturity in New Zealand review found that most service providers have a basic level of asset management including asset management framework, policy, a plan and information systems (Castalia Limited, 2017). All asset management plans reviewed as part of this study adhered to the International Infrastructure Management Manual best practice template and terminology but the quality of the plans and the level that they were adhered to varied between service providers. For small and medium service providers, the understanding of level of service and asset performance rarely went above the regulatory requirements. It was found that service providers of all scales engaged well with other council functions (i.e. finance). Service providers across all scales have recently been turning towards sector guidance and collaboration because of growth and affordability changes and the requirement to meet new regulations. In contrast, the Audit NZ report (2017) found that the majority of organisations have been stagnant with asset management, there has been no improvement. These are conflicting accounts of asset management improvement.

It is critical that a drinking-water supplier operates an effective maintenance and inspection programme. WSPs should incorporate a programme and should make clear the risks associated with not following the programme (Government Inquiry into Havelock North Drinking Water, May 2017). It was found that a lack of attention to important details of infrastructure maintenance contributed to the failure of the bore system during the Havelock North contamination event (Government Inquiry into Havelock North Drinking Water, May 2017). The council did not have written maintenance and inspection programmes for the bores and the Inquiry concluded that these programmes should have been in place to require regular inspection as well as testing of pumps and alarms.

The National Performance Review also found that almost all water suppliers that participated in the study had carried out condition assessments of some of their water supply pipelines (and almost 60% had assigned gradings to all pipelines), however the condition assessment approaches vary meaning that comparisons of pipe condition around New Zealand in difficult (Water New Zealand, 2017). This review also found that over 80% of participants have in place processes for assessing the condition of their above-ground water assets, however only a third assess all of their assets as part of each three-year asset management cycle.

Generally speaking, larger service providers have more mature asset management systems because of the improvements in analysis and data collection, the increased specialisation and the ability to attract and retain talent. They are also more likely to conduct formal, regular asset condition assessments. Some larger councils are moving towards 'tactical prioritisation' and using sophisticated techniques such as rapid-flood analysis to identify critical assets. Smaller suppliers tend to carry out any proactive maintenance based on the knowledge of age and criticality held by a few individuals (Castalia Limited, 2017).

The vast differences in asset portfolios for councils in New Zealand are reflected in Figure 3-1. This shows that there are three suppliers with a large value of assets and then a large number of smaller suppliers. These smaller suppliers are less likely to be able to set-up and maintain robust asset management systems.

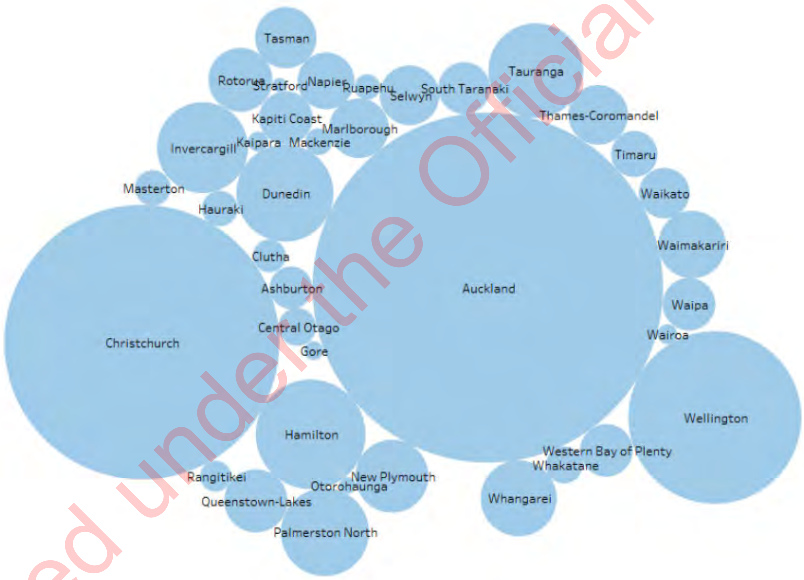


Figure 3 1: Total Value of Three Water Assets by Supplier (Water New Zealand, 2017)

Asset management in three waters is less mature than New Zealand's energy sector and roading sector and the water sectors in Australia and Scotland (Government Inquiry into Havelock North Drinking Water, December 2017). Asset management in the local government sector has stronger management systems than the health and tertiary sectors because of the inherent risk, however many health and tertiary organisations run self-supplies. Smaller councils have weak management systems due to the lower inherent risk (Audit NZ, 2017)

3.6.3 Quality Assurance

Quality assurance relates to the organisation's understanding of reliable information and data. Reliable and high-quality information and documentation of systems and procedures is critical for a variety of reasons including to provide a robust basis for decision-makers. This includes information on asset condition and any maintenance backlog, performance and future demand (Castalia Limited, 2017).

Local authorities generally have access to a lot of data, but it is not always used well or is not always the best information to support decision making. Operational staff often have information of the condition of assets, but it is not always communicated to managers and decision-makers. It is critical that decision makers have access to this information and that they have an understanding of how assets perform throughout the life cycle (Castalia Limited, 2017).

The Three Waters Review found that information received for governance decisions was generally good but that this was not universal. The review identified that there is an opportunity to improve the quality of information and advice at councils through use of guidance or regulation (Castalia Limited, 2017). The Stage 2 Inquiry noted that Hastings District Council had a backlog of quality assurance documentation and had to increase staff numbers to clear this (Government Inquiry into Havelock North Drinking Water December 2017).

One of the key components of quality assurance for drinking-water suppliers is water quality monitoring. The Three Waters Review (Castalia Limited, 2017) noted a few issues with monitoring. These include:

- A delay in receiving monitoring tests which results in the potential for pathogens to spread before action is taken
- A current emphasis on monitoring because of the Havelock North contamination event which may not continue as memory of the incident fades
- Blurred accountability due to monitoring expectations coming from the CEO and council officers

4 Capability Categories

4.1 Capability Category Framework

The resources reviewed were used to define the capability framework shown in Table 4-1. This framework relates to drinking-water capability only, rather than an organisation capability as a whole.

In addition to the organisational capabilities set out in the capability matrix, there are a number of other matters that can constrain a water supplier's ability to deliver. These include such things as the ability to raise finance, debt limits imposed by others, and the community's willingness to pay. These other matters go beyond the scope of this report

In terms of the capability levels in the matrix, 5 is the highest capability and 1 is the lowest. 3 is the minimum or core requirement.

Table 4-1: Capability Category Framework with Definitions/Examples for each Measure

No.	Capability	Sub-Capability	Weighting	1	2	3	4	5
1	**Governance**		**15%**					
1.1		Governance – providing leadership and strategic direction, driving organisational culture, making skilled decisions, and having accountability for decisions.	15%	Inadequate definition of roles and responsibilities and a general confusion in decision-making processes	Roles and responsibilities are unclear Decisions are often short-sighted or reactive	Governance roles are defined and there is an overall strategy Decisions are made based on effective briefings and relevant information	Governance roles are defined and there is an overall strategy Decisions are made based on effective briefings and relevant information Identifies and resolves trade-offs Better than Level 3 but not at Level 5	Based on an overall strategy with clear priorities Uses high quality information Identifies and resolves trade-offs Takes a long term view/whole of life approach Uses appropriate consultants Has an appropriate governance culture Makes provision for assurance (MartinJenkins, 2017)
2	**Management**		**25%**					
2.1		Management capability	5%	No evidence of management capability	Managers do not have the required competency and are potentially still learning the skills required for the role	Managers are responsible for organising staff and making key decisions They understand the importance of employing competent staff, using external expert advice when required	Managers are held accountable and understand responsibilities They understand the importance of employing competent staff, using external expert advice when required They plan for staff absences, capacity and resourcing	Managers are held accountable and understand responsibilities Management is transparent and traceable There are clear targets and clear levels of responsibility delegation They are proactive and strategic planning for staff absences, recruiting and resourcing including finding expert advice when require
2.2		Future planning	10%	No documented attempts to plan for future	Planning for the next year is carried out	Long Term Plan planning is carried out to the regulated requirement	Robust long term planning is carried out and there is some consideration into possible changes such as increased treatment requirements, reduced water availability compared to demand and climate change	Robust long term planning is carried out and there is an appropriate level or peer or external review Substantial consideration and action are given possible changes and a range of risks such as increased treatment requirements, reduced water availability compared to demand and climate change Scenario planning is carried out

No.	Capability	Sub-Capability	Weighting	1	2	3	4	5
2.3		Organisational culture	5%	Standard of care requirements do not seem to be understood/taken seriously Collaboration and H&S are carried out by coincidence rather than by a structured or intentional approach	Standard of care requirements are understood but there is still work need to meet a satisfactory level Collaboration and H&S are carried out by coincidence rather than by a structured or intentional approach	Standard of care is taken seriously There is some collaboration between departments within the organisation and between relevant organisations H&S is seen as important	Standard of care is taken seriously There is strong collaboration between departments within the organisation and between relevant organisations Proactive H&S culture	Standard of care is taken seriously and proactively There is strong, and structured, collaboration between departments within the organisation and between relevant organisations Proactive H&S culture is a top priority
2.4		Staff training	5%	No available staff training	On the job staff training that is not formalised or is not specific for the tasks carried out by the staff member	A small training budget per person Sufficient staff numbers to carry out day to day tasks but not to consider strategic planning	Formal training and on the job training is provided for each staff member	A training plan is followed for each staff member which includes formal training as well as on the job training Training is specific to the role
3	**Financial Capability**		**20%**					
3.1		Financial management	15%	Budget setting is not evident, and spending is typically reactive	There is an attempt at budget setting but inadequate information is used to determine the dollar value Less than half of the budgets are expended.	Budget setting is carried out for those items identified in the Long Term Plan The majority of the budgets are expended as per the LTP	Budget setting is carried out for those items identified in the Long Term Plan and consideration is given to those items not foreseen. Virtually all of the budgets are expended as per the LTP	A robust analysis is carried out of the likely budget required to meet known future expenditure, possible expenditure and unforeseen expenditure. Budgets are set aside for asset renewals All of the budgets are expended as per the LTP
3.2		Procurement capability	5%	Procurement is ad-hoc and informal The desired outcomes are often not achieved	Procurement is ad-hoc and informal but individuals have learnt lessons from previous failures to improve the success rate	A procurement plan is in place and the desired outcome is sometimes achieved	A procurement plan is in place and project scoping is developed The desired outcome is often achieved	Procurement is generally successful and projects are scoped and sourced in a way that promotes effective outcomes
4	**Technical Capability**		25%					
4.1		Water supply technical capability	15%	There is little to no technical capability around water supply	There is a high level understanding of the technical aspects of water supply	Operational staff/contractors and asset managers are aware of the most relevant technical aspects of water supply as related to their scheme	Operational staff/contractors and asset managers are aware of the most relevant technical aspects of water supply as related to their scheme and are beginning to upskill to be best prepared for changes in the future	Operational staff/contractors and asset managers are conversant with their requirements as drinking-water suppliers are understand the likely requirements for change in the future

No.	Capability	Sub-Capability	Weighting	1	2	3	4	5
4.2		Competence in commercial, regulatory, engineering, public policy, Iwi interests and project management	10%	Staff do not have appropriate competencies	Staff have a base level of competence, but organisation lacks depth	Staff have adequate competence to meet the day-to-day requirements and consultants are brought in when required Community consultation is carried out for key issues	Staff have adequate competence to meet the day-to-day requirements and to carry out future planning Consultants are brought in when required and there is an effort to upskill/recruit to fill competency gaps Community consultation is carried out for key issues	Staff are highly competent, including knowing when and how to get high-quality external advice. Community consultation and engagement is common practice
5	**Systems**		**15%**					
5.1		Risk and compliance	5%	No documented attempt at risk management and/or compliance	Risk management documents are prepared as box ticking exercises but not adequately used. Compliance weak.	Risk management documents are prepared and utilised Past issues and events are referenced in the WSP and training material. Compliance achieved for some supplies.	Risk management documents are prepared and utilised Past issues and events are referenced in the WSP and training material and well known to operators, asset managers and elected members. Compliance achieved for most supplies.	Risk management documents are considered key documents and are used in decision making Past issues and events are at the forefront of operators, asset managers and elected members minds and are referenced in the WSP and training material. Compliance always achieved
5.2		Asset management	5%	No documented attempt at asset management plans Inadequate asset management information	Asset management documents are prepared as box ticking exercises but not adequately used Incomplete asset information is available	Asset management documents are prepared to the standard required by the regulations Asset information is mostly complete and stored in an appropriate system	Asset management documents are prepared and used High quality asset data is available	Asset management documents are prepared and used to inform long term planning Conduct regular, formal asset condition assessments Use of advanced asset management systems Asset management IIMM level 4 or 5
5.3		Quality	5%	Quality assurance is not carried out	Quality standards are not evident and any quality assurance done is carried out on an ad-hoc basis	Quality system is in place, and regular audits undertaken.	The importance of quality assurance is understood, and a quality system is in place, regular audits are undertaken, and organisation is ISO accredited.	Quality is of the upmost importance to organisation. Inaccuracies in information are thoroughly investigated and mitigation measures are applied. Quality system is in place, regular audits are undertaken, and organisation is ISO accredited.

4.2 Capability Category Framework Check

The Six Fundamental Principles of Drinking-Water Supply were identified by the Stage 2 Inquiry (Government Inquiry into Havelock North Drinking Water, December 2017). These principles have been used to check that the capability categories identified in this report are adequate. Table 4-2 summarises the capability categorise that reflect each principle.

Table 4-2: Check of Capability Categories against the Six Principles of Drinking-Water Supply

Principle	Section of Capability Framework
Principle 1: A high standard of care must be embraced	1.1, 2.1, 2.3, 2.4, 5.3
Principle 2: Protection of source water is of paramount importance	2.1, 2.2, 5.1, 5.3
Principle 3: Maintain multiple barriers against contamination	2.1, 4.1
Principle 4: Change precedes contamination	1.1, 2.1, 4.1
Principle 5: Suppliers must own the safety of drinking water	1.1, 2.1, 2.3, 2.4, 4.1, 5.1
Principle 6: Apply a preventive risk management approach	2.2, 2.3, 4.1, 5.1

4.3 Categorisation

A very high-level categorisation of New Zealand's council-controlled drinking-water suppliers (65 in number) was carried out using judgement calls based on the Beca team's existing knowledge of the suppliers and the data available in the National Performance Review (Water New Zealand, 2017). This assessment is aimed at providing the Ministry with an early indication of the existing capability range. It does not identify individual suppliers' scores. As the Beca team involved has not worked with every New Zealand supplier, and does not have a complete knowledge of each organisation, further work to confirm this categorisation is recommended.

A rating for each council-controlled drinking-water supplier was identified and then the weighting as shown in the capability framework was applied. This resulted in a total score from 0 – 100% for each supply with 100% being the highest possible level of capability. Figure 4-1 and Table 4-3 summarises the results. This figure and table show the same information.

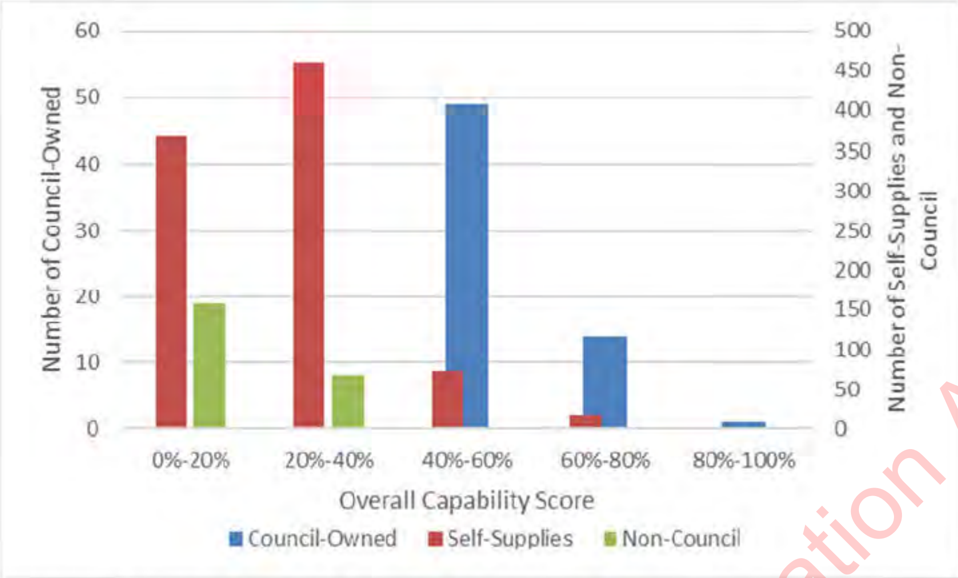


Figure 4-1: Summary of the Frequency of Drinking-Water Suppliers Categorisation

Table 4-3: Number of Suppliers with each Overall Capability Score

Overall Capability	Council-Owned	Self-Supplies	Non-Council Networked
0%-20%	0	368	158
20%-40%	0	461	68
40%-60%	49	74	0
60%-80%	14	18	0
80%-100%	1	0	0

This shows that most council-controlled drinking-water suppliers have an overall score of 40-60% with some scoring higher. 40-60% is considered the base capability for meeting requirements.

A rough assessment of the number of self-supplies and non-council supplies in each category was also carried out. As the figure shows, there are a much greater number of self-supplies and non-council supplies and they are likely to have lower capability.

Table 4-4 shows a further breakdown of the capability scores for council-owned water supplies. Most council-owned supplies have scores of 2 or 3 for each capability. The table shows that scores of 2 are more common for management capability, staff training, procurement capability, asset management and quality. This indicates that these are areas of weakness.

Table 4-4: Frequency of Capability Scores for Council-owned Water supplies in each Category

	Governance	Management				Financial Capability		Technical Capability		Systems		
	15%	5%	10%	5%	5%	15%	5%	15%	10%	5%	5%	5%
Score	1.1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	5.1	5.2	5.3
1	0	0	0	0	0	0	0	0	0	0	0	0
2	17	**27**	6	13	**28**	13	**38**	10	13	20	**36**	**26**
3	37	35	49	45	25	50	21	49	47	40	24	35
4	10	2	9	6	10	1	5	4	4	3	4	3
5	1	1	1	1	2	1	1	2	1	2	1	1

5 Areas of High Tourism

5.1 Identification of Areas of High Tourism

The aim of key question number 3 is to understand the capability of suppliers in high tourism areas to cope with tourist-driven peaks in demand. To answer this question, an analysis was carried out to identify which towns in New Zealand are most significantly affected by tourist-driven peaks and then the capability of water-suppliers in these areas was assessed. During Stage 1 of this study, data on New Zealand's international overnight visitors that stay one night or more in the top 50 destinations was obtained from Tourism New Zealand. These numbers were compared to the permanent population of each town. International visitor to permanent resident ratios ranged from 616:1 to 1:1. It was determined that a ratio of 10:1 or more is a reasonable cut-off for the point in which the risk of a supply not coping with tourist driven peaks increases. This was based on a judgment call.

The analysis using Tourism New Zealand data had a few limitations. The data only included international visitors and so it was possible that a few high tourism towns were missed off the list because they are predominantly visited by domestic visitors. Also, the Tourism New Zealand data did not provide an indication of seasonal fluctuation.

For Stage 2 of this study, further investigation into the availability of data including domestic tourism was carried out. Statistics New Zealand collects monthly data on guest nights in each region, however this is not broken down to a town level. This data was analysed in two ways; the ratio of average guest nights to permanent resident of each region was quantified and the ratio between the maximum and minimum number of guest nights in each region was also quantified. Similar to the analysis of the Tourism New Zealand data, a judgement call was made as to what ratios are a reasonable cut-off for an increase in risk of a supply to cope with tourist driven peaks. The available data was only broken down to a regional level and so assumptions about the most likely town(s) to receive guests were made. Analysis of this data added a further 18 water supplies. It is worth noting that 12 of these supplies are along the Otago Rail Trail and they are a mix of council-owned and private supplies. There are a total of 52 towns on the high tourism list. This list can be seen in Appendix A.

5.2 Cost to Upgrade Areas of High Tourism to Meet DWSNZ

In 2018, Beca prepared a report for the DIA titled *Cost Estimates for Upgrading Water Treatment Plants to Meet Potential Changes to the New Zealand Drinking Water Standards*. This report included high-level cost estimates to give an indication of the likely capital and increased operational costs of bringing all networked supplies (both council-owned and non-council owned) up to the DWSNZ (Scenario 1). The analysis also considered a second scenario to understand the cost of abolishing the secure groundwater classification (Scenario 2).

The capital and operational costs for each of the high tourism drinking-water suppliers (Appendix A) were pulled from the 2018 DIA study cost database. Therefore, the methodology and assumptions used to establish the 2018 DIA study also apply here. Although it seems likely that the concept of low-risk groundwater not requiring treatment will be retained, proving that a particular source is low-risk will likely be difficult and expensive for small suppliers. Providing treatment may be a simpler option. Therefore, we have also included the cost estimate for Scenario 2 of the DIA study. The high tourism list included ten towns that are not known to have drinking-water supplies. It is likely that the houses and businesses in these towns have self-supplies. The cost of upgrade to these supplies has been estimated based on information from the 2018 DIA study. It is assumed the cost of upgrade is the same as that required for a small supply. This population range was selected as a new small supply may be constructed or there may be multiple tourist serving establishments with self-supplies within each township.

Using the 2018 DIA costing database, the total cost to upgrade the 52 supplies was estimated to be $64 million ±30%. The overall median cost per water supply is $340,000. If self-supplies are excluded, the median is $460,000 per water supply however there are still two water supplies with very large costs that increased the total estimate dramatically.

It is important to note that only costs directly associated with achieving compliance with the drinking-water standards are included. The current compliance status of supplies has not been revisited since the 2018 estimate and so it is possible that compliance of specific supplies has improved or lessened however the effect on the total estimate is likely to be small. The estimates assume that existing treatment plant capacities are adequate and therefore make no provision for capacity increases. 18 of the high tourism supplies identified were fully compliant. The cost estimates exclude upgrading or replacement of existing assets, or any other infrastructure which may be needed or desired as part of a treatment plant upgrade. Depending on the condition of the existing assets, and the appropriateness of the existing treatment process for the quality of the sourc water, these costs can be significant (in the order of $1 to $2 million per plant for smaller plants). There are seven small plants on the high tourism list, as well as ten towns with no known supplies that have been costed based on a small supply. This means that the total costs could be significantly higher and in the realm of $81 – 98 million ±30%. Table 5-1 summarises the cost estimation results and Table 5-2 shows this broken down by supply size.

Even with the additional $1 to $2 million per plant for smaller plants added, these estimates are likely to be less than the total required to upgrade all 52 high tourism supplies. Most sites will likely require enabling works for the upgrades. This may include construction of buildings, roads and other infrastructure such as wastewater systems, upgrades to power and controls systems and procurement of additional land. Standardisation of designs or use of containerised/modular equipment solutions may reduce costs of some of these additional enabling works items.

Table 5-1: Summary of Cost to Upgrade Areas of High Tourism

Parameter	Value
Number of high tourism supplies identified	52
Estimate of Probable Capital Cost using 2018 DIA Database*	$64 million ±30%
Estimate of Probable Capital Cost Including Allowance for Small Supplies*	$81 – 98 million ±30%
Estimate of Probable Annual Operating Cost*	$2.1 million

*Including towns with no known WTP (households and businesses in the towns likely have a self-supply and this has been estimated based on the average costs for small supplies)

Table 5-2: Summary of Cost to Upgrade Areas of High Tourism Broken down by Supply Size

Supply Size	Frequency	Total Cost* (±30%)
Self-supply	10	$ 18 million
Small	9	$ 13 million
Minor	21	$ 11 million
Medium	2	$ 3 million
Large	10	$ 44 million

*Including additional allowance for small supplies (same applies to self-supplies)

5.3 Capability of Drinking-water Suppliers in Areas of High Tourism

The list of high tourism drinking-water supplies includes supplies that have a high ratio of visitor numbers compared to the number of permanent residents, as well as areas that see a large fluctuation in guest nights throughout the year. Many tourist destinations have difficulty funding the infrastructure required to support a large number of tourists compared to their rate base. Some destinations with large tourist populations have a high seasonal variation in visitors numbers that can lead to treatment plant difficulties. This occurs when there are short peaks in visitors at a certain time of year which increases water demand well above the remainder of the year.

The cost estimate shown in Section 5.2 shows that the cost of upgrading all of these supplies to the DWSNZ is significant. 57% of the 42 supplies on the list require upgrades to meet the DWSNZ and there are a further ten towns with no known supply/a self-supply. Although compliance with the DWSNZ is not one of the identified measures of capability, the lack of funding associated with non-compliance is strongly correlated with a lack in governance, technical and financial capability.

Excluding the ten towns without known drinking-water supplies, the average capability ranking of the 52 high tourism supplies is 46%. This is within the 40-60% range seen as an average for council-owned supplies throughout the country. Although there is a high percentage of drinking-water supplies on the high tourism list that require upgrades to meet the DWSNZ, this analysis does not show that the operators of these supplies have substantially less capability than the overall average. It is likely that compliance issues are more closely linked to the ability to collect rates/fees from the permanent residents to cover visitors.

Queenstown Lakes District Council has been used as an example of a supplier with large tourist visits who are developing capability to better understand fluctuations in tourism numbers and have better asset management systems than other councils with similar rating bases (Controller and Auditor-General, 2018). It is worth noting that Queenstown Lakes District Council has an almost continuous tourist season while other destinations have greater fluctuations in visitor numbers. Developing capability does not necessarily mean that they have a large enough rating base. They are currently considering other ways to raise funds for tourist related infrastructure costs.

6 Non-Council and Self-Supplies

6.1 Capability of Non-Council and Self-Supplies

Figure 4-1 and Table 4-3 show that the capability of non-council and self-supplies has been assessed to be substantially less than that of council-owned supplies. There are three types of non council supplies:

- Self-supply
  - A person or business supplies water to their own property or buildings
  - This is often homes, farms and small businesses
  - There is no known compiled list of these supplies
- Specified self-supply
  - A person or business supplies water to community-purpose buildings owned by them
  - This includes schools, hospitals, churches, and community centres
  - ESR's website has a compiled list of these supplies, last updated August 2018
- Non-council networked supply
  - Where a person or business supplies water to multiple properties by pipeline
  - These are typically owned by community organisations

The Ministry's annual monitoring report includes compliance information for both council and non-council networked supplies with populations above 100 people but very little information is collected on self-supplies and specified self-supplies.

Self-supplies and specified self-supplies do not come under the requirements of the DWSNZ, they are covered by the Building Act. However, the Building Act requires that potable water is provided and in New Zealand, this is generally taken to mean compliance with the DWSNZ.

Non-council suppliers do not always seem to understand their responsibilities and the risks associated with providing drinking-water. Often, water is supplied by a single person or a small business that does not have expertise in drinking-water supply or public health. Maintaining and monitoring the supplies is probably only a small part of the supplier's role and his/her focus is likely to be mostly on other tasks. It is not uncommon to see a technician responsible for drinking-water supply that does not have separate tools for the wastewater and drinking-water systems, upgrades the network without considering cross connections and backflow, does not understand sampling procedures including interpreting and acting on the results received, and generally is unaware of the risks of the system. Because of the small size of these supplies, and the funding and capability gaps, they are typically too much of a stretch for the limited DWA resources.

Lifting the capability of the 225 non-council networked supplies would be a momentous task if the current operating structure remains. Training and systems/tools would need to be rolled out throughout the country and it may be difficult to gain buy in from all suppliers to invest in this extra time. One feasible scenario would be to transfer all non-council networked supplies to local councils. This would mean that these supplies would be operated by more capable operators (generally) and there would likely be efficiencies in training, management, sampling and general activities. This is likely to be a lower cost solution than improving the capability of all current suppliers. The legal aspects of this transfer are likely to be complicated and the best mix of asset ownership, operations and responsibility would need further consideration. We recommend that a number of pilot studies are carried out to provide further insight into the costs, complications and general feasibility of this scenario.

It is unlikely to be practical to transfer self-supplies and specified self-supplies to local councils because of the large number of them. There are 921 specified self-supplies and the number of additional self-supplies is not recorded but was estimated as part of the concurrent DIA study as being between 261,000 - 319,000. The best outcome for these supplies would generally be to have operations and maintenance outsourced. This would improve the capability of those operating and monitoring the supplies and would allow for an increased level of shared learning between adjacent supplies. The cost of outsourcing operations and maintenance has only been estimated for specified self-supplies. This due to the high number of self-supplies, as well as the practicality of mandating self-supply owners to pay for outsourced operation and maintenance.

6.2 Cost to Upgrade Non-Council and Self-Supplies to Meet DWSNZ

This section summarises the results of the 2019 DIA study, titled *Additional Analysis on Drinking Water Costs for Compliance.*

As stated in Section 6.1, we believe that the best outcome to improve the capability of those operating non-council networked supplies would be to transfer these supplies to the local council. In addition to the costs taken from the DIA study (capital, operating, WSP establishment and WSP review), we have included a cost estimate to account for the cost of transferring drinking-water supply ownership. This includes indicative estimates for the following tasks:

- Transfer of knowledge from existing operators to new (assume overlap in pay for two persons)
- Drafting of O&M manuals and monitoring procedures
- Preparing as-built drawings for existing assets
- Gathering all available information on existing water supply including design information, monitoring data, and information on past events

Note, this estimate does not include legal costs associated with establishing O&M contracts or transfer of ownership. The cost of outsourcing operations and maintenance for specified self-supplies has been assumed to require the same tasks bulleted above for non-council networked supplies. The estimate of cost transferring drinking water supply ownership is concept-level estimate only, not based on any knowledge of the installations nor evidence of any existing O&M information available, with a likelihood that the estimate may vary by ±50%. The estimate has assumed hours for each of the bulleted tasks, at a rate of $150/hour. The estimate has also included a complexity factor to account for more complex water treatment plants (such as conventional or membranes) requiring more hours for some of the tasks compared to a moderate or simple treatment plant (cartridge filters and UV or bores and chlorine respectively).

Table 6-1 gives a summary of the costs to upgrade non-council networked supplies from the 2019 DIA study. Note, the costs for networked supplies serving >25 people originate from the 2018 DIA study, but have been taken from 2019 DIA report.

Table 6-1: Summary of Cost to Upgrade Non-Council Networked Supplies

Parameter	Value
Non-council networked supplies serving > 500 people	
Number of non-council networked supplies identified*	14
Estimate of Probable Capital Cost using 2019 DIA Study	$5 million ±30%
Estimate of Probable Capital Cost including allowance for greenfield type site developments	$98 million ±30%
Estimate of Probable Annual Operating Cost using 2019 DIA Study	$0.1 million
Estimate of cost transferring drinking water supply ownership	$0.5 million ±50%
Non-council networked supplies serving 25 - 500 people	
Number of non-council networked supplies identified*	211
Estimate of Probable Capital Cost using 2019 DIA Study	$47 million ±30%
Estimate of Probable Capital Cost including allowance for greenfield type site developments	$210 million ±30%
Estimate of Probable Annual Operating Cost using 2019 DIA Study	$2.6 million
Estimate of cost transferring drinking water supply ownership	$4.5 million ±50%
Non-council networked supplies serving < 25 people	
Number of non-council networked supplies identified*	1,017 – 5,085
Estimate of Probable Capital Cost using 2019 DIA Study	$32 – 210 million +30%
Estimate of Probable Capital Cost including allowance for greenfield type site developments	$50 – 300 million +30%
Estimate of Probable Annual Operating Cost using 2019 DIA Study	$13 – 86 million +30%
Estimate of WSP Initial Cost using 2019 DIA Study	$5 – 25 million
Estimate of Annual WSP Review Cost using 2019 DIA Study	$1.0 – $5.0 million
Estimate of cost transferring drinking water supply ownership	$16 – 80 million ±50%

*This is the total number of schemes identified, however not all are non-compliant.

For the costs taken from 2019 DIA study, a number of assumptions were made which still hold here. A key assumption is that only costs directly associated with achieving compliance with the DWSNZ are included. Costs associated with capacity increases, infrastructure not associated with compliance e.g. access roads, improving resilience or redundancy or improving raw water quality are not included.

For the supplies serving > 25 people, an additional $253 million should be included to allow for greenfield type developments for a more representative value of the true cost ($160 million for 25 – 500 supplies and

$93 million for > 500 supplies). This is shown in the table. It is assumed these supplies already have WSPs in place and are reviewing them regularly (i.e. no additional cost).

For networked supplies serving < 25 people, the DIA study did not differentiate between council and non-council. For the purposes of this report it has been assumed that 90% of the < 25 people networked supplies are non-council. This is based on the percentage of non-council supplies in the incomplete register of networked supplies serving < 25 people. It is assumed that all of these suppliers will need to prepare WSPs and review them every 5 years. If one third of these supplies do not have existing infrastructure to support treatment to DWSNZ and the cost of providing that infrastructure is $50k then an additional $18-90 million should be included to allow for greenfield type developments for a more representative value of the true cost. This was assumed in the 2019 DIA report.

Table 6-2 gives a summary of cost to upgrade specified self-supplies and self-supplies. It is assumed that all of these supplies will need to prepare WSPs and review them every 5 years.

Table 6-2: Summary of Cost to Upgrade Specified Self-Supplies and Self-Supplies

Parameter	Value
Specified self-supplies	
Number of specified self-supplies identified*	921
Estimate of Probable Capital Cost using 2019 DIA Study	$81 – 150 million ±30%
Estimate of Probable Capital Cost including allowance for greenfield type site developments	$130 – 200 million ±30%
Estimate of Probable Annual Operating Cost using 2019 DIA Study	$6.7 – 13 million ±30%
Estimate of WSP Initial Cost using 2019 DIA Study	$4.8 million
Estimate of Annual WSP Review Cost using 2019 DIA Study	$1.8 million
Estimate of cost outsourcing O&M (same requirements as for transferring drinking water supply ownership)	$19 million ±50%
Self supplies	
Number of self-supplies identified*	261,000 - 319,000 ±10%
Estimate of Probable Capital Cost using 2019 DIA Study	$856 – $1,360 million +30%
Estimate of Probable Annual Operating Cost using 2019 DIA Study	$185 – $294 million +30%
Estimate of WSP Initial Cost using 2019 DIA Study	$1,304 - $1,594 million
Estimate of Annual WSP Review Cost using 2019 DIA Study	$261 - $319 million

*This is the total number of schemes identified, however not all are non-compliant.

The DIA study uses a register of specified self-supplies to identify the number of supplies, population served, region, and source water. If one third of these supplies do not have existing infrastructure to support treatment to DWSNZ and the cost of providing that infrastructure is $250k then an additional $46 million should be included to allow for greenfield type developments for a more representative value of the true cost. This was assumed in the 2019 DIA report.

The DIA study determines the number of households that are self-supplies by subtracting the population served by networked supplies (from the drinking water register) from the total NZ population (from Statistics NZ population estimate for 2018). Adjustments have been made for specified self-supplies that are residential such as prisons and defence bases. The number of people per household is based on Statistics NZ data. 95% of self-supplies are assumed to be non-compliant with DWSNZ. It is acknowledged that many households may have existing treatment, but it is assumed this would be inadequate to meet the DWSNZ. Non-compliant supplies are assumed to have no existing (appropriate) treatment.

7 Rural Supplies

7.1 Discussion of Rural Supplies

In the 50s, 60s, and 70s, the New Zealand government (through the Ministry of Works) provided a substantial subsidy for both on-farm and off-farm portions of piped rural water supply schemes (Lincoln College, 1975) (Wise, 1967). These rural water schemes had a number of objectives including provision of water throughout the entire farm, reduced risk of a water shortage, and provision of what was considered high quality water for farm homesteads and community buildings in the area (Wise, 1967).

The aim of these subsidies was to encourage land owners to band together to establish these rural schemes to improve farming outcomes. Before this time, many farmers were more reliant on the climate and on stock races that were becoming difficult to maintain and were at high risk of contamination. The piped schemes were often built using a large amount of labour supplied by the land owners however consulting engineers were often used for the design and construction management. The Ministry of Works reviewed the proposed scheme to check that it was technically sound, and the application was made through the local council.

Many of the schemes installed at the time were constant flow systems. This means that each customer is supplied with a maximum predetermined quantity of water over a 24-hour period (Wise, 1967). This reduces peaks in demand and allows smaller and therefore lower cost pipes to be used. Pipe materials were often asbestos cement for the earlier and larger capacity schemes and increasingly PVC for small capacity as it came to replace the use of asbestos cement.

Groundwater was the prefer ed water source due to the reduced effect of flooding on water quality, however surface intakes with infiltration galleries were commonly constructed. When treatment was installed, it was often limited to pH correction to reduce the corrosivity of the water. This was often done with an aeration tower to release carbon dioxide. Settling and/or filtration was also sometimes used to reduce turbidity and iron. In the later years of the subsidy, disinfection (generally by chlorine) was becoming more commonly required for subsidy acceptance. The schemes were generally installed with a reservoir sized for 6-8 hours of storage however storage volumes as high as two days were common in the earlier years of the subsidy. Pumps were generally stopped and started based on reservoir level and otherwise automatic control of the scheme was minimal. The topography of the region often meant that schemes included booster pump stations, break-tanks and pressure reducing valves (Lincoln College, 1975). Consumers were required to provide a sealed tank with a ballcock to receive the supply. The tank was required to hold 24 hours of storage. Airgaps on the farm tank were generally also required (Wise, 1967).

Many of these schemes have now been taken over by the local council although some are still operated by the farmers. Over the years, it has been common for farmers to add connections to these schemes without documenting the changes. In general, there is often little documentation for these schemes including drawings, design details and changes.

With the introduction of the DWSNZ, a number of these schemes have been upgraded to include more advanced treatment however there are also many supplies that are generally unchanged from their original installation. In some cases, low cost treatment (such as cartridge filters and UV) has been installed in an attempt to gain compliant status however the treatment is often not enough to provide year-round compliance due to flood events increasing turbidity. The catchment risk assessments for these schemes can result in a high treatment requirement due to the increase number of livestock in the area.

Section 7.3 describes the methodology for how a list of rural supplies was gathered. The compliance of neighbourhood supplies is unknown. If all of these rural neighbourhood supplies are DWSNZ compliant than the total compliance level for the list of rural supplies is 9%. If none of the rural supplies are compliant that the total compliance level drops to 6%. A compliance level of 6-9% for rural supplies on this list is much lower than the national average. Because the consumers are generally profiting from using the water supply as part of their farming business, it should be easier for water suppliers to justify increased costs. However, consumers are often unwilling to pay for upgrades as they come at a significant cost and they often do not agree that the risks are high enough to justify this.

The cost of treating the entire rural water supply, when the majority of the water goes to stock, does seem like an inefficient thing to do. This is why the Rural Agricultural Drinking-Water Supplies (RADWSs) guidelines were drafted.

7.2 Rural Agricultural Drinking-Water Supplies

There are currently five RADWSs in New Zealand. These are Wainuioru Rural, Kaiwera, Otikerama, Montalto and Methven/Springfield. The opportunity to certify supplies as RADWS was introduced due to concerns that rural agricultural water suppliers would be unfairly burdened by the compliance requirements. Therefore, a separate class for rural agricultural drink ng-water supplies from which 75% or more of the water is used for agricultural purposes was developed

The intention was that compliance requirements would be reduced as water would not need to be treated for human consumption, this could be carried out more cost effectively through point-of-entry or point-of-use treatment. The guideline allows communities to decide who is responsible for the costs of treatment and maintaining the assets. Once certified as a RADWS scheme, there are a number of different options to comply.

Despite the large number of rural supplies in New Zealand, very few have sought RADWS status. This is largely due to confusion in the industry about the benefits and the liabilities. Even when a supply is certified as a RADWS, the water supplier is responsible for providing water that can be adequately treated by a point-of-entry or point-of-use system. These systems require low turbidity and so in many cases the supplier is forced to filter the water ahead of distribution. This can add considerable cost.

Many water suppliers struggle to understand where liabilities lie if a consumer falls ill from the water. The guidelines clearly state that the responsibility for the final water quality lies with the building owner as per the Building Act 2004. However, the supplier has a responsibility to advise the building owner of the water quality being supplied and what extra treatment may be required.

The low uptake in RADWS certification may be partially due to a low level of publicity around the guidelines. It is unknown how much promotion of these guidelines is carried out by DWAs but there is the potential to improve this. Additional guidance on the process for become RADWS certified could also be of value because in some instances the perception is that there is a large amount of additional work required to show proof.

7.3 Cost to Upgrade Rural Supplies

A list of rural drinking-water supplies was compiled by:

- Carrying out a general Google search for rural drinking-water supplies
- Reading the description of water supplies on every council website
  - Note that a number of water supplies not listed in the ESR database were identified with this process. In some instances it may because the council websites do not describe the supplies using their official name or because to supplies are not officially for drinking-water supply and are intended for stock water only.
- Searching the ESR database for the key words; rural, RWS, scheme and No
- Inclusion of additional rural schemes that are known to Beca through past work.

This methodology resulted in a list of 81 rural supplies and it is unlikely that this list is complete. This list is shown in Appendix B.

The cost of upgrading most of these rural supplies was compiled from the 2018 DIA costing database however 23 of these supplies serve populations of less than 100 people and so are considered neighbourhood supplies. This means that compliance is not reported on. The DIA costing database does include an estimate of upgrade costs for neighbourhood supplies based on an assumed compliance level, however, these estimates are likely to be insufficient for many rural supplies. Although these rural neighbourhood supplies serve small populations, they are likely to most have large capacities as they also provide stock water. Therefore, the cost to upgrade the 23 neighbourhood rural supplies has been estimated as an average of the cost of all other rural supplies.

Using the 2018 DIA costing database, the total cost to upgrade the 81 supplies was estimated to be $24.9 million ±30%. This is an average cost of $430,000 per water supply. As stated in Section 5.2, this estimate only includes costs directly associated with achieving compliance with the drinking-water standards. Both Scenario 1 and 2 from the 2018 DIA study are included. The current compliance status of supplies has not been revisited since the 2018 estimate and so it is possible that compliance of specific supplies has improved or lessened however the effect on the total estimate is likely to be small. The estimates assume that existing treatment plant capacities are adequate and therefore make no provision for capacity increases.

The cost estimates exclude upgrading or replacement of existing assets, or any other infrastructure which may be needed or desired as part of a treatment plant upgrading. Depending on the condition of the existing assets, and the appropriateness of the existing treatment process for the quality of the source water, these costs can be significant (in the order of $1 to $2 million per plant for smaller plants). There are 60 small plants on the rural supply list which means that the total costs could be significantly higher and in the realm of $85 - 150 million. Table 7-1 summarises the cost estimation results. As stated in Section 5.2, these estimates are likely to be less than the total required to upgrade all 42 rural supplies. Standardisation of designs or use of containerised/modular equipment solutions may reduce costs of some of the additional enabling works items.

Table 7-1: Summary of Cost to Upgrade Rural Supplies

Parameter	Value
Number of rural supplies identified	81
Number of neighbourhood rural supplies	23
Number of compliant rural supplies (does not include neighbourhood)	5
Estimate of Probable Capital Cost using 2018 DIA Database	$25 million ±30%
Estimate of Probable Capital Cost Including Allowance for Small Supplies	$85 – 150 million ±30%
Estimate of Probable Annual Operating Cost	$0.8 million

8 Areas of Weakness and Improvements

The capability categorisation included in Section 4.3 shows that there was a relatively high frequency of council-owned suppliers with the low score of 2 in management capability, staff training, procurement capability, asset management and quality. A one-hour long workshop was carried out with five senior Beca employees to brainstorm potential improvement methods to all capabilities with a focus on these weaknesses. The aim of the workshop was to discuss ways that the Ministry could influence drinking-water suppliers' capability, however many of the ideas listed below may be considered outside of the Ministry's control. For the purposes of the brainstorm, it was assumed that aggregation of drinking-water suppliers will not be mandated. Some of the possible improvement methods identified may become less relevant if aggregation occurs. The discussion outcomes are summarised in Table 8-1. The possible improvements that we believe have the most potential are shown in bold.

It would be beneficial to discuss these possible improvements, as well as brainstorm other options, in a workshop with the Ministry and DIA.

Table 8-1: Areas or Weakness and Improvements - Summary of Discussion Outcome

No.	Capability Category	Current Weakness	Possible Improvement
-	**General**		
	All	Considering the high importance of drinking-water, the industry has a relatively low standard of care when compared to other industries responsible for protecting human life such as transport and aeronautical	**A licensing system would improve practices. The licensing system should include an assessment of capability and low scores could result in increased support from the DWA or more serious action. Licensing could be required for all water suppliers (including specific self-supplies). The licence application form for private water suppliers in New South Wales** (2019) **includes requirements to show proof of organisational, technical and financial capacity. It seems to be a rigorous process where ownership, insurances and general capability are assessed. There are many other examples of rigorous licensing systems.** **The grading system is no longer used. This system made it clear to the public when improvements to their water supply were needed and made them more likely to agree with funding them. It also put pressure on asset**

No.	Capability Category	Current Weakness	Possible Improvement
			owners and those in governance to improve their grading. It is worth considering if this can be brought back into use in some form. **The licensing and/or grading systems could be linked to funding to provide further incentive to improve.**
		Non-council networked supplies specified self-supplies and self-supplies have particularly low capability	As discussed in Section 6.1, lifting the capability of the large number of non-council networked supplies, specified self-supplies and self-supplies would be a momentous task. For the purposes of this report we have assumed that non-council networked supplies would be transferred to councils, specified self-supplies would have operations and maintenance outsourced and self-supplies would continue to be operated as is. This would be a favourable scenario as non-council networked and specified self-supplies would be operated by more capable operators (generally). One of the most likely alternatives that would also improve capability is that the regulator is required to provide greater technical support and training for these supplies. This would require a much more hands on regulator. Affordability and the necessary upskilling for these supplies will be a key issue and so a comparison of costs for these two scenarios should be made.
1	**Governance**		
1.1	Governance – providing leadership and strategic direction, driving organisational culture, making skilled decisions,	Accountability is sometimes lacking. Council-owned supplies are governed by elected members who have control over important decisions but do not always see themselves as being responsible for providing safe	**Those in governance roles should a clear understanding of the risks and requirements for providing safe drinking-water. It is also important that control over decisions is matched with responsibility for the decision**

No.	Capability Category	Current Weakness	Possible Improvement
	and having accountability for decisions.	and compliant drinking-water. In some cases, they may be more concerned with public perception so that they can be re-elected.	**outcomes. This could be improved by:** • **Encouraging/requiring that those in governance roles are involved in WSP workshops so that they understand the risks and reasons for decisions being made** • **Requiring that WSPs include a list of individuals responsible for each aspect of the water supply so that decisions are made with more weight and transparent responsibility** • **Provide water suppliers with guidance or requirements for risk structure and the responsibilities for mitigating these risks** **Holding those in governance accountable for their decisions will likely mean that elected members will do more to educate the public so that they understand, and support, decisions being made.**
		Those in governance understand that compliance with the Health Act is a requirement but see compliance with the DWSNZ as optional. This means that less importance can be placed on it.	**Removing the "all practicable steps" clauses in the Health Act would make it clear that compliance with the DWSNZ is required.**
		Those in governance often have a limited understanding of best practice in drinking-water supply and may believe that compliance with the DWSNZ is the only target. Understanding of the other required capabilities is sometimes lacking.	As above, including those in governance in WSP workshops would increase understanding of risks. Making responsibilities clear would also encourage upskilling.
2	**Management**		

No.	Capability Category	Current Weakness	Possible Improvement
2.1	Management capability	Similar to listed above under governance, managers are not always fully aware of their responsibilities. They often have time, budget and political pressures applied to them from those that are more senior.	As above, requiring that WSPs include a list of individuals responsible for each aspect of the water supply will increase the understanding of decision-making importance.
		It is common to see inadequate resource and capability levels as well as a lack of succession planning for those operators and asset managers. General resourcing, and hiring successors for key staff before retirement, is often not fully in the control of managers as it relates to the budget available for salaries. However, managers should be able to have some influence on resourcing decisions.	Resource and succession planning guidelines could be prepared to provide guidance for drinking-water suppliers based on the number of supplies operated and the scale of them. These guidelines could also aid discussions that managers have with those more senior as it may strengthen the importance of further hiring.
2.2	Future planning	Long term plans are required for council-owned water supplies but how robust these plans are can vary. Some councils will consider climate change, scenario planning and risk reviews while others will not. Non-council water supplies often do not carry out future planning.	Requiring review of long-term plans may improve future planning. This is discussed further under 3.1.
2.3	Organisational culture	Collaboration between nearby water suppliers is currently limited. Increasing the level of collaboration would improve capability and may allow for efficiencies in shared designs, development of tools/systems and procurement methods.	Regulators could take more of a role in coordinating activities of adjacent water supplies. This may include coordinating regular meetings/workshops or sharing lessons learnt between water suppliers. Staff exchanges may also aid in collaboration.
2.4	Staff training	There are no requirements for operators and asset owners to be trained or licensed.	**Mandating training or having a licensing system would greatly increase the capability of many suppliers. This could be done**

No.	Capability Category	Current Weakness	Possible Improvement
			with a formalised apprenticeship programme or training regime. **It would be beneficial if there were multiple stages of training so that operators, in particular, could reach different levels of competency and see career progression options.**
		Small water suppliers often have only a small number of people and they are professionally isolated from others is the industry. They can struggle to develop systems and tools for operating water supplies. It has been observed that those small supplies that contract out operations often have better outcomes. This is because the companies that operations are contracted to tend to be national/international companies that have access to systems and procedures including H&S documentation, O&M manual templates, trainings and lessons learnt from other sites.	More could be done to link water suppliers together to improve efficiencies. Organisations like WIOG, Water NZ and IPWEA already provide conferences and training sessions however the cost and time commitments for these mean that not all can attend. Mandatory training as part of the licensing and career progression recommendation above may aid this.
3	**Financial Capability**		
3.1	Financial management	It is common to see unrealistic budgets in long term plans or no budget planning (especially for non-council supplies). It is also common to see that rates collected for three waters are used on other projects.	**All council-owned water suppliers are required to prepare long term plans with budgets but there is no such requirement for non-council suppliers. As discussed above, there is variation in how robust these long term plans are and it is also common to see inaccurate budget setting (optimism biases).** **A financial regulator could be established to provide oversight on the budgets being set in long term plans. The regulator would:**

No.	Capability Category	Current Weakness	Possible Improvement
			• **Compare the budgets set across all supplies as this may result in identification of projects that have been inadequately priced** • **Review and promote efficient procurement practice with a focus on whole of life costs** • **Confirm that money collected for water supply is in fact going fully to fund water supply** • **Check that funding for depreciation is occurring and that this funding is going to the correct assets** **Ideally this regulator would be for council and non-council owned water supplies.**
		Many smaller water suppliers struggle to provide affordable drinking-water due to a small number of rate/fee payers. Other water suppliers have difficulty collecting fees if the average income is low.	Ideally cost sharing would occur between larger/more affluent supplies and smaller/less affluent supplies. This is not always possible within the current structure of water suppliers. A system of subsidies for less affluent towns would be beneficial.
3.2	Procurement capability	Some water suppliers have ineffective procurement methods which mean that they do not always receive the goods and services required. This can be a result of procurement policies as well as inefficient project scoping. The procurement templates produced by New Zealand Government Procurement have worked well to date.	Shared service agreements between nearby water suppliers may aid in improving procurement outcomes. This may result in cost savings due to the economies of scale.
4	**Technical Capability**		
4.1	Water supply technical capability	In some cases, public health risk is not fully understood and	The training and licensing recommended above should

No.	Capability Category	Current Weakness	Possible Improvement
		meeting the DWSNZ is seen as a box ticking task.	include upskilling suppliers in public health and the related risks.
4.2	Competence in commercial, regulatory, engineering, public policy, Iwi interests and project management	Small water suppliers may find it difficult to employee people that are competent in a large range of required technical capabilities either because it is hard for them to attract these skilled individuals or because multiple people are generally required to provide these capabilities and the scale of the water suppliers does not allow for this.	**A number of possible improvements were discussed:** • **A series of standard designs and/or specifications would create cost and time efficiencies. It seems that there are repeating issues and similar resulting designs for many water suppliers throughout the country. There would be efficiencies in standardising the process and solutions. In some cases, these may be containerised or modular units.** • **A panel of designers and suppliers would allow water suppliers to select suitable services and equipment even if they have reduced understanding of the related technical capabilities**
5	**Systems**		
5.1	Risk and compliance	Historically, DWAs have been lenient in enforcing compliance. This has resulted in a reduced urgency for suppliers to improve compliance.	**DWAs should be Drinking-Water Compliance Officers in name and responsibility. Further ability to enforce is required.**
5.2	Asset management	Competencies in asset management can vary across water suppliers. Even within one council, asset management systems for transport are generally much better than those for water. This is at least partially because robust systems are required for NZTA funding.	**Linking funding to an organisation's capability in asset management (and other) would improve practices.**
5.3	Quality	Nothing specifically discussed	-

9 Concluding Remarks

The literature review carried out was valuable for informing the capability categorisation framework. The high-level categorisation of New Zealand's drinking-water suppliers gives an initial indication of where most suppliers lie, however it is important to emphasise that this categorisation was based on a judgement call and that it needs to be refined with further work.

The initial study has now been expanded to include part of the Stage 2 scope. Additional analysis and costing of high tourism, non-council and rural supplies has been included. This information has been further expanded on using information from the concurrent DIA study.

If the Ministry would like to gain a better understanding of the cost of compliance, then it is recommended that a pilot study is carried out. This could include assessment of the actual requirements (drinking-water upgrades and any enabling works) for a selection of water supplies in varying capacity and condition categories. These assessments could be used to improve the cost estimates of these schemes, and then used to benchmark the estimates completed to date.

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A

Appendix A – Tourist Data

Location	Permanent Population	Number of International Visitors	Ratio of International Visitors to Permanent Population	Ratio of max:min guest nights	Assumed WTP
From Tourism NZ Data					
Lake Tekapo	369	227,362	616	-	Tekapo
Punakaiki	100	42,762	428	-	Punakaiki
Milford Sound	220	83,106	378	-	Milford Sound
Fox Glacier	252	89,987	357	-	Fox Glacier
Aoraki/Mount Cook National Park	350	95,074	272	-	Mt Cook
Haast	240	49,320	206	-	Haast
Te Anau	2,628	419,526	160	-	Lake Te Anau
Franz Josef	2,611	386,040	148	-	Franz Josef
Akaroa	624	60,571	97	-	L Aube Hill
Paihia	1,719	153,728	89	-	Paihia
Hanmer Springs	840	72,383	86	-	Hanmer
Coromandel	1,503	102,668	68	-	Coromandel
Twizel	1,137	75,025	66	-	Twizel
Russell	720	38,946	54	-	Russell Township-Commercial
Queenstown	25,271	1,137,430	45	-	Kelvin Heights
Wanganui	1,215	46,882	39	-	Wanganui
Abel Tasman National Park	1,236	45,457	37	-	Richmond
Wanaka	13,633	499,656	37	-	Wanaka, Beacon WTP
				-	Wanaka, Western WTP
Picton	2,745	99,366	36	-	Speeds Road,Picton
Oamaru	2,475	76,893	31	-	Oamaru
Kaikoura	3,552	106,449	30	-	Mackles Bores
Hokitika	3,447	90,482	26	-	Blue Spur, Hokitika
Taupo	23,501	488,334	21	-	Lake Terrace
Whitianga	4,368	81,534	19	-	Whitianga
Waitomo	4,419	76,527	17	-	Mokau, Waitomo
				-	Waitomo Holdings Ltd
Rotorua	52,914	892,175	17	-	Matipo
				-	Utuhina
Raglan	2,736	45,847	17	-	Raglan

Westport	4,035	53,817	13	-	Sergeants Hill, Westport
Greymouth	8,320	96,323	12	-	Coal Creek, Greymouth
Tongariro National Park (Ruapehu)	No water supply	68,411	-	-	Tongariro National Park*
Waiheke Island	No water supply	50,910	-	-	Waiheke Island*
From Statistics NZ Data					
Central Otago	17,895	-	-	10.56	Alexandra
		-	-		Clyde
		-	-		Ranfurly
		-	-		Omakau
		-	-		Chatto Creek*
		-	-		Lauder*
		-	-		Oturehua*
		-	-		Wedderburn*
		-	-		Waipiata*
		-	-		Kokonga*
		-	-		Hyde*
		-	-		Middlemarch*
Clutha	16,890	-	-	5.6	Owaka
Fiordland	12	-	-	8.738	Lake Te Anau
Waitaki	20,829	-	-	7.14	Lower Waitaki Pumps
Whakatane - Kawerau	39,054	-	-	9.24	Whakatane Plant
Wairarapa	9,528		-	3.75	Huangarua Reservoir
		-	-		Ruamahanga

*No known WTP, costs not currently included

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B

Appendix B – Rural Water Supplies

1	Albury, Opawa Sream Sth
2	Albury, Opawa Stream Nth
3	Amuri Rural Pumphouse
4	Ashley Rural
5	Athol
6	Balmoral
7	Blueskin
8	Blythe Pumphouse - Hurunui No.1
9	Brunswick-Westmere
10	Bushy Creek Rural
11	Cannington/Motukaika
12	Clydevale Pomahaka
13	Coopers Creek
14	Dalethorpe
15	Dovedale Rural
16	Downlands
17	Dry Acheron, Selwyn RWS
18	Earnscleugh Water Scheme
19	Eastern Bush / Otahu Flat RWS
20	Eighty Eight Valley Rural
21	Evans Flat
22	Fernleigh Supply Plant
23	Fordell
24	Galatea Road Supply
25	Gary Rd Water Supply
26	Geraldine
27	Gibralter Rural Scheme
28	Glenkenich Rural
29	Glentunnel, Selwyn RWS
30	Hakataramea
31	Halcombe-Stanway
32	Hamama Rural
33	Hartleys Rd, Malvern Hills
34	Highbank Society Water Supply
35	Hikutaia
36	Hook/Waituna
37	Hunterville
38	Kaikoura East Coast Rural
39	Kaiwara
40	Kaiwera
41	Kincaid Rural Water Supply
42	Kiwitea Plant
43	Lichfield
44	Lower Moutere Scheme 1
45	Lower Moutere Scheme 2
46	Lower Waihao
47	Lower Waitaki Pumps
48	Lumsden, Lintley Road
49	Matatoki
50	Maxwell
51	Methven

52	Methven/Springfield
53	Moa Flat
54	Montalto
55	Mowhanau Beach TP
56	Mt Somers
57	North Bruce
58	Oaro
59	Oroua No. 1
60	Otaio/Makikihi
61	Otama
62	Otikerama
63	Parallel Rd, Pukerimu
64	Parnassus Rural
65	Peaks Pumphouse
66	Peel Forest
67	Puerua
68	Queensberry Irrigation Scheme
69	Queensbury, Indigo Scheme
70	Rangitata Huts
71	Rockford Road Pump Station
72	Seadown
73	Te H2 Oro Water Supply
74	Te Moana
75	Waiau Home Stream Plant
76	Waihaha Filter Station
77	Waihaorunga
78	Waikakahi
79	Wainuioru Rural Water
80	Waitahuna
81	Waituna West

RE-ASSESSMENT OF THE RISKS OF PROTOZOA IN NEW ZEALAND'S NATURAL WATERS

Kathryn Jessamine, Andrew Watson (Beca Ltd) and David Ogilvie (Ministry of Health)

ABSTRACT

The publication of the 1995 and 2000 editions of the Drinking Water Standards New Zealand (DWSNZ) expanded the focus of drinking water treatment onto the risks of protozoa. A large portion of the costs of the upgrading work on New Zealand's treatment plants since then has been in response to the addition of the protozoa requirements.

National baseline monitoring for protozoa in our natural waters has been going on since 2009, funded by the Ministry of Health and undertaken by Massey University. Over an 8.25 year period 28 sites across New Zealand were tested, including representative groundwater wells and springs, bush catchments, intermediate rivers and lowland rivers. The results show that:

- None of the samples collected from shallow groundwater/spring sites have contained protozoa although 8% of samples contained *E. coli*. These sites were deliberately selected because they were shallow or not secure, and had a history of occasionally containing *E. coli.*
- Less than 3% of bush catchment samples and less than 5% of intermediate river samples contained protozoa.
- No supplies sourcing water from lowland rivers would be required to achieve more than 3-log removal of *Cryptosporidium* oocysts for protozoal compliance.

The Catchment Risk Categorisation approach in DWSNZ (for supplies serving up to a population of 10,000) requires that shallow groundwater/spring sources need to achieve 3 log credits, intermediate river samples need to achieve 3 or 4 log credits, and lowland rivers need to achieve 4 log credits. Although DWSNZ allows for a water supplier to collect and analyse 26 samples over the course of a year to determine their source's specific protozoal risk, the $25,000 cost of this alternative approach can be a significant barrier for smaller water suppliers. The eight years of protozoal monitoring is showing that by using the Catchment Risk Categorisation approach, the risks of protozoa in a source water are likely to be overstated, particularly in groundwater.

The paper presents the results of the New Zealand monitoring for protozoa, considers this in the context of what has been found in the USA and elsewhere, discusses international legislative and best practice requirements and offers some provisional guidance on whether DWSNZ is too conservative. With DWSNZ likely to be revised as an outcome of the Havelock North Drinking Water Inquiry, this paper helps inform that revision process and may thereby reduce upgrading costs for smaller water supplies - particularly those that have groundwater as their source.

KEYWORDS

Drinking water, protozoa, source water, DWSNZ

PRESENTER PROFILE

Kathryn Jessamine is an environmental engineer with nine years of experience in the water industry in New Zealand, the United Kingdom and Canada. She also has a post-graduate diploma in public health and is particularly interested in the ways in which health, engineering and the environment are inextricably linked.

1 INTRODUCTION

Protozoa are a class of parasitic microorganism commonly found in surface waterways in New Zealand (Government Inquiry into Havelock North Drinking Water, 2017) and globally (US Environmental Protection Agency, 2002). Exposure to protozoa such as *Giardia* and *Cryptosporidium* can cause illness even in healthy individuals, usually acute gastrointestinal illness lasting two or more weeks (US Environmental Protection Agency, 2002; Ministry of Health, 2017). Exposure generally occurs from consuming food or water contaminated with protozoan oocysts originating from animal or human faecal matter. *Giardia* and *Cryptosporidium* are endemic in livestock, birds and domestic and feral animals in New Zealand (Government Inquiry into Havelock North Drinking Water, 2017) and diseases associated with these organisms are globally recognised as among the most common waterborne diseases (US Environmental Protection Agency, 2002). Due to the nature of gastrointestinal illness, many people do not seek medical attention and therefore a significant proportion of cases go unreported or unidentified (Ball, 2006).

Protozoa present a particularly difficult risk for water supplies because they can be infectious even at low levels of contamination. Only a single organism can cause illness (Boak & Packman, 2001; Bouchier, 1998). Oocysts can survive in adverse conditions (including anaerobic conditions), are resistant to conventional disinfection methods such as chlorination, are difficult to detect at such low concentrations, and are not well indicated by other indicator microorganisms (Craun, et al., 1998; Moulton-Hancock, et al., 2000; Bouchier, 1998; Rose, et al., 1991; Government Inquiry into Havelock North Drinking Water, 2017; Khaldi, et al., 2011). Oocyst viability in cold water or soil is estimated to be months or as much as a year (Dworkin, et al., 1996; Bouchier, 1998; Schmoll, et al., 2006).

The publication of the 1995 and 2000 editions of Drinking Water Standards New Zealand (DWSNZ) shifted the focus of drinking water treatment onto the risks of protozoa as a potential cause of illness. A large portion of the costs of the upgrading work on New Zealand's treatment plants since then has been in response to the addition of the protozoal requirements. Despite this, in 2016-2017, only 83.1% of the New Zealand population on networked drinking water supplies serving greater than 100 people were receiving drinking water that complied with the protozoa requirements of DWSNZ. Achievement against these requirements is more difficult for smaller water supplies, and this is reflected by lower compliance rates for water supplies serving 5,000 or fewer people (Ministry of Health, 2018).

Protozoa are generally considered to be a surface water problem because the filtering action of soil provides protection for groundwater sources (Boak & Packman, 2001; Schmoll, et al., 2006; Merkle & Macler, 2000; Howard, et al., 2006). This lowered risk for groundwater is acknowledged in the DWSNZ (Ministry of Health, 2018). However, Stage 2 of the Havelock North Drinking Water Enquiry reported that "*there is a wide body of evidence in the literature that Cryptosporidium outbreaks associated with groundwater supplies can and do occur*" (Government Inquiry into Havelock North Drinking Water, 2017). Monitoring of New Zealand's groundwater sources has yet to find evidence of protozoan contamination, and it may be that the current requirements for addressing the risks of protozoan contamination of drinking water in some groundwaters are overly onerous.

2 MONITORING OF AQUATIC PROTOZOA IN NEW ZEALAND

National baseline monitoring for protozoa in New Zealand's natural waters has been going on since 2009, funded by the Ministry of Health and undertaken by Massey University. Up to the end of March 2018 a total of 660 quarterly samples had been collected from 28 sites across New Zealand. The sites include representative groundwater bores and springs, bush catchments, intermediate rivers and lowland rivers. The results of this monitoring are summarised in Table 1 below.

Table 1: Summary of Massey University Protozoa Monitoring 2009 2018

Catchment Type	**Number of Sites as of 2018**	**% Samples Containing *Cryptosporidium***	**% Samples Containing *Giardia***
Groundwater/springs	8	0%	0%
Bush Catchments	No longer monitored[i]	1%	3%
Intermediate Rivers	7	1%	5%
Lowland Rivers	5	43%	59%

Analysis of the results shows that:

- None of the samples collected from shallow groundwater/spring sites have contained protozoa although 8% of samples contained *E. coli*. These sites were deliberately selected because they were shallow or not secure, and had a history of occasionally containing *E. coli*
- Although over 80% of samples from bush catchments and intermediate rivers contained *E. coli*, less than 3% of bush catchment samples and less than 5% of intermediate river samples contained protozoa.
- Although 43% of lowland river samples contained *Cryptosporidium* and 59% contained *Giardia*, no supplies sourcing water from lowland rivers would be required to achieve more than 3-log removal of *Cryptosporidium* oocysts for protozoal compliance.

In 8.25 years of monitoring, no protozoa have been found in groundwater/springs and very few samples from bush catchments or intermediate rivers have contained protozoa. Even though *Cryptosporidium* was found more frequently in lowland rivers, the concentrations of oocysts were less than 2.5 oocysts per 100mL, and were not high enough to require greater than 3 log removal. Most of the *Cryptosporidium* oocysts were found in autumn and spring.

We note that the samples are only taken quarterly and therefore, on the face of it, do not provide the same rigour of characterisation as the fortnightly sampling required in DWSNZ. However, for those sources which have been in the sampling programme for the full 8.25 years, 33 samples have been taken, in excess of the 26 required by DWSNZ.

Under the current DWSNZ, non-secure groundwater/springs would require 2-5 log removal for protozoa depending on the surrounding catchment characteristics. However, this monitoring indicates that this may be overly conservative since no protozoa have actually been found in New Zealand groundwater/springs in eight years. The remainder of this paper focuses on the risks of protozoa contamination of groundwater.

3 MANAGING PROTOZOA IN GROUNDWATER

Groundwater is widely used as a drinking water source internationally, as it is considered to be of *"generally good microbial quality in its natural state"* (Schmoll, et al., 2006). In the UK, 28% of drinking water comes from groundwater sources (Schmoll, et al., 2006) and in the USA, groundwater is commonly used for smaller water supplies and is often untreated (Macler, 1996; Murphy, et al., 2016; Schmoll, et al., 2006; Wallender, et al., 2014). In New Zealand, groundwater is a relatively common source of drinking water, with an estimated 45% of networked supplies serving more than 25 people having a groundwater source.

There is an argument that protozoa should not occur in 'true' groundwaters because their relatively large size (compared to bacteria and viruses) enables them to be entrapped within the layers of soil (Merkle & Macler, 2000; Ministry of Health, 2018). However, several recent reports acknowledge that contamination can and does occur (Bouchier, 1998; Schmoll, et al., 2006). Groundwater is sometimes referred to as the 'hidden sea' because the pollution pathways and processes are not visible, and are subsequently less well understood (Schmoll, et al., 2006).

3.1 NEW ZEALAND'S LEGISLATIVE REQUIREMENTS

In New Zealand the drinking water system is administered by the Ministry of Health primarily through the Health Act (1956) and DWSNZ. Following the Government Inquiry into the Havelock North drinking water contamination event, many aspects of the DWSNZ are under review.

Currently under the DWSNZ, protozoa are considered a priority 1 determinand and treatment is required for all water sources covered by the DWSNZ except for secure bore water. Bore water is considered secure if it can be demonstrated that contamination by pathogenic organisms is unlikely, including demonstrating that the source is not directly affected by surface or climatic influences through proving the age of water in the aquifer (greater than one year) or that the chemical composition of the water is stable. The bore itself must be satisfactorily constructed and sampling of water must prove absence of *E. coli* contamination (Ministry of Health, 2008).

For all other water sources (including non-secure groundwaters) compliance with the protozoa criteria is achieved when *"the treatment process used meets specified performance requirements"* (Ministry of Health, 2008). The minimum level of treatment required for groundwaters is 2 log removal for protozoa. The default log credit requirements are based on catchment type and are summarised for groundwaters in Table 2 (Ministry of Health, 2008).

Table 2: Default DWSNZ Protozoa Risk Assignment by Groundwater Type

Type of Groundwater	**Log Credits Required**
Springs and non-secure bore water 0 to 10 m deep are treated as requiring the same log credit as the surface water in the overlying catchment	3-5
Bore water drawn from an unconfined aquifer 10 to 30 m deep	3
Bore water drawn from deeper than 30 m	2
Secure, interim secure, and provisionally secure bore water	0

Alternatively, waters suppliers can collect and analyse 26 samples over the course of a year to determine their source's specific protozoal risk, however the $25,000 cost of this is a significant barrier for smaller water suppliers.

The Health Act also requires water supplies providing drinking water to more than 500 people to develop and maintain a water safety plan. A water safety plan is intended to describe the management of the water supply using quality assurance and risk management principles and to cover all aspects of the supply including source water issues, potential contaminant sources and pathways, and actions to be taken in the event of monitoring transgressions or treatment failures.

The DWSNZ relate to the performance of water supply systems, and does not contain specific requirements for the siting and security of bores, however extensive guidance is provided in the Guidelines (Ministry of Health, 2018).

3.2 INTERNATIONAL BEST PRACTICE

The requirements for addressing the risk of protozoa contamination in DWSNZ have largely been based on the US Environmental Protection Agency's (EPA) Surface Water Treatment Rule (1989), Long Term 2 Enhanced Surface Water Treatment Rule (2006) and Groundwater Treatment Rule (2006) because of the extensive work done in the USA in quantifying and investigating drinking water risk. The World Health Organisation (WHO) also provides guidance on the risks of protozoa in groundwater, and the concept of Water Safety Plans was adopted in New Zealand (as Public Health Risk Management Plans) prior to the release of the WHO Guidance. Elsewhere, many countries have been working on best practice guidelines for managing risks, including in the UK.

3.2.1 USA

In the USA the EPA considers the presence of protozoa in groundwater to indicate the risk of surface water contamination. Consequently, the EPA's Groundwater Rule does not include requirements for testing or treating for protozoa. Under the Groundwater Rule, limestone (karst), fractured bedrock and gravel aquifers are defined as 'sensitive' (US Environmental Protection Agency, 2006), and for these sources, the State must prove the presence of a hydrogeological barrier e.g. confining layer or carry out faecal indicator source water monitoring to retain 'true' groundwater status (Schmoll, et al., 2006).

Groundwaters not able to meet the Groundwater Rule requirements are covered by the Surface Water Treatment Rule (SWTR), and are referred to as groundwater under direct influence (GWUDI). The SWTR defines GWUDI as "*any water beneath the surface of the ground with* (Department of Health Drinking Water Section, 2005)*:*

1. *"significant occurrence of insects or other microorganisms, algae or large-diameter pathogens such as Giardia, or*

2. *significant and relatively rapid shifts in water characteristics such as temperature, conductivity, turbidity, or pH which correlate closely with climatological change or surface water conditions."*

This definition implies that the groundwater source is located close enough to a surface water source that it can receive direct surface water recharge and is therefore at risk of contamination from protozoa which are not normally found in 'true' groundwaters.

Each State is responsible for determining the conditions that signify GWUDI. Two examples of the approach taken by States, from Connecticut and Ohio, are summarised below. Connecticut carries out a preliminary assessment to determine if a groundwater source is potentially GWUDI (Department of Health Drinking Water Section, 2005). The assessment considers:

- Distance from surface water sources
- History of disease outbreaks
- Monitoring history for indicator organisms
- Turbidity
- Construction of bore

If an existing or new groundwater source fails to meet any of the criteria in the preliminary assessment, it is considered to potentially be under the influence of surface water. That source must then carry out further testing to prove that it s not GWUDI, carry out remedial works so that the preliminary assessment criteria are met, or provide treatment in accordance with the SWTR.

Ohio determined that a "*standard, but flexible*" approach to determining the potential of aquifer contamination is best. The resultant prescriptive process is designed to promote uniform application across all sites (Ohio EPA, 2014). The risk assessment process is triggered by positive *E. coli* results or persistent total coliforms in existing groundwater wells or in new well approval samples. A Hydrogeologic Sensitivity Assessment (HSA) is then carried out. If required, the HSA may recommend that further investigation, in the form of an Assessment Source Water Monitoring (ASWM) is carried out.

The HSA is a risk assessment process, that produces a "*relative ranking of the source water sensitivity to pathogen contamination*" (Ohio EPA, 2014). The HSA assigns positive or negative scores based on the hydrogeologic barriers and recharge pathways identified at the supply site. This produces a 'barrier index' which provides a relative measure of the risk of contamination at that site. The HSA scores for the following criteria:

- Source water susceptibility
- Vadose zone characteristics
- Saturated zone characteristics
- Aquifer characteristics
- Potential for induced recharge
- Well construction

Based on the barrier index, a source is classified as 'pathogen sensitive', 'Intermediate Sensitivity' or "Pathogen Non-Sensitive". This classification then guides how the source catchment should be managed.

3.2.2 WORLD HEALTH ORGANISATION

The World Health Organisation has a Framework for Safe Drinking-Water based on three key requirements (Schmoll, et al., 2006):

- Health based targets based on an evaluation of health concerns
- Development of a Water Safety Plan
- A system of independent surveillance that verifies that the system is operation properly

Water Safety Plans are considered a means of "*comprehensive risk assessment and risk management….that encompasses all steps in the water supply from catchment to consumer*" (World Health Organisation, 2017). There are three key components of a water safety plan:

- System assessment to determine if the water supply can deliver water of a quality (and quantity) that meets targets
- Identifying operational control measures to identify changes in water quality
- Management and communication plans

Specific to the risks of protozoa in groundwater, WHO guidance recognises that groundwater is often of good microbial quality but the potential for contamination exists if the protective measures provided by natural filtering mechanisms of the soil are short circuited (above or below ground), and that contamination is more widespread than previously believed (Schmoll, et al., 2006; World Health Organisat on, 2017). However, the WHO guidance also acknowledges that although a *"significant percentage of groundwater sources are contaminated"*, bacteria and viruses are the main agents of contamination and recognises that *"in developed countries…viruses can be regarded as the most critical microorganisms with respect to groundwater contamination and health risks"* (Schmoll, et al., 2006).

Shallow groundwater is assumed to be at the greatest risk of contamination because of the potential for it to be under direct influence of surface water, and treatment is generally for these sources is recommended. Deeper and confined aquifers are regarded as being at lesser risk of contamination and are generally considered to be well protected from contamination without treatment (World Health Organisation, 2017).

The WHO also provides extensive guidance on assessing the potential for groundwater contamination and managing agricultural, social and industrial sources of pollution. The guidance is intended to indicate the scope and scale of assessment, rather than technical guidance. The WHO promotes the use of water safety plans, groundwater protection zones and sanitary surveys as tools to protect groundwater sources.

3.2.3 ELSEWHERE

Suggested best practice management for contamination of groundwater is similar to that provided in Guidelines (Ministry of Health, 2018) and generally includes the following aspects (Merkle & Macler, 2000; Wallender, et al., 2014):

- Source water protection barriers (e.g. location in relation to surface water and sewage sources)
- Well and water system integrity barriers
- Septic system design and maintenance
- Operations and system maintenance barriers
- Disinfection requirements.

Some larger water suppliers have established protocols for assessing the risk of protozoan contamination in groundwater supplies. At Southern Water in the UK, the risk assessment procedure identifies ten key factors for protozoan contamination (Boak & Packman, 2001). For each factor, the appropriate risk level for a particular supply is selected from a hierarchy which gives a score for each factor. Each factor is weighted slightly differently to produce a final overall risk score. The ten key factors are:

- Land use (intensity of livestock)
- Sewers and septic tanks (intensity)
- Geology/hydrogeology (aquifer type and cover)
- Potential for rapid bypass of aquifer unsaturated zone
- Potential for induced recharge from surface water bodies
- Site drainage
- Borehole construction/integrity
- Headworks
- Historic water quality
- Treatment level

The final risk score allows the sources to be prioritised (high, medium and low) and is used to determine which sources should have continuous Cryptosporidium monitoring and for more detailed investigation and, if required, remedial action should take place.

4 OUTBREAKS OF WATERBORNE PROTOZOAN ILLNESS

Outbreaks of waterborne, protozoan illness in New Zealand are relatively common, however there is insufficient information available to be able link these outbreaks with groundwater supplies. Overseas there are a number of reported outbreaks of cryptosporidiosis and giardiasis associated with groundwater supplies, however many of these have clear system and/or hydrogeological shortfalls that have led to contamination of the source.

Factors contributing to potential for contamination of groundwater have been identified in the literature. Several of these have been identified as likely causes of contamination in outbreak reports. The main contamination factors are listed below, and generally match with the management best practices discussed earlier (Macler, 1996; Bouchier, 1998; Hynds, et al., 2014; Ministry of Health, 2018):

- Quality of bore construction
- Proximity to contamination sources e.g. septic tanks, livestock
- Security of bore heads (poorly constructed bores three times more likely to have protozoan contamination (Hynds, et al., 2014))
- Hydrogeologic conditions including karst or fissure-dominated flow conditions, connections to river aquifers, shallow vadose zone, shallow aquifer depth
- Proximity to surface water
- Heavy rainfall events

Several studies have shown that attack rates for waterborne protozoan illness are often higher in communities with groundwater supplies compared to communities with surface water supplies (Frost, et al., 1997; Craun, et al., 1998; Wallender, et al., 2014). This may be due to endemic presence of protozoa in surface waters leading to a certain level of resistance amongst individuals who regularly consume that water. In contrast, in groundwater supplies, contamination is more of a transient event, and those drinking the contaminated water do not have a tolerance and are therefore more susceptible to developing illness as a result of the contamination.

4.1 NEW ZEALAND

Giardiasis and cryptosporidiosis are notifiable diseases in New Zealand and the numbers of outbreaks in New Zealand are reported on each year. In 2014, 2015 and 2016 (the latest three years where information is available), *Giardia* and *Cryptosporidium* were the top two causes of waterborne disease outbreaks in New Zealand (by number of outbreaks), as summarised in Table 3 (ESR, 2018; ESR, 2016; ESR, 2015). However, there is insufficient information to be able to attribute the outbreaks to a specific type of water (surface or ground) supply.

Table 3: Waterborne Protozoa Outbreaks in New Zealand

Year	2014	2015	2016
Number of Giardiasis and Cryptosporidiosis outbreaks	33	12	8
Total number waterborne outbreaks	42	19	14
Number of notified cases of Giardiasis and Cryptosporidiosis	103	73	25
Total number of notified cases of waterborne illness	131	89	1007[ii]

The following is a list of historic outbreaks of waterborne illness caused by protozoa (Ball, 2006; Ministry for the Environment, 2007). Only one, at Peketa in 1996, is known to have had a groundwater source. For the remaining outbreaks, the source of drinking water is surface water or unknown.

- Dunedin, 1987-1988: Increased risk of giardiasis in micro-strained part of water supply compared with sand-filtered part in a surface water supply (Fraser & Cooke, 1991).
- Whangarei, 1990: increased incidence of giardiasis in the part of the city with unfiltered water
- Auckland, 1993: 34 cases of giardiasis.
- Tauranga, 1995: one notification of cryptosporidiosis at a school.
- Denniston, 1996: four cases of giardiasis in an unregistered, untreated, unprotected water supply
- Peketa (Kaikoura District), 1996: three cases of giardiasis, groundwater supply reported to be discoloured and faecal coliforms detected.
- Waikato (Ohinemuri, Morrinsville), 1996/97: 14 cases of giardiasis.
- Waikato district 1997: 170 cases of cryptosporidiosis. Associated with turbidity spikes in water supply originating from filter backwash and/or backflow from farms. No oocysts or faecal coliforms detected.
- Tauranga district, 1997: cryptosporidiosis from bore water source but illness associated with contamination of open storage tank
- Masterton, 2003: *Cryptosporidium* detected in water supply, but no cases of disease.

4.2 OVERSEAS

A review of international literature found a number of reported outbreaks of giardiasis and cryptosporidiosis associated with groundwater supplies. These are listed in Appendix A. In many of the outbreaks reported, it was either not possible to identify the relative security of the groundwater source from the information available or there was an easily identifiable route of contamination, generally because of poor bore construction or contamination from surface water. Many of the types of groundwater sources involved in the outbreaks, e.g. those with adits (infiltration galleries) (Bouchier, 1998) would be discouraged from use in New Zealand. In the USA, many outbreaks associated with protozoa in (assumed secure) groundwater supplies were later found to be under the influence of surface water (US Environmental Protection Agency, 2006). A study in Norway did not find protozoa to be the cause of any outbreaks associated with groundwater between 1984 and 2007 (Kvitsand & Fiksdal, 2010).

Many groundwater supplies are untreated, and several of the outbreak studies focused on untreated groundwater supplies. However, outbreaks were also reported in groundwater supplies with treatment, suggesting that poor aquifer management and bore security, rather than simply a lack of treatment, are significant factors in protecting groundwater supplies from protozoan contamination.

5 MONITORING OF PROTOZOA IN GROUNDWATER

Although monitoring of non-secure groundwater in New Zealand has not yet found protozoa, they have been found in the USA, the UK and elsewhere.

In general, the quality of monitoring data is limited unless details of the hydrogeological and bore construction conditions are known and can be linked directly to the number of samples testing positive for protozoa. In many cases this information is not available. Other sources have also noted that although they are aware of protozoa monitoring programmes, the data is not always published or available (Merkle & Macler, 2000). It may be that the monitoring data available is subject to publication bias where only those studies obtaining positive results (that being the unusual or unexpected result) making it to publication.

Monitoring results are also influenced by the sample methodology, sample volume (Boak & Packman, 2001) and testing methods. Some studies have found that protozoa counts are seasonal (Rose, et al., 1991; Gallas-Lindemann, et al., 2013; Ministry of Health, 2018), and others that protozoa is more likely to be found under continuous pumping conditions or with increased sampling frequencies (Khaldi, et al., 2011; Bouchier, 1998).

5.1 NEW ZEALAND

The results of the ongoing monitoring by Massey University for the Ministry of Health show that none of the 160 samples collected from eight shallow groundwater/spring sites over the last eight years have contained protozoa. These sites were deliberately selected because they were shallow or not secure, and had a history of occasionally containing *E. coli*. Details of the eight groundwater/spring sites are summarised in Table 4.

Table 4: Summary of Groundwater Monitoring Sites in Massey Study

Site number	Description
1	Fed by two springs in high-productivity pastoral area Depth <10 m at well head
2	Natural spring. Depth <10 m
3	Bore (not secure) in urban area. Depth 20 to 40 m
4	Bore in high-productivity pastoral area. Depth <10 m
5*	Spring: 3500 m3/d.
6*	Spring: 3300 m3/d.
7*	Well
8*	Rural bore

* Sites 5-8 added to study in September 2016

Earlier testing in 2008-2009 by Massey University for the Ministry of Health found no protozoa in 65 samples taken from seven shallow bores. Individual water suppliers have also been monitoring bores for protozoa and provided results to the Ministry of Health. A further 759 samples were collected from 29 non-secure bores around New Zealand did not find protozoa. Recent testing in Hastings (following the Havelock North outbreak) took 382 samples from 7 bores and did not find any protozoa.

A summary of all the available New Zealand monitoring data is provided in Table 5. No protozoa have been found in more than 1,366 samples taken from 51 non-secure and secure bores in New Zealand in the period 2005-2018.

Table 5: Summary of New Zealand Groundwater Protozoa Monitoring

Study	Number of Samples	Number of Sites
Massey 2009-2018 (ongoing)	160	8
Massey 2008-2009	65	7
Water Supplier Monitoring 2005-2018	759	29
Hastings 2016-2018	382	7
Total	1,366	51

5.2 OVERSEAS

A literature search for international monitoring for protozoa in groundwater found 15 studies and one pooled analysis across nine countries in North America and Europe. The results of these studies are summarised in Appendix B.

Of the 15 studies found, only two reported not finding protozoa in the groundwater samples tested. In the pooled analysis, *Cryptosporidium* was found in 6 out of 9 studies and *Giardia* in 3 out of 10 studies. Eleven of the 14 studies contained sufficient information to estimate the number of samples that tested positive for *Giardia* or *Cryptosporidium*. Out of 507 groundwater samples taken, 73 tested positive for either *Giardia*, *Cryptosporidium*, or both[iii].

Some of the studies compared contamination in different types of groundwater. Unsurprisingly, infiltration galleries were found to be more likely to be contaminated than springs, with vertical wells least likely to be contaminated (Moulton-Hancock, et al., 2000, Hibler 1988 in Hancock, et al., 1998).

6 CONTAMINATION PATHWAYS

Although groundwater has previously been considered a 'safe' source of drinking water free from protozoa, recent literature has begun to highlight the potential risks of protozoan contamination of groundwater. There is growing recognition that "*not all groundwater is of consistently high quality*" and that there is possibility for rapid contamination of groundwater from surface water sources, especially after rainfall recharge (Bouchier, 1998). The previous sections have demonstrated that protozoan contamination of groundwater is occurring, and this section outlines the potential pathways through which contamination may be happening.

The structure of the aquifer and the soil layers above it affects how water and contaminants (including protozoa) are transported. The depth to water table and soil moisture are important factors in the ability of soil above the aquifer to provide a barrier to contamination by filtering out microorganisms. In aquifers with shallow cover, there is a shorter distance over which straining can occur, and soil moisture facilitates movement of contaminants as well as limiting adsorption in the soil. The ability of a soil matrix to filter out protozoa depends on the relative size of the oocysts to the pores. Entrapment of pathogens is most effective in the upper soil layers due to predatory organisms, competition from established microbial communities and sunlight and up to 99% of *Cryptosporidium* oocysts are retained in the upper soil layers Schmoll, et al., 2006). This straining mechanism can be bypassed, for example by sewers located below the soil zone. Shallow groundwater sources are more likely to be impacted by heavy rainfall, due to direct surface water contamination and mobilisation of organisms in the unsaturated zone by water percolating. (Schmoll, et al., 2006).

The characteristics of the aquifer also influence the potential for protozoan contamination. In dual porosity type aquifers, water is mainly stored in interstices in the rock matrix, with flows occurring through fractures which are much larger than oocysts. Evidence suggests that these type of aquifers (fractured rock and karst with limited unconsolidated soil overlayers) allow protozoan contamination despite not being influenced by surface water (Merkle & Macler, 2000). Other aquifers are granular and these may provide improved straining of contaminants depending on pore size (Morris & Foster, 2000). Figure 1 shows that *Cryptosporidium* oocysts are larger than the typical 1µm pore size of chalk aquifers, but within the pore size range for other aquifer types e.g. sandstone (Bouchier, 1998).

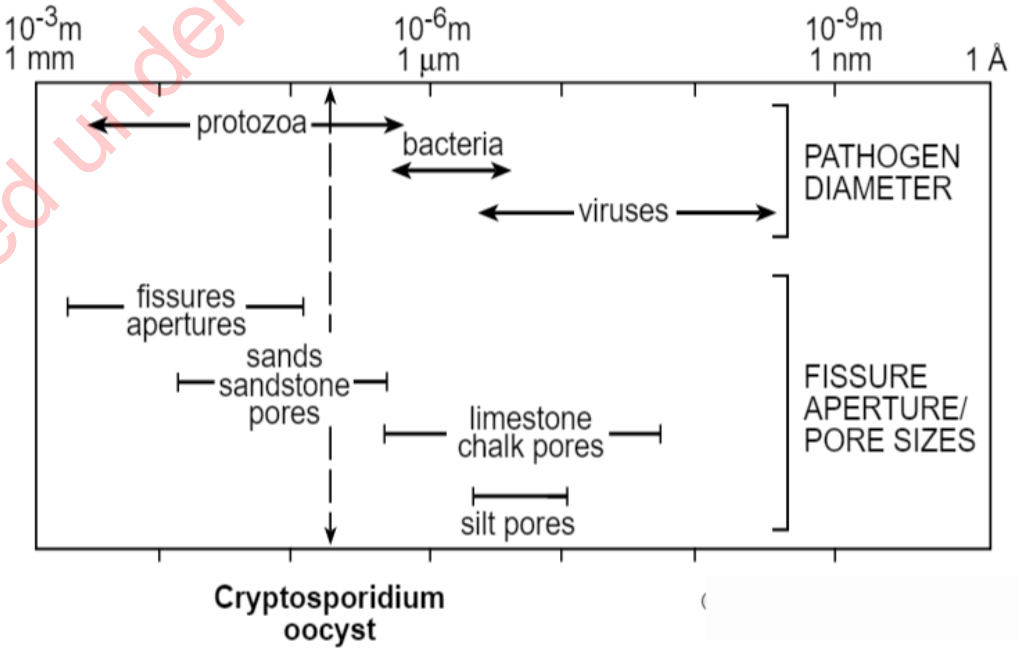

Figure 1: Pathogen diameters compared to aquifer matrix dimensions (taken from ARGOSS, 2001; British Geological Survey ©NERC in Schmoll, et al., 2006)

Aquifer vulnerability can be classified based on the level of confinement, aquifer attenuation ability and the travel time to the saturation zone. The residence time in aquifers can also be a barrier for contamination (if it exceeds the expected lifespan of an oocyst). In karstic aquifers the residence time is only weeks to months, whereas in sedimentary and deep aquifers the residence time is measured in years. The distance to the contamination source is also important. Contaminants can be transported long distances in karst or, highly fractured aquifers, but for other types of aquifer, the distance is limited to tens or hundreds of metres depending on the specific hydrogeology (Schmoll et al., 2006).

7 DISCUSSION AND CONCLUSIONS

The Havelock North Drinking Water Inquiry has focused attention on the vulnerability of groundwater and bores to microbial contamination. Eight years of monitoring of non-secure groundwater in New Zealand has not found any evidence of protozoan contamination, and suggests that the treatment requirements in New Zealand may be too conservative.

Internationally, outbreaks of waterborne protozoan illness and positive results for protozoa in groundwaters are being reported. However, from the information available, often the presence of protozoa in groundwater can be attributed to contamination occurring due to unfavourable hydrogeological conditions, or poor bore security and/or construction. Some of the geological conditions known to have the higher risks of contamination e.g. karst aquifers, are uncommon in New Zealand[iv]. International best practice uses the presence/absence of protozoa as an indication if a groundwater source is at risk of contamination from surface water, but the New Zealand data shows that even though E. coli was present in 8% of samples no protozoa were found

Currently the DWSNZ requires all non-secure groundwater supplies to provide treatment for protozoa (except for supplies serving up to 500 people who choose Section 10 compliance). This is particularly problematic for small water suppliers as even if they spend money to carry out testing and prove their source is at a reduced risk, a minimum of 2-log removal for protozoa is still required. The monitoring carried out to date suggests that these non-secure groundwater supplies in New Zealand may not be at risk of protozoan contamination. The WHO suggests that, based on their small size and longevity in the environment, viruses have the highest potential to be transported to and within groundwater and that bacteria and viruses should be the microbiological contaminants of priority for groundwater supplies (Schmoll, et al., 2006).

As a result of the Havelock North Drinking Water Inquiry, many aspects of the current drinking water system are being examined and with the expected changes to the DWSNZ there is a window of opportunity to make changes. At the time of writing, the Ministry of Health has already convened working groups to discuss, amongst a variety of other issues, the relative risks of protozoa in groundwater. The DWSNZ should balance the need to protect the health of New Zealanders against risks and costs, and identify priority microbiological contaminants. Based on the information presented in this paper, it would appear that the requirements for the control of protozoal risk as categorised in the current DWSNZ do not reflect the actual presence of this organism in New Zealand groundwater and should be managed with lower default controls compared to bacteria and viruses, which should continue to be areas of focus. In order to support this there are two recommended courses of action:

- Review US State guidance on determining risk of groundwater contamination

- Investigations into the transportation and entrapment of protozoa in New Zealand aquifers

The authors also recommend that the value of continuing the current protozoan monitoring programme should be re-assessed in the light of the results to date and the findings of this paper.

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[i] Previously seven sites were monitored. None had protozoa numbers high enough to require greater than 3-log removal

[ii] In 2016 there were a large number of notified cases due to a large outbreak of campylobacter in Havelock North

[iii] This is an estimate only as it was not always possible to determine whether positive results occurred simultaneously or separately for *Cryptosporidium* and *Giardia*

[iv] Information about aquifers in New Zealand can be found at https://data.mfe.govt nz/layer/52675-location-and-extent-of-nzs-aquifers-2015/data/

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APPENDIX A – SUMMARY OF INTERNATIONAL OUTBREAKS OF WATERBORNE PROTOZOAN ILLNESS

Location	Time	Outbreak details	Hydrogeological details	Contamination pathway
Unknown - could be UK and/or USA	Unknown	5 of 11 cryptosporidiosis outbreaks (Lisle and Rose 1995 in Hancock, et al., 1998)	Groundwater or springs	Not detailed
USA	Unknown	33% of the 12 most recent waterborne outbreaks of cryptosporidiosis (Hancock, et al., 1997 in Morris & Foster, 2000)	Groundwater wells	Not detailed
North Thames, UK	1997	1 outbreak with 345 confirmed cases of cryptosporidiosis (Willocks, et al., 1998)	Deep chalk wells in a semi-rural area close to river	Suspect ingress through chalk interstices or surface water contamination through a bore fault. Unusual weather conditions (dry followed by rain)
USA	1971-2008 1971-2011	14 of 248 outbreaks associated with untreated groundwater were caused by *Giardia* (240 of 23,478 cases) (Wallender, et al., 2014) 13.3% of waterborne disease outbreaks caused by *Giardia* however in the more recent period 1990-2011 this has risen to 33.3% (Adam, et al., 2016)	Untreated groundwater (includes GWUDI)	Not detailed These two studies may use the same CDC data set
Washington State, USA	1994	1 outbreak (Dworkin, et al., 1996)	Two deep wells	Suspected contamination from adjacent treated effluent irrigation system due to poor condition of well and poor condition of irrigation system
Warrington, UK	1992-1993	1 outbreak with 47 reported cases (Bridgman, et al., 1995)	Sandstone aquifer with shallow cover. Deep vertical wells	Subsidence and fissures provide route for ingress of surface water. One of the wells also found to drain a nearby field

England, UK	1990-1998	11 suspected *Cryptosporidium* groundwater contamination events (Bouchier, 1998)	Wells and springs in a range of aquifer types including river gravels, sandstone, chalk and karstic limestone	Surface water contamination noted as possible contamination route for many
Texas, USA	1998	One outbreak of cryptosporidiosis with 89 confirmed and 1300-1500 unconfirmed cases (Bergmire-Sweat, et al., 1999 in Howard, et al., 2006)	Deep wells (>30m) in a karst aquifer. Wells located 400m from creek	Not detailed.
Pennsylvania, USA	1993	551 cases of cryptosporidiosis (Moore, et al., 1993 in US Environmental Protection Agency, 2006)	Karst aquifer	Not detailed.
Norway	1984 – 2007	None out of 102 outbreaks were associated with protozoa (Kvitsand & Fiksdal, 2010)	Various groundwater	Not applicable

APPENDIX B – SUMMARY OF INTERNATIONAL MONITORING OF PROTOZOA IN GROUNDWATER

Entries in bold have been included in the sample summary presented in Section 5.

Location	Findings	Comments
20 states in the USA	19 of 166 groundwater sites tested positive for *Giardia* and/or *Cryptosporidium* (Moulton-Hancock, et al., 2000): • 211 samples from 121 vertical wells. 5% sites positive • 48 samples from 31 springs. 23% sites positive • 80 samples from 10 horizontal wells. 40% sites positive • 44 samples from 4 infiltration galleries. 50% sites positive	Number of positive samples not provided (only sites) Note some of the data from this study may be included in the Hynds pooled analysis
17 states in the USA	• **1 of 18 groundwater sources positive for *Giardia*** (Hancock, et al., 1998) • **6 of 7 spring samples positive for *Cryptosporidium*** (Rose, et al., 1991) • **0 of 7 spring samples positive for *Giardia*** (Rose, et al., 1991)	**No further details available**
USA	17 of 74 wells tested positive for *Cryptosporidium* (Hancock, et al., 1997 in Morris & Foster, 2000)	No further details, including number of samples available
Ohio, USA	16 samples from 16 wells did not find protozoa (Fong, et al., 2007)	No further details available
Washington State, USA	**1 of 2 samples from 2 wells tested positive for *Cryptosporidium*** (Dworkin, et al., 1996)	**Deep Wells (150m and 180m) adjacent to wastewater irrigation system** **Note this study is included in the Hynds pooled analysis**
USA and Canada	*Cryptosporidium* found in 6 of 9 studies *Giardia* founds in 3 of 10 studies (Hynds, et al., 2014)	Karstified, unconsolidated, fractured bedrock, un-fractured bedrock and diverse. Limited information available to be able to link studies to number of samples or groundwater type
Unknown (possibly Canada)	• 5 of 36 springs and • 2 or 40 wells and • 5 of 16 infiltration galleries Tested positive for *Giardia* (Hibler 1988 in Hancock, et al., 1998)	Number of samples unknown Note this study may be included in the Hynds pooled analysis

England	**Approximately 8 out of 258 samples tested positive for *Cryptosporidium* at 3 of 6 sites** (National Cryptosporidium Survey Group, 1992)	**Positive results occurred in late spring. Sites chosen because they were considered 'safe' deep boreholes, or where quality was known to be affected by rainfall or surface water**
Italy	• **No *Giardia* or *Cryptosporidium* found in 14 samples at one site** (Briancesco & Bonadonna, 2005) • **2 of 18 groundwater samples positive for *Giardia* and 0 of 18 for *Cryptosporidium* (Lonigro, et al., 2006 in Giangaspero, et al., 2007)** • **2 of 14 groundwater samples positive for *Giardia* and 1 of 14 for *Cryptosporidium* (Di Benedetto, et al., 2005 in Giangaspero, et al., 2007)**	**No further details available**
Finland	**40 samples taken from 20 sites and 4 samples at 4 sites positive for *Giardia*** (Pitkänen, et al., 2015) • **1 driven in unconfined, sand and gravel aquifer, well depth 8m** • **2 dug in semiconfined sandy aquifers, well depth <5m** • **1 drilled in deep confined, bedrock aquifer, depth unknown**	**Well types selected based on high potential for contamination. Aquifer types varied. Positive results in autumn.**
France	• **8 of 9 spring samples positive for *Cryptosporidium* and 1 of 9 for *Giardia*** • **4 of 9 wellbore samples positive for *Cryptosporidium* and 0 of 9 for *Giardia*** • **9 of 9 continuously pumped wellbore samples positive for *Cryptosporidium* and 1 of 9 for *Giardia*** (Khaldi, et al., 2011)	**Site located in karst aquifer in area of agricultural land use plus direct influence of surface water**
Portugal	**1 of 39 samples from a single groundwater site positive for giardia and 23 of 39 positive for *Cryptosporidium*** (Lobo, et al., 2009)	**No further details available**
Norway	**20 samples taken from 20 groundwater sites** (Gaut, et al., 2008)**:** • **3 of 20 samples positive for *Cryptosporidium*** • **0 of 20 samples positive for *Giardia***	**Bedrock**
Germany	**5 of 66 groundwater samples positive for *Cryptosporidium* and 1 of 66 for *Giardia*** (Gallas-Lindemann, et al., 2013)	**Radial and vertical well(s) further detail unknown**