UBC Wastewater Management Alternatives

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1.0 INTRODUCTION

The University of British Columbia (UBC) Point Grey campus is responsible for providing utility services to its growing population. Metro Vancouver has identified UBC as a potential site for implementing localized wastewater treatment. In response, the current UBC water cycle is reviewed in the following assessment.

1.1 UBC Sustainability

A pearl among the elite, UBC expresses a distinguished passion for sustainable initiatives. The University has implemented programs to conserve water in accordance with UBC's adoption of Policy #5 - Sustainable Development. In 2006, the $35 million Ecotrek program was completed, saving UBC $2.6 million annually in energy and water costs (Ecotrek, 2010). A reduction of water consumption by 30% was achieved through the installation of 3,000 low consumption plumbing fixtures in over 250 buildings (Ecotrek, 2010). New buildings constructed on campus must meet good or higher within the Leadership in Energy and Environmental Design (LEED) green building rating system. There are four levels of certification that recognize performance in water efficiency. Programs such as Ecotrek fulfill the UBC Policy #5 requirement of responsible fiscal management that enables the university to continue to pursue these goals of sustainable living.

At UBC sustainability is defined beyond the scope of a simplistic dictionary statement. The UBC Sustainability Academic Strategy (SAS) Working Group understands sustainability as “the emergent property of a societal conversation about the kind of world we want to live in, informed by some understanding of the ecological, social and economic consequences of our individual and collective actions” (UBC, 2009). With this concept in mind we must address current wastewater issues of transportation, leaks and misuse of water.

1.2 UBC Current Wastewater System

1.2-1 Water Source

Metro Vancouver’s potable water is collected from the Seymour and Capilano watersheds. The water flows throughout the city through a network of reservoirs, pumping stations and water mains (Giratalla, 2011). It is then treated through filtration systems and transported through a water main to the Burrard Inlet. From there, the water is then transported to the Sasamat Reservoir located near the UBC Campus (Giratalla, 2011). UBC Utilities distributes water throughout the Point Grey campus, and purchases approximately 4.2 million cubic metres of water per year from Metro Vancouver. Eighty-five per cent of water used on campus leaves as waste via the sanitary sewer, to be pumped to the Iona Island Wastewater Treatment Plant in Richmond, British Columbia (Giratalla, 2011). A distribution pie chart of the estimated composition of UBC’s average water demand (137 L/s) by use from Giratalla (2011) has been provided for general knowledge of water use at UBC (please refer to Graph 1 in Appendix D). It is important to note that it currently costs

UBC $0.60 per cubic meter for potable water, plus an additional $0.40 per cubic meter for disposal. Over a full year this adds up to approximately $2.5 million (Giratalla, 2011).

1.2-2 Water Distribution System

The water distribution system at UBC comprises of an extensive network of piping infrastructure including water mains, steam pipes, sewers and storm mains. Since there are no water storage facilities on campus, the water supplied to UBC is initially stored at the Greater Vancouver Water District (GVWD) Sasamat Reservoir (Urban Systems, 2010). The water is piped from the Sasamat Reservoir through the University Endowment Lands (UEL) water system to supply the Powerhouse Booster Pump Station located at 2040 West Mall (Babich, 2005). The three electric booster pumps receive the water at 60 PSI and increase the pressure to 100 PSI (Babich, 2005). The Powerhouse Station supplies the entire upper pressure zone and maintains a constant discharge pressure (Urban Systems, 2010). The low pressure areas are supplied through the 16th Avenue lower pressure zone connection (Urban Systems, 2010). The upper and lower pressure zones are separated by PRV stations which maintain constant downstream pressure.

The UBC water distribution system has a loop arrangement. Most areas are supplied with more than one pipe allowing for temporary shutdowns by UBC Utilities to conduct repairs and upgrades. The water supplied to campus is for domestic use, research, irrigation, and fire suppression systems. The sanitary sewerage system discharges wastewater to the GVS&DD sanitary sewer system (Urban Systems, 2010).

1.2-3 UBC Raw Sewage Flow Data and Wastewater Content

Recent raw sewage flow data suggests that the average flow at UBC from January – June 2010 was 1,944,992,233 Litres. In comparison to 2002 where the total sum flow was 6,264,073,018 Litres, we have seen a significant reduction of wastewater flow. This exalts the fact that UBC is effectively reducing its footprint and progressing towards sustainable standards. All data stated in this section is from *UBC Sewer Flow 2001 -2009 Raw Data*.

UBC's wastewater is analyzed twice annually by an analytical testing laboratory known as Maxxam Analytics. The purpose of a wastewater analysis is to determine the content of the wastewater that is exiting the campus. Maxxam's wastewater analysis provides a chemical analysis and a breakdown of elements by atomic spectroscopy. The content and elements of wastewater leaving UBC is well within the standards set by GVRD Sewer Use Bylaw. For example, the average biochemical oxygen demand of the wastewater is 32.5mg/L. This is fairly minor compared to the City's allowable quantity of 500 – 1000mg/L. In addition, the average total suspended solids amounts to 30mg/L, in comparison to the City's allowable limit of 600mg/L. Moreover, there is an average pH of 7.16 and an average water hardness ($CaCO3$) of 28.7mg/L. We have summarized the chemical analysis and a breakdown of elements and components by atomic spectroscopy that Maxxam provided (Wastewater Analysis, 2010) and have compared it with the GVRD Sewer Use Bylaw standards in tables 1 and 2 located in Appendix D.

1.2-4 Wastewater Treatment

The wastewater generated on the UBC campus is transported to the Iona Wastewater Treatment Plant (IIWWTP) in Richmond. The sewer system is largely a combined sewer system, allowing the mixing of storm water and wastewater, and in heavy weather events, can result in overcapacity of the system. The result is discharge of overflow through numerous outfalls directly into the Burrard Inlet or the north arm of the Strait of Georgia, without first being treated (Metro Vancouver, 2008). The release of this untreated water has negative implications for both environmental and human health.

Once at the primary IIWWTP, the raw sewage is treated via mechanical processes. This occurs in three steps. First, the water passes through a coarse screening filter that removes large debris including plastics, paper products, etc. Next, the water flows through a long-channelled grit removal system where many particles either settle to the bottom or float to the top and are removed by scrapers. This process largely reduces the inorganic content of the wastewater, removing sand and gravel (Grant *et al.*, 2002). Lastly, gravitational settling tanks allow remaining solids (now called sludge) to sink. These mechanical processes help reduce the total suspended solids and biochemical oxygen demand in the water, factors that would put a strain on the receiving water body, through nutrient loading and competition with the surrounding environment for oxygen (Oberg, 2010). Approximately 50% of the solids and 30-40% of the BOD are removed during these processes (Levit, 2011).

The plant also has a temporary chemical storage and handling facility (chemically enhanced primary treatment) that helps it meet regulatory requirements. This involves the addition of a primary coagulant and a flocculent aid to the water to aggregate solids that do not settle. The water is disinfected with chlorine before it is discharged into the Strait of Georgia through a 7.5km outfall, 90m below mean sea level (Oberg, 2010). The use of excess chlorine in the disinfection process may lead to toxic compound loading in the receiving environment (Oberg, 2010).

The removed sludge is further processed to be used as bio-solids: fertilizers, top soils, and other growth substrates. The Metro Vancouver wastewater treatment plants produce 70,000 tonnes of bio-solids every year (Levit, 2011). Primary sludge from the clarifying filters is thickened by way of gravity and then sent to an anaerobic digester of mesophillic (37 degrees Celsius) conditions to produce, among other things, methane. The methane is used to generate electricity through co-generation for on-site use. The stabilized sludge, now with 99.9% of the harmful bacteria removed (Levit, 2011), is transported to sludge lagoons for storage, and eventually used as bio-solids.

2.0 ALTERNATIVE OPTIONS

The University of British Columbia has been identified as a potential site for implementing localized wastewater management. Two decentralized wastewater management alternatives are proposed as an alternative method to UBC's current system: a free water surface constructed wetland and an on-site treatment plant with reclamation facility.

2.1 Constructed Wetlands

The first wastewater treatment alternative proposed for the UBC Point Grey Campus is a traditional primary and secondary treatment facility, with further purification by an on-campus constructed wetland. This option focuses on exploiting natural processes, in additional to more traditional technical processes, to purify UBC wastewater to a quality that can be safely re-used on campus.

2.1-1 Treatment Process

The primary and secondary components of this treatment train will include standard primary and secondary treatment techniques, including pre-screening, settling of suspended solids, and activated sludge (to reduce the organic content). As these processes will occur in closed facilities, it will be possible to add an anaerobic digester to facilitate the capture of useful by-products from the wastewater, such as methane for electricity, and bio-solids for fertilizer.

Following primary and secondary treatment, the effluent will enter a constructed wetland for further purification. The constructed wetland will be designed to resemble natural wetlands, and will remove unwanted substances from the wastewater through natural processes. In this proposed set-up, effluent leaving secondary treatment will enter the wetland, and will slowly pass through the flow bed, coming into contact with the vegetation and microorganisms of the wetland. The plants and microorganisms will then use or decompose a significant portion of the remaining biodegradable content in the water. Water leaving the wetland will be of higher quality than the effluent discharged from the Iona Wastewater Treatment plant, and will be suitable for non-potable re-use.

2.1-2 Resource Reclamation

This wastewater treatment option will not only treat wastewater but will also re-introduce valuable resources into the UBC system. The proposed set-up will allow reuse of the treated water exiting the constructed wetland for non-potable uses on campus, such as irrigation and coolant water. This aspect will contribute to a closed-loop water system at UBC, following in the footsteps of Sustainability Street where the new CIRS building is located (UBC Campus Sustainability, 2000).

The anaerobic digester portion of this treatment process will facilitate the capture of methane and other gases, which can be converted into the electricity that will power the treatment plants. In this way, the energy requirements of this package option should not increase the campus energy demand, after the initial installation of the treatment plants.

Bio-solids in the form of fertilizers, top soil, and other construction material will result from the treatment and consolidation of the solid components of the wastewater. These useful by-products will be stabilized during treatment and can be used for the above mentioned purposes, either on campus, or they can be sold to buyers in the surrounding community.

2.1-3 Costs

Assuming a plant capacity of 12 million litres per day, the total capital cost of the constructed wetland would be between $483,000 -$9.9 million (please refer to calculation 1 in Appendix B). The total land required for treatment would be between 4.9 - 30.4 hectares, based on EPA Constructed Wetland Design Manual guidelines (2000). Average maintenance costs work out to $3, 370 per hectare per year, and may cover costs for active mosquito control, animal control, and removal of accumulated sediment from the wetland cell. Following, total constructed wetland costs would range from $34,000 - $102,000 per year (calculation 2). Treatment of water would come at a cost of under $0.02 per cubic meter (calculation 3).

Addition of the primary and secondary treatment plants will contribute a capital cost of near $10 million (calculation 4). So, overall capital costs for this wastewater treatment package including primary, secondary, and constructed wetland treatment, may be near $20 million.

It is important to note that while capital costs for the wetland are relatively low when compared to big industrial plants, they require large amounts of land which may play a role in overall feasibility.

2.1-4 Benefits to the Community

This wastewater treatment option has the potential to make a significant contribution to the community. The constructed wetland and surrounding area will have inherent aesthetic appeal, and may serve as a recreation site since the water will be treated to a safe level prior to entering the wetland (there would, however, be safety hazards if the water was only primarily treated before entering the wetland (EPA, 2000). The construction of the wetland will also introduce a new potential wildlife habitat into the area, with the potential to support biodiversity (again, this would not be appropriate if the water were not at least secondarily treated prior to entering the wetland). Research opportunities are likely to result, not only to aid in implementation of this project, but for additional monitoring and improvement of the system, and to help with implementation of similar projects elsewhere. The hope is that this more sustainable and localized treatment would serve as a model for other communities, and would also facilitate public awareness and education on issues such as wastewater management, resource consumption, and biodiversity, to name a few. As mentioned previously, this treatment process also offers the option to sell bio-solids produced in the anaerobic digester to members of the surrounding community.

2.2 On-Site Treatment and Reclamation Facility

The second wastewater treatment alternative proposed for the UBC Point Grey Campus is an on-site primary and secondary treatment plant, along with a water reclamation facility. This option focuses on reclaiming and recycling water to ideally create a closed-loop water system on campus.

2.2-1 Treatment Process

The wastewater collection system at UBC would be redirected to pass through an on-site and centralized treatment facility located south of 16th Ave on UBC endowment lands. The plant capacity would be designed to treat all wastewater collected on campus. The initial capacity would be 12 million litres of effluent per day, with the option of expansion.

During the primary settling procedure, the wastewater sits in large settling tanks for approximately 2 hours, allowing for the organic solids to settle. The water is then sent to a secondary process where the water is exposed to aerobic microorganisms through the activated sludge process. The water is then further purified through microfiltration, reverse osmosis membrane, and high-intensity ultraviolet (UV) light. Microfiltrations membranes are made of polypropylene hallow fibres, which draw water but exclude suspended solids and bacteria (GWRS, 2009). The reverse osmosis processes forces the water under high pressure to pass through semi-permeable membranes. This removes “dissolved chemicals, viruses and pharmaceuticals in the water” (GWRS, 2009). The last step involves the water to be exposed to high-intensity UV light with the addition of hydrogen peroxide. Water leaving the facility will be of higher quality than the effluent discharged from the Iona Wastewater Treatment plant, and will be suitable for non-potable re-use on campus.

2.2-2 Resource reclamation

The reclamation facility will able to recycle 100% of the water treated. The water is pure enough to be re-introduced into the UBC water system for indirect potable use such as toilet flushing, fire suppression systems, industrial cooling and irrigation. UBC currently purchases potable water for irrigation, which accounts for 21% of the campus’ total water use (Levit, 2011). Utilizing reclaimed water for this purpose could lead to economical savings over time, as less potable water is required to be purchased. The remaining water can be sold to the city for irrigation, recharging ground water aquifers, or simply be released into the environment.

Heat reclamation from the sewage entering the system is also an option that can be implemented at the facility. A heat exchanger can be installed to recover the heat energy from the wastewater. This recovered energy can be used to heat surrounding buildings in the U-Town community and would assist with reducing GHG emissions.

2.2-3 Costs

Assuming a plant capacity of 12 million litres per day, the total capital cost of the treatment and reclamation facility would be approximately $50 million (please refer to calculation 4 in Appendix C). The total land requirement is roughly 1 hectare. The operation costs include plant maintenance, electricity requirements and labour, totalling up to $1.2 million per year (calculation 5). The cost to treat the water will be under $0.65 per cubic meter (calculation 6). This is cheaper than the current cost to purchase potable water and treat the wastewater through Iona which is roughly $1.00 per cubic meter (Levit, 2011).

2.2-4 Community Impact

This alternative wastewater treatment option can positively impact the UBC Point Grey community. UBC currently exports its wastewater to the Iona facility which is not only cost inefficient, but more importantly it does not allow for the re-use of this wastewater. Sewer heat recovery can provide surrounding buildings with a reliable source of heating energy. Environmental impacts that may prohibit the advancement of this project include land requirements and the psychological barrier of the population against using reclaimed water. However, there is a large research and partnership potential for this project as the reclamation facility would be the first of its kind in Canada.

3.0 SUSTAINABILITY MATRIX

3.1 Purpose

UBC's sustainability pledge reads:

> *"I pledge to explore and take into account the social, economic and ecological consequences of my decisions. I pledge to use the knowledge I gain at UBC to improve the sustainability of the communities in which I live, learn and work."*

By using a triple bottom line approach, UBC will look at three main points; social, economic, and environmental. These three topics are broken down into more specific areas of interest to determine whether or not UBC is doing what they have promised to better their community. Under the social category they look to improve human health and safety, make UBC a model sustainable community, and increase the understanding of sustainability inside and outside the university. Next, the economic aspect ensures that they achieve ongoing economic viability, maintain and enhance their asset base, and finally maintain and maximize the utilization of the physical infrastructure. To finish, the environmental component seeks to reduce pollution, conserve resources, and to protect biodiversity.

By assessing these three general categories, and further looking at the subsets that come with each of these, we feel that our matrix covers the goals that UBC has set regarding sustainability. Throughout our matrix we have analyzed each of the points under the social, economic, and environmental categories thoroughly. From the amount of GHG and other harmful pollutants emitted, to the community perception of our proposed projects, and even the unit cost of water treated, all of these points and more have been assessed to ensure that we take not only a comprehensive and holistic view, but also that we have no over-lapping indicators to ensure maximum efficiency, and a truly representative view of sustainability.

3.2 Criteria

Capital Cost is a very important criterion as it is usually one of the main considerations when deciding the feasibility of a project, although we do not agree that money should be the main limitation to sustainability issues—although in reality, it often plays a deciding role. When comparing our two possible options, economics may not have been a top priority, but when these options would be presented to UBC, a comparison of the cost of each option would be looked at and highly considered before making a final decision. Next we have the ***Cost of Treatment***. Not only is there an initial capital cost but additionally the cost incurred when the wastewater goes through the "cleaning" process and is disposed of or, hopefully, re-used at UBC. This cost also plays a big part in deciding between the two options for the same reasons stated above. GHG and other emissions such as methane must be considered, and ***Manageable Emissions*** is a key criterion we used to determine whether or not emissions from the wastewater treatment process can be managed in either of the proposed establishments. ***Minimal land requirements to meet total UBC community demand*** was another criterion that represents an important issue: exactly how much land each option takes up is critical when making a decision. Because land is becoming so valuable, the more land that is taken up from our options, the less desirable that option will be.

In the attempt for UBC to become a closed-loop system the ***Resource recovery*** becomes an important criteria when evaluation the two alternatives. The ability to re-distribute the wastewater for either domestic or agricultural purposes could aid UBC in becoming a self-providing community. Another consideration is the effect that the new wastewater treatment system will have on the surrounding natural environment, more specifically, if it will ***support biodiversity***. When proposing both of these options we are looking to better the community and environment, and any option that hurts the environment would be hard to undertake. As the wastewater gets processed the ***Water Quality*** will be measured to determine whether it meets current standards to be re-distributed in one way or another. Water quality is based on the successful removal of suspended solids/BOD/COD, the balance of pH, whether it is free of pathogens or not, and to make sure it contains no hazardous chemicals.

Next is a basic assessment of the ***Technology Readiness Level,*** stating whether it is a proven technology, a recent technology, or if it is under development. ***Lifespan*** is another criterion that is obvious but important. Constructed Wetlands don't last even half as long as a Reclamation Facility, and this will come into play when deciding an option to go with. If our proposed systems are not ***Able to use less energy than current system,*** we will have an efficiency problem, and we might even have to look at the option of just leaving the current system as is because it is in fact more efficient. ***Perceived acceptable community response*** is important because the community represents a part of the decision, whether they perceive our options as viable and possibly successful comes down to their own decision. A ***Research Opportunity*** and the ***Potential for Public Awareness/Education*** is important to assess, as it will show whether our ideas can be used to further help the UBC community and other communities. We are attempting to make UBC a model community so that others can adopt our successful implementations of sustainable structures.

3.3 Quantitative Indicators

Dollars - Although we were able to get an approximate value of how much each of our options would cost, we still ranked them in categories of Low, Medium, and High.

Dollars per m3 of water treated - UBC currently bases their potable water and wastewater costs on a cost per meter cubed (m3). We felt that it was only fair to assess the cost per m3 of the treated water that would be processed through either the Reclamation Facility or the Constructed Wetland. By doing this we allow ourselves to compare the numbers we found with that of the current costs that UBC and Metro Vancouver incur on a daily basis. Rather than having a lump sum cost, it is more useful to break it down and make it comparable to other, more current, establishments.

Hectares of land - The cost of real estate rises every year, and due to the fact that we are attempting to implement a new sustainable establishment on the UBC Point Grey Area, the cost to occupy a large space of land will most definitely be a key factor in the final decision. For projects implemented on campus, although UBC owns the university land, a project that takes up a large amount of space will not allow as much flexibility to implement additional sustainability upgrades on campus. By scaling established wetland, primary and secondary treatment, and reclamation facility projects to the size of UBC's treatment demand, we found that the Reclamation Facility would take up about 1 hectare, and the Constructed Wetland would occupy 4.9 - 30.4 hectares, both to manage a capacity of about 12 million litres per day, the current campus load.

Years - Another obvious key factor in deciding between these two options was the longevity of each option, more specifically, how long they will be able to actively function. This is important because a project with a short lifespan will require a new investment of capital costs to replace the worn out system. Shown in the matrix, the reclamation facility will last more than 50 years compared to the wetlands which will only last about 15 to 20 years.

3.4 Qualitative Indicators

For all of the other indicators we used either a ranking system, yes/no, or a simple 1, 2, 3 regarding what the outcome would most likely be (i.e. a loss, net neutral, or a gain). These quantitative measures were used not only because we felt that these indicators were important to support our analysis but also because we could not find sufficient information on certain indicators due to the lack of time and resources available. To use the manageability of emissions we had to use a low, medium, and high model because concrete data was not easily available. By doing this we were able to include this indicator which is usually the first thing to be looked at when assessing the effectiveness of each option. For indicators such as the ability to re-use the wastewater, a simple yes or no would suffice. This is because you can either use it, or you cannot (and UBC currently does not). What you can use it for is another point, usually either for agricultural purposes or re-distributed for domestic purposes such as toilets.

The "1, 2, 3" scale was used to determine whether or not the we indicated positive, negative, or net neutral results for either of the options. This information was found using other, established, facilities that were similar to ours, although sometimes in different climates which was accounted for. Finally, a ranking system was used for the "perceived acceptable community response", and was measured on a scale from 1 - 10, 1 being very poorly perceived and 10 being very highly perceived. The reason for this is because a community response is much more subjective and yes or nor or 1, 2, 3 analysis would not be extensive enough.

4.0 RECOMMENDATIONS

An overall comparison of both wastewater management alternatives was conducted using the sustainability matrix developed. The assessment analysis leads us to recommend an on-site primary and secondary treatment plant along with reclamation facility to deal with UBC's wastewater in a more sustainable way.

4.1 Economic Feasibility

The capital cost of the constructed wetland is a fifth of the cost of a treatment and reclamation facility, although when considering the pre-treatment for the wetland, it is more likely to be near 40% the cost required to implement reclamation facility proposal. Looking at operating costs, constructed wetland costs are quite minimal, as little electrical energy and mechanical maintenance are required. They are thought to be "high management, low maintenance" systems (EPA, 2000). The reclamation facility would require full-time staff which would contribute to 25% of the 1.3 million dollar per year operation cost. Another 25% is spent on electricity (GWRS, 2009). However, if a sewage heat recovery system is implemented, there may be significant energy savings.

Regarding the cost of treatment, the constructed wetlands would cost pennies per cubic meter to treat ($/m3). This would allow for considerable savings of roughly $0.40/m3, with even more savings as a portion of water can be recycled for irrigation. The reclamation facility will cost under $0.65/m3. This cost is more expensive than the current system, however it allows for 100% water recovery, and this increase in treatment cost would be at least partially offset by the reduced amount of potable water needed to be purchased from Metro Vancouver. Water reclaimed from the reclamation facility will be of higher and more reliable quality than what is reclaimed from the constructed wetland. The reclaimed water can therefore be used for more processes than irrigation.

4.2 Environmental Feasibility

When reviewing the environmental sustainability indicators, the reclamation facility requires much less land than the constructed wetland. It is estimated that the reclamation facility option will occupy 1 hectares, whereas the constructed wetland option will occupy somewhere between 4.9 and 30.4 hectares. This land requirement may be too much to feasibly fit on campus. However, studies have shown that effective pre-treatment can reduce the required wetland area. Alvarez *et al.* report a 30-90% decrease in required wetland area when anaerobic digestion is used as pre-treatment (Alvarez *et al.*, 2008). It is important to note that this 30-90% decrease in size was seen in Spain, and Spain has a warmer climate than our project site. The previous land calculations were based on wetlands that act as secondary treatment, so it is possible that this land decrease would apply to our project, where the wetland functions in polishing the already-secondarily treated effluent. More research would be required to obtain an appropriate size for the constructed wetland for this particular site.

When assessing GHG emissions, it was difficult to quantitatively measure the impact for each option. A qualitative approach was taken, leading to the reclamation facility fairing preferentially. With the constructed wetland option, GHG reductions would result from capture of methane from the primary, secondary, and anaerobic digester portions of the wastewater treatment. However, the decomposition processes that take place in the wetland itself would release GHGs, particularly methane. The wetland plants would be able to offset a portion of the emitted GHGs since they convert carbon dioxide in the air into oxygen through photosynthesis. The electricity requirement of the reclamation facility would be the largest contribution to GHG emissions, assuming that the electricity is produced form non-renewable sources. The addition of the sewage heat reclamation pump, can allow for significant GHG emission reductions from the surrounding community. If resident building switch from natural gas heating to heat energy recovered from sewage, their GHG emissions can be reduced by 70% (Johnston, 2009).

A key advantage of the constructed wetland system is that minimal amounts of electrical energy are required for product operation. This is may be an important fact for stakeholders and UBC decision-makers concerned with issues of present value energy-use reduction, and supplying future campus energy demand. On the other hand, the reclamation facility would require a large amount of electricity to run its system.

4.3 Technical Feasibility

Both options have been proven and are functioning in other cities. There are numerous constructed wetlands projects throughout Europe, Australia, and North America (Vymazal, 2010). Reclamation facilities can be found in Orange County, US and Singapore, although they are still relatively recent technology. This supports the fact that there is technical knowledge and expertise available to assist UBC with implementing one of these options.

When considering Vancouver's climate, the seasonal changes may be a variable factor for the constructed wetland option. Humid summer conditions may support mosquito populations, presenting a potential for disease transmission. Additionally, certain conditions must be met for a constructed wetland to function as theoretically intended. Sufficient aerobic area (oxygenated open water area) is required for completion of the nitrification process that removes the solid nitrogen content (EPA, 2000) and this can be undermined by a heavy oxygen demand introduced by unintended high nutrient loads. Phosphorus removal relies on seasonal uptake by plants—but this uptake method is relatively low (EPA 2000), and on contact with appropriate media present in the wetland (Vymazal, 2010). The system may not be resilient to large inflows of chemicals as the chemicals may harm the living components of the wetland. Conversely, the reclamation facility will operate in more controlled condition as all processes are indoors.

4.4 Social Aspect

Social aspects that were considered included research and partnership opportunity, as well as potential for community awareness and education, and perceived community response. We predict that both proposed projects will provide an opportunity for research, both for the implementation of the projects, as well as related to regular monitoring and upgrades. A reclamation facility on UBC’s campus would significantly contribute to the overall understanding of water reclamation facilities, since it would be the first of its kind in Canada, and one of a few in the world. A constructed wetland on campus would contribute to the understanding of wetland functioning for wastewater removal in this climate, as there are currently limited data for this area. Both projects would also provide the possibility for community awareness and education programs related to wastewater management, resource use, and sustainability. The perceived community response of these projects is expected to be positive, as they both represent UBC commitment to improving sustainability. The constructed wetland was given a slight edge over the reclamation facility since it aims to work within the natural environment and even more, support or enhance biodiversity (as opposed to just having a neutral or negative impact). However, the reclamation facility was also highly rated because of its effectiveness and reliability in wastewater treatment.

4.5 Conclusion

Assessment of the two proposed wastewater treatment alternatives highlighted key strengths and weaknesses of each project with respect to sustainability, as captured in our sustainability matrix. The key feasibility factors that led to our final decision include:

- The land requirements of the constructed wetland are very high for a campus of fixed size
- Treatment in the reclamation facility is to a higher quality and is more reliable since it is in an enclosed facility and not directly vulnerable to changes in climate
- The lifespan of the reclamation facility is expected to be around 50 years, whereas the lifespan of the constructed wetland is expected to be around 15-20 years.

Considering all aspects of sustainability, we recommend for treatment of UBC’s wastewater an on-campus primary and secondary treatment plant in combination with a water reclamation facility. Implementation of this wastewater management system will address improvements to the current wastewater treatment system in key areas including economic, environmental, technical, and social feasibility.

5.0 LIMITATIONS

Throughout the course of this project, we encountered some challenges in acquiring relevant data as well as developing a system to assess the sustainability of each option.

5.1 Data limitations

Our limitations did not necessarily stop us from providing an analysis, but it just required our group to use a qualitative assessment of certain criteria and indicators. To start off, we found it very difficult to retrieve concrete information on the amount of GHG and other pollutants that could possibly be released from either of our options. As this is a very important indication of whether a project is feasible we were incline to use a scaling method, rather than leaving such important out of our analysis. Assumptions were used where needed, when determining what the community response may be we had to rank it on a scale from 1 - 10, and assume how we felt an average community member would perceive each of the options. Another limitation was determining the amount of energy required to run each system, although we could figure out a general idea of how efficient each alternative is, it was hard to pin-point exactly how well they could do. This resulted in using the yes/no option about whether or not the two options were more efficient than the current one that is in place.

We were also limited with the amount of time we had to complete this project. The scale of our task was quite large, and analyzing each and every detail of these types of processes would take much longer than the four months that we were allotted. To have the ability and time to actually go out into the field and test certain measures and retrieve concrete data would have aided our group in our research. Also being limited by the fact that there was not local information easily attainable and that we had to base some of our outcomes off of projects established in other geographical areas, this was also a limitation that we had to deal with. It is important to note that all figures obtained for this report are strictly estimated projections.

5.2 Sustainability Assessment Challenges

The method of assessing the sustainability of new projects is a fairly new concept to UBC. As a structured approach currently does not exist, our group developed a sustainability matrix from a limited amount of background information. An initial hurdle our group encountered was grasping a proper understanding of criteria and indicators, and how they can assess sustainability. Our matrix was then developed from three main points: social, environmental, and economical aspects. Initially, the matrix was confusing, as many indicators and criteria overlapped. Over time, the matrix was re-evaluated to ensure that all key points were covered. For this assignment, the sustainability matrix has been detailed to assess wastewater management options. However, the same matrix can be used as a foundation in assessing other projects that may be introduced to the UBC campus. Having said that, adjustments to our matrix might need to be made for other projects because of a number of factors. One example being the climate change in different geographical areas will have a big impact on the results our matrix produce.

6.0 REFLECTION

To begin with, the scope of this project required an immense amount of research, and our group had no previous knowledge of the wastewater management topic. We were guided through six distinct phases prescribed by the course outline, although we found that the timing of certain phases could have been slightly adjusted as it was hard to make such important decisions so early on in the project. Out of all the presenters, we found that Waleed Giratalla, Water and Waste Engineer of the Campus Sustainability Office, provided the most relevant information, and the rest of our information was collected through research.

An initial problem was to comprehend both the criteria and indicators; it came as a bit of a hurdle near the beginning. Considering a whole Phase was devoted to creating a matrix which was comprised of criteria and indicators, as a group we made sure that we had a thorough understand about both of these terms. Another limitation was the small amount of time allotted to complete such an extensive analysis of this topic. It was difficult to properly fill out our matrix due to this lack of time and information available, a qualitative approach was used at times, again due to the lack of information regarding quantitative data.

Furthermore, at times it was not necessarily finding information about both of our final options, but rather finding local information or information in a similar geographical area. Being limited to using information from geographically distant establishments, we had to use data that would not convert to the Vancouver climate in an effective way. This is an obvious limitation because many privately owned companies do not publicize all of their information, and we found it hard to gauge certain areas of our two options.

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Appendix A
Sustainability Matrix

Table 1. Sustainability Matrix – Criteria and Indicators

	Criteria	Indicator	Recycled Water	Wetlands
Economic Feasibility	Capital Cost (including purchase of land, labour, buildings, construction, time cost, and equipment)	dollars - high/med/low High - $ 40 - 100 million Medium - $ 10-40 million Low - $ 0-10 million	High ($50 million)	Low (Under $10 Million)
	Cost of treatment	dollars/m3 of treated water	$0.65/m3	$0.02/m3
Environmental Feasibility	Manageable emissions (including GHG and other pollutants)	Low- Minimal concern Medium- High-	Medium-low	Medium - High
	Minimal land requirements to meet total UBC community demand	Acres of land	1 Hectare for 12 million Liters/day	28 Hectares for 12 million L/day
	supports biodiversity	1) potential to enhance current biodiversity 2) expected net neutral 3) potential to harm or decrease current biodiversity	2	1
	Water Quality -successful removal of suspended solids/BOD/COD -Balanced pH -Free of pathogens -No hazardous chemicals	1)Water is pure enough for potable use 2) Meets secondary treatment water quality expectations 3)Does not meet water quality expectations	1	2

	Criteria	**Indicator**	**Recycled Water**	**Wetlands**
Technical Feasibility	Technology readiness level (TRL)	1) Proven technology 2) Recent technology 3) Under development	1/2	1
	Potential for Reclamation	Water Reclamation Heat Reclamation Nutrient Reclamation (Y/N)	Water -Yes Heat -Yes Nutrient -Yes	Water -Yes Heat -Yes Nutrient -Yes
	Life Span	Years	> 50 Years	15-20 Years
	Able to use less energy than current system	Joules (Yes/No)	Yes with Heat Reclamation	Yes
Social Feasibility	"perceived acceptable community response"	ranking system - Scale 0-10 (0 being most unfavourable response towards project; 10 being the most favourable response)	8	9
	Research and Partnership Opportunity	Yes/No	Yes	Yes
	Potential for Public Awareness/Education	Yes/No	Yes	Yes

Appendix B
Authorship Statement

AUTHORSHIP STATEMENT

We verify that the attached document is our original work. All group members have contributed equally to this report. References were made in-text to acknowledge the source of researched information. The capital and operation costs, land requirements, and other figures for both wastewater management alternatives have been calculated from sample projects. They are an estimate only, and do not appropriately represent the true value of a project implemented on campus. The opinions expressed throughout the document are solely of the authors, and do not necessarily reflect the views of the University of British Columbia.

We would like to extend our thanks to the APSC 364 course leaders, Gunilla Oberg, Nicole Dusyk, Liz Ferris, and Matt Dolf for providing insightful feedback and support throughout the different phases of this project. Our group progressed smoothly throughout the course of this assignment. All members participated in weekly team meetings and completed their assigned work on time. Each with a different undergraduate degree and strengths, team members contributed to the project with the best of their ability.

Appendix C
Calculations & Data

1.0 Constructed Wetland Capital Cost

2.0

1. one requires 4-25 acres per million gallons of flow per day (EPA, 1999)
2. if 12 million litres per day = 3 million gallons per day
3. therefore, 12 -75 acres
4. 1 acre = 0.405ha
5. therefore, 4.9ha - 30.4ha minimum land requirement
6. if $34,600 -$237,200 per ha ($1997 USD) (EPA, 1999)
7. Adjusted for inflation using US Labour Statistics http://www.bls.gov/data/inflation_calculator.htm

   $47,709 - $327,069

8. Table 1: Cost Analysis

	Low (4.9 ha)	High (30.4 ha)
Low Range ($47,709)	$233,774	$1,450,354
High Range ($327,069)	$1,602,638	$9,942,898
Maintenance Cost	$16,513	$102,448

2.0 Constructed Wetland Maintenance Cost

1. $3370 per hectare (EPA, 1999)
2. Multiply by low and high land requirements

3.0 Constructed Wetland Treatment Cost

From Calculation 2. Using an average operation cost of $82,000 per year.
The production cost to treat the water is $0.02/m3 assuming 12,000,000 L per day.

4.0 Treatment + Reclamation Facility Capital Cost

Primary and Secondary Treatment
Source: New Winnipeg Plant (Kenter, 2010)
Cost: $300 Million
Capacity: 400 Million L/day
Land: 1.2 hectares of land

Wastewater Recycling Facility
Source: GWRS (GWRS Cost, 2010)
Capital Cost: $481 Million
Operation Cost (including primary+secondary): $24.9 million per year
Capacity: 70 MGPD
Land: 20 acres of land

*Assuming UBC would treat approximately 12,000,000 L/day (UBC Sewer flow, 2009)

Calculated - UBC Primary and Secondary Treatment
Assuming 3% of the size
Cost: $10 million
Capacity: 12,000,000 L/day
Land: 0.4 hectares of land

Calculated - UBC Recycling Facility
Assuming 5% of the size
Cost: $22 million
Capacity: 12,000,000 L/day
Land: 0.4 hectares of land

Cost to retrofit and redirect wastewater collection pipelines
-Cost to have recycled water pipelines enter building for toilet flushing
-Cost to have recycled water pipelines installed for irrigation
Assuming $18 Million

Total
Cost: $50 million
Capacity: 12,000,000 L/day
Land: 0.8 hectares

5.0 Treatment + Reclamation Facility Operation Cost Calculation

Wastewater Recycling Facility
Source: GWRS (GWRS Cost, 2010)
Operation Cost (including primary+secondary): $24.9 million per year
Continuation from calculation 4.

UBC operation cost would be 0.05* $24.9 million = $1.24 million
Max cost. Cost can be minimized through sewage heat recovery.

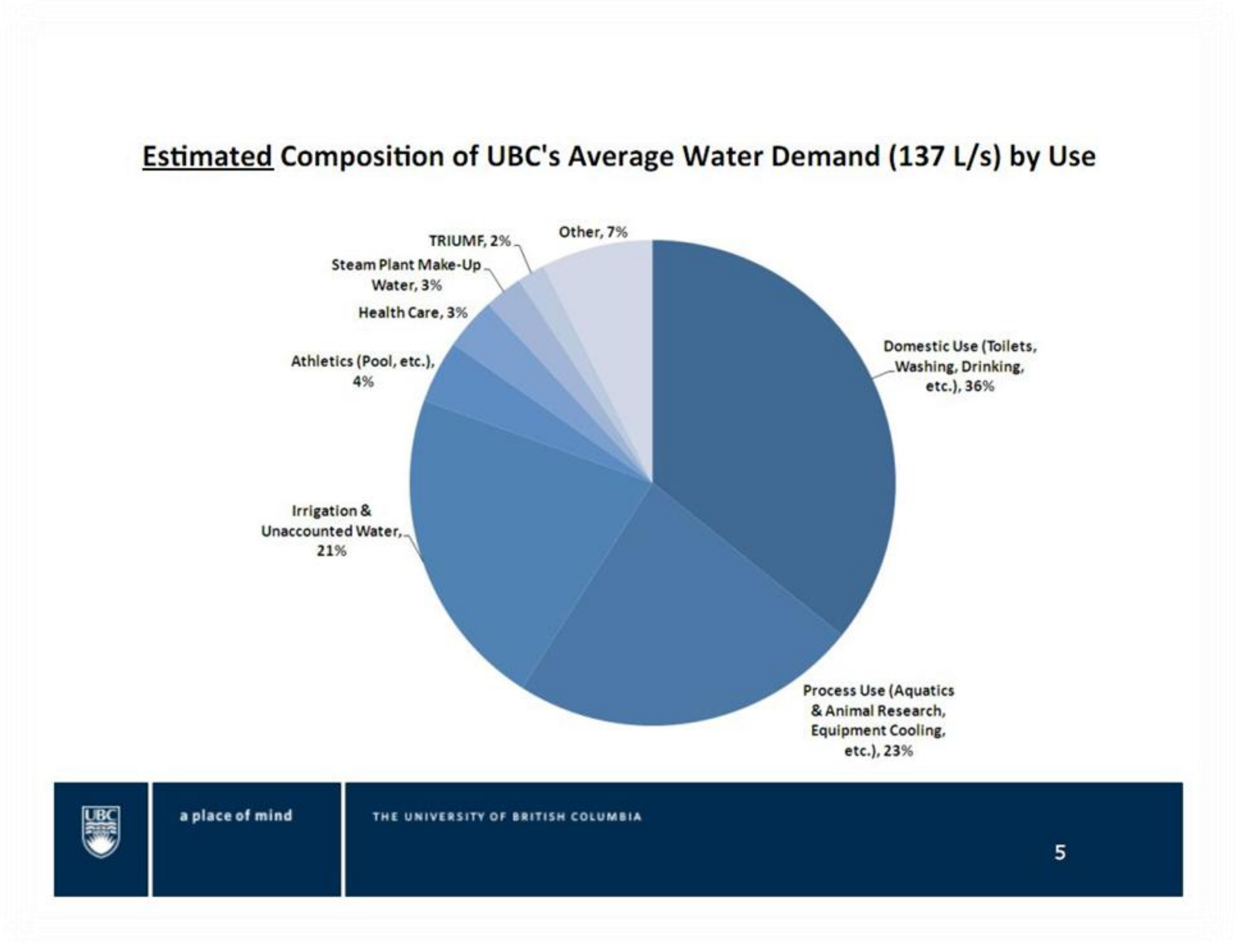
6.0 Treatment + Reclamation Facility Treatment Cost

GWRS System
Source: (Calsbad, 2009)
$800 per acre foot of treated water

UBC System
Similar cost. Equals to $0.65/m3

Appendix D
Background Information

Graph 1: Estimated Composition of UBC’s Average Water Demand by Use



Estimated Composition of UBC's Average Water Demand (137 L/s) by Use

a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA

Note: All data has been compiled and arranged from Maxxam Waste Water Analysis 2010 and Fact Sheet for GVRD Sewer Use Bylaw HSE Tool #08.

TABLE 1: Elements - Comparison of UBC and GVRD Sewer Use Bylaw Standards

Elements	**Units**	**UBC North Composite**	**UBC South Composite**	**GVRD Sewer Use Bylaw**
Aluminum	mg/L	0.27	0.08	50
Antimony	mg/L	<0.0005	<0.0005	
Arsenic	mg/L	0.0007	0.0005	1
Barium	mg/L	0.014	0.006	
Beryllium	mg/L	<0.0002	<0.0002	
Bismuth	mg/L	<0.002	0.001	
Boron	mg/L	<0.1	<0.1	50
Cadmium	mg/L	0.0001	0.0001	0.2
Chromium	mg/L	<0.002	<0.002	4
Cobalt	mg/L	<0.0005	<0.0005	5
Copper	mg/L	0.044	0.043	2
Iron	mg/L	0.42	0.35	10
Lead	mg/L	0.0034	0.0007	1
Lithium	mg/L	<0.01	<0.01	
Manganese	mg/L	0.018	0.042	5
Mercury	mg/L	<0.0002	<0.0002	0.05
Molybdenum	mg/L	<0.01	<0.001	1
Nickel	mg/L	0.001	0.002	2
Selenium	mg/L	<0.0008	<0.0008	1
Silicon	mg/L	4	2	
Silver	mg/L	0.0002	0.0004	1
strontium	mg/L	0.071	0.031	
Thallium	mg/L	<0.00005	<0.00005	

Tin	mg/L	<0.005	<0.005	
Titanium	mg/L	<0.01	0.04	
Uranium	mg/L	<0.0001	<0.0001	
Vanadium	mg/L	<0.005	<0.005	
Zinc	mg/L	0.04	0.04	3
Zirconium	mg/L	<0.002	<0.002	
Calcium	mg/L	10	8	
Magnesium	mg/L	2	1	
Potassium	mg/L	6	7	
Sodium	mg/L	16	14	
Sulphur	mg/L	<60	<60	

TABLE 2: Components - Comparison of UBC and GVRD Sewer Use Bylaw Standards

Components	**Units**	**UBC North Composite**	**UBC South Composite**	**GVRD Sewer Use Bylaw**
Total Hardness (CaCo3)	mg/L	33.1	24.3	
Biochemical Oxygen Demand	mg/L	34	31	500-1000
Chemical oxygen Demand	mg/L	170	112	
Conductivity	uS/cm	260	360	
pH		7	7.32	5.5 -12.0
Total Suspended Solids	mg/L	45	15	600

CHART 1: Rendered from Table 1 Data

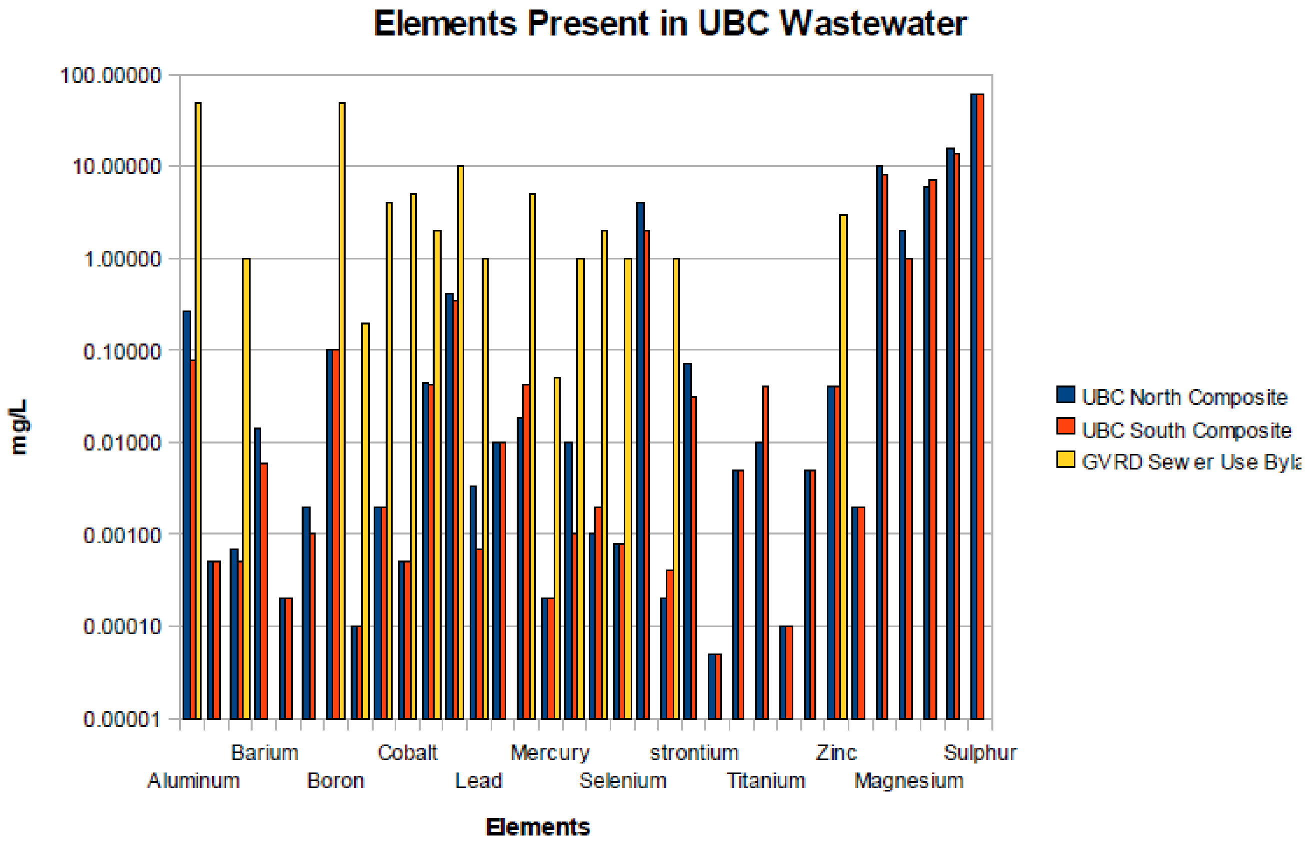


Table 3: Types of Pollutants in Wastewater

	Types of Pollutants	
Categories	**Forms**	**Effects**
Disease causing agents	Bacteria, viruses, protozoa, parasitic worms etc.	Can Cause death
2. Oxygen-Demanding Wastes	astes decomposed by oxygen-demanding bacteria	Deplete oxygen levels in water, causing other organisms in water to die
3. Water Soluble Inorganic Pollutants	Acids, Salts, Toxic Metals	Large quantities cause death to organisms in water, render water unfit to drink
4. Nutrients	Water-Soluble Nitrates and Phosphates	Deplete oxygen levels in water
. Organic Compounds	Oil, Plastics, pesticides	Can kill humans and aquatic life
6. Water-Soluble Radioactive compounds	Radioactive Compounds	Birth Defects, dangerous

Source: (Lenntech, 2009)

Table 4: RAW Sewage Flow Data (2002 - 2010 comparison)

Year	Total Sum Flow (L)	North Composite Flow	South Composite Flow
January –June 2010	1,944,992,233	1,331,457,318	613,534,915
2002	6,264,073,018	3,010,307,973	3,253,765,045