Water Conservation Option Study

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Introduction

Water conservation is a key component to a more sustainable future at UBC. UBC's estimated water demand is divided into many sectors. Among these sectors, domestic use, processes and irrigation systems require a higher water demand. It is important to consider how UBC can help in reducing water consumption by implementing strategies that could be beneficial and sustainable. Equal balance between environmental, social and economical aspects of sustainability is the most effective strategy in order to improve sustainability goals. Effective water conservation management is crucial in order to attain eco-efficient and sustainable water conservation on campus.

To become more sustainable, the water conservation option study plans to lessen the University's environmental footprint caused by water consumption and effluent discharge.

Goals and Objectives

- Reduce water consumption by decreasing the amount of water consumed through utility functions at UBC
- Propose effective water conservation options and evaluate each option based on the proposed criteria and indicators
- Inform the reader of ways in which to assess options using the evaluation matrix explained in the study
- Discuss the recommendations and option rankings
- To explain the limitations of assessment methodology pertaining to the study

Figure 1: The University of British Columbia

Water Conservation Sustainability Actions

The 2011 Water Conservation Option Study represents collaborative and informative alternatives to conserving water at UBC.

To measure sustainability, an evaluation matrix will be used to assess sustainability throughout looking at the options.

The 5 proposed options are:

- Irrigation using groundwater
- Behavior change programs
- Low-flow infrastructure and Retrofitting
- Rainwater harvesting for non-potable use
- Storm water harvesting for potable use

Criteria and Indicators will be used to evaluate the options.

Recommendations and a final ranking list of the options will be explained.

A brief discussion of the limitations based on the methodology of assessment and the study will be proposed.

The study will conclude final statements and remarks pertaining to the study.

Brief Overview of the options

Irrigation using groundwater: Installation of wells will be used to pump out groundwater from UBC's aquifer. Groundwater will act as an alternative water source for irrigating fields and parks near the outskirts of the campus.

Behavior change programs: Behavior change programs will incorporate smart meters and student awareness campaigns to promote and encourage students, faculty and staff to help reduce water consumption on campus.

Low-flow infrastructure and Retrofitting: The retrofit project will include the installation of dual-flush toilet system and motion sensor faucets in core buildings such as the SUB, libraries and residences at UBC. New buildings will include dual-flush toilets.

Rainwater harvesting for non-potable use: Rainwater will be harvested from future building rooftops, transported through pipes and stored underground in a cement tank for future non-potable use.

Storm water harvesting for potable use: Storm water will be collected in the Northern Catchment Area on campus and will be collected, stored, treated to potable standards for future potable use.

Options

A New Look At Irrigation:

Description:

UBC should have a self supplying irrigation system. A new system of irrigation - installation of wells to pump out groundwater from the UBC's aquifer using pressure pumps. Water will also be stored in fountain ponds to give aesthetic value along with storage for water for when not being used. Implementing irrigation control systems (as in UBC Okanagan) to best manage the use of the irrigation systems. This system will provide water to the farm, botanical gardens and the play fields near the botanical gardens. It is a sustainable option as potable water is not being used for irrigation and also the amount of water leakage at UBC can be accounted for once the irrigation system is separated from main water supply.

Cost Implications:

Capital: $135,000 (wells, pumps, irrigation system)

Maintenance: Cleaning wells and managing energy sources is minimal.

Net Operating Cost Savings: Savings – Net Operating Costs: $300,000 - $100,000 = $200,000

Savings: Approx. 15% of UBC's potable water is used for irrigation or is lost to unknown leaks. This will be the first step in distinguishing the amount of water that goes for irrigation and the amount of water that is being lost to leaks. Hence, once the water supply for irrigation from Sasamat reservoir is discontinued the amount lost to leaks can be found. If some of the irrigation pipes were leaking then there would no longer be a need to upgrade them. Then the money savings from irrigation and pumping the water to irrigation sites can be calculated.

State of Development:

Groundwater wells are a mature development around the world. No other place in BC has used the combination to provide for irrigation. Other sites with Implementation include: UBC Okanagan uses groundwater wells and the smart irrigation control systems; Groundwater wells are used for agriculture around the world.

Environmental Impacts:

A decrease in the amount of water in the aquifer might be a concern, but as the water is going into irrigation some water will go back to the ground. However, infiltration from rainwater will replenish the water. A slight increase in energy usage in order to pump water out of the ground will be evident.

Co-benefits:

- Energy will be saved as there would be no need to pump water from Sasamat Reservoir to the irrigation sites.
- Potable water will not be used for irrigation.
- Figure out how much water is leaking and how much is used for irrigation.
- Research Potential:
- The technology could be expanded to cover other water needs on campus. The utilization for these and the various mechanisms can be further researched.

Potential Controversy:

As it is a new project for the location with the combination of wells the required scale for start-up is not well known. Constructing a new system might have to go through a long process of approval because a new system for potable water needed at these locations will have to be developed or a filtration unit would have to be installed to clean groundwater and make available as potable water.

Stakeholders:

- UBC plant operations
- UBC farm
- UBC governing bodies

Low-flow infrastructure and Retrofitting:

Description:

Institutional uses account for 36% of the total water consumption at UBC. Institutional uses include toilet and faucet usage. Specifically, toilet usage is one of the main contributors to institutional uses on campus. On average, a single toilet consumes 1.6-3.5 gallons of water daily (Giratalla, 2011). The dual-flush toilet is a modified version of the standard toilet and includes 2 flush option buttons: Standard flush which consumes 1.6 gallons of water per day and the Eco-Friendly flush which consumes 0.8 gallons of water per day (Boston University Sustainability; Kohler Co., 2011). The dual flush toilet could potentially save up to 6,000 gallons of water annually per toilet while conserving 40% more water[1] when compared to a the standard 3.5 gallon toilet. The retrofit project will include the installation of a dual-flush system on pre-existing toilets, and replacing older faucets with motion sensor faucets in core buildings and residences. Motion sensor faucets will consume a maximum 0.17 gallons of water per 10 seconds of use (Toto U.S.A. Inc., 2009). New buildings will incorporate new dual-flush toilets.

High-level cost implications: Capital Cost: ~ $1,230,000*

	Number of units	Price per unit in dollars ($)	Total Price in dollars ($)	Water saved in gallons per unit	Total water conserved in Liters (L)
Retrofit low-flow toilets	2,000	24.37	**48,740**	803	7,300,000
Retrofit low-flow sensor faucets	3,000	169.99	**509,970**	654	8,927,100
Installing new dual flush toilets	2,000	333.33	**666,660**	803	7,300,000
Operational costs			**4,000**		

*Please refer to Appendix B for calculations

State of development:
A dual-flush toilet fixture will include 0.8 and 1.6 gallon dual-flush toilet option buttons.
Meets the standard requirements for flushing performance based on the EPA (Environmental Protection Agency) (Boston University Sustainability). Motion sensor faucets will include a maximum of 0.17 gallons of water per 10 seconds of usage (Toto U.S.A. Inc., 2009).
Sites where the dual-flush has been implemented: University of Saskatchewan has successfully incorporated water efficient washroom fixtures such as motion sensor faucets and dual-flush toilets in the Learning Commons in the Murray building (The University of Saskatchewan, 2011). **University of Boston** has successfully incorporated dual-flush toilets in 25 locations around campus and in the Student village #2 throughout all 47 floors (Boston University Sustainability). **The University of Western Ontario** achieved a successful dual-flush system with improved recirculation of grey-water by assembling dual-flush toilets and altering the size of the valve assembly so that flushes are either "long" or "short". For instance, the engineering building with 100 toilets has saved up to 80,000 gallons of water per year with the new dual-flush toilet system (Buchal & Barghi, 2005).

Environmental impacts: Dual-flush toilets and motion sensor faucets will decrease the amount of fresh water consumed in the long-run, thus decreasing environmental impacts so that more fresh water is put to good use.
Co-benefits of retrofitting: Not only is the dual-flush system saving water, but it will also save energy as well through the use of the 2 different pumping pressure options.

Research Potential: This technology could expand by implementing a grey-water recycling system to dual-flush toilets. This will further reduce the use of potable water in toilets while reducing water consumption.
Potential Controversy: Approval time of the project might take long, higher capital costs, behavior change is required to achieve effective long-term water savings.
Stakeholders: UBC Government, Metro Vancouver, UBC Plant Operations, Staff and students

Behaviour Change Program

Description

The University of British Columbia currently consumes an average of 137 litres of water per second (Giratalla, 2011). With thirty six percent of this water flow consumed by domestic uses such as washing, flushing and drinking (Giratalla, 2011), individual end users' behaviours and preferences have direct influence on UBC's aggregate water usage. Although the university's ECOTrek program has "retrofitted over 300 academic buildings with energy and water efficiencies, including fixing leaks and installing low-flow fixtures" (University of British Columbia), the current 2010 Integrated Master Plan has been no campus wide public campaign to encourage everyday users to reduce water usage.

The Canada Mortgage and Housing Corporation has conducted a survey and summarized the results of many Canadian municipal water conservation initiatives (D. H.Waller, 2001). Eighty seven percent of the municipalities studied had "promoted public awareness, with distribution of print material". A campus wide marketing initiative could potentially be created to capture some of these benefits that certain municipalities are experiencing. While the Canadian Mortage and Housing Corporation concludes that "public information is an essential component of any water conservation program", some academics are sceptical of the effectiveness of information campaigns to promote voluntary household water conservation.

This behaviour change would require the immediate need to install smart meters in approximately 40 academic buildings. Feedback on water consumption will then be provided on the online dashboard system currently in place for electricity use. From this, conservation campaigns will be designed to encourage students and faculty members to reduce their consumption based on specific behaviour changes.

Cost implications:

The capital cost required for this option is approximately $200,000. The majority of the capital costs cover the forty smart meters to be installed in academic buildings. The operational costs are at around $6700 per year, covering the cost of employing a campaign designer and manager.

Potential savings

Of all five options, the potential savings that can result from this is the least predictable. Few municipalities use awareness campaigns on their own. For example, the city of Richmond launched a program that includes residential water metering, pricing as well as retrofit rebates (D. H.Waller, 2001; City of Richmond, 2011). As such, we can only conservatively estimate the potential savings to be between one and three percent of domestic use.

Rainwater Harvesting for indoor non-potable use

Description: UBC receives 5 billion liters of rainfall annually and its annual potable water consumption is 4.3 billion liters/year. Currently at least half of UBC's total water consumption is thought to be going towards supplying its base flow for institutional processes that demand a constant supply of water (UBC Sustainability, 2011). UBC's water is bought solely from Metro Vancouver with no supplementary sources. Considering the amount of rainwater that UBC receives it would be wise to consider the option to build rainwater catchments and install a closed loop system as it can cut down the university's reliance on purchasing water from Metro Vancouver.

This system would be implemented on approximately 30 rooftops on campus each with their own cement cisterns built underground to store the water. Rainwater will hit the roof of a building (the catchment area) then runs into a gutter system that funnels the rainwater into the cistern. When needed the water in the cistern will be pumped out and used to supplement the building's base flow (Abdulal et al., 2006). Purification and filtration methods will be necessary for the water collected as it is to be used indoors.

The following formula was used to calculate rainwater that can be caught at UBC:

Vancouver's average annual rainfall (1120mm) x coefficient of runoff (0.9) x roof area (1,000,000m2) = Water volume (1,008,000,000 L/year)

A coefficient of runoff of 0.9 was used to obtain a rough estimate as not all water that hits the roof will be caught. (Chan et al.,2004)

UBC could implement these rainwater catchments feasibly and be on its way to becoming self-sufficient for its water needs and contribute to a sustainable way of living.

Cost Level Implications: The total cost will involve the consideration of all of the materials involved in the production of the system including pipes, pumps, reservoirs and filtration, the required labour for its construction and both the labour and materials needed for the maintenance of the final rainwater catchment system (Environment Agency, 2008). ~$200,000

State of development: Rainwater catchment systems have been used around the world since antiquity but recent larger scale projects have been implemented at many universities.

Other sites of implementation: Jamia Hamdard Univesrity, Delhi, India. (Ahmad, 2006) University of Dalhousie, Newfoundland, Canada (Abdulal, 2006)

Environmental Impacts: The different materials that were used in the construction of the different roofs have the potential to contaminate the water, although it is not being utilized for potable usage. Chances of overflow of the underground cisterns must be considered as they could severely impact UBC's soil and water balance.

Co-benefits of rainwater catchments: While the collection and reuse of rainwater is an effective way to provide water for multiple uses, it also simultaneously reduces the strain on the existing water infrastructure, and reduces the impact of storm water runoff.

Research Potential: The technology could be expanded to cover other water needs on campus.

Potential Controversy: As buildings at UBC are not uniform as each roof has a different drainage pattern. The amount of water that can be collected from these roofs will vary from building to building. The estimated litres of water that could be caught can be much lower or higher than preliminary studies such as these can predict.

Stakeholders: UBC Government, Metro Vancouver, UBC Plant Operations, Staff and students

Storm Water Collection and Treatment to the Potable Level:

Description:

UBC has pursued a natural systems approach to storm water management in the South Campus (Grigg, 2011). Such an approach has helped reduce cliff erosion, beautify public spaces, provide wildlife habitat and reduce the negative downstream impacts of surface water run-off (UBC Board of Governers, 2010). In the northern campus catchment, this approach is not possible due to the closeness in proximity that development has occurred to the cliffs. Currently, a single spiral drain exists (Urban Systems, 2010) and about 1,200,000 meters^3 of storm water flows through it annually and is released into the ocean. This number was derived from rough calculations based upon catchment area calculated through Google Earth (≈1 million m^2) and average rainfall (≈1.2 m). The storm water option would divert this flow to a filtration facility where the water would be treated back to a potable level and piped to the Powerhouse Booster Pump Station located at 2040 West Mall (Urban Systems, 2010), where all potable water enters the campus distribution system. This option would require extensive infrastructure requirements and the development of a water storage system either by an open pond or in underground storage tanks. The treatment process of storm water is comparable to water desalinization, in that it is highly energy intensive and requires pumping the water through a membrane system at vary high pressures (McArdle et al., 2011). An estimated 125,000,000 L/year of potable water would be contributed to the system by this option; however, this number is highly flexible and depends on the storage capability and treatment capacity of the system developed.

High-level cost implications*: Capital Cost: ~ $5,000,000+, Operational costs savings: ~ $-75,000 per year.

* Please refer to Appendix B for calculations

Status of Storm Water Harvesting Systems Around the World: Few storm water systems currently exist that treat the water to a potable level. Even fewer systems exist that contribute this water directly from the treatment plant to the potable system. Most of the systems treat collected storm water and then add this water to a large reservoir that contains the general water supply for a municipality. However, a recent case study into the viability of storm water treatment in Newcastle, Australia concluded that potable water could be produced at a cost of about AU$2.70 per m^3, and within the context of the value of water in Australia this cost is not a deal breaker (McArdle et al., 2011). As treatment and filtration technologies advance, storm water collection will become increasingly economically viable.
Environmental impacts: The collection of storm water will reduce the amount of this water that is released into the ocean providing benefits from reduced pollution. The process of treatment is very energy intensive and this option is likely to have a comparably large carbon footprint.
Demonstration Value: Because so few storm water collection systems currently exist, a system at UBC could provide numerous opportunities for research and academic involvement.
Potential Controversy: The option would be economically expensive. There may also be public concern over the safety of such a system because the water is contributed directly back into the potable system.
Stakeholders: UBC Government, Metro Vancouver, UBC Plant Operations, Staff and students

Developing an Assessment Tool

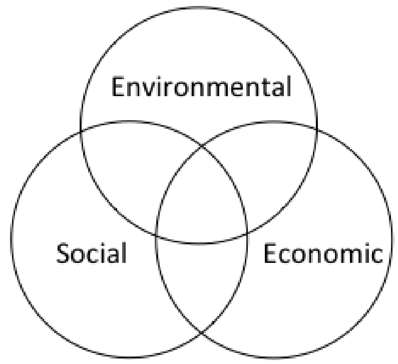
In 2010, The UBC Board of Governors adopted *The Campus Plan* to guide the management and development of the UBC Vancouver campus in a way that successfully meets the University's future academic and community needs.

The overall sustainability goals of this plan are to achieve:

> "…more sustainable, efficient, effective and convenient land use distribution patterns; integrated approaches to managing open space, energy and infrastructure systems; a pedestrian and cycling friendly campus and a socially engaging environment that fosters a thriving academic community (UBC Board of Governers, 2010)"

In regards to water conservation on the UBC campus, *The Campus Plan* does not establish clear objectives on how to evaluate possible water conservation strategies within the more general goal of a sustainable campus. Because of this, it was necessary to development an assessment tool that could act as a bridge between possible water conservation options and the overall sustainability goals of UBC.

This assessment tool is composed of a series of criteria and indicators developed within three the components of sustainability, these components being economic, social, and environmental objectives.



Each component was connected with a specific goal…

- **Environmental:** To reduce the ecological footprint of UBC
- **Social:** To promote and instill values of conservation and sustainability
- **Economic:** To ensure long-term financial feasibility of UBC's water system

All three of these components were split into several criteria and indicators. The environmental component contains water, energy, material, and temporal indicators. The social component accounts for social disruption, demonstration value, and public exposure. The economic component consists of capital costs, operational costs and a ten-year return on investment.

Also, not fitting in within any specific component, our assessment tool accounted for inherent risks within an option, the degree to which it diversified water sources to help build resiliency, and the flexibility it would have to link up with future water conservation initiatives.

This criteria and indicator sheet was developed to contain both quantitative and qualitative data to give a full representation of how each option might impact sustainability on the UBC campus. Because of this, it is designed to be a tool that informs planners on each option, rather than a tool that would rank each option and in essence make the decision for planners. This is especially important because sustainability is a flexible concept and the assessment tool should not be useful for only a single interpretation of sustainability.

Findings

Based on our set of fifteen indicators, we evaluated each of our five options to forecast their potential effects on environmental, social and economic sustainability. A full chart of our assessment is available in Appendix B.

Of particular importance was our measurement of the potential litres per year of input water reduced. Our first option, using groundwater for irrigation fared best in this sector. With irrigation and unaccounted water use taking up 21 percent of UBC's overall consumption, using groundwater for irrigation can significantly relieve demand. While it is unknown at present how much of the twenty one percent is actually used for irrigation and how much is leaked and unaccounted for, implementing irrigation by groundwater would allow UBC to more easily gauge its losses. This first option will allow for up to 500 million litres a year in input savings, although it will have no effect on the amount of exported wastewater.

The second option- using behaviour change programs to encourage a reduction in water use has a much less certain amount of savings. Based on our conservative estimate of one to three percent reductions in domestic use, this option will offer between 11 million and 33 million litres of savings per year, only a fraction of the capability of option 1. The behaviour change program option does offer the benefit of reducing wastewater output at the scale as imports. Our third option of using low-flow offers a small but quite certain amount of water conservation. This tried and tested option has potential of reducing both municipal water purchased and waste exported to the Iona treatment plant by 24 million litres per year. The next option of collecting rainwater for non-potable use has a much higher water conservation potential. This can reduce water purchased from the GVRD by about 300 million litres per year. The storm water collection option offers a modest amount of savings- of 125 million litres a year. Figure 1.1 summarizes these findings.

Fig. 1.1- Water import savings

Indicator	Option 1 – Irrigation using Groundwater	Option 2 – Behavioral Change Program	Option 3 – Low-flow washroom infrastructure	Option 4 – Rainwater for non-potable uses	Option 5 – Storm water for potable uses
L per year of input water from GVRD reduced.	~ 500,000,000 L/year	~ 11,000,000 to 33,000,000L/year	~ 24,000,000 L/year	~300,000,000 L/year	~ 125,000,000 L/year

Another important indicator that we have identified is the ten year return on investment. By combining the long term running costs, capital cost requirements, and potential savings, we have found that the most economically favourable option is using storm water for irrigation at around 4100%. This results from a combination of a high water savings potential, an opportunity for UBC to identify leaks and faults in the current system once irrigation is supported by a local water supply. Rainwater collection also ranks high in potential return on investment at approximately 700% over ten years. This likely results from relatively low capital cost requirements with gravity driven collection devices. The third option of retrofits offers a positive, predictable but modest return on investment of 16 percent. Since ECOTrek has already improved the most inefficient fixtures in buildings, the potential savings are limited as a result. Both the behaviour change program and storm water treatment option have potentially negative returns on investment. The storm-water system has prohibitively high capital cost requirements while the behaviour change program has limited and unknown savings potentials.

One of our unique indicators that we believe is the diversification of water source supply for emergency resilience. Recognizing the important advantage of having potable or near potable water supplies ready on campus in the event of failure of municipal supplies, we have identified three options that diversify UBC's emergency water supplies. Ground water harvesting, rain water capture, and storm water treatment all involve some form of storage of freshwater. This water can be treated and consumed in an emergency.

Recommendations:

The following are our recommendations for UBC ranked in order of how they did against our sustainability assessment tool. Although we have put forth one option as the best we do not believe that only one should be considered for implementation. Rather, we believe that UBC should look into a variety of options as there is no single answer when it comes to water conservation.

First Choice: Groundwater for Irrigation- This was our first choice as it ranked highest in our sustainability assessment tool. Although it is a BAU option and would not be groundbreaking, this system was found to have a high ROI, low environmental risks if managed properly, able to use low-impact materials and would cut down on UBC's reliance on water bought from Metro Vancouver by being a closed loop system. However, this system will come with an increase in energy use, a medium research potential and potential risk from seismic activity.

Second Choice: Low flow infrastructure and retrofitting- This option did not do as well in our sustainability assessment tool. Although it will be highly effective in conserving water the high cost level implications and the amount of construction required of this option make it our second choice. This option would decrease energy use, has a low risk and would reduce consumption and wastewater. It is certainly a BAU option as it has had a widespread implementation. Although many low flow fixtures were implemented at UBC during the EcoTrek program we recommend UBC to consider implementing dual-flush toilets, more motion sensor faucets in core buildings and residences, and installing low-flow infrastructure in all future buildings on campus.

Third Choice: Rainwater harvesting for non potable use- This was our third choice due to it being an unproved system and because it would not reduce the amount of water consumed, just diversify the source of the water. This option had a very high ROI and would be a very feasible option to implement at UBC. Considering the amount of rainfall the campus receives this system would also be the least disruptive in attaining an alternative source of water. One drawback to this system is that it can only be heavily relied upon during the winter months when there is an exceptional amount of rain but cannot be relied upon in the drier summer months.

Fourth Choice: Behavioral Change Program- This was our fourth choice as the results and efficacy of any behaviour change programs cannot be easily or accurately predicted without a pilot program. A behaviour change program would involve low cost implications and has the potential of being a very effective method for encouraging water conservation. However, this program would have a very low overall impact on how much water is conserved. We believe that this program would work best in conjunction with advanced demand monitoring systems. While the installation of smart meters does increase the capital costs, the meters provide many ancillary benefits and will serve numerous purposes beyond gauging behaviour change programs.

Fifth Choice: Storm water for potable use- This option ranked last against our assessment tool as we did not find it would be a desirable option for water conservation at the UBC. It did not score well in any of our meta-categories. However the main reason for it being our last choice was because of how high the costs of implementation would be. We believe it would only be an economically efficient initiative when other alternatives for water conservation or reuse do not exist. Conditions that may make this option more feasible in the future at UBC are a dramatic increase in the price of water, a decrease in purification technology's cost and energy demand, and a well thought out mechanism for managing, storing and transporting the storm water in a way that is low risk.

Limitations:

Data:

One of the major limitations faced by our group in this project was access to accurate and recent data. Access to most data that was relevant to our options was restricted or not available at all. For the retrofit option our group wanted to compare the data from the ECOtrek project, however the details of that project are not publically available. Also for the groundwater for irrigation option the financial details were very difficult to obtain – including the price of the wells and other equipment. Some of the data could have been obtained by getting in touch with the respective agencies, but was not possible due to factors like time.

Sustainability:

As there is no universal definition of sustainability each group attempting to achieve sustainability through their project would have to come up with their own understanding of the term 'sustainability'. This along with UBC's lack of detailed objectives for future projects left our group in a situation whereby we had to figure out these details before looking into the project options themselves.

Assessment Methodology:

While evaluating our options and providing a recommendations list to UBC our group did not use a quantitative and ranking scheme. Instead we used our assessment matrix and discussed out the options while making a pros and cons table. The eventual recommendations list was made through subjective decisions made by the consensus of the group members. This approach has both its advantages and disadvantages. This method allowed us to not simply numerically rank the options and pick the one that topped the ranking chart, but instead were based on critical thinking done by not just one but five people. Also the final recommendations list is not the one that we came up with at the first time; we have revised this list a couple of times. However, as there is a lack of a method of ranking and the judgment is subjective the list can be challenged and changed, given more details and data for the options.

The qualitative indicator choices made in the assessment matrix – high, medium, and low – can have different interpretations by different people. What one person might think of the term 'high' vs. 'low' might be different from another person's perspective and thus the evaluation of some of the indicators would be seen differently by different people.

Reflection:

Project:

APSC 364 is quite a time demanding course. To research for water conservation option, then running them through an assessment matrix and finally recommending UBC the options that should be adopted requires a lot of time. However, as the course only runs for a term and thus just for 4 months, our group found that we had to rush through some sections of the project and were not able to provide the time that was needed for those sections. For example: carrying out our own group field research, getting accurate data, etc.

As all the group members were from different backgrounds it was helpful as we all approached the project in a unique way. This project gave a platform for all the different scopes of education to come together and develop something useful for UBC plant operations. With a group consisting of people from different backgrounds – commerce, arts, science, forestry - helped cover most aspects of a project, including the financial, social, environmental and scientific. However, as none of the group members were an expert on the topic being researched this limited the quality of the final product of the project in some ways. We all were not fully aware as to how the UBC plant operations work neither had any of us worked on any big project development. Due to lack of time and expertise some assumptions for the project had to be made. To list a few – it was assumed that the price for water bought and sold would remain constant over the next ten years; all systems being installed will be done so without any problems with the governing bodies; and all projects can be up and running in about the same amount of time.

Group Dynamics:

Even though our group started as two groups and when we were merged as one group we were skeptical on how things would work out. However, in retrospective what happened was for the better. As the group was big compared with other groups we had trouble finding common meeting timings, but other than that a bigger was better for the output for the project. We could each explore a different option and then educate the rest of the group on that option. Also as a bigger group we were able to explore the options and the project as a whole from numerous angles and perspectives which we might have missed out if we were a smaller group.

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APPENDIX 1: Matrix for Criteria and Indicators

Criteria	Indicator(s)	Objective	Justification
Water Conserved	L of input water from GVRD reduced. L of output water to Iona Island reduced	To become more sustainable, UBC should look to lessen the University's ecological footprint caused by water consumption and effluent discharge. It also looks to reduce its expenditure and overall dependency on potable water imports and wastewater exports to and from Metro Vancouver	This indicator will measure how much water is conserved from both the input water system to UBC and the output system from UBC to Iona, taking into account both the upstream and downstream impacts of the UBC water system
Energy Use (Indirect Measure of GHG Emissions)	Circle one: 1. Decreases energy use 2. Little to no effect on energy use 3. Increases energy use	Despite electricity in BC largely being produced through hydro generators, there are still significant environmental and social concerns associated with new power generating projects, including GHG emissions. Reducing energy use is an important sustainability goal for UBC to help British Columbia meet its conservation needs.	Even though energy and water are resources that are intimately linked, the information at our disposal only allows us to make a rough estimate on how each option might impact campus energy consumption
Changes in Temporal Distribution of Water Flow	Does option conserve water during times of peak flow or stress? Circle one: 1. Yes 2. No	The value of water is highly variable throughout different times of the day and different times of the seasons. It is during these times, when the most stress is on the water infrastructure, that water conservation should be targeted.	Generally, an option that conserves significant portions of water during the summer months or during the morning to mid afternoon would be given a yes in this indicator. This is a flexible indicator that will need to be adapted and judged a little differently for each option, however, that does not mean that is is of any less value.
Use of low impact materials and Infrastructure	Will this option be material intensive Circle one: 1. High Intensity 2. Medium Intensity 3. Low Intensity	To account for the environmental footprint of new infrastructure developments, the project should aim to use low impact materials that have minimal environmental impacts on a life-cycle basis of evaluation.	It is difficult for us to evaluate this indicator with the limited information that we have however we feel that it is an important consideration when evaluating any new infrastructure addition through a sustainability perspective.
Degree of Social Interruption	Are deliberate changes in behavior required for effectiveness? Circle one: 1. Significant and disruptive 2. Significant but non-disruptive 3. Insignificant	The social impacts of the project should maintain convenience for users and stakeholders and their behavioural patterns to help ensure effectiveness of implementation and prevent a reduction in quality of life.	While promoting sustainable thinking is always a good thing, some changes in sustainable living may not be viewed favorably by the general public. This indicator seeks to take account for any inconvenience cause by an option.

Demonstration Value	Would a successful demonstration of this option contribute significantly to its implementation elsewhere? Circle one: 1. Innovative 2. BAU Research Potential: 1. High 2. Medium 3. Low	As a public institution and leading centre of research, UBC should be committed to being a catalyst for sustainable development throughout BC and the rest of the world. To do this, it should take on projects that will generate new data and new examples of sustainability in action.	UBC can be a leader in sustainability by adopting highly innovative options to conserve water as to encourage their implementation elsewhere. Research potential can be a valuable method for catalysing change elsewhere. Research potential of an option is critical in determining its long-term worth to society.
Transmission to Population	Amount of direct public exposure (estimated range annually) 1. Low (0-100) 2. Medium (101-1000) 3. High (1000+) (Indirect exposure will likely correlates with demonstration value)	As a public institution, UBC should seek to instill values of sustainability both with those who directly participate in activities on campus and those who may learn about sustainable initiatives on campus through indirect means such as a newspaper.	This indicator shows how many people will be directly exposed per year to a conservation option. Because indirect exposure would be much harder to evaluate it is omitted. However a correlation between demonstration value and indirect exposure would be expected
Costs	ROI 10 years (%) Capital Cost Requirement ($) Net Operation Cost Savings ($/yr)	In addition to ecological concerns, UBC has powerful financial incentives to monitor and and reduce its water consumption. Options should be financially responsible if they are to be funded with public funds or student tuition payments.	Looking at ROI would show if a system is cost-effective in the long-run. Capital costs represent the cost of taking an idea from paper to real life implementation. Net operating cost savings compares the cost of an option per year to the value of water conserved. A positive number would represent money saved.
Associated Risks	Are their significant financial risks associated with the project? Circle one: 1. High 2. Medium 3. Low Potential environmental and other impact risks (list)	Every action comes with an inherent level of risk. Understanding the likelihood and severity of such risks will help guide more responsible decision making	Financial risk can have a single consequence of losing money and us this simplified into high medium and low. Environmental risks can be multidimensional and should be described in more detail
Diversification of Emergency Water Sources	Does this provide an additional source of water for use in regional emergencies?	An objective should be to improve the safety and security of resources in the event of an emergency.	In general, more diverse systems are more robust system. Additional inputs of water could be valuable during extreme events.
Flexibility	Compatibility with future sustainable water management systems. 1. High compatibility 2. Medium compatibility 3. Low Compatibility 4. No Compatibility	Water conservation options should aim to be compatible with existing and future projects as this would lead to more room for research and improvement.	This indicator is to help ensure systems do not become outdated and obsolete, existing systems must be modular and easy to upgrade.

APPENDIX 2: Evaluation of Each Option

Indicator	Option 1 – Irrigation using Groundwater	Option 2 – Behavioral Change Program	Option 3 – Low-flow washroom infrastructure	Option 4 – Rainwater for non-potable uses	Option 5 – Storm water for potable uses
L per year of input water from GVRD reduced. L per year of output water to Iona Island reduced.	~ 500,000,000 L/year N/A	~ 11,000,000 TO 33,000,000 L/year ~ 11,000,000 to 33,000,000L/year	~ 24,000,000 L/year ~ 24,000,000 L/year	~300,000,000 L/year 0 L/year	~ 125,000,000 L/year 0 L/year
Energy usage in comparison with BAU usage. Circle one: 1. Decreases energy use 2. Little to no effect on energy use 3. Increases energy use	Increase energy use: New pumps to access ground water would require an increase in energy	Decreases energy use: Decreased water use would decrease energy footprint of system	Decreases energy use: New low flow infrastructure would not be any more energy intensive than older infrastructure; it reduces water use and thus energy consumption	Little to no effect on energy use: Increased energy use from treatment may be compensated by decrease in energy use through conservation of water	Increases energy use: Filtering and pumping process involved in this option are very energy intensive
Will this option be material intensive Circle one: 1. High Intensity 2. Medium Intensity 3. Low Intensity	Medium intensity: New well construction will be required but much of the piping infrastructure will remain intact	Low intensity: May require materials like brochures and posters but no new major developments	Medium intensity: Changes in fixtures should not require any major changes in the piping infrastructure	High intensity: Secondary piping infrastructure will be needed to create a secondary non potable system for base flow	High intensity: Storage system and treatment plant will require significant new materials and construction
Does option conserve water during times of peak flow or stress? Circle one: 1. Yes 2. No	Yes: Irrigation occurs during summer months when Vancouver faces a water deficit.	Yes: Public awareness campaigns will likely reduce peak and average demand approximately equally by encouraging end users to use less	No: Majority of savings are during winter when campus is busiest and water is more plentiful. Peak flows are not expected to be significantly reduced	No: Unless sufficient storage capacity is created, option may not be operational in the summer months	No: Lack of storm water run-off during summer months would prevent full year implementation.
Are deliberate changes in behavior required for effectiveness? Circle one: 1. Significant and disruptive 2. Significant but non-disruptive 3. Insignificant	Insignificant: Change would only be for the people working in that area as they would have a major access to the system.	Significant and disruptive: Success of the option is dependent on deliberate changes in user's behaviour that may be viewed as disruptive	Significant and non-disruptive: Changes may be required in the way water services are implemented but not in the quality of the water service itself	Insignificant: Change will not require deliberate behavioural change	Insignificant: However, there may be concerns over the safety of direct water reuse, and this could be seen as disruptive to the social order
Would a successful demonstration of this option contribute significantly to its implementation elsewhere? Circle one: 1. Innovative 2. BAU- (Business As Usual)	BAU: Groundwater has been used as a resources for thousands of years	Innovative: Instantaneous metering, conservation competitions and workplace training are now just starting to be implemented.	BAU: Although several places in North America have already begun to use low flow infrastructure, a demonstration of this option would not have a significant impact to other universities.	Innovative: Rainwater harvesting systems usually exists on an individual building scale and a single large incorporated system would be highly innovative	Innovative: While water reuse projects for the potable water supply are taking hold elsewhere in the world, there is a reluctance in North America to consider these types of projects (Soroczan, 2002).

Research Potential Circle one: 1. High 2. Medium 3. Low	Medium: There is a potential to research to study the affects of such systems on groundwater (eg: on the water table) and how more sustainable systems can be developed using groundwater harvesting.	Low: The public sector may be interested but there is little opportunity to profit from this.	Low: Low flow fixtures are commonplace in many parts of the world and they would not likely generate new research at UBC	High: Large scale rainwater harvesting could have numerous educational and research opportunities	High: Both technical and social research could be carried out of the operation and perception of these systems.
Amount of direct public exposure (estimated range annually) 1. Low (0-100) 2. Medium (101-1000) 3. High (1000+) (Indirect exposure will likely correlates with demonstration value)	Low: Only operations staff would be directly exposed to the development of a new system Exposure can be increased by providing courses or field trips for this system	High: Success of option depends on it reaching out to large amounts of people	High: All users of the public facilities at UBC are likely to be exposed to these changes in fixtures	Low: Only operations staff would be directly exposed to a new rain harvesting system	Low: Only operations staff would be directly exposed to a new storm water collection system
ROI 10 years (%) Capital Cost Requirement ($) Net Operation Cost Savings ($/yr)	ROI: ~1500% Capital: ~$135,000 Net Savings: ~$100,000/year	ROI: -70% to 70% Capital: ~$200,000 Net Savings: ~$7,000 to $35,000 per yr	ROI: ~15% Capital Cost: ~$1,000,000 Net Savings: ~$20,000	ROI: ~700% Capital Cost: ~$200,000 Net Savings: ~$150,000	ROI 10 years: -15% Capital Costs: ~$5,000,000 Net Savings: ~$-75,000
Are their significant financial risks associated with the project? Circle one: 1. High 2. Medium 3. Low Potential environmental and other impact risks (list)	Low: It is a mature system that has been well researched and is used widely around the world. Hence, less chances it will cause financial risks. Potential disruption in environment when wells are dug May cause disturbance in water table and surrounding environment	Low: There are very few capital costs associated with marketing campaigns. No potential environmental risks	Low: Low flow infrastructure has proven to be reliable and cost effective No potential environmental risks	Medium: Smaller scale projects have been cost effective but little is known about the risks of a larger system No potential environmental risks, potential water to be harvested does not provide a service elswhere	High: Project would require significant engineering and technical challenges and there are few comparison projects to truly assess risks involved Destabilization of the cliffs due to increased development and altered hydrology Potential public backlash to the project over water quality concerns
Diversification of water source supply for emergency resilience. 1. Yes 2. No	Yes	No	No	Yes	Yes
Compatibility with future sustainable water management systems. 1. High compatibility 2. Medium compatibility 3. Low Compatibility 4. No Compatibility	Medium - High compatibility: Even though it is a closed system that would not interlink with future sustainability initiatives. the water from the ground can be used for other systems.	High Compatibility: Public behavior change programs can integrate with the introduction of new technologies	High Compatibility: Potential of Retrofitting low flow infrastructure and adding in dual flush toilets could increase in the future	High compatibility: Many potential (future) uses for the stored rainwater and new systems could be linked to this system	Medium Compatibility: Provides new water source but could interfere with sustainable energy initiatives

APPENDIX 3: Calculations and Other Supporting Details for Evaluation of Options

Option 1: Irrigation

Costs:
Capital:
- Wells = 5 on average for $100,000 (Water: UBC Sustainability, 2011)
- Pressure pumps/tanks = $2000 x 5 = $ = $10,000 (Agricultural Sprinklers)
- Irrigation System = $ 10,000 (ref)
- Other Equipment (if needed) = approximately $5000
- Total = ~ $135,000

Net operational cost savings:
- Net savings - Net operational costs = $300,000 - $101,200 = $197,600 = approx. $200,000

Net Operational Costs:
- Worker payments = Average $20/person/hour and at 20 hours per week for a year (considering the system does not run year round) = $20,000 /year x 5 workers = $100,000/year
- Office equipments and services costs = $100/month = $1,200/year
- Maintenance costs for the system are very minimalistic.
- Total = $101,200

Net Savings from reduced water purchase:
- Water savings = 500,000,000 L/year = 500,000 cubic meters/year
- Cost of water = $.60/cubic meter (Water: UBC Sustainability, 2011)
- 500,000 x 0.60 = $300,000/year - savings

ROI (for a ten year period):
= (savings from investment over 10 years/cost of investment) x 100
= (200,000x 10)/135,000 x 100 = 1481.481% = approx. 1500%

Option 2: Behavior Change

Capital:
- 40/60 meters for academic buildings x 5000 = $200,000
- Dashboard website upgrades to include water usage and costs: $5000

Net Operational Costs:
- Negligible maintenance
- New work-study position: 56 wk x 10 hrs/wk x $12 = $6720/yr
    - This work-study position will design promotional displays to encourage water use reduction based on monthly water usage data.

Net Savings from reduced water purchase
- 1-3 percent savings in domestic use
- 11292307 to 33876921.6L annual usage savings
- Cost of water = $.60/cubic meter
- Purchase reduced
    - Low: 15,553 x 0.60= $9332/yr
    - High: 46,660 x 0.60 = $27996/yr
- Water treatment reduced
    - Low: 15,553 x 0.30 = $4666/yr
    - High: 46,660 x 0.30 = $13998/yr

ROI:
High: Annual operations savings: ([(27996+13998-6720=35274) x 10] - 205000) / 205000 = 72%
Low: Annual operations savings: ([9332+4666-6720=7278) x 10] - 205000) / 205000 = -64%

Option 3: Retro-fitting Low-Flow Infrastructure

Capital:
$48,740 + $509,970 + $666,660 + 6,000 (40 hours of labor * 150 rate) = ~$1,230,000

	Number of units	Price per unit	Total Price	Water saved in gallons per unit	Total Water conserved
Retrofit low flow toilets	2,000	$24.37	$48,740	803	7,300,000L
Retrofit low flow sensered faucets	3,000	$169.99	$509,970	654 [3]	8,927,100L
Installing new dual-flush toilets	2,000	$333.33	$666,660	803[4]	7,300,000L
Operational costs	-	-	$4,000.00	-	-

Option 4: Rainwater Harvesting
Water Savings Estimation:
The following formula was used to calculate rainwater that can be caught at UBC:
Vancouver's average annual rainfall (1120mm) x coefficient of runoff (0.9) x roof area (300,000m2) = Water volume (300,000,000 L/year) (Grant et al. 2002)
A coefficient of runoff of 0.9 was used to obtain a rough estimate as not all water that hits the roof will be caught.
Volume of water contributed: ~300,000,000 L/year

Cost Estimation:
Capital Cost: Involves materials such as piping, storage container, and basic filtration system
Materials:

- Piping = $199.50
- Drainage Screens: $69.50
- Pumps
- Cement tank: 30,000L = 6,810.62 USG = $6,810.62 (i.e. 1$/USG)

Operational Cost: Involves labour costs for pipe fitters, plumbers, building the storage container, and maintenance

- Pipe fitter's wage: $27.43/hr Plumber's wage : $25.55/hr (Chan et al, 2004. Abdulal et al, 2006)

Option 5: Stormwater

Water Savings Estimation:

4. Water purification system capacity: 500 m^3/day
5. Days to remain operational in a year: 250 days
6. Volume of water contributed: 125,000,000 litres (500 m^3/day • 250 days)
7. Estimated volume of stormwater storage system to ensure sufficient input quantities throughout yearly cycle of operation: 10,000 m^3 (20 day reserve)

Cost Estimation:

3. Estimated capital costs
    a. #1 Estimate: $10 million (Sibley, 2010)
    b. #2 Estimate: $2,180,640 (Filteau & Moss, 1997)
    c. Average: ($10,000,000+$2,180,640) / 2 ≈ $5,000,000
4. Estimated operational costs
    a. Production cost per m^3 output: $1.20/$m^3$ (Drioli & Macedonio)
    b. Gross Production Costs: $1.20 / m^3 • 125,000 m^3 = $150,000
    c. Value of Water Savings: $0.60 / m^3 • 125,000 m^3 = $75,000
    d. Net Operating Costs: $75,000 - 150,000 = -$75,000
    e. ROI Ten Year: [($75,000 / year • 10 years) / $5,000,000] • 100 = 15%