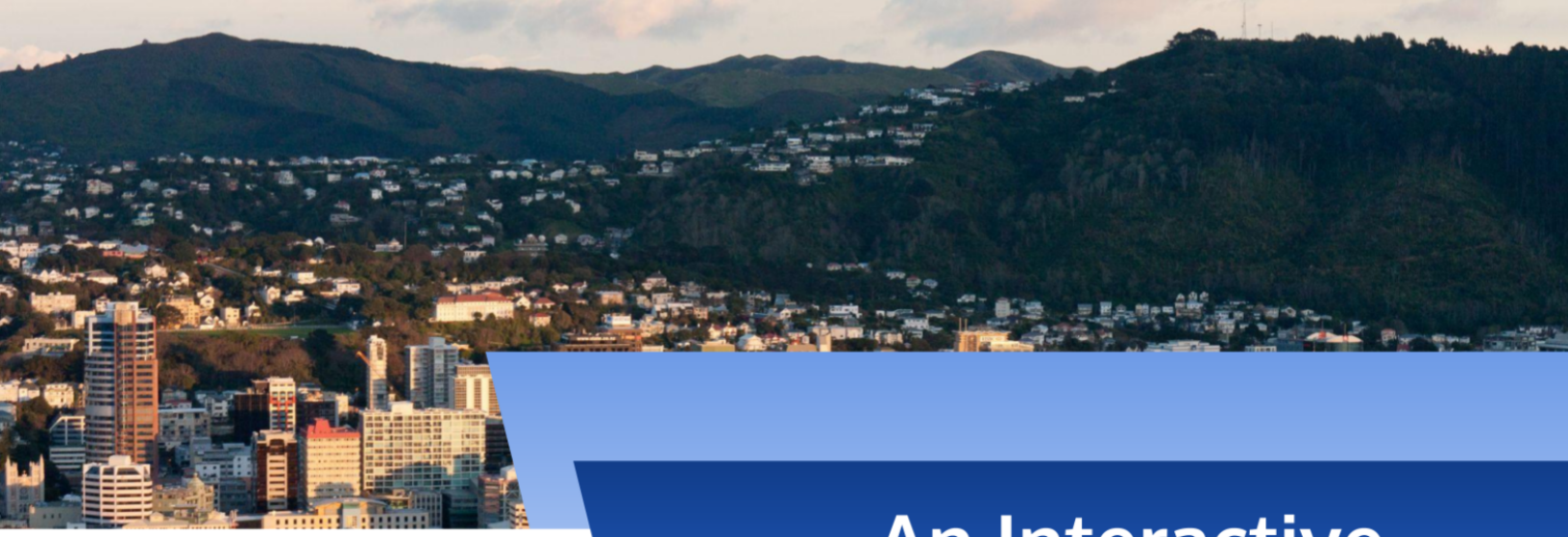

2022

An Interactive Qualifying Project
Wellington, NZ

Assessing Innovative Freshwater Management Solutions

In collaboration with the Greater Wellington Regional Council and the Whaitua Te Whanganui-a-Tara Committee

Authors:

James Barrera, Reagan Brunelle,
John Gabelmann, Michaela Mattson

March 4, 2022

WPI

Greater Wellington
Te Pane Matua Taiao

Assessing Innovative Freshwater Management Solutions in Wellington, New Zealand

An Interactive Qualifying Project submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the degree of Bachelor of Science

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Abstract

The purpose of our project was to create a set of recommendations to improve water quality in Wellington, New Zealand. We accomplished this by interviewing water quality experts in Wellington as well as Massachusetts, U.S, and reviewing successful water quality management practices implemented in Massachusetts and beyond. Our research identified areas of critical need and potential intervention in Wellington. Our recommendations include possible communication strategies needed to make the proposed technical solutions more effective within the context of Wellington.

Acknowledgments

We want to thank several people and organizations who helped make this project possible. Primarily, we would like to thank WPI and the GWRC for allowing us to complete this project and interact with real-world problems and solutions.

We want to extend a huge thank you to our primary sponsors, Pat van Berkel, Tim Sharp, and Ross Jackson for providing invaluable education and guidance on the intricacies of water quality struggles in Wellington. They are phenomenal people and have been a large contributing factor to ensuring this project ran smoothly and bore good results.

We would also like to thank the WPI faculty who advised us in this process, Ingrid Shockey, Shana Lessing, and Yunus Telliel. They ensured that our project stayed on track and that all of our ideas were taken into account and communicated effectively in this report. Without them, this project would have been a near-impossible task to complete in the allotted time frame.

Finally, we want to thank all of the people who agreed to talk to us in our series of interviews. We started this project with little to no knowledge of water quality, and with the help of these 9 people, assembled this entire report with a bit of help from outside sources. The goodwill required to educate and assist a team of students, and give them a look into the incredibly intricate world of water quality management, is something which we are very grateful for.

Authorship

Our group compiled the information in this report in a collaborative manner, such that no one person was responsible for a given section. The report overall was written and edited by the entire group, along with editorial guidance by our WPI faculty advisors. Outlining was done in collaboration with the entire group, and each member edited each section of the report on their own throughout the writing process.

Executive Summary

Introduction

Since the colonial occupation of New Zealand, freshwater quality and scarcity have become increasingly important issues. Without intervention, this way of life will quickly become entirely unsustainable for the people, animals, plants, ecosystems, and bodies of water of New Zealand. The end goal of this project was to help develop new ideas towards water quality solutions in Wellington. It was also critical to keep in mind that water quality management measures must be noninvasive to the environments and communities which rely on the bodies of water, and most of all must adhere to the ideals of Te Mana o te Wai: the priority of water above all else. In order to do this, we identified 3 objectives: (1) understand the areas of critical need relating to the three water networks (water supply, stormwater, and wastewater) and the quality of the waterways; (2) identify innovative freshwater management best practices that are being applied around the world and finally; (3) gather feedback about the feasibility of implementation in the Wellington context.

Literature Review / Background

Whether we recognize it or not, access to freshwater is a privilege that has a huge impact on quality of life. While access to freshwater is critical around the world, there is something to learn from the Māori framework which holds a particular connection to this responsibility. Water contributes to their identity as part of a wider web of interrelationships and wellbeing. This view holds that the health of water should be prioritized as above the needs of humans for the resource, and sets a tone for the cultural value needed to address water quality issues.

The Whaitua Implementation Programme (WIP) was completed by the Whaitua Te Whanganui-a-Tara Committee and published in September 2021, with about 100 recommendations for water quality and quantity around Wellington. The local Māori representatives also produced a set of recommendations known as Te Mahere Wai, and in this document, they ensure the water will meet the needs of their cultural values and practices. Of particular interest is the concept of **Te Mana o te Wai**, which states that apart from the needs of people, it is most important to consider the needs of the water above all else. Observing Te Mana o te Wai has nuanced implications for long-term outcomes. If we prioritize water, we prioritize life. The interaction of the two is undisputed. With communities dependent on the bodies of water surrounding Wellington, the water is also dependent on the people to take care of it, and this project aims to aid in its revitalization.

Despite New Zealand's reputation for having a pristine natural landscape, there are areas in Wellington Harbour that are struggling to maintain basic levels of water quality. The WIP is very conceptual and involves significant training of the public to view water with higher standards. It also calls for a workforce to address water quality and government action. Problems such as stormwater handling and toxic algal blooms have been discussed, but research still needs to be done as to how to implement the program.

In sum, a review of the literature revealed that enhancing water quality is key for New Zealand to grow as a nation, and all the more pressing in a time of climate change and

biodiversity loss. Actions will require a culture willing to ensure the values of Te Mana o te Wai and its importance towards the health and wellbeing of water sources. This is vital to acquire adequate funding for water-quality enhancing innovations. Developing technologies that can better handle stormwater and sewage, like Water Sensitive Urban Design and rainwater harvesting can make a significant impact.

Methodology

The goal of our project was broken down into three main objectives. Our first objective was to understand areas of critical need relating to three water networks: water supply, stormwater, and wastewater management. To do this, we conducted interviews with members of the GWRC and the Whaitua Te Whanganui-a-Tara Committee, as well as other water experts that our sponsors helped us identify. We relied on the perspectives of stakeholder groups in Wellington to point to areas in dire need of assistance and continued to focus on those areas in further research. In addition to direct communication, we also conducted archival research. By looking at the factors that had changed across time, we could compare and contrast a variety of factors that contributed to water conservation and quality challenges facing Wellington. The second objective was to identify best practices in freshwater conservation and quality solutions from around the world. We focused our efforts on interviews with local water quality management experts and then turned to case studies to supplement some of the areas for innovation we had identified in our interviews. Our third objective was to gather feedback about the feasibility of implementation in Wellington. For this objective, we conducted virtual interviews with the same Wellington experts from Objective 1 to gauge opinions on our recommendations and their implementation. Interviews were an important resource since they guided a constructive conversation on the topic and were important to ensure that any recommendations we made fulfilled Te Mana o te Wai.

Results and Discussion

Objective 1 was designed to assess the areas most in need of help. We began to see active determinants to water quality, such as urbanization, which is causing habitat loss and increased runoff with higher pollutant content. We viewed areas that would have to be considered when taking steps forward, things such as the prominent Māori culture. Finally, we began to see factors that would be essential to success if used properly, or a large handicap if ignored. The two main areas of this topic are governmental regulation and public outreach.

The interviews with those connected to water quality management and protection in Wellington provide great insight into the critical needs that are our priority to be addressed. From

the findings in Objective 1, our team culminated lists of interview questions for global water experts. We looked to global water management practices for suggestions to make which would address some of the critical needs we had identified.

Due to the overwhelming complexity and contextual nature of water quality management, not all of our global research can be directly translated to the Greater Wellington Region. Our team conducted research on a variety of water management practices, specifically in Massachusetts, and although they will not all be directly included in our recommendations, we still feel it is important for those at the GWRC to review. It is important to learn about the different ways water is being managed, and the systems that are in place which allow for this management.

Recommendations / Future Directions

When first approaching this project, we expected to complete it with a list of concrete, technical recommendations for the GWRC, suggesting things like installing more bioretention swales here or putting rain barrels here. However, once we became more educated on the complexities of water quality management, our initial idea for the structure of recommendations began to fade away, and we had to reframe our thinking. The many social, political, and economic factors that make up water management could not be simplified into a problem-solving process and required our team to re-evaluate our approach to recommendations. Some of our recommendations have developed into more of a discussion of what approaches to water quality are working, why they are working, and some of the difficulties with implementation. Information is one of the most important items we were able to deliver, even if we did not have all of the answers to how it would be implemented in the Greater Wellington Region.

One of the first things we took note of when doing the first rounds of interviews with those in Wellington is the abundance of pollutants in rivers, streams, and other sources of water. Those in Wellington seemed enthusiastic about the case studies we conducted for automated river cleaning implements and the ideas that came along with them, though we found that implementation of these devices would cause challenges. Currently, similar devices are relatively common in other parts of New Zealand but quite uncommon in Greater Wellington. Additionally, we learned that there are Friends of River groups who organize volunteer labor for rubbish collection. Though recommending concrete solutions can be situational, we advise the GWRC and those involved in similar implementation processes to not discount their ideas entirely.

In Wellington, there are seeds of low-impact developments (LIDs), but work needs to be put in to make these a common practice. Wellington should create a focus on green infrastructure over gray infrastructure, and educate developers and landowners alike to achieve this goal. Stronger regulations and a stronger push for green infrastructure are likely the way to ensure success within these areas.

Lawmakers in New Zealand have adopted similar watershed regulations to what we have found in Massachusetts. In our review, we wanted to focus on solutions that balance protecting the water and keeping it open to public use, as the water is such an important part of Iwi and Māori culture.

To our surprise, we learned that for the most part, there has been a lot of ignoring the problems of climate change. The increased number of cyclones and their harshness, as well as

saltwater getting into aquifers due to rising sea levels, proves that climate change is happening. Given the current impact of climate change and the need for urgent action, our team suggests a stronger movement towards these focuses. We recommend more focus on disaster prevention to mitigate the effects of climate change and rising sea levels. We also recommend educating communities, fellow agencies, and developers involved in implementing preventative solutions about the science and impacts of climate change.

Increasing public awareness and education measures will be an important part of working towards a more sustainable vision in water quality management. Public education measures are a good way to teach the public about what they can do in their day-to-day lives to improve water quality. It is our group's suggestion to leverage online advertising, social media, and other forms of community outreach to make it easier for the public to engage with water quality improvement in their daily lives. We recommend incorporating interactivity into water quality improvements. The result of this is higher community education and interaction with sustainability ideas, which in turn will lead to more social motivation to improve water quality.

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List of Acronyms and Abbreviations

AWC	Aquarion Water Company
AWWA	American Water Works Association
CSO	Combined Sewer Overflows
CWA	Federal Clean Water Act of 1972
DCR	Massachusetts Department of Conservation and Recreation
DFG	Massachusetts Department of Fish and Game
DKP	Massachusetts Towns of Duxbury, Kingston, and Plymouth Bays
DWSP	DCR's Division of Water Supply Protection
EEA	Massachusetts Executive Office of Energy and Environmental Affairs
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GFS	Grass Filtration Strip
GIS	Geographic Information System
GWRC	Greater Wellington Regional Council
LID	Low Impact Development
LWSAP	MWRA Local Water System Assistance Program
MAPC	Metropolitan Area Planning Council
MassDEP	Massachusetts Department of Environmental Protection
MC-FRM	Massachusetts Coast Flood Risk Model
MDC	Massachusetts Metropolitan District Commission
MVP	Massachusetts Municipal Vulnerability Preparedness
MWRA	Massachusetts Water Resource Authority
OSRD	Open Space Residential Design
PILOT	Massachusetts Watershed Payment in Lieu of Taxes
SWMI	Massachusetts Sustainable Water Management Initiative
TSS	Total Suspended Solids
USGS Survey	United States Geological
WIP	Te Whaitua te Whanganui-a-tara Implementation Programme
WRP	DWSP's Watershed Preservation Restriction Program
WsPA	Massachusetts Watershed Protection Act
WSUD	Water Sensitive Urban Design

1. Introduction

Since the colonial occupation of New Zealand, freshwater quality and scarcity have become increasingly important issues. Before European arrival, Māori communities maintained a more balanced relationship with the natural landscape around them, with a particularly strong respect for the bodies of water that provided food, hydration, and environmental wellbeing. In recent times, freshwater aquifers are drying up and, as the population grows, pollution and other stressors on these natural water sources are worsening. Especially as urbanization accelerates in Wellington, communities are no longer able to maintain water quality, and in some cases are struggling to obtain enough clean water for their daily lives. Without intervention, this way of life will quickly become entirely unsustainable for the people, animals, plants, ecosystems, and bodies of water of New Zealand.

We had an opportunity to work in collaboration with the Greater Wellington Regional Council (GWRC) to assess strategies that aim to preserve the health and wellbeing of Wellington's natural environment through outreach and innovation. A GWRC subcommittee, Whaitua te Whanganui-a-Tara, recently published a list of recommendations intended to help combat the impending water crisis that faces Wellington. Ideally, the subcommittee would like to utilize these recommendations as a starting point to provide freshwater solutions for Greater Wellington. In collaboration, our team analyzed these documents, and used them as a framework to design a series of interviews with water quality experts in Wellington and conducted research on potential physical and regulational implementations found elsewhere in the world. The end goal of this process was to help develop new ideas towards water quality solutions in Wellington. In this process, it was also critical to keep in mind that any physical measures taken to improve water quality must be noninvasive to the environments and communities which rely on the bodies of water, and most of all must adhere to the ideals of Te Mana o te Wai: the priority of water above all else.

The Greater Wellington Regional Council has made strides in identifying the problems that face freshwater management in Wellington but has struggled to map potential actions to address these problems effectively. Therefore, the goal of this project was to support the GWRC

with freshwater quality, quantity, and flow solutions in the Wellington region. In order to do this, we identified 3 objectives: (1) understand the areas of critical need relating to the three water networks (water supply, stormwater, and wastewater) and the quality of the waterways; (2) identify innovative freshwater management best practices that are being applied around the world and finally; (3) gather feedback about the feasibility of solution implementation in the Wellington context. Through this process, we hope to improve access to clean water in the Greater Wellington area, while also improving the overall health and wellbeing of the water.

2. Literature Review

The following section discusses the importance of water conservation and quality management in greater depth. We profile the perspectives of critical stakeholders including the Greater Wellington Regional Council as well as the subcommittee, the Whaitua te Whanganui-a-Tara Committee. We investigate innovations in water conservation techniques, such as water-sensitive urban design, and feature case studies in water quality management in Australia, Bangladesh, and the U.S.

2.1 Water as Life in New Zealand

Whether we recognize it or not, access to freshwater is a privilege that has a huge impact on quality of life. This is true individually, locally, and globally, yet water reserves are not always treated in a way that reflects this importance. In New Zealand, freshwater is critical to all aspects of life including the economy, landscape, and lifestyle. Out of the 268,000 km^2 of land in New Zealand, 425,000km are rivers, and there are numerous other bodies of water as well, including some 400 lakes and 200 aquifers (Stewart-Harawira, 2020). These regions support crucial biodiversity, including Aotearoa's rich bird populations and many species of land and aquatic life. The freshwater system supplies essential economic sectors such as agriculture, tourism and recreation, and hydro-power generation, in addition to household use in the country.

Figure 2.1: Wellington Harbour sunset. Wellington Harbour is an important part of the water cycle in Wellington and the areas surrounding it (Wellington Central Waterfront | Wellington, New Zealand, n.d.)

While access to freshwater is necessary around the world, there is something to learn from the Māori framework which holds a particular connection to this responsibility. Water contributes to Māori identity as part of a wider web of interrelationships and wellbeing and is important for genealogical relationships that shape culture, values, and traditions (Stewart-Harawira, 2020). Māori recommendations for stewardship of freshwater can ensure monitoring and management. This view holds that the health of water should be prioritized as above the needs of humans for the resource, and sets a tone for the cultural value needed to address water quality issues. Although colonial ideologies do not understand water in the same way as the Māori, different viewpoints in water conservation efforts can be advantageous (Armoudian & Pirsoul, 2020).

A rapid decline in water quality has started to gain attention both locally and globally. Dr. Laurel Tierney, a fisheries and aquatic scientist, manager, and facilitator with 45 years of experience in New Zealand, has noted that "some of our water bodies have moved beyond the intensive care stage - beyond help and into the hospice" (*New Zealand's Freshwater Health Crisis*, 2017). The freshwater systems of New Zealand were even labeled as some of the worst in the world in 2017, which is alarming for an economy so dependent on freshwater (Dymond et al., 2016). While agriculture is one of the economic sectors most reliant on clean waters, it also contributes to the decline in both water quantity and quality. The production of new pastures and farmlands has rid New Zealand of about 90% of the original wetlands (Armoudian & Pirsoul, 2020). The growth of the agricultural industry, and specifically dairy farming, has brought an increase in water pollutants due to fertilizer, pesticides, and industrial farm runoff. The latter of those listed has the potential to lead to contamination crisis, such as the Havelock North contamination event which occurred in 2016 when an outbreak of campylobacteriosis from sheep farm runoff resulted in the deaths of 4 elderly residents, as well as 45 hospitalizations, and more than 5,000 illnesses (Armoudian & Pirsoul, 2020). This event was among the catalysts prompting interest in water quality and new policies that support monitoring.

Recognizing the depletion of water quality is only the beginning, as there are both obstacles and critical steps in addressing this crisis. As a first step, the government of New Zealand has required that all regions develop plans to improve water quality. This project in

particular will focus on the greater Wellington region, specifically the rivers and water bodies near Wellington Harbour. In this area, two separate articles of recommendations have been curated for water improvement.

One of the committees which produced a set of recommendations is the Whaitua Te Whanganui-a-Tara Committee, a subcommittee of the Greater Wellington Regional Council aimed at addressing water preservation. The Whaitua Implementation Programme was completed by the Whaitua Te Whanganui-a-Tara Committee and published in September 2021, with about 100 recommendations for water quality and quantity around Wellington. The local Māori representatives also produced a set of recommendations known as Te Mahere Wai, and in this document, they ensure the water will meet the needs of their cultural values and practices. Of particular interest is the concept of **Te Mana o te Wai**, which states that apart from the needs of people, it is most important to consider the needs of the water above all else. Observing Te Mana o te Wai has nuanced implications for long-term outcomes. Prioritizing the health of the waterbody above all human needs implies a connection between the two. Humans cannot exist without water, but water can exist without us. If we prioritize water, we prioritize life. The interaction of the two is undisputed. With communities dependent on the bodies of water surrounding Wellington, the water is also dependent on the people to take care of it, and this project aims to aid in its revitalization.

2.2 Partners in policy and innovation

In the long run, the project described by the Greater Wellington Regional Council is meant to be a multi-billion NZD project spanning over decades of hard work and collaboration. The recommendations formulated by the Whaitua te Whanganui-a-Tara Committee point out key players that are necessary to get the ball rolling towards the next stages of Wellington's water crisis. From the Te Whanganui-a-Tara Whaitua Implementation Programme and the Te Mahere Wai O Te Kāhui Taiao, we see key stakeholders in the project: the water itself, the Greater Wellington Regional Council, the Whaitua te Whanganui-a-Tara Committee, and the residents of Wellington. Each is profiled in greater depth below.

Te Mana o te Wai

Prioritizing the water itself means advocating for water across time and beyond changes in policy or use requirements. The idea is not new to New Zealand, as it already honors laws that establish advocacy and rights to non-human elements of the community. Te Mana o te Wai describes the vital importance of water and the hierarchy that comes with it. This approach states that all decisions around usage or economic gain of water must prioritize the water's health and wellbeing (Wellington City Council, 2021). Te Mana o te Wai has been in New Zealand policy, National Policy Statement for Freshwater Management, since 2014 but has been recently updated in 2020 under the NPS-FM 2020 policy. The wording specifically places freshwater first to preserve its mauri/mouri, health. Second in the policy priority is providing action for essential human health. This includes maintaining drinking water or water usage for survivability. The third priority acknowledges water usage to support human gain and welfare, such as their social, economic, and cultural well-being (*Te Mahere Wai o Te Kāhui Taiao*, n.d.).

The most famous case that demonstrates the ranking of priority in Te Mana o te Wai is from 2017 when the Whanganui River was granted the legal right to “personhood” by New Zealand, an important political decision that was heard worldwide (Aho, 2019). Personhood is projected to the body of water by a committee of Māori “guardians” that speaks for its well-being as if it was a person. This milestone further demonstrates the value of a collaborative vision of perspectives in shared resource management (Charpleix, 2018).

The NPS-FM 2020 policy upholds this partnership by placing further provisions on state and local authorities as well as regional councils, known as the National Objectives Framework (*Essential Freshwater*, 2020). For councils to give effect to the values illustrated in Te Mana O Te Wai, they must follow five principles as stated in NPS-FM 2020. (1) Actively involve Tangata Whenua (indigenous Māori people) in freshwater management. (2) Enable the application of a diversity of systems of values and knowledge such as matauranga Māori, to the health and well-being of water bodies and freshwater ecosystem. (3) Engage with communities and Tangata Whenua to identify long-term visions, environments outcomes, and other elements of the NOF. (4) Apply the ranking of priorities when implementing the NPS-FM 2020 requirements and the

NOF. (5) Adopt an integrated approach ki uta ki tai (Māori Philosophy of interconnected environments) to the management of freshwater (*Essential Freshwater*, 2020).

The Greater Wellington Regional Council

The GWRC is one of 16 regional and unitary councils in New Zealand that are responsible for the well-being of its communities and environments. In terms of water management and supply, the council collects and treats all drinking water of four major cities on the southern tip of the Northern Island. These include Wellington, Upper Hutt, Lower Hutt, and Porirua. The GWRC works with an approximate population of 487,700 residents, with 35 million passenger journeys made on the region's transportation system every year and a booming tourism sector. Consequently, it is important to them to have a reliable system of water management (*Greater Wellington's Role and Functions | Greater Wellington Regional Council*, n.d.). Overall, the GWRC's core functions are to promote Quality for Life through urban planning concerns such as controlling pollution, sewage management, parks and recreation, and fresh drinking water for greater Wellington ("Te Whaitua Te Whanganui-a-Tara Implementation Programme," 2021).

Whaitua te Whanganui-a-Tara Committee

The GWRC has established 10 committees to oversee specific core functions, including the Whaitua te Whanganui-a-Tara Committee. This committee is a group of local individuals from Upper Hutt, Lower Hutt, and Wellington. Their long-term goal is to develop and execute programs to improve water quality in Greater Wellington. They are reaching this goal by making recommendations to the GWRC. Their latest document, the Whaitua Implementation Programme (WIP), charts the path and first steps to reform Wellington's dealings with water quality for years to come and contains specific recommendations, strategies, and proposed actions ("Te Whaitua Te Whanganui-a-Tara Implementation Programme," 2021).

The GWRC and the Whaitua committee share their overarching frameworks of how to maintain sustainability and connection to the elements that keep us alive. In a time of climate change and overpopulation, the interrelationship of human and water wellbeing is of high interest

to restore. Planning for resilience and in a way that recognizes the interrelationships that support life is the strongest foundation.

2.3 Baseline Assessments from the Greater Wellington Regional Council

The GWRC consists of 5 regions that are each developing water quality improvement programs (New Zealand Government, 2021). We will focus on recommendations for the Wellington Harbour region as seen in Figure 2.2.

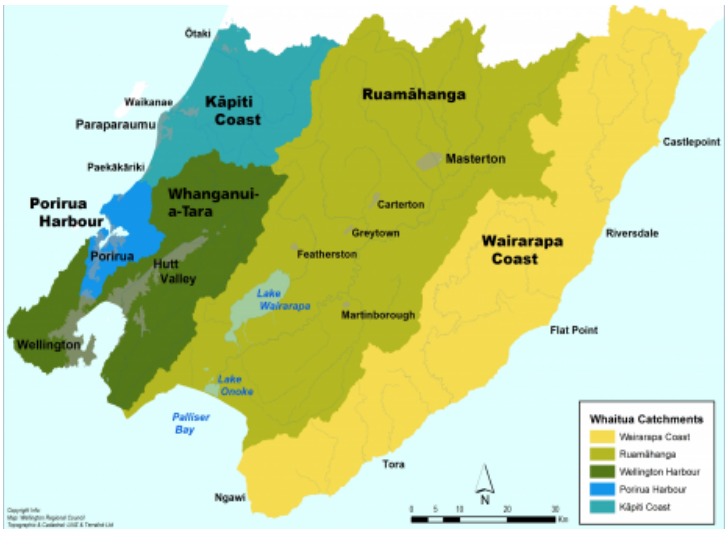

Figure 2.2: Whaitua Regional Layout (New Zealand Government, 2021)

Despite New Zealand's reputation for having a pristine natural landscape, there are areas in Wellington Harbour that are struggling to maintain basic levels of water quality. Samples have been analyzed on a basis of clarity, oxygen content, dissolved reactive phosphorus, nitrates, nitrogen, ammonia, and E. coli bacteria. Poor results point to the most prevalent issues such as stormwater runoff and sewage, which tend to come hand-in-hand with high E. coli levels. The Mangaroa River and Waiwhetu Stream are both graded "poor" due to stormwater runoff, sewage, and agricultural runoff in the area. The Karori and Kaiwharawhara streams are only graded as "fair", as E. coli and urban stormwater levels are too high. Most of the beaches are in good standing, except for the Eastbourne coast of the Harbour and the Owhiro and Robinson's Bays (*Whaitua*, n.d.).

The Te Whaitua te Whanganui-a-Tara Implementation Programme has presented over 100 recommendations that prioritize water, then people, and then social, economic, and cultural values. These ideas are geared towards cleaning up pollution and preventing it in the future through innovative technologies and educating the public on good water using practices. The program is very conceptual and involves significant training of the public to view water with higher standards. It also calls for a workforce to address water quality and government action. Problems such as stormwater handling and toxic algal blooms have been discussed, but research still needs to be done as to how to implement the program (*Whaitua*, n.d.).

Members of these task forces have offered some perspectives on the program's progress. Our sponsors emphasized a common issue is that New Zealand has been lacking innovation for quite some time. Instead of developing new and long-lasting approaches, they have defaulted to fixing the problems at hand just enough to get by until the problem occurs again. They agree that stormwater and sewage handling need to be addressed with respect to infrastructure, and they suggested that there is room for additional solutions for flooding, rainwater collection, greywater reuse, and stronger pipe systems. These are all aspects of GWRC's Water Sensitive Design for hydraulic neutrality.

2.4 Water Sensitive Urban Design

Innovation in environmentally sound water quality systems shows considerable promise. For example, Water Sensitive Urban Design (WSUD) is one of the main approaches for tackling the problems faced by communities like Wellington around the world (Wong, 2006). At face value, the concept of WSUD is simple, to raise the availability and lower the demand for water in an urban area while ensuring that the local environment is taken into consideration and fostered. There are many examples of innovative policies or architectural features that can be put into place which constitute WSUD. For example, looking at demand reduction is one category of WSUD approaches (Sharma, 2018). This approach involves lowering the local need for water, both on a community and commercial level. A method of accomplishing this is making household appliances more efficient or matching the "fit for purpose" of the water being used (Wong, 2006). One way this approach has been implemented is in systems when potable water is used to flush toilets or take showers. Naturally, water used for showering has a certain standard

of cleanliness required, but not as high a standard as drinking water. For this reason, it would make sense to clean shower water only to the degree of sanitization needed for a shower and to clean only water meant for consumption to a higher standard.

Another way to reduce water "demand" is to increase the supply of clean water. An aspect of this that is very prevalent in WSUD is rainwater reclaiming systems. Many of these systems also provide the added benefit of controlling the flow of rainwater. For example, devices that can be attached to households to collect rain runoff from roofing can protect the home's foundation from the damage caused by constant rainfall (Wong, 2006).

An example of this practice in a more public context would be rain gardens and bioretention swales (Dunnett & Clayden, n.d.). These swales feature small sections of landscaping. They are usually much longer than they are wide, and have a slight slope down to the center, as shown in Figure 4, below (Kazemi et al., 2011).

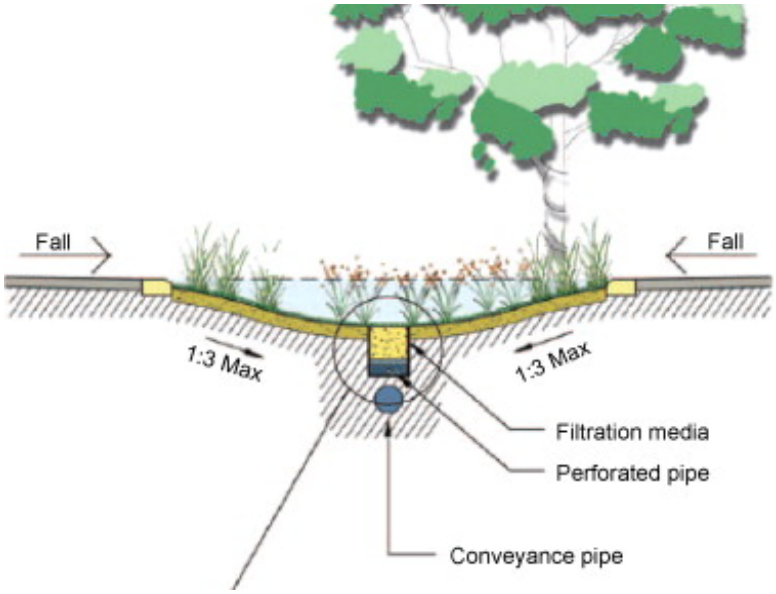

Figure 2.3: A diagram showing the dimensions and general layout of the vegetation in a bioretention swale (Kazemi et al., 2011).

The purpose of the indentation of a bioretention swale is to collect water through an artificial drainage system. This is water that will then be collected and filtered to be recycled into the water system as water that can be used for drinking and household needs (*Bioretention Swale*, 2017). Beyond the use of simple water collection, bioretention swales, similar to roof water collection systems, can alter the flow of water and prevent runoff from causing damage

(*Sustainable Technologies Evaluation Program (STEP)*, n.d.). By acting in a similar way to a storm drain system, the swales accrue water to prevent it from overflowing and causing damage to the surrounding environment.

What truly sets a bioretention swale away from a traditional storm drain with a tank attached is its ability to filter water. Specifically, in this case, the bioretention feature indicates that the swale is a built-in correlation with soil, plants, and microbial environments that foster the filtration of rainwater (Kazemi et al., 2011). This can save significant time and energy costs by skipping a significant portion of the filtration process necessary to create clean water used for drinking and other household purposes. Additionally, the biological factors involved with a bioretention swale have been shown to increase the wellbeing of the ecosystem when compared with traditional green spaces such as parks, increasing local biodiversity of both flora and fauna (Kazemi et al., 2011).

2.5 Relevant Case Studies: Innovations and Trials

In this section, we feature two ideas in greater detail. First, we learn from cases of Water Sensitive Urban Design projects. Second, we evaluate the efficacy of rainwater harvesting on a large scale.

Case 1. WSUD: Practical Applications

WSUD has proven to be incredibly useful as a way to manage water resources. In particular, the bioretention swales previously mentioned have shown a remarkable ability to control runoff and filter water. In a study performed near a parking lot in Toronto, the implementation of a bioretention swale resulted in 60% less runoff than traditional concrete, indicating its ability to manage runoff and prevent damage from occurring as a result (*Sustainable Technologies Evaluation Program (STEP)*, n.d.).

In a study performed in Maryland, bioretention swales were shown to provide active filtering benefits. The study analyzed the total suspended solids (TSS) found in water before and after passing through a bioretention swale. These included compounds such as nitrates, zinc, and copper which can be harmful to consume. Water analyzed the following permeation through a

bioretention layer was shown to be 47% less likely to contain 20 mg/L TSS, showing in full the ability of bioretention swales to process and filter water in real-world situations (Davis, 2008).

WSUD has been employed around the world in many places. Perhaps the most relevant of places is its implementation in Australia, which is markedly similar to New Zealand in ecosystem and climate, making it a good approximation for the potential success of WSUD applications in New Zealand. The main concern when applying WSUD to real-world situations in Australia appears to be related to public conception. Many Australians disliked the presence of swales as in many cases it disrupted local parking or other municipal spaces (Sharma, 2018). However, it is notable that as a demand reduction method, swales are a relatively low impact when compared with more active processes, such as metering the water on a house to monitor for cost.

Case 2. Rainwater Harvesting in Bangladesh

Dhaka is a major city in Bangladesh that has an overreliance on groundwater. The Dhaka Water Supply and Sewerage Authority (DWASA) has reported that 87% of the water demand is met by groundwater and 13% from treated sources. An overreliance on groundwater over a long period of time has depleted underground aquifers, caused landslides, and has damaged soil and vegetation. Rainwater harvesting provides a means of replenishing aquifers, supplying water during droughts, and minimizing damage during storms (Rahman et al., 2014).

Rooftop collection methods can send water directly to aquifers, water bodies, or storage facilities, and are typically inexpensive yet reduce water bills tremendously. Additionally, the DWASA requires that drinking water pH be between 6.5 and 8.5, which has been easily attained by natural rainwater (Rahman et al., 2014).

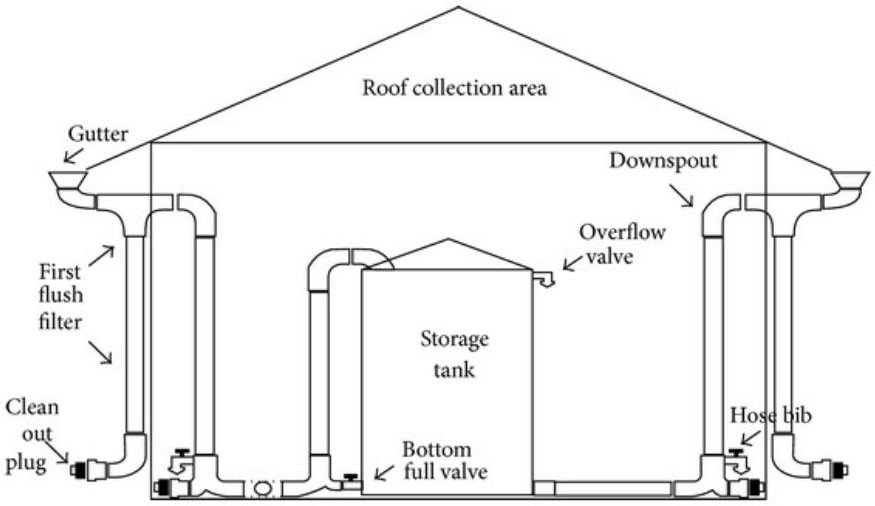

Figure 2.4. Rainwater Collection Model (Rahman et al., 2014).

A test site in Dhaka estimates demand for 243,000 liters per month for 60 people. During heavy rainfall in the summer months, about 5 liters were collected per storm. This provides another source of potable water for residents and also limits stormwater overflow. Overall, rainwater harvesting methods provide supplemental water in urban areas of Bangladesh that are enough to cut costs and take some of the pressure from groundwater (Rahman et al., 2014).

These two case studies illustrate the modern innovations being applied to places where freshwater scarcity is a concern. Both bioretention swales and rooftop collectors have been applied to address problems and have been successful in improving the availability of water for drinking and bathing, as well as decreasing water damage during storms. Additionally, these case studies illustrate the need to predict and preempt latent issues which may arise during the implementation of freshwater conservation apparatuses. If potential drawbacks are not minimized, it could lead to the implementation of these devices to be successful in freshwater salvage, but still, fail the community by proving to be more disruptive than it is worth based on the water it can produce. This is an issue that cannot be addressed on a numbers-only basis.

2.6 Summary

In sum, a review of the literature revealed that enhancing water quality is key for New Zealand to grow as a nation, and all the more pressing in a time of climate change and

biodiversity loss. Actions will require a culture willing to ensure the values of Te Mana o te Wai and its importance towards the health and wellbeing of water sources. This is vital to acquire adequate funding for water-quality enhancing innovations. Developing technologies that can better handle stormwater and sewage, like Water Sensitive Urban Design and rainwater harvesting can make a significant impact.

3. Methodology

The primary goal of our project was to support and assist the Greater Wellington Regional Council (GWRC) to assess methods of water management and innovative systems that can have the feasibility to improve water quality in the Greater Wellington Region. In order to achieve this goal, three objectives were proposed.

- First, our group needed to understand the areas of critical need which were affecting water supply, stormwater, and wastewater management in Wellington.
- Second, our group identified innovative freshwater management best practices that were being applied around the world.
- Finally, in our third objective, we gathered feedback about the feasibility of implementation for these solutions.

We hoped these objectives would engage the opinions of our primary stakeholders to take steps towards solving the problem while ensuring that the values of all affected parties were respected.

Figure 3.1: Methodology Outline

3.1 Understanding Areas of Critical Need

Our first objective was to understand areas of critical need relating to three water networks: water supply, stormwater, and wastewater management. To do this, we conducted interviews with members of the GWRC and the Whaitua Te Whanganui-a-Tara Committee, as well as other water experts that our sponsors helped us identify. We realized the recommendations outlined in the Te Whaitua te Whanganui-a-Tara Implementation Programme were not organized into a particular priority list (Wellington City Council, 2021). Committee

members involved in planning the document were interviewed to determine which areas of critical need in water quality management they felt were most pressing at the current moment. Similarly, interviews with local experts outside of the committee could highlight critical needs and expectations outside the Whaitua Implementation Programme. The interviews were also beneficial, as they allowed us to gauge the views of our interviewees both as water quality experts and citizens of Wellington. This process helped us narrow down the scope of our project to 2-3 areas of critical need, rather than the 10-15 originally proposed in the Implementation Programme.

Figure 3.2: Water Infrastructure in New Zealand (New Zealand, 2015)

Interviews with water experts from the Wellington area were conducted virtually through the online platform ZOOM, using the questions found in Appendix B, which served as a baseline to stimulate conversation with the interviewee. At times, however, the baseline was deviated from to obtain more context or detail regarding a specific area. Each of the team members took ownership of a specific portion of the interview, to get a stronger feel for their individual area of expertise and allow them to have more comfort and knowledge when going in-depth with an expert in a particular area. When performing these interviews, consent was always acquired before the discussion and recording as seen in Appendix A. We relied on the perspectives of stakeholder groups in Wellington to point to areas in dire need of assistance and continued to focus on those areas in further research.

In addition to direct communication, we also conducted archival research. Although it was important to understand the public perceptions in Wellington, it was also important to understand the factors that led us there. By reviewing the information found in the Implementation Programme, we were able to gain a strong background understanding of what the members of the Whaitua te Whanganui-a-Tara thought were some of the sample areas of need, while also further understanding the social, cultural, and political dynamics that surrounded them. In particular, Māori values maintain a strong connection with nature and deep respect for the bodies of water that surround the place in which they live. With European colonial occupation, the freshwater quality began to diminish and freshwater sources began to run dry (Stewart-Harawira, 2020). Additionally, in recent times, the urbanization of the Wellington area has caused a large amount of habitat loss and has made controlling stormwater much more difficult, resulting in a distracting decrease in the quality of drinking water. By looking at the factors that had changed across time, we compared and contrasted a variety of factors that contributed to water conservation and quality challenges facing Wellington.

3.2 Identify Innovative Freshwater Solutions in use Around the World

The second objective was to identify best practices in freshwater conservation and quality solutions from around the world. We focused our efforts on interviews with local water quality management experts and then turned to case studies to supplement some of the areas for innovation we had identified in our interviews.

Within our local community, we reached out to experts throughout the Commonwealth of Massachusetts to gauge their views on Wellington's critical needs. Experts such as Executive Director Frederick A. Laskey of the Massachusetts Water Resource Authority (MWRA). The MWRA’s role is to provide fresh drinking water and sewage management in the Boston and Metrowest area. Furthermore, Director Laskey’s role is to implement related programs for the MWRA over time. Laskey was a great resource that we found since a big portion of our project revolved around ease of implementation for water-related needs (*Welcome to MWRA.COM*, n.d.).

Figure 3.3: MWRA Deer Island Wastewater Treatment Plant (MWRA - Deer Island Public Access, n.d.)

Another notable resource we found were those at the Metropolitan Area Planning Council (MAPC) which serves 8 regions in the Commonwealth to improve and organize infrastructure, urbanization, policy planning, and many similar actions to the GWRC for the urban population in their respective locations. Also similar to the GWRC and the Te Whaitua te Whanganui-a-Tara Implementation Programme, the MAPC has an extensive regional plan that spans to 2050, MetroCommon 2050 (*MetroCommon 2050*, n.d.). The MAPC helped us get a better understanding of how they approach water quality management implementation compared to the GWRC's strategies. By interviewing those at the MWRA and MAPC, we learned how our local community addresses and implements water quality needs in comparison to the GWRC.

Once we compiled our list of local experts, we conducted interviews with them to assess their experience of certain solutions, what the experts think the solution has accomplished well, and to understand what they think could be improved upon. The main goal of these interviews was to assess the expert's views on Wellington's critical needs. Additionally, it was important to ask what unexpected problems have occurred in their implementations and how the process had undergone changes over time after their initial response. Our interviews led us to potential steps towards improvement that we could then investigate further, in order to have supplemental information to provide to our sponsors.

3.3 Gather Feedback about Feasibility of Implementation

Our third objective was to gather feedback about the feasibility of implementation in Wellington. For this objective, we conducted virtual interviews via ZOOM and recorded them with consent, to gauge opinions on our recommendations and their implementation. We compiled a list of questions to guide the interviews that we felt would be effective for gathering feedback about each recommendation, Appendix D.

The people that we interviewed for this objective were the same water experts from Objective 1. We felt that probing the minds of these experts with semi-structured interviews was an effective method to predict the success or failure of potential water quality improvement measures we have discovered. We used some of the feedback from this objective to guide further research in Objective 2. Gathering feedback from experts in Wellington was useful to gain a more comprehensive understanding of the factors at play in the region, and helped identify potential problems with certain site-specific suggestions or methods of implementation. Interviews were an important resource since they guided a constructive conversation on the topic and were important to ensure that any recommendations we made fulfilled Te Mana o te Wai.

4. Results and Discussion

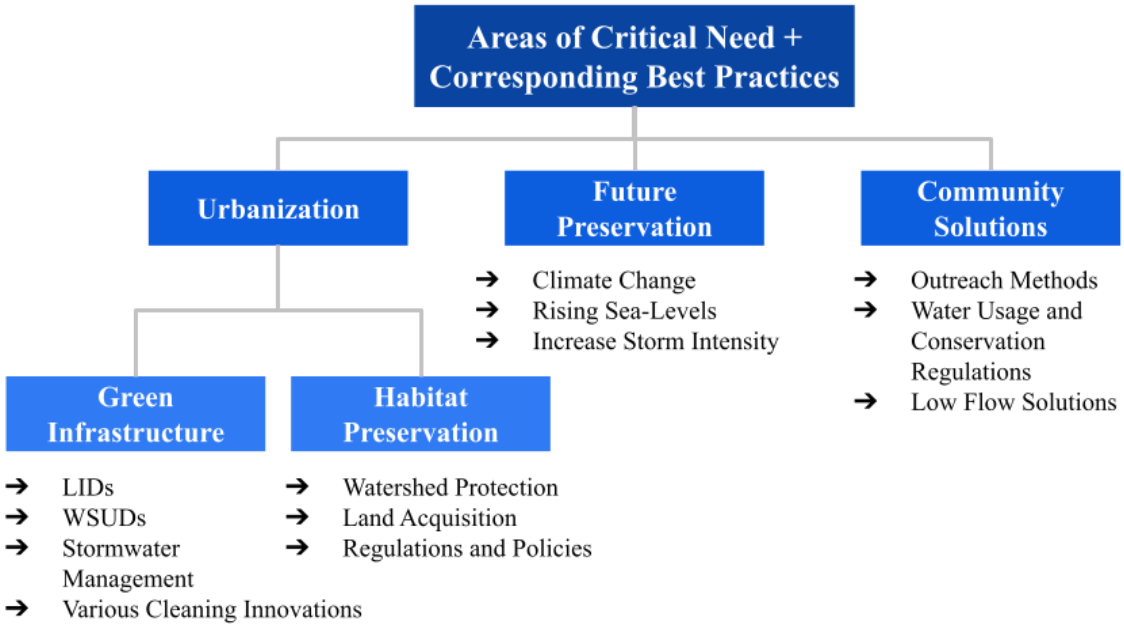

Figure 4.0: Chapter 4 Overview Chart

4.1 Objective 1 Findings

Objective 1 was designed to assess the areas most in need of help. As we progressed through the process of the interviews, a general pattern began to arise. We began to see active determinants to water quality, such as urbanization, which is causing habitat loss and increased runoff with higher pollutant content. We also came to understand the significance of Māori culture in New Zealand, recognizing that Māori frameworks should be considered in future objectives. Specifically, we must consider these frameworks when talking with experts in Massachusetts and trying to adapt methods from other areas of the world to the particular culture of New Zealand. Finally, we began to see factors that would be essential to success if used properly, or a large handicap if ignored – namely, governmental regulation and public outreach. Regulation, if used properly, can assist in enforcing water quality standards and ensuring that proper protocol is followed. Public outreach and education can inform people on the proper disposal of waste and lead to more motivation to spend resources to achieve infrastructure improvement.

Considerations when Making Steps towards Improvement

One thing that cannot be ignored when working in New Zealand is the native culture of the Māori people, who highly value a strong connection with nature. This cultural value comes into play in water quality management with the idea of hard and soft design solutions. Hard design solutions are those which involve chemicals or machinery, whereas soft design solutions make use of natural methods, such as plants that remove pollution from runoff. In general, soft design features are much more in line with Māori cultural values, because they place the environment in very high regard. Because of this, we placed a strong emphasis on soft design features when conducting interviews and research on potential developments. Despite this, the relatively dire conditions in Wellington may present a need to rely on hard design to bring water quality to a point where soft design can sustain it. All of this is not to say that soft design cannot be used in collaboration with hard design when taking initial action, in fact, many soft design measures are already being taken to improve water quality. Fetu Warena Ese, a graduate landscape architect, outlined an example of this in an interview, speaking on the willows which have been planted on the Hutt River, or the Te Awa Kairangi as it is known by the Iwi. These willows have strong root systems that keep river banks intact, decreasing sedimentation and preventing pollutants from entering the river. Soft solutions like these will be essential to focus on when advising on water quality improvements.

Another central aspect of cultural value in New Zealand is **Te Mana o te Wai,** an idea that highlights the value of water for its own intrinsic value rather than its use for human gain. Those working to improve water quality unanimously emphasized the importance of Te Mana o te Wai. Going forward, it will be something that will need to be constantly considered to make recommendations to aid water quality in New Zealand.

Factors that Detract from Water Quality

One of the main causes of water quality deterioration in Wellington has been urbanization. Wellington has lagged behind its sister cities in New Zealand and is now experiencing a large population and development boom. With that boom come many growing pains. As Alastair Smaill, former programme leader of the Whaitua te Whanganui a tara said

“Until quite recently, I think that Wellington was probably 25 to 30 years behind in [urbanization], so there’s a whole raft of things we have to sort out and catch up on” (A. Smaill, Personal Interview, January 19, 2022). Paying attention to and seeking to combat the issues that arise with urbanization will be essential to improving water quality in Wellington. Urbanization’s two main impacts on water quality pertaining to stormwater runoff and habitat loss.

As highlighted by Martin Pillsbury, infiltration of water into the soil is much lower in urban areas due to the high amount of pavement (M. Pillsbury, Personal Interview, February 1, 2022). This causes much larger amounts of runoff to travel out of cities, washing many pollutants with them. However, the problem does not stop there. In Wellington’s case, the runoff generally travels to the Hutt River. Since much of the water is washing into the river and not infiltrating into the soil, the flow of the river dramatically increases, causing it to begin to interact with harmful substances, such as animal manure or fertilizer that may be present in farms around the river. For this reason, when understanding urbanization, it is very important to consider the impact that ignoring stormwater management can have.

Habitat loss is a result of the significant death and displacement of the natural flora and fauna during the process of urbanization. As mentioned previously, many florae have a very important role in water quality maintenance, specifically in the areas of pollutant filtration and sedimentation control. However, it is important to consider the state a habitat must be in to reimplement such flora. Smaill highlighted this double-edged sword when he said, “You can do some nice riparian planting and the stream will look really good, but if the water quality is crap, nothing's going to live there” (A. Smaill, Personal Interview, January 19, 2022). As mentioned earlier, it will be particularly crucial to find solutions that can bring water quality back to the point where it can be sustained by soft design, such as the willows mentioned by Ese in the previous section.

Avenues Towards Success or Failure

Public outreach and education are going to be two of the make-or-break factors in water quality solution implementation. Public education is very important for water quality, both to educate communities and to motivate them to take political action towards change. Currently, as we were told by our interviewees, the general citizens in New Zealand are relatively apathetic

about water quality management. When asked about current public involvement, Smaill put it this way, “there's a huge issue with people even knowing that water quality is bad and how that might affect them, both in terms of their health and in terms of what they might have to pay in the future to improve it” (A. Smaill, Personal Interview, January 19, 2022). As mentioned, the main importance of public outreach is twofold. First, communities must be educated in how to take care of the water systems to maintain the use of the water for health benefits. Ese emphasized this concerning cultural connection and natural values, telling us that his “big takeaway is that it's all about learning. When [he] was younger, [they] didn't really get to learn much about how plants work or how the environment can affect the people and vice versa” (F. Ese, Personal Interview, January 27, 2022). When people understand their connection with the environment, they can make more informed decisions about water quality and take better care of the water and environment around themselves in turn.

Secondly, teaching the public about the importance of water quality can help with compliance and motivation to use funds toward infrastructure improvement. Smaill noted that “improving awareness is really key because the cost of the improvements is going to be so significant that if the general taxpayer doesn't want it to happen, it won’t” (A. Smaill, Personal Interview, January 19, 2022). This underlines the duality of public awareness: if used properly in implementation, then it could prove to be a massive help. However, if it is ignored, it could prove to be a massive hindrance, and could even stop progress from occurring at all.

The final, and perhaps most complex area of all the subjects for water quality improvement is governmental policy and regulation. Regulation, although it can be a thorn in the side of those trying to improve water quality, can often be a help to their efforts. Smaill noted that “when governments actually outline what the rules are, it actually in many ways makes your decision-making easier” (A. Smaill, Personal Interview, January 19, 2022). This underlines an added benefit of regulation. Not only can it help to implement water quality solutions, but it can also narrow focus on which improvements should be implemented and which are not feasible due to regulatory restrictions.

Unfortunately, the reality of the situation is not so cut and dry. Governmental regulatory bodies deal with the combined interest of all parties involved, encompassing those who want to

pay for infrastructure improvements, and those who do not, or those who want to continue to build new developments and continue urbanization, and those who do not. All of this comes together to form a complex web of benefits and determinants to consider when implementing water quality regulations. Ultimately, this idea was summarized simply by Smaill with the idea that “the main part of government actually wants to improve water quality but they also want more houses and more roads, so there's actually a tension within government about that” (A. Smaill, Personal Interview, January 19, 2022). It comes down to the question of which resources and how much of them will the government be willing to spend in their attempts to improve water quality. Paying attention to and utilizing that “tension” to the utmost level will be another essential part of efficiently working towards water quality solutions.

4.2 Objective 2 Findings

The interviews with those connected to water quality management and protection in Wellington provide great insight into the critical needs that are our priority to be addressed. From the findings in Objective 1, our team culminated lists of interview questions for global water experts, Appendix C. We looked to global water management practices for suggestions to make which would address some of the critical needs we had identified.

Discussions with Members of the Commonwealth of Massachusetts

Our research of water experts brought us to essentially our “backyard” on our side of the globe. Due to the unfortunate remote nature of this project, we found that by connecting with local water experts in the Massachusetts area, we would have an opportunity to gain a deeper understanding of our own community as well as those in Wellington. Greater Boston and Metrowest have seen great success in their water management innovations and usage practices. Stephen Estes-Smargiassi notes that in 1984, Boston Harbor was considered “America's Dirtiest Harbor” due to sewage overflow and the lack of facility management (MIT Water Club, 2017). Thus, the Massachusetts Water Resource Authority, MWRA, was born. The MWRA is a regional wholesaler, catering water and sewer to 61 cities and towns in the metropolitan area. With innovations and policies enforced by the MWRA, by 2014, Boston was voted America's Best Drinking Water by American Water Works Association (MIT Water Club, 2017).

Similarly, we sought connections with the Metropolitan Area Planning Council, MAPC, which is a similar agency to that of the GWRC. The MAPC's mission is to "promote smart growth and regional collaboration" in areas such as sustainable land use, protection of natural resources, public safety, economic development, clean energy, healthy communities, and much more for all people in the region. They also highly value engaging the public to stay informed and be involved in improving the future (*MAPC About Us*, n.d.).

Two Way Learning

Several water quality experts we contacted from Massachusetts believe they have a lot to learn from those in New Zealand. Martin Pillsbury, Environmental Planning Director at the MAPC, expressed that he was surprised to see the true importance of water and natural resources to the Māori people. "Wait a minute, we're trying to help them? They can help us to have that starting off, the high-level framework set of assumptions and set of values, that values water. That has a vision… that really puts water at the center of life, which actually is what it is. Whether you acknowledge it or not, the fact you have a culture that acknowledges that, and then is trying to find ways to operationalize that assumption or that set of values…I think that's just amazing" (M. Pillsbury, Personal Interview, February 1, 2022). Though implementing a similar set of values in Massachusetts or even in The United States as a whole may be unrealistic, we have seen that understanding this set of Māori values in a document as sophisticated as the Whaitua Implementation Programme is a great eye-opener to experts halfway across the world. The fact that Massachusetts has been successful in its water management practices even without the deep-rooted values present in New Zealand is an indication of the potential for success in improving water quality in the Greater Wellington Region. We can learn from Māori values, and Wellington can also use them as a resource for water management practices.

Review of Potential Solutions from Massachusetts

Massachusetts Solutions to Combat Urbanization and Stormwater

Discussion of Gray vs Green Infrastructure

From our interviews with experts in Massachusetts, we learned the importance of recognizing 'Gray' vs. 'Green' infrastructure when considering water management. Gray refers

to physical developments, with the potential of obstructing the ecosystem around it. This includes curbs, gutters, drains, and piping. Whereas green infrastructure refers to more natural systems that provide benefit for both human and nature's well-being. Those include wetlands, the introduction of native vegetation, floodplains, etc. Green infrastructure tends to mimic the natural flow of nature and considers its importance as well (O. US EPA, 2015b). One of the main examples discussed amongst the Massachusetts experts was Low Impact Developments (LIDs).

Low Impact Development and Green Solutions

The MAPC has implemented a LID Toolkit that provides practical fact sheets on methods that communities and developers can implement in their region. The Toolkit highlights methods such as rain gardens, bioretention, permeable pavement, and green roofs (*Low Impact Development Toolkit*, n.d.).

One example on the MAPCs tool kit is that of Grass Filter Strips (GFS). Filter strips are implemented on low-angle slopes to treat sheet flow runoff. They are designed to filter out sediment and other pollutants from stormwater and overflow. To the MAPC, GFS can be more effective than swales at removing polluting solids and trash from runoff before the water is transported through pipes or to another method of treatment. On the side of gray infrastructure, the benefits of GFS see the implementation act as a gutter to remove suspended pollutants and reduce the discharge rate. The MAPC reports a removal rate of Total Suspended Solids (TSS) ranging from 40%-90%. Effectiveness depends on various factors as well. In urban areas, Grass Filter Strips provide needed landscape to parking lots and roadways, as well as snow storage for winter months. Grass Filter Strips are a good example of LIDs that aid nature's flow and can provide "pretreatment" for stormwater, removing waste and harmful runoff (*Fact Sheet*, n.d.).

Figure 4.1: Grass filter strip is being used as pretreatment for parking lot runoff directed to an infiltration basin. Note concrete level spreader (at right) to facilitate sheet flow across the filter strip (Fact Sheet, n.d.)

Permeable Pavement in Massachusetts is also highlighted in the MAPCs LID Tool Kit, as well as the EPA website for successful green infrastructure examples (R. 03 US EPA, 2015). Green parking measures such as permeable pavements allow for rain and stormwater to filter into the pavement and store it where it falls, in a grooved pavement design. This reduces runoff and minimizes pollutants introduced from parking areas. The drawbacks of such pavement include the cost as they are more expensive to install compared to traditional pavements. Also, over time, the permeable pavement would be worn down by constant friction from car tires. This is why, as seen in Figure 4.2, permeable pavement is specifically implemented in the parking spot areas and the roadway corridors remain as regular pavement. Similarly, permeable pavement installation also involves maintenance, due to particles, pollutants, and other things that may cause clogging within the groves ("Permeable Pavement," 2017).

From a U.S. Geological Survey (USGS), installation of permeable pavements in Wilmington, MA, data analysis show gravel pave (normal material) had an average observed infiltration rate exceeding 5,000 in./hr, whereas permeable pavement displayed an average observed infiltration rate of 49 in/hr to 69 in/hr (*Demonstration 3*, n.d.).

Figure 4.2: Permeable pavers, porous asphalt, and bioretention cells at the Silver Lake beach parking lot, Wilmington MA (Demonstration 3, n.d.)

We decided to highlight GFS and Permeable Paving in this section because unlike many of the MAPCs implementations in their toolkit, our team was unable to find in-depth development information of the respective processes in the GWRC's Whaitua Implementation Program.

MWRA Pipe Rehabilitation Program

The MWRA implemented the Pipeline Rehabilitation Program which has provided millions of dollars in ZERO-interest loans for community pipes and lead service restorations and removal. This MWRA program works as part of their Integrated Water Supply Improvement Program and the Local Water System Assistance Program (LWSAP) For Member Communities. LWSAP provides a total of $725 million in interest-free loans to perform water system improvement projects. These loans are expected to be repaid by communities to the MWRA over 10 years (*Local Assistance Programs: LWSAP and LLP*, n.d.).

Similar to Wellington, many of the existing pipelines before the program were of the expanding colonization era and the urbanization that came of it. When digging up old piping, Boston pulled wooden pipe laid in 1795. While this may look like an extreme example, there still exists old, corroding cast iron piping, as well as unlined concrete. Greater Boston saw that more than half of the 6000 miles of community pipes were unlined. So, the MWRA implemented the

rehabilitation program. Due to the MWRAs high-quality water sources and treatment methods, there was no need to spend the money to implement more expensive methods such as those used in communities along the Mississippi or Ohio Rivers. As a result, they were able to convince their stakeholders and regulators to invest in pipes using the money that they would have spent implementing more expensive methods (MIT Water Club, 2017).

The program allows communities to invest in many qualifying projects. To name a few, eligible communities can resource LWSAP funding towards:

- Replacement or abandonment of unlined water main
- Replacement or abandonment of asbestos cement pipe or other water pipeline work performed for water quality purposes
- Identification and replacement of water service connections constructed of lead pipe, lead-lined pipe, brass pipe, or other services in poor condition
- Water storage tank installation, rehabilitation, or replacement
- Engineering planning, design, and construction services associated with the above items. (*Local Assistance Programs: LWSAP and LLP*, n.d.)

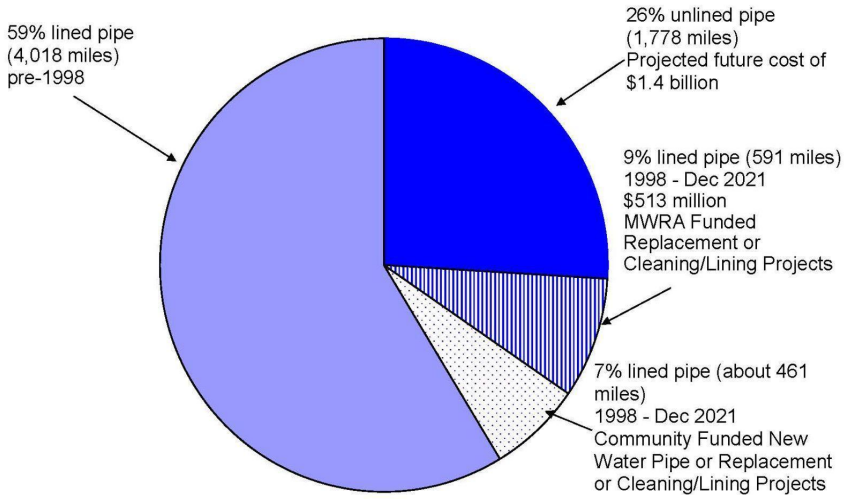

Figure 4.3: Regional Water System Lined and Unlined Pipe 6,828 Miles of Community Water Mains. Updated through December 2021 (Local Assistance Programs: LWSAP and LLP, n.d.)

Future Facility Planning to Combat Climate Change

The MWRA constantly follows climate change science and understands the impacts of rising sea levels that can affect their facilities and operations. The eastern coast has seen many

high-impact storms and nor'easter hurricanes that cause flooding and increased rainfall damages to entire communities. Due to this, the MWRA focuses on the evaluation and implementation of certain measures to allow their facilities to withstand a significant storm event (*MWRA - How MWRA Is Preparing for Climate Change*, n.d.).

Most notably, the MWRA's famous Deer Island Water treatment plant was designed for these specific purposes. To maintain the hydraulic capacity, the plant raised the elevation of the process tank by 1.9 feet and increased the tunnel diameter from 24 feet to 24.25 feet. If these measures were not in place, as the sea level rose, the capacity of the plant would drop (MIT Water Club, 2017). According to Stephen Estes-Smargiassi, Director of Planning and Sustainability at MWRA, "This was the first place anywhere in the country and, I think, first place anywhere in the world someone invested real concrete money in climate change adaptation" (MIT Water Club, 2017).

All MWRA coastal or near coastal facilities, both water operational and administrative, have been evaluated for climate change and sea-level rise. Evaluations follow the 100-year flood elevation regulated by FEMA, and new facilities apply those projections in their design along with incorporating an additional 2.5 feet of elevation.

Figure 4.4: Flood Elevations At Chelsea Creek Facility (Climate Resiliency At MWRA (PDF), 2019)

Figure 4.5: Chelsea Headworks reinforced elevated foundations and flood protection (Climate Resiliency At MWRA (PDF), 2019)

If they are not going to be able to renovate already existing facilities in the next 15 years then they are installing methods to make them more reliable. Short-term flood control measures are being set in place as well such as doorway stop logs. As seen in Figure 4.6, these add extra protection to doorways and other entry points that are easily prone to flooding.

Figure 4.6 (left): Doorway stop log protects facilities from potential flooding (MWRA - How MWRA Is Preparing for Climate Change, n.d.)

Figure 4.5 (right): Alewife Brook Pump Station stop log (MWRA's Climate Change Strategy, 2018)

Doorway stop logs, also known as removable stop log flood barriers, are engineered in various ways to provide protection and defense from high-velocity water loads and impact forces. These systems are often constructed out of cost-efficient low-carbon steel and aluminum

alloys (*Stackable "Stop Log" Flood Barrier*, 2016). Many are modular systems that can cater to various heights and have fixed, nonobstructive end posts. The horizontal beams stack on top of one another while in the posts for easy installation then can be easily stored when not in use ("Flood Log™ Flood Barriers," n.d.).

As seen in Figure 4.7, raised platform equipment platforms are also being implemented as a protection measure against flooding, rising sea levels, and higher tides.

Figure 5 (left): Alewife Brook Pump Station Raised Outdoor Equipment
Figure 5.5 (right): Alewife Brook Pump Station Raised Indoor Equipment
(Climate Resiliency At MWRA (PDF), 2019)

All these measures are important considerations because, as Stephen Estes-Smargiassi states, "I don't want [Boston] to be what happened in New Jersey after Superstorm Sandy where all facilities are offline for months" (MIT Water Club, 2017). Superstorm Sandy was the most destructive hurricane from the Atlantic Ocean in 2012. The storm effectively inflicted nearly $70 billion in damage across the U.S East Coast and Caribbean nations. As an agency, MWRA sees the importance of preventing destructive disasters and takes the appropriate measures of implementing preventative solutions. It is recognized that if such a disaster occurs, the community can rely on the MWRA to continue catering to their water quality needs.

Solution Management Resources in Urban Developments

Our research makes clear that many of the critical issues need much more than just one "innovative solution". In discussion with experts in Massachusetts, we found a benefit in having methods to assess solutions rather than just implementing them.

The Massachusetts Audubon Society, a non-profit that values protecting nature for people and wildlife throughout Massachusetts, has a very detailed Low Impact Development (LID) analysis tool that is to be utilized when LID recommendations are to be implemented into, primarily, residential developments. This analysis review tool was recommended to Massachusetts' Municipal Vulnerability Preparedness (MVP) program, in a series of webinars hosted by the Executive Office of Energy and Environmental Affairs (EEA) and The Nature Conservancy (*Ensuring Success Webinars -- Municipal Vulnerability Preparedness (MVP) Program's Tool Box | Mass.Gov*, n.d.). The Excel-based tool (found on their website) is a method to encourage considering the feasibility of nature-based solutions in communities. It incorporates best practices from local, regional, state, and federal sources that allow users to evaluate existing land. This evaluation takes into account over 30 considerations including street width, erosion control measures, sidewalk drainage, and more (*Bylaw Review*, n.d.). Furthermore, the tool allows users to consider existing policies and bylaws such as local zoning, site plan review, subdivision rules and regulations, stormwater or LID bylaw, and cluster or Open Space Residential Design (OSRD) bylaw (*Ensuring Success Webinars -- Municipal Vulnerability Preparedness (MVP) Program's Tool Box | Mass.Gov*, n.d.). Though the tool is to focus on residential developments, the concept of the tool can be carried to many other forms of development or redevelopments.

Another example of an analysis and management tool used in Massachusetts is an interactive Geographic Information System (GIS) map from the Sustainable Water Management Initiative (SWMI, "swimmy"). In 2012, the EEA released the SWMI committee in compliance with the Water Management Act that incorporates stakeholders and staff across Massachusetts departments such as the Department of Environmental Protection (MassDEP), the Department of Fish and Game (DFG), and the Department of Conservation and Recreation (DCR) (*Sustainable Water Management Initiative | Mass.Gov*, n.d.). The SWMI committee brought along an interactive map containing information on approximately 1,500 Massachusetts water sources and subbasins that comprises information contributed by the stakeholders. The map has capabilities to display biological categories, groundwater withdrawal categories, and net groundwater depletion data layers. The map also incorporates features to analyze Fish Sampling Data Points.

Of the total subbasins, 1,372 subbasins were analyzed for the fish and habitat analysis. The tool is intended to be used by Public Water Suppliers (PWS), consultants, watershed groups, government agencies, and other parties to visually express and evaluate the impact of groundwater movement and levels (*Sustainable Water Management Initiative (SWMI) Technical Resources | Mass.Gov*, n.d.).

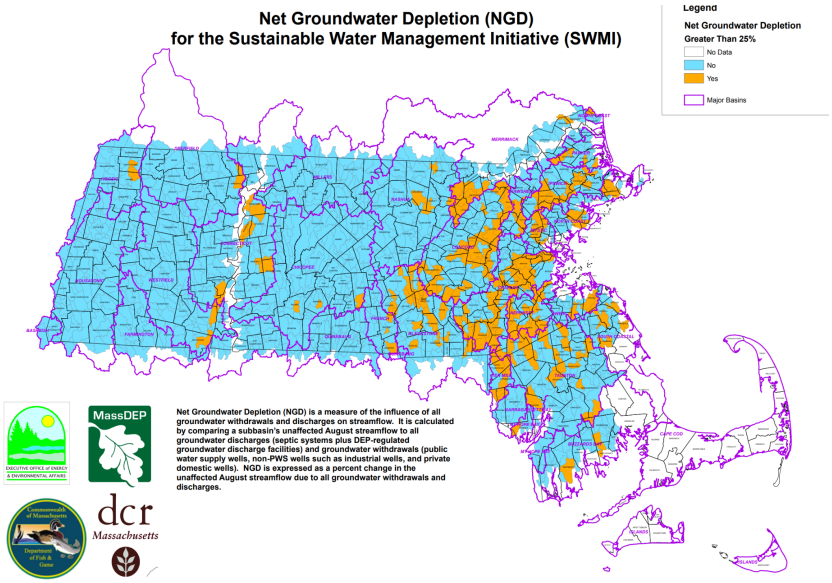

Figure 4.8: SWIMI Net Groundwater Depletion Greater than 25%. Blue - no, orange - yes (SWMI Interactive Map, n.d.)

Massachusetts Policy in Preservation of Habitat and Nature

MWRA Watershed Protection Act

The MWRA's Watershed consists of three main source waters in the state with five other sources as a backup supply. The three, Quabbin Reservoir (412B Gal), Wachusett Reservoir (65B Gal), and Ware River (amount varies) have been determined as some of the least polluted sources available and require minimal treatment in disinfection and corrosion control (*MWRA Watershed Protection*, n.d.). In compliance with the federally issued Safe Drinking Water Act in 1986 (O. US EPA, 2015a), Massachusetts passed the Watershed Protection Act Legislation in 1991 (WsPA). This legislation, in short, is a set of land use regulations that limits alterations to the surrounding land of main watershed sources. This Act is updated every 5 years, the most recent is that of 2019 - 2023 (*DCR Watershed Protection Plan FY19*, n.d.).

The key aspect of the WsPA regulates land alterations within 400 feet of the Reservoir banks and 200 feet of their tributaries (Primary Zone), and other lands between another 200 feet and 400 feet of tributaries, surface waters, aquifers, and wetlands (Secondary Zone). Alterations to the Primary Zone include construction, evacuation, grading, paving, dumping, filling, changing runoff characteristics, dredging, and any generation, storage, or discharge of pollutants. Alterations to the Secondary Zone include dense developments, alteration of bordering vegetated wetlands, impervious surfaces and septic density limits, outdoor storage/use of hazardous materials, petroleum products, and other hazardous materials. Of course, there are exceptions such as existing uses before the act, lawful reconstructions, and certain residential uses, but even those are regulated to not hinder the purpose of the Act. Landowners and developers do have the option to submit an Advisory Ruling Application, which gives an informal identification of whether the WsPA applies to a proposed activity. Overall, types of development, density, amount of paved surface, and proximity to a water source all contribute to types of pollutants. So it is important to keep native land persevered from such alterations (*Watershed Protection Act | Mass.Gov*, n.d.).

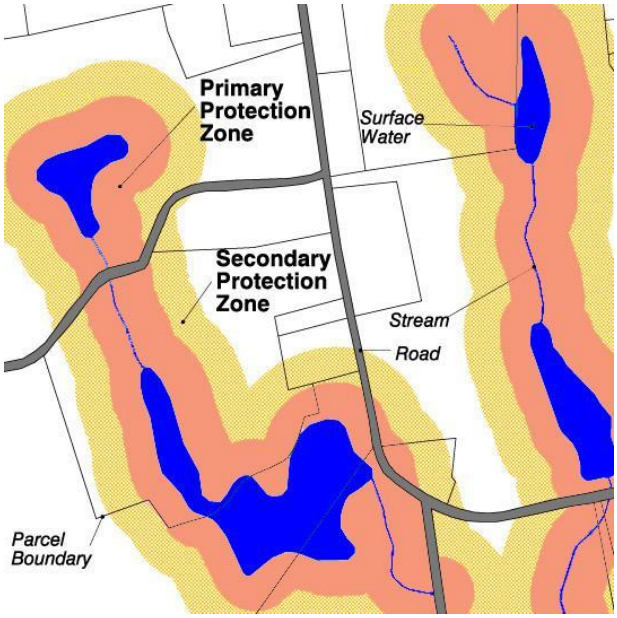

Figure 4.9: Watershed Protection Act's boundary zones (Watershed Protection Act | Mass.Gov, n.d.)

Figure 4.10 displays the evolution of housing development in the vicinity of Chaffin Pond in Holden, Massachusetts. The birdseye images overlook a period from 1995 to 2005 during an age when the WsPA is in early effect.

Figure 4.10: WsPA Example from (left to right)1995, 2000, 2005 (Primary Protection Zone in red and Secondary Protection Zone in yellow) (DCR et al., n.d.)

Executive Director of the MWRA, Fred Laskey, explained in our interview that the Act is in place because the land around a reservoir is clean, which helps water be clean. There are no harmful developments around the sources, so water is protected (F. Laskey, Personal Interview, February 3, 2022). Protection of the WsPA and similar plans are enforced by the 2004 creation, the Department of Conservation and Recreation (DCR), and its Division of Water Supply Protection (DWSP). Such as additional regulations such as engine regulation for outboard motors on boats from DCR property. These motors are limited to 20-horsepower for 2-stroke engines, and 25-horsepower for 4-stroke engines. The DCR also enforces general rules such as No person being allowed within any land of the Watershed system except 1 hour before sunrise and 1 hour after sunset. And while on DCR property, there are prohibited actions to not injure, deface, destroy, or remove any piece of Watershed Property (*Watershed Regulations Revisions*, n.d.). The mission of the DWSP is to protect and preserve the water supply sources for residents of the Commonwealth and the Greater Boston region (*DCR Division of Water Supply Protection | Mass.Gov*, n.d.).

DCR Watershed Land Acquisition

The DCR enforces land alteration restrictions and watershed protection by acquiring land to preserve the natural conditions surrounding the reservoirs. Managing the watershed lands in natural conditions is one of the best ways of preserving the pure water supply it surrounds. This is because of the natural filtering processes a forested landscape provides to the source. In a keynote presentation, the DCR explains that "replication of these natural processes using infrastructure-based treatment and filtration is inferior to and more expensive than, the incomparable benefits derived from watershed land" (DCR et al., n.d.). Much of the funding for the DCR's land acquisition from surrounding communities come from the MWRA, who since the beginning, invested over $150 million to protect the watershed. This is all made possible due to the DCR Watershed PILOT Program, Watershed Payments in Lieu of Taxes. Put simply, the PILOT program is a method that DCR compensates communities, paid in full by the MWRA (*Watershed Payments in Lieu of Taxes (PILOT) | Mass.Gov*, n.d.).

The DWSP has also incorporated the Watershed Preservation Restriction Program (WPR) that allows for the DCRs coordination with private landowners and third parties. By law, the landowner must give up certain rights to their land such as prohibited activities that can harm the surrounding water quality. However, in doing so, the DRC has full range to monitor the land and enforce its protection (*Story Map Journal*, n.d.).

Milestones seen by the DWSP see over 500 parcels of fee acquired, over 22,000 acres protected, and over 5,500 acres in WPRs acquired. All contributing to the reason Massachusetts won Exemplary Source in Water Protection by AWWA in 2010 (DCR et al., n.d.).

Massachusetts Water Usage Regulations

Low Flow Solutions

The MWRA provides many online Community Support Programs to inform communities and personnel ranging in a variety of Sewer System and Water System Topics. Of the Water System Topics, the Water Conservation and Efficiency section provides important information on how to save water in residential, industrial, commercial, and institutional locations. This helps

maintain the regional water demand below the water supply system's safe yield (300 million gallons per day)(*MWRA Community Support Program*, n.d.).

Water-efficient toilets are among those low-flow solutions outlined to communities by the MWRA. According to the MWRA, flushing accounts for about one-third of the water used in a home each day. By upgrading to a low-flow toilet, a home's water consumption could permanently be cut by approximately 25% (*MWRA Facts About Ultra Low Flush Toilets*, n.d.). Implementing a low-flow toilet into a residential home can be difficult due to the varieties of toilets on the market and cost, so the MWRA helps with some preliminary information on the topic. As per a few examples; Gravity toilets are the most common and relatively cheapest option ($100-$200). This type of toilet releases water through a flapper valve driven by gravity to clear out the bowl. Pressure Assisted Toilets are hybrids of gravity and flush valves as they operate using a pressurized tank. They tend to cost around $200. Flushometer toilets are common in commercial buildings as they do not require a back tank but rely on a pressure operation from the building's main water supply. These are priced at approximately $300 (*MWRA - Water Efficient Toilets*, n.d.). The MWRA provides helpful advice, statistics, and external links to much more that help aid a homeowner to make the decisions of a low-flow toilet. They also highly advocate the public implement toilets that meet the EPA criteria for water efficiency and performance, such as WaterSense labeled toilets, an EPA-sponsored program (O. US EPA, 2016).

Expanding on low-flow solutions, the MWRA also highlights the usage of low-flow water fixtures such as slower heads and faucet aerators. In fact, they provide water-efficient retrofit kits at NO COST to members in 61 Massachusetts communities. Whether residential homeowners, housing authorities, property managers, etc, the MWRA asks only to fill out a simple online request form for preliminary information then mails the kits (*Home Page - Water Conservation*, n.d.). These easy-to-install kits include a low-flow showerhead (2.0gpm), a faucet aerator (1.5gpm), dye tablets for silent toilet leaks, and an instruction/informational manual. The MWRA can afford free distribution of the kits because they buy them in bulk (*MWRA - Water Conservation and Efficiency Main Page*, n.d.). In their Fiscal Year for 2021, the MWRA reports the distribution of 6,714 water-saving fixtures kits (*NPDES Report on Water Conservation*, n.d.).

Limitations on Lawn Water

Massachusetts limitations on lawn water is a notable method of water conservation as part of the Water Management Act Program by MassDEP. These lawn restrictions are intended for cities, towns, and golf courses to reduce summer water usage. Though varying based on the water system or community, the restrictions often entail; (1) Limitations on the hours of the day you may water. (2) Limitations on the number of days per week you may water. (3) Restrictions to automatic sprinklers or irrigation systems. (4) A complete ban on outdoor watering (*Outdoor Water Use Restrictions for Cities, Towns, and Golf Courses | Mass.Gov*, n.d.). MassDEP assesses potential water systems for participation by reviewing annual statistical reports of information such as high summer-to-winter water use differences. These statistics suggest that there is a significant amount of lawn watering in the summer months (*Outdoor Water Use Restrictions for Cities, Towns, and Golf Courses | Mass.Gov*, n.d.).

The Aquarion Water Company (AWC), a water supplier for several Massachusetts communities, promotes that customers who cut back on outdoor sprinkler irrigation and other uses have helped to save more than 2 billion gallons of water across the AWC system in the past 3 years (*Aquarion MA Water Quality Reports*, n.d.). The mandatory irrigation regulation schedule for AWC works per address number. If the last digit of your address number is EVEN (0, 2, 4, 6, or 8) then you are instructed to water only on EVEN-numbered days. Similarly, if the last digit of your address number is ODD (1, 3, 5, 7, or 9) then you are instructed to water only on ODD-numbered days. Residents are asked to water on their respective days between a choice of 12:01 am - 9:00 am or 5:00 pm - 12:00 am. By following the mandatory schedule for sprinkler irrigation, customers are cutting back on their water bills and saving millions of gallons each year (*Massachusetts Irrigation Schedule*, n.d.).

Community Outreach and Education

Along with its Community Support Programs, the MWRA has made great strides in its community outreach in both the public and academic sectors. First, the MWRA provides conservation education brochures for local distribution to assist communities, environmental groups, and other stakeholders wanting to learn more about the topic. The brochures provide

education on why it is important to save water and how to conserve both indoor and outdoor to improve the water quality in homes and communities (*MWRA Tips for Water Conservation*, n.d.). This education material is provided in retail locations and community centers at no cost. During the Fiscal Year of 2021, MWRA distributed over 83,234 pieces of printed materials. Similarly, in FY21, the MWRA distributed more than 910,000 copies of their Annual Drinking Water Quality Report, mailed to every household in their service area (*NPDES Report on Water Conservation*, n.d.).

For further questions and clarifications, the MWRA also maintains its very own water conservation hotline, (617) 242-7283 / (617) 242-SAVE. This is a valuable system to extend further resources and valuable information to members of communities who want to learn more.

The MWRA also makes water conservation school education and awareness for the future generation a priority. The School Education Program is designed to provide a science-based curriculum by educational curriculum development, conducting classroom presentations, wide-spread teacher training, continual follow-up, and support to educators including distribution of thousands of coloring books, bookmarks, and water conservation guides (*NPDES Report on Water Conservation*, n.d.). During the 2020-2021 school year, the MWRA conducted 75 classroom presentations, reaching approximately 2,010 students in pre-kindergarten through college-level classes. The School Education Program also contributed to MASS STEM Week, a week of education in schools, museums, and organizations by the Massachusetts Executive Office of Education and the STEM Advisory Council.

Though only a few are named here, the MWRAs public outreach strategies demonstrate effectiveness towards conservation and remaining comfortably stable below the safe yield of 300 million gallons per day (*NPDES Report on Water Conservation*, n.d.).

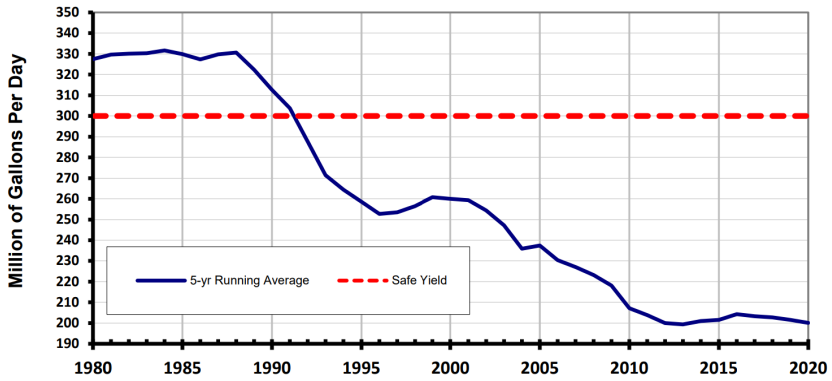

Figure 4.11: MWRA Reservoir Withdrawals (5-year average) (NPDES Report on Water Conservation, n.d.)

Case Studies from Massachusetts

Boston Harbor, "Dirtiest Harbor in America, 1984"

The Boston Harbor is an important local case study to look at because of its transformation from one of the most polluted harbors in the country to a thriving waterfront. Another reason to consider this case study is the parallels to the water crisis in the Greater Wellington Region. Boston Harbor had plentiful resources and high-quality water while sustaining native tribes, but both of these things depleted after European settlement. Rapid urbanization and population growth in the Boston area strained coastal resources and contaminated the harbor. Salt marshes were filled in to accommodate the booming population, and further expand the city. One of the main contributing factors to Boston Harbor's poor water quality was the wastewater contamination from sewage disposal. Boston Harbor became so polluted that it was referred to as the "harbor of shame" in 1980. Charles River, one of the harbor's tributaries, received a D rating in 1995 because it met boating standards only 39% of the time, and swimming standards only 19% of the time (Bowen et al., 2019).

Boston Harbor was able to vastly improve its water quality through the Boston Harbor Project, one of the largest wastewater infrastructure projects conducted in the USA. The Federal Clean Water Act of 1972 (CWA) required secondary treatment of sewage and even had a grants program that would provide up to 75% of construction costs. Cleaning up Boston Harbor was not as simple as following these guidelines, as the Metropolitan District Commission (MDC), the

agency responsible for wastewater treatment for much of the Boston metropolitan region, originally applied for a waiver from the requirement. During this delay, the neighboring city of Quincy attempted to halt new sewer hookups, which they failed at, but the threat expedited the problem-solving process. The MWRA, the organization we have conducted several of our interviews with, was created in response to this dilemma. The organization was formed in 1984, and they were quickly held responsible for rehabilitating water and sewer systems and bringing them into compliance with the CWA. The Boston Harbor Project was federally mandated to have construction started in 1990, and completed by 1999 (Armstrong & Wallace, 2001).

The Boston Harbor Project invested about $3.7 billion into the Deer Island Waste Treatment Plant. The redesign of the Deer Island Waste Treatment Plant involved secondary treatment of sewage, conversion of sludge into fertilizer, and diversion of treated wastewater. The outfall location was changed to Massachusetts Bay, and monitoring suggests there are minimal adverse effects from this diversion. A large improvement made during this project was the cessation of ocean sludge dumping. When processing the sewage, it is separated into wastewater and solids. The wastewater is chemically disinfected and discharged into Boston Harbor, while the solids are converted into fertilizer. Raw sludge is moved to digesters where microbes decompose organic solids, destroy almost all disease-causing pathogens, and then accumulate as biosolids. The MWRA then ships this mass by barge to the Quincy Pelletizing Plant. At this plant, sludge is mixed with a coagulating agent then pressed into sheets with wide fabric belts. Any removed water is pumped back through the sewers to one of the treatment plants. The pressed “sludge cake” is then baked at 320 degrees Celsius to destroy all pathogens and bacteria, remove up to 90% of the remaining water, and form it into the final fertilizer pellet (DeCocq et al., 1998)**.**

In the Boston Harbor Project, another $1 billion was spent in treatment for combined sewer overflows. Standard sewer pipes often overflow, and this overflow is caught in pipes called combined sewer overflows (CSOs). As part of the BHP, the MWRA had to upgrade all of these CSOs to include screening and chlorination before releasing waste directly into the harbor and its tributaries (DeCocq et al., 1998). This helped reduce the flow of contaminants into the harbor.

The Boston Harbor Project managed to convert the Boston Harbor from a shameful location to one that supports a growing population and draws tourists and locals to its shores. Its aggressive agenda helped push the city to make the changes that were needed to improve the water quality and the city's sewage treatment practices.

MAPC Partnered Proposal with Wampanoag Tribe

Recently in Massachusetts, the MAPC has been in partnership with the towns of Duxbury, Kingston, and Plymouth Bays (DKP), to assess beneficial nature-based solutions for stormwater management and coastal resilience in 2 years. Of the key deliverables DKP addresses, there is a highlighted importance to prioritize Herring Pond Wampanoag and the Wampanoag Nation. As per the proposal document, "The Wampanoag have lived in Southeastern Massachusetts for more than 12,000 years… Their land, livelihoods, health, and community were stolen from them through colonization" (*Final_DKPCreating Natural Solutions_MVPActionProposal.Pdf*, n.d.). The focus on creating nature-based solutions prioritizes the Wampanoag, allowing them to advocate for the land that was once theirs. Martin Pillsbury, Environmental Planning Director, explained that this proposal was less of an effort in outreach but more in collaboration, "bringing the Native American Collaborators of this project at the center, not just an exterior group" (M. Pillsbury, Personal Interview, February 1, 2022). The project hoped to find measures and implementation strategies in science that can reflect the Wampanoag Nations culture. This project plan is in ordinance with the Massachusetts Coast Flood Risk Model (MC-FRM). The MC-FRM displayed a detailed analysis of potential flood and overflow pathways in the present day and future conditions up to the turn of the next century. It combines both government and tribal data that contribute to future assessments. Despite the efforts, the project fell shy of getting funding. Pillsbury reflects that this type of proposed document is hard to implement in Massachusetts, and most of the United States because colonialism hit the Native Americans harder than most indigenous tribes. The Wampanoag Nation was once strong but has been persecuted and marginalized to the point they have been nearly erased from history (*Final_DKPCreating Natural Solutions_MVPActionProposal.Pdf*, n.d.). It is difficult to make a substantial policy change when opposing 300 years of colonial traditions (M. Pillsbury, Personal Interview, February 1, 2022).

Case Studies Beyond the Commonwealth

River Pollution Cleaning Solutions

Looking outside of Massachusetts for river pollution cleaning strategies has provided us with a diverse set of potential measures. These measures both offer pollution cleaning right to the source and implement automatic river-wide devices to capture floating debris and rubbish. Plastic bottles and similar waste are huge issues in today's age that can obstruct ecosystems and harm their wildlife.

The Bubble Barrier of Amsterdam is a unique catchment that was constructed in 2019 by the Waternet Utility Company to protect the North Sea from plastic pollution in the city. This is different from most catchments because it catches plastic underwater instead of only on the surface. It does so by pumping air through a tube to essentially blow a screen of bubbles directing a current towards the surface and therefore does not prevent wildlife or ships from traveling through as well. As seen in Figure 4.12, the system is placed on a diagonal to the waterway, which uses the natural flow to guide the rubbish into the collection system at the riverside ("Bubble Barrier Amsterdam," n.d.). Initial tests of the system displayed a collection percent of 82% to 86% of the test material (*12 Systems for River Cleanup · Designed Conscious*, n.d.).

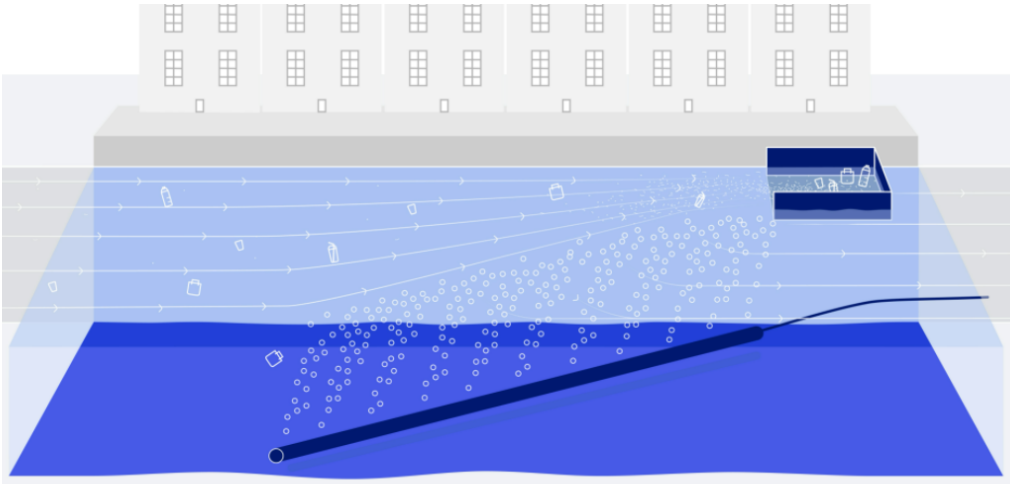

Figure 4.12: Diagram of the Amsterdam Bubble Barrier in action ("Bubble Barrier Amsterdam," n.d.)

Another innovation we found is the River Cleaning System in Italy. This system uses a diagonal array of floating, rotating devices to pass surface waste out of the river to a collection point, seen in Figure 4.13. The barriers are anchored with flexible lines to the river floor and act as if they were a series of normal buoys. So, if a larger object or boat comes across the system, they are pushed out of the way then return to their starting positions. This design is 85% effective, runs by the river's power, and is easily scalable to any river. Like the Bubble Barrier, the River Cleaning System does not block wildlife from passing through and protects the surrounding ecosystem ("River Cleaning - The Revolutionary System for Cleaning Rivers," n.d.).

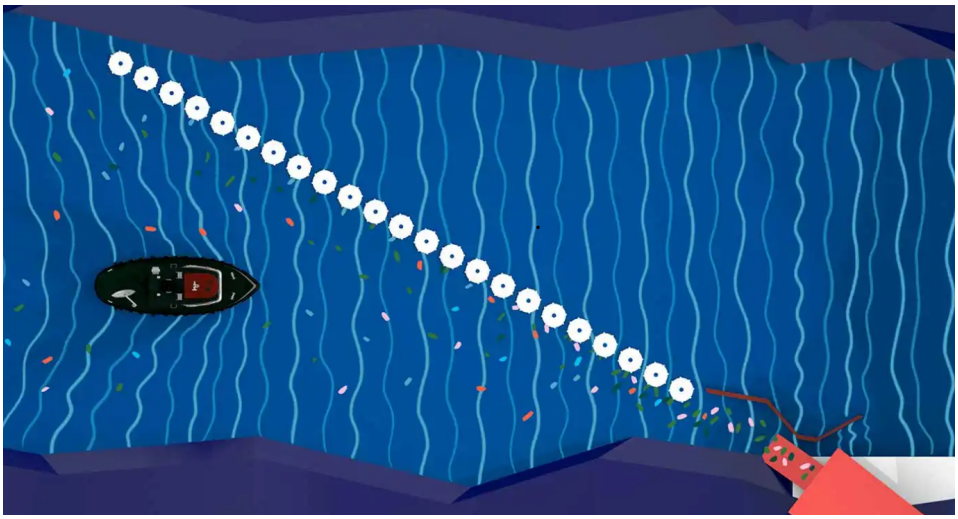

Figure 4.13: Diagram of Italy River Cleaning System ("River Cleaning - The Revolutionary System for Cleaning Rivers," n.d.)

Developments like these can clean rivers with little inconvenience to the public. They come from dense urban settings which incorporate methods of transportation through waterways. Both these solutions are viable methods to decrease the amount of floating pollution in a waterway. Unlike a net, these implements provide easy integration within the ecosystem so fish can swim easily and boats can travel without disruption. These river cleaning systems also have the capabilities to be autonomously powered by an energy-efficient source like solar energy, which can reduce manpower and unnecessary energy consumption.

4.3 Discussion

Due to the overwhelming complexity of water quality management, and how much of it is dependent on governmental structure, not all of our global research can be directly translated to the Greater Wellington Region. Our team conducted research on a variety of water management practices, specifically in Massachusetts, and although they will not all be directly included in our recommendations, we still feel it is important for those at the GWRC to review. It is important to learn about the different ways water is being managed, and the systems that are in place which allow for this management

5. Recommendations and Future Directions

5.1 Reflections on Recommendations

When first approaching this project, we expected to complete it with a list of concrete, technical recommendations for the GWRC, such as installing more bioretention swales or putting rain barrels in some specific locations. However, once we became more educated on the complexities of water quality management, our initial idea for the structure of recommendations began to fade away, and we had to reframe our thinking. Water quality management can be seen as a "wicked problem," a term that was coined by design theorists Horst Rittel and Melvin Webber (*Wicked Problems – Transition Design Seminar CMU*, n.d.). This type of problem does not have a direct solution and instead has complexities that transcend the abilities of traditional problem-solving. Some of the factors that qualified water quality management in Wellington as a "wicked problem" were the multiple stakeholders involved, the degree to which government policy and regulation influenced it, and its deep-rooted connection to cultural and social norms.

"Wicked problems" contrast with "tame" problems that can be approached with a specific methodology to produce a concrete answer. As STEM students, we were used to studying "tame" problems within science and engineering, which is why our group had a different initial perspective of the types of recommendations we would be able to make. In our studies, we have been taught to follow a particular process to find a solution, and give a concrete answer to each problem. The many social, political, and economic factors that make up water management could not be simplified into a problem-solving process and required our team to re-evaluate our approach to recommendations.

Figure 5.1: Wicked Problem Diagram of Water Quality Management

While our recommendations may not be as clear-cut as we initially believed they would be, we still were able to offer a set of ideas that can be effective in addressing challenges of water quality management. We have found some solutions—e.g., permeable pavement—that are similar to the technical solutions we initially set out to give, but our deliverable has shaped up to be far more multifaceted due to the complexity of the situation. Some of our recommendations have developed into more of a discussion of what approaches to water quality are working, why they are working, and some of the difficulties with implementation. Information is one of the most important items we were able to deliver, even if we did not have all of the answers to how it would be implemented in the Greater Wellington Region.

5.2 Objective 3 Findings

Based on the research we conducted in the Results and Findings section, along with guidance from our Sponsors, we compiled a brief list of important topics to touch upon in our Objective 3 interviews with those in Wellington. The main purpose of these interviews was to run some of those solutions to get a reaction and input on if they are feasible to implement in Wellington. All while taking into account the cultural and political factors that may differ

between Wellington and Massachusetts. See Appendix D for objective 3 interview questions. These final discussions with members of the Wellington community helped our group culminate the results of our project into developed recommendations.

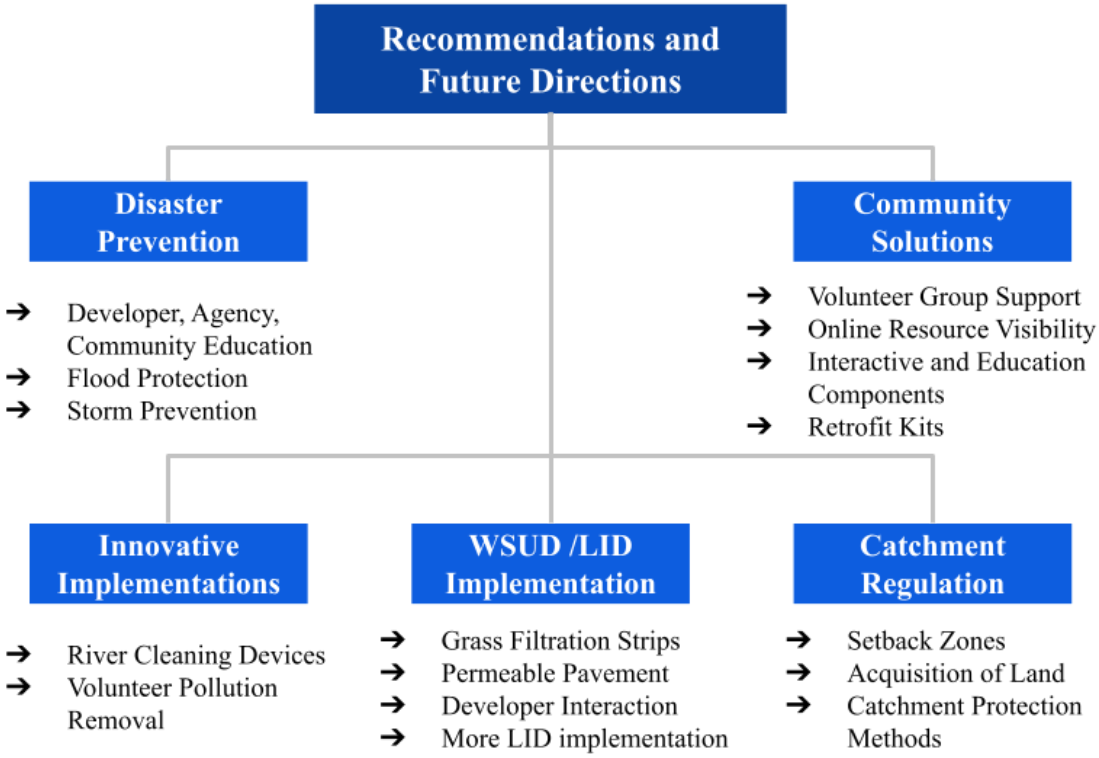

Figure 5.2: Recommendations and Future Directions Chart

5.3 Considerations of Innovative Implementations

One of the first things we took note of when doing the first rounds of interviews with those in Wellington is the abundance of pollutants in rivers, streams, and other sources of water. Those in Wellington seemed enthusiastic about the case studies we conducted for automated river cleaning implements and the ideas that came along with them, though we found that implementation of these devices would cause challenges. Currently, similar devices are relatively common in other parts of New Zealand but quite uncommon in Greater Wellington.

In Wellington's case, we learned that there are two main direct sources of debris. Those that are flushed down from the catchment as well as those that come up the end of the river on the tide. Currently, there are methods such as filters and grates at the end of stormwater pipes but

those can be unreliable during extreme storm conditions. The case studies we reviewed would be more beneficial to implement on the portions of the river containing more downflow pollution.

Additionally, we learned that there are Friends of River groups who organize volunteer labor for rubbish collection. These groups provide excellent programs for volunteers to aid in much of the pollution build-up on the banks from those tide events. However, as described by Grant Webby of the Friends of Waiwhetū Stream, these volunteers are generally organized once a month (G. Webby, Personal Interview, February 15, 2022). Though volunteer labor is a low-cost way to keep pollution out of the water, an automated, 24/7 river cleaning device can save in pollution that is expelled further down water sources and into the harbour.

Volunteering programs and less technical cleaning methods can adhere to the concept of Te Mana o te Wai but the reality is that it is very difficult to revert to the traditional ways of taking care of water sources. To revive these traditional ways, we need to rethink the design of our socio-economic systems. For example, one of the challenges of going back to these traditional ways is to imagine not having plastic water bottles entirely. This would be a huge step and is most likely not going to happen. Thus, we suggest that developing new engineering and technical measures such as floodplains and wetlands can be more effective while the efforts to revive the traditional ways are introduced (T. Sharp, Personal Interview, February 20, 2022).

The concept of having a machine to collect rubbish is also not entirely the issue to focus on. Alastair Smaill of the GWRC described there to be a perception of “high cost” in the public and agencies' eyes. Due to the fact of being “new”, innovations bring along “new cost”, and according to Smaill, most of that perception was not valid. Though there are maintenance and manufacturing costs to consider, in the long run, those costs are not particularly high in comparison to what you are gaining. As Smaill pointed out, “implementations of these types of devices can be seen by some to be ugly, but the [pollution] needing to be cleaned is also ugly” (A. Smaill, Personal Interview, February 17, 2022).

Though recommending physical measures can be situational, we advise the GWRC, and those involved in similar implementation processes, to not discount new ideas entirely. New innovations come along all the time so the challenge is not necessarily finding solutions but involves removing inappropriate preconceived notions that can hinder involvement in

implementation. Such as the “high cost” perception shared between communities and developers (A. Smaill, Personal Interview, February 17, 2022). So the GWRC should also implement methods of educating and connecting developers and communities to resources that influence their decisions in the right direction for innovative implementations.

5.4 Developers LID/WSUD Implementation

In Wellington, there are seeds of low-impact developments (LIDs), but work needs to be put in to make these a common practice. Wellington should create a focus on green infrastructure over gray infrastructure, and educate developers and landowners alike to achieve this goal. Utilizing a toolkit similar to that of the MWRA would be useful to make LID facts and methods of implementation accessible. Two forms of LIDs that we focused on during our Objective 3 interviews were Grass Filter Strips (GFS) and permeable pavement. Those we interviewed in Wellington were typically familiar with these ideas, however, it did not seem like these LID features were pushed for in new developments. There was positive feedback on these ideas based on their current uses, but the consensus was that developers do not use LID features in their projects enough. When asked about the use of GFS and permeable pavement in the Wellington Region, Webby stated, “They are used, I'm aware of that. But I think it needs to be pushed more proactively as a solution.” To increase the use of these solutions, Alastair Smaill suggested an education program to be implemented for helping driveway companies use the permeable pavement. A similar program could also be utilized for introducing developers to other LIDs.

While these ideas were supported, it was not without concern. One item of concern was the buildup of debris within the grooves of permeable pavement or the wearing down of this pavement. Permeable pavement is most successfully implemented within parking spots and not areas of high traffic such as the traffic lanes in a parking lot to delay deterioration. Additionally, a large deterrent for green infrastructure is the cost of it. Developers may not be inclined to implement LIDs just for the sake of it if they are more costly than other types of infrastructure. A requirement for some of these LIDs in new developments would likely be the best way to ensure implementation if there is not a push for their use by developers. Even requirements are not always enough, as Grant Webby mentioned people often ignore or are ignorant of planning regulations, such as requirements for minimum permeable areas. Stronger regulations and a

proactive campaign for green infrastructure are likely the way to ensure success within these areas.

5.5 Watershed/Catchment Protection

Lawmakers in New Zealand have adopted similar watershed regulations to what we have found in Massachusetts. Setback zones are commonly used to limit activities close to water bodies, but it has been difficult to get the public on board with regulating land. Common strategies to push regulations include private companies donating land to government agencies, public trusts, and voluntary submission to regulations where someone wants to preserve their wetland. Smaill highlighted both reserve and development contributions and how they can be utilized to protect the land. A reserve contribution involves either donated land or money to purchase land to preserve it. On the other hand, a development contribution requires the developer to supply money for infrastructure. This could be used to create an infrastructure that treats water. Both of these contributions can be used to implement watershed regulations. Nonetheless, it is important to prioritize public land over private land so that newly acquired public land will have a strong precedent to follow.

We have also learned that it is not enough to regulate watersheds, rather it is also important to enhance them. Aquifers get water from rivers and rain, which have the potential to bring along pathogens and chemicals. This can come from factories and especially lead battery recycling. The quality of such streams needs to increase to supply more clean water. In our review, we wanted to focus on solutions that balance protecting the water and keeping it open to public use, as the water is such an important part of Iwi and Māori culture. It would be ideal to allow for recreation such as swimming and fishing but not in all streams, as some are more connected to aquifers.

5.6 Future Planning and Disaster Prevention

We learned that Wellington and large portions of New Zealand's North Island were struck by Cyclone Dovi on February 12, 2022. This cyclone left thousands without power and saw mass amounts of flooding and damage. "Wellington's second wettest day on record" headlines the

New Zealand Herald (*Cyclone Dovi*, n.d.). As a result, our objective three interviewees were keen to discuss future planning.

Currently, the approach in Wellington for taking preventative action is lacking. There is a government-level action regarding stormwater hazard and flood hazard mapping that estimates the effects of climate change, but those are more methods of storm prediction. Though Wellington is beginning to recognize the importance of stormwater Low Impact Developments they currently don't have many physical solutions implemented in their community to face those problems head-on. Our interlocutors in New Zealand expressed concern that such climate change conversations in Wellington do not often turn into action.

The increased number of cyclones and their harshness, as well as saltwater getting into aquifers due to rising sea levels, prove that climate change is happening. However, the public awareness to actively contribute to climate change prevention seems little to none. It is apparent those in Wellington are behind in terms of taking any action. As for most challenges of implementations, funding for projects is difficult to organize too. Who is paying? What are the regulations? "Any time you mention climate change to funders… they sort of run out of the room," said Smaill. This brings back the conversation discussed in section 5.3 about how developers and funders turn their heads at feared, unknown costs.

Given the current impact of climate change and the need for urgent action, our team suggests a stronger movement towards these focuses. Cyclone Dovi was a prime example of the types of disasters communities and agencies need to be prepared for. To do so, these communities need to recognize the cruciality of the problems at hand. "It's nothing like a crisis to sort of precipitate some of these things… The experience of having your sewage station completely flooded for two weeks will bring that to the forefront of people's minds" exclaimed Smaill (A. Smaill, Personal Interview, February 17, 2022).

Being on the Northern East Coast of the United States, Massachusetts is prone to hurricanes and nor'easter disasters, similar to cyclones in New Zealand. Measures to combat these disasters are well-known in Massachusetts as well as in Wellington. The difference is that the MWRA takes action in communicating with developers to install such methods. For instance, evaluating facilities for withstanding hurricane categories and flood levels is one of the utmost

important parts of the MWRA's prevention, and is required. Though renovations to facilities will require long-term time, facility evaluations can start now. As an agency, the MWRA sees the importance of preventing destructive disasters and taking the appropriate measures of implementing solutions. It is recognized that if such a catastrophic disaster occurs, the community can rely on the MWRA to continue catering to their water quality needs during those times. We think this standard is important for the communities surrounding the GWRC and local water authorities to be recognized in Wellington as well.

Our group has learned the immediate importance of future planning for disaster prevention. Communities should have reliable water facilities and treatment methods whenever unfortunate events occur putting them at harm. We recommend more focus on disaster prevention to mitigate the effects of climate change, rising sea levels, and higher tides. The Whaitua Implementation Programme outlines a number of long-term solutions, which is appreciated but we recommend there be more focus on those short-term solutions as well. Evaluations of facilities and implementations, whether coastal or other disaster-prone locations, should be considered as a requirement to prevent such disasters. We also recommend educating communities, fellow agencies, and developers involved in implementing preventative solutions about the science and impacts of climate change. Cyclones and floods are becoming more frequent so it is beneficial to reintroduce and reinforce plans for the future as they are responsible for protecting communities. All these concepts also highlight Te Mana o te Wai in protecting the movements and characteristics of water as it pertains to human and environmental relationships.

5.7 Community Solutions

As mentioned in the previous section, increasing public awareness and education measures will be an important part of working towards a more sustainable vision in water quality management. There are a few ways of going about this process. One way is supporting community organizations, such as the Friends of Waiwhetū Stream. These organizations work in local areas to clean waterways and improve water quality. Friends of Waiwhetū Stream work with a local stream, cleaning out pollution and introducing plants that decrease sedimentation onto the banks of the Waiwhetū Stream. When talking to Grant Webby, secretary of Friends of Waiwhetū stream, he noted that the group can frequently communicate with the general public

while doing projects. He said that people frequently will come up to them and ask them what they are doing, giving them a chance to educate the public while also working on improving the quality of local water bodies (G. Webby, Personal Interview, February 15, 2022). Having a group organization such as this one which is open to the general public also provides a low barrier to entry, allowing people to become impassioned to improve water quality easily. Our group recommends that the GWRC continues to put resources into supporting or creating these types of groups, as they are one of the best ways of interacting with and educating the public while also improving water quality.

Public education measures are a good way to teach the public about what they can do in their day-to-day lives to improve water quality. These resources have been created and polished, and are located on websites such as Wellington Water and the GWRC homepage. However, it seems that their current visibility is quite low. It is clear that these resources were made with a significant amount of care and consideration, and would be valuable resources if the public were able to find them. By making it easier for the public to use these guidelines, motivation to improve water quality and public education on taking care of water could improve drastically. Therefore, it is our group's suggestion to leverage online advertising, social media, and other forms of community outreach to make it easier for the public to engage with water quality improvement in their daily lives.

The final community-based improvement we recommend is to incorporate interactivity into water quality improvements. An example of this was brought to our attention when speaking with Ross Jackson, who noted that the artificial wetlands built on the Hutt River have drawn the attention of many people due to their visibility from the nearby highway. Jackson stated that he believes that this visibility and attention cause people to ask questions regarding water quality, about their needs and purpose. The result of this is a more informed community, which in turn will lead to more social motivation to improve water quality (R. Jackson, Personal Interview, February 15, 2022). Because of this, it is our group's recommendation to allow community members to interact with solutions. Even something as simple as a sign with a few sentences could be enough to engage with the public and lead to a strong foundation for water quality improvement in Wellington.

Another issue related to the visibility idea is how to allow citizens to take action themselves to improve water quality in their daily lives. One program being employed in Massachusetts is the idea of community retrofit kits, which are supplied to community members with the intention that they will install them in their own homes, improving their household water efficiency. In Massachusetts, they are supplied free to citizens to increase installation compliance. When water quality advisors were asked about the feasibility of a plan similar to this one, the consensus was that it would be a positive plan. The main concern raised was that some people may already have parts of the retrofit kits, such as aerators on their faucets which are relatively common. For this reason, it may be necessary to customize these kits to a degree. Regardless, these plans seem like an excellent way to engage the community while also improving water efficiency.

Conclusion

Overall, this project gathered feedback and generated new connections between water quality experts from Wellington and Massachusetts. As the project began to enter its third objective phase, it became apparent to our group that providing meaningful feedback on an issue so complex as water quality management would be difficult. It took an abundance of research and consideration to provide recommendations in these areas. When advising our sponsors on these problems, it was important to consider that irresponsible advice could end up worsening the very issue we were trying to solve. With that in mind, the number of recommendations we were able to offer is relatively substantial, and we feel that we have made useful progress in areas central to water quality improvement. Another interesting pattern that emerged is that some of our recommendations echo, rather than modify or augment, the initial proposal from the GWRC. We felt that this was important to include nevertheless, as the repetition would demonstrate that independent sources concur with the GWRC's initial proposal prioritization of these areas. Overall, we feel that when comparing the complexity of the problem and the amount of time allocated for this project, we were able to provide strong feedback that can feasibly be implemented to improve water quality in the Greater Wellington Region.

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Appendices

Appendix A. WPI Interview Preliminaries

Without recording, ask if you have permission to record.

If the participant answers “yes”, then, tell your participant the following with the camera/recorder rolling:

“This project is recording interviews as part of an educational project. By appearing on camera/audio, you are consenting to the use of your image/voice for the purpose of our project which will be published on the WPI website.”

“We are here on [say the date] to talk about [project and objective description]”

“We will be aiming to keep the interview to 45 - 60 minutes”

Continue your interview as scheduled

Appendix B. Objective 1 Interview Questions

1. **Introduction - Project Summary**

We are a team of students from Worcester Polytechnic Institute in Massachusetts, USA, working in collaboration with the Greater Wellington Regional Council to assess methods of water management and innovative systems that could have potential feasibility in the Greater Wellington Region. This phase of our project is to conduct interviews with local water experts in the Wellington area to discover current areas of critical need in water quality management.

We were given your name by, [insert name], who has told us you are [insert profession and relation]

a. Do you have any questions about our project?

b. Can you briefly describe your connection to water quality in the Wellington Area? Connection to the GWRC?

2. Te Mana o te Wai Based Questions

a. What are your opinions on the Te Whaitua te Whanganui-a-Tara Implementation Programme and its recommendations?

b. How do you think the Implementation Programme will improve water quality needs over time?

c. How has Te Mana o te Wai affected your line of work and community?

3. Initial Questions - Understanding Interviewee

a. Why is your profession/the water quality connection important to you?

b. Why might it be important to general citizens and the Greater Wellington community?

c. Would you consider your profession in water quality an area in need of improvement in the Wellington area? How so?

d. Has the public been shown how your profession is dealing with this area of need?

e. Does the public share your opinion?

4. Objective 1 In-Depth Questions

a. In your opinion, what is the most critical area(s) of need in terms of water quality in Wellington?

b. What measures have been taken, if any, to alleviate this (these) problem(s)?

c. Can you think of any solutions/measures which may help to address this problem?

d. Do you think that Urbanization is an area of priority, in terms of stormwater management and habitat preservation?

5. Regulations and Policies

a. Overall, what other local, government, and/or traditional policies are in place that help or hinder water management solutions?

b. Which measures are easier to implement than others and why? Might relate to the previous question

c. Do you know of any potential solutions that could be implemented to aid in this problem?

d. How to drive change in political action?

6. Closing

a. Is there anything else you would like to bring up/talk about?

b. Is there anyone else that you think would like to talk to us? If so, would you mind giving us their contact information, or emailing it to us sometime after this meeting?

We appreciate your time and interest in being interviewed for our project. We hope to stay in contact as our project develops.

Appendix C. Objective 2 Interview Questions

1. **Introduction - Project Summary**

We are a team of students from Worcester Polytechnic Institute in Massachusetts, USA, working in collaboration with the Greater Wellington Regional Council to assess methods of water management and innovative systems that could have potential feasibility in the Greater Wellington Region. This phase of our project is to conduct interviews with local water experts in Massachusetts to discuss Wellington's critical needs and potential solutions offered in the Commonwealth.

We were given your name by, [insert name], who has told us you are [insert profession and relation]

a. Do you have any further questions about our project?

b. Can you briefly describe your connection to water quality in the Greater Boston and Massachusetts Areas?

2. New Zealand Understanding

Even if they don't have questions it might be important to highlight these ideas

a. At the GWRC in Wellington, we are working alongside the Te Whaitua te Whanganui-a-Tara Implementation Programme, which is…

b. A big highlight in the program is the cultural Māori concept of Te Mana o te Wai which is…

c. The GWRC tasked us with finding innovative solutions around the world…

3. Initial Questions - Understanding Interviewee

a. Why is your profession and its water quality connection important to you?

b. Why might that connection be important to general citizens but also MA as a whole?

i. We found that the MWRA's unofficial slogan is "Drink with Confidence, Flush with Pride".

c. Does the public share your opinion?

4. Objective 2 In-Depth Questions

We found that Wellington is facing critical issues such as rapid urbanization which has led to several problems including:

i. Stormwater drainage issues

ii. Sewage and other pollution runoff into natural bodies of water

iii. Ability to monitor water health in natural bodies of water

iv. Loss of habitat preservation

v. Lack of public involvement and interest in improving water quality

Address each, and feel free to deviate in your answer, we conducted some research on solutions in place in MA currently…

Stormwater Management

a. In our research, we found that the MAPC values Low Impact Developments, what is the importance of LIDs and how has Massachusetts utilized this concept? Especially in urban locations? *(for MAPC interview)*

b. Can you speak to Boston's success at Deer Island and its importance? *(for MWRA interview)*

c. Boston, has a combined sewer overflow control system, tailored system to direct waste and CSOs (Combined Sewer Overflows) when and where it was necessary. Can you explain this process and any other stormwater solutions? (for MWRA interview)

Conservation and Protection of Natural Habitats

d. What is the importance of preserving nature when it comes to water quality?

e. How are you able to differentiate the importance of a practical facility to preserve nature?

Urbanization

f. What methods are in place for Boston to combat growing infrastructure and urbanization?

Public Interest and Involvement

g. Can you talk about some of your public outreach strategies/education to get communities on board with expensive projects and integration of policies?

h. Has public involvement sparked political change in their respective communities?

5. Continued In-Depth Questions

a. How have you informed the community about what you're doing?

b. How is your department or line of work getting funding?

c. Are there any solutions, project involvements, or case studies you are passionate about coming from Massachusetts?

d. Have these methods/solutions been modeled after a specific place or already existing projects around the world?

5. Regulations and Policies

a. Overall, what other local, government, and/or traditional policies are in place that help or hinder water management solutions?

b. Which measures are easier to implement than others and why? Might relate to the previous question

6. Closing

a. Is there anything else you would like to bring up/talk about?

b. Is there anyone else that you think would like to talk to us? If so, would you mind giving us their contact information, or emailing it to us sometime after this meeting?

We appreciate your time and interest in being interviewed for our project. We hope to stay in contact as our project develops.

Appendix D. Objective 3 Interview Questions

1. **Introduction - Project Summary**

As a reminder, our project is about finding innovative water quality solutions. Since our last time speaking, we spoke with water quality professionals in Massachusetts to discover innovative ways that they are dealing with water quality and what solutions they are implementing. The main purpose of this interview with you is to run some of those solutions by you to get input on if they are feasible to implement in Wellington, taking into account the cultural and political factors that may differ between Wellington and Massachusetts. We would also like to hear any potential modification you could think of that may help to optimize or make certain solutions more feasible.

2. **Solutions to implement/improve upon**

We have conducted case studies on various **River Water Cleaning Systems** such as:

- Bubble Barrier - Amsterdam

- River Cleaning System - Italy

These bring pollution cleaning right to the source and implement automated river wide devices to capture floating debris and rubbish

a. Has Wellington implemented similar designs along with riverways or streams?

b. What is the feasibility or challenge of implementing such a solution?

c. Would the concept of an automated device help or take away from Te Mana o te Wai?

One of the prominent solutions we found was **highly permeable surfaces** in urban areas. Storm drains are a classic example of this, but there are also new solutions such as permeable pavement and grass filtration strips.

a. Are you familiar with these solutions?

    i. [expand and explain the solutions further]

b. How do you feel they would work in the Wellington context?

c. What is the feasibility of getting such developments underway?

3. Social Steps for improvement

Online toolkit geared at community information, informs people on how to act following varying standards of water quality. In looking around, we saw a lot of information that informs the public on websites connected to the GWRC like Wellington Water. Something that differs from what the Massachusetts Area Planning Council does is they have a toolkit more geared at developers, informing on where to install swales when creating new developments, or how and where to include permeable pavement.

a. Does anything like that exist for the GWRC?

b. Is there any way you could think to improve the accessibility of the website so that people are more likely to be able to find it?

c. How well would such an implementation work for developers and communities?

The Massachusetts Water Resource Authority has a program where they provide **water-efficient retrofit kits** at NO COST to members in 61 Massachusetts communities. These kits are easy-to-install kits include a low-flow showerhead, a faucet aerator, dye tablets for silent toilet leaks, and an instruction/informational manual. The MWRA buys in bulk to make affordability better. In their Fiscal Year for 2021, the MWRA reports the distribution of 6,714 water-saving fixtures kits.

a. Would a similar type of kit work in wellington?

b. What would be the public reaction?

    i. Would this offer them more exposure and education in the water quality crisis to make more of a difference?

4. Policy and Regulation

Watershed Protection Act

We found that the state of Massachusetts and the MWRA regulates land alterations by Primary and Secondary zones. Primary zone restrictions are focused on limiting changes to the landscape, while Secondary zone restrictions are focused on potential pollutants used in the area. Having harmful developments surrounding the watershed protects the land. “Clean land helps water be clean”

Land Acquisition Program

This program protects over 20,000 acres and uses government funding through taxes to acquire land of third parties and outside landowners to preserve it.

a. Are there similar watershed protection methods in Wellington? Open vs closed sources?

b. Do these methods restrict developments to protect the watershed?

c. Are there issues with private property owners and their cooperation in watershed regulations?

d. Would implementing a program such as the land acquisition program be beneficial for Wellington in protecting already owned land?

e. Is there feasibility in implementing any new regulations that can help reduce onsite pollution?

5. Water Usage Regulations

In Massachusetts, we found successful implementations of low-flow toilets, gravity toilets, gray water systems, and limitations on lawn water usage.

a. Are these solutions prominent in Wellington?

b. What challenges might be seen in trying to implement them more frequently?

6. Investing for the Future - Climate Change

We learned that many coastal or by-water facilities are appraised to last longer than any regular appraisal due to climate change and rising sea levels. For example, MWRA coastal

facilities have their foundations and piping systems raised more than they should be due to rising sea levels.

a. Has Wellington implemented methods to combat future disasters and climate change?

b. How are those methods implemented? How can they be improved upon?

Appendix E. List of Contacts

New Zealand Contacts

Alastair Smaill	GWRC Urban Water Programme Manager Environmental Policy Previous Groundwater Hydrologist
Fetu Warena Ese	Landscape Architect Advisor for Ngati Toa (Porirua Iwi, Mana Whenua)
Grant Webby	Secretary of environmental care group, Friends of the Waiwhetū Stream Principal Hydraulic Engineer at Damnwatch Engineer
Pat Van Berkel	Conservation Advocate GWRC Community Representative Committee Member of Friends of the Hutt River
Ross Jackson	Renowned Landscape Architect Greater Wellington's Flood Protection Division Environmental Management GWRC Project Adviser
Tim Sharp	Whaitua Committee Programme Manager Environmental Policy

Massachusetts Contacts

Fred Laskey	Executive Director at MWRA
Martin Pillsbury	Environmental Director at MAPC
Stephen Estes-Smargiassi	Director of Planning and Sustainability at MWRA