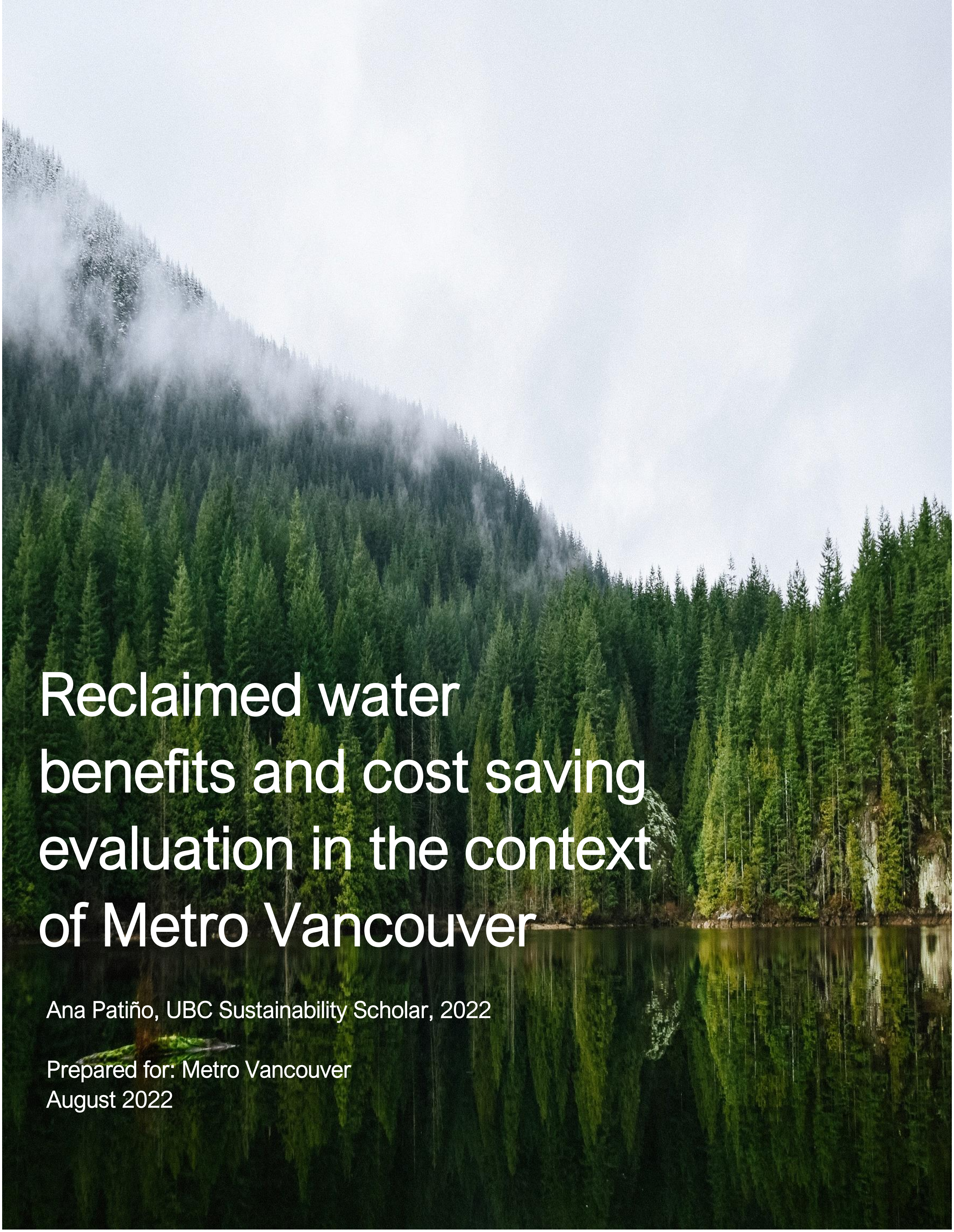


Reclaimed water benefits and cost saving evaluation in the context of Metro Vancouver

Ana Patiño, UBC Sustainability Scholar, 2022

Prepared for: Metro Vancouver
August 2022

DISCLAIMER

Acknowledgements

The author acknowledges that the work for this project took place on the unceded ancestral lands of the xwməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), Stó:lō and Səl̓ílwətaʔ/Selilwitulh (Tsleil- Waututh) Nations.

The author would like to thank the following individuals for their contribution, feedback, and support throughout this project.

Jeff Carmichael, Division Manager at Metro Vancouver

Allen Sebastian, Senior Project Engineer at Metro Vancouver

Sumeet Gulati, Professor at the Faculty of Land and Food Systems

Executive summary

The challenge of finding more sources of fresh water is a matter of global urgency. Metro Vancouver is facing risks associated with variable snowpacks heading into the peak demand summer season, earlier snowmelt, warmer temperatures, and a growing population increasing the demand for potable water. The conventional approach to alleviate these potable water demand risks is through water conservation efforts and the expansion of source, treatment, and supply facilities usually at substantial infrastructure costs. The use of reclaimed water may be another alternative to mitigate these impacts.

This study conducted an impact assessment of the effects of reclaimed water in the Metro Vancouver region, considering environmental, economic, and social factors. Many different potential benefits and costs were screened. Of those, four impacts that are expected to represent greater welfare changes for the community and/or the ecosystem, were evaluated in greater detail. These are:

Increase in the supply of potable water: Reclaimed water could replace potable water use in certain industries, reducing demand for valuable potable water. This could also reduce peak consumption seasons and reduce the impact of long-term stressors.

Improvements in recreational areas for swimming: Reduced effluent discharge due to increased effluent treatment and reclaimed water diversion could lead to better effluent quality, which could lead to having more beaches open for residents' enjoyment, which is highly valued by the community.

Infrastructure cost avoidance: Represents the biggest potential benefit of water reclamation for the region. The provision of reclaimed water acts as an expansion of water supply by default, avoiding or downsizing future projects. This represents potentially large savings for the region, with the possibility of increasing investment in other areas.

Potable water operation and maintenance cost avoidance: Reclaimed water could reduce ongoing costs for potable water treatment and delivery. Costs of reclaimed water provision could be recovered from industry, institutions, and other users, reducing pressure on potable water rate payers.

The costs that Metro Vancouver would incur in the implementation of water reclamation are related to the capital, operation, and maintenance costs. At its new wastewater treatment plants, Metro Vancouver is planning to treat effluent to a standard that is likely to meet or exceed reclaimed water quality guidelines. As a result, some of the necessary investments are already in the organization's budget. Therefore, with evidence that the potential benefits could outweigh the investment, it is expected to be manageable to implement water reclamation in the region.

The following concern would be setting the market structure for this valuable resource and provisioning service. To do so the study evaluated prospective users, potential supply capacity, and the pricing structure for this resource.

- Prospective users: Metro Vancouver is targeting wastewater treatment at the Greater Exposure Potential level. This quality level will allow 40% of the industries from the region to use reclaimed water for various purposes where water quality requirements match.

- **Potential supply capacity:** With a generation of 434BL of wastewater per year, the maximum quantity of reclaimed water that Metro Vancouver would be able to provide is up to 38BL annually; this is equivalent to 27% of the non-residential drinking water consumption.
- **Pricing structure:** Setting the price will depend on the context and requirements of the region as it would determine the behaviour of the market.

After this study, in case Metro Vancouver contemplates the possibility of implementing water reclamation, there are some recommendation and next steps that will be important to consider:

- The environmental valuations were based on benefits transfer, implying that the estimates were based on parallels with other regions. Although these studies allow us to understand welfare perceptions, it is recommended to perform an environmental valuation study in the Metro Vancouver region to get a more accurate perception of local value from the residents.
- The costs associated with the distribution of reclaimed water are still unknown. It is recommended to develop a detailed projection of the distribution costs that would need to be incurred. This would complete the benefit-cost analysis in terms of the distribution systems that Metro Vancouver could afford, whether it is trucks or even the construction of pipe systems.
- Setting a market for reclaimed water in the Metro Vancouver region is another important priority. As this is a new commodity for the region, it is recommended to develop strategies to target the different users according to their needs, requirements, and fears, and educating them about the benefits of water reclamation.
- Within setting the market for reclaimed water, pricing is a challenge that require more research. The initial findings suggest that is not recommended to set the price higher than potable water, because this would disincentivize the demand for reclaimed water. Nevertheless, more research on appropriate pricing and evidence of practices elsewhere is recommended.

With the ultimate goal of planning for future water supply structures being the community welfare, it was demonstrated that water reclamation is an activity that could be worth the investments when including both, environmental and financial benefits, as referenced in this study. Further efforts are required to accomplish its implementation in the Metro Vancouver region.

Contents

Glossary

Freshwater: water available in natural water bodies that is available for multiple uses, from recreation to being diverted for further treatment.

Potable/drinking water: water that is treated to a certain quality and is suitable for human consumption.

Wastewater: water that has been used for multiple purposes and cannot be reused.

Effluent: wastewater that is treated and disposed into water bodies.

Reclaimed water: effluent that is further treated to certain quality and could be re-used for different purposes.

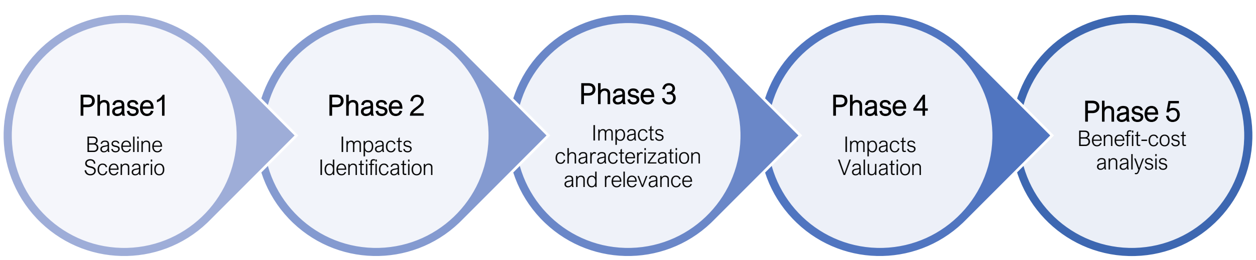
Welfare: general wellbeing that could happen by any environmental, economic, or social improvement.

Purpose

The challenge of finding more sources of fresh water is a matter of global urgency. Today, Metro Vancouver is developing supply strategies to cover future community's expectations, such as water facility expansion. There are other approaches, however, to alleviating future stressors to the supply system. Exploring the use of reclaimed water, as an alternative to displacing potable water use in sectors where such water quality is not necessary, offers a way to mitigate the challenges of climate change and water demand, especially in peak seasons.

This study will conduct an impact assessment of the effects of reclaimed water in the region. This methodology considers the potential environmental, economic, and social effects of water reclamation. These effects are then characterized and valued, with the goal of informing policy makers about the relevance of these impacts. This first section will outline the technical concept of the total economic value and explain the valuation methods used in this report.

The following assessment will be divided into five phases. The first phase introduces Metro Vancouver's baseline water scenario, including the context of the problem, the water structure of the



region, its wastewater generation, the potential users of reclaimed water, and a pricing approach. The second phase identifies potential impacts at each stage of the water reclamation cycle. These impacts are classified as environmental, financial, or social. In the third phase, each impact is characterized and ranked according to its relevance. In the fourth phase, the most relevant impacts will be valued in dollars, if possible. Finally, phase five will compare the required investment to implement water reclamation against its probable or possible benefits.

The report closes with conclusions about the feasibility of implementing water reclamation in Metro Vancouver, and recommendations for policy makers about what are the next steps for its implementation. This will involve a cost-benefit analysis based on the above-mentioned dollar values, as well as providing qualitative information that may be considered in assessing any potential water reclamation project.

Understanding economic value and valuation methods

The fundamental question to explore is: what are the impacts of providing and using reclaimed water? To understand these impacts, it is necessary to classify them according to their category, understand the values associated with them, consider value in the context of social welfare, and finally, explains the methodologies that have been used to monetize those values. Taking these steps will ensure effective comparison of benefits and costs for any reclaimed water project Metro Vancouver might undertake.

Impact Categories

Three categories of impact will be considered in this study: environmental, social, and financial. Environmental impacts encompass the natural resources, animals, and other organisms that might experience any change in their current behaviour or status due to the introduction of a water reclamation project. Social impacts are those which affect communities and regions in terms of what they value, such as heritage and cultural values, or what they consume, which might have direct or indirect uses. Finally, financial impacts are related to the project's monetary effects. These could include investments that society has no longer has to pursue, or could postpone, thanks to the new project. Such benefits are also known as avoided costs.

Ecosystem goods and services (EGS)

Before diving into the impacts associated with the environmental and social categories, we must first understand the role of the ecosystem in humans' daily activities. Having identified these environmental benefits, or ecosystem goods and services (EGS), we will then be able to assess which ones might be enhanced by water reclamation. There are four main types of ecosystem service:

- **Provisioning services:** outputs that humans can extract from ecosystems, such as food, water, or fuel.
- **Regulating services:** regulation of climate, air and soil quality, water purity, etc.
- **Habitat or supporting services:** provision of habitats for organisms to support biodiversity.
- **Cultural services:** recreation, tourism, aesthetic appreciation, or spiritual experiences.

In identifying potential water reclamation impacts for Metro Vancouver region, especially environmental and social impacts, we shall see that EGS may improve in every case. Keeping in mind the definitions and roles of each ecosystem service will establish a framework to recognize the effects.

The concept of value

In assessing water reclamation projects, *value* refers not only to the fiscal impacts or effects of water reclamation, but also their community-perceived value. To capture these diverse types of value, and to quantify them where possible, this report uses the total economic value (TEV) framework.

Market value is defined as the actual price that is already established for any given good or service. Nevertheless, there are other goods and services provided by the ecosystem that do not have a market value, they are usually not traded in any market. Thus, the total economic value of any given service could have, or not, market values associated with them.

The total economic value (TEV) framework is a widely used tool that can help us to address the definition of value. Policy makers could then make decisions based on the welfare provided by the ecosystem services. Figure 1 gives a detailed definition and examples of TEV for water ecosystems.

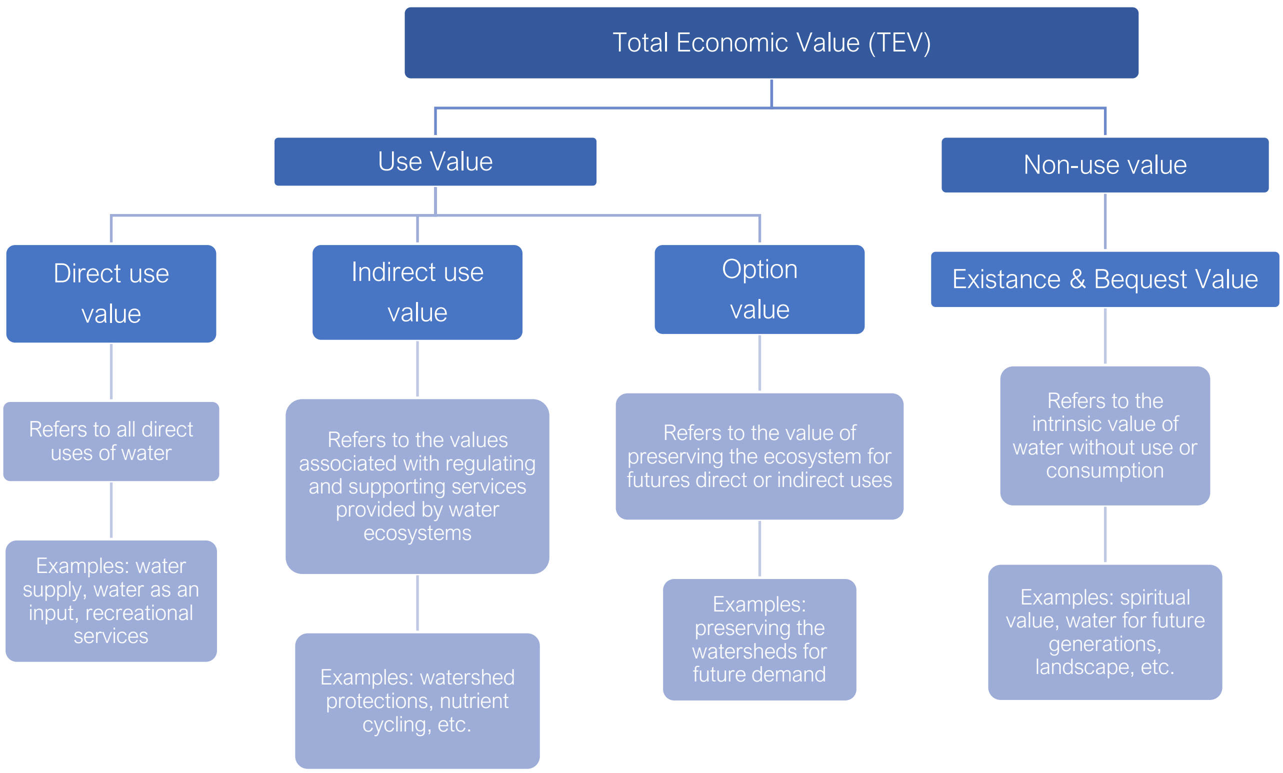


Figure 1. Adapted figure from Assessing the environmental and economic value of water: review of existing approaches and application to the Armenian context, (EU, OECD & UNECE)

Therefore, recognizing that there is a total economic value for water ecosystems and water reclamation activities, it is also possible to recognize that communities perceive benefits from them. The valuation of these impacts is relevant for making decisions about any development project.

Valuation methodologies

The methods used in impact assessment vary depending on the impact category and whether or not they have a market value. The two approaches that will be used in this report are the market-based approach methodology and revealed and stated preference techniques.

The market-based approach reflects the value of a good or service according to the price that is already established in the market. It could reflect profits from a commodity, avoided costs of a project, or contribution of any input in a production process. But when there is no market value for the EGS, which is usually the case in environmental economics, there are two approaches. The first one consists of asking people about their Willingness to Pay (WTP) for any EGS, the second one is revealing the welfare of the EGS based on observing individual choices and modelling the information through econometrics.

When there is no market value, the revealed and stated preferences techniques require a considerable investment in budget and time. When time and/or budget do not allow it, it is possible to consider studies from other regions and transfer the benefits, as long as the study area and the community share similarities with the research area and demographics. This is called benefit transfer.

Phase 1: Context and water structure in Metro Vancouver

The Greater Vancouver Water District, corporately operating as Metro Vancouver is responsible to source, treat and reliably supply drinking water to its member jurisdictions which in turn deliver this service to the region, its residents, industries, and businesses.

Access to abundant fresh water is a privilege that the Metro Vancouver region enjoys, but climate change coupled with a growing population may stress the ecosystem in the future. Planning ahead for drinking water supply will help to maintain the balance between the community's needs and the ecosystem.

While growing demand is an issue, Metro Vancouver has implemented many programs to encourage water conservation and continues to work actively with its members on new conservation initiatives. These efforts have been successful and the water consumption per capita has steadily decreased in the last couple of years (Metro Vancouver, 2019). Nevertheless, although Metro Vancouver is planning for future demand, challenges in the supply of fresh water available for drinking water use, are still likely to occur.

Not taking action in time could bring social, environmental and financial undesirable effects. Communities could experience shortages of potable water, interfering with desired community growth. Wildlife and biodiversity might be compromised, stressing the ecosystem's normal behaviour. And investments would likely be much larger for supply water facilities and water treatment plants.

Water reclamation could help to mitigate these risks. It refers to using treated sewage effluent as an alternative or supplementary water source. The effluent can be further treated as necessary to allow use for non-potable and, in some regions, potable purposes depending on the sector/user. As there are environmental, social, and financial benefits, there are also certain costs associated with its provision. It requires investment in technology that will treat or clean the effluent to a certain level depending on the user's requirements. It also requires investment for its distribution, which could be through tucks or pipes depending on the quantity provided.

Supply, demand, and water cycle in the region

Metro Vancouver sources its water from the Capilano, Seymour and Coquitlam watersheds, three areas that are protected and closed to the public in order to ensure the safety, quality, and reliable supply of fresh water to the region. Then the collection of the water takes place in three main reservoirs and three supplemental alpine reservoirs. The high elevation of these water sources helps with energy optimization for the pumping process, leaving gravity to do part of the job for its distribution.

Metro Vancouver provides drinking water to different regions in the lower mainland to a population of 2.6 million people. With a demand of 390 billion litres per year[1], around 73% goes to residential use, while the remaining 27% is used for non-residential purposes: industrial, commercial, and institutional (ICI) sectors.

Finally, to close the cycle of sourced water, the wastewater that remains from the various uses, is collected and treated with the specification under the National Performance Standards for effluent, and then it becomes the effluent that will end up in the Fraser River or the ocean of the region.

The following section will analyze the volumes of potable water consumption and the quantity of effluent water that is currently disposed into water bodies. This will allow us to explore the potential capacity of water reclamation and the impacts in the region.

Potable Water consumption in the region

For the purpose of a baseline scenario, this section identifies the volumes of potable water use in the region, and the distribution and magnitude of water consumption per sector. Water demand is divided into residential use and non-residential, where the latter includes commercial, institutional, industrial, and agricultural segments of consumption. For reference, Table 1 shows the quantity of potable water consumed in a year per segment.

Table 1. Annual water consumption by sector (billion litres) in the GVWD, 2019

Water use category	Annual consumption (billion litres)	% of total
Residential use	**284.4**	**73.3%**
Non-residential use	**103.8**	**26.7%**
Commercial	52.3	13.5%
Institutional	22.3	5.7%
Industrial	16.3	4.2%
Agricultural	5.4	1.4%
Other	1.6	0.4%
Unknown	5.9	1.5%
Total	**388.2**	**100%**

The expected growing demand for freshwater is an aspect that policymakers are following. Metro Vancouver is projecting an increase in the population of 35 thousand residents per year, and based on 147 thousand litres of potable water consumption per capita per year for all uses, the requiring annual increase in freshwater diversion would be approximately 5.1 billion litres.

After the potable water is consumed or used, the remaining wastewater is the next element that will be evaluated. This will allow us to understand how much water is being deposited into natural water

[1] Average demand in 2017 and 2018, taken from Outlook 2120

bodies instead of consumed or retained in the fields, but also to set expectations on the potential volumes of demand for reclaimed water.

Wastewater generation

With a provision of 388 billion litres of potable water per year, wastewater is also an important output to consider for the implementation of a water reclamation project. This section will evaluate what is Metro Vancouver doing and what can be done. Table 2 shows the amount of effluent that is disposed into natural water bodies per WWTP, a significant amount that could be used as a resource rather than waste.

Table 2. Wastewater generation per treatment plant, 2019.

WWTP	Effluent in billion Litres, 2019
Annacis Island	196.4
Iona Island	180
Lions Gate	27.7
Lulu Island	25.1
Northwest Langley	5.3
Total Effluent	**434.5**

This effluent complies with certain treatment criteria that are regulated by the Ministry of Environment and Climate Change Strategy (MOECCS), which gives special focus to the maximum concentration of BOD and Total Suspended Solids (TSS) allowed to be disposed in natural water bodies. The environmental management act, through the municipal wastewater regulation, determines the effluent quality requirements as well as the disposal conditions based on the class (See table 3 for reference).

Table 3. Information taken from Environmental Management Act, Municipal Wastewater Regulations.

Requirement	Class A	Class B	Class C
BOD_5 (mg/L)	10	10	45
TSS (mg/L)	10	10	45
Fecal Coliform (MPN / 100 mL)	median:2.2 any sample: 14	400, if maximum daily flow is ≥ 37 m3/d	n/a
turbidity (NTU)	average: 2 any sample: 5	n/a	n/a
nitrogen (mg/L)	Nitrate-N: 10 total N: 20	n/a	n/a

Currently, the Annacis Island and Lulu Island WWTP dispose an effluent of Class B, while Iona Island, Lions Gate and Northwest Langley are categorized in Class C according to the BOD and TSS parameters. Nevertheless, as it will be explored in the following section, wastewater treatment quality is expected to improve according to the Integrated Liquid Waste and Resource Management Plan (Goal 2), which encourages the region to migrate to a more sustainable integrated resource recovery system, including higher quality disposals, and the incursion of a filter disk technology in in future WWTP projects.

Reclaimed water

Knowing that reclaimed water is a valuable resource, and recognizing that Metro Vancouver produces large amounts of wastewater, the following question is: what has been done about it? This section will explore the different approaches for water reclamation in Canada, as a guide to deduce relevant information and actionable items for Metro Vancouver.

At the federal level, the government has provided the Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing (Health Canada, 2010), but at the provincial level, British Columbia is the only region in the country with a regulation on the reuse water (BC Public Services, 2018). Table 4 shows the different guidelines that include the recommendations of using reclaimed water across the country.

Table 4. Information taken from Water reuse and recycling in Canada — history, current situation, and future perspectives, 2020

Province	Approach
British Columbia	• Municipal Wastewater Regulation, Reclaimed Water Requirements, 2018 • Reclaimed Water Guideline, 2013
Alberta	• Guidelines for Residential Rainwater Harvesting Systems, 2010 • Fact sheet on Alternative Solutions Guide for Small System Water Reuse, 2017
Ontario	• Water and Energy Conservation Guidance Manual for Sewage Works, 2019
Atlantic Provinces	• Atlantic Canada Wastewater Guidelines Manual: Guidelines for treated effluent irrigation and golf courses, 2006

Throughout Canada, there are multiple examples of residential, commercial, institutional, and industrial applications, but most of these examples are focused on on-site wastewater treatment systems (Rossum, 2020) rather than a centralized treatment and distribution of reclaimed water. Metro Vancouver is already optimizing wastewater turning it into renewable natural gas, biofuel production, and using sewage for heating and cooling. However, there remains a significant recovery opportunity with the treated effluent resource coming out of its WWTPs in the region.

According to the Municipal Wastewater Regulation, reclaimed water is defined as "municipal wastewater that is (a) treated by a wastewater facility, and (b) suitable for reuse in accordance with the province regulation". Thus, one fundamental question worth asking is how much reclaimed water could be made available for use, and whether this would be a significant volume of water relative to the amount of water used in the region.

As previously mentioned, the quantity of effluent is even higher than the water demand in the region, showing great potential for water reclamation. This means that the resource of effluent is available, but whether it is feasible is a matter of evaluating its benefits versus its costs.

The following sections will evaluate the market structure for water reclamation, from the possible users to the potential volumes of reclaimed water that the organization could provide, and closes with a reference for pricing structure.

Potential users of reclaimed water

The potential demand for reclaimed water will be determined by the water quality requirements of each sector and the accessibility given the provisioning capacity of the organization. According to the Municipal Wastewater Regulation from BC, the categories of reclaimed water are presented as follows:

1. **Indirect potable reuse (IPR)**: any use of reclaimed water to replenish a potential potable water source.
2. **Greater exposure potential (GEP)**: uses for which public contact is likely or that present a risk to the receiving environment.
3. **Moderate exposure potential (MEP):** public contact is likely minimal, public access is restricted and users are educated about the risks. There is a moderate risk to the receiving environment.
4. **Lower exposure potential (LEP):** public access is restricted, and users are not likely to have contact with it, commercial or industrial uses in nature and users are educated about the risks. It presents a low risk to the receiving environment.

Based on this information, Metro Vancouver has decided to encourage wastewater treatment to the greater exposure potential (GEP), as it would allow for a wide range of potential uses. In fact, the activities that might use reclaimed water at GEP are agricultural crops, golf courses, cemeteries, residential lawns, greenhouses, silviculture operations, urban reuse and landscaping around parks, playgrounds, schools, irrigation for frost protection and crop cooling, toilet and urinal flushing, decorative uses such as ponds and water attraction.

According to the current parameters of the WWTP from Metro Vancouver, Annacis Island and Lulu Island plants are closer to the GEP effluent quality, complying with two out of four factors. By the contrary, the remaining three plants barely comply with one.

Although this might sound challenging, the organization already planned the replacement of Iona Island, Lions Gate, and Northwest Langley plants by better technology that complies with tertiary treatment. Even though it is necessary to confirm the treatment quality of these plants compared to the GEP quality, this initiative is already encouraging better qualities for the effluent.

Table 5. Quality parameters according to the potential level of exposure compared to the current quality of each Metro Vancouver WWTP

Parameter	Indirect potable reuse	Greater exposure potential	Moderate exposure potential	Lower exposure potential	Annacis Island	Lulu Island	Iona Island	Lions Gate	Northwest Langley
Ph	site specific	6.5 to 9	6.5 to 9	6.5 to 9	7.2	7.1	7.2	7.1	
BOD5 (mg/L)	5 mg/L	10 mg/L	25 mg/L	45 mg/L	9.6	5.8	64.6	63.8	14.3
TSS (mg/L)	< 5 mg/L	-	-	-	13	5	51.9	52.8	18
Turbidity (NTU)	max. 1 NTU	av. 2NTU or max. 5 NTU	n/a	n/a	Not available				
Fecal Coliform (/100mL)	median < 1 CFU or < 2.2 MPN	median < 1 CFU or < 2.2 MPN or max.14 CFU	median 100 CFU or max. 400 CFU	median 200 CFU or max. 1000 CFU	-	-	-	-	-
Effluent (mL)	n/a	n/a	n/a	n/a	196,379	25,133	180,029	27,664	5,261

Therefore, based on the sectors that could use reclaimed water at GEP level, the maximum quantity that Metro Vancouver Utility would be able to provide is up to 38 billion litres[2], which is equivalent to 27% of the non-residential use. While in theory this could be the demand for reclaimed water annually, in practice the capacity of water reclamation in the region reduces the probability of supplying this amount at the moment. Nevertheless, having in mind the magnitude of the demand is helpful to value its importance.

Demand study for a pilot reclaimed water facility – Metro Vancouver

In order to construct the baseline scenario there was a first attempt to quantify the reclaimed water demand in the region. This study was performed in 2016 by Pinna Sustainability for Metro Vancouver, with the objective to find out if there was sufficient demand for a pilot facility, and how would the distribution work from the Lulu Island and the Northwest Langley WWTPs.

As a pilot project, the demanded quantity identified was only 31.5 million litres per year, which represents only 0.1% of the total potential of reclaimed water. Nevertheless, this gives an important outlook on the feasibility of reclaimed water in practice.

Table 6. Reclaimed water potential demand for a pilot project.

WWTP	End use	Volume (Annual million litres)
Lulu Island	Sewer line flushing, hydro excavation, street sweeping, nursery irrigation	8.5
Northwest Langley	Aggregate washing, truck washdown, ready mix ingredient, sewer line flushing, hydro excavation	23
	Total	31.5

[2] Subsectors such as Recreation (10BL), Education (7.3BL), Agriculture (5.4BL), Industries (5.3BL), Transportation (4.5BL), Petroleum & Allied (1.8BL), Utilities & Miscellaneous (1.6BL), Forest Products (1.2BL), Service Stations (0.8 BL), and Construction (0.6BL).

According to the study, factors such as the technology used for treating the wastewater, the logistics of distribution, and whether it requires a truck bay at WWTP or pump and pipe infrastructure, are important considerations for the development of the project. However, there are other factors that should be included in the decision of implementing water reclamation, that is why the next phase of the study will focus on the identification and relevance of environmental, social, and financial benefits of using reclaimed water.

Table 7. Summary table of the baseline scenario.

Concept	Billion litres
Total water diversion = Total water consumption	388.3
Total Effluent	434.5
Expected water demand increase per year	5.1
Water consumption per sector	
Residential use	284.4
Non-residential use	103.9
Potential users of reclaimed water	38.5
Non-potential-users of reclaimed water	65.4
Expected reclaimed water demand pilot project	0.03

Pricing structure reference

Pricing structure is part of establishing a market. The report has already mentioned the potential dynamic of the demand and supply, but up until now it has not considered the price of reclaimed water. This section will take a reference of how utility companies in the US have established their prices, allowing us to draw parallels and extrapolate structures from others who have experience in the field.

The challenge of pricing reclaimed water falls into two categories: the costs and its purpose. It is of importance as it will determine the behaviour of the market, that is why it has been studied by different organizations and utility companies. In 2007, (O'Reilly & Pierce, 2008) funded by the American Water Works Association and Water Environment Federation from the US, surveyed 500 water reuse utility companies to understand how they were establishing their prices.

It was found that cost recovering in water reclamation is low. The survey showed that organizations typically recover less than 25% of the annual operating cost. This is usually due to the rates charged, which in most cases are less than the potable water rate, even though reclaimed water treatment cost is usually higher than potable water treatment costs.

Therefore, discussing how to establish the rates is prevailing for the market structure, as rates could be set to incentivize reclaimed water use, but they might also be set based on the water needs of the region. Consequently, the distribution of how these companies were charging for the provision varies depending on their purpose. Three main conclusions were gathered:

- 9% of the companies determined their rates based on market analysis, which happens to be set as the rate for potable water.
- 14% of the surveyed companies based their rates on their service costs.

- 19% based the price according to a percentage of potable water rates, which are usually those who want to promote its consumption, varying their rates from 20% to 100% of potable water rate, with the median percentage being 80%. There were even some companies that reported that they did not charge for the provision.

In general, the study demonstrated that there is a trend toward setting the rates at a level to incentivize reclaimed water use. Nevertheless, it is also important to recognize that the majority of the respondents were from California (46%), a state well known for its shortages of water.

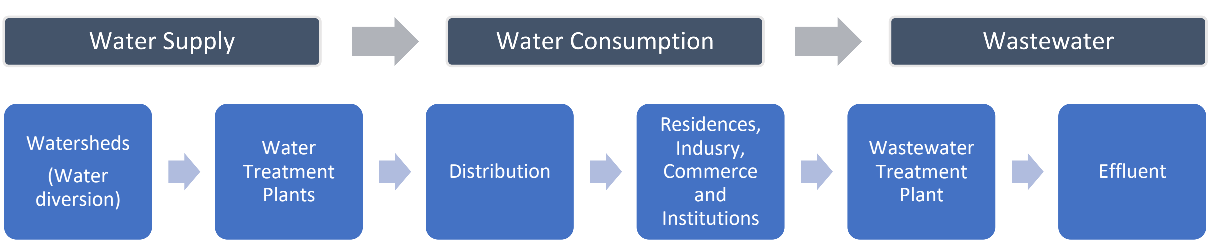
Pricing structure therefore will depend on the context and requirements of the region, and in case of a successful implementation of this activity, Metro Vancouver would have to determine the price based on the potential users. Weather the price should be subsidize or not is a matter of deciding how important is for Metro Vancouver to incentivize reclaimed water use.

Phase 2: Impacts identification

The approach in this section is to review what has been demonstrated to be the impacts of water reclamation from different studies around the world, and then identify in the context of Metro Vancouver what are the benefits that can be extrapolated.

The U.S. Environmental Protection Agency recognizes the following environmental impacts due to water reclamation: it decreases the freshwater diversion from sensitive ecosystems, it decreases the wastewater discharges to sensitive water bodies, it creates or enhances wetlands and riparian habitats, and prevents or reduces pollution (M. Molinos, Hernández-Sancho, & Sala-Garrido, 2011). Besides, there are financial implications such as investment avoidance (Hurlimann & McKay, 2005), and the decrease of the operational costs of WTP, all of which are financial in nature, impacting Metro Vancouver's cash flow.

To simplify the explanation, water cycle is divided into three main stages: water supply which includes water diversion, facilities, and the treatment process; water demand which includes the demand for water and an aqueduct and sewage system; and the wastewater output which includes the wastewater treatment plant and the effluent dumped into natural water bodies. In each stage different organisms, communities, and/or stakeholders are affected, and this will be part of the identification process.



Environmental impacts:
the implications of water reclamation on the environment are wide, touching on every stage of the water cycle. In the water supply stage, there could be water flows improvement in the watersheds, and as a consequence, a provisioning service of water flows regulations; this is classified as an indirect use value and the agents involved are different organisms and species that live in the area.

In the second stage of water consumption, the prominent impact refers to an increase in freshwater supply, as more industries would be using reclaimed water, more potable water would be left for potable uses. One way of understanding this impact is to see water reclamation as an optimization of potable water consumption, explained by potable water not being wasted in activities that do not require this quality. Therefore, this is classified as a provisioning service and direct use value, and the direct implication is on the community.

Finally, the wastewater stage is also affected by water reclamation. As the quality of the effluent would be enhanced, there are two impacts that can be traced. First, there could be an improvement in wildlife and biodiversity given a better environment for the species and organisms that live in the influence and receiving area; this is classified as an existence, non-use value. Second, there might be improvements in fishing as well as recreational areas, this also represents a direct implication in the community and is classified as direct uses of a provisioning service by water ecosystems.

Social impacts: the category of social impacts takes place in two of the stages, water supply and wastewater. It happens given the improvements in wastewater treatment. The community might value this effect given the symbolic or spiritual value of the enhanced spaces. These conservation consequences are provisioning services that give existence, heritage, and cultural values to the community.

Financial Impacts: the financial category is represented by the benefit of avoiding capital and operational cost, and by the investment costs that would be incurred in a project of water reclamation. These impacts are reflected in the three stages of the water cycle and could imply the avoidance of an expansion of water supply facilities, and/or an increase in the investment for better technology to treat the wastewater. This has a direct implication in the institutional investment and cashflow of the organization, but also on how public funds are invested compared to the welfare perceived by the community.

Having identified the environmental, social, and financial impacts of water reclamation in the different stages of the water cycle, the next step is to characterize and explain in detail how each of them fit the context of Metro Vancouver, and how relevant are for the region.

Phase 3: Impacts characterization and relevance

Identifying the impacts of water reclamation is not enough, that is why this phase focuses on the exploration and characterization of each impact in detail. Special attention will be given to the effects in the organisms, animals, communities, and stakeholders that are impacted by water reclamation. Factors such as the probability of occurrence, the magnitude, and the influence area will be considered to determine the relevance of the impact in the region.

This phase further evaluates the impacts worth including in the cost-benefit analysis for a water reclamation project. This will help policy makers to make decisions based on the most important effects of this activity.

Environmental impacts

Water flows improvement

Water reclamation impacts the demand and supply of water. In the first case, the demand for potable water would decrease; for the second case, the flow of fresh water will be maintained in local waterways as more industries would be using reclaimed water instead of potable water. In general, this implies a freshwater flow improvement in the upstream area, which might cause a positive effect on the habitat service provided by the ecosystem.

There are many organisms and wild animals located upstream that would benefit from an improvement of water flows, not to mention the recovery of the vegetation, wetlands, and estuaries (Ojeda, 2008). But in order for the water flows to improve, and as a consequence to have a significant impact on the habitat service in the long term, reclaimed water should be larger than the growing demand.

In fact, potable water demand is expected to grow by 5.1 billion litres per year, representing 18% of the potential reclaimed water, but the capacity of providing this volume is not at that level yet. Additionally, potable water demand is expected to keep growing throughout the years, meaning that the diversion of freshwater will increase, making it more challenging for Metro Vancouver to maintain the watersheds levels. This would eventually reinforce the need for new and sustainable sources of water, which could be reclaimed water.

Although this impact should be in the big picture, with the expected growing diversion of freshwater of approximately 5.1 billion litres per year, the alteration could be marginal or even not suffer any alteration, leaving this impact with a low relevance score.

Increase in the supply of potable water

Water reclamation could be perceived as a way of increasing freshwater supply, displacing potable water consumption in some industries that do not require this quality, and therefore, increasing the availability of potable water for the community. This, in the context of Metro Vancouver is an important impact as it has implications in the planning of water supply in the long term, but also in the challenges of potable water supply in peak seasons, which makes us consider how the community value this provisioning service throughout the year.

The demand study of a pilot project showed that the demand from industries for reclaimed water is year-round, implying a better distribution of potable water, and leaving more freshwater for the community and environment to enjoy. Thus, one assumption is that the quantity of reclaimed water might increase over time according to the adaptation of the policy, which could bring value to the community development. This increase in water reclamation might compensate the long-term ecosystem stressors.

Consequently, there will be lower snowpacks arriving to the summer season, earlier snowmelt, and warmer temperatures (Metro Vancouver, 2019). These dynamics will imply that water supply will not last as usual, making it more challenging during peak demand seasons. Therefore, increasing water supply is a highly relevant impact considering the importance of this resource in the communities' daily lives.

Improvements in wildlife and biodiversity in the water bodies receiving higher quality effluent

As part of the Liquid Waste and Resource Management Plan, Metro Vancouver is targeting improvements in wastewater treatment. This might imply the reduction and prevention of pollution in natural water bodies receiving the effluent (M. Molinos-Senante, 2011), meaning that less undesirable pollutants would be discharged into natural water bodies, and therefore, it is expected that wildlife and biodiversity benefit from it.

The strategy in place is migrating the current wastewater treatment technologies to meet GEP standards for the reclaimed water. This might have an impact in the water around the Fraser River or the ocean that receives the effluent from all the sewage stations, as the overall quality could improve. Nonetheless, there are certain chemicals such as "PBDEs, hormones and sterols, pharmaceuticals and personal care products (PPCPs), and other types of pesticides" that are present in wastewater but are not yet controlled for disposal (Metro Vancouver Liquid Waste Services Environmental Management and Quality Control., 2020).

Moreover, it is hard to isolate the effects of the effluent quality versus the different pollutants that these natural water bodies receive. As a result, while there are organisms that would benefit from improvements in the effluent quality, there are still other pollutants that are affecting marine life in the area, and therefore this might no longer be considered a relevant impact due to water reclamation. More research should be performed in order to identify how effluent with great exposure standards might benefit these natural water bodies.

Improvements in fishing areas due to improvements in the wastewater quality:

Although Metro Vancouver complies with all the effluent regulations, there are some risks associated with the use of water bodies that are receiving these disposals. In fact, Metro Vancouver does not recommend the use of the water disposal areas for a period of 48 hours, not for fishing, recreation, or for drawing water for agricultural or industrial purposes.

The presence of different pollutants impacts the provisioning service of fishing and there are risks associated with human ingestion of certain fish exposed to these effluents. Even with the current standards, the effluent quality causes an additional effort for the seafood industry, fishermen and/or the government to determine the fish quality. Nowadays, the government limits the type of commercial fish that the industry can get from certain areas.

Mussels, oysters, clams and scallops are species that are impacted by the quality of the water where they live. In fact, the Department of Fisheries and Oceans (DFO) restricts and closes some areas for harvesting bivalve shellfish due to the contamination of the water and how this seafood can be harmful for human consumption (Government of Canada, 2022).

According to DFO, human activities such as municipal wastewater treatment systems are one of the reasons behind the closure and restrictions for harvesting bivalve shellfish in certain areas. Nevertheless, there are other factors such as natural processes like runoff from land (Government of Canada, 2022). Additionally, there have been studies explaining the impact of WWTP on shellfish and the economic consequences associated with it in zones of fishing-dependent communities (Evans, Athearn, Chen, Bell, & Johnson, 2016).

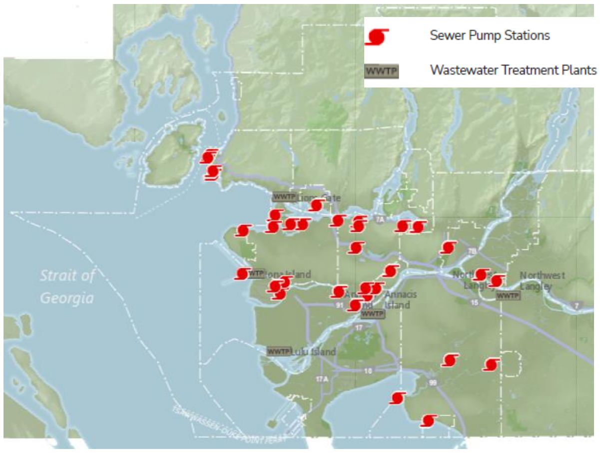


Figure 2. Image taken from Metro Vancouver from the Regional Liquid Waste System Map, June 2022

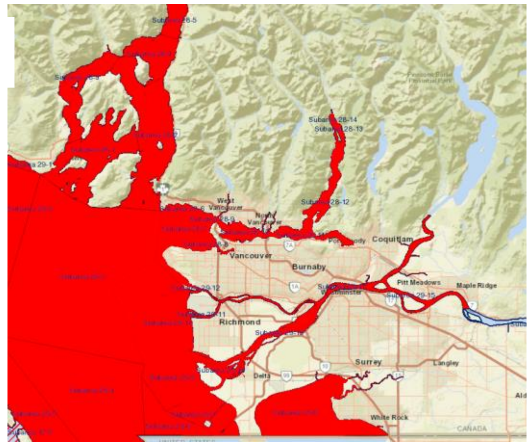


Figure 3. Image taken in July, 2022 from the [Government of Canada]() for the real-time openings and closures of Canadian harvesting areas for bivalve shellfish

---

In fact, the Environmental Management Act, in the Municipal Wastewater Regulation section, provides the requirement for water discharges in shellfish harvesting areas, where the acceptable median or geometric mean MPN fecal coliform organisms must be less than 14/100 mL at the edge of the initial dilution zone. This in the context of reclaimed water is important as this parameter would be met according to the targeted water treatment quality of GEP, but there are still other pollutants that should be considered.

Consequently, isolating this impact would be challenging and would require specific research, with an allocation of budget and time. And recognizing that Metro Vancouver is not a region strong in the shellfish industry (Fisheries and Oceans Canada, 2018), improvements in fishing areas might not be a relevant impact due to water reclamation.

Improvements in recreational areas for swimming due to improvements in the wastewater quality

Improvements in recreational areas is another impact that reclaimed waters bring for the community enjoyment. Due to water quality, people are prevented from “swimming, paddle boarding, surfing, or any activity in which the whole body can be immersed, and water will likely be swallowed” in some beaches throughout the year (Vancouver Coastal Health, 2022). Thus, a constraint for performing these activities might cause welfare losses created by the recreational limitations that people from the region and tourists might experience.

Once again, the closure of certain areas cannot be 100% associated with the WWTP, but according to the Vancouver Coastal Health, WWTP bypasses is one of the causes of beach closure. Accordingly, the improvement of the wastewater quality could mitigate the closures of beaches. For reference, Figure 4 shows the closures of certain beaches due to water quality.

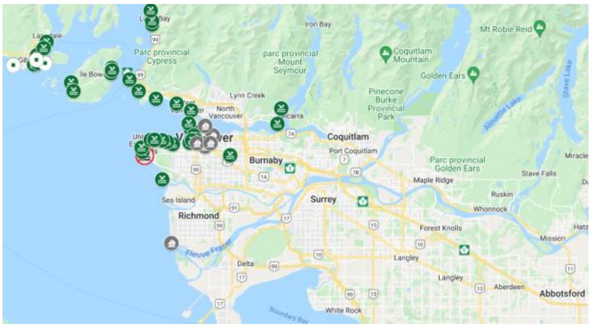


Figure 4. Image taken in June 2022 from Vancouver Coastal Health for Beach water quality reports.

Thus, with an effluent quality at GEP parameters, which fulfills the standards of fecal coliform for recreational use waters, it is possible that the frequency of beach closures could be reduced. Yet, there would be other pollutants from other sources different from the WWTP affecting the water quality. But since swimming is highly valued among the residents in the Vancouver Coast & Mountains region, this could be considered a moderate relevant impact.

Social impacts

Enhancement in heritage and cultural values due to improvements in the ecosystem

Water reclamation plays an important role in ecosystem conservation, and in some cases, it could also reduce the intervention in water bodies. These effects might affect heritage, cultural or spiritual values for different communities. This case is enhanced when we acknowledge that the residents of Metro Vancouver live, work, and learn on the shared ancestral, unceded and traditional territories of many Indigenous peoples, including 10 local First Nations[3], which also recognize the heritage and cultural value in it.

An improvement in the effluent quality would create a better environment for wildlife and biodiversity for sure, nevertheless, the effects on them are not strictly clear. Besides, there are other factors that are not controlled and might impact their ecosystem as well. Therefore, there is a small marginal benefit that communities might not even perceive, and as a consequence, the enhancement of heritage and cultural values is low as well.

Besides, Metro Vancouver constantly recognizes its relevance and follows the permitting, environmental, heritage protections and provisions of the Province and Federal requirements where applicable, and also applies conservation programs to preserve different species.

Operation and maintenance cost avoidance of potable water

Currently, around 40% of different industries in Metro Vancouver, which consume 38 billion litres of potable water per year, are using such water quality when they actually do not require it. This creates inefficiencies and misallocation of this valuable resource, while instead, the community could use it for drinkable purposes. This is a social impact as it better allocates financial resources for the community.

[3] Katzie, Kwantlen, Kwikwetlem, Matsqui, Musqueam, Qayqayt, Semiahmoo, Squamish, Tsawwassen, and TsleilWaututh

The benefit of avoiding the operation and maintenance costs of potable water is related to a better allocation of this resource. This means that the total operating budget cost of potable water would not be in vain or wasted, on the contrary, the community could take advantage of this resource, especially in peak seasons when shortages of water occur.

Thus, this is an impact with a high probability of occurrence, and a considerable magnitude given the stressors in the ecosystem: climate change risks, lower stocks of water for summer seasons, and a growing population demanding additional 5.1 billion litres of water every year.

Benefits of avoiding capital and operational cost

Future infrastructure cost avoidance

In order to cover the future demand and face the possible scenarios of climate change in the next century, Metro Vancouver has forecasted the water demand according to the population growth and climate scenarios. As a response, there are seven alternatives of water sources that would be available for construction or expansion in case they are required (Metro Vancouver, 2019). In fact, an additional 20 to 50 billion litres of annual water supply is expected to be required by 2070 to avoid water shortages, and 40 to 70 billion litres by 2096 (Metro Vancouver, 2019)

Several options for future water supply expansion projects are being considered to meet the future drinking water demand. These new facilities come with certain challenges, from high operating costs to higher levels of pumping and treatment requirements. Other than showing that Metro Vancouver is foreseeing future demand for freshwater, this also shows an opportunity of optimizing water reclamation given the great investments that the region anticipates incurring.

Contrary to providing potable water by facilities' expansion, water reclamation increases water supply with the same building capacity. Thus, the growing demand is covered at a certain point, and as a consequence the construction of water facilities, dams, and pipes can be postponed or downsized. This could avoid large investments, and therefore it becomes a remarkable impact, optimizing the available natural resources and budget.

Relevance matrix

The preceding sections have characterized all the impacts that apply to the context of Metro Vancouver, although some of them are more relevant than others. Therefore, there is a need of screening impacts that merit further assessment, and leave behind those that are less likely to occur or that have low influence on the community. To do so, a relevance score will be assigned to each impact.

Relevance scores were assigned based on the probability of occurrence, the magnitude of the impact, which communities would be impacted, and how broadly the impacts would occur geographically. Table 7 shows the summary of these factors and concludes with the relevance score.

Table 8. Summary table of the relevance of reclaimed water impacts

Impacts	Probability of Occurrence	Magnitude	What is involved?	Influence area	Relevance
Water flows improvement	Low	Small	Wildlife and biodiversity	Upstream watersheds	Low
Increase in the supply of potable water	High	Great	Communities	Metro Vancouver	High
Improvements in wildlife and biodiversity due to improvements in the effluent quality	Low	Small	Wildlife and biodiversity	Areas around the sewer pump stations	Low
Improvements in fishing areas due to improvements in the effluent quality	Low	Small	Seafood industry and recreational fishing	Areas around the sewer pump stations	Low
Improvements in recreational areas for swimming due to improvements in the wastewater quality	Moderate	Moderate	Metro Vancouver communities, tourist	Beaches close to the sewer pump stations	Moderate
Enhancement in heritage and cultural values due to improvements in the ecosystem	Low	Small	Communities that value existence of biodiversity	Metro Vancouver	Low
Infrastructure Cost Avoidance	Moderate	Great	Metro Vancouver	Watersheds	High
Operation and Maintenance Cost Avoidance	High	Great	Potable Water treatment plants	Metro Vancouver	High

Impacts with moderate and high relevance score are expected to represent greater welfare changes for the community and/or the ecosystem. Therefore, the following section will attempt to valuate them according to the methodologies explained in the theory section.

Phase 4: Valuation of the use of reclaimed water in Metro Vancouver

The valuation process of the different benefits associated with water reclamation depends on the nature of the impact. There are certain methodologies that can be followed to monetize these benefits, but it should always be coupled with the characterization and awareness of their intrinsic value.

Environmental benefits valuation

Increase in the supply of potable water

One way of monetizing the benefit of increasing water supply is through the understanding of how residents from Metro Vancouver value the provision of this ecosystem service. Therefore, the stated preferences technique throughout the willingness to pay (WTP) is a good approach for this impact. The objective would be to know the value of an increase in water supply for the community, which would be represented as their willingness to pay for it.

To find this value for the residents of Metro Vancouver, a whole study should be developed, from the survey design to its econometric modelling. This would require an investment of time and budget that can be avoided with benefits transfer. Thus, a study funded by the Canadian Water Network in 2009 that inquired about the WTP of Canadian residents for the use of reclaimed wastewater, would serve as a reference to understand how people from the region value an increase in the water supply. Although Canada-wide results aren't the best for extrapolating them to the Metro Vancouver region, we can still draw some conclusions that may helpfully inform us.

To capture the concept of water reclamation, (Dupont, 2013) formulated the matter of an increase in water supply as a reduction of the water use restrictions in summer, meaning that an increase in water supply would imply fewer restrictions for the community in a peak season. This study becomes relevant as it allows the benefit transfer because of two reasons: they measured the increase of water supply in the context of water reclamation, and the study was done in Canada, making it easier to extrapolate the community's perceptions due to similarities with Metro Vancouver's demographics. For instance, specific attention will be given to the assumptions that the study did to better fit the case for the region.

A sample size of 1135 respondents across Canada were asked how much they would be willing to pay to avoid water use restrictions in summer of 30% and 10% reduction, opting for reclaimed water for toilet flushing. Although the ultimate objective of Metro Vancouver would not be using the water for toilet flushing, the concept of water reclamation remains for the use of other industries using treated water at GEP standards.

Additionally, the study evaluated the avoidance of a 30% and 10% water use restriction. In this case, the maximum potential water reclamation in Metro Vancouver at the moment is 38.5 billion litres, which happens to be 13.5% of the total residential use. Therefore, for the purpose of Metro Vancouver context, there will be a benefit transfer for the values found in the study with a 10% restriction avoidance.

In terms of the characteristics of the sample of the study, table 9 shows the study's demographics compared to the population in Metro Vancouver. But most importantly are the results of the econometric model, where the relevant values were age, whether they believe in drought predictions, if they have heard about the concept of water reclamation, if they agree or not with the use of reclaimed water for toilet flushing, and if they believe that others will not comply with water restrictions; the shocking part is that income was not found as a relevant variable for determining the WTP.

Table 9. Summary table of the demographics of the study versus demographics in Metro Vancouver

Variable	Study	Metro Vancouver
Male	55%	49%
Age	47	41
Income per household	$ 77,905.3	$ 126,170.0

Thus, the estimated annual WTP per household, supposing an avoidance of 10% water use restriction in the summer is $155 (Canadian dollars 2021). With an average annual water bill of $500 in BC, the WTP would represent a 31% increase for Metro Vancouver households' water bill. Hence, to find out the total economic value that the residents perceive from an increase in water supply in Metro Vancouver, it takes to multiply the WTP ($155) by the number of households in the region (951,295), with a result of $147,6 million CAD yearly.

Finally, although the initial question was in terms of avoidance of water use restrictions, the final purpose was to extract the welfare value of water reclamation providing an increase of water supply. The question was posed in a hypothetical scenario, and it does not mean that there will not be water restrictions in peak season, but it shows how the residents from Metro Vancouver value the availability of this resource in the context of climate change risks and a growing population.

Improvements in recreational areas for swimming due to improvements in the wastewater quality

According to Destination British Columbia, the corporation that leads tourism in the province, around 43% of people living in the Vancouver, Coast & Mountains region participate in swimming in freshwater and 28% enjoys swimming in the ocean (Tourism BC & NRG Research Group, 2014). And given the benefits that the community perceives from the provisioning service of these water ecosystems, there are economic losses associated with the closures of some areas due to the water quality.

One way to evaluate this impact is through the WTP to enhance the ecosystem service provided by beaches in Metro Vancouver. But this methodology would require time and budget to investigate the perception of the residents, therefore, benefits transfer will also be used in this case. This will help us draw helpful parallels from a similar study in Canada as there is no similar studies in Metro Vancouver.

The closest study to the context of Metro Vancouver and effluent quality improvement is from Ontario, and it wondered about the benefits to beach users from water quality improvements. The study made by (Ecologistics Limited, 1990), and funded by the Ontario Ministry of the Environment after numerous beach closures due to bacterial contamination, interviewed 318 people to find out the WTP of Ontario's residents for very good quality water and to prevent declining water quality at the beaches.

Given the purpose of water reclamation in Metro Vancouver, and the fact that effluent quality is expected to improve to the parameters suitable for swimming, the interest for the benefit transfer is reflected in the WTP for very good quality water at the beaches. The study included in the analysis variables such as family income, whether the beach user group had children, the number of trips to any beach in Ontario in the previous year, and the expected number of visits to any beach in case the water quality was very good. After the data modelling, it was found that the WTP for very good quality at the beach ranges from $95.46 to $180.98, being the average on $123.70 Canadian dollars from 2021.

The average household income in Metro Vancouver is around $126,170 for 2021, which happens to be around $40 thousand higher than the average income of the respondents of the study, which was $83,040. On the other side, the median household income of Metro Vancouver ($92,138) is similar to the average income of the study. Consequently, there could be a benefit transfer, but given that the average income is higher for the region, the conditions of the study around improving water quality suitable for swimming purposes could be seen as a conservative approach, as the WTP for the people in the Metro Vancouver could even be higher.

Therefore, from the information provided by Destination British Columbia about the 28% of the population enjoying swimming in the ocean, we could assume that this portion of households would be willing to pay for very good water quality for swimming at the beaches. Thus, with 266,362 households, the total economic value of the region would range from $25,427,153 to $48,205,645 yearly, being the average $32,949,353.

Social benefits valuation

Operation and maintenance cost avoidance of potable water

Water treatment costs are part of the costs structure of providing freshwater to any industry, but the fact that there are some industries that do not require potable water for their production processes interferes with the optimization of resources, both environmental and financial. These costs could be considered misallocated; therefore, the avoidance of these costs is a welfare gain for the region.

The monetary calculation requires the quantity of reclaimed water that is displacing freshwater consumption, and this is challenging as there is uncertainty about the actual volume of reclaimed water, nevertheless, with the potential of water reclamation, a range of benefits could be found.

This valuation does not mean that the treatment cost would not be incurred by the WTP, nevertheless, it is a cost that would be well spent for the general welfare of the community and the enjoyment of potable water rather than wasting this water quality when not required.

Financial benefits valuation

Future infrastructure cost avoidance

Considering the projected population growth and the different scenarios of climate risks, future infrastructure would be required to fulfill the community demand for water. Thus, the costs that might be necessary to construct or expand water supply facilities, could perhaps be avoided by instead providing reclaimed water to certain industries. Therefore, we will explore when the shortages of water will happen, and the cost for Metro Vancouver to fulfill that demand.

Thus, when evaluating the system as is, without water reclamation and without the construction of new water facilities, by 2070 the region would experience shortages of water of 20 to 50 billion litres, and 40 to 70 billion litres by 2096 (Metro Vancouver, 2019). This gap between the future demand and the actual capacity is an important factor that should be measured.

The construction of new water facilities could therefore fulfill water demand, nonetheless, this does not necessarily account for the optimization of water as a resource, especially considering the distribution of water consumption throughout the year, and the scarcity that is projected in summer.

In this sense, the risks to the water supply system could be mitigated by introducing water reclamation to the equation. It is not only fulfilling the demand for water what makes this activity relevant, but also that it accounts for environmental and social impacts.

The valuation of this impact implies that even if there might not be a complete avoidance of the a construction, the downsize represents important savings for Metro Vancouver's cashflow, and therefore, an optimization of the financial resources arises.

Capital and operational required investment for water reclamation

As important as the environmental, social, and financial benefits that Metro Vancouver might perceive from water reclamation, are the costs of the implementation of this activity. This will allow us to compare investment efforts with the benefits perceived. Therefore, in this section different costs from the pilot project, and then scaled-up costs to a higher capacity will be presented for reference.

In 2018 Metro Vancouver presented the projection of the capital investment of a reclaimed water demonstration facility. The estimates were based on the assumptions that the maximum capacity daily flow of reclaimed water was 2 million litres/day, providing the service for a 10-year period under GEP quality, and a construction of a truck filling station.

The required capital investment for the pilot project was $1.1 million dollars, and when scaling the costs for the capacity of scenarios 1 and 2, the total investment is estimated at $667 million dollars and $1.9 billion dollars respectively. This does not include site civil and structural costs, they only refer to the equipment, mechanical, and electrical and Instrumentation.

Table 10. Estimations adapted from Reclaimed Water Demonstration Facility, City of Richmond and Metro Vancouver 2018. Prices adjusted to 2021

Parameters	Value Pilot Project	Scenario 1 (10% of total water demanded)	Scenario 2 (27% of total water demanded)
Equipment	$1,008,396	$524,639,904	$1,454,790,317
Mechanical	$63,688	$33,135,152	$91,881,494
Electrical and Instrumentation	$118,885	$61,852,283	$171,512,122
Total costs	**$1,190,969**	**$677,759,340**	**$1,879,124,303**

The current effluent of the North Shore, Northwest Langley, Iona Island WWTP sum 212 billion litres of wastewater a year, which means that in both scenarios, these plants would be able to fulfill the demand for reclaimed water. These WWTP were taken as a reference as they are the facilities that will be upgraded to comply with GEP quality.

On the other hand, the estimated operational costs are presented in table 12, where the company Brown and Caldwell projected that the operations would be continuous, involving staff 8hr/day, 7 days per week, and a fill truck station limited to 5 days from 7 a.m. to 3 p.m. This was scaled up to both scenarios and Table 12 shows the costs that would be incurred.

Table 11. Estimations adapted from "A Reclaimed Water Demonstration Facility -Comparing Disc and Membrane Filtration, 2019". Prices adjusted to 2021.

Item Annual Cost	Value Pilot Project	Scenario 1 (10% of total water demanded)	Scenario 2 (27% of total water demanded)
Chemicals	$3,783	$2,152,608	$5,968,222
Energy	$12,682	$7,216,836	$20,009,068
Equipment replacement	$2,990	$1,701,704	$4,718,066
Membrane replacement	$3,301	$1,878,274	$5,207,615
Total annual operating cost	**$22,755**	**$12,949,422**	**$35,902,971**

Although Scenario 2 represents a higher provision of water reclamation, the associated costs are much higher, both in capital investment and operation and maintenance costs. Therefore, scenario 1 ends up being a better investment opportunity for Metro Vancouver, even if benefits are higher for scenario 2.

To summarize, the initial capital investment for a reclaimed water facility that could provide between 10% and 27% of the total water demand would range from $667 million dollars to $1.9 billion dollars. Operational costs would range from $12 million to $35 million dollars yearly. Note however that distribution costs are not included in this scope. These should also be evaluated.

Phase 5: Benefit-cost Analysis

After monetizing the benefits of water reclamation for the Metro Vancouver region, and listing the different costs associated with the technology required to achieve GEP quality, we can perform a benefit-cost evaluation to assess whether this investment is worth the costs based on the collected information.

Assuming that by 2050 Metro Vancouver would require a new raw water storage facility in one of the watersheds as an example, a forecast of the environmental, social, and financial benefits and costs would enable Metro Vancouver to make a decision based on the NPV of the different alternatives of fulfilling future water demand.

The benefits calculations will depend on the impacts of water reclamation. The values for the environmental benefits will be determined by the number of people willing to pay for an increase in the supply of fresh water, and for the improvements in recreational areas for swimming. Besides, the cost avoidance will depend on the quantity of reclaimed water to calculate the operational and maintenance costs, and the infrastructure downsize. These calculations were expressed in previous sections.

Comparing two scenarios, with and without the implementation of water reclamation, we conclude that the water reclamation scenario incurs additional capital, operational and maintenance costs, and would also incur ongoing costs for distribution. However, it also downsizes dam investment costs and ongoing water treatment costs, and also provides other environmental and social benefits. Based on this evaluation, water reclamation may be a good option as one means of meeting future water needs in the region. However, as noted, not all costs have been incorporated, and local estimates of benefits should be developed to explore such a scenario further.

Conclusions and recommendations

Reclaimed water could provide substantial benefits to the Metro Vancouver region, with those benefits potentially outweighing the costs of setting up such systems. Potential financial, environmental, and social benefits were reviewed, and estimates were prepared for benefits relevant to Metro Vancouver's situation. Such impacts included infrastructure cost avoidance, O&M cost avoidance of potable water, increases in potable water supply for the community, and water quality improvements in beaches in the region.

I. Infrastructure cost avoidance is the biggest potential benefit of water reclamation for the region. Such a project represents potentially large savings for the region, with the possibility of increasing investment in other areas.
II. Increase in the supply of potable water shows that the residents of Metro Vancouver value water resources highly. In the context of water reclamation, this implies alleviating peak consumption seasons and long-term stressors.
III. Water treatment plants' operation and maintenance cost avoidance indicates better allocation of Metro Vancouver's resources (both financial and natural), prioritizing potable water consumption for communities rather than industries.
IV. Improvements in recreational areas for swimming represent the value that the residents give to the possibility of having more beaches open for their enjoyment.

- **Recommendation 1:** Both environmental valuations were done with WTP using benefit transfers. Although these studies allow us to understand welfare perceptions by the residents, it is recommended to perform the study in Metro Vancouver to get a more accurate perception of welfare from the residents.

The costs that Metro Vancouver would incur in the implementation of water reclamation are related to the capital, operation, and maintenance costs. Although it is a large investment due to the required technology to achieve reclaimed water quality, part of this investment is already included in the organization's budget. We could therefore conclude that Metro Vancouver has been preparing for a shift in the effluent management, and as a result, it is expected to be manageable to implement water reclamation in the region. Special attention should be given to measuring and achieving TSS, Turbidity, and Fecal Coliform parameters in the two plants that are not yet planned to be upgraded.

With the evidence of the feasibility of water reclamation, the following concern would be the market structure for this valuable resource and provisioning service. In terms of supply capacity, the potential of water reclamation depends on the capacity for storage and on the distribution of this resource throughout the year. In fact, toilet flushing represents higher demand for reclaimed water, but how optimal this might be would depend on the distribution requirements.

- **Recommendation 2:** it is necessary to develop a detailed projection of the distribution costs that could be incurred for water reclamation. This would complete the evaluation in terms of the distribution systems that Metro Vancouver could afford, whether it is trucks or even the construction of pipe systems.

The demand also requires attention, although the potential users of the GEP quality are wide, as reclaimed water would have the highest quality before potable treatment, there might be some concerns and distrust about the quality, how to include reclaimed water in their production processes, and the possible effects on public health.

- **Recommendation 3**: it would be necessary to develop strategies to identify and target potential users according to their needs and concerns, and educating them about the benefits of water reclamation.

From the context of a region that is plenty of fresh water, pricing structure would also be an important factor that would determine how the market would behave. Establishing the price based on market analysis is a way of capturing the WTP from different sectors, but this would require a study that would be costly and time consuming. Another approach is to set the price based on the provisioning service cost; it could be tricky as this pricing might disincentivize the willingness to use reclaimed water. Finally, defining the rate based on a percentage of the potable water price is the most common approach, and is usually the case for those who would like to encourage its use. Although this last one might not pay back the costs, it serves as an incentive to displace potable water use.

- **Recommendation 4**: according to the water system in the Metro Vancouver region, it is not recommended to set the price higher than potable water, this would disincentivize the demand for reclaimed water. Nevertheless, more research should be done, being a market analysis worth the investment to figure out the price.

The ultimate goal of planning for water supply structures is community welfare. Thus, value could be represented as a better allocation of natural or financial resources, or simply the welfare that society perceives as the desired development of the region. It was demonstrated across the report that water reclamation plays an important role in planning for future water supply: it accounts for the long-term optimization of the water system, it also affects the seasonal consumption. In the big picture, this is an activity that is worth the investments when including both, the environmental and financial benefits referenced in this study.

References

A.G. Anderson, J. G. (2016). Microplastics in personal care products: Exploring perceptions of environmentalists, beauticians and students. *Marine Pollution Bulletin*, 454-460. doi:https://doi.org/10.1016/j.marpolbul.2016.10.048.

Akoueson, F., Sheldon, L. M., Danopoulos, E., Morris, S., Hotten, J., Chapman, E., . . . Rotchell, J. M. (2020). A preliminary analysis of microplastics in edible versus non-edible tissues from seafood samples. *Environmental Pollution*, Volume 263, Part A. doi:https://doi.org/10.1016/j.envpol.2020.114452.

Ayres, A., Gerdes, H., Goeller, B., Lago, M., Catalinas, M., García Cantón, Á., . . . Ian. (2014). *Inventory of river restoration measures: effects, costs and.* REFORM.

BC Public Services. (2018). *Environmental Management Act, Municipal Wastewater Regulation.* Victoria: BC Public Services. Retrieved from https://www.bclaws.gov.bc.ca/civix/document/id/crbc/crbc/87_2012

Dupont, D. P. (2013). Water use restrictions or wastewater recycling? A Canadian willingness to pay study for reclaimed wastewater. *Water Resources and Economics*, 61–74. doi:http://dx.doi.org/10.1016/j.wre.2013.03.002

Ecologistics Limited. (1990). *Benefits to beach users from water quality improvements.* Toronto,: Queen's Printer for Ontario. Retrieved from https://archive.org/details/benefitstobeachu00ontauoft/page/n27/mode/2up

EU, OECD & UNECE. (n.d.). *Assessing the environmental and economic value of water: review of existing approaches and application to the armenian context.* OECD & UNECE. Retrieved from https://www.oecd.org/env/outreach/AM%20Water%20Value.pdf

Evans, K. S., Athearn, K., Chen, X., Bell, K. P., & Johnson, T. (2016). Measuring the impact of pollution closures on commercial shellfish harvest: The case of soft-shell clams in Machias Bay, Maine. *Ocean & Coastal Management*, 196-204. doi:https://doi.org/10.1016/j.ocecoaman.2016.06.005.

Fisheries and Oceans Canada. (2018). *Regulating and Monitoring British Columbia's Shellfish Aquaculture Facilities.* Government of Canada. Retrieved from https://waves-vagues.dfo-mpo.gc.ca/Library/40875982.pdf

Gaw, S., Thomas, K. V., & Hutchinson, T. H. (2014). Sources, impacts and trends of pharmaceuticals in the marine and coastal environment. *Philosophical transactions of the Royal Society of London*. doi:https://doi.org/10.1098/rstb.2013.0572

Government of Canada. (2022). *Reasons for shellfish harvesting area closures*. Retrieved from Government of Canada: https://www.dfo-mpo.gc.ca/shellfish-mollusques/reasons-raisons-eng.htm

Health Canada. (2010). *Guidelines for Domestic reuse Water for Use in Toilet and Urinal Flushing.* Ottawa: Health Canada. Retrieved from https://www.canada.ca/content/dam/canada/health-canada/migration/healthy-canadians/publications/healthy-living-vie-saine/water-reclaimed-recyclee-eau/alt/reclaimed-water-eaux-recyclees-eng.pdf

Hurlimann, A., & McKay, J. M. (2005). Contingent Valuation by the Community of Indirect Benefits of Using Recycled Water - An Australian Case Study. *International Conference on the Efficient Use and Management of Urban Water*, 520-529. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2476167

M. Molinos, S., Hernández-Sancho, F., & Sala-Garrido, R. (2011). Cost–benefit analysis of water-reuse projects for environmental purposes: A case study for Spanish wastewater treatment plants. *Journal of Environmental Management*, 3091-3097. doi:https://doi.org/10.1016/j.jenvman.2011.07.023.

M. Molinos-Senante, F. H.-S.-G. (2011). Cost–benefit analysis of water-reuse projects for environmental purposes: A case study for Spanish wastewater treatment plants. *Journal of*

Environmental Management, 3091-3097. doi:https://doi.org/10.1016/j.jenvman.2011.07.023

Metro Vancouver. (2019). *Water Supply Outlook 2120.* Burnaby: Metro Vancouver. Retrieved from http://www.metrovancouver.org/services/water/WaterPublications/WaterSupplyOutlook2120.pdf

Metro Vancouver Liquid Waste Services Environmental Management and Quality Control. (2020). *The 2020 Greater Vancouver Sewerage and Drainage District, Environmental Management and Quality Control Annual Report.* Burnaby: BC: Metro Vancouver.

O'Reilly, D. M., & Pierce, C. (2008). Survey Examines Reclaimed Water Rates, Charges. *Waterworld*, 18-19. Retrieved from https://www.waterworld.com/home/article/16189791/survey-examines-reclaimed-water-rates-charges

Ojeda, M. I. (2008). Economic valuation of environmental services sustained by water flows in the yaqui river delta. *Ecological Economics*, 155-166. doi: https://doi.org/10.1016/j.ecolecon.2007.06.006

Rossum, T. V. (2020). Water reuse and recycling in Canada — history, current situation and. *Water Cycle*, 98-103. doi:https://doi.org/10.1016/j.watcyc.2020.07.001

Tourism BC & NRG Research Group. (2014). *2009/10 Outdoor Recreation Study.* Tourism BC. Retrieved from https://www.destinationbc.ca/content/uploads/2018/08/Outdoor-Recreation-for-Distribution-14Jan13-FINAL-DRAFT-2.pdf

Vancouver Coastal Health. (2022, June 12). *Beach water quality reports*. Retrieved from Vancouver Coastal Health: http://www.vch.ca/public-health/environmental-health-inspections/pools-beaches/beach-water-quality-reports