April 2014

ENVS/SUST 3502 - Campus as A Living Laboratory

Ryan Currie - BSc. Environmental Science
Claire Freedman - BA Environmental Sustainability & Sociology and Social Anthropology
Andrew Ross - BSc. Environmental Science & Urban Planning
Malcolm Smith - BA. Environmental Sustainability & International Development Studies
Daniel Clarke - BA. Environmental Sustainability

[FEASIBILITY OF RAINWATER HARVESTING AT DALHOUSIE'S AGRICULTURAL COLLEGE]

Table of Contents

			Page #
Executive Summary			3
Abstract			3
1.0	Introduction		4
	1.1	Background	4
	1.2	Goals & Objectives	5
	1.3	Definitions	6
2.0	Research Methods		7
	2.1	Description	7
	2.2	Procedures	7
		2.2.1 Gather Information	7
		2.2.2 Internet Resources	8
		2.2.3 Cost-Benefit Analysis	8
	2.3	Variability, Reliability, Trustworthiness	10
	2.4	Limitations	10
	2.5	Delimitations	11
3.0	Results		11
	3.1	Calculations	11
	3.2	Summary of Results	15
4.0	Discussion		15
5.0	Conclusion		16
6.0	References		17

Executive Summary

After considering water usage and rain fall at Dalhousie’s Agricultural Campus we determined it would be advisable to install one 12,500 Gallon water harvesting and filtration system to supplement irrigation needs. The campus currently operates on a well-water system, with the intention of using city water supply in the coming future. The Collins building, located on the campus has three large flat rooftop surfaces which are optimal for rain water runoff, and there for collection. The campus has three main greenhouses of which one is watered daily and two are watered daily during the course of the spring and summer months. Through the installation of a rainwater harvesting system, the campus could save approximately 953.19$ annually in water costs. After the initial cost and installation fee we predict an 11 year payback period for the device, after which the University would be profiting from their investment. By making use of naturally available rainwater, the level of sustainable recognition would increase drastically for Dalhousie. This solution offers a leading environmentally conscious alternative to city water use, and has much potential for growth and the possibility of being adopted by others.

Abstract

This report covers a diverse range of methods to establish the feasibility study of a rainwater harvesting system at Dalhousie's Agricultural Campus. Methods used include online research and data collection, onsite visitation, and finally a cost-benefit analysis. The Agricultural Campus’ location was chosen following a brief talk with Rochelle Owen, who highlighted its suitability due to the amount of irrigation taking place for its greenhouses. The cost-benefit analysis determined that the implementation of a rainwater-harvesting system to collect rain run-off from roof of the Harlow Institute. A calculation using this building which is centrally located amongst the green houses is economically feasible with a return on investment of 11 years. A rainwater harvesting system will be used for irrigation, all the while improving the quality of groundwater and reduce demand on water supplies in addition to the associated monetary spending. This document hopes to serve as a standard for the Agricultural Campus’ Facilities Management, The Town of Truro, as well as other agricultural based regions across the world.

1.0 Introduction

As societal progression ensues, the vitality of our water resources is becoming an area of increased attention. Many conflicts internationally have arisen regarding water resources often surrounding the mismanagement and anthropogenic contamination of the resource. The current global context of rainwater harvesting is one of an emerging sustainable technology. Although non-potable reuse of water can already be found in most regions of the world, rainwater harvesting is still being refined for use in both urban and rural settings (Okun, 2000). With a growing global population and trend towards urbanization, the concentrated demand for water is increasing. Rainwater harvesting offers the benefit of decreasing the reliance on existing water infrastructure, while decreasing the unnecessary use of potable water for irrigation. As a result of the improvements in filtration and treatment systems rainwater collection continue to provide regions around the world with supplies for agricultural needs, potable water and a variety of other broad purposes. The Harlow Institute, with close proximity to greenhouses and pre-existing water infrastructure, is one of many possible sites to harvest rainwater at the Agricultural College. If all of the 9874 square feet of surface area on the roof was used on this building, over 285,000 gallons of rainwater could be collected corresponding to savings in excess of just less than $1000 per year. The most effective way for the campus to harvest rainwater is to install an above ground 12,500 gallon tank, corresponding to an 11 year return on investment. The implementation of such a system would further cement Dalhousie as a leader in sustainable practices amongst other universities, reduce the Truro Campus' dependency towards municipal water, and contribute to a healthy, proactive campus.

1.1 Background

In our research we came across many examples of large-scale urban rainwater harvesting systems currently in place at various locations similar to Dalhousie University. The Lady Bird Johnson Wildflower Centre in Austin, Texas is estimated to collect 300,000 gallons of rainwater per year, with 4 integrated cisterns and a 17,000 square foot roof catchment (Winterbottom, 2000). The University of North Carolina at Chapel Hill boasts one of the most comprehensive water management systems of any campus in the world, including a rainwater harvesting system with 10 cisterns ranging from 5,000 to 350,000 gallons (Hoyt, S.; Shea, C).

Currently at Dalhousie University there are multiple buildings designed for rainwater harvesting. The Mona Campbell building, along with Risley Hall and the new LeMarchant Street residence were all designed with rainwater harvesting systems integrated1. However, these

[1] Meeting with Rochelle Owen, Dalhousie Office of Sustainability

large scale urban rainwater harvesting systems can be quite expensive; Dalhousie's office of sustainability estimates a 50-year and a 40-year payback period for the systems located on the Mona Campbell Building and the LeMarchant Residence, respectively2. In fact, these payback periods are considering the cost of installation when incorporating the rainwater harvesting system into a design prior to construction. As Okun (2000) discusses in his article, the cost effectiveness of a rainwater harvesting system can decrease significantly when retrofitting an existing building. Although these North American examples of urban rainwater harvesting systems are quite expensive, that is not the norm for this technology. In fact, most of the literature found was studying or developing smaller scale and less expensive rainwater harvesting systems for agricultural use. The materials for a small scale agricultural system can be very inexpensive and easy to implement, while improving water availability (Sturm, et al. 2009). A campus focused on agricultural education would not only benefit from the conservation of potable water, but would allow students the opportunity to work hands on with an emerging sustainable agricultural technology.

The Dalhousie Agricultural Campus, located in Truro, Nova Scotia represents an ideal site for use of rainwater harvesting systems. The high demand for non-potable water to irrigation, the low cost of rainwater harvesting systems, and the value of the technology as an education tool all rationalize its consideration. This feasibility study will look at possible quantity and placement of rainwater harvesting units around the agriculture campus for a cost-benefit analysis. An assessment of this water collection technology is especially pertinent and timely because the campus will be switching their source of water from privately owned wells to the municipal water supply in the near future. This change will have significant financial implications, as a critical resource that was free will soon have a price per volume associated with its use. Although this transition to municipal water supply may represent an increase in campus operational cost, it can also represent a financial incentive for the use of rainwater harvesting. Furthermore, with the Agriculture Campus still developing their Master Plan, a feasibility study of this nature is more likely to be considered for inclusion.

1.2 Goals & Objectives

a) Collect current relative data

b) Determine the feasibility of a rainwater harvesting system at Dalhousie's Agricultural College

c) To determine the advantages of using a rainwater harvesting system

d) Provide useful recommendations along with our analysis

[2] Meeting with Rochelle Owen, Dalhousie Office of Sustainability

e) Provide future research options

f) Decrease Dalhousie's ecological footprint

This report will include a full description of the importance of rainwater harvesting and all methods that were used for data collection. A step by step procedure of our study will guide readers through our journey from data collection, calculations, and finally to our recommendations. A discussion on the reliability and validity of our results will take place and any difficulties than we encountered along the way. After our recommendations to the University are complete, we will give our recommendations on potential future studies.

1.3 Definitions

In this section, we would like to clarify the definitions of the following words for use in this report:

Sustainability: Meeting the needs of the present without compromising the needs of the future.[3]

Potable Water: Water that is safe for human consumption.[4]

Irrigation: The artificial application of water to the soil to produce plant growth and supply water requirements not satisfied by rainfall.[5]

Run-off Coefficient: The percentage of collectable water that will land on a given surface.[6]

---

[3] Sustainable Measures. *Definitions of Sustainability*. 2010. Retrieved from: http://www.sustainablemeasures.com/node/35

[4] Potable Water. (January 01, 2008). Civil Engineering, 54

[5] Ecomii, Irrigation. 2008. Retrieved from: http://www.ecomii.com/science/encyclopedia/irrigation-agriculture

[6] Lancaster, B. (2014). Rainwater Harvesting for Drylands and Beyond. Chelsea Green Publishing Company. Retrieved April 10, 2014, from http://www.harvestingrainwater.com/rainwater-harvesting-inforesources/water-harvesting-calculations/

RHS: The term rainwater harvesting system will be abbreviated to RHS for the purposes of brevity

2.0 Research Methods

2.1. Description

For our study on the feasibility of a rainwater harvesting system (RHS) for the agricultural campus in Truro, NS we needed to use several different methods. We wanted to see whether a RHS would be financially beneficial for the campus. We started out by doing various research to establish a basic understanding for rainwater harvesting. Using several databases, we gathered information and looked at other case studies. We were able to see how a RHS would work on another campus. Then we needed to assemble the quantitative data to more clearly examine the feasibility through different websites online. Finally we were able to complete the study with a cost-benefit analysis, which gave us a more direct answer for the feasibility of a RHS. Our main research method as the cost-benefit analysis, but our first two steps of looking at case studies and collecting data were still very important.

2.2. Procedures

The following is the order in which our procedure for the study was completed from start to end:

2.2.1. Gather Information

Although we had had some previous knowledge on rainwater harvesting from other Sustainability courses, we still required a more in-depth understanding, facilitating additional research on the technology. Using databases such as, Web of science, ebscohost, and others we could expand our knowledge. We also looked at several case studies of RHS on other university campuses to get an idea of the system in practice. Also we took a trip to the agricultural campus to get some great pictures, tour the campus for a better view of the layout and ask a ground maintenance manager a few informal questions about the campus water use. This step was crucial to get a solid base layer of information, so we could easily move onto the next step knowing what data we required.

2.2.2. Internet Resources

Several key pieces to our study were taken from different internet sources. Data such as average rainfall, pricing for Truro water and RHS components, area of building surfaces, and rainwater collection potential were all obtained from internet resources. Google maps proved to be a helpful resource, as it has a tool that allowed us to calculate the square footage of the building we selected, the Harlow Institute. For the average rainfall per year we simply used a Nova Scotia government website. Then we looked at the collection potential to calculate the amount of water that could be collected in 1 inch of rain per square foot (Braewater, 2014). Another important figure was the coefficient for runoff, which was retrieved from a study done by Brad Lancaster (Lancaster, 2014). The final step was to factor in the costs of water received from the municipality, the RHS components, and the labor for installation. There are several different companies that sell RHS, so it was easy to find the price on system. A recent application by the town of Truro to increase water prices enabled us to get the exact cost of water this year and the next (NSURB, 2013). The more difficult part was to calculate the installations fees. We used stats Canada for the average wage of a plumber and excavator then approximated the hours required for completion.

2.2.3. Cost-Benefit Analysis

The final step for our study was to combine what we learned from the databases and the data collected online. The cost-benefit analysis can be divided into 5 steps as follows:

1) Collection Area

By using Google maps we calculated the square footage of the Harlow Institute, which will give us the total area that can collect rainwater.

2) Potential Water Collected

After we had found the average annual rainfall for Truro, we could then calculate the potential rainfall. A study done by Braewater gave us the constant for one inch of rain in one square foot of area (Braewater, 2014). We used the following equation:

(Collection Area)(Rainfall) x 0.623 = Collection Potential

Now that we had the total potential water collection, we could use the coefficient for water runoff to calculate the actual water collected in the following equation:

(Collection Potential) x (Runoff Coefficient) = Actual Collection

3) Cost and Water Usage

Next we looked the cost of water for next year to get an exact price per meter cubed. Using the already collected data, we could calculate the savings per year with the following equation:

(Water Rates for 2015)(Water Collected) = Annual savings

4) Installation Fees

A major step was to calculate the total for installation fees to give Dalhousie a realistic payback period for their RHS. Using stats Canada for hourly wages and approximating the hours needed for completion, we were able to calculate the installation fees.

5) Payback Period

Our final step was to add together the total costs and benefits to see how long it would take the agricultural campus to make their money back on the RHS. The total costs were the installation fees and price of the system itself. The benefits were the annual saving that was calculated earlier in step 3. Here's the final equation

(Total cost) / (Annual savings) = # years for payback

2.3. Variability, Reliability, and Trustworthiness

We wanted to create a credible feasibility study to ensure it can be seriously considered, if ever used by Dalhousie. We ensured that our data was as accurate as possible with the resources available to us. However certain pieces of data could change and create different results. For example the average rainfall could change to increase or decrease the water collection total. But that's to be expected, as the weather cannot be foreseen. The methods used do enable the study to be repeated by someone. Also the format and methods of our study helped us calculate exactly what we needed to give Dalhousie a proper payback period to clearly see the feasibility. Our study was also very easy to understand by using simple steps and data collection techniques. We believe that our study is trustworthy through the simple process, easy data collection and clear link between data that we used to state the feasibility of a RHS on the agricultural campus in Truro.

2.4. Limitations

Unfortunately we had a couple limitations with our study that can possibly affect the payback period. The first has to do with climate change and the fact that the average rainfall could decrease or even increase significantly. Although a decrease in rainfall would increase the payback period, if the rainfall would happen to increase we could shorten the years required for payback. Rainfall is a variable that is out of our control, so we did our best to get an accurate measurement. Another limitation was the availability of the costs for installation. We couldn't find any hard to data for the total time and costs for the workers needed to complete the project. The time and costs varies from different companies, so the installation fees could be much higher, which would increase our payback period. We used stats Canada to get an average wage per hour to help give us idea of the installation fees. We knew from the beginning that getting real data for the fees would be difficult, but it is still very easy to insert the correct costs for a more accurate feasibility study.

2.5. Delimitations

A major delimitation we had was the scope of our study. The agricultural campus uses a lot of water and the buildings are fairly spread apart. We decided to go a bit smaller for our study to make sure that it could be rationally accomplished given our time and resources. We decided to only use the Harlow Institute being close to the water tower and its large roof for more potential collection. Also it's within close range of nearby greenhouses, which accounts for much of their water use. A much larger study could expand to more buildings to collect more water but we were happy with our scope because we got a sensible payback period of 11 years. We initially stated our delimitations when we started the assignment to avoid starting a study we could not have finished.

3.0. Results

3.1. Calculations

Collection Area

Based on information gathered on water use at Dalhousie's Agricultural College, the most accessible area to implement a rainwater harvesting system would be in the immediate area surrounding three major greenhouses currently in use on campus, and another large greenhouse (3 times larger than current greenhouses) that will be completed within the next year. The green houses that are currently in place are located in the Collins Building and the Women's Institute of Nova Scotia (WINS), and the future greenhouse will be located on maintenance property adjacent to the Turf Research Building. While irrigation does not always occur year round, the majority of irrigation takes place in the spring, summer, and falls months making it ideal for a rain water harvesting system.

The building with the largest surface area is also the building located centrally between all current and future greenhouses. This building is known as the Harlow Institute, and has enough green space around its perimeter to allow for the installation of a large scale rainwater harvesting system and easy access to pre-existing water sources.

The Harlow Institute consists of a main building containing 3 large wings:

Section	Length (ft)	Width (ft)	Total (sqft)
Main Building	190	35	6650
Wing #1	48	26	1248
Wing #2	41	26	1066
Wing #3	35	26	910

Total: 9874 sqft

Potential Water to be Collected

Using data collected from the Province of Nova Scotia (2006), the Town of Truro receives approximately 1,178.1 mm (46.38 inches) of usable rainwater annually. To calculate our annual rainwater collection potential, we used the following equation:

(Collection Area)(Rainfall) x 0.623 = Collection Potential

Where: Collection Area = Square Footage of Harlow Institute Roof
Rainfall = Amount of rain in inches, and
We used 0.623 as a constant because according to BraeWater (2014), every one inch of rain on one square foot of a collection area equals 0.623 gallons of rainwater.

Therefore, when we insert our values obtained for square footage and approximate annual rain amount we get:

(Collection Area)(Rainfall) x 0.623 = Collection Potential
(9874 sqft)(46.38 in) x (0.623) = 285,306.66 gallons of **POTENTIAL** harvestable water

The roof of the Harlow Institute is made mainly by concrete/asphalt; however, it also consists of small amounts of metal for venting systems and tar for sealant purposes. According to calculations provided by Brad Lancaster (2014), the runoff coefficients for these surfaces are as follows:

Metal: 95%
Concrete/Asphalt: 80-95%

Tar: 85%

Using a runoff coefficient of 90% - meaning 90% of all rain falling on the roof *will* runoff, and 10% will be lost to factors such as evaporation, wind, leaks, and infiltration into the catchment surface - we get:

(285,306.66 gallons) x (90%) = 256,775.994 gallons of **ACTUAL** harvestable water

Cost of Water

The primary source of water in the Town of Truro is provided through the Truro Water Utility. The Nova Scotia Utility and Review Board (NSURB, 2013) accepted an application from the Town of Truro to increase water rates as follows:

Year	Cost/m³ (Effective April 1 of given year)	% increase
2013	$0.93	N/A
2014	$0.96	3.125%
2015	$0.98	2.041%

A grounds maintenance manager informed us of current water usage at the pre-existing green houses, and the expected water usage for the new greenhouse:

Greenhouse	Days in Use	Water Usage/day (gal)	Total Gallons (gal)
Collins #1	30	30	900
Collins #2	92	30	2760
WINS	365	30	10,950
New	365	90	32,850
			Total: 47,460

264 US liquid gallons = 1 m³ of water
Therefore: 47, 460 gal = **179.77 m³** of water

Using our calculated collection potential and water rates of 2015 we are able to save:

256,775.994 gallons = **972.64 m³** of water,
And if consumption rate = $0.98/m³, then ($0.98/m³) x (972.64 m³) = **$953.19** in **POSSIBLE** annual savings

or,

($0.98/m³) x (179.77 m³) = **$176.17** in annual greenhouse water consumption savings

Installation Fees

According to Save The Rain Campaign (2014), a plumber would be needed to complete internal pipework in the rainwater harvesrting system, and excavation work to level out the land for stability. Using hourly wage data provided by Statistics Canada (2008), and adjusting prices using the CPI to 2014 levels we get the following hourly wages:

Profession	Hourly Rate in NS (CAN$)
Plumber	31.61
Equiptment Operator	27.72

We assumed excavation will be completed in one 8 hour day, and plumbing will be completed in two 8 hour days.

Excavation: ($27.72/hr) x (8 hrs) = $221.76
Plumbing: ($31.61/hr) x (8hrs) x (2 days) = $505.76

Total Installation Costs: $221.76 + $505.76 = **$727.52**

Payback Period

To ensure all potential rainwater is harvested for use at Dalhousie's Agricultural College - for greenhouse use or otherwise - cost of rainwater harvesting system is based on 12,500 gallon complete rainwater harvesting kit as advertised on RainHarvest Systems website (RainHarvest Systems, 2014).

Costs (CAN$):
Rainwater Harvesting Kit: $9,820.79
Total Installation Fees: $727.52
Total Costs: **$10,548.31**

Benefits (CAN$)

Annual Water Savings at Constant Water Consumption Fee ($0.98):
$953.19
Environmental Benefits: immeasurable

Return on Investment:
($10,548) / ($953.19) = **11 Year Return on Investment**

3.2. Summary of Results

Based on the potential annual rainwater collection amount (972.64 m^3) in our study area it was determined that the total amount of water costs that would be saved is $953.19 annually. Although Dalhousie would experience a negative net benefit for the 11 years immediately following the complete installation, they would experience a positive net benefit beginning in the 12th year. Therefore, if a rainwater harvesting system was installed at Dalhousie's Agricultural College under these conditions, investment costs would be returned within 11 years. Since the rainwater harvesting system would be in place for many decades, after this 11 year return time Dalhousie would be making an increasing amount of money annually.

4.0. Discussion

With the consideration of these results, not only is it safe to say that rainwater harvesting is a feasible opportunity on the agricultural campus, but that it can actually be profitable for the University. Furthermore, in conducting our research on ideal site location for the proposed system, we identified additional opportunities for rainwater harvesting application in other parts of the campus.

This represents a significant finding for our research, as adoption of this technology would not only be feasible for our proposed scale of implementation, but could be even more cost effective when applied on a larger scale. Our proposed rainwater harvesting system can supplement municipal water used for irrigation in the Collins building, but would not be sufficient to meet water demand for irrigation use in other parts of the campus. Although we could not obtain exact volumes of use, according to the facilities management staff, the soccer field represents the largest consumer of water for irrigation[7]. There are also additional greenhouses attached to the Cox building, which could potentially have their water requirements met by rainwater harvesting. In fact, given the substantial roof area of the Cox building and its proximity to the soccer field and attached greenhouses, consideration of rainwater harvesting at the agricultural campus should also explore the potential here.

[7] Meeting with Darwin Carr, Dalhousie Agricultural Campus Grounds Co-Manager

While we expected our findings to support the proposal's feasibility, the payback period was shorter than anticipated. With Dalhousie University's investment in rainwater harvesting on Studley Campus, systems with 40 to 50 year payback periods were approved. Although our proposed system is significantly smaller in capacity than the Mona Campbell or Risley Hall, the initial costs are recuperated much more quickly. The fact that our proposal has this degree of difference in payback period from existing Dalhousie RHS make it hard to imagine actual costs falling outside a threshold tolerable by the University. Despite the unavoidable margin for error when conducting research and data analysis of this nature, we remain confident in the feasibility of this proposal.

Some of the sources of error were highlighted by our research on the topic of rainwater harvesting. While our research revealed a variety of techniques for calculating volume of water collection, our selected method maintained a conservative approach to prevent a false positive in our results. The conservative approach to estimating feasibility also will help prevent factors such as precipitation variability from significantly increasing the payback period. In light of existing research studies, successful operation of a rainwater harvesting system also requires education in proper cleaning and maintenance practices (Li et al. 2000). While our research could not provide a cost for this to factor into our feasibility assessment, the financial implications seem minimal. None-the-less, the significance of proper education in maintenance and cleaning was emphasized necessary to have a well-functioning and sanitary system.

When discussing the implications of our research for new and existing theory, there is not a lot for this report to contribute. As we were not performing explanatory or exploratory research, we were not looking to challenge or create theory, but rather use existing research to guide our feasibility assessment. However, that is not to say there isn't potential for our research to indirectly influence theory, and this has to do our research's implication for practice. With an educational institution implementing this technology, it is bound to receive attention from academics, and that could lead to changes in practice as well as theory. These changes could include innovations in materials used, system design, and operating procedures. Students could even use the technology to challenge existing theory on rainwater harvesting, such as methods for estimating the percentage of rainfall capture. Although our research may not directly influence theory or practice regarding rainwater harvesting, the implementation of a RHS on Dalhousie's agricultural campus could have indirect implications.

5.0. *Conclusion*

The cost-benefit analysis that was conducted regarding the feasibility of installing a rainwater harvesting system on the Dalhousie Agricultural Campus suggested that in fact, it *is* a feasible option that should be seriously considered. The installation of a rainwater harvesting system would not only benefit Dalhousie monetarily, but also move them towards becoming a leader in the utilization of sustainable resources on campus making a lasting impression on other universities, firms, and the general public.

We recommend Dalhousie to install a 12,500 gallon rainwater harvesting system that will exceed all water irrigation demands for all greenhouses located in the close vicinity of the Harlow Institute. Furthermore, we believe that the Harlow Institute would be the perfect building to attach a rainwater harvesting system to due to its central location situated between four major greenhouses and its overall large surface area perfect for collecting rain runoff. Dalhousie should move forward with this decision in a timely matter to save on future labor and material cost increases, as well as future water costs that will be charged by the Truro Water Utility; the sooner a rainwater harvesting system is put in to place, the sooner Dalhousie will see a return on investment. We believe so strongly that rainwater harvesting is the solution to bypass future environmental degradation and water costs, that we also recommend Dalhousie to consider the installation of other large or small scale rainwater harvesting systems on both the Halifax and Truro campuses. By implementing a rainwater harvesting system into planned renovations or the construction of new buildings on campus, costs associated with the construction or renovation of buildings with the sole purpose of installing a rainwater harvesting system would be absorbed.

Dalhousie has so many great opportunities to invest in rainwater harvesting systems on both campuses that would result in both economic and environmental benefits. At Dalhousie's Agricultural College, research could be conducted into the future implementation of rainwater harvesting systems for irrigation purposes in areas such as the Rock Garden, the soccer field, or the Chef's Garden. The Rock Garden research could easily be incorporated into cost-benefit analysis completed above due to its close proximity to the Harlow Institute and the surrounding study area. The Chef's Garden is a 1.1 acre organic vegetable garden that is currently irrigated through precise computer systems. Having precise water measurements would allow for an extremely definite cost-benefit analysis to be completed. The soccer field uses the most water for irrigation purposes compared to any other irrigation use at the Agricultural College, and implementing a rainwater harvesting system for that use would save Dalhousie thousands of dollars annually. It may also be beneficial to research whether or not it is better to have one large scale rainwater harvesting system located in a central location, or many small scale rainwater harvesting systems located at many places throughout the campus. Rainwater harvesting systems have many uses besides irrigation too; usages for things such as flushing toilets and laboratory uses can also provide many great research opportunities for the future use of rainwater harvesting.

6.0. References

Baguma, D.; Loiskandl, W.; Darnhofer, I.; Jung, H.; Hauser, M. (2010). Knowledge of measures to safeguard harvested rainwater quality in rural domestic households. Journal of Water and Health, 8(2), 334-45.

BraeWater. (2014). *FAQs: How much rainwater can I potentially harvest and use for non-potable applications?* Fairfax: Watts Water Techonologies Company. Retrieved April 10, 2014, from http://www.braewater.com/support/faq/#how_much_rainwater_can_i_potentially_harvest_and_use_for_non-potable_applic

Lancaster, B. (2014). *Rainwater Harvesting for Drylands and Beyond.* Chelsea Green Publishing Company. Retrieved April 10, 2014, from http://www.harvestingrainwater.com/rainwater-harvesting-inforesources/water-harvesting-calculations/

Li, Fengrui; Cook, Seth; Geballe, Gordon T.; Burch Jr, William R. (2000). Rainwater harvesting agriculture: An integrated system for water management on rainfed land in china's semiarid areas. Ambi AMBIO: A Journal of the Human Environment, 29(8), 477-483.

NSURB. (2013). *Town of Truro Water Utility: Schedule of Rates for Water and Water Services.* Halifax: Nova Scotia Utility and Review Board. Retrieved April 11, 2014, from http://www.truro.ca/component/option,com_docman/Itemid,676/gid,1931/task,doc_view/

Okun, D.A. (2000). Water reclamation and unrestricted nonpotable reuse: A new tool in urban water management. Annual Review of Public Health, 21, 223-45.

Province of Nova Scotia. (2006). *Geopgraphy and Climate.* Halifax: Government of Nova Scotia. Retrieved April 10, 2014, from https://www.novascotia.ca/playground/geography.asp

RainHarvest Systems. (2014). *Water Tanks- Plastic: Above Ground Tanks.* Atlanta: RainHarvest System LLC. Retrieved April 11, 2014, from http://www.rainharvest.com/water-tanks-plastic/above-ground-tanks.asp

Save The Rain. (2014). *Rainwater Harvesting - Questions and Answers.* United Kingdom: Hydro International. Retrieved April 11, 2014, from http://www.savetherain.info/media-centre/rainwater-harvesting-faqs.aspx

Statistics Canada. (2008). *Construction union wage rates and indexes.* Stats Canada. Retrieved April 11, 2014, from http://www.gov.nl.ca/lra/stats/statistics_canada_construction_union_wage_rates_june_2008.PDF

Sturm, M.; Zimmermann, M.; Schutz, K.; Urban, W.; Hartung, H. 9th WaterNet/WARFSA/GWP-SA Symposium: Water and Sustainable Development for Improved Livelihoods. (2009). Rainwater harvesting as an alternative water resource in rural sites in central northern Namibia. Physics and Chemistry of the Earth, 34(13-16), 776-785.

Tabatabaee J, H. M. (2010). Rainwater harvesting potentials for drought mitigation in Iran. Water Science and Technology : A Journal of the International Association on Water Pollution Research, 62(4), 816-21.