Final Report

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Abstract

The Algonquins of Barriere lake are in need of a more sanitary and reliable source of water for everyday use. Rainwater harvesting is proven to be the most feasible and reliable source of water for the Algonquin community. Through various prototyping and testing we have developed a rainwater harvesting system that incorporates a gutter collection system, natural filtration system, storage facility and an integrated dispersion facility to accommodate for the small nature of the net-zero homes.

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1. Introduction:

The Algonquins of Barriere lake have been living in less than ideal living conditions for many years, and both the provincial and federal government of Canada have come to realize that action must be taken to ensure the health and safety of the people living in the community. Since 2006, in collaboration with the provincial and federal governments as well as with third-party management for federal funding, the community has gone through many changes to try and enhance the quality of life in the community. Despite the efforts to fix socio-economic issues within the community, many problems concerning the availability and reliability of clean water are still present.

The existing sources of water in the community come from the nearby water source of rapid lake which is already polluted and will continue to become more polluted with the building of a dam upstream. Additionally, the water treatment facility that currently exists on the reserve is at maximum capacity and is deteriorating, therefore, it will need serious renovations to accommodate for increasing water use and to provide higher quality water. Our team has developed a rain harvesting system that will ensure that each house in this community has a reliable and safe source of drinking water. With the implementation of our design, each house can have the rain harvesting system installed that is relatively low maintenance and very cost efficient.

Our design is split into four major subsystems which work together to ensure our design is easy to use and maintain while being a reliable at the same time. First the water is harvested using 8 feet of aluminum gutters that drain into an above ground water tank that is situated on a 4’ wooden stand. The aboveground water storage tank is highly advantageous for the concept of the net-zero sheds because gravity will eliminate the need to use a pump to move cold water to the interior sink. The natural filtration system lies in the bottom of the tank; therefore, water will filter has it moves through the tank and into the piping. The filtration system is made of all-natural materials which allows for easy maintenance and is also very cost effective because realistically the filtration system will need to be changed quite frequently due to the nature of rainwater harvesting and the design would be extremely flawed if the filtration system was expensive. Once the water is filtered it will move through the piping and into the shed directly to the sink which is integrated into the bed frame to maximize space within the shed. If the users have a need for hot water, then this will require extra energy to pump the water up to the hot water tank in the roof of the shed and to be circulated through the water solar heating device and back down to the sink.

2. Design Criteria/Problem Statement (User’s Needs):

The first step of the design process is empathizing with the client and understanding the situation. From our client meetings and our own research, we determined a list of needs and the resulting solution that we needed to complete.

#	**Need**	**Design Criteria**
1	Water or snow can be purified	Filtration system
2	Filter stops leaves and animals	Corrosiveness and contamination resistance
3	Water system is low cost	Cost ($) Material used
4	Water system is long lasting	Service life of the product Condition to withstand temperature
5	Water system is easy to or self regulate	Disposing of waste Reliability
6	Water system functions through censor and manually	Height (m)
7	Large water capacity for 1-2 people per shed	Volume (L)
8	Water system can melt snow	Heating system
9	Water system is rust proof	Contamination resistance
10	Tank is of reasonable weight	Weight (kg)
11	Tank has safety precautions	Safety (fire, leaks or flood)
12	Sewage	Disposing of waste
13	Tank prevents algae growth from spoiling water reserve	Contamination resistance Appearance
14	Shape	Dimensions (m)
15	Easy assembly	
16	Delivers hot and cold water	Heating system
17	Water speed	Speed (L/min)

Table 1: Needs and design criteria.

Using this list of needs, we derived our problem at hand, and came up with the follow problem statement: We need to provide potable water to a home at the Algonquins of Barriere Lake Reserve by collecting, filtering, and distributing rainwater. We will use gutters, gravity, and a homemade filtration system to effectively do this.

3. Benchmarking:

The next step in the design process was to look at all the possible solutions to this problem. In a benchmarking table, all the aspects of design are listed, then rank them. The goal of this was to ensure that our solution was the best possible one. We compared our initial water system to the Maxwater 5 stage reverse osmosis system, and Wayfair DIY Rain Barrel Diverter and Parts Kit (oil drum) in the following chart:

Water System Specification	Importance (weight)	Homemade	Maxwater 5 stage reverse osmosis system	Wayfair DIY Rain Barrel Diverter and Parts Kit (oil drum)
Cost	5	$100 or less	$300	$60 (without barrel)
Volume	5	216 L	87 L	218 L
Weight	3	240 kg	100 kg	236 kg
Filtration	5	Yes	None	None
Material	4	Metal and glass	Metal	Metal
Service Life	5	20 years	filters require replacing annually	10 years
Appearance	2	Black	Silver	Black
Heating	5	Yes	None	None
Shape	0	Cube	Cylinder	Cyldinder
Safety	5	Yes	Yes	Possibly
Dimension	2	0.6m x 0.6m x 0.6m	H: 0.36m R: 0.28m	H: 0.85m R: 0.286m
Drainage	4	Yes	None	Yes
Operating Temperature	5	-45 to 40 ºC	4 to 49 ºC	0 to 49 ºC
Delivering Temperature	4	hot to cold	3 to 38 ºC	0 to 49 ºC
Running Speed	3	5.7 L/min	8.3 L/min	4.5 L/min

Corrosiveness Resistance	4	Yes	Yes	Possibly
Easy Assembly	3	Yes	intermediate	intermediate
Total		171	115	115

Table 2: Benchmarking with three different possible solutions.

From this, we created an Engineering Design Specification table that clearly lays out what we need to include in our design, what it represents and how to verify it.

#	**Design Specifications**	**Relation (=,< or >)**	**Value**	**Units**	**Verification method**
	Functional Requirements				
1	Stability of tank	=	Yes	N/A	Test applying movement on the base
2	Volume (Amount of water it holds)	=	216	L	Analysis of how much water is needed
3	Filtration system	=	Yes	N/A	Test with different water samples with different Temperatures
4	Melting the snow during winter (heating system)	=	Yes	N/A	Test heating system with snow
5	Transporting water through installed pipes	=	Yes	N/A	Test the flow of the water in the pipes

6	Disposing waste water	=	Yes	N/A	Analyze how much waste-water is disposed daily
7	Cost	<	100	$	Estimation of value and analysis of final cost
8	Weight (filled)	=	240	kg	Analysis
9	Dimensions (Width, height, depth)	=	0.6 x 0.6 x 0.6	m	Analysis of water needed and then calculating it accordingly
10	Material used	=	Glass and Metal	N/A	Testing the function of the material
11	Conditions to withstand (Temperature)	=	-45 - 40	^{o}C	Testing in such Temperatures
12	Height	>	Faucet	m	Analysis
	Non-Functional requirements				
13	Service life of the product	=	20	years	Analysis of service life based on material used
15	Reliability	=	Yes	N/A	Test (different conditions and situations)
15	Safety (fire)	=	Yes	N/A	Test

16	Appearance	=	Yes	N/A	Paint it black, to absorb Sunlight (Heat Energy)
17	Safety (leaks or flood)	=	Yes	N/A	Test
18	Corrosiveness and contamination resistance	=	Yes	N/A	Test

Table 3: Engineering design specification table.

4. Conceptual Design:

Now that we had determined all the aspects that the design had to contain, we can piece everything together to create the conceptual design. A conceptual design is the main idea for the design before going into prototyping. We have determined that the sand filtration system will be the most ideal method of filtering the rain water upon collection. This filtration system is particularly beneficial because it is very cost efficient and easy to maintain. When considering the fact that this filtration system will need to filter over 1000L on a yearly basis, this filtration system must be easy to and cost efficient to change up every few months. Therefore, this method of filtration will cost approximately $100 less each year, opposed to the next cheapest filtration system. Another benefit of the sand filtration system, is that it coincides with the entire concept of the net zero shed, because the sand filtration system is very environmentally friendly. The sand filtration design is also extremely user friendly because it is simply 4 layers of different materials, therefore, as long as the users have a diagram of how to layer these materials then they can change the filter whenever they feel the need.

The water collection method we have determined to use is aluminum gutters. After understanding the design of the tarp method, it is clear that although the tarp has the possibility of harvesting more water in the summer, it is unable to withstand a heavy snow load, and it is also much less strong in defending against the natural elements. Since the three sheds are going to all connect together, one gutter on the back of the shed is what we have chosen to use. The gutters will be made out of aluminum because aluminum is a relatively strong metal that is cost efficient and will not rust easily, also aluminum is fairly light, therefore, the structure won't have to account for too much extra weight. The initial cost of the aluminum gutters may be a bit costlier, however, the gutters will have a longer lifetime than the tarp.

We have chosen to have a permanently outdoor water tank situated about a meter away from the shed and a meter above the ground level on a metal structure. The benefits of having a water tank outside of the shed, is that because it is outside of the structure, it leaves more space inside the structure for other storage and increased living space, and it also allows for the tank to be larger and, therefore, store more extra water in months/seasons with higher precipitation. Due to the climate around barrier lake, a main concern for having the water tank outside is that the water inside the tank or pipes connecting to the shed will freeze. To account for this climate limitation, the tank will be well insulated and will also be of dark coloring to allow for solar heating on sunny winter days. The structure in which the tank will be situated on will also be made of metal with brick components, therefore, the users of the shed will be able to start a fire underneath the tank to melt snow/thaw ice in the tank. Lastly, as we assume that gutters may not be very efficient in the winter months where the main precipitation will be snow, to account for this, the lid of the tank will be removable, so users can manually shovel snow into the top of the shed then warm the snow up via the underneath stove structure.

5. Prototype 1:

We had a slight change in our design before our first prototype. We changed our method of melting snow from using a wood stove idea to having a copper heating coil suspended in the tank. It would be attached to a wood piece that laid across the diameter of the tank, secured by a clip to allow there to be change in height. This would allow the user to place the coil in the correct position to melt snow.

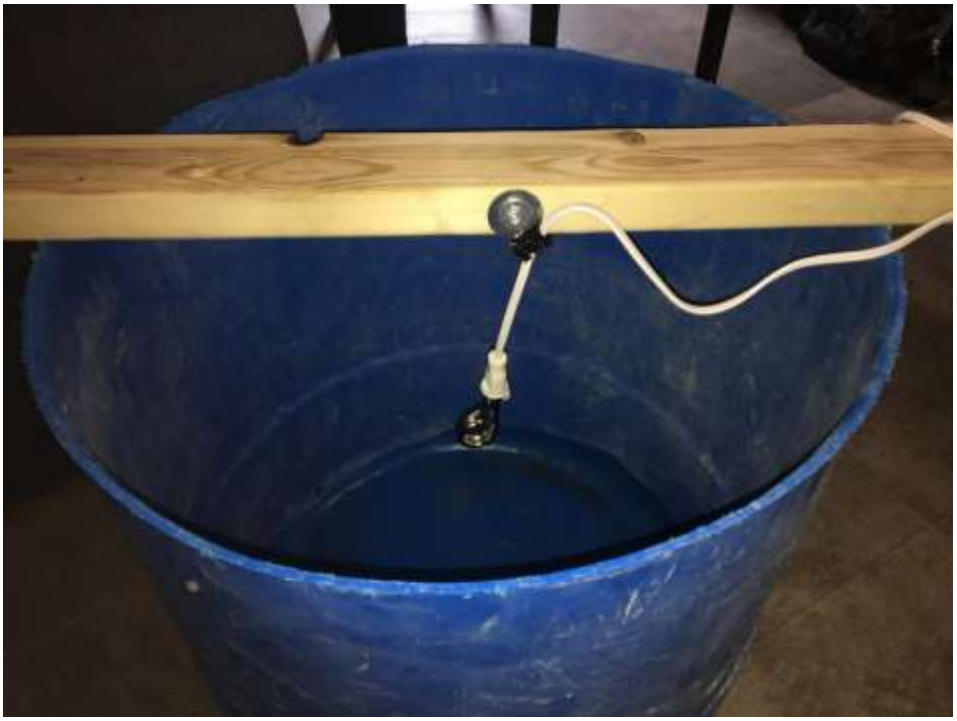

Figure 1: Prototype 1, heating coil and support.

6. Prototype 2:

Our team also decided on another major design change for the second prototype that we designed. In Prototype 1 we planned on melting snow with a coil. After further investigation, we determined that with the minimal amount of power that we could use from the solar panel, this aspect of our design was not feasible. From here we decided that we could not effectively melt snow in the winter for use. Prototype 2 was building the stand in which our water tank/filter was going to sit on. We used recycled 2 x 4 treated wood to build this. With the proper supports, we built this so that it could hold the mass of the tank and filter full of water.

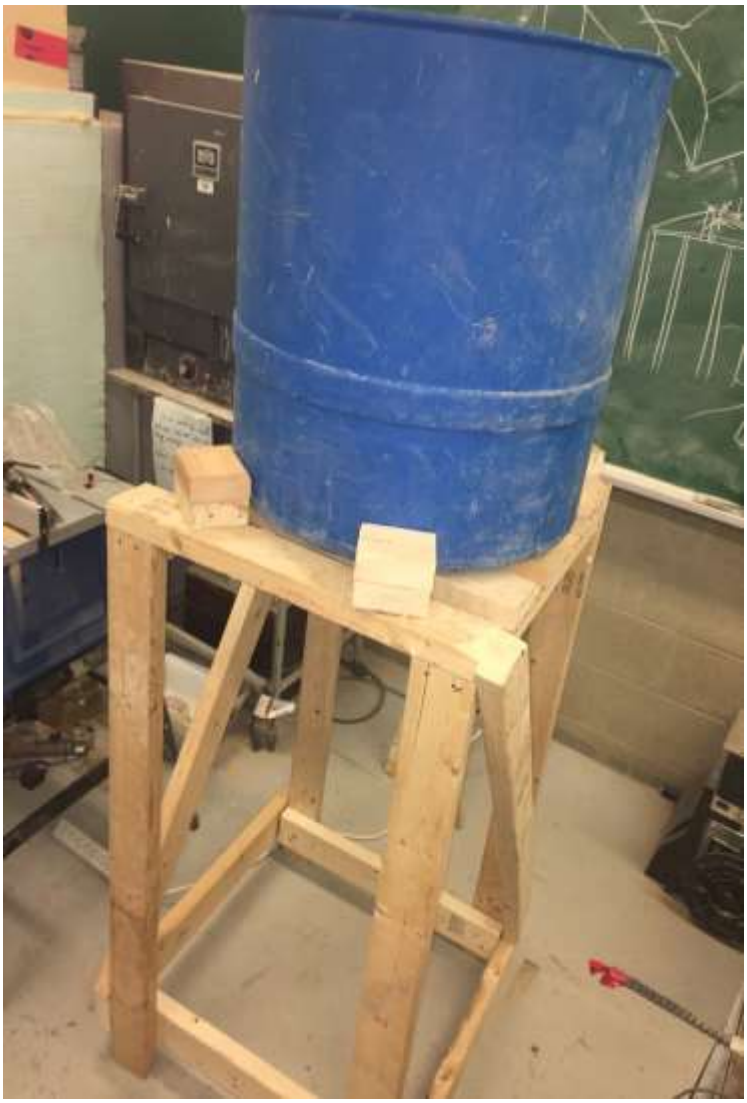

Figure 2: Prototype 2, tank and filter stand.

7. Prototype 3:

Our final prototype, Prototype 3 was our finished product. This is where the whole system came together as one piece to complete our task. It started with rain landing on the roof, which would fall into the gutter on the back of the shed and run to the lower end of the gutter that had a drain in the bottom. The water drained through ½" pex pipe, through a hole in the plywood lid, and into our water tank. At the bottom of the tank, there was a layer of gravel, a layer of sand, a layer of activated carbon, then a cloth over the drain at the bottom. The tank was suspended 4' high on the top of our stand. The water would drain out of the bottom of the tank into pex pipe which ran through a hole in the bottom of the shed where it split two ways. One pipe went directly to the sink to provide colder water, and the other pipe led to a water pump. This pump would pump the water back out through another hole in the shed, into a water heater designed and built by the solar team, and then back through another hole into the shed and into a smaller, hot water tank located on a shelf along the back wall of the shed. There was a hole in the bottom of the shelf where a pipe exited the tank, went down to the bottom of the shed and then up to the sink. The hot water and cold water pipes were controlled by faucets, and then they met in the middle in a valve that had a hand sensor to control in built by the solar team. When the sensor turned on, the valve would open, as well as the pump would turn on to pump more water through the heater to the hot water tank. The water came out above a metal sink with a hole in the bottom containing a funnel, which connected to a final pipe that ran through a hole in the bottom of the shed and drained the water out.

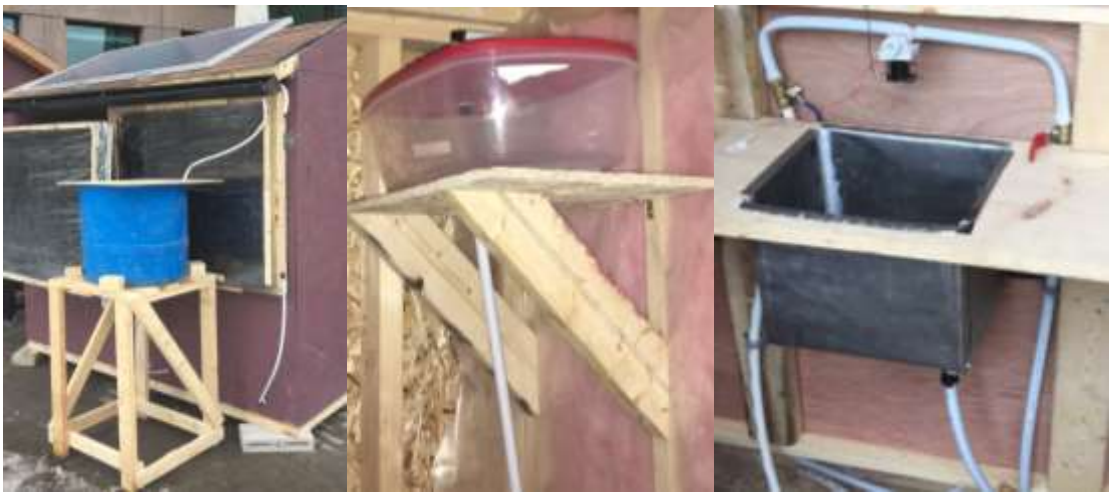

Figure 3: Prototype 3, final product consisting of collection, tanks, piping, distribution.

8. Conclusions/Recommendations:

The prototyping and testing of our rain harvesting design has led to the discovery of some major flaws within the design and has also led to the development of new design ideas. Through the failure of our initial filtration system, we have discovered that it is important to have a strong filtration system, however, the multiple layers of aggregate, sand and carbon can not be too dense otherwise that will lead to poor water flow and that will cause our entire design to fail. When recreating this design in the future, the layers of material in the filtration system must be thick enough but not overdone. Another flow that we dealt with through the testing of the final prototype is the inability of the cocking and pipe connectors to hold together with the pressure of the water pump. Moving forward, the design must be adapted to ensure there is not leakage in the piping; this could be done using strong pipe connectors that are screwed together rather than fit tightly and cocked together.

With further testing and prototyping our rain harvesting design could be implemented and constructed in many homes as low cost, low maintenance, and fully functional water source for communities who are in need of a clean and reliable source of drinking water. The entirety of our design incorporates a collection method, filtration method, storage facility and water source that is very user friendly.

The absence of clean drinking water is a major problem in a number of first nation and indigenous communities across Canada. 78 first nation communities across Canada are currently under long-term water advisories and many are forced to boiling their water before using it (Government of Canada, 2018). The federal government has made a goal to have a all long-term drinking water advisories to be lifted by march of 2021 (Government of Canada, 2018). Our design could benefit many first nation communities all over Canada in aiding with keeping the commitment that the Canadian government has made.

9. Bibliography/References:

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