Analysis 3: Mechanical System #2: Greywater - Breadth

Background

Hotels generate a large amount of greywater from showers, sinks, and laundry. Currently this water is being expelled through the storm water and sanitary systems out to the city sewer system; none of it is being recycled. Each guest room has a typical bathroom with a shower, sink, and toilet. Because the Residence Inn Marriott is for long term stay the rooms also have kitchenettes with a sink, which increases the greywater production in each room. However, the Residence Inn does not have on-site laundry facilities like that of a more typical hotel. The only laundry facility present is a small bank of public washers and dryers, about 5 each. The Residence Inn sends their laundry to a third party service for cleaning. This greatly reduces the amount of greywater production.

It is possible to reuse water from showers, sinks, and laundry areas and expel it as blackwater that is not sanitary for reuse. The water being recycled is called greywater. Greywater is “washwater”. It is wastewater that contains all the waste from showers, sinks, and laundry areas with the exception of toilet waste and food waste from garbage disposals. There are significant differences between greywater and blackwater from toilets. Greywater can be cleaned either mechanically or biologically and recycled throughout a building or used for irrigation of landscaping and gardens. Blackwater cannot be cleaned or recycled due to fecal and other contaminants in the water. A general diagram of a typical residential greywater application can be seen below. Given enough space, this application is also viable for commercial buildings.

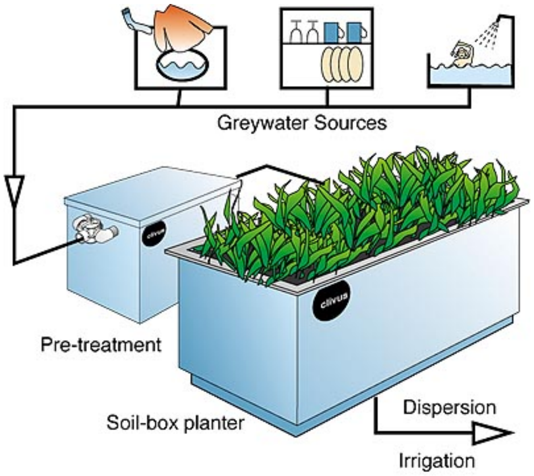

Figure 22: Residential Greywater System
Courtesy of www.greywater.com

The institution of a greywater system into a commercial or residential building can greatly reduce water consumption and help the plants and environment of the surrounding site.

Goal

One possible solution is to use shower water to flush toilets by implementing a constructed wetlands greywater system. Since the linens are sent to a third party service for cleaning, in this case the laundry water will not be used. The shower water will be analyzed for cleaning and recycling to flush toilets.

This breadth focuses on implementing a constructed wetlands greywater system, to reduce the water usage and add value to the building. This will be achieved by reducing the water need while providing a better system at a minimal cost. Constructability will also be analyzed to ensure the system can be built and managed.

Resources

- Southland Industries – Mike Miller
- Mechanical option faculty – Professor Moses Ling
- Agricultural Engineering faculty – Professor Robert Cameron
- Mechanical Textbook: Mechanical and Electrical Equipment for Buildings. 9th ed.

Constructed Wetlands Analysis

Please refer to Appendix F for calculations, diagrams, pictures, and cut sheets.

❖ *Step 1: Defining the Constructed Wetlands Greywater System*

- A constructed wetlands greywater system cleans the greywater biologically. This means the “constructed wetland system (CWS) pre-treats wastewater by filtration, settling, and bacterial decomposition” as defined by the University of Minnesota.
- This system is intended to mimic the system currently in use at Penn State’s Center for Sustainability.
  - “[This is a] natural wastewater treatment facility that mimics nature's own processes found in wetlands and marshes to remediate contaminated water. Micro-organisms break down and digest the waste, as they do in our outdoor ecosystems, found in closed aerobic and anaerobic tanks. Inside the biofilter’s greenhouse, tropical plants, flowers and a fish flourish in open aerobic tanks, continuing this filtering process. Since the plants are doing most of the work, the Ecological Systems Lab offers a low impact, less costly and less energy intensive alternative to chemical waste water treatment.”
  - Please visit: www.engr.psu.edu/cfs/index.aspx?p=1, for more information regarding Penn State’s Center for Sustainability.
  - Please refer to Appendix F for site pictures from March 19, 2008.

- The system intended for the Residence Inn will not need the closed aerobic treatment chambers because there will be no solid waste. Those chambers are only used in conjunction with a septic system to filter out and breakdown solid waste products. Shower water does not contain any solid waste and can be fed directly from the building into the "biofilter" tanks.

❖ *Step 2: Defining How the Constructed Wetlands Greywater System Works*

- The constructed wetlands system works by utilizing naturally occurring plants to filter out contaminants. This process typically takes 10 days to ensure the water is contaminant free. These contaminants in our shower water are actually helpful for plants like cattails, papyrus, and elephant ears; commonly used plants in a constructed wetlands system.
    - Commonly found contaminants in shower water are nitrogen, ammonium, phosphorus, and toxic organics such as chemical cleaning products; these materials are readily absorbed and used as nutrients in wetland plants.
    - Shower water usually does not contain pathogens, heavy metals, and dissolved inorganics that can cause harm if ingested.
    - Please visit http://www.epa.gov/nrmrl/pubs/625r00008/html/html/625R00008.htm for more information regarding greywater contaminants.
    - Please refer to Appendix F for select charts from the EPA.

Figure 23: Papyrus and Elephant Ears
Located at Penn State's Center for Sustainability

- The plants are held in a series of three to four "biofilter" tanks. The first three tanks contain the plants that can absorb the highest level of containments. The last tank, called the clarifier tank, contains small plants that usually float on the water and absorb the remaining few contaminants.

Figure 24: Clarifying Tank
Located at Penn State's Center for Sustainability

- From the clarifier tank, the water is funneled to a lined rock bed containing two types of rock, 3” to 5” rock and small pea gravel. These rocks filter more contaminants that the plants cannot absorb.
- After the rock bed filtering process, the water must be sent through a contained sand filter to eliminate any remaining particles or contaminants. Then the water can be sent back to the building.
- Because this system is intended use the water to flush toilets, the water must be potable. If there were to be a serious water crisis and the water supply was shutdown, the water in the tank of the toilet would to be used as the potable water supply. To achieve this, chlorine tablets should be added to the water to ensure there is no bacteria or other contaminants and is safe for ingestion.
- Figure 25 below shows a diagram of the system. The blue lines are the city water supply, the red are greywater, and black is black water. The arrows indicate the direction of the water flow. As seen, the water travels the shower and becomes greywater, then is treated and sent back in to flush toilets and becomes untreatable blackwater.

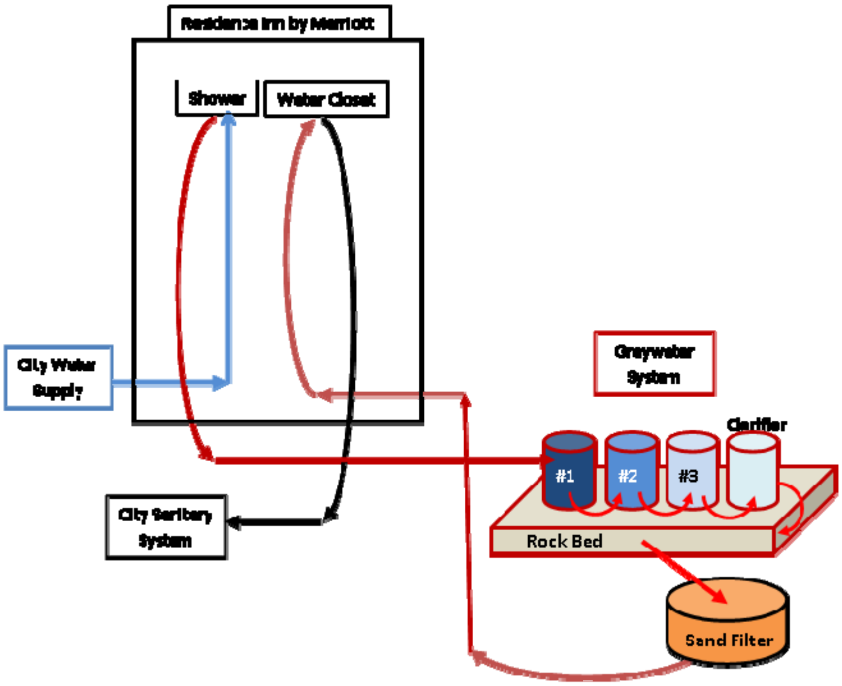

Figure 25: Constructed Wetlands Flow Diagram

❖ *Step 3: Options of the Constructed Wetlands Greywater System*

- Hotels produce approximately 60 gallons per day of greywater for each typical 2 person room. This translates to 30 gallons per person per day.

- The occupancy rate of a Residence Inn averages 81%, which in this case equals 203 people.
- The equipment used in the Residence Inn are low flow fixtures, using 2.5 gpm and 1.6 gal/flush for the shower head and toilet, respectively.
- This equates to 50,750 gallons of greywater production over ten days, but only 9,744 gallons of demand for ten days. There is a surplus of 41,006 gallons per ten days, approximately 4,100 gallons a day.
- There are three possible options to utilize all of the clean water produced:

    - The water can be deposited into the bay area near Alexandria, VA. This requires a National Pollutant Discharge Elimination System permit from the city, and a monitoring system. This option is not feasible for a hotel. The permit is very expensive and to properly monitor the water is unreasonable for a hotel.

    - The water can be supplied to a neighboring building to also flush toilets or clean laundry with. This option also requires extra permitting beyond that of a normal building permit; as well as a greater amount of piping to connect the buildings together. This option also poses coordination issues. It would be very difficult to ensure the system was built correctly. If not built correctly there would be serious health concerns of the occupants possibly ingesting untreated water. Overall, this option is not feasible due to cost and complexity.

    - The water can be used to enhance the aesthetics of the hotel by adding a waterfall, fountain, or greenhouse. This option requires a small amount of additional piping, two extra tanks and pumps to run the system, as well as minimum maintenance. The two extra tanks are required to store the water used in the fountain and for the fountain itself. This does provide more aesthetic appeal which could bring in more guests to the hotel. The waterfall or fountain would need to be fenced in to prevent any children from climbing in to swim or play, or from being harmed. This is the most feasible option.

❖ *Step 4: Implementing the Constructed Wetlands Greywater System*

- A fountain and greenhouse will be implemented into the constructed wetlands system. However, not all of the water will be used. The system will produce approximately double the volume needed for the toilets, enabling the other half will be used for the fountain. This is due to space constraints onsite.
- As noted earlier, the water needed for flushing toilets is 974.4 gallons per day, 9,744 gallons per ten days. Doubling the volume equals 1,950 gallons per day to be able to supply the building and the fountain.

- Based on the occupancy rate of 81%, 83 people produce 2,075 gallons per day which equals 5.5 floors of the hotel.
- The system must be sized to accommodate ten days of water and rock volume.
  - This system must process 20,750 gallons of water every ten days.
  - The water volume equals 2,774.3 CF. This is multiplied by 25% as a safety factor and rock volume, which equals 3,467.8 CF.
  - Half of this volume is stored in the rock bed; 1,734 CF.
  - A typical constructed wetland is 3' deep. By dividing by 3, the required wetland area is 578 SF. This does not include the area of the tanks.
  - The tanks must hold the other half of the water, 1,734 CF equals 12,969.3 gallons.
    - Due to tank restrictions, this system will essentially operate as two cleaning systems. The water will be split into two sets of the cleaning and clarifying tanks, which requires eight tanks. Each tank must hold at least 6,484.7 gallons.
- Each tank is sized at 6,800 gallons, is 10' in diameter and 12' high. The tanks will be buried so that only 3' are above ground level. These tanks add an area of 628.3 SF, making the total area required 1,206 SF. A greenhouse of 25' by 50' will be able to house the tanks and rock bed.

Figure 26: Penn State's Center for Sustainability Greenhouse
Courtesy of Penn State's Center for Sustainability website.

- The sand filter, fountain, and fountain storage tanks are also sized at 6,800 gallons. The sand filter and fountain storage tanks are buried underground, between the greenhouse and the fountain.
- The fountain and storage tank are connected in a loop. The fountain has an overflow near the top that will drain water into the storage tank below ground. In turn that water will then be pumped back into the fountain for reuse. This circular system is ideal, so that all the water is used in the fountain and can be evaporated.
- The constructed wetlands system produces 2,075 gallons per day. Half goes to the fountain and the other half is used for flushing toilets. However, this is 63.1 gallons per day more than the required amount for the building demand of 974.4 gallons. This excess allows for days when the water demand will be higher than designed for. Thus there must be another storage tank in the building. The extra storage tank inside the

building is 500 gallons and is tied into the booster pump system to pump the water to all 15 floors. This tank has an overflow that directs water to the city's sanitary system.

- A system rendering can be seen below. As shown, the fountain is in the foreground with the storage tank underneath it in white. The sand filter is the brown box below ground that feeds into the building. The greenhouse holds the cleaning and clarifying tanks. Flowers and plants can be grown in the rock bed. Flowers are shown inside the greenhouse to increase the aesthetic appeal; this can be seen in Figure 28 on the following page.

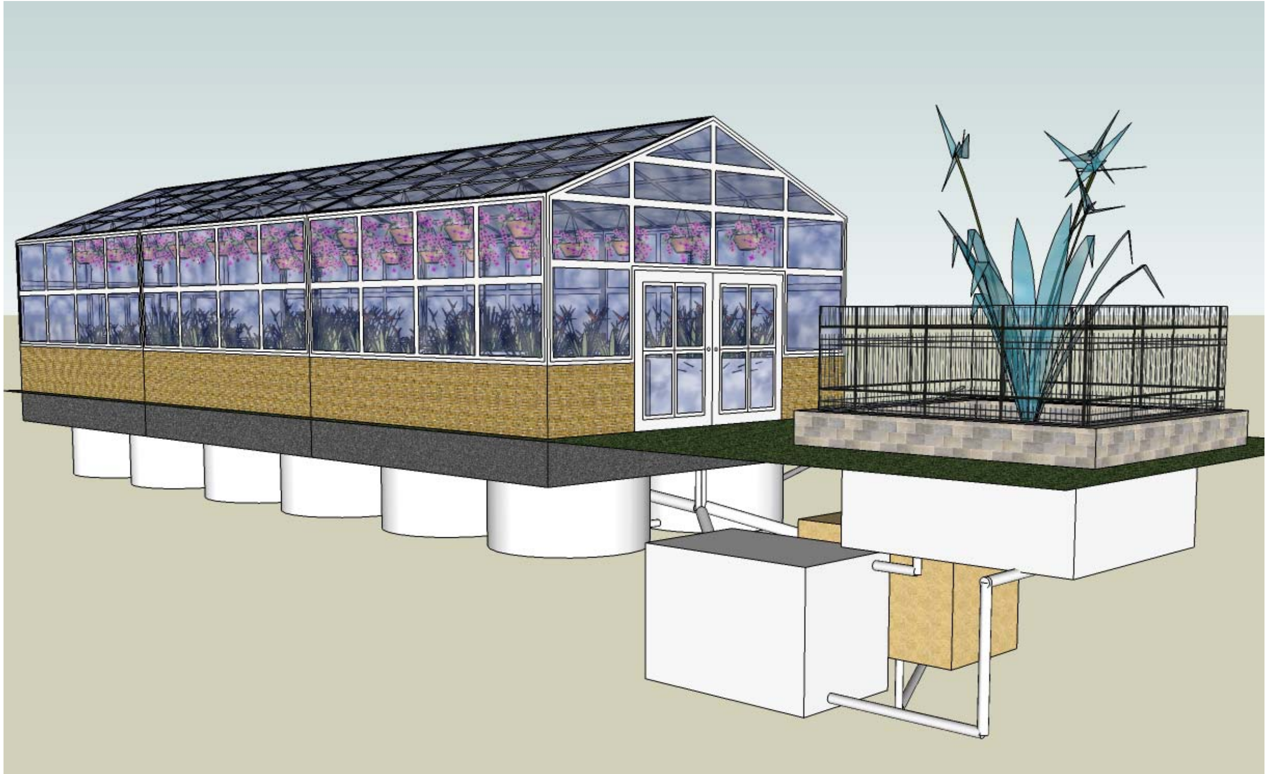

Figure 27: Constructed Wetland Greywater System Rendering
Created in Google SketchUp

Figure 28: Interior View of the Greenhouse
Created in Google SketchUp

Cost Analysis

By instituting a constructed wetlands greywater treatment system, an additional $88,787.52 must be added to the project budget. This is for materials only; additional excavation and crane usage would increase this cost. A typical greywater system is about $150,000.00. This is most likely how much the constructed wetlands would cost after the excavation and crane time were factored in.

However, by installing this system, 757,375 gallons of water would be saved each year. This equates to saving $518.80 per year on water costs according to Virginia American Water Company, who services the Alexandria area. The overall appeal of the system could help bring in more guests generating more revenue.

Constructability Review

The construction of the system is similar to that of any building. Excavation occurs first, then the underground piping and lining are installed. Next the tanks would be set and the stone backfilled in around them. Finally the fountain and greenhouse would be constructed. This process would require more equipment and crane usage, which could make the construction of the building more complex because of site constraints. The extra excavation and construction would add time to the schedule, the piping alone would add 6 days. The excavation and

construction could add a great deal more than that. Construction time was not added into this analysis.

The extra storage tank and booster pump needed inside the building pose another challenge. The original system's booster pump is located on the P-1 Level on the south end of the building. There is no space there to add another pump and tank. The new pump and tank would need to be located at the north end of the building where parking spot 30-C is located. This spot is between a mechanical shaft riser and an electrical room. By blocking this space and adding another booster pump room, there would be ample space to house the system. This can be seen in the figure below, and on Drawing P-103 in Appendix F.

Figure 29: North End of Building Footprint, Drawing P-103

By placing the booster pump room in space 30-C, architectural problems would also arise. There are a certain number of spaces for this building which fulfill a LEED requirement. If the number of spaces drops below the limit, that LEED point will be forfeited.

The metro tracks also pose an obstacle for construction. The additional crane would have to large enough to lift the tanks, the heaviest being about 1,600 lbs, but small enough to fit below the metro tracks. This poses the greatest challenge; the crane and the system must not damage or even touch the metro track, as mandated by the Washington Area Metro Transit Authority. Once the system is built, its footprint is also not permitted to be under the footprint of the metro tracks.

This greatly limits the space available to utilize for the constructed wetlands. Figure 30 and 31 on the next page show a plan view of the layout and a three dimensional view at the metro track. These figures show that the space is extremely limited but the system will fit without disrupting the limitations of the metro tracks.

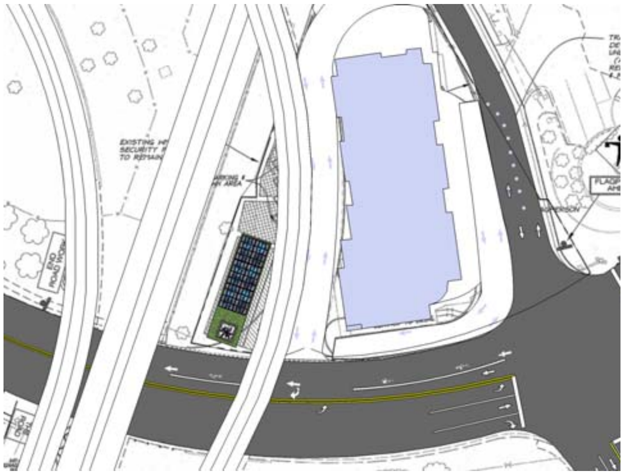

Figure 30: Site Plan with Constructed Wetlands System Created in Google SketchUp

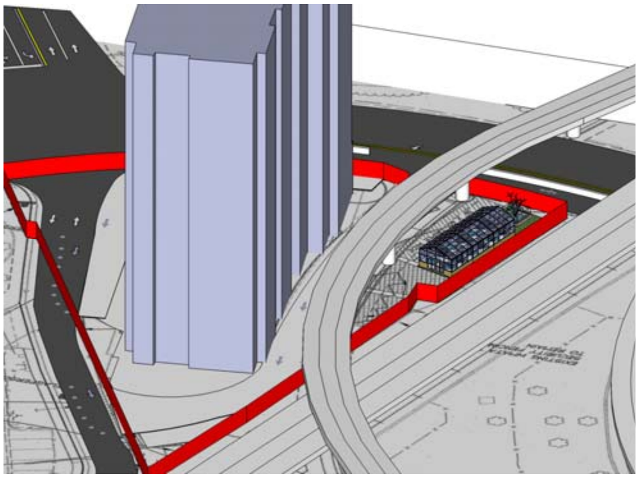

Figure 31: Aerial View from North End Created in Google SketchUp

Conclusion & Recommendation

Based upon this analysis the constructed wetland greywater treatment system has both positive aspects and negative aspects associated with it. These aspects should be considered when deciding to install a constructed wetland system.

- If the system is installed it adds at least $88,787.52 to the total budget, as well as schedule time. But it saves $518.80 and 757,375 gallons of water annually.
- If the system is not installed, time and money are saved, but 757,375 more gallons of water will be used annually. It also saves bringing an additional crane to the site and the site congestion associated with the construction.

Considering these factors, the owner of the project would play the deciding role. The system would be recommended if the owner is focused on helping the environment and aesthetic appeal of the building. However, the system would not be recommended if the owner is only concerned with the bottom line, saving money.

* This system will be addressed again in the Critical Industry Research Conclusion Area where a final conclusion will be made with regards to this project and owner.