SEA Case Competition 2020

ENVELOPE A

Waqas Ahmad, Farris Hamid, Tess King, Sohaib Hassan

For: Richard Bezak (Vice President)

Dated: November 2, 2020

Ryerson University

(Highlighted words and phrases are things that need to be changed when the final formatting is complete)
Words in italics are the criteria that have been copy and pasted from the RFP
The hyperlinks in brackets indicate the citation there that is needed

1. EXECUTIVE SUMMARY

1.1 Subject Matter

Our task is to address water quality issues that affect the 38km river spanning from Oak Ridges Moraine to Lake Ontario by coming up with a proposal to help restore the Don River to what it once was. More specifically, your solution should focus on addressing 4 specific challenges that affect the Don River: chlorides, phosphorus levels, and erosion/ seasonal flooding. [18]

1.2 Methods of Analysis

The key proponents of our include designs that reduce the amount of road salts from entering the river, as well as implementing a water treatment in order to remove the already-added salts.

1.3 Findings

The proposed findings include: A barrier between the landscape and the river, such as bioswales and berms, and a chemical design equipment as part of water treatment called the electrodialysis.

1.4 Conclusions

We design these proponents in order to address the 4 Don issues such as chlorine salts, phosphorus and erosion/seasonal flooding. Each design contributes to the lowering of these problems, and overall, are to fulfill the RFP requirements.

2. PROJECT UNDERSTANDING

The Don River is a 38 km long river that has its headwaters sources on the Oak Ridges Moraine and mouth ending at Lake Ontario around the Keating channel. The river features several tributary rivers such as the Taylor Massey Creek, and the Don River West and Don River East Branch [11]. Fig 1 shows the extent of the Don river. However over the past 200 years many of the significant wetland areas within the Don River Watershed have been drained or filled while city building and urban development have taken place. This urban development has led to an increase of issues arising including floods and river pollution [12]. Flooding is a major concern on the Don River because of its geography of running through low lying ravines which makes the river an incredibly efficient rainwater runoff collection system. For example in August 2005 a storm deposited more than 150mm of rain and the Don RIver rose over three meters in about four and half hours that resulted in flooding a portion of the Don valley parkway and overwhelmed the combined sewer systems in some neighborhoods which caused dumping of raw sewage into the river [11].

If efforts such as removing impermeable surfaces to close to ravince slopes, aggressive replanting pf native vegetation, and removal of channelized section of the river, and re-establishing wetlands were taken on the Upper Don watershed, as has been taken on Lower Don naturalization projects, the risk of flooding would be greatly reduced [12]. Thus we aim to focus our rehabilitation efforts primarily on the Upper Don river segment of the river.

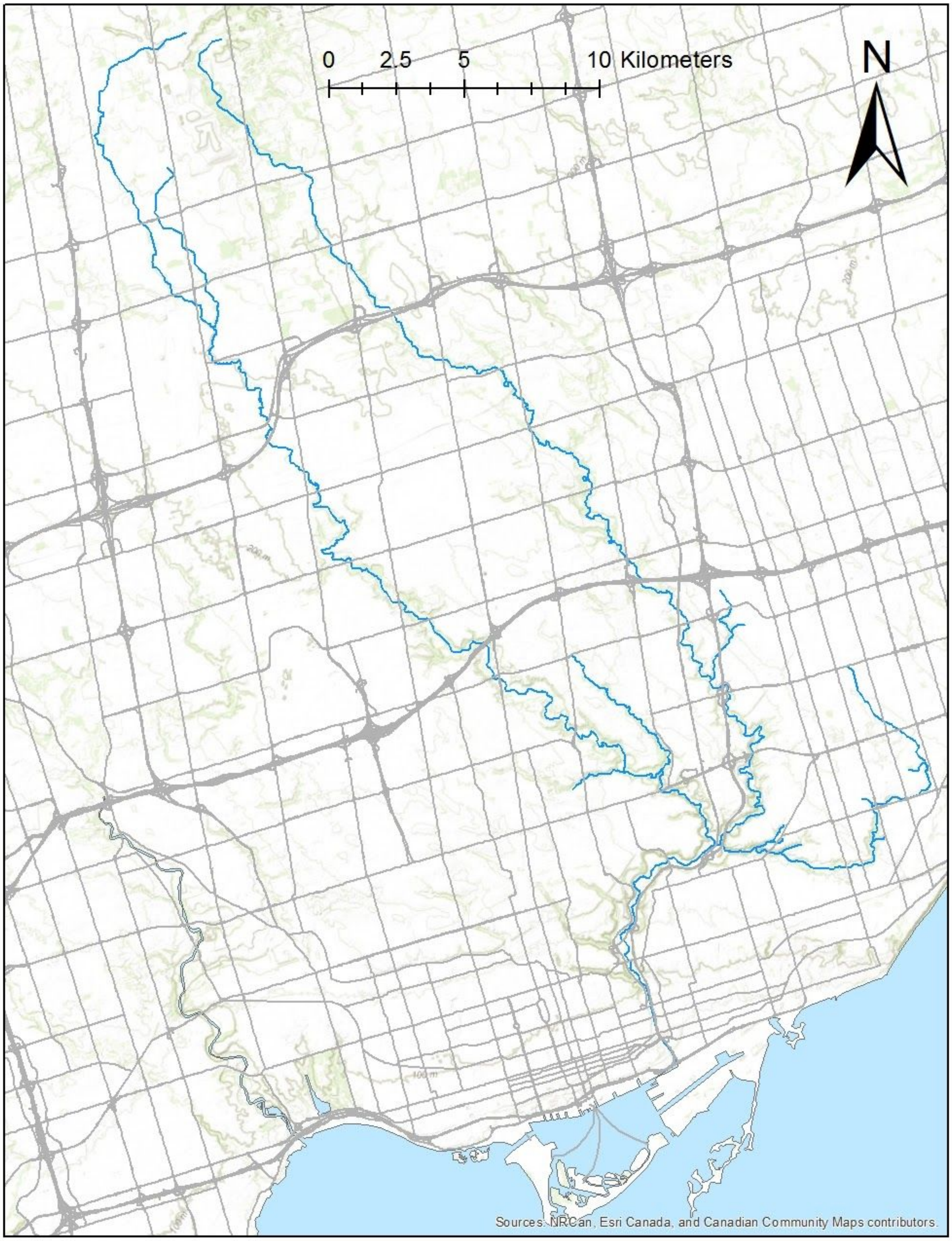


Fig. 1 Map of the Don river

2.1 Objectives

Our project aims to address the issues of chlorine salts pollution primarily due to runoff from the road into the Don River, erosion of the river's banks and seasonal flooding. A stark indicator of the urban growth and development that has taken place around the Don River is the chloride content in the river itself, which permeates into the river primarily through road salt runoff and has increased by 68 percent in the past 20 years. In a survey done of 349 Canadian rivers and 10 lakes done by Environment Canada between 2003 and 2005, the Don River placed in the bottom five percent of rivers in terms of pollution levels [11]. Through our implementation of targeted berm structure and natural filtration ditch bioswale placements and engineered river stream diversion plan we aim to mitigate the harmful effects of erosion and seasonal flooding. Additionally we aim to use electrodialysis as a means to reduce the chloride and by extension algae levels in parts of the river.

2.2 Scope and Deliverables (Schedule B)

- *Describe the key elements of the Project scope as identified in Schedule B (RFP Requirements); List the specific deliverables that will be provided to address the Project scope; Indicate the standards, policies and/or guidelines that will govern the work required to produce each deliverable.*
-
- Policies and guidelines

2.3 Anticipated Challenges/High Level Risks

- *Identify the key challenges that are anticipated throughout delivery of the Project and explain how the identified challenges will be addressed;*
- *Identify the high-level risks associated with the Project and a strategy for managing each of the identified risks.*

- **Bioswales -** If designed improperly, bioswales will have very little pollutant removal. They also do not seem to be effective at reducing bacteria levels in stormwater runoff. Because of the linear nature of bioswales, stormwater should ideally enter via sheet flow. Pre-treatment (such as grassed verges) and erosion control must be part of the design in order to avoid sedimentation of the channel. [21]

- **Berms -** Typically, the concern for lifetime expectancy of a berm is the river's breach of berm, therefore, these structures will be upgraded over time to accommodate higher river flows. It is important to consider the critical roles of the floodplain when considering flood control projects. To simply create a larger, deeper stream channel with setback berming will more often than not result in failure. This method is therefore only recommended where minimal or temporary flood control is needed, and other methods are not possible. [13] Typically. the size, soil condition, and topography of the site must be considered before selecting, sizing, and installing a stabilized berm. They should be installed before upslope construction activities begin, particularly any activities causing soil disturbance. They should be maintained until the contributing area is fully stabilized and vegetation is established. Soil berms should be stabilized immediately with vegetation, erosion control blankets, or similar measures to prevent the berm from eroding and becoming a source of sediment in runoff.

- **Electrodialysis -** Non-charged, higher molecular weight, and less mobile ionic species will not typically be significantly removed. Electrodialysis becomes less economical when extremely low salt concentrations in the product are required and with sparingly conductive feeds: current density becomes limited and current utilization efficiency typically decreases as the feed salt concentration becomes lower, and with fewer ions in solution to carry current, both ion transport and energy efficiency greatly declines. [22]

3. TEAM ORGANIZATION AND QUALIFICATIONS

3.1 Team Name and Logo

Our team name has been chosen to be Achelous who is a Greek river God and god of freshwater bodies in general. Figure X shows our team logo

Fig. X

3.2 Team Organization

Team Contract/Roles & Responsibilities

- Farris Hamid - Working with CAD as per the Innovation Alternatives

- First-Year Mechanical Engineering
- Some CAD Experience

- Sohaib Hassan - Setting up Microsoft Project
- Tess King -
- Waqas Ahmad -

"Provide an organization chart that clearly defines the organizational structure of the Project team, including defined roles and responsibilities, as well as work delegated between Project team members."

4. APPROACH

In this section we aim to outline in detail our proposed solutions for the Don River rehabilitation. These solutions include Biowales, a natural ditch filtration system, raised berm structures, and the design and implementation of an electrodialysis plant.

4.1 Biowales

One of our proposed solution to mitigate the effects of chloride pollution running off into the river from the salt on the roads is by implemented a natural filtration ditch that will be built on the side of the road in areas where it runs close to the river in order to catch the dirty water that washes off of roads when it rains or snows. Biowales are channels dug into the earth that are designed to catch storm runoff, miscellaneous debris and pollution and filter it out via gravel, rocks and other natural means before discharging the water back out into the river [14]. The drainage path of the bioswale is meant to maximize the amount of time that the storm water remains in it so that the most pollutants can be filtered out. Below in Fig. X is an example of what a bioswale could look like when placed beside a road.

FIG. X : Schematic picture of what a natural ditch/ bioswale looks like[citation]

There are also numerous benefits of bioswales including that it creates more habitat for wildlife with the vegetation that are planted, reduced non-point source pollutants, reduces the prevalence of standing water that can breed mosquitoes and develop algae and additionally they are aesthetically pleasing [15]. Increasing green space and vegetated areas greatly helps with trapping more water from storm runoff. To implement this design we aim to include a patch work of detached bioswales in and around the upper Don river.

4.1.2 Cost estimates for Bioswales

Table 1 below shows a high level overview comparison of different costs for a couple different kinds of landscaping strategies. Bioswales have low capital costs and low operating and maintenance costs as well as only requiring general mowing to keep the vegetation neat and tidy during the growing months.It is estimated that bioswales only require 5-7 percent of construction costs to maintain. They also have a 5-20 year effective life. According to the US EPA, bioswales are relatively low cost stormwater techniques, ranging between \$3.33/m^2 to \$6.66/m^2 (CAD). Their costs vary according to the price and availability of lands for a given development site however usually land prices are generally less than \$12.92/m^2.

Table 1: Cost comparisons of different green engineering landscape strategies [16]

Comparison of Capital and Maintenance Costs for Landscape Strategies				
Strategies	*Capital Costs*	*O&M*	*Maintenance*	*Effective Life*
Infiltration Trench	Moderate to High	Moderate	Sediment Debris Removal	5-10
Infiltration Basin	Moderate	Moderate	Mowing	5-10
Bioretention	Moderate	Low	Mowing Plant Replacement	5-20
Detention Ponds	Moderate	Low	Annual Inspection	20-50
Wetlands	Moderate to High	Moderate	Annual Inspection Plant Replacement	20-50
Bioswales	Low	Low	Mowing	5-20
Filter Strips	Low	Low	Mowing	20-50
Porous Pavements	Low	Moderate	Semi-Annual Vacuum Cleaning	15-20
Green Roofs	High	Moderate	Plant Replacement	20-25

Bioswales are also cheaper than earth or concrete ditches in application cost. A Break down of the cost comparison between bioswales and earth/ concrete ditches are outlined in table 2.

Table 2: Comparing application costs of concrete ditches versus bioswales [16]

Comparative Cost Breakdown between Concrete Ditch and Bioswale		
Application	*Unit*	*Cost & Range*
Earth/Concrete Ditch	$/m	36.00-75.00
Bioswale	$/m	12.00 - 15.00

Table 3: Cost breakdown of a Bioswale for it’s estimated lifetime of 25 years

Cost Breakdown for a Bioswale over 25 years													
Item	*Required Cost per Year (2005 Dollars)*												
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*...*	*25*
Installation*	10,000												
Mowing		100	100	100	100	100	100	100	100	100	100		
Reseeding-Replanting		100	100	100	100	100	100	100	100	100	100		
Remove & Replace													10,000
Total Cost	10,000	200	200	200	200	200	200	200	200	200	200		10,000
Annualized Cost	$600 / year												

*Land acquisition and Developer Cost not included. Not included in annualized cost

Table 3 shows the capital installation and annual maintenance costs for a bioswale, using a surface area of 80m^2 to treat runoff from 0.2 hectares. These cost calculations were based upon a bioswale with a surface area of 80m^2. Biowales are only projected to have a maximum lifespan of 25 years, so after that they need to be replaced.

4.2 Berms

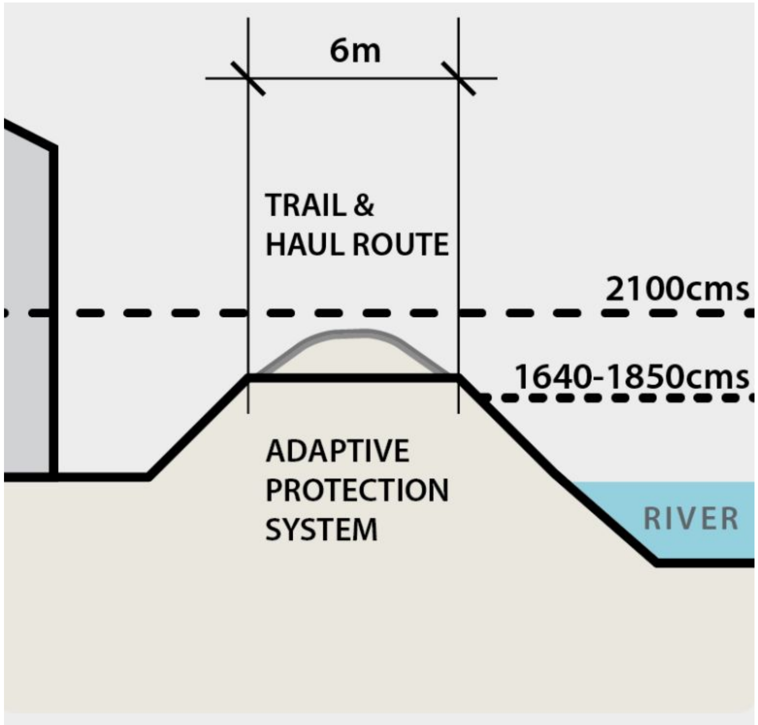
4.2.1 Environmental management

"As part of urban growth around the Don is chloride, mostly from road salt, which is up 68 percent over the past 20 years" [11]. However, our idea of road-management is to install a berm beside the road in order to mitigate the amount of road salts entering the river. A berm is a level space, shelf, or raised barrier, usually made of compacted soil separating two areas [10]. Berms are used to control erosion and sedimentation by reducing the rate of surface runoff. Berms contain dense sediment materials that decrease water velocity, control flow rates and absorb excess water in the event of a flood. Normally placed in communities or sites prone to flooding, berms act as barriers, further mitigating flood water impacts. Berms are an effective form of flood mitigation so long as they are built large enough to handle flood flows. For this reason, berms are often coupled with other mitigation measures such as dams and dry-ponds. [5]

As part of real-world applications, in the 1980s, Drumheller built berms systems throughout the city, which proved beneficial for all subsequent flooding, including the 2013 event, which is portrayed in the image below. However, in the past, Drumheller was not so lucky in the floods of 2005 and throughout the 1980s [9]. As a result of these previous floods, the town spent large amounts of money to raise homes, build berms, and implement tough bylaws around building in flood zones. While previous efforts paid off in Alberta's 2013 flood event, Drumheller plans to continue building on flood prevention measures to enhance preparedness. To upgrade and maintain lateral berms, Drumheller is requesting another $12 to $15 million from the Province to mitigate future floods. [7]

IMAGE 1 - Drumheller Overflood into the valley through weather and environmental changes

4.2.2 Preliminary Design



Berm Design as part of Alberta’s Municipal Development Plan [9]

As part of Alberta’s Municipal *flow of change plan*, the berm is the basis of the design for the flood protection system as they help us raise the barriers when the river rises. The berms being considered are meant to protect a neighbourhood from flooding, not just the few homes along the river. An adaptable system needs to protect to a range of flow-rates that will protect people and property in a variety of flood scenarios. [9]

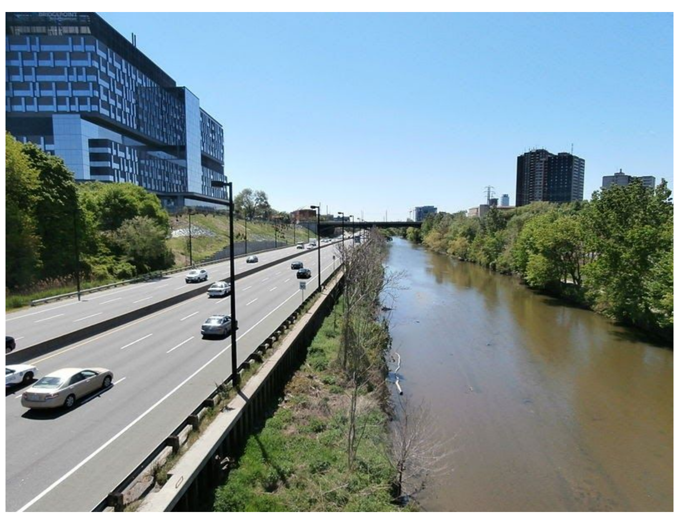
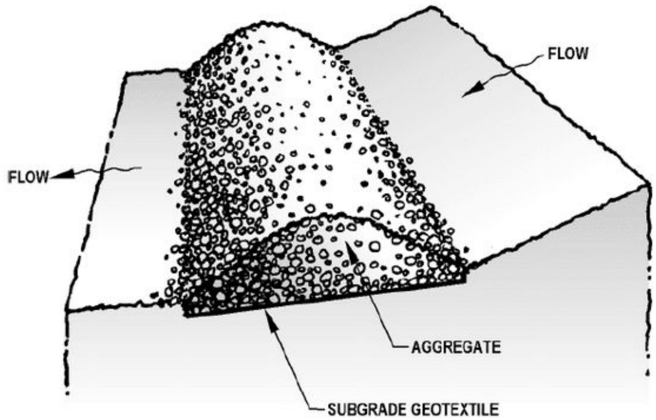


IMAGE 1 - The Don River and the Don Valley River Park [17]



This image shows a schematic of a berm
Schematic of a berm constructed from compacted aggregate. (Source: Clean Water Services, 2008)

Stabilized earth/soil berms are constructed from compacted soil, compost, mulch/wood chips, aggregate, or other filtering materials. Soils with sand content exceeding 70 percent may not be effective for berms experiencing high velocity flows. Berms constructed of wood chips, compost, or mulch are recommended for flatter areas (i.e., < 6%) while berms constructed of earthen materials are more suitable for steeper slopes [8]. Berms are effective for treating smaller, flatter drainage areas. Berms can be used on larger sites by installing multiple berms to partition the drainage area so that individual structures are not overwhelmed by incoming flow. Berm effectiveness is reduced when slopes exceed 10 percent. Soils used to construct berms should be free of roots, large rock, vegetation, organic matter, and other non-soil material. Soils with sand content exceeding 70 percent may not be effective for berms experiencing high velocity flows. Berms constructed of wood chips, compost, or mulch are recommended for flatter areas (i.e., < 6%) while berms constructed of earthen materials are more suitable for steeper slopes [8].

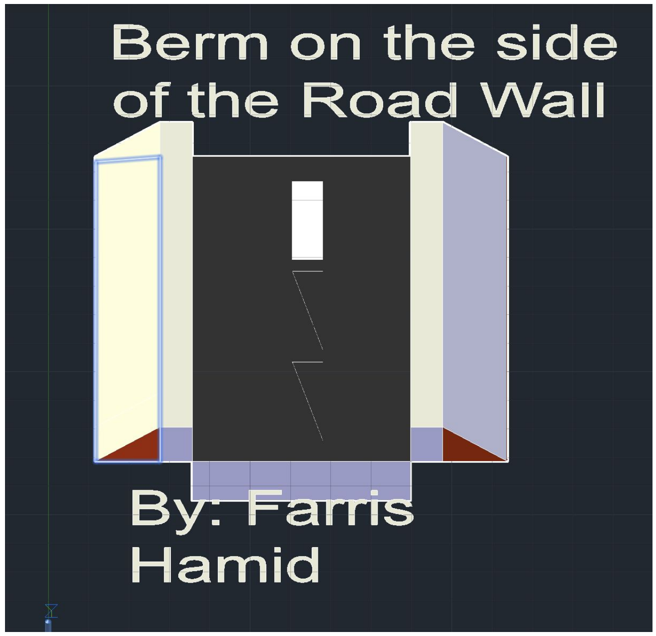


FIG. 1 CAD Modeling of Roadside Berm

As part of the preliminary design, we decided to construct the berm beside the roads with which the river flows directly underneath it. FIG. 1 displays the roadside berm CAD modeling, the black rectangle and white stripes is the road , which is supported by the already erected road walls along with sediment-controlled berms beside them. The road wall, such as the one shown in IMAGE 1, implementing the berm along with it would allow for it to act as a barrier for the road salts from directly entering the Don river.

4.2.3 Cost Estimates for Construction

The cost of building a lateral berm range depending on size, use and materials. For flood mitigation, transverse berms are typically larger and more expensive [5]. The Table below contains the original documentation for the Erosion Control Alternatives Cost Calculator, but in the $CAD version. The original documentation could be found under Source 4.

US TO CAD CONVERSION ($US 1 - $CAD1.33-1.45)

1’ x 2’ Compost Berms	Low Cost Est.	High Cost Est.
Materials and Installation Cost	$1388.00	$1675.17
Regular Inspection and	$2393.10	$2393.10

Sediment Removal Cost		
Repair and Replacement Cost	$208.73	$251.28
Compost Removal Cost	$0	$0
Total	$3989.83	$4319.55

12” Diameter Composite Filter Socks	**Low Cost Est.**	**High Cost Est.**
Materials and Installation Cost	$1595.40	$1861.30
Regular Inspection and Sediment Removal Cost	$2393.10	$2393.10
Repair and Replacement Cost	$71.79	$71.79
Sock Removal and Disposal Cost	$21.27	$21.27
Compost Removal Cost	$0	$0
Total	$4081.56	$4347.46

3’ Silt Fencing	**Low Cost Est.**	**High Cost Est.**
Materials and Installation Cost	$1111.46	$1536.90
Regular Inspection and Sediment Removal Cost	$2393.10	$2393.10
Repair and Replacement Cost	$555.73	$768.45
Compost Removal Cost	$191.45	$426.77
Total	$4251.74	$5125.22

4.3 Electrodialysis(ED)

4.3.1 Environmental management

The ED process has been found as a reliable treatment method for waste water since more than half-a-century. The current methods of reducing or controlling the salinity in a stream of water is either costly or invasive i.e. non environmentally friendly. Such as reverse osmosis, ultra-filtration, nano-filtration and ion exchange, ED has shown more benefits. Some of the advantages are as follows: no need of osmotic pressure, no additional chemical requirement, high quality product, environment friendly. The main demerit of ED process is membrane fouling which causes increase in membrane resistance, flux decline, decreases ions migration yield and high level of polarization.

The ED process can help in recycling or reuse valuable products and it has been regarded as an important technique for sustainable development because it is an environment friendly process. Its driving force is electric potential difference and thus biomass and organic materials will remain in the product stream. EDR could be used to prevent fouling and it is a more efficient technique. [20]

4.3.2 Preliminary design

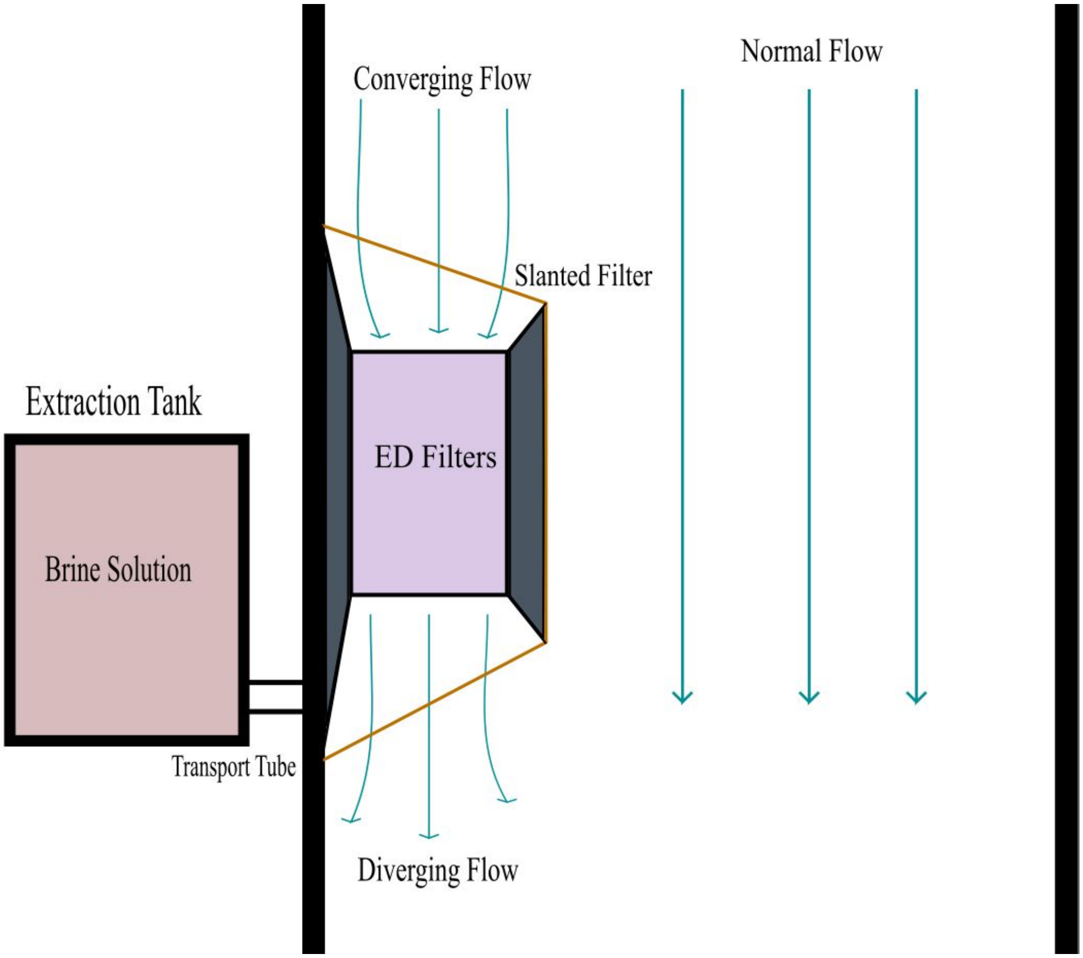


Figure X: ED implementation schematic.

The general design of an electrodialysis plant takes the input of water from a reservoir of stationary, therefore some modifications were made to the existing design in order to make it suitable for a system with a constant flow of water.

Slanted Filters

The main objective of this project is to make the Don river suitable for wildlife to flourish as it did in the past. So, the slanted filters are an important function of the implementation that completely eliminate the risks posed to the wildlife. The filters will prevent all animals and larger debris from flowing into the ED module pipes. The slant of the filter will prevent the animals and debris from getting stuck at the filter due to the water pressure behind the filter and will allow them to slide along the filter and join the main flow of the river.

Converging and Diverging flow

The flowing river cannot simply flow into the pipes of the ED modules, therefore it needs to be guided into them with the proper pressure and velocity. Using converging ducts will help in achieving the desired pressure and flow velocity. Using these converging ducts will also eliminate the need for using pumps, which will help in reducing the overall cost of the plant. The diverging ducts will be used to normalize the flow of the treated water so that it matches the flow of the river.

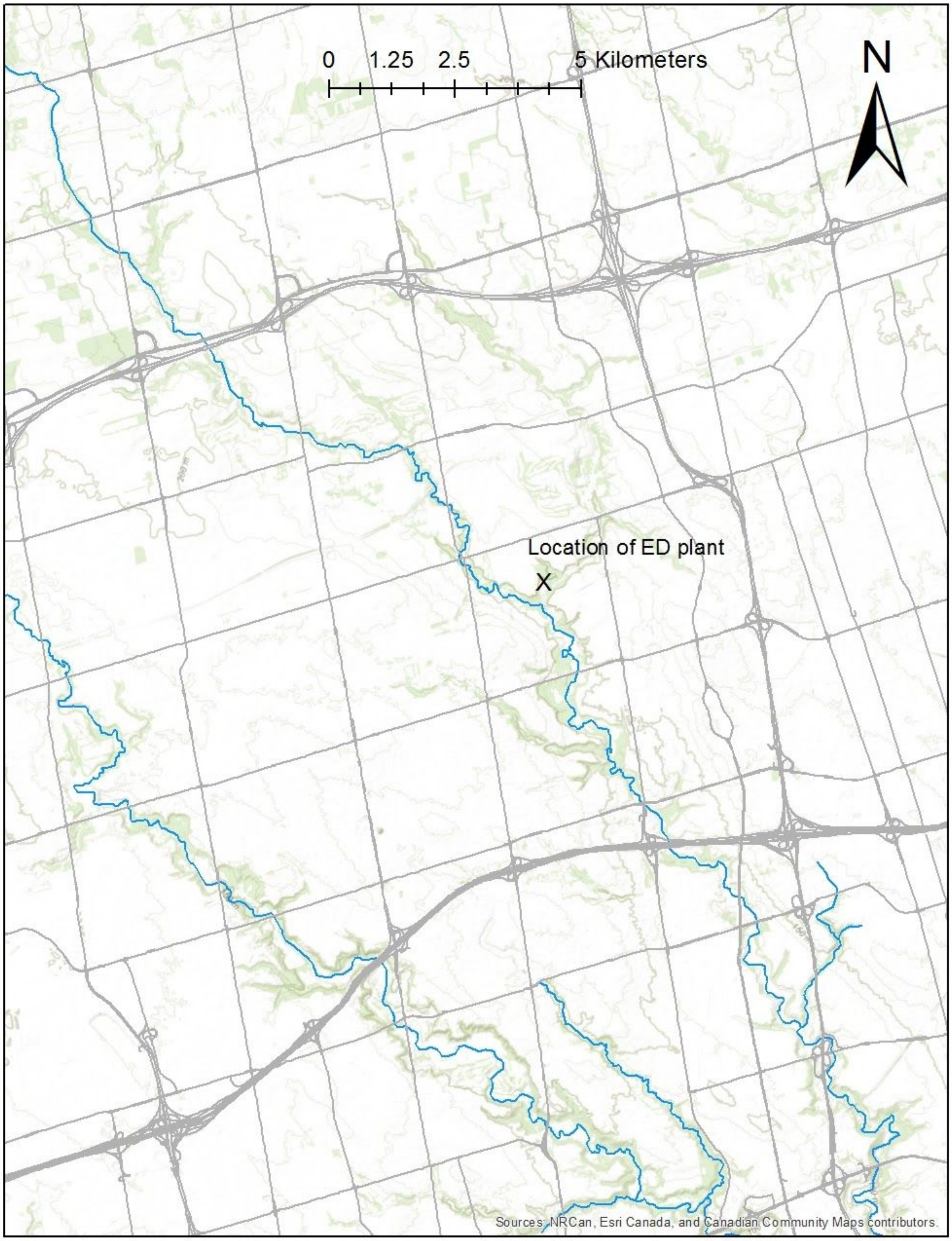
Modified Flow Processing

The Don river has an average depth of 9m and an average width of approximately 28km with the maximum being around 40km. The average flow rate of the Don river is approximately $4m^3/s$ (16,400,000L/hr), treating the entire river using electrodialysis is unfeasible, however if a certain portion of the flowing water is treated, it will bring down the overall chloride levels by an effective amount. The desired fraction of the river to be treated was determined to $1/13^{th}$.

This fraction will require a total of 100 individual modules of the ED system. Each ED system has the capacity to treat 10,689L/hr of water. Having a total of 100 modules gives us a total of 1,068,900L/hr of treated water. The specifications of the ED system in question are 3.2m×1.5m×1.725m. Using 100 modules side by side covers a total length of 0.15km.

Effectiveness

In the Don river, the highest chloride levels exist at the DM6.0 station with a total concentration of approximately 500mg/L [TRCA]. Based on the average flow rate of the river, one cross section of the river has 16,400,000L flown through it with an overall chloride concentration of 7.66×10^9 mg. Using 100 modules of ED a total of 1,068,900L of water is treated, and this clean water later joins with the remaining water that did not go through the ED system. The total combined water will have the chloride levels of 467mg/L which is a reduction of 33mg/L. This is a very effective result, and it will, over time combined with the berms and bioswales, reduce the chloride levels to the desired amount of 120mg/L.



https://www.usbr.gov/research/bgndrf/win2018/15Costello.pdf https://cduaws.nmwrri.nmsu.edu/wp-content/uploads/PreviousResearchPDF/Optimization-of-Electrode.pdf

https://cdn.saltworkstech.com/wp-content/uploads/2020/08/Flex-EDR-Spec-Sheet-RL.pdf

4) Process Industry Applications

1.	*Brine Concentration*
2.	*Demineralization (e.g. Boiler Feedwater)*
3.	*Desalination of Industrial Wastewater for Reuse*
4.	*Demineralization of food products*
5.	*Recover of valuable electrolytes or acids from rinsing baths in metal (surface) treatments*
6.	*Sectors where ions need to be removed from a process flow or must be concentrated (e.g. chemicals industry)*

4.3.3 Cost Estimates for Construction

5. SCHEDULE

- *Proponents must submit an electronic copy of the proposed project schedule. This schedule must:*
- *Demonstrate a realistic understanding of the Project and its implementation.*
- *Provide a discussion of the underlying assumptions associated with the proposed project schedule;*
- *Present a logical organization and flow of project tasks with sufficient detail to determine the sequence of activities related to the achievement of project milestones;*

- *Proponents must use MS Project to develop their project schedule. If you are an Aerospace, Chemical, Civil, Electrical or Mechanical engineering student, you should be able to download MS Project for free using the following link Microsoft Education Hub Store and your Ryerson*

6. INNOVATIVE, VALUE-ADDED ALTERNATIVES

7. CONCLUSION

The biggest polluters of the Don are not factories, farms, mines or mills...the worst pollution in the Don comes from "storm water" [23]. The methods proposed are as follows: One of the ideas to reduce stormwater runoffs in urban areas is by installing bioswales in urban communities, such as parking lots, sidewalks, roadside, etc... Bioswales are effective when it comes to stormwater management. The biggest advantage bioswales offer is reducing stormwater runoff. According to the American Society of Landscape Architects (ASLA), a 4-meter bioswale can reduce about 25% of total rainfall runoff. The effectiveness of bioswales extends to their ability to filter stormwater naturally. The soil and vegetation in bioswales can root out pollutants and contaminants that would otherwise end up in stormwater systems and bodies of water. By reducing the amount of water that ends up in city stormwater systems and cleaning what does go in, you can approach resilience from two directions [25]. The second approach was installing berms alongside roads along the river stream. Berms can also serve a functional role. Installing berms in low-lying areas is a good way to prevent water from pooling. Drainage problems that occur on flat lots can often be corrected by adding berms [24]. The last method explained was the use of electrodialysis in the river to desalinate the already existing and future runoff salts in order to purify the water. It is used to transport salt ions from one solution through ion-exchange membranes to another solution under the influence of an applied electric current, thus serving as an alternative to reverse osmosis (RO) as a desalination mechanism. Electrodialysis reverse has the ability to perform at very high water recovery due to its polarity reversal which allows for treatment, without any chemicals, of feeds with concentrated salt scale factors well beyond saturation. With the addition of an antiscalant EDR pushes its salt tolerance even further. Unlike RO, which is a pressure driven process, EDR works by flowing feed water over the surface of ion exchange membranes, while an electric field removes ions across the latter. EDR doesn’t have a compact fouling layer like RO which limits its recovery efficiency. However, a major disadvantage of EDR is that it doesn't remove microorganisms and organic contaminants, such as organic phosphorus. Thus, a post treatment is always necessary if high quality water is required. Therefore, the techniques mentioned in the Approach Section convey some of the methods that could be used in order to prevent further flow of stormwater pollutants entering the river. Implementing the three proposed designs, berms, a bioswale and electrodialysis would overall contribute to improving the water quality of the Don River by reducing the amount of recurring pollutants such as road salts, some phosphorus and erosion from storm runoffs.

WORKS CITED

[1]P. A. Eisenstein, "16 Miles of Smart, Safe and Sustainable Highway Being Built in Rural Georgia," *TheDetroitBureaucom*. [Online]. Available: http://www.thedetroitbureau.com/2018/08/16-miles-of-smart-safe-and-sustainable-highway-being-built-in-rural-georgia/. [Accessed: 29-Oct-2020].

[2] "FILTREXX CAD FILES," *Filtrexx International :: Filtrexx CAD files*. [Online]. Available: https://www.filtrexx.com/en/resources/design-specs-cads/filtrexx-cad-files. [Accessed: 29-Oct-2020].

[3] "EDGESAVER STREAM BANK STABILIZATION SYSTEM." Filtrexx Sustainable Technologies. https://www.filtrexx.com/application/files/2414/7386/3253/FILTREXX_EDGESAVER_STREAM_BANK_STABILIZATION_SYSTEM_-_REINFORCED_WITH_RIPRAP_TOE.pdf. [Accessed: 29-Oct-2020]

[4] "Erosion Control Alternatives Cost Calculator." GreenScapes. https://archive.epa.gov/wastes/conserve/tools/greenscapes/web/pdf/erosion.pdf [Accessed: 29-Oct-2020]

[5] *Alberta WaterPortal*. [Online]. Available: https://albertawater.com/flood-mitigation/berms. [Accessed: 30-Oct-2020].

[6] "Filtrexx SiltSoxx: 8,'" *Stormwater BMPs and Erosion Control Supplies*. [Online]. Available: https://shop.stormwater.pro/shop/erosion-sediment-control/filtrexx-siltsoxx-8-inch/?v=e71bc9c013d9. [Accessed: 30-Oct-2020].

[7]"Drumheller flood preparations paid off, mayor says." CBC News Calgary. Published September 27th, 2013. http://www.cbc.ca/news/canada/calgary/drumheller-flood-preparations-paid-off-mayor-says-1.1870694 [Accessed October 29, 2020]

[8] "Sediment control practices - Stabilized earth/soil berm Sediment control practices - Stabilized earth/soil berm," *Sediment control practices - Stabilized earth/soil berm - Minnesota Stormwater Manual*. [Online]. Available: https://stormwater.pca.state.mn.us/index.php?title=Sediment_control_practices_-_Stabilized_earth/soil_berm. [Accessed: 30-Oct-2020].

[9] *The New Drumheller MDP & LUB*. [Online]. Available: https://landplanning.drumheller.ca/. [Accessed: 30-Oct-2020].

[10] "BERM: meaning in the Cambridge English Dictionary," *Cambridge Dictionary*. [Online]. Available: https://dictionary.cambridge.org/dictionary/english/berm. [Accessed: 30-Oct-2020].

[11] Politis, "Death and rebirth on the Don River," *Canadian Geographic*, 30-Jun-2016. [Online]. Available: https://www.canadiangeographic.ca/article/death-and-rebirth-don-river. [Accessed: 30-Oct-2020].

[12] "Urban Waterways: the East Don River," *The Meaning of Water*, 11-Apr-2020. [Online]. Available: https://themeaningofwater.com/2019/07/10/urban-waterways-the-east-don-river/. [Accessed: 30-Oct-2020].

[13] "Setback Berming." New York City Department of Environmental Protection , New York, 2006. Available: http://www.catskillstreams.org/pdfs/instreamtablepdfs/Berming.pdf. [Accessed: 30-Oct-2020].

[14] P. A. Eisenstein, "16 Miles of Smart, Safe and Sustainable Highway Being Built in Rural Georgia," *TheDetroitBureaucom*. [Online]. Available:

http://www.thedetroitbureau.com/2018/08/16-miles-of-smart-safe-and-sustainable-highway-being-built-in-rural-georgia/. [Accessed: 30-Oct-2020].

[15] M. S. U. E. Terry Gibb, "Bioswales can improve water quality resources," *MSU Extension*, 20-Sep-2018. [Online]. Available: https://www.canr.msu.edu/news/bioswales_can_improve_water_quality_resources. [Accessed: 30-Oct-2020].

[16] "Urban Stormwater Economics ." Available: https://www.daniels.utoronto.ca/sites/daniels.utoronto.ca/files/old/Kesik_TGDS_CB-Study_Oct2008_Appendix_D.pdf [Accessed: 28-Oct-2020]

[17] Watmough, Mark. Don Valley Parkway, May 2013 Available: https://commons.wikimedia.org/wiki/File:Don_Valley_Parkway_May_2013.jpg [Accessed: 29-Oct-2020]

[18] Bezak, Richard, RYERSON SUSTAINABLE ENGINEERS ASSOCIATION REQUEST FOR PROPOSAL, 2003. [PDF] Available: SEACase2020_RFP.pdf

[19] "Filtrexx is the leader in Sustainable BMPs and Installation Services to protect our soil, water and environment.," *Filtrexx SiltSoxx is the Original Compost Filter Sock. Solutions for Sediment & Erosion Control, Stormwater Management, Pollutant Removal, and Bank Stabilzation*. [Online]. Available: https://www.filtrexx.com/en. [Accessed: 31-Oct-2020].

[20] "(PDF) Application of Electrodialysis in Waste Water Treatment and Impact of Fouling on Process Performance," *ResearchGate*. [Online]. Available: https://www.researchgate.net/publication/325957609_Application_of_Electrodialysis_in_Waste_Water_Treatment_and_Impact_of_Fouling_on_Process_Performance. [Accessed: 31-Oct-2020].

[21] "Bioswales," *CRD*, 10-Nov-2013. [Online]. Available: https://www.crd.bc.ca/education/green-stormwater-infrastructure/bioswales. [Accessed: 31-Oct-2020].

[22] *Electrodialysis - Advantages and Disadvantages*. [Online]. Available: http://www.separationprocesses.com/Membrane/MT_ChpED-6.htm [Accessed: 31-Oct-2020].

[23] "311 Knowledge Base," Biggest polluters of the Don River. [Online]. Available: https://www.toronto.ca/311/knowledgebase/kb/docs/articles/parks,-forestry-and-recreation/urban-forestry/biggest-polluters-of-the-don-river.html. [Accessed: 31-Oct-2020].

[24] T. Williams, “Berms are useful in landscaping,” The Augusta Chronicle, 28-Apr-2013. [Online]. Available: https://www.augustachronicle.com/newstimes/news/2013-04-28/berms-are-useful-in-landscaping. [Accessed: 31-Oct-2020].

[25] “4 Key Benefits of Bioswales for Stormwater Management,” Facility Management and Commercial Building Resource. [Online]. Available: https://www.buildings.com/news/industry-news/articleid/21512/title/bioswales-4-key-benefits-stormwater-management. [Accessed: 31-Oct-2020].

[26] Ronan K. McGoverna, Syed M. Zubairb, John H. Lienhard Va, *The cost effectiveness of electrodialysis for diverse salinity applications*. Available: https://mcgov.files.wordpress.com/2014/07/mcgovern-zubair-lienhard-the-cost-effectiveness-of-electrodialysis-for-diverse-salinity-applications-preprint.pdf. Accessed: 31-Oct-2020

[27] Electrodialysis/ED Reversal. Available: https://www.lenntech.com/Data-sheets/ED-ZLD-interactive.pdf. Accessed: 31-Oct-2020