

Can Constructed Wetlands be the Future of Wastewater Treatment?
A Policy Analysis Determining the Gaps Within Canadian Legislation

by

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Abstract

Treating wastewater is a vital resource for ensuring the health and safety of residents and the environment. With the constant advancements in society, Canada's municipal wastewater system is continually being modified and updated to incorporate changes in technologies, water quality standards and policies. The introduction of constructed wetlands in municipal wastewater treatment systems has been a new revolution to combat the conventional systems inefficiencies. A review of the current system is done to understand where constructed wetlands can be introduced.

The conclusion of this study will help to promote change in municipal wastewater systems and incorporate techniques that benefit residents as well as the environment.

Key words: constructed wetlands, wastewater, municipalities, treatment, efficiency, policy analysis.

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Introduction

Managing city wastewater is crucial to ensuring the health and safety of community members. It is a required resource that can reflect the standard of living within a community. Canada's wastewater treatment legislations vary from municipality to municipality. There are a variety of techniques for wastewater treatment, which is selected based off municipality standards and the purpose of treated effluent. Recently constructed wetlands have been introduced into selected municipalities for wastewater treatment. Constructed wetlands are man-made bodies of water that can be used in the purification process of wastewater (Environment Canada, 2006). The wastewater is filtered and treated using natural processes performed by specific plant species and microorganisms. Constructed wetlands would be able to combat the removal of suspended solids, biodegradable organic matter as well as nitrogen and phosphorus (Brix et al., 2000). This treatment technique is found to be a versatile and beneficial option for the wastewater treatment system.

Statement of Problem

This study focuses on the gaps in Canadian legislation around constructed wetlands used in wastewater treatment. This technique can help reduce resource demands, while also creating a new habitat for some species (United States Environmental Protection Agency, 2000). It provides many benefits to the residents, facility operators and the environment. This technique for wastewater treatment has yet to be embedded within the Canadian legislation, which limits the acceptance and expansion of this technology. The incorporation of this technique will aid in future design plans for new wastewater

treatment facilities and provide a greater understanding of constructed wetland benefit for residents.

Purpose Statement

This study will undergo a policy analysis where legislations are reviewed and analyzed to determine how best to incorporate constructed wetlands into wastewater treatment systems. Canadian regulations must be thoroughly reviewed to determine what policies will be chosen and edited. A review of all three levels of government will be necessary to determine what policies to focus on and where specific changes need to be made. Once the policies are chosen, they will be heavily analyzed to create a concrete list of suggestions for the implementation of constructed wetlands. These edits will create an inclusive well-rounded policy, which can be used as an example for other governments to learn and adapt.

Research Question

“Following a policy analysis determining the gaps within Canadian legislation, can constructed wetlands be seen as the future of municipal wastewater treatment?”

Hypothesis

It is hypothesized that after reviewing the scholarly literature, the focus of research will be on regulations at a provincial and municipal level. This is because there is a greater focus on wastewater treatment regulations within these levels of government rather than the federal level. This will result in multiple policies being analyzed and edited, allowing for constructed wetlands to be fully integrated into Canadian legislation.

Definition of Terms

This is a list of words throughout the text that should be understood to fully comprehend the study.

ABC: Association of Boards of Certification Atlantic Canada Water and Wastewater, which is the board where they decided if a certification is appropriate and meets the educational standard for approval.

Constructed wetland: Engineered bodies of water that have specific plant species, soil types and microorganisms to treat water (United States Environmental Protection Agency, 2000).

Effluent: The discharged water that has underwent all the wastewater treatment stages.

Hydraulic retention times: This is the period of time it takes for wastewater to undergo treatment. This is measured separately for each step of the process, not the total treatment time (United States Environmental Protection Agency, 2000).

Influent: Used to describe wastewater prior to treatment (United States Environmental Protection Agency, 2000).

Limitations of the Study

This study will undergo a policy analysis of Canadian legislation to determine the gaps within wastewater treatment systems. Due to the limited amount of time and wide variety of legislations, it may be difficult to provide solutions to multiple policies. If focus is placed on one policy, it will require heavy analysis and edits. To thoroughly review and analyze a policy it will require a deep understand around the constructed wetland technique and the wastewater treatment process.

Another limitation to this study will be to find case studies of constructed wetlands used in municipal wastewater treatment as well as embedded within their legislation. This technique is relatively new to municipal wastewater treatment and can be hard to find legislation. This would be helpful when the edits to Canadian legislation are made so that there are policies to reference and further support these changes.

Chapter 2

Literature review

A variety of sources have shown the importance of law reform and analysis because of the constantly changing society of which legislations reflect upon. The Canadian government takes into consideration the changes within the medical community, social issues and technology to alter laws to better suit the needs of the population (Department of Justice, 2015). These changes are the reason that the Canadian laws are constantly being reformed to ensure it satisfies the needs of current society. Though many new concerns arise that question our countries morals and laws, this can make it difficult for a consensus among citizens on if the laws should stay the same or change.

A multitude of research findings have indicated constructed wetlands can be utilized as a water filtration system. These studies show the dynamics between water filtration systems and the natural environment. Researchers have suggested that constructed wetlands are a suitable water filtration system to combat pollution, eutrophication and unsafe drinking water (Jing, 2002). A variety of constructed wetland systems have been researched to determine which outputs the highest quality effluent. The conventional wastewater treatment system must be evaluated to understand the benefits constructed wetlands can bring to the system.

Constructed wetlands are engineered and managed systems that operate off biological, physical and chemical processes in an ecological system (United States Environmental Protection Agency, 1999). They are systematically planned to ensure all components (plant organism, water flow, viable land, temperature etc.) are used to maximize benefits.

Specific plant organism, soil types and microorganisms are thoughtfully chosen for each constructed wetland because of the different types of wastewater influent being treated (United States Environmental Protection Agency, 1999). There is generally a positive correlation between research on constructed wetlands and their ability to filter wastewater. Brix refers to wetlands as the kidneys of the landscape and strongly believes that a constructed wetland is a tool that can be used to improve water quality (1995). They are viewed as having low-energy consumption, low maintenance requirements and high efficiency outcomes (Jing, 2002). This system, according to Lissolo et al., can be seen as too good to be true and therefore deters some governments away from this technique (2002). It can be difficult to introduce and implement a new system for a municipal wastewater treatment facility because of the wide variety of stakeholders involved (Environment Canada, 2006).

Historically wetlands have been viewed as wasted space and were often drained and replaced by agricultural land (Brix, 1995). It was not until the 1980s that constructed wetlands in cohesion with wastewater treatment were gaining popularity (Jing, 2002). These systems were mainly use to filter runoff from acid mines, storm water, industrial activities, agriculture and municipal wastewater (Jing, 2002). Since wetlands have always served as a natural water treatment system, scientists believe that constructed wetlands can be the solution to our wastewater treatment demands (Wastewater gardens, 2012). There has been a growing appreciation for the benefits natural wetlands have on ecosystems, which has led some to question why conventional treatment methods with their greenhouse gas emissions and increasing costs are still being used (Lissolo et al.,

2002). Without the inclusion of constructed wetlands in wastewater legislation, this technique can never develop into its potential. Regulations will be the guiding principles to help designers and facility owners move towards constructed wetland treatment.

Constructed wetlands have yet to dominate the world's wastewater treatment systems due to challenges of communication between advisory boards for municipalities and scientists who research wetlands (Lissolo et al., 2002). There are numerous types of constructed wetland systems that have been developed to suit a variety of wastes and climates. The two most common ones were surface flow and subsurface flow wetlands. A simple way to determine the difference is that the surface flow wetland has water exposed to the environment whereas the subsurface flow uses a mixture of clay or gravel to cover the water surface (Jing, 2002). Surface flow wetlands are the predominant type used in North America, but can vary depending on the exact location of the wetland (Brix, 1995). Surface flow wetlands lay stagnant for periods of treatment, which can increase the breeding grounds for mosquitoes (Brix, 1995). Lissolo et al., describes subsurface flow wetlands as superior to free surface flow because of its increased efficiency in eliminating total suspended solids from wastewater as well as reducing disease carrying vectors such as mosquitoes (2002). They are also beneficial in colder climates due to the water surface being covered, protecting it from ice (Lissolo et al., 2002). Both systems focus their filtration around eliminating four specific variables: suspended solids, organic matter, phosphorus and nitrogen (Jing, 2002). The process of choosing the best-suited wetland design will be based off location, climate and volume of wastewater.

Most studies that focus on specific constructed wetlands highlight the system's hydraulic retention time. This is a unit of measurement that determines how long each step the wastewater takes to be processed in the wetland (United States Environmental Protection Agency, 2000). These numbers vary from study to study as well as from wetland design. It is optimal for the retention time to be lower, therefore increasing the amount of water being treated in a specified time (United States Environmental Protection Agency, 1999).

The reasons for choosing one system over another would be determined by the location of the treatment facility, climate, land availability, wetland design, plant species composition and the type of wastewater influent (Brix, 1995). Temperature variation is crucial in determining which wetland is best suited for the area. Cold weather can affect the treatment performance; therefore seasonal climates must carefully choose a system where the efficiency during the winter months is minimally impacted (United States Environmental Protection Agency, 1999).

The history of wastewater management is important to determine the reasoning behind our current wastewater treatment facilities. Looking into the obstacles throughout history is important to determine the turning point where wastewater management strategies were introduced. The past provides scientists, engineers, architects etc. with the opportunity to use this information in order to test and design new concepts for wastewater management (Brown, 2010). It was only until The Age of Sanitary Enlightenment and The Industrial Age, where wastewater management became an important aspect of society (Brown, 2010).

The technological evolution of wastewater filtration systems began with the primary treatment, where gravity systems were put in place to aid in the removal of heavy solids and organic matter. This was the most common filtration system across the United States until 1972 when it became mandatory for secondary treatment under the *USA Clean Water Act* (Brown, 2010). The secondary treatment came to rise where microorganisms were used to convert organic materials into carbon dioxide and energy. There are two types of secondary treatments: biofilms and activated sludge. Once this became mandatory, more technologies emerged to perfect the quality of wastewater, which translated to the protection of not only human health but the health of the environment (Bouwer, 2000). Tactics were created to minimize the risk of eutrophication and eliminate the spread of water-borne diseases. This created a platform for environmental decision making through policies that would become a necessary part of western society.

With the rise in population and the increased standard of living, the need for wastewater management is at an all time high. New systems must be adapted to support larger populations, while ensuring the integrity of the environment. There are more demands placed on agriculture systems where water runoff issues are leading to huge environmental consequences. This is where history and scientific evidence become important in determining the next step for our wastewater systems. As the price of oil rises the need for new technologies are essential to reduce facility costs as well as limit environmental harm (Bouwer, 2000). The implementation of constructed wetlands can be seen as a viable solution to many areas around the globe. These technologies are well

studied and understood but new policies must be integrated to promote these low cost, low impact and high efficiency treatment options. As the fresh water resource is decreasing, the need for wastewater management is crucial for survival.

A group in Scotland called What Works Scotland is an organization that was developed to identify how to best provide the public with meaningful knowledge around legislation changes and help citizens become more involved in law reform (What Works Scotland, 2015). Their focus is on determining the benefits and pitfalls of the system in order to make logical and meaningful changes for the community. Their main focus is to transform the public sector to improve the well being of the population and change the overall service design to increase efficiencies. They support the use of evidence collected around community needs, in order to plan and deliver change within the public sector. They have 4 aspects that help guide their goals (What Works Scotland, 2015). The first is taking what they learned from individual projects and interventions to transform the system. The second aspect is to determine what is working in society and what is not, this will help them gauge what the community needs and help create widespread equality over the country. This can reduce injustices because the government will learn what areas are not getting sufficient resources and help create an equal balance between cities. The third aspect is reviewing large-scale reform programs and determining if they were successful and how it affected the overall system. The last aspect is looking at why some communities have a greater need than others. This information can help bridge the gap and contribute to a balanced approach. This law reform program encourages public involvement and participation throughout communities; it changes the perception of

legislation and makes it more accessible and inviting for citizens. Law reform groups usually focus on a particular set of issues such as civil rights or areas around disadvantaged groups (Harvard Law School, 2015). Policy oriented advocacy focuses on research, policy analysis and advocacy, lobbying for legislation and media advocacy (Harvard Law School, 2015).

The variety literature that was analyzed in this section displays the positive impact constructed wetlands can have within municipal wastewater systems. The benefit of this system is that it has been around for many decades but has yet to be combined with municipalities. This implementation could boost the awareness and prevalence of constructed wetlands throughout Canada. This technique has the potential to completely change the way wastewater treatment is viewed and allow people to develop a deeper appreciation for the natural environment.

Chapter 3

Methods

The methods that will be used to guide this study is through a policy analysis framework. The policy analysis approach creates recommendations and advice to update and improve current legislations. To determine if the policy is accepted or not depends on how well the issue and arguments justify the action. It is the researchers role to invest time with the policy to understand, interpret, criticize, and synthesis the policy as well as find others for comparison and improvements (Bardach, 2011). Policy analysis applies to both social and scientific research and is pursued by governmental and non-governmental agencies. They are usually directed at designing, implementing and evaluating existing policies, programs and other aspects being adopted or considered (Dobuzinskis et al., 2005).

There are four steps that will be followed to complete the policy analysis to receive meaningful results (Patton & Sawicki, N.A).



Figure 1: This infographic outlines the four steps of the policy analysis that will be used to guide this study.

The first step is defining the opportunity and addressing questions such as: What areas of research need to be examined to gain the required knowledge around the issue? What has caused the interest in this issue? Was there a specific event or activity that created the awareness around the issue? Does this require immediate attention?

These are some of the questions that need to be answered to gain an overall sense of the issue and determine the main focus.

The second step is establishing goals; what are the overall goals of the project to ensure the desired outcome is met? This is critical to determine how to translate the opportunity into a list of intended goals, which will allow a clear path to achieving a logical outcome. The goals must be detailed by describing how they will specifically target areas of policies. This process will increase the clarity of analysis and ensure the desired outcome is met.

The third step is selecting the policies for analysis. Based off the completed research and in depth understanding of the problem, specific policies will be evaluated. These policies will be chosen based off the relevance to the proposed problem. They will be analyzed to determine the gaps of knowledge within them in order to help build upon a list of suggestions for law reform. By looking at various policies it will help determine the different alternatives possible and required steps to make these changes possible. As well as help limit the number of policies chosen for analysis.

The fourth step is to determine a list of proposed changes to the policies. This can even become more specific and place focus on solely one level of government or one policy. The more policies being analyzed the broader the solutions will become, which can be beneficial if the problem is a national issue rather than localized. These proposed solutions will help fill the gaps in missing legislation and be able to replace out of date information. This can also help bring awareness to new technologies or changes within society. It can help generate public awareness around policy concerns and become engaged with policy reform.

The three levels of government being reviewed are the Canadian Environment Act, the Nova Scotia Environment and Halifax Water. These three government sectors will be reviewed to determine which policies would benefit the most from having constructed wetlands added to the wastewater treatment process. This sector of the government has specific regulation around wastewater treatment and the suggestions may be heavily targeted around this legislation. It is important to review all sectors of government to ensure that the gaps within the legislations are known so that meaningful suggestions can be achieved. These three sectors of government will be analyzed by looking at the current laws to determine how it can be improved to better include constructed wetlands as a viable option for wastewater treatment.

Chapter 4

Results and Analysis

The following section outlines the outcomes of completing a policy analysis to incorporate constructed wetlands within Canadian legislation. These four steps were vital to ensure logical changes are made to accommodate any knowledge gaps or discrepancies present within the legislations.

Step 1: Defining the Opportunity

Research was gathered to help define and understand the function and process of a constructed wetland within a wastewater treatment setting. Constructed wetlands are engineered systems designed to help filter wastewater through the use of the natural processes of microorganisms, plant species and soil types (United States Environmental Protection Agency, 2000). Recently this has become a popular design decision within municipal wastewater treatment systems, but has been implemented in other realms of the environment for many years (United States Environmental Protection Agency, 2000). There are a variety of plant species, soil types and microorganisms to choose from when designing a constructed wetland. These decisions are based on the location of the intended wetland and the type of wastewater being treated: industrial wastewater, human wastewater or farm runoff (Wastewater Gardens, 2012).

The Wastewater Treatment Process

The basic wastewater treatment process undergoes four stages to output a quality effluent: preliminary, primary, secondary and tertiary (Environment Canada, 2006). The preliminary treatment is in charge of controlling odor and removal of the majority of solids, debris and grit (Environment Canada, 2006). The primary treatment is where

wastewater is transferred into a large tank and sits, allowing any oils to settle at the top and sediments or sludge to rest on the bottom. The oil is then drained off and the sludge is transported for disposal or reuse (Environment Canada, 2006). Secondary treatment is where a variety of chemical compounds are removed using biological processes (Brix, 1995). There are many different techniques for this stage because of the varying types of wastewater influent present. As shown in *figure 1* Constructed wetlands would be classified as a secondary treatment stage. The final stage is tertiary treatment, which is the highest treatment level that is necessary when effluent is discharged into sensitive environments (Environment Canada, 2006). It is a refined treatment that can remove small unwanted particles or left over pharmaceuticals (Brix, 1995). These four stages complete the wastewater treatment system though some facilities focus solely on one stage, others incorporate three or four of them. There is a lot of variability within each wastewater treatment system.

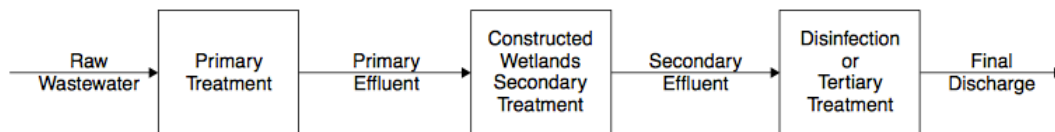


Figure 2: Outlining the basic steps of a wastewater treatment process. The following figure is from the United States Environmental Protection Agency (2001, pp.22)

The Design Choice

When choosing a wetland design there are many variables that must be taken into account such as: land area, climate, topography, the facility budget and the type and volume of effluent (United States Environmental Protection Agency, 2000). There are two major design types for constructed wetlands: surface flow constructed wetlands (SFCW) and

subsurface flow constructed wetlands (SSFCW) (United States Environmental Protection Agency, 2000).

SFCW use an aerobic process for water treatment, where most of the biological activity occurs near the surface of the water, mimicking natural wetlands. As shown in *figure 2* they have a shallow design, allowing the wastewater to move slowly throughout the wetland as the chemical, biological and physical processes occur (Wastewater Gardens, 2012). The hydraulic retention time for this design is much quicker compared to SSFCW, but requires a greater amount of land area (United States Environmental Protection Agency, 2000).

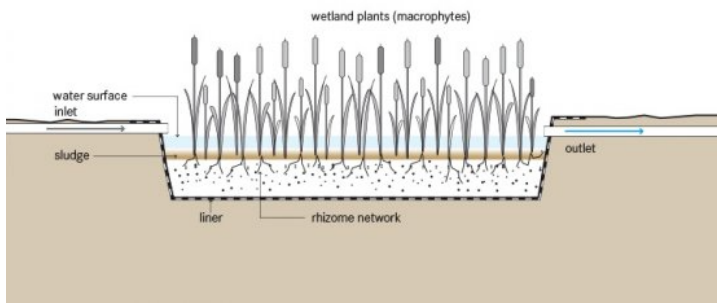


Figure 3: Diagram displaying the design and process of a surface constructed wetland. (Sustainable Sanitation and Water Management, 2014).

SSFCW is the alternative design in which the water surface is covered by clay or gravel and undergoes an anaerobic process (Wastewater Gardens, 2012). This design takes up to 80% less space than the SFCW design because of the increased depth of the wetland. There are two subtypes to this design: horizontal flow and vertical flow. The horizontal flow, shown in *figure 3*, allows water to travel from left to right as the water treatment progresses. The vertical flow design processes wastewater from top to bottom,

accounting for only two-thirds of the space a horizontal flow would require (Wastewater Gardens, 2012).

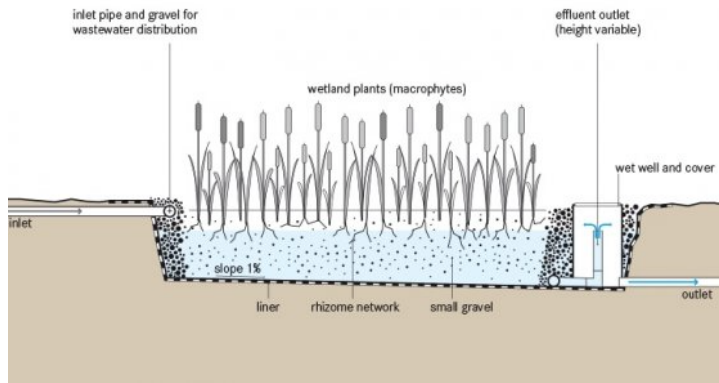


Figure 4: Diagram of the design and process of a horizontal subsurface constructed wetland. (Sustainable Sanitation and Water Management, 2014).

The Conventional System

Constructed wetlands used in wastewater treatment facilities have several benefits over the conventional system, which is predominately used throughout Canada. They would replace one of the most common technologies, activated sludge treatment. This conventional process is where microorganisms are used to breakdown organic matter and transforms waste into carbon dioxide, water and other inorganic compounds (World Bank Group, 2016). There are three steps to this treatment:

1. Placing wastewater into large reactor containers where the microorganisms are introduced and mixed throughout. Aeration technology is used to incorporate oxygen into the reactors to increase the efficiency of the microorganisms.
2. The liquid is transferred into another tank where it remains still for any sediments/microorganisms to settle at the bottom.

3. The completely treated effluent is then transported to its next destination, while the remaining sediment is reintegrated into the first step.

This process requires high amounts of energy due to the aeration demands, which means it needs oxygen to be continuously filtered throughout the reactor container. There are many variations of design techniques for this system and they all vary based off the site location, type of wastewater and the facilities budget. This system does require a lot of human attention with highly trained staff and routine laboratory tests; this can increase the operation and maintenance budget (Environment Canada, 2006).

The Benefits of Constructed Wetlands

Since most businesses are striving towards efficiency within their business models, constructed wetlands have become appealing to developers because of their low energy requirement. The only energy input required during this treatment phase is to move the wastewater throughout the wetland; the plant and microorganisms complete all of the waste filtration. These systems are low-tech thereby reducing construction costs. Minimizing machinery involved in the treatment process reduces the costs for repairs and updates, as well as the skill level required for operators. Constructed wetlands are not only economically beneficial, but also environmentally appealing. Though aesthetics cannot be quantified, they are still a vital attribute to any community (Wastewater Gardens, 2012). In many developing cities, green space has become a focus, providing residents with the opportunity to interact with nature, while providing a new habitat for surrounding species (United States Environmental Protection Agency, 2000).

For best results of a constructed wetland facility, it is important that developers understand certain conditions present in the location, prior to design decisions. There are many factors that increase the systems productivity and others that diminish it, some aspects can be adjusted while others cannot. Certain constructed wetland designs require large areas of land making them more feasible for rural communities. These systems have minimal mechanical features allowing them to be easily operated and maintained (United States Environmental Protection Agency, 2000). They require minimal human input because it is essentially self-sufficient, though weekly water tests are conducted to ensure the water quality standards are met. Rural communities tend to have a less diverse/lower-skilled workforce making constructed wetlands a viable option to increase employment (Wastewater Gardens, 2012). Most rural communities have smaller budgets than urban centers, making affordability and efficiency two very important factors when planning for a new facility (United States Environmental Protection Agency, 2000). They want to ensure that potential repair costs are low, while also meeting the water quality standards. Though some constructed wetland designs require a lot of square footage, land in rural areas is usually inexpensive making it more viable than an urban setting (Wastewater Gardens, 2012). Other factors such as, volume of water intake, community population and climate are important in determining the optimal design decision. By incorporating constructed wetlands into this wastewater treatment system it can increase the diversity and focus on other aspects that the existing processes may not target.

Step 2: Establishing Goals

Setting goals to determine what will be accomplished within the policy analysis and how conclusions will be met.

Goal One:

Ensure thorough research has been completed to fully understand:

- a. The definition of a constructed wetland.
- b. How constructed wetlands filter the wastewater.
- c. The benefits constructed wetlands have over the conventional technology.
- d. Where constructed wetland will be introduced into the system.

Goal Two:

Determine the level of government to target:

- a. What level of government will have the most impact for facilitating change to wastewater systems?
- b. How will the policies differ from level to level?
- c. Should a new legislation be created?

Goal Three:

Determine the number of policies being evaluated:

- a. Is there a policy that can be updated to incorporate constructed wetlands or would it be more beneficial to create a new one?
- b. Should the focus be solely on one policy or many?
- c. Should there be changes to policies from every level of government?

Goal Four:

Once all prior steps have been achieved

- a. What is the biggest achievement of this policy analysis?

- b. Would the use of a case study on the new policy demonstration the changes?

Step 3: Selecting Policies for Analysis

These are the policies that have been chosen, reviewed and edited:

I - Water and Wastewater Facilities and Public Drinking Water Supplies Regulations

II - The Facility Classification Standards

These two policies above are from the Nova Scotia legislation and it was found that analyzing policies at the provincial level was most beneficial because of the content it covers. The three levels of government focus on different aspects of wastewater treatment. The three levels of government that were assessed are: The Canadian Federal Government, The Nova Scotia Provincial Government and The Halifax Regional Municipal Government. The municipal government is responsible for wastewater management, ensuring that all residents have access to water treatment systems (Halifax Water, 2015). They have various by-laws that focus on limiting the types of discharge allowed in public sewers by residents or industries (Canadian Council of Ministers of the Environment, 2009). The provincial government is responsible for the wastewater treatment operations that include the facility standards, operator certifications, maintenance standards, discharge limits, and facility classifications (Canadian Council of Ministers of the Environment, 2009). The federal government does not specifically focus on wastewater treatment but rather ensuring water quality throughout the country is held to high standards.

The reasoning for choosing legislations from the provincial level is because it focuses on the physical facility where water treatment takes place. This is a good starting place to

introduce change in legislation because it is during the pre-construction and construction phase. Ensuring the concept of constructed wetland technology be introduced during these phases creates an easy transformation to the conventional design layout for the proposed treatment facility. These two policies are focused on the specifics about the facility standards and the variety of treatment systems. By introducing constructed wetlands into these policies they will be considered a credible design option and encourage old facilities to upgrade to this technique.

Step 4: Creating a List of Proposed Changes

The policies that were chosen above have been edited to incorporate constructed wetlands into the wastewater treatment process. The original policies lacked any application or opportunity pertaining to constructed wetlands within the wastewater treatment process. These suggestions can help incorporate this technology into existing or upcoming wastewater facilities.

I – Water and Wastewater Facilities and Public Drinking Water Supplies Regulations

The first legislation examined was the Water and Wastewater Facilities and Public Drinking Water Supplies Regulations (Environment Act, 1994). This document focuses on facility regulations, the certifications required for operating a facility and for operators who work at the facility. This regulation is divided into two sections: Facility Classifications and Operator Certifications, and Monitoring of Public Water Supplies. The suggested edits and additions have been outline below.

Operation Certification: Section 14 – 18

These sections outline the various standards and certifications that classify a

facility as legally eligible to start operations. These sections outline the levels of certification required for various operator positions, but do not state the names of the certifications. To ensure that an operator has the proper certification they must contact the Atlantic Canada Water and Wastewater Voluntary Certification Board for approval. The following suggestions are two certificates that can be used to help an employee operate and maintain a facility that uses constructed wetlands technology. These certificates provide an operator with the knowledge about operating and managing constructed wetland technologies.

UNSECO – IHE: Institute for Water Education

Course: Constructed Wetlands for Wastewater Treatment

This online course provides an understanding of the basics of wastewater treatment, the functions of constructed wetland technology and the knowledge of operating and maintaining of the system (UNESCO-IHE, 2016). This certification provides the participant with the skills to develop and design a constructed wetland system that could be implemented into a wastewater facility. This course would be most beneficial for persons already in wetland management and/or wastewater treatment.

Rutgers –The State University of New Jersey

Course: Wetland Construction: Planning and Functional Design

This course is outlined to develop a further understanding into the topics of: hydro geomorphology, water budget calculations, estimating stream flow and producing basic hydrographs (Rutgers University, 2016). This certificate will

be most applicable for persons within the following job sectors: environmental consulting, field biologist, wetland scientist, design/civil engineers or architects (Rutgers University, 2016). Other sectors of environmental fields may also be applicable.

These two certifications will not be added directly to the document, but rather be brought to the Atlantic Canada Water and Wastewater Voluntary Certification Board (ACWWVCB) to determine if the certificates are eligible for operations of a constructed wetland. They will also have to decide at what level these certifications will be granted. The ACWWVCB requires that there be a minimum standard for operator certifications to ensure the protection of both human health and the environment (Atlantic Canada Water & Wastewater Association, N.A). In 1984, Nova Scotia created the operator certificate program that began as a voluntary mission to further educate the workforce but became mandatory 12 years later (Nova Scotia Environment, 2015). These programs ensure that employees are competent and prepared for all job requirements. Meeting national standards for water quality is vital to maintain trust of residents and government. Offering additional certifications with the focus on constructed wetlands in wastewater treatment will provide a greater diversity of skills to the Canadian workforce as well as providing new job opportunities.

II – The Facility Classification Standards

The second policy that was reviewed was The Facility Classification Standards (Nova Scotia Environment, 2009). This standard has been embedded within the Water and

Wastewater Facilities and Public Drinking Water Supplies Regulations and focuses on the classification system for different facilities. The facility class system is based on a point system that was developed by the Association of Boards of Certification (ABC) for the use of the Nova Scotia Environment (Nova Scotia Environment, 2009).

They established and divided wastewater treatment facilities into four classes based on a simple point system. This point system is based off a variety of factors that contribute to the size of facility, population of community served, volume of water treated etc. (Nova Scotia Environment, 2009). The classes are ranked 1- 4, 4 being the most advanced facility in terms of efficiency and water quality.

Table 1: Class levels of wastewater facilities based on point system. (Nova Scotia Environment, 2009).

Class I	30 points<
Class II	31 – 55 points
Class III	56 – 75 points
Class IV	76 point >

These points are tallied using the chart below that outlines the specific aspects of a wastewater treatment facility and the various technologies and techniques that can be used in the wastewater treatment process.

Table 2: This is part of the point system showing how the facilities acquire their class level. The suggested edits in red have been added to incorporate constructed wetland technology. (Nova Scotia Environment, 2009).

ITEM	POINTS
Preliminary treatment	
Plant pumping of main flow	3
Screening or Comminution	3
Grit Removal	3
Equalization	1
Primary treatment	
Clarifiers	5
Imhoff Tanks or similar	5
Secondary Treatment	
Fixed-film reactor	10
Activated Sludge	15
Stabilization ponds without aeration	5
Stabilization ponds with aeration	8
Surface flow constructed wetland	5
Subsurface flow constructed wetland	8
Tertiary Treatment	
Polishing ponds for advanced waste treatment	2
Chemical/physical advanced waste treatment without secondary treatment	15
Chemical/physical advanced waste treatment following secondary treatment	10
Biological or chemical /biological advanced waste treatment	12
Nitrification by designed extended aeration only	2
Ion exchange for advanced waste treatment	10
Reverse osmosis, electro dialysis and other membrane filtration techniques	15
Advanced waste treatment chemical recovery, carbon regeneration	4
Media filtration	5
Membrane filter procedures	3
Use of fermentation tubes or any dilution method; thermotolerant coliform determination	5

The addition made in the Secondary Treatment section of the point system chart in table 2, was critical for the incorporation of the two design types of constructed wetlands. The surface flow constructed wetland was allotted 5 points because it provides a quick treatment time yet requires a large area of land. The subsurface flow constructed wetland was allotted 8 points because of its ability to intake large volumes of water while requiring a small area of land. These two edits are necessary for the incorporation of

constructed wetlands because they need to be recognized as a viable option for secondary treatment.

Below are additional sections that could be added to further incorporate constructed wetlands facilities into specific classes.

Energy Efficiency:

This would be a meaningful addition to the chart because of the increased importance that energy and conservation have had on other sectors of society. It is important that new projects be mindful of their energy use to reduce the facilities' cost and environmental impact. This can be measured by recording energy inputs of different treatment facilities for the length of the complete treatment process. Once collected this data will be analyzed to determine the different energy inputs for the specific types of treatment systems. Systems with a lower energy requirement will be allotted a higher point score than systems that have a high energy demand. This will benefit constructed wetland technology because they require very little energy during their treatment stage, allowing them to have a high score.

Energy Input (kWh)	Points
$x_1 <$	TBD
$x_1 - x_2$	TBD
$x_2 - x_3$	TBD
$x_3 >$	TBD

Length of Treatment:

Outlining the length of time it takes to complete all water treatment steps to ensure effluent reaches water quality standards. The length of water treatment can vary from system to system depending on the technique used. In Table 2 it outlines the various

types of wastewater treatment for each phase of the process. The treatment systems that has a shorter treatment time will have a higher weighted score where as systems with long treatment times will be low scored. This can have one negative impact for treatment systems that undergo longer treatment times but output higher quality effluent. To solve this problem the point chart can be divided into the four steps of the treatment process (pretreatment, primary, secondary and tertiary) and determine the length of time for each system. For example there are four different methods to complete the pretreatment process, each method must record the length of time it takes to complete its job. These will then be added to the chart and the method with the fastest time achieves the highest point value. This will then be done to the remaining steps of the wastewater treatment system.

Treatment time (Days)	Points
$x_1 <$	TBD
$x_1 - x_2$	TBD
$x_2 - x_3$	TBD
$x_3 >$	TBD

Maintenance Costs:

The cost associated with maintaining a facility is important when classifying it; facilities that require less maintenance will be ranked higher than those requiring more. This is justified because facilities with high maintenance costs will require a larger budget and can be physically demanding in terms of mechanical updates or complex repairs. If a facility is highly advanced with lots of technical machinery, it may require continuous maintenance or frequent updates to be done by a highly skilled person. This can make these systems less appealing to municipalities that have lower budgets or less access to a high skilled workforce. Though this is a reasonable new section for the point system, it

will not have a high point rating because it is not a critical factor for determining the level of a facility.

Cost (\$)	Points
$x_1 <$	TBD
$x_1 - x_2$	TBD
$x_2 - x_3$	TBD
$x_3 >$	TBD

The Valuation of a Facility's Square Footage Compared to the Volume of Water Treated:

This section is looking at the relationship between the size of the facility and the volume of water it treats. The optimal, high point rating would be a facility that has a small square footage and a high volume of water treated. Due to the high cost of land, it is beneficial if a facility can treat a large volume of water on a small area of land. This makes the facility more economically efficient because the facility will have a lower square footage, while proving the necessary requirements to meet water quality standards. A surface flow constructed wetland would acquire a low ranking score because of the large amount of area needed for treatment, yet a vertical subsurface constructed wetland requires less area, resulting in a higher point score.

Square foot of land $y=1 \text{ ft}^2$	Volume of water treated (liters)	Points
y	$< x_1$	TBD
y	$x_1 - x_2$	TBD
y	$x_2 - x_3$	TBD
y	$x_3 >$	TBD

These four additions to the point systems table are four independently unique criteria, which could be realistically incorporated into the existing legislation. They each focus on a different aspect of the constructed wetland system, while also amalgamating together

effectively. They all include constructed wetlands as a viable option but do not have a bias towards them in terms of scoring them higher than other systems. Due to the additions of four new sections, logically a new point system, shown in Table 3, would be created to accommodate the increase of total points.

Table 3: The new point system, in red, was created to account for additional sections as suggestions for implementation.

Class I	40 points<
Class II	41 – 70 points
Class III	71 – 100 points
Class IV	101 point >

The changes made to these policies were chosen based off the research and analysis that was done in steps 1-3 of the policy analysis. This prior research allowed for logical changes to be made for a practical addition to Canadian legislation.

Chapter 5

Conclusion

Wastewater treatment is a critical aspect of society because of its importance for all municipalities to ensure a high standard of living for all its residents. Governments place significance on human health and the environment when creating policies around wastewater. The process of incorporating constructed wetlands into municipal wastewater systems was found to be a logical and rational decision. There was abundant research to support the claim that wetlands can filter wastewater in an environmentally and economically efficient way. With their low mechanical input and high environmental benefits, constructed wetlands appear to be a good decision for the future of wastewater.

Undergoing the policy analysis to find the required policies to effect change was a good method that allowed the necessary steps to be done to achieve the intended outcome. The four-step analysis had a logical layout where evidence could be collected prior to edits being made. A setback was not finding any current legislation around municipalities that include constructed wetlands in wastewater treatment. This would have been a good reference to compare the similarities and difference between the policies.

In terms of the future of wastewater treatment, there is a developing plan within Canada that has suggested a harmonized approach to treatment legislations. All three levels of government have agreed that having different wastewater policies and standards is creating more problems than solutions, this has been the kick start to create a nation-wide plan to eliminate discrepancies. This will help effectively manage all 3,500 plus wastewater treatment facilities in Canada (Canadian Council of Ministers of the

Environment, 2009). This is a good strategy when looking to the future because having a nation-wide plan will allow constructed wetland technology to be available throughout Canada. This will help inhibit the use for this technology throughout all the provinces, making the changes to Nova Scotia's legislation a stepping-stone towards the future of this brilliant technique.

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