UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Sustainable Stormwater Management at UBC: An exploration of the South Campus Catchment

John Arnett, Brad Hignell, Alexandra Hlynka, Rosalind Sadowski

University of British Columbia

APSC 364

March 27, 2012

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John Arnett

Brad Hignell

Alexandra Hlynka

Rosalind Sadowski

Table of Contents

Introduction 2

-Current Stormwater Management Practices and Policy 2

-Challenges and Goals 4

Methods 6

-Criteria Matrix 7

Options 9

1 .0 - Detention Pond Servicing the UBC Farm 9

1.2 - Detention Pond Servicing the UBC Farm & Botanical Gardens Nursery 9

2.0 - Mandate for Greenroof Incorporation on New Developments 10

3.0 - Greenroof Retrofit on Thunderbird Parkade 11

Conclusions 13

Recommendations 15

Reflection 16

- This page has been extracted

Appendices 17

-Appendix A: *Option Location Map* 17

-Appendix B: *Additional Considerations for the Detention Ponds* 18

-Appendix C: *Detention Pond Size Calculations* 21

-Appendix D: *Cumulative Irrigation Metering Data* 22

-Appendix E: *CMHC Model for Detention Pond Construction Costs* 23

-Appendix F: *Construction Costs for Detention Pond* 24

-Appendix G: *Pond Parameter Calculations* 26

-Appendix H: *Additional Pond Costs* 27

-Appendix I: *Criteria Matrix* 28

References 32

i – Introduction

The field of stormwater management at UBC presents several opportunities to contribute to the university's sustainability and climate objectives. Management practices have evolved considerably throughout past years to reduce environmental impacts. However, UBC can take additional steps to manage stormwater as a resource, in order to reduce environmental and economic costs to the university.

Current Stormwater Management Practices and Policy

The UBC Vancouver campus consists of four stormwater catchment areas. This report focuses on the South Catchment area. This watershed receives on average 1200mm in annual rainfall[1]. The soils approximately consist of 0.5m of organic topsoil, which rests above 30m of relatively impermeable glacial till[2]. This unique combination creates considerable runoff, which currently causes severe erosion, but could be captured and re-used. UBC has started to adopt alternative management practices, as exhibited by the stormwater management features in the Wesbrook Village development.

UBC purchases its water from Metro Vancouver. Water is a valuable resource to the UBC campus; however, water pricing poorly captures this value. BC boasts some of the cheapest water rates in Canada, and Canada's municipal water prices are amongst the lowest in the world[3]. UBC pays \$0.68/m^3 in the off-peak and \$0.88/m3 during the peak season (June-September)[4].

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1 Alpin & Martin Consultants and Holland Barrs Planning Group. (2005, January). *A sustainable drainage strategy for the south campus neighbourhood*.

2 Ibid.

3 Sustainable Infrastructure Society. (2011). *Water pricing.* Retrieved from http://www.waterbc.ca/community/programs/long-term-financial-planning/water-pricing-plan/

4 The University of British Columbia. (2011, May). *Water Action Plan Discussion Paper*. Retrieved from http://sustain.ubc.ca/sites/sustain.ubc.ca/files/Discussion%20Paper_Water_FINAL_updated-May2011_4.pdf

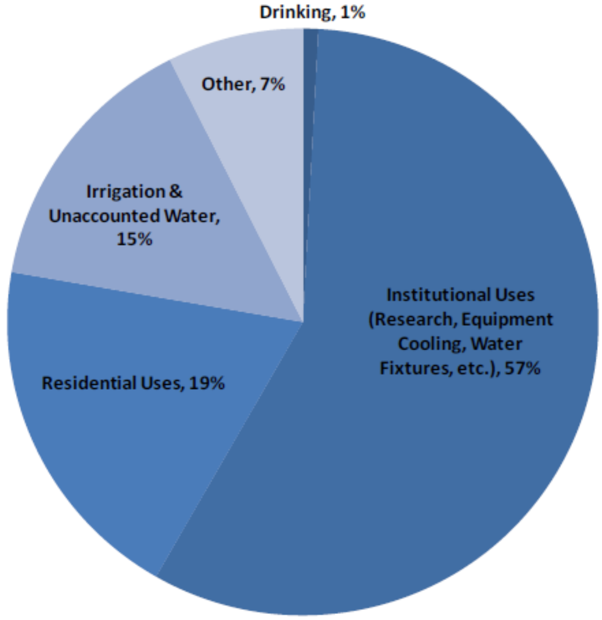

Figure 1: Estimated Composition of UBC's Water Demand (137L/s)[5]

The water supplied by Metro Vancouver is piped over 20km, from either the Capilano or Seymour reservoirs, before it reaches the Vancouver campus. Figure 1 depicts the various sources of demand for UBC's water supply. Irrigation represents 15% of this demand, which could almost entirely be supplied by stormwater re-use. Currently, stormwater is channelled through a series of pipes on campus that lead to one of four outfalls.

A number of regulations and jurisdictions govern stormwater management at UBC. These include:

- Provincial: The BC Ministry of Water, Land and Air Protections sets and controls water quality standards to maintain consistent quality across the province[6]. The BC Ministry of Environment also determines permitted uses of storm water for irrigation under Municipal Sewage Regulations.
- Municipal: Metro Vancouver recommends municipalities manage stormwater on a watershed basis, as a complement to broader land management and ecosystem planning. Metro Vancouver also publishes a series of Stormwater Source Control Guidelines[7], which provide information on best practices for stormwater management.

5 Ibid.

6 British Columbia. Ministry of Agriculture, Food and Fisheries. *Treating irrigation and Crop Wash Water for Pathogens.* [Abbotsford] January 2003.

7 Metro Vancouver. (2011). *Stormwater management*. Retrived from http://www.metrovancouver.org/services/wastewater/sources/Pages/StormwaterManagement.aspx.

-Vancouver campus: As an owner-operator, UBC controls the majority of its infrastructure and resource regulation. UBC Utilities serves as the main regulatory body; they oversee water distribution, natural gas distribution, steam distribution, storm drainage, sanity sewers, and power utilities[8]. Stormwater management intersects with a number of official UBC plans and policies, which were incorporated into the decision matrix. Please refer to the Criteria Matrix subsection of "Methods".

Challenges and Goals

As noted in the South Campus Northeast Sub-Area Neighbourhood Plan, "the general strategy for South Campus drainage is to retain rainfall from small, frequent events, detain rainfall from larger events, and convey runoff from extreme events"[9]. Major shortcomings of the current stormwater management system, as identified in the Sustainable Drainage Strategy for the South Campus Neighbourhood include:

- Erosion: the Peninsula Cliff faces have been severely degraded through erosion. Run-off from increased development and infiltration challenges, due to the campus' unique soil structure, contribute significantly to this issue.
- Lack of re-use: Stormwater management represents an opportunity to create a closed-loop resource management system at UBC, as this water could be captured and re-used to reduce potable water consumption.
- Water quality: At the outfalls, water testing revealed higher than acceptable levels of various metals. Water quality must be addressed to enable stormwater re-use and ecosystem preservation[10].

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8 UBC Properties Trust, "A Sustainability Drainage Strategy for the South Campus Neighbourhood" January 2005

9 University of British Columbia. (2005, January). *South campus northeast sub-area neighbourhood plan.*

10 Alpin & Martin Consultants and Holland Barrs Planning Group. (2005, January).

In addition to these ecological concerns, UBC must also adapt to expected population increases. UBC aims to significantly increase its population of permanent residents. Utown@UBC currently hosts a population of 16,500 residents, and the university expects a near doubling in permanent residents, bringing the population to an estimated 30,000 by 2025[11]. This increase will result in 24 hectares of new residential land and approximately 2000 new housing units, up from the current 800 units. South Campus will thus experience a substantial increase in building footprint[12].

In order to address some of these concerns and developments, UBC has adopted a number of goals. Some of the most relevant to this project include:

Reductions in Municipal Water Purchases

- 2015 Target: Reduce potable water use for irrigation by 50%
- 2020 Target: Reduce potable water use for irrigation by 75%[13]

Run-off Coefficient

UBC mandates all new developments must maintain the existing run-off coefficient of 30%, which allows for 70% infiltration[14].

11 Robinson, J. (2012, Jan 17). *Next Generation Sustainability at UBC*. Presentation to APSC 364, University of British Columbia, Vancouver, BC.
12 University of British Columbia. (2005, December 8). *UBC Comprehensive Community Plan*.
13 Paderewski, A. (2012, January). *Stormwater for irrigation: Student project idea exploration* [Presentation slides]. Retrieved from http://blogs.ubc.ca/apsc364/category/alicias-group/.
14 Ibid.

ii – Methods

The four options presented in this report represent the final outcome of several phases of research. In Phase 1, we analyzed the current state of stormwater management at UBC, applicable rules and regulations and the potential environmental, social and economic implications of any decisions. In Phase 2, taking into account the scoping document and the needs of our client, we developed four options for consideration. These included:

1) Green roofs
2) A detention pond for the UBC Farm and for the Plant Operations' Nursery
3) Turfstone pavers
4) Household rainwater collection campaign

After further consultations with our client, we chose to modify and in some cases eliminate certain options. The final recommendations evaluated in Phase 4 are outlined in the third section of this report titled "Options".

- The green roof option was developed as two options; a retrofit of the Thunderbird parkade and as a criteria for new development.
- The Plant Operations' Nursery was discarded, as it was determined that no above-ground detention facilities could be built anywhere on campus besides the UBC Farm. As such, we chose to develop two locations for a pond on the Farm; one pond to service only the Farm, and one pond to service both the Farm and the Botanical Gardens Nursery.
- Turfstone pavers were deemed incompatible with UBC's unique geography. While increased infiltration is typically a desirable stormwater management outcome, UBC's soil composition and erosion issues do not allow for infiltration-based alternatives. Although it may be a viable option for the northern section of campus, there are not enough 'paved' areas at the Farm, Gardens, or UTown@UBC that are required to see results.

- The recommendation to engage households (users) with rainwater management would have to be directed to the University Neighbourhood Association, as they administer household-level projects in South Campus neighbourhoods. As such, this was not an applicable recommendation for our clients who are affiliated with UBC core operations.

Criteria Matrix

During Phase 3, we developed a set of criteria with which to evaluate proposed options. In determining these criteria, we analyzed UBC's policies, plans and agreements, and developed an A, B or C ranking as indicators. Certain plans were highlighted as most relevant to this project:

- UBC Vancouver Campus Plan
- Sustainability Academic Strategy
- Place and Promise Strategic Plan
- Inspirations and Aspirations report
- Sustainable Drainage Strategy
- Cliff Erosion Mitigation Plan

We chose to assign a numeric value to each A, B or C ranking so their sum would give a numeric score for each option. An 'A' ranking is most desirable and was awarded 3 points, a "B' ranking was awarded 2 points, and a 'C' ranking is least desirable and is awarded 1 point.

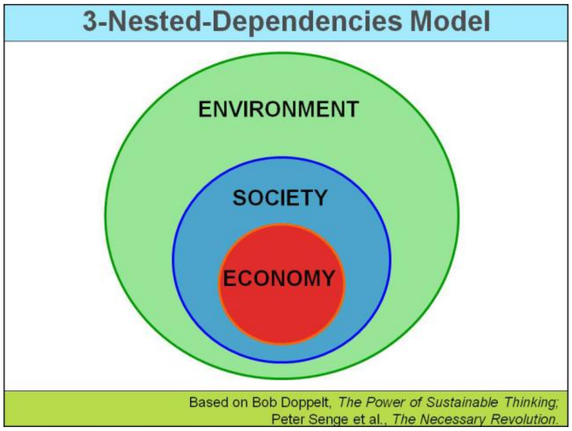

Figure 2: Conceptualizing 'Sustainability'[15]

Overall, we wanted our options to be "sustainable", which is difficult to measure, as UBC chooses not to use a unified institutional definition of the concept. We chose to begin with the traditional 3-dimensional definition, which divides "sustainability" into environmental, social and economic realms.

We felt the model of 3-nested dependencies, shown in Figure 1, most effectively acknowledges how the economy can and should only exist within a thriving natural and social environment. Nonetheless, we recognize that financial considerations serve as a bottom-line for all university decisions. We believe the red colour of the economy circle in this model emphasizes the centrality and necessity of financial sustainability. Using this model as our basis, we believe our criteria reflect both the over-arching importance of environmental conservation as well as the need for financial feasibility. To review the decision matrix, please refer to Appendix I.

15 Willard, B. (2010, July). *3 sustainability models*. Retrieved from http://sustainabilityadvantage.com/2010/07/20/3-sustainability-models/

iii – Options

1.0 – Detention Pond Servicing the UBC Farm

1.2 – Detention Pond Servicing the UBC Farm and the Botanical Gardens Nursery

A detention pond would be created to serve as a reservoir for irrigation for the UBC Farm. In addition it will regulate peak flows by acting as an equalization basin and has potential to act as a habitat for native plant and wildlife species. As well, biophysical processes can occur in the pond that can break down potential pollutants, improving runoff quality.

Size, cost, and payback period for the pond options are found below in Table 1. The 2009 estimates are for a very dry summer, so a pond of this size would not be necessary for an average year, but would be necessary if UBC was planning on maintaining full irrigation supply throughout very dry summers. The 2011 figures are more indicative of a slightly drier than average year. For more detail see Appendix D. These payback times are very long, but would be reduced if the price of water increases, which is not unlikely.

OPTION	Runoff Shortage [m3]	Pond Size [m3]	Capital Cost [$CAD]	Payback Period [years]
Farm, 2011 data	2500	3250	237 000	90
Farm + BGN 2011	6100	7930	450 000	61
Farm , 2009 estimate	4700	6110	337 000	114
Farm + BGN 2009 estimate	17500	22750	817 000	113

Table 1: Size, cost, and payback period for the pond options.

Two scenarios were examined for both detention ponds. The first scenario used a slightly drier than average summer, as gathered from 2011 irrigation metering data for the South Campus and 2011 monthly Environment Canada rainfall statistics for Vancouver[16]. The second scenario examined a very dry summer using 2009 rainfall statistics and derived monthly irrigation quantities. Runoff from rainfall was calculated and subsequently subtracted from irrigation volumes. Positive numbers indicate that irrigation demands are greater than available rainwater and stored water would be needed to supply the difference. Monthly shortages were cumulated to determine the necessary reservoir volume.

Both detention pond options scored 38 points in the decision matrix, as seen in Appendix I.

-For project location refer to Appendix A.

- For design particulars of the pond refer to Appendix B.

-For pond size calculations, refer to Appendix C.

-For installation costs refer to Appendices E and F.

2.0 – Mandate for Greenroof Incorporation on New Developments

UBC intends to substantially increase the South Campus population. We propose that 50% of new developments in the area be required to build extensive green roofs. This is an attractive option for a numerous reasons, including mitigation of urban stormwater runoff, increased natural habitat, aesthetic benefits, and potential for rainwater collection. In addition, green roof implementation can deliver between three and 13 LEED points, which can be beneficial for developers[17].

With these development targets, we can expect to see building footprint increase from 17% (current), to a projected 30% by 2025 (based off of current densities and footprints)[18]. We estimated that the total increase in building footprints within the South Campus catchment would be 131,800 m^2. A mandate for 50% green roof cover on new buildings would reduce annual stormwater

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[16] National Climate Data and Information Archive. (2012, March 14). *Canadian Climate Normals 1971-2000. Retrieved from* http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=889&autofwd=1&month1=0&month2=12

[17] U.S. Green Building Council. (2006, Sept 15). *USGBC in the news details*. Retrieved from http://www.usgbc.org/News/USGBCInTheNewsDetails.aspx?ID=2604.

[18] University of British Columbia. (2009). Draft UBC Vancouver campus plan to 2030. *Part 4: Reference material.*

runoff by as much as 47,449 m^3/yr. This finding was based on the following simplified calculations:

$$total\ anticipted\ footprint\ growth\ (131{,}800 m^{m2}) \times annual\ water\ flux\ \left(\frac{1.2m}{m^2}\right) \times greenroof\ reduction\ coefficient\ (0.3) = 47{,}449 m^3/\text{year}$$

For the average theoretical building on South Campus (440m^2 based on current Westbrook building footprints) we can expect an extensive greenroof of 220m^2 to mitigate 79 m^3 of rainwater per year. The remaining runoff could be harvested and used for local irrigation.

Premium costs were based of several sources and websites that cited installation of green roof products. Xero Flor, a Canadian company, can install greenroofs at approximately \$108/m^2[19]. The average premium investment on a 220m^2 building would be approximately \$23,760.

3.0 – Greenroof Retrofit on Thunderbird Parkade

Green roofs are widely acknowledged as a valuable strategy to combat environmental issues within urban areas. However, one of the largest problems with retrofitting buildings is the added weight of the Green Roof system. Re-structuring roofs to support green roof infrastructure can substantially add to development costs, which often acts as a deterrent to municipalities, property owners and developers. As a result, we recommend a green roof retrofit for the top level of a parkade. The structure is already strong enough to bear the weight of a green roof and will not require extra reinforcement.

Implementation of a sedum mat style green roof on the top level of Thunderbird Parkade could substantially mitigate peak flow while reducing annual stress on the current system by up to 3500m^3 annually.

[19] XeroFlor Canada. (2009). *Materials*. Retrieved from http://www.xeroflor.ca/types-and-systems/materials.html

Cost implications:

At present value greenroof providers such Xero Flor Canada® offers the complete greenroof installation at $108/m^2$. Thunderbird parkade's total upper parking lot area is approximately 9700 m^2. The total cost of installing a green roof on Thunderbird parkade's top level would cost approximately $1,047,000, but would provide an excellent potential for research and development of green roof technologies in a temperate climate.

It is difficult to calculate the payback period for green roof developments, as considerable debate exists regarding how to value the services provided by green roofs. One study estimates green roofs can reduce the length of a building payback period by 20-25%[20].

[20] Clark, C., Adriaens, P. & Talbot, F. B. (2008). Green roof valuation: A probabilistic economic analysis of environmental benefits. *Environmental Science and Technology 42*: 2155-2161.

iv- Conclusions

Final Rankings (as calculated from the chart in Appendix I)

1. Detention Ponds: Both received an equal ranking of **39 points**. The pond to service both the Farm and the Botanical Gardens' Nursery evidently costs more, so if financial restraints were of particular concern, we would recommend the smaller pond for just the Farm. However, considering UBC would likely want to use stormwater-sourced irrigation for the Botanical Gardens' Nursery in the future, it would seem sensible to invest in a larger pond to service both.
2. Mandate for Greenroof Incorporation on New Developments: **37 points**. This option ranked higher than the retrofit option because there are no upfront capital costs. UBC would not have to cover the cost of greenroof installation for these new buildings, as the cost would instead be borne by developers. However, this mandate might lower property values by an undetermined amount, which could result in lost revenue for the university.
3. Greenroof Retrofit on Thunderbird Parkade: **31 points**. This option is also ranked lower because fewer residents are likely to interact with a parkade roof, while a 50% target for greenroof installation on new buildings would potentially impact large numbers of South Campus residents.

Best Practice Concerning Environmental Impacts

We categorized environmental impacts as including the water, climate and ecosystem criteria. The detention ponds most effectively met water-related objectives, and performed relatively well as a means to reduce erosion and improve water quality. However, the pond does not overtly reduce emissions, while green roofs have considerable potential for carbon storage, making green roofs more useful from a climate perspective.

Best Practice Concerning Social Impacts

We took social impacts to include research potential, impact on community behaviour and aesthetics. In terms of these criteria, the green roof mandate is the most beneficial option. Implementing green roofs on this scale would provide considerable research opportunity for how best to install and use green roofs in the Pacific Northwest climate. In addition, this policy would affect the largest number of residents and thus hopefully provide the greatest opportunity to impact public perceptions of stormwater.

Best Practice Concerning Financial Impacts

The policy option to mandate 50% green roof development has the least financial impact for the university, as costs and benefits would be absorbed by developers. As a result, the detention ponds are the most financially sensible investment. While they may have a relatively lengthy payback period, they would serve to eliminate municipal purchasing of water for irrigation on the Farm and Botanical Gardens Nursery properties.

v- Recommendations

We would recommend an adaptive management approach, which allows for changes in plans as South Campus continues to develop and expand. We chose 50% as a green roof target because it allowed for significant adoption but would not restrict all developments. Nonetheless, we recognize that UBC is reluctant to impose too many constraints on developers, as this may reduce property values. However, in the future UBC may wish to place further restrictions on developers as available land declines and competition for remaining property increases.

All of our options focus on the technical aspects of stormwater management. However, stormwater management plans could more effectively incorporate users. Rainwater re-use, through the use of rain barrels, is a relatively simple household activity that can reduce potable water demand for irrigation and other household uses. We would recommend that future groups work with the University Neighbourhood Association to investigate possibilities of how to manage stormwater on the individual level and what smaller-scale initiatives might be pursued by UNA properties.

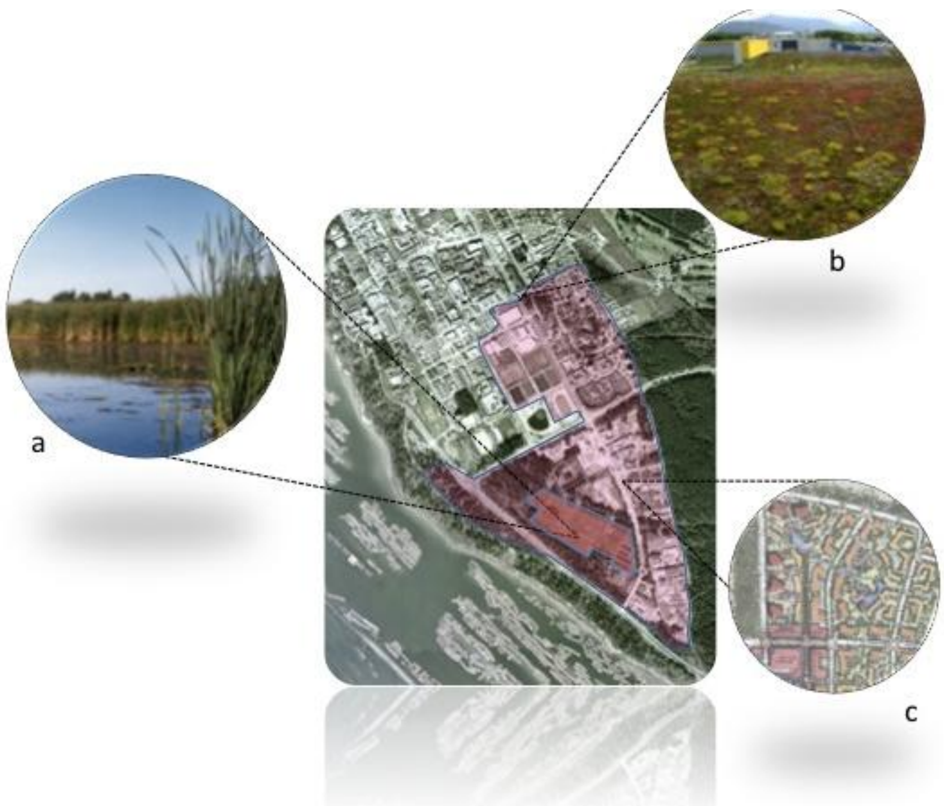
In terms of future research opportunities, we would also recommend that UBC investigates how best to incorporate higher water pricing into its operations. While it would not be in UBC's short term interests to advocate for higher prices at the municipal level, this could prove beneficial in the long term. Higher prices, which more accurately reflect the full cost of potable water as a resource, would provide better incentive for the university to implement closed-loop water solutions, and provide incentive for residents to adopt stormwater re-use practices.

Each project offers different strengths and we acknowledge that UBC's stormwater management requires a suite of options to address all stormwater goals. Although the detention pond scored slightly higher than the green roof alternatives, UBC should pursue an integrated approach to stormwater, one that incorporates closed-loop water solutions into all building and community design on South Campus. Detention ponds and green roofs, as well as other solutions not mentioned here, can contribute to a re-conceptualization of stormwater as an opportunity and a resource.

vii – Appendices

Appendix A: Option Location Map

Map depicting locations of proposed stormwater retention projects in the South Campus catchment. Total catchment is highlighted in light red. Both detainment pond options would be located on the 24-hectare UBC Farm site, in the southeast corner where the Farm property meets the Botanical Gardens nursery property. The darker red shade indicates the location of both properties.



a = Detention Pond(s)[1]

- The pond location will have to be sensitive to the sanitary sewer than runs beneath the proposed location site

b = Thunderbird Parkade Greenroof Retrofit[2]

c = Proposed mandate for 50% greenroof cover on new development[3].

[1] Otanobee Conservation Authority. Accessed online: http://www.otonabee.com/orca/land/the_marsh.htm
[2] Sky Gardens. Accessed online: http://www.greenroofs.com/blog/tag/dr-stephan-brenneisen/
[3] UBC south campus Northeast sub-area neighborhood plan 587a. Intro to Physical planning & urban Design. Professor M. Senbel.

Available Runoff

Many assumptions factored into calculating the required size of a detention pond to supply the UBC Farm and the Botanical Gardens Nursery (BGN) with irrigation water. The pond's catchment area was conservatively assumed to be the 24 hectares occupied by the UBC Farm, although available water will likely be supplemented by drainage from the forested land to the west of the farm. See Appendix A for the catchment area. Rainfall on the farm site is currently diverted into a ditch that runs along the edges of the farm, which will be funnelled into the detention pond. The fractions of rainfall that are reported to evaporate (40%), runoff (10%) and infiltrate (50%) in Vancouver were modified to account for the relative impermeability of the glacial till that underlies the topsoil on the farm[4]. According to the 2005 report by Alpin and Martin, there is "up to 30 m if relatively impermeable glacial till" underneath the topsoil. In addition, Tim Carter from the UBC Farm supplied anecdotal evidence that "no water permeates the glacial till" and also said that the water basically infiltrated through the topsoil, ran along the surface of the glacial till layer until it met the ditch, where it would flow along the ditch. The drainage pipe installed throughout the farm in the 1960s would aid this flow of water. As the glacial till is not absolutely impermeable and to keep figures conservative so as to not over estimate water collection, it was assumed that 10% would infiltrate through the glacial till while the rest could be collected. The evaporation fraction was assumed to remain unchanged, so the fraction of water that did not permeate the glacial till was added to the runoff, making the runoff fraction 50%. The spreadsheet simply refers to this fraction as runoff, though strictly speaking it is not entirely runoff. This water was therefore available to supply the detention pond with water for irrigation. Monthly rainfall statistics were multiplied by the area of the farm to get the total rainfall volume, and half of this would be available for collection.

Sizing

The size of the pond was determined by subtracting the 2011 monthly metered irrigation water from the monthly available runoff. This was initially calculated using 2011 rainfall data, then for 2009, which had a very dry summer, using Environment Canada data for both 2011, 2009, and average rainfall. However, the available irrigation data was for 2011, so the 2009 irrigation was estimated using the data from 2011. It is assumed that plants only need to be irrigated when it is not raining, so the monthly irrigation required should be inversely proportional to the monthly rainfall. To do this, the runoff from the dry summer months from June to September was compared and it was found that there was 1.52 times more runoff in 2011 than in 2009. Runoff is proportional to rainfall, therefore doubling rainfall doubles runoff. The most important parameter was the maximum cumulative deficit between available runoff and irrigation, as this would be the required

[4] See Condon (2010)

pond size. To account for evaporation, leakage and extreme drought, this volume was multiplied by a factor of 1.3 to ensure the pond would be large enough to accommodate irrigation needs. The effects of climate change are ignored in this model.

Depending on plans at the farm, the dimensions of length, width and depth, of the pond may be changed, as design for the Farm and BGN (2009) has a very large surface area and may encroach on crops. For example, it may be advantageous to have a long and narrow pond, although this could be more expensive to build as for the same volume there would be increased area on the bottom and sides of the pond, which would require a greater quantity of clay lining. The depth of the pond is limited by the width, so a pond that is exceedingly narrow must be increasingly lengthy.

Location

The location for the reservoir was selected on the recommendation of Tim Carter. As he has worked on the farm for several years it makes sense to use his recommendation as he has a thorough understanding of the requirements of the farm and any relevant restrictions. It can be found on the map located in Appendix A.

Tim Carter also mentioned that the trees growing along the edge of the farm will need to be cut back as they are adversely shading crops. The crops have to be planted far enough away from the tree line to get adequate sunlight. The pond could potentially be located partially on the same land as these trees, as the trees would not grow further if inhibited by the pond. This would eliminate the cost of forest maintenance and increase farmable land. However, the chosen site would need to avoid the sanitary sewer running underground along the edge of the farm.

Pricing

Two methods were used to determine the cost of the pond. First, a somewhat detailed series of calculations of the specifications of the pond were done in accordance to the Canadian Mortgage and Housing Corporation model. See Appendix G for an explanation of the calculations. Their model was dated 1991 so costs were adjusted for inflation to give $546 605 in 2012 dollars for construction costs for the Dry Summer model for the Farm and BGN and is highlighted in pink in Appendix E.

The other method was used a formula from a 1999 report conducted for the City of Vancouver on Stormwater Best Management Practices (BMP) that used price as a function of volume. After adjusting for inflation, this method yielded a similar figure of $604 511 for construction. This value is highlighted in pink in Appendix F. The latter method was subsequently used in evaluation of the different potential options due to its relative simplicity. The cost of this reservoir project varies depending on the assumptions used. This model estimated maintenance costs as 3-6% of construction costs, so 3% was used as it was assumed that 6% would be more likely if the pond was used for aesthetics as well, whereas the design was focused on function alone. The pond is situated in the far corner of the farm where it is rarely seen. The final maintenance figures seem slightly excessive, as it is unlikely that the joint pond would require $25,000 in annual upkeep. However, we chose to err on the side of caution in our projections.

The 2011 metered monthly water usage of the Farm and BGN was 23 772 m^3. When multiplied by the peak water rate of $0.88/$m^3$, yearly irrigation cost $20 880. This figure, minus the 3% annual maintenance of $7382, yielded the yearly savings of stormwater use for irrigation. The construction costs were divided by this amount to give a payback period of 61 years, assuming business as usual. *The price of water may go up in the future as the city grows and demand increases, decreasing the payback time of the pond.*

Similar calculations were made using the 2011 data for the option where only the Farm receives irrigation. Both of these options were reassessed using the 2009 runoff data and the estimated irrigation data that had been scaled up by a factor of 1.52. All construction costs were multiplied by a factor of 1.35 to account for design costs, in accordance with the 1999 Stormwater BMP report. *The 2009 figures should be used if the university wants to stop using city water for irrigation while maintaining full irrigation capacity in the driest of summers*.

Clay Lining

To seal the pond to minimize leakage a layer of compacted clay will be installed. It needs to be 20 cm thick to function properly. The amount of clay required was found by using the dimensions of the pond to calculate the wetted area and multiplying this by the required thickness. This can be seen in Appendix G. The cost was found by multiplying the volume by the price of clay $7.50/t [5] and by the bulk density of compacted clay, 1.746t/m^3.[6] This is tabulated in Appendix H.

Additional Costs

To adhere to provincial water quality requirements, the water must be treated if it is going to be sprayed on crops[7]. Treatment options vary in price, so a middle-of-the-road price was used for estimation purposes for each option. The cost of treatment is relatively insignificant compared to the construction cost of the reservoir, as are the required pump and piping required to hook up to the existing system(s). See Appendix H for a table of the additional costs.

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[5] (http://www.youngssandandgravel.com/pricelist.htm)
[6] http://www.simetric.co.uk/si_materials.htm
[7] British Columbia Water Quality Factsheet. Retrieved from http://www.al.gov.bc.ca/resmgmt/publist/500Series/512000-3.pdf

Appendix C: Detention Pond Size Calculations

The monthly metered irrigation data was found by subtracting the cumulative reading from the previous month. Available runoff was subtracted from this figure in each case, giving negative values when runoff can supply irrigation demands and positive values when monthly runoff falls short of irrigation demands. The pond should be sized to accommodate cumulative monthly shortages.

Monthly Metered Irrigation (m3)				Surface Runoff-farm2011 (m3)	Surface Runoff-farm2009 (m3)	Average (1971-2011) Surface runoff month - farm (m3)	Farm Irrigation minus farm runoff 2011 (m3)	2011 Farm shortage TOTAL (m3)	Farm + BotG Irrigation minus farm runoff 2011 (m3)	2011 Farm +BGN shortage TOTAL	Scaled 2009 Irrigation Farm (m3)	Scaled 2009 Farm Irrigation - Runoff (m3)	Cumulative shortage (scaled)	Scaled 2009 Irrigation Farm + BGN (m3)	Irrig-runoff	Cumulative shortage (scaled)
Date	Farm	BGN	Farm+BGN													
Jan-11			0	20640	12768	16692	-20640		-20640		0	-12768		0	-12768	
Feb-11			0	9864	6576	13656	-9864		-9864		0	-6576		0	-6576	
Mar-11			0	18240	11856	13416	-18240		-18240		0	-11856		0	-11856	
Apr-11	30.85042	100	130.85042	11472	9312	10020	-11441.1		-11341.1		46.90266	-9265.1		198.9352	-9113.06	
May-11	27.23546	450	477.23546	11256	8616	8148	-11228.8		-10778.8		41.40675	-8574.59		725.5531	-7890.45	
Jun-11	553.8643	2453	3006.8643	4920	1296	6576	-4366.14		-1913.14		842.0538	-453.946		4571.412	3275.412	
Jul-11	1986.033	2837	4823.0332	4512	2400	4752	-2525.97		311.0332		3019.416	619.4164		7332.579	4932.579	
Aug-11	4771.424	3340	8111.4238	2352	3192	4692	2419.424		5759.424		7254.116	4062.116		12332	9140.002	
Sep-11	2130.593	3090	5220.5928	8352	7872	6420	-6221.41		-3131.41		3239.194	-4632.81		7936.999	64.99881	
Oct-11	211	1515	1726	8832	20160	13500	-8621		-7106		320.7886	-19839.2		2624.081	-17535.9	
Nov-11	6	220	226	14832	33840	21420	-14826		-14606		9.121951	-33830.9		343.5935	-33496.4	
Dec-11	0	0	0	10416	8784	19272	-10416		-10416		0	-8784		0	-8784	
			0	0		0	0		0		0	0		0	0	
Total	9717	14005	23722	125688	126672	138564	-115971		-101966		14773	-111899		36065.15	-90606.8	
Average	809.75	1167.083	1976.8333	10474		11547	-9664.25	2419.424	-8497.17	6070.457	1231.083	1231.083	4681.532	3005.43	3005.43	17412.99
								USE		USE			USE			USE
				June-Sept	June-Sept	June-Sept		2500		6100			4700			17500
Area farm	Units			20136	14760	22440										
24000	m2															

Cumulative monthly shortages that would need to be met by saved water from previous months

Note all negative numbers denote an excess of stormwater relative to irrigation needs

Monthly shortage: Irrigation demands exceed possible runoff capture

Summer runoff ratio 2009/2011 - Used to scale up irrigation associated with less rainfall 0.657754 (less in 2009)

Summer months when irrigation demand is highest - potentially exceeding runoff

The available irrigation data for the Farm, Botanical Gardens Nursery, and Plant Operations Nursery was used as a basis for water demand and pond sizing. There was no monthly data for UBC Farm #3 or for the Plant Ops Nursery, only a yearly total for the former and a total for the latter that spanned three summers. The missing data was found by scaling proportionally to monthly readings for similar meters, the Farm #3 scaled with Farm East and the Plant Ops Nursery compared to the Gardens.

Irrigation Meter Reads - UBC Farm, Botanical Gardens and Plant Ops Nursery

	Meter Reads (cu.m)				
Date	UBC Farm West	UBC Farm East	UBC Farm #3	Botanical Gardens	Plant Ops Nursery
21-Apr-11	7	10	13.85041551	100	15.88004284
20-May-11	8	21	29.08587258	550	87.34023563
21-Jun-11	30	244	337.9501385	3003	476.8776865
21-Jul-11	108	1044	1445.98338	5840	927.394502
22-Aug-11	355	2941	4073.407202	9180	1457.787933
16-Sep-11			0	12270	1948.481257
19-Sep-11	500	3860	5140		0
21-Oct-11	500	3861	5350		0
24-Oct-11				13785	2189.063906
21-Nov-11	504	3863	5350	14005	6672
					(for 3 summers)
					2224
					(for 1 summer)
			Not real data. For modeling purposes numbers are proportionally larger than Farm East Nov-11		Not real data. For modeling purposes numbers are proportionally smaller than Botanical Gardens Nov-11
		east/ #3 ratio			Gardens/Nursery ratio
	21-Nov-11	0.722056075			6.29721223

The Canadian Mortgage and Housing Corporation model provides unit costs for constituent parts of a detention pond. When pond parameters are determined they are simply multiplied by their unit costs and added up. The source was from 1991 so they were scaled to present dollars by multiplying by 1.3191 using the Bank of Canada online inflation calculator.

Cost Category	**Type of Cost**	**Unit Price ($)**	**Unit**	**Cost**
Capital	Rip Rap	12	m2	40377.6
	Riser	1800		
		7200		7200
	Outlet pipe	250	m2	
Installation	Excavation	12	m3	273000
	Earthworks	4	m3	91000
	Vegetation	1	m2	
Maintenance	Landscaping	2	m2	480
	Sediment removal	1	m2	
	Labour (removal)	120	h	12000
Disposal	Sediment Disposal	60	m3	

	in 1991 dollars	in 2012 dollars
TOTAL capital cost	414377.6	546605.4922
TOTAL maintenance	12480	16462.368

Inflation	1999-2012$	1.3191

Design for Very Dry Summer - 2009

Metro Vancouver BMP Guide to Stormwater 1999								
Using Real 2009 Runoff Data and scaled 2009 irrigation data								
Cost:	$28.90 x (35.31V)^0.70			Scaling factor:		1.519756839		
Required reservoir size (m3)			17500				4700	
			22750	(FS= 1.3)			6110	
	Farm and Bot. Garden Nursery:				Farm Only			
		construction	w. design etc.			construction	w. design etc.	
	1999	392928.2244	530453.1	[$]	1999	156550.7282	211343.5	[$]
	2012	604510.9383	816089.8	[$]	2012	248507.9252	335485.7	[$]
	Irrigation Cost F+BGN				Irrigation Cost Farm			
	31732.52	[$]			12995.38	[$]		
Maintenance	3%	18135.32815	24482.69	[$]	3%	7455.237757	10064.57	[$]
	6%	36270.6563	48965.39	[$]	6%	14910.47551	20129.14	[$]
		Irrigation-maintenance [$]	Payback time (yrs)			Irrigation-maintenance [$]	Payback time (yrs)	
		7249.829797	112.5667			2930.808968	114.4686	

Design for Slightly Drier than Average Summer -2011

Metro Vancouver BMP Guide to Stormwater 1999								
Using Real 2011 Data								
Cost:	$28.90 x (35.31V)^0.70							
Required reservoir size (m3)			6100				2500	
			7930	(FS= 1.3)			3250	
	Farm and Bot. Garden Nursery:				Farm Only			
		construction	w. design etc.			construction	w. design etc.	
	1999	187895.9746	253659.566	[$]	1999	100633.9681	135855.9	[$]
	2012	333295.408	449948.801	[$]	2012	175277.9325	236625.2	[$]
	Irrigation Cost F+BGN				Irrigation Cost Farm			
	20880	[$]			9717	[$]		
Maintenance	3%	9998.862241	13498.464	[$]	3%	5258.337976	7098.756	[$]
	6%	19997.72448	26996.9281	[$]	6%	10516.67595	14197.51	[$]
		Irrigation-maintenance [$]	Payback time (yrs)			Irrigation-maintenance [$]	Payback time (yrs)	
		7381.535974	60.9559856			2618.243732	90.37555	

Appendix G: Pond Parameter Calculatior

The pond was designed in accordance with the Best Management Practices Guide for Stormwater. The sides of the pond have a slope of 3:1 so they will be stable. The pond is rectangular. Dimensions of the pond were found by setting the depth at a desired fixed value and then varying the bottom width of the pond to attain the desired volume. Other dimensions were a function of depth and bottom width, for example, the bottom length is triple the bottom width. The size of the pond shown below is for a very dry summer, similar to 2009, which would irrigate both the Farm and the BGN.

Calculator to find the area required for compacted clay lining as a function of bottom width					
Enter desired depth			depth	6	[m]
			bottom length	72.18	[m]
Change bottom width to achieve			bottom width	24.06	[m]
the desired volume			top length	108.18	[m]
			top width	60.06	[m]
*22 750 m3 reservoir shown as example			volume	22757.8248	[m3]
			side area	541.08	[m2]
			end area	252.36	[m2]
			bottom	1736.6508	[m2]
			Total area (lining)	3323.5308	[m2]
			perimeter	336.48	[m2]
			area perimeter	3364.8	[m2]
			surface area	1736.6508	[m2]

Appendix H: Additional Pond Costs

		Pond volume [m3]	Pond lining area [m2]	Clay liner, compacted	$/ton	bulk density [kg/m3]	Unit Price [$/m3]	Volume required [m3]	Total cost, liner [$]		Pump cost [$]	Pipe cost [$]	Water treatment cost [$]	Total Cost Extras [$]
				blue clay	7.5	1746	13.095							
Farm + BGN, 2009		22750	3323.5					664.7	8704.247		5000	50000	30000	93704.25
Farm 2009		6110	951.5					190.3	2491.979		2500	25000	15000	44991.98
Farm + BGN 2011		7930	1087					217.4	2846.853		5000	50000	30000	87846.85
Farm 2011		3250	590					118	1545.21		2500	25000	15000	44045.21

Criteria	Indicator(s)	Objective(s)	Justification	Detention Pond – Farm Only	Detention Pond – Farm and BGN	Green roof on Thunderbird Parkade	Green roofs on 50% of new development
Research opportunity	Option likely to create opportunities for student and faculty research, both during and after implementation: (A) Many (B) Few (C) None	In accordance with Place and Promise objective to increase the quality and impact of UBC's research and scholarship by improving infrastructure and generating financial support from non-traditional sources -Also see the *Sustainability Academic Strategy* by using UBC as a living lab	Provide tangible opportunities for the UBC community to learn from sustainable stormwater management practices	A- There are many research opportunities associated with this option. For example, water quality of the runoff downstream of the reservoir can be compared to data before the system was installed.	A- There are many research opportunities associated with this option. For example, water quality of the runoff downstream of the reservoir can be compared to data before the system was installed.	A- Option has been shown to provide ample research opportunities at other universities and municipalities. The School of Architecture and Landscape Architecture at UBC already operates the Greenskins Lab, dedicated research of green roof technologies.	A- Option has been shown to provide ample research opportunities at other universities and municipalities. The School of Architecture and Landscape Architecture at UBC already operates the Greenskins Lab, dedicated research of green roof technologies.
	Potential for available funding (as indicated by grant opportunities): (A) Many (B) Few (C) None		Creates new streams of financing for research, which is a fundamental aim of a university	B- Few funding sources have been identified at this point. However, Metro Vancouver could support investigations into local water quality.	B- Few funding sources have been identified at this point. However, Metro Vancouver could support investigations into local water quality.	A- Many, other municipalities (e.g. Toronto) already provide subsidies for green roof infrastructure; UBC has the potential to seek research grants for implementing green roofs on campus.	A- Many, other municipalities (e.g. Toronto) already provide subsidies for green roof infrastructure; UBC has the potential to seek research grants for implementing green roofs on campus.
Water	Reduction in purchased municipal water: (A) significantly reduces purchased municipal water (B) minor reduction in purchased water (C) No change in purchased water	Relates to UBC's goal to reduce potable water use for irrigation purposes by 50% in 2015 and 75% in 2020 Builds on *Inspiration and Aspiration* successes in reducing UBC's water consumption Also supports BC's Living Water Smart Target which calls for 33% more efficient water use by 2020	Decreases operational costs while contributing to sustainable resource use	A- Water purchases for the farm will essentially cease	A- Water purchases for the farm and botanical gardens nursery will essentially cease	C- No change in water purchased, as no water would be directly stored from this development	C- No change in water purchased, unless some type of storage was implemented in association with the green roofs
	Contributes to closed loop water system (A) storage opportunity (B) no storage opportunity		Reduces need for external water provision, contributes to sustainable closed systems at UBC	A- 6110 m3 of storage will be created. (see Appendix F)	A- 22 750 m3 of storage will be created. (see Appendix F)	B- Little storage opportunity. However, peak hydrograph flows are reduced	B- Little storage opportunity. However, peak hydrograph flows are reduced
	Reduces water turbidity: (A) significantly reduces turbidity (B) minor reduction in turbidity (C) no change	Aligns with the 2005 *Sustainable Drainage Strategy* recommendation that stormwater runoff be of as high a quality as possible, to expand opportunities for re-use	Improves quality of runoff flowing into surrounding streams, Fraser River and Strait of Georgia, which helps safeguard UBC's natural assets and	A- Significantly reduces turbidity. As water is detained in the pond, there is time for flocculation and sedimentation to occur, reducing turbidity of the outflow.	A- Significantly reduces turbidity. As water is detained in the pond, there is time for flocculation and sedimentation to occur, reducing turbidity of the outflow.	B- This roof only occupies a small percentage of South Campus land, meaning it would have a minor impact on runoff	B- Depending on type of greenroof and specific location, greenroofs have the potential to reduce turbidity, by reducing peak flow

	Reduces waterborne toxins: (A) significantly reduces toxins (B) minor toxins reductions (C) no reduction in toxins		the surrounding ecosystems	A- Significantly reduces toxins. Physical and biotic processes in wet ponds reduce a wide variety of pollutants.	A- Significantly reduces toxins. Physical and biotic processes in wet ponds reduce a wide variety of pollutants.	C- Little potential to reduce waterborne toxins	C- Little potential to reduce waterborne toxins
Ecosystem and Climate concerns	Provides habitat for native species (A) extensive habitat (B) minor habitat (C) no new habitat created	One of the *UBC Vancouver Campus Plan* goals is to design the public realm to accentuate and support nature, which could be seen as including support for habitat creation	Contributes to overall function of ecosystem habitat and ecosystem services, often neglected in urban areas	B- A small amount of habitat will be created. It is a relatively small pond compared to the size of the South Campus Catchment Area.	B- A small amount of habitat will be created. It is a relatively small pond compared to the size of the South Campus Catchment Area.	B- Green roofs have potential to provide habitat for some species; however the amount of additional green space created is not that significant when compared to the total campus surface area	A- Depending on specific construction methods and plant composition green roofs have a high potential to provide habitat for native species, some green roofs have even been show to support threatened native plant communities, such as those found in the Gary oak ecosystem.
	Erosion reduction (measured by peak flow reduction): (A) significant reductions (B) minor reductions (C) no reduction	Supports aims of the *Cliff Erosion Mitigation Plan*, a joint effort by UBC and Metro Vancouver	Reduces property damage and helps maintain vulnerable coastal ecosystem Key concern identified during initial consultations with Building Operations staff, so any stormwater management technique must address this issue	B- Minor reductions. It is a relatively small pond compared to the size of the South Campus Catchment Area.	B- Minor reductions. It is a relatively small pond compared to the size of the South Campus Catchment Area.	A- Potential to reduce peak flow (proxy for erosion) up to 30%[1].	A- Potential to reduce peak flow (proxy for erosion) up to 30%.
	Potential GHG emissions reductions (A) Reduces emissions (B) no impact on emissions (C) increases emissions	Reduce GHGs in accordance with the *UBC Climate Action Plan*	Aids in achieving goal of zero GHG emissions by 2050	B- No impact on emissions.	B- No impact on emissions.	A- Has potential to reduce emissions as plants will absorb carbon as they grow. This roof could also reduce the urban heat island effect by lowering the amount of dark surfaces on campus	A- Has potential to reduce emissions as plants will absorb carbon as they grow.
Economic Considerations	Maintenance costs: (A) no ongoing maintenance costs (B) moderate ongoing maintenance costs (<$20,000 per year) (C)	Helps deliver a Balanced budget annually in accordance with *Place and Promise* report	Contributes to financial sustainability at UBC, which is essential for the university to continue operating	B- Maintenance costs would average $10 000 /year	B- Maintenance costs would average $24 000 /year	B- As a roof surface, the parking garage is quite large, and thus might require slightly more maintenance than a green roof on top of a standard-	B- Depending on extent of the green roof, maintenance costs could potentially be quite low

[1] UBC School of Architecture and Landscape Architecture. (2011). *Greenskins lab*. Retrieved from http://www.greenskinslab.sala.ubc.ca/selectedProjects.html

	frequent ongoing maintenance (<$20,000 per year)					sized building	
	Decreases utility bills (as measured by annual spending on water and electricity): (A) high reduction (B) moderate reduction (C) little or no reduction			A- High reduction, as water purchases would steeply decline. Electricity for pumping is not a factor as water is presently pumped so there is no significant change.	A- High reduction, as water purchases would steeply decline. Electricity for pumping is not a factor as water is presently pumped so there is no significant change.	B- After a premium investment, green roofs can reduce heating and air conditioning costs in the Vancouver climate. However, this would not save costs for UBC, rather, it would improve the business of this option for devleopers.	C- Parkades do not require energy for heating or cooling, and thus the retrofit would not reduce spending on electricity. Unless the water absorbed by the green roof was stored at a later date, the retrofit would not reduce spending on water.
	Initial capital cost. (A) <$10,000 (B) $10,000-$100,000 (C) >$100,000			C- $337 000	C- $817000	C- $1,047,000	A- $23,760 for an average 220m2 building. This cost would be borne by the developer, not the university
	Payback Period: (A) <15 years (B) 15-30 years (C) >30 years			C	C	N/A	N/A
	Longevity of proposed solution: (A) system must be replaced after 40+ years (B) system must be replaced after 20 – 40 years (C) System must be replaced after <20 years	Maximizes utilization of infrastructure in accordance with goal 4.3.3 of the *Inspiration and Aspirations* report	Contributes to financial sustainability at UBC, reduces need for future capital/material inputs, which can pave the way for lower consumption patterns across campus	A- System will last forever with proper maintenance. Maintenance costs include sediment removal, ensuring the reservoir maintains adequate volume. The drainage ditch that was dug in the 1960s which will feed the reservoir has not been maintained and is still functioning well.	A- System will last forever with proper maintenance. Maintenance costs include sediment removal, ensuring the reservoir maintains adequate volume. The drainage ditch that was dug in the 1960s which will feed the reservoir has not been maintained and is still functioning well.	B- Product may need to be replaced after 30-40 years depending on construction and design	B- Product may need to be replaced after 30-40 years depending on construction and design
Technical Feasibility	Has this option been implemented in a university or similar setting in the last decade? (Y/N)	This acts as a measure of applicability to the UBC context	If the option has been applied in a similar setting, with relative success, it is more likely to be successfully implemented at UBC. Also, UBC can learn from the setbacks	N- But a similar option was implemented at Clemson University[2]	N- But a similar option was implemented at Clemson University	Y- CIRS building supports a small greenroof with native plants	Y- CIRS building supports a small greenroof with native plants

[2] Clemson University. (2005). *Rainwater Harvesting System.* Retrieved from http://www.clemson.edu/sustainableag/rainwater.html.

			and difficulties of this prior project				
	How did users rate this option when implemented elsewhere? (A) Highly positive (B) Satisfied (C) Dissatisfied	This is a means to gauge potential user satisfaction with the proposed solution, based on reception elsewhere	We cannot measure community satisfaction or support for a particular approach at this stage, so our next best alternative is to glean this information from similar projects	N/A	N/A	B- The roof in CIRS is in its infancy, and so this difficult to assess. From anecdotal evidence, building users seem pleased with it as a visual element. However, users are not allowed to access the garden unsupervised, which may reduce interest/satisfaction with the garden	A- Depending on specific location and planning, greenroofs across 50% of new buildings could lead to higher user engagement, which would likely increase satisfaction.
Social Considerations	Impact on community behavior: % of South Campus users which visit or interact with proposed option: (A) 30+ (B) 15-30 (C) <15	Contributes to behavioral change goals likely to be encompassed in future iterations of UBC sustainability planning	Measures community buy-in and engagement with environmental sustainability actions at UBC, ensures stormwater management is more than simply a technological fix	C- Little foreseen direct impact, as the reservoir is located at the far corner of the farm, and the farm is not a frequent destination of many South Campus residents. However, it may inspire residents to implement rain harvesting systems of their own.	C- Little foreseen direct impact, as the reservoir is located at the far corner of the farm, and the farm is not a frequent destination of many South Campus residents. However, it may inspire residents to implement rain harvesting systems of their own.	C- While the top floor of the parkade would remain accessible to the public, it is doubtful more than 15% of residents would have reason to visit to this site	B- If South Campus is anticipated to double in population, and 50% of those residents live in buildings with green roofs, approximately 25% of residents would have direct exposure and/or access to green roofs
	Aesthetic benefits: the proposal is visually pleasing and improves the built environment (A) provides potential benefits (e.g. increased green space, public art) (B) no foreseen impact (C) potential for detrimental impact	Supports the *UBC Vancouver Campus Plan* aim to "rediscover UBC's sense of place and natural west coast beauty"	Improves quality of life at UBC, creates desirable living and working environment on campus	A- if wildlife is drawn to the pond, this could add a visually appealing element to the farm	A- if wildlife is drawn to the pond, this could add a visually appealing element to the farm	A- Green roofs provide high aesthetic value, especially in urban areas. For example, the greenroof at the Vancouver library was constructed to provide an enjoyable view to surrounding office buildings. This roof would be visible from the adjacent Pharmaceutical Sciences building.	A- Green roofs provide high aesthetic value, especially in urban areas. For example, the greenroof at the Vancouver library was constructed to provide an enjoyable view to surrounding office buildings
	Total score: 'A' rankings represent positive attributes for a given criteria. Points were assigned to each letter grade. A= 3, B= 2, C= 1.			8 A's, 5 B's, 3 C's =**39**	8 A's, 5 B's, 3 C's =**39**	5 A's, 6 B's, 4 C's =**31**	8 A's, 5 B's, 3 C's =**37**

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