UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Filtration of Cistern-collected Rainwater for the New SUB

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APSC 262: Sustainability Project

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ABSTRACT

The AMS is in a process of building a new SUB. Various groups are researching on different kinds of stoves, rooftops and filters for use at the new SUB. Our group decided to focus on different types of water filtration systems. We researched on different filtration systems that could be used for the new SUB. Upon evaluating different types of filtration systems, we decided that a UV filtration system would be best suited for the new SUB. Despite a number of disadvantages, advantages override the debate on using a UV filtration system. A general idea and a methodology of the filtration system will be introduced briefly at the beginning of the report. The report will be followed by focused assessment of the triple bottom line in regards to the UV filtration system.

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List of Abbreviations

POU – Point Of Use

SUB – Student Union Building

UV – Ultra Violet

LEED –Leadership in Energy & Environmental Design

1.0 INTRODUCTION

Since the Student Union Building (SUB) was built over 40 years ago, it has become the most frequented building on the campus. Due to the growth in the student population over the years, the current SUB facilities are gradually becoming insufficient to meet the demands of over the 50,000 students and faculty staff. Therefore, the new SUB is currently entering the design phase and construction is underway to be completed in 2014. The New SUB will collect rainwater and store it in cisterns for reuse. The rainwater cistern systems will consist of a catchment area connected to the cisterns, located on basement, and a distribution system including an electrically driven pump, and copper or plastic pipe. The New SUB will also have a rooftop garden where urban agriculture will take place in order to produce food. Therefore, the water from the cisterns needs to be gone through a filtration system for potable water because the polluted water may affect food safety.

Rainwater treatment and water re-use technologies have improved significantly in recent years [1]. Effective microbial disinfection in the processing of potable water is essential. According to our research, of many kinds of filtration systems, ultraviolet (UV) filtration is the best for the new SUB because of the low maintenance technology. Also, the UV disinfection is a non-chemical disinfection method that kills all known spoilage microorganisms including bacteria, viruses, yeasts and moulds. Therefore, it is an environmentally friendly technology which eliminates the need for chemical treatment while ensuring high levels of disinfection.

In this report, a triple-bottom-line assessment is conducted on the use of UV disinfection for the rainwater cisterns so that the water can be used for irrigation in the roof, in consideration of social, environmental and economic assessment. This paper will not only investigate how rainwater management for reuse affects the society and what socio-institutional barriers for rainwater management are, but also explore in detail the UV filtration of rainwater in reference to environmental and economic assessment.

2.0 SOCIAL ASSESSMENT

One of the most important evaluation criterions for the filtration of cistern-collected rainwater is to consider the social assessment. To assess the filtration of cistern-collected rainwater for the new SUB in terms of the social perspectives, we have discussed the reasons why rainwater or rainwater management is required for people's health, and social and institutional barriers for rainwater management through a survey.

2.1 Rainwater Management

Rainwater can pollute rivers or lakes in an urban area like Vancouver. Owing to increase in human populations and thus urbanization, 30 to 50 percent of the Earth's surface has been transformed to concrete constructions and roads [2]. Relationships between road density and common water quality constituents such as chloride and lead are linearly related as seen in Figure 1.

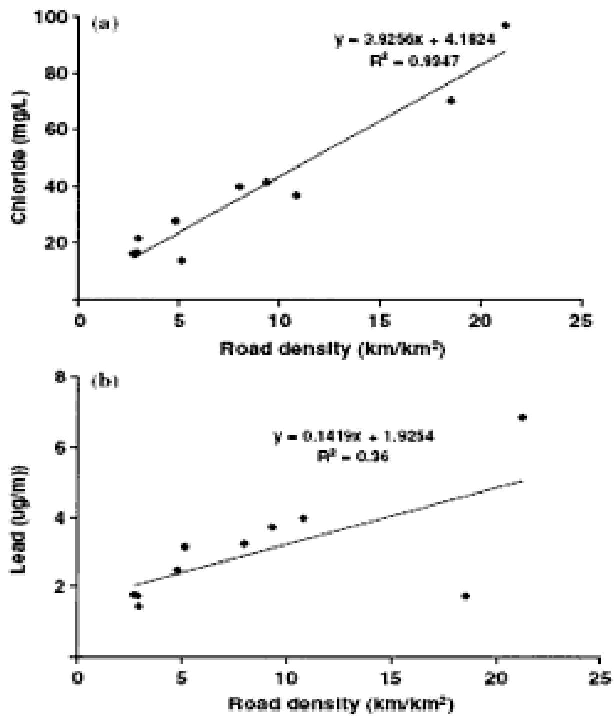

Figure 1: Example Relationships between Road Density and Common Water Quality Constituents [3].

Urbanization of the landscape profoundly affects the quality of rainwater and the ultimate condition of nearby rivers, lakes, and oceans. When it rains, rainwater can be absorbed into the earth in forest, field, or meadow. However, in urban areas like Vancouver, rainwater pools up on hard surfaces such as driveways, roads, and rooftops and is polluted. The polluted rainwater is one of the largest and fastest growing threats to global water resources [3]. This is because most of the runoff carries pollutants from parking lots, streets, lawns, and industrial and construction sites to rivers, lakes, and oceans, consequently leading to beach closures, fishing and swimming advisories from bacteria and other pathogens carried by runoff [3]. In Vancouver, it rains most of the time in the winter season and storm water is considered as an environmental threat. However, depending on how rainwater is effectively treated, it can also be considered as a useful source of water supply. Indeed, in a recent report released, the authors argued rainwater needs to be considered as a water resource rather than as a waste product [4].

In the rooftop of the new SUB, there are several sites where rain gardens will be installed to add beauty to the campus while capturing and filtering rainwater. Also, rainwater collected by the roof stored in tanks or cisterns in the new SUB can be used to supply water for toilet flush. It is believed that this strategy, the use of rainstorm water for the gardens and the toilet flush, may result in a reduction of more than 40% of treated water consumption. Therefore, once widely adopted, this technology can result in a considerable reduction in investments necessary to increase the plant capacity for treating water and the resulting liquid[5].

2.2 Social and Institutional Barrier for Rainwater Management

In 1999, Niemczynowicz argued, "improved rainwater quality management requires a transition from 'old-world' management to one that operates in a 'total water cycle' [6]." Several commentators have tried to explain the challenges to change to a more sustainable urban water management, and they are beginning to identify that major barriers are "not purely technological, but rather social and institutional [7]." Indeed, Wong argues that, "institutional impediments are not well addressed, and are often beyond current concerns of many sectors of the urban water industry, which are more concerned with strengthening technological and planning process expertise. [8]"To understand what drives and limits technology adoption for rainwater management, over 800 urban water professionals in three Australian capital cities completed an online questionnaire survey in November, 2006.On average, over 80% of urban water professionals across Brisbane, Melbourne and Perth highlighted they recognized a very high level of importance on protecting receiving waterway health, as seen in Figure 2. However, the professionals in the community and state government did not place importance on protecting receiving waterway health. The decreasing trend is common across the three cities, with a substantial difference with perceived political views. Also, in Vancouver, we would expect the same result as these cities.

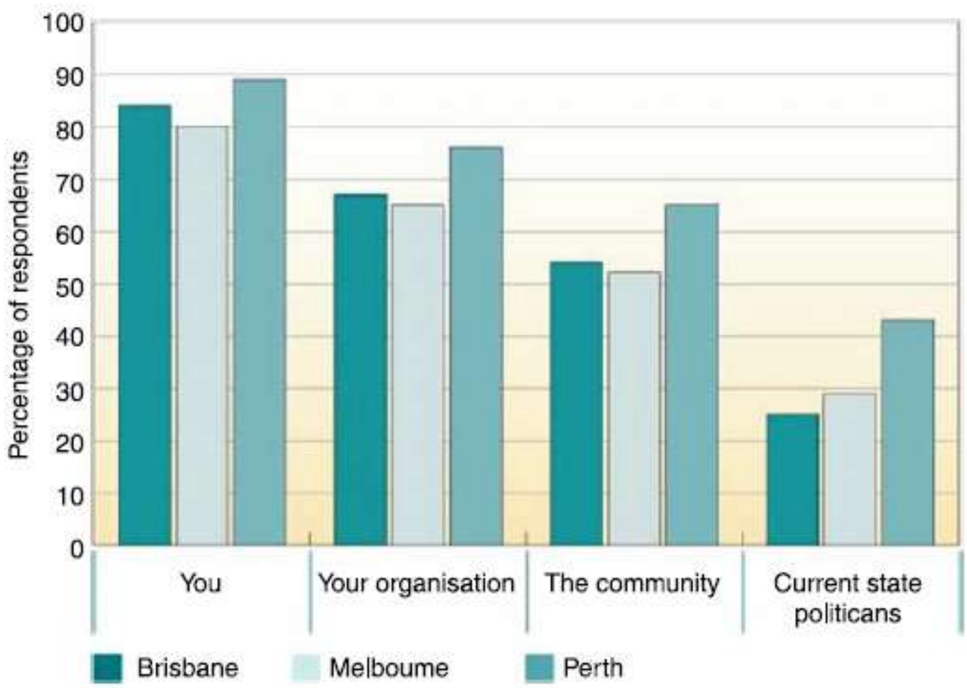

Figure 2: Perceived Importance of Protecting Waterway Health (high and very high responses) [4].

The results revealed that professional communities placed a high level of importance on improving rainwater quality, while politicians placed a substantially lower level of importance on rainwater quality management. Finally, According to Brown and Farrelly, raising greater socio-political fund and developing key demonstration projects with training events are recommended as useful policy interventions to solve current social and institutional barriers [9].

3.0ENVIRONMENTAL ASSESSMENT

There are many environmental benefits of using a water filtration system. First, since more people will drink the filtration water, fewer water bottles will be consumed. As a result, less garbage will be produced which benefits the environment. Second, less water will be wasted because the filtration system will collect the rainwater and reuse it. More specifically, using a UV water filter is a great way to benefit the environment. UV filtration uses a UV light source and is an excellent way to destroy bacterial organisms. UV-C rays destroy 99.9% of harmful organisms. UV light is an invisible light that has a shorter wavelength than a regular visible light.

3.1 Operation of General Filtration Systems

First, a catchment on the roof is used to collect the rain water [10]. After the water reaches the gutter, it is transported to a UV filter. A gutter is used as a bridge between the transport and the catchment. Before the water reaches the UV filter, it goes through an additional water filter. After that, it goes through the UV Filter. Harmful microorganisms of the water are absorbed by the DNA after being penetrated by UV-C rays. After the water is filtered, it is stored at a cistern [11]. The water in the cistern can be used for water irrigation, toilets and portable water.

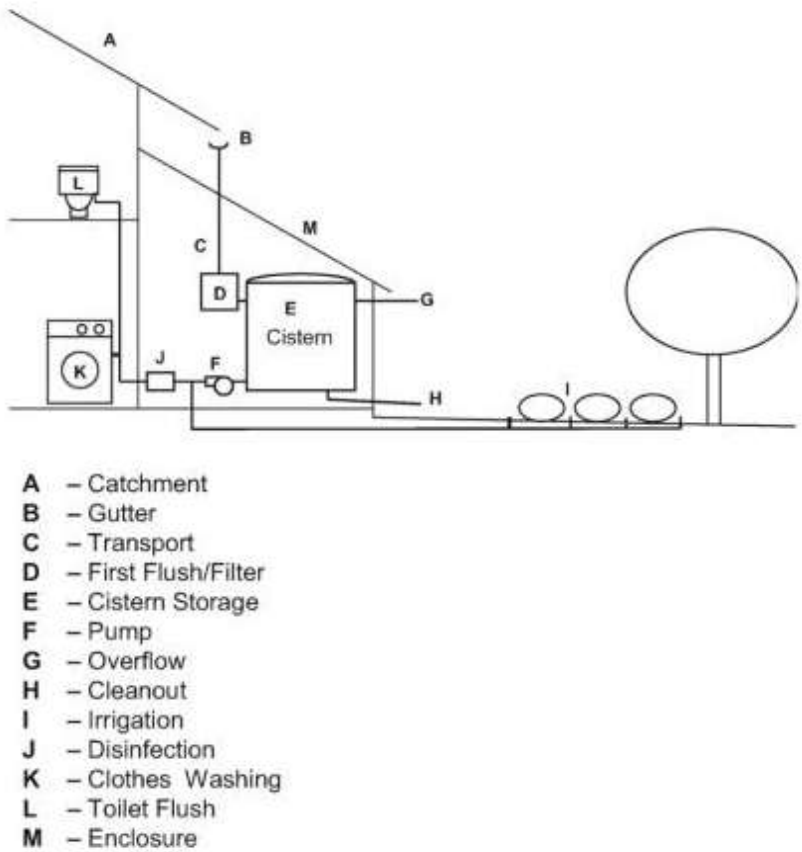

Figure 3: Schematic of the Basic Rainwater Harvesting System [12].

3.2 Operation of the UV Filtration System

A UV filter contains a light lamp that generates UV-C rays [13]. The water is exposed to UV-C rays once the water enters the UV filter. Harmful microorganisms are absorbed by the DNA after being penetrated by UV-C rays. As a result, there will be no bacteria left in the water.

3.2.1 Advantages of Using UV Filter

One of the best advantages of using a UV filter is that there is no chemical usage [14]. Since there is no chemical usage, the color of the water and the taste do not change after going through the filter. Another benefit is that the filter is easy to install and maintain [15]. Only two water connections and a power plug need to be connected. The UV light bulb needs to be replaced only once a year. On the other hand, other types of filters such as a chlorine filter needs to be replaced every twice a month. The UV filter is also energy efficient. Only 60W power is required to generate a UV filter. Compared to other electronic devices, the UV filter does not require that much power.

3.2.2 Disadvantages of Using UV Filter

There are also some disadvantages of using a UV filter. A pre-filtration system such as POU water treatment is required for this filter. Boiling the water and using a sand filter are two options of POU water treatment. POU treatments are used to get rid of paint debris, wastes from birds and other dusts. Another disadvantage of using a UV filter is that it requires an electrical cable. Other filters generally do not require any power sources.

4.0 ECONOMIC ASSESSMENT

This part discusses general advantages of using the UV filtration system and how the rainwater filtration system will bring benefits to UBC students and the new SUB users economically. Also, the total cost of the UV filtration system including installation and maintenance cost will be examined.

4.1Economic Benefits of Using a Filtration System

One of advantages of using the UV filtration is easy to install and maintain the system. To maintain the system, the user needs to replace the only UV lamp at every given period to ensure that the system is purifying the rainwater. The UV lamp costs about from $100 to $250 depending on the size of the system [16]. This will save a lot of money since the user does not need to hire specialists to check the system. Some filtration systems are required that the specialist should come to maintain or replace some parts of the systems [12].

In addition, the size of the UV filtration system is extremely compact. For example, one of *Water Tiger's* product that is designed for communities of less than 5,000 households, resorts, schools, hospitals, and more is merely 81cm high, 20cm wide, and 23cm deep [16]. By using the UV filtration system, the user can save a lot of space and use the space for something else [13].

4.2Estimation for Total Cost of the UV Filtration System

At this point in time, the new SUB design has not yet been finalized. We can only assume some factors and estimate the cost according to the assumptions that we make. According to the New SUB 100 percent schematic design report, the size of cistern varies depending on how much rainwater we use. In this report, we decided on a scenario which would use 100% of the rainwater for the flush fixture demand because it appeared to be the best choice in comparison to all other scenarios (see Table 1). When we assume to use the scenario, 2,450 m^3 of rainwater available annually (about 648605 gallons) for capture from the 2719 m^2 roof catchment area, which is the half of the roof (see Table 2). Using Table 2, from The City of Vancouver, we can estimate how much we can save by using rainwater filtration [18]. The total annual savings from the collected rainwater will be approximately $2343 (2.51*(648605/623)).

	Scenario 1 none	Scenario 2 22 m^3	Scenario 3 1100 m^3	Scenario 4 48 m^3	Scenario 5 18 m^3
Flush fixtures (toilets, urinals)	32% (0)	50% (1)	100% (2)	50% (1)	32% (0)
All fixtures (toilets, urinals, lavatories, showers, kitchen sinks)	48% (2)	60% (2)	94% (2)	60% (2)	48% (2)
Meets LEED exemplary performance requirement for WEc3?	Y (1)	Y (1)	Y (1)	Y (1)	N (1)
Meets LEED process water requirement? (reduction ≥ 10% of baseline indoor water use)	N (0)	N (0)	N (0)	Y (1)	Y (1)
Potential LEED water efficiency points	**3**	**4**	**5**	**5**	**4**
Rainwater harvested (m^3/year)	**0**	**672**	**2454**	**1241**	**540**

Table 1: Estimated Indoor Waste Savings and Potential LEED Points for Each Scenario [17].

Description	Value
Total Roof Area	5439 m^2
Rainwater catchment area (hardscape only – 50% of roof)	2719.5 m^2
Cistern collection efficiency	75%
Annual precipitation	1202.4 mm
Annual precipitation volume	3,270 m^3
Cistern Collection efficiency	75%
Annual precipitation available for cistern	2,450 m^3

Table 2: Rainwater Harvesting System [17].

Water & Sewer Rates for 2011			
Metered Water Rate per Unit,	$2.251	1 Unit =	623 Imperial Gallons 100 Cubic Feet
Metered Sewer Rate per Unit,	$1.596		2,831.6 Litres 2.831385 Cubic Meters

Table 3: Utility Metered Rates 2011from City of Vancouver [18].

We have to examine the SUB design and the weather condition to find the best filtration system. From Table 4, we can estimate the amount of rainwater that the new SUB will attain each month. The worst cases, with the smallest and the largest amount of rain fall, were 43.4mm and 134.6mm respectively, in B.C.'s history [19]. The efficiency of cistern's collection is 75% (see Table 2). Thus, we can calculate the amount of rainwater needed to be filtered as between 118m^3 (about 63.7 gallon) and 366m^3 (about 197.3 gallon) a day. Using this data, we can choose capacity of filtration of system.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation:													
Rainfall (mm)	143.6	173.5	153.1	117	86.7	69.9	49.1	48.3	71	131.9	219.5	211.5	1474.9
Snowfall (cm)	15.3	10.2	2.7	0.9	0	0	0	0	0	0	2.7	11.8	43.6
Precipitation (mm)	178.8	183.8	155.8	117.9	86.7	69.9	53.4	50.8	73.3	147.8	239.2	231.3	1588.6
Extreme Daily Rainfall (mm)	**134.6**	77	59.7	52.3	43.4	53.8	73.7	69.9	61	103.6	85.9	85.3	
Date (yyyy/dd)	**1968/18**	1945/06	1946/25	1946/10	1926/04	1942/14	1972/11	1927/31	1939/14	1956/19	1955/02	1956/08	
Extreme Daily Snowfall (cm)	**36.8**	14	20.3	6	0	0	0	0	0	0.2	24.1	30.5	
Date (yyyy/dd)	**1935/20**	1955/27	1951/04	1981/12	1926/01+	1926/01+	1926/01+	1926/01+	1926/01+	1984/31	1973/19	1937/25	
Extreme Daily Precipitation (mm)	**134.6**	77	67.4	52.3	43.4	65.4	73.7	69.9	61	103.6	85.9	85.3	
Date (yyyy/dd)	**1968/18**	1945/06	1997/18	1946/10	1926/04	1992/13	1972/11	1927/31	1939/14	1956/19	1955/02	1956/08	
Extreme Snow Depth (cm)	10	8	1	0	0	0	0	0	0	0	6	**17**	
Date (yyyy/dd)	1982/03+	1986/16	1982/12	1981/01+	1981/01+	1981/01+	1981/01+	1980/01+	1981/01+	1981/01+	1985/27	**1980/06**	

Table 4: Canadian Climate Normals 1971-2000 for British Columbia [19].

In order to estimate the cost of the UV filtration for the SUB, we visited the website of *Water Tiger*, a local water filtration company located in Victoria, and corresponded through email about the estimated the cost of the UV filtration system. According to the representative from Water Tiger (APPENDIX), the cost of installation will come to approximately $30,000-40,000, including treatment equipment and installation. In addition, the maintenance cost will be less than $1000, including consumable filters, UV bulbs, and chlorine. According to the New SUB 100 percent schematic design report, a 1,100 m^3 cistern (about 290000 gallons) is required to store all water. The cost of cistern varies depending on its size, material, and location (above or below the ground). Due to the widely ranging variety, we were not able to estimate the cost of the cistern. In short, total cost of the UV filtration system will be around $50,000.

5.0 CONCLUSION

In this report, we examined the UV filtration system for our new SUB using a triple-bottom-line assessment which included social, environmental, and economical assessments. Upon completing the assessment, we are confident that the UV filtration system is the best method suited for the SUB for the following reasons. The UV filtration system is an environmentally friendly system that does not require any chemicals to operate. In addition, usage of the filtration system will reduce the polluted water and save water resources for our society. According to our estimation, we could save $2343 per annum. The UV filtration system has great benefits economically thanks to its low maintenance and installation cost as well as its compact size. For the listed reasons, we hope that the UV filtration system is selected for the new SUB.

6.0 REFERENCES

[1] Argue, J. R. “Demonstration project in source control technology: Theory and practice.”, *HydraStorm'98*, Adelaide, Sep 1998.

[2] P.M. Vitousek, H.A. Mooney, J. Lubchenco, and J.M. Melillo. “Human domination of Earth’s ecosystems.” *Science* 277(5325), pp.494-499, 1997.

[3] National Research Council, *Urban stormwater management in the United States.*, Washington: the National Academy of Sciences, 2009, pp.13-46.

[4] R.R. Brown and M.A. Farrelly, “Sustainable Urban Stormwater Management in Australia:Professional Perceptions on Institutional Drivers and Barriers.” Edinburgh, pp.1-10, 2008.

[5] Koen Steemers,Simos Yanna. “Architecture, city, environment- proceedings of PLEA 2000”, Jul 2000, pp.191

[6] Niemczynowicz, J. “Urban hydrology and water management–present and future challenges.” *Urban Water* 1(1), 1999, pp. 1–14.

[7] Maksimovic ´, C. & Tejada-Guibert, J. A. “Water Management: Deadlock of Hope?” *Frontiers in Urban.* Cornwall, UK: IWA Publishing, 2001

[8] Wong, T. H. F. “Water sensitive urban design: the journey thus far.” *Aust. J. Water Res*. 10(3), 2006, pp. 213–222.

[9] Brown, R. R. & Farrelly, M. A. “Delivering Sustainable Urban Water Management: a review of the hurdles we face.” *Water Science and Technology, 2009, pp.* 839-846

[10]Belinda Hatt, Ana Deletic, Tim Fletcher, “Integrated Stormwater Treatment And Re-Use Systems - Inventory Of Australian Practice,” June 2004.

[11] USEPA. 2004. Presentation – 2004 UVDGM Review Meeting. Orlando, Florida. 13 June 2004.

[12] F.L. Jordan, R. Seaman, J.J. Riley and M.R. Yoklie, “Effective Removal of Microbial Contamination from Harvested Rainwater Using a Simple Point of Use Filtration and UV-disinfection Device,” Vol. 5, No. 3, September 2008, 209-218.

[13]Regina Sommer, Alexander Cabaj, Georg Hirschmann, and Thomas Haider, “Disinfection of Drinking Water by UV Irradiation: Basic Principles - Specific

Requirements – International Implementations," R. Sommer et al. January–February 2008.

[14] J. A. Guerrero-Beltr n and G. V. Barbosa-C novas, "Advantages and Limitations on Processing Foods by UV Light," *Food Science and Technology International* 2004.

[15] Ashok *Gadgil,* Anushka *Omscher, David* Greene, and *Peter Miller, "*Field-testing UV Disinfection of Drinking Water," September, 1997.

[16]Water Tiger™. (2011, March). Hallett™ Ultraviolet Water Purification with patented Crossfire Technology™. Water Tiger™. Victoria, BC. [Online]. Available: http://www.watertiger.net/UV/hallett.htm

[17] New SUB Project Committee et al. (2010, Dec.). New Sub Project 100% Schematic Design Report. University of British Columbia. Vancouver, BC. [Online]. Available: http://mynewsub.com/site/?p=419

[18] Environment Canada. *Canadian Climate Normals 1971-2000.* [Online]. Available: http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?Province=ALL&StationName=vancouver&SearchType=BeginsWith&LocateBy=Province&Proximity=25&ProximityFrom=City&StationNumber=&IDType=MSC&CityName=&ParkName=&LatitudeDegrees=&LatitudeMinutes=&LongitudeDegrees=&LongitudeMinutes=&NormalsClass=A&SelNormals=&StnId=888&

[19] City of Vancouver. *Utility Metered Rates 2011*. [Online]. Available: http://vancouver.ca/fs/treasury/utility/meterRates.htm

7.0 APPENDIX

Email from Mr. Adam Scheuer, who is working at Water Tigera™.

From: Adam Scheuer
Sent: Thursday, March 24, 2011 2:43 PM
To: 'Sungjin Woo'
Subject: RE: Estimation for New SUB at UBC

The treatment side of this equation is fairly straightforward. I recommend basic filtration and UV sterilization. More than likely the health inspectors would also require chlorination. I can put some budgets together, but still have some questions on your numbers. I will use gallons as that is what I'm used to and I find it easier to make mental checks on the numbers:

According to the attachment you sent these are the applicable numbers:

- Cistern is 1100 m3 = 290,000 gallons
- Daily FLUSH usage for rainwater is 2454m3/year = 1777 gallons per day (I will round up to 1800)

I've attached a chart showing what the cistern level would like over the course of a year if you were starting the year with a full tank and using the monthly rainfall numbers I pulled off the internet.

With these numbers you would have an annual shortfall of 55000 gallons which would be made up of city water.

Assuming 1800 GPD demand, costs for a system would be roughly in this ballpark.
Components:

1) First-flush system
2) Chlorine dosing
3) Cisterns
4) Pumps
5) Self-cleaning filter
6) 5 micron bag filters
7) UV system

Installation - $30,000-40k (includes treatment equipment and installation, does NOT include cisterns)
Annual Maintenance (includes consumables – filters, UV bulbs, chlorine) – less than $1000

Keep in mind these are very rough numbers. Without a proper engineered design, there are many assumptions built in to these numbers.

Good luck on your project!

Adam Scheuer
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