Greywater Implementation in Montgomery County

Jason Winik, Phoo Chit, Jessica Dassen,
Lauren Wilson, Jessica Rothman, Megan Lewis

Under the supervision of Professor Rachel Lamb

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Gerrit Knaap, NCSG Executive Director
Uri Avin, PALS Director

Contents

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James Poore - Division Chief Facilities Management

Amanda Aparicio - Departmental Sustainability Coordinator

Executive Summary

Montgomery County Parks Department needs to adopt an alternative water source to secure the future of their water supply at their Damascus and Cabin John facilities. A greywater system is a viable option. Greywater is a sustainable, innovative water source collected from sinks and ice shavings for reuse options, conserving water, and reducing energy. Construction and design of these facilities will require new and retrofit strategies. As greywater contributes to a significant percentage of wastewater in public areas, including parks and ice rinks, a proper treatment system is required to remove bacteria and organic compounds. One such system is the Aqua2use Greywater Treatment System, which is a storage and sanitation system that is appropriate for non-potable water reuse and is economically beneficial.

This document will provide the blueprints, permits, costs, and the distribution and treatment processes for a greywater system for new and retrofit facilities. Case studies conducted in the Lee Valley facility in England and Citizen Bank Arena in Ontario, California will aid in determining the design and construction of the greywater ice rink system. The implementation of a greywater system in Spain will help determine the organization of a new or retrofit system. Quantitative assessments of water usage from toilets and ice rinks at the Cabin John facility, accompanied by indirect expense reductions that a greywater system generates, will aid in determining implementation costs. These systems will also comply with the plumbing code of Maryland, EPA's 2012 water reuse guidelines, and the 2011 NSF/ANSI 350 for design, operation, and monitoring requirements.

This paper aims to propose a system that provides alternate reuse options projecting at least a 30% reduction in water consumption. This result came from the Rockville 2017 Water Quality Report, which concluded that the use of an alternate toilet-flushing program resulted in a 40% decrease in water consumption when using an alternate non-potable water source.

Introduction

Montgomery County Department of Parks currently uses best management practices that reduce water consumption in parks, including low-flow toilets and motion sensor water faucets. The county is interested in implementing more best management practices that reduce potable water consumption, including treatment and reuse of ice rink shavings and sink and shower water in the existing Wheaton and Cabin John ice skating facilities as well as the new Damascus facility to be built.

There is currently no greywater implementation in Montgomery County parks, but using greywater in restrooms and resurfacing the skating rinks is possible. Ice shavings from resurfacing ice rinks can contain unsanitary items such as blood, hair, paint chips, mouth guards, and band aids. For this reason, it cannot be reused as greywater before being treated. Our goal is to therefore determine the sanitation process necessary to reuse this water on the ice rinks or for irrigation. One potential use for this water could be in the resurfacing/rink creation process of a new ice sheet. A method for collecting sink and shower water to be reused for toilet flushing will also be investigated.

Within this scope, the following objectives have been prioritized: 1) research applicable greywater treatment and sanitation processes and clarify the components of successful greywater systems implemented by other jurisdictions and how they can be implemented to be used for ice rinks and restrooms facilities; 2) provide tailored recommendations for retrofitting existing facilities as well as future facilities considered by Montgomery County Department of Parks; 3) determine the permitting process required to implement greywater reuse standards and procedures in restrooms and ice rinks as well as the cost-savings and return on investment of a greywater system.

This final deliverable has been separated into chapters according to the topics each team member has researched pertaining to the objectives. Chapters 1 and 2 discuss the technical components of implementing a greywater system which align with objective one; Chapters 3 and 4 discuss the actual implementation of a greywater system in the freestanding restrooms and the ice rink, which align with objective two; Chapters 5 and 6 discuss the permitting process and cost of implementation that is needed to install a greywater system, which aligns with objective three. The final deliverable concludes with the group's final recommendations and remarks regarding the implementation of greywater systems in Montgomery County parks.

Precedent Statement

Environmental Science and Policy students at the University of Maryland researched the implementation of greywater systems during the Fall 2017 semester with the intent of designing such a system for Montgomery County Department of Parks. This plan was developed under the direction of the Partnership for Action Learning in Sustainability (PALS) program and Professor Rachel Lamb. The information and recommendations included in this document are based primarily on literature review and case studies. Although the Montgomery Parks System is unique, these cases serve as parallel systems upon which to base our design. An ice rink facility that entirely uses greywater does not exist, thus this deliverable serves as a starting point for implementing such a system. This would be the first of its kind, and we are excited to be a part of this process.

Chapter 1: Sanitation Process and Available Greywater Treatment Technologies

Introduction and Overview of Current Water Usage

The overall objective of the group project is to create a general standardization for Montgomery County Parks Department to reuse greywater at the Cabin John and Wheaton ice rinks, as well as a new ice rink that will start construction in 2020. The main objective for this study is to collect information regarding the greywater sanitation process and the current greywater treatment technologies. Montgomery County Parks Department wants to recycle the greywater collected from ice rinks, showers, and sinks to be reused in toilets, irrigation, and possibly resurfacing the ice rinks. Montgomery County Parks Department has spent over $90,000 on water bills for Cabin John ice rink over the course of two years and reusing the greywater for the ice rinks can reduce their spending on water bills (Poore, J. personal communication. October 16, 2017). This chapter will include the current greywater treatment technologies, detailed explanation of greywater sanitation process, and description of which treatment system will be suitable for ice rinks and restroom facilities.

Determining the Current Treatment Process

The main objective for this paper is to answer the research question which is "What are the current available greywater treatment technologies, and which treatment plans will be applicable for ice rinks and restrooms facilities?" The approach is to study the basic sanitation process and different types of sanitation processes through literature reviews, then investigate the different types of greywater treatment technologies that are available. Finally, one must analyze which one will be applicable for the ice rinks. As mentioned above, Cabin John ice rink will have two greywater treatment systems, one of which will treat greywater from ice rinks and the other from bathroom facilities. The reason for having two separate treatment systems is that it will not be cost efficient to connect the pipelines from the holding tank containing melted ice shavings and the greywater from the restrooms. Some of the restrooms are outside of the ice rink building, which would increase costs of combining the two. There is also a concern that potentially hazardous paint will be in the ice shavings, which increases the necessary filtration of the ice rink shavings. However, after determining if the ice shavings contain paint, future ice rink facilities may be able to combine greywater from the sinks, showers, and rink shavings into one tank, streamlining the treatment process.

Basic Sanitation Process and Available Greywater Treatment Systems

This section will focus on explaining the basic sanitation process and available greywater treatment technologies that might be suitable for the ice rink and restroom facilities. The basic sanitation process includes collecting the raw greywater into a tank. The tank may contain a mechanical filter or filter pad to separate the solid material from the liquid. The water would then go through biological treatment to remove the bacteria, and then it would go through a final filter. The water would be disinfected afterwards, and the clean, but non-potable water would be stored in a tank. There are different filtration systems and also different types of disinfection processes of greywater. For the filtration system, there are filtration pads, sand filtration, and granular filtration, which uses volcanic tuffs. Two types of disinfection processes include UV disinfection and Chlorination.

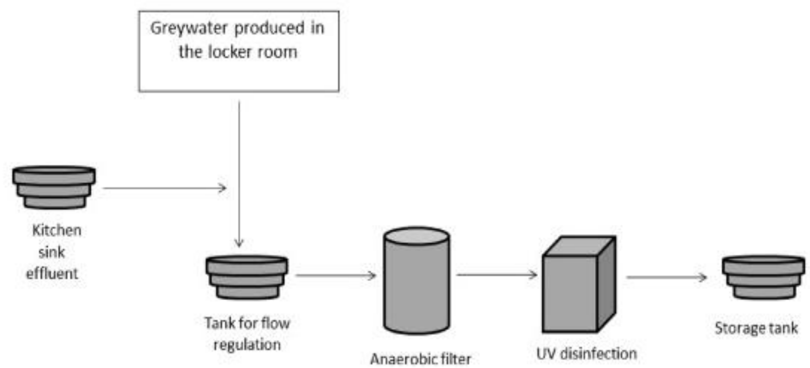

Figure 1.1

Greywater Treatment Unit Couto, E. d., Calijuri, M. L., Assemany, P. P., Santiago, A. F., & Lopes, L. S. (2015).

There are various types of greywater treatment technologies. Different brands of differing system types use different treatment processes as mentioned above. Most of the treatment systems are suitable for domestic uses, and good for a small-scale water usage. As for the commercial or a larger scale usage, there are treatment systems with bigger tanks that can be located either underground or outside of the facilities. Cabin John ice rink has four locker rooms with two showers, one toilet, one sink, men's restrooms with three urinals, three toilets, three sinks, and women's restrooms with six toilets, and three sinks. Greywater treatment for these restroom facilities would be suitable with companies like BioMicrobics and Aqua2use, examples that use greywater treatment systems that meet the permit requirements for the EPA for using treated greywater.

The most popular brands of greywater treatment systems include Aqua2use and BioMicrobics. Aqua2use model GTWS1200 is a commercial size system that can process about 300 gallons a day. For the Cabin John ice rink, there are three rinks that consist of 200x100ft, 200x85ft, and 90x45ft. These rinks are shaved about 24-30 times a day. Their holding tank has 100ft^3 capacity. For this kind of large scale greywater treatment for the ice rinks, Aqua2use will not be sufficient to treat the greywater from these ice rinks. However, for the freestanding bathrooms that are outside of the building, this Aqua2use model is suitable, as this system is compact (72x72 in) and not as expensive as other brands. This brand will be discussed more in Chapter 3.

BioMicrobics has three models for their greywater treatment systems. Their BioBarrier® MBR (Membrane BioReactor) System uses membrane technology, and can process from 375 gallons to 4500 gallons a day, depending on the model. This brand can process higher amounts of greywater, but due to its large size (41ftx12ft), the whole system, excluding the control

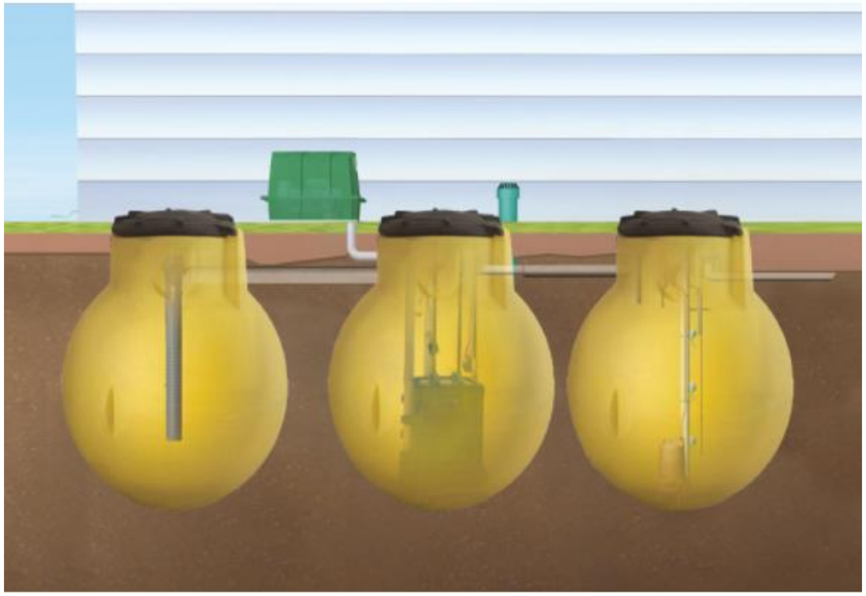

Figure 1.2
BioBarrier Greywater Treatment System.

panels, would have to be planted underground. This would not be recommended to be used for the existing facilities, as digging up the concrete and retrofitting to install this system would require closing the facility, and it would thus not be cost efficient. However, this may be a useful system for a new facility beginning construction.

Chapter 2: Limitations to Reusing Ice Rink Water

Background of Rink Resurfacing
Ice skating rinks are home to several potential reuses of greywater. Most obviously, bathroom sink piping could be

restructured to use soapy greywater as water for flushing toilets. A more challenging problem arises when dealing with ice shavings from resurfacing ice rinks. This process adds significant loads of water to waste treatment plants, when in reality, the water could serve several purposes in place of using fresh potable water. One constraint to implementing a greywater system into ice rinks is determining the quality of greywater that is safe for bathroom and rink resurfacing. This study required analysis of what levels of hazardous contaminants are acceptable for flushing toilets and resurfacing ice rinks, as well as what methods are best to filter out contaminants to reach a safe level.

Research Method of Ice Shaving Contaminants

This portion of the document aims to identify the hazardous compounds in ice shavings and how to remove them. The water used on ice rinks is not pure water. It is chemically treated by WSSC, and contains an assortment of paint colors. Thus, the water needs to be filtered if it will be repurposed. A literature review was performed on the known chemicals found in the ice.

The primary toxin found in the Jet Ice Limited red, blue, and white rink paint is octylphenoxypolyethoxyethanol, as identified by the Cabin John Ice Rink staff. The documents produced by Jet Ice Limited provide basic safety information about the compounds' reactivity, toxicological properties, and methods to prevent hazards to human health. While helpful, the fact sheet did not discuss how to remove paint from water, or how the paint may affect nearby irrigated fields if leaked (Material Safety Data Sheet 2003).

Determination of octylphenoxypolyethoxyethanol's impact on the soil surrounding Cabin John was performed next. Literature reviewed focused on toxicity to animals and the residence time in the soil and natural environment. A toxic chemical may hinder grass growth in fields and do more harm to ecosystems than would make the greywater use worth it.

A soil survey of the 108 acres surrounding Cabin John Ice Arena was performed to analyze how potent a chemical could be to the local environment. Compact soil is a major indicator for low permeability. This indicates chemicals would easily leach to rivers and streams nearby, proving deadly to aquatic life. Methods of removing octylphenoxypolyethoxyethanol for either irrigation or resurfacing were discussed last.

Health and Environmental Assessment of Octylphenoxypolyethoxyethanol

The literature review determined that Jet Ice Limited ice rink paint can be toxic to both humans and the environment. Human contact can result in eye, skin, or respiratory damage if not treated properly (Material Safety Data Sheet 2003). Octylphenoxypolyethoxyethanol entering the eye causes irritation and must be flushed with water for fifteen minutes. Medical attention must occur immediately. Contact with skin is slightly hazardous, and results in severe irritation over prolonged exposure (2003). If inhaled, one must move to an area with fresh air and receive oxygen if breathing proves difficult (2003). Information regarding serious skin contact, serious inhalation, or serious ingestion is not currently available.

Chronic health effects are possible as well. Mammalian somatic cells can become mutagenic and potentially result in cancer. Octylphenoxypolyethoxyethanol is a class 4 carcinogen, although there is no evidence to support the cancer-causing properties (Material Safety Data Sheet 2003). The toxins can also cause reproductive and developmental damage in females. Oral doses of 65,500 mg/kg were fed orally to mice and resulted in cancer and birth defects, but no studies were performed on humans (Material Safety Data Sheet 2003).

Environmental properties of octylphenoxypolyethoxyethanol were also investigated. It is combustible at elevated temperatures and is flammable in the presence of extreme heat. Short term products that result in degradation of the environment have not been studied extensively, however it is possible that long term residence time issues may arise (Montgomery County Government 2017). As the compound degrades, the oxygen and carbon dioxide molecules that construct octylphenoxypolyethoxyethanol are less toxic than the chemical. Other than the effects of octylphenoxypolyethoxyethanol on female mice, no studies regarding environmental impacts have been carried out (Montgomery County Government 2017).

After determining the effects of the paint on human and environmental health, methods to remove octylphenoxypolyethoxyethanol were identified. Microdialysis is new way of effectively removing a sample of TX, an industrial form of octylphenoxypolyethoxyethanol, that had not been researched thoroughly before (Opitz et al 2015). Previous means of extracting TX as a precipitate has involved organic solvents and chromatographic separation (Opitz et al 2015). When low concentrations of detergents were present in solution, low amounts of TX were found. But as the amount of TX and other additives present in solution increased, the amount of TX present in the spectroscopy were found (Opitz et al 2015).

Sludge formation can isolate precipitates, like TX, from water and be filtered out while iron and ferric ions suspend solids in water. Following the addition of these compounds, the authors of one study tested the water for turbidity, chemical oxygen demand (COD), color, and volume of sludge in water. COD removal reached up to 91% from bioflocculation, color removal reached 99% with coagulant and PO (Aboulhassan et al 2007). From the literature review performed, one of these methods must be used to remove TX from the paint in Cabin John Ice Rink before reuse of the water.

Soil and Wildlife Impacts

If water is not used for ice rink resurfacing but rather for irrigation, an assessment of soil structure needed to be completed. Web Soil Survey, a USDA online tool, can provide specific information about soil type and properties for any location in the United States. A 108-acre plot that included Cabin John Ice Rink, forest, and other fields was chosen to see how paint chemicals might impact the nearby landscapes.

Figure 2.1 is a visual representation of the study region. Each separate soil type is designated by a black outlined polygon. Yellow polygons show medium soil compaction, red show high soil compaction, and white show flat urban lands with no soil exposed to the surface. All but the urban surfaces shown in Figure 2.1 and Table 2.1 show that the study region has medium to high soil compaction throughout. The denser the soil, the more runoff occurs that will carry any potential chemicals and toxins across the land surface without percolating or entering the soil (D'Haene et al 2008). TX can then be found throughout any irrigated field, such as the baseball field labeled 65B in Figure 2.1. This ice rink is approximately seven miles away from the Potomac River and so smaller streams and tributaries of the Potomac can be contaminated easily (Ten-year Comprehensive Water Supply and Sewerage Systems Plan 2017). The land in this region is also highly elevated, with all of it aside from urban land being 3-25% sloped (Soil Survey Staff 2013). Uneven surfaces speed up the leaching and runoff process due to gravity. One final soil property of importance is that all soils mentioned are silt loams. Silt loams consist mainly of both silt and clay layers throughout. Silt particles are loosely held together and allow for water to easily enter the soil, while clay is compact. The combination of these, according to Web Soil Survey staff make silt loams prime land for farming or fields (2013). Compaction from young athletes playing baseball or other sports and large machinery crush the soil, diminishing the mentioned benefits.

Figure 2.1
Soil map of Cabin John Ice Rink.

Map Unit Symbol	Map Unit Name	Slope	Compaction Susceptibility	Acres	% of AOI
1C	Gaila silt loam	8-15%	High	8.4	7.70%
2B	Glenelg silt loam	3-8%	Medium	60.2	55.40%
2C	Glenelg silt loam	8-15%	Medium	4.7	4.40%
54A	Hatboro silt loam	0-3%	Medium	1.8	1.60%
65B	Wheaton silt loam	0-8%	Medium	16	14.70%
116D	Blocktown channery silt loam	15-25%	Medium	0.5	0.50%
400	Urban land	NA	NA	17.1	15.70%

Table 2.1

Soil types and characteristics of Cabin John Ice Rink.

Chapter 3: Components of a Greywater System

Parallel Systems to Cabin John

This chapter of the document will provide an evaluation of the components of the greywater system and its potential reuse in the Cabin John facility. Montgomery County is seeking the implementation of an innovative technique in potable and non-potable water management that is efficient and appropriate for water reuse. The technique will require the retrofitting of the existing plumbing infrastructure and fixture systems at the Cabin John facility in order to collect greywater from sinks and showers to be reused for toilet flushing and landscape irrigation. Further discussion of the greywater treatment system will include the description and operations of two greywater case studies conducted in Doha, Qatar and Mallorca Island, Spain, as well as a proposal for the adoption of a greywater system by Montgomery County for a sustainable approach to potable and non-potable water management.

Research Methods of Existing Greywater Facilities

Two studies were conducted utilizing a greywater treatment system that Montgomery County could utilize at their Cabin John facility. The first study was conducted at a Junior College building in Doha, Qatar in 2015. The system was designed and constructed to incorporate greywater for interior and exterior uses. The greywater was collected from sinks and cycled through an Aqua2use GWTS1200 system, where it subsequently went through a pre-filtering stage using a series of filters to remove large and small particles, treating approximately 300 gallons of water. The water was then transported through two treatment chambers using an ultraviolet disinfectant. The treated water was transported to a holding tank for toilet flushing and landscape irrigation as needed. Water consumption and management was measured to evaluate water-use efficiency, and energy measurements were taken to evaluate energy efficiency over a three-year period.

The second study was conducted in Mallorca Island, Spain at a hotel with eighty-one rooms and nine floors. The intention was to provide a safe indoor greywater system to flush toilets at the hotel (March, & Orozco 2004). The reuse system collected water from sinks and sent it through a filtration stage, sedimentation process, and then finally disinfected with sodium hypochlorite. The treated water was temporarily stored in a ground level tank and pumped to a higher-level tank that was connected to six tanks, diverting the water to the hotel rooms toilets for flushing. The water temperature operated at approximately 32 degrees Celsius for effective treatment. Water analysis and sampling was conducted on raw and treated greywater in order to evaluate the quality of the reused greywater and for removal efficiency of the system.

Possible Greywater Implementation

The greywater system in Doha, Qatar using Aqua2use showed an 85% reduction in potable water usage from the implementation of the system in 2015. The filtered greywater operates as a backup watering system for landscape irrigation and toilet flushing. The greywater system in Spain used sedimentation, filtration and disinfection treatment, and allowed them to function for one year without any major problems. The shift in water distribution didn't affect the characteristics of the treated water. Both systems were successful in implementing a greywater system that potentially reduces water consumption and provides a reduction in energy use. However, the sedimentation, filtration and disinfection system requires more research in their disinfecting process because the greywater produced in the study area was contaminated with bacteria. The Cabin John facility will undergo a plumbing retrofit that requires a separation of the sink pipes from the main union pipes (that distributes water to the sewer) and capping each of them. The sink pipe will then attach to another union pipe that connects to a treatment system. The most beneficial system is Aqua2use because this system is an appropriate treatment source for removal efficiency and will provide a model for their new facility in Damascus (Figure 3.2).

Greywater Retrofit at Cabin John

The greywater in this paper included water from sinks and showers reused for toilet flushing and landscape irrigation (Figure 3.1). The combination of greywater and rainwater was proposed, but results from studies indicated that the addition of rainwater introduces very little benefits in water saving efficiency. The water treatment system suggested for Montgomery County is the Aqua2use treatment system that utilizes the necessary components required for bacteria and solid waste removal efficiency.

Information presented in this research suggests that adopting this type of system can provide economic and environmental benefits. However, problems could arise that prevent the successful implementation of this type of system. The problem of plumbing retrofitting installation and cost, acceptance from society, along with other unknowns that could develop into major concerns.

The implementation of a greywater system for Cabin John facility will provide a significant decrease in water demand and serve as a pilot system for Montgomery County in the reuse of natural resources.

Figure 3.1
Aqua2use greywater treatment system (GWTS1200) working principle on how it reuses greywater for toilet flushing and landscape irrigation (Aqua2use Greywater Treatment System 2010).

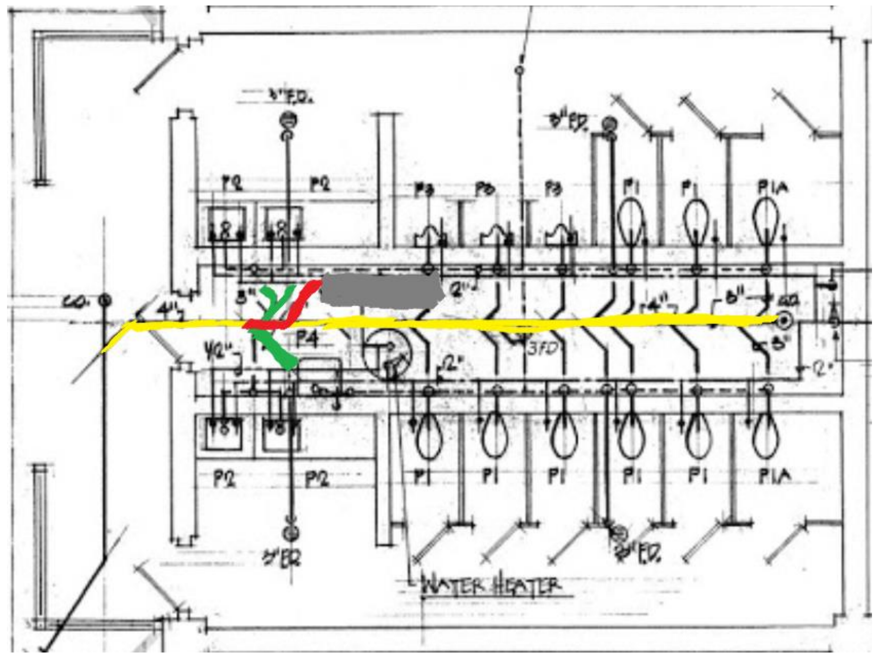

Figure 3.2
Current Blueprint for Cabin John Standard Bathroom. The sinks pipes (green) should be separated from the main pipes (yellow) and connected to another union pipe (red) that connects to the Aqua2use system (grey).

Chapter 4: Greywater Ice Rinks

Overview of Ice Rink Shavings

Ice shavings present many different possible re-uses. Each layer of ice that is shaved off the ice rinks can be reused in different ways before being sent into the sewer system. One way ice shavings can be reused is in resurfacing. Reusing the ice shavings would help reduce the amount of freshwater used on the ice in the ice rink facilities every day. This would be sustainable and possibly save money in water costs.

Existing Greywater Ice Rink Facilities

In order to look at how Montgomery County Department of Parks would implement a greywater system, a case study was conducted looking at how other facilities have reused ice shavings. One of these facilities is in Ontario, California. They have a functioning recycled ice rink however, they are not necessarily using the ice shavings to re-surface. They have a stormwater capture facility that they treat to re-surface. In this facility, their ice rink includes a portion of recycled rainwater. Although Ontario does not use the ice shavings, they have a recycled ice rink so it is a possibility to build a greywater ice rink. Another facility that reuses ice shavings is the Lee Valley White Water Centre in Hertfordshire, England. In the Lee Valley system, the Zamboni shaves the ice off the rink. Next the Zamboni dumps the ice shavings into a hot well that is heated from the waste heat of the refrigeration plant. There the ice shaving melt and the liquid is easier to transport and filter. Then the ice melt is pumped through strainers and a UV filter into a holding tank in the roof. They then use this water in their toilets and urinals. The holding tank also has the ability to be supplemented by clean, potable water in the event the ice shavings are insufficient in filling the toilets and urinals.

Although Lee Valley does not use their ice shavings to re-surface their rinks, their process of capturing the ice shavings and treating the ice shavings can be implemented in the Montgomery Parks facilities for possible reuse in irrigation, bathrooms, and possibly on the ice rink itself.

Retrofitting Cabin John for Greywater Use

Cabin John presents some issues because the facility is already in place and the building has a lot of concrete. In order to reuse the ice shavings in either the ice rink or the toilets, the holding tank would not be placed on the roof like in the Lee Valley system, but instead in an annex off to the side of the where the current Zamboni machines are held, as seen in Figure 4.1. A building 25 feet by 25 feet would need to be built where the blue X is located in the blueprint in Figure 4.1. That location is right next to where the Zamboni's are located and where the current holding tank is. In addition, there is space there to build. Since it is near the current holding tank, constructing and piping is easier than if the building were farther away. The annex would house a holding tank a little bigger than the current holding tank.

The process for capturing ice shavings would work as follows: the Zamboni would shave the top layer off the ice, it would dump the ice shavings into the current holding tank, the melted ice shaving would then be pumped through a strainer and filters to remove any frozen items such as hair ties, mouth guards, and anything else. Then the melted ice shaving would be dumped into the new holding tank that would be in the annex. That holding tank would have a heated rotational component to keep the melted ice from refreezing and to keep Legionella bacteria from forming. The water could then be pumped directly to the Aqua2use systems for the toilets and urinals in the Cabin John facility. The facility does have a lot of concrete so it would take a substantial amount of construction. But once the water is in the holding tank, and the piping infrastructure is in place, the toilets could have greywater in them. Any excess ice melt that is not used in the toilets, could either be treated for irrigation purposes or dumped into the sewer. By building an annex and leaving the current clean water toilet system in place, there is a backup in case the ice shavings are insufficient or there is an issue with the ice shavings. In case of a malfunction, the facility could turn a valve and return to entirely potable water in the toilets and urinals.

The process to reuse the shaved ice on the rinks is similar to using the greywater is toilets. Pumping the water from one holding tank to the second holding tank is the same except that the catchment filter would be placed under the grate that is over the current holding tank. This is to ensure easy maintenance. The catchment filter would be either mesh or metal and need to be cleaned and checked regularly. This filter would be responsible for removing any items that were frozen into the ice so the material needs to be sturdy and the gaps need to be small. There is not much known about the risks associated with reusing ice shavings for resurfacing. The quality and integrity of the water may decrease after each shaving period. In addition, there may be freezing issues if the water quality is too poor. There are also unknown health issues with using greywater. We were unable to test the ice shavings so we do not know for sure what is in the ice melt. Further testing on the ice melt is required before moving forward with resurfacing efforts. If it is deemed safe to reuse the ice melt without any further filtration system, then the Zamboni can draw water right from the second holding tank in the annex building.

If there is a need for more filtration, an ultraviolet filtration system can be implemented and constructed. The Aqua2use system outlined in Chapter 3 will help purify the water. This UV system is similar to the one that Lee Valley uses. The systems would be built in the annex building where the second holding tank would be located. This means that the annex building may have to be a little larger. The ice melt would be pumped from the existing holding tank in the Cabin John facility to the Aqua2use systems in the annex. The filtration system would then clean the water and deposit the filtered ice melt into the holding tank. Once the melted ice shavings are in the second holding tank, a nozzle and pipe would be placed on the side of the tank to transfer the water from the second holding tank to the room where the Zamboni's are held. When preparing to re-ice the rinks, the Zamboni would be filled with 50% greywater and 50% fresh, potable water. This is not a perfect estimate and trials might have to be conducted in order to discover what is the correct mixture of greywater and freshwater to use each icing. The reason that the re-icing cannot be 100% greywater is because the shaving and dumping process does not recapture 100% of the ice. In addition, the integrity and quality of the water is compromised a bit when going through the icing, shaving, and filtration process. Mixing the greywater with potable water will hopefully mitigate some of these issues.

Issues With Greywater for Resurfacing

As mentioned earlier, there are no other functioning ice rinks that reuse ice shavings for resurfacing. This means that there is not much data about the quality of ice melt. Furthermore, there are no previous examples to base another facility on. Another issue is the filtration system. The Aqua2use systems can only filter so much water per day. Chapter 3 and Chapter 6 go further into detail about the systems but the amount of ice shavings far surpass the ability of one Aqua2use system to purify. This means that if Montgomery Parks wants to build a greywater ice rink, many Aqua2use systems would need to be used. Multiple systems require more intense infrastructure and

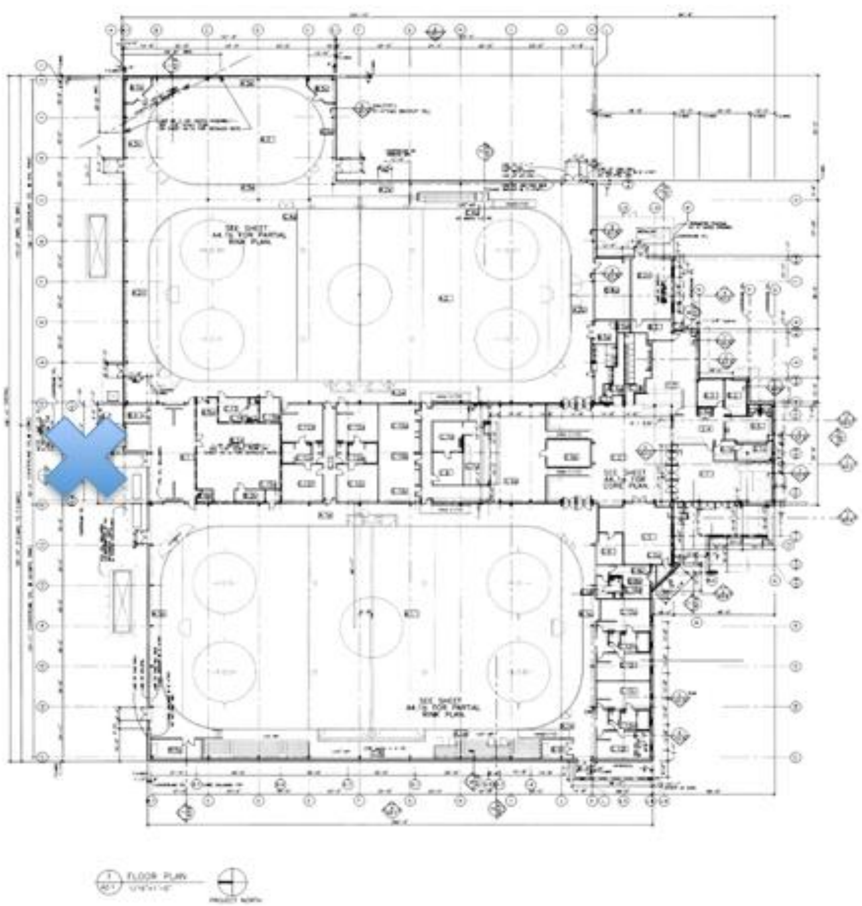

Figure 4.1
Current Blueprint for Cabin John Facility with Blue X for projected new building.

a higher risk of malfunction. It is possible to create a test ice rink and use one or two filtration systems to purify enough ice melt to test on a studio ice rink. By creating a smaller test project, Montgomery Parks can see if the benefit is strong enough to try implementing greywater ice rinks on a large scale.

Chapter 5: Permitting & Regulations

Introduction and Overview of the Permitting Process

The regulations of greywater systems fall under federal, state, and local government agencies, all of which address the implementation of greywater systems via policies and permits. The study initially reviewed literature on state and county building and plumbing policies to find pertinent local codes. After reviewing the 2013 Plumbing & Fuel Gas Code provided by the Washington Suburban Sanitary Commission, the federal quality standards were reviewed, as provided in the Environmental Protection Agency's 2012 Guidelines for Water Reuse. Although some states have their own greywater system standards, Maryland does not. Montgomery County Parks Department must rely on the WSSC to set the permitting process, which in turn relies on federal water quality standards. There is also no federal-wide standard for greywater in place. Rather, the standards set by the NSF and the EPA are meant as suggested regulatory guidelines to serve as guidance for water re-use opportunities. A NPDES permit will not be necessary in this case, neither for plumbing, ice rink resurfacing, nor for irrigation systems, barring any surface water discharge. The current permitting process would begin with the parks staff having a certified engineer draft a plumbing plan and submit that with a Long Form Permit Application to WSSC. Upon approval, construction can begin, and federal guidelines denote the water quality standards once the system is in place.

Researching the Permitting and Regulatory Process

In order to determine local codes pertinent to implementing a greywater system in Montgomery County Parks, Tom Buckley, Planning and Cross Connection Section Manager at WSSC was contacted to retrieve the 2013 WSSC Plumbing & Fuel Gas Code. This document pertains to greywater used in restrooms and re-icing rinks at Cabin John and other new and existing facilities.

The Maryland Department of the Environment's Wastewater Permits Program was reviewed to determine the state and local permits required to use treated greywater for irrigation purposes. The MDE's Guidelines for Use of Class IV Reclaimed Water was reviewed to determine if a discharge permit is required to transport the treated water to an underground cistern used in stormwater storage, as well as any stipulations on the area of use. Federal regulations involving the discharge of greywater from the ice rink to a stormwater cistern for irrigation was investigated by contacting Ginny L. Davis, Public Information Center Specialist from the US EPA, as well as reviewing the National Pollutant Discharge System (NPDES) guidelines.

To determine the water quality standards greywater systems must adhere to, including toilet flushing, irrigation, and ice rink resurfacing, the EPA's 2012 Guidelines for Water Reuse was reviewed. This document contains both the EPA standards, as well as the NSF/ANSI 350-1 regulations for water quality.

State & Local Permitting

The permitting and regulatory process for using greywater in restrooms and ice rinks falls under two legislative levels; state and federal. Maryland does not have state-wide regulations for greywater systems. Instead, the state defers to local plumbing codes for water re-use systems ("Wastewater Permits Program" 2017). In the case of Montgomery County Department of Parks, the WSSC is the sanitation commission governing over all retrofitting and new construction plumbing projects involving access to the sewer. A permit must be acquired before any construction begins. A long form permit is submitted through WSSC and must be completed by a registered plumber and accompanied by design plans. This is done through the e-permitting system on WSSC's website under non-residential replacement fixtures for retrofitting cases. This application is available under non-residential new construction for new park fixtures (*2013 WSSC Plumbing & Fuel Gas Code* 2013). The applicable subsections are listed in Table 5.1.

Federal Water Regulations

As noted in chapter 9 of the WSSC plumbing code, water quality standards are set by the EPA for states without their own set of standards. The 2012 EPA Guidelines for Water Reuse include both the standards set by the EPA as well as the NSF/ANSI 350-1 regulations. The NSF/ANSI standard 350-1 for greywater outlines an intended greywater system should be performance tested for six months on the site of use. The system can be monitored remotely after it is in place. The standards set by the NSF are not federally required, though adherence to these standards can gain a site up to 10 points in LEED certification in the water efficiency category (*2012*

Guidelines for Water Reuse 2012). NSF/ANSI Standard 350-1 standards are available in Table 5.2.

The greywater from ice shavings that could potentially be used for irrigation purposes is not permitted or regulated under WSSC because it does not involve sewer access. The water will go from a filtration system to an underground cistern without mixing with surface waters. Since NPDES permits are written for discharges to surface waters, there's no regulation or guidance under NPDES for reuse of wastewater. If there is a wastewater treatment plant discharge that proposes to reuse the effluent, it would normally be treated to whatever standards are needed to protect the surface water since there would most likely still be some of the effluent discharging to the surface water. If 100% of the effluent is being reused and there is no surface water discharge, as is the proposed system, no NPDES permit would be required (Davis 2017). The MDE notes that if the non-potable water is produced and treated on-site and used for incidental irrigation with a 25-foot buffer between the park and neighboring property, a discharge permit can be applied for, which would exclude the system from the requirements of MDE's reclaimed water guidelines (*Guidelines for Use of Class IV Reclaimed Water: High Potential for Human Contact* 2016). For water not covered by a discharge permit, the EPA has suggested regulatory guidelines that serve as guidance for water re-use opportunities in states such as Maryland that have not developed their own criteria ("Permits" 2017). These guidelines are in Table 5.3.

Upon completion of the literature review, the following tables contain pertinent codes and regulations.

Chapter 9		
Section Title	Subsection	Description
901.3- General Definitions	4.2	Graywater system: A decentralized water re-use system that employs on-site treatment of the discharge from specific plumbing fixtures such as bathtubs, showers, lavatory sinks, clothes washers, laundry tubs/trays, etc. thereby producing recycled water for various specific non-potable uses.
902.1- Permit Requirements	1.3	Use Within the Building: Any utilization of non-potable water within the building, including but not limited to, toilet and urinal flushing; mechanical system make-up; equipment cooling; etc.
904.1- General System Design	1.1	Construction Documents: Design plans shall include plan views, including exterior tanks and associated piping, complete elevation schematics, and corresponding equipment schedules. Zoom and scale shall be adequately enlarged to facilitate a clear understanding of all equipment, appurtenances and flow direction.
904.5- Minimum Water Quality Standard		It is the responsibility of the appropriate State and County Government Agencies to establish water quality standards. At a minimum, non-potable water produced for plumbing, mechanical and industrial process as allowed by this Code, shall meet the parameters set forth by the Maryland Department of the Environment – Class IV effluent water quality standard, or other equivalent standards established by local authorities.
904.6- Piping	1	Graywater Collection Piping. Graywater collection piping systems and associated collection reservoirs/sumps shall be protected from the sanitary sewer system by segregation, an air gap or a backwater valve.
905.3- Disclosure and Signage		Water Re-use Equipment Room. In all water re-use equipment rooms there shall be a disclosure sign, or signs as needed. Each sign provided shall have highly visible lettering a minimum of a ½" in height on a contrasting background with the following text: "This building utilizes a water re-use system that produces non-potable water for [describe use]. Prior to commencing any plumbing or mechanical work on premises, by law you must consult with the system operator."

Table 5.1

Subsection of Chapter 9 of the 2013 WSSC Plumbing & Fuel Gas Code.

	Class R		Class C	
Parameter	Test Average	Single Sample Maximum	Test Average	Single Sample Maximum
$CBOD_5$ (mg/L)	10	25	10	25
TSS (mg/L)	10	30	10	30
Turbidity (NTU)	5	10	2	5
E. coli[2] (MPN/100 mL)	14	240	2.2	200
pH (SU)	6.0 - 9.0	NA[1]	6.0 - 9.0	NA
Storage vessel disinfection (mg/L)[3]	≥ 0.5 - ≤ 2.5	NA	≥ 0.5 - ≤ 2.5	NA
Color	MR[4]	NA	MR	NA
Odor	Nonoffensive	NA	Nonoffensive	NA
Oily film and foam	Nondetectable	Nondetectable	Nondetectable	Nondetectable
Energy consumption	MR	NA	MR	NA

[1] NA: not applicable
[2] Calculated as geometric mean
[3] As total chlorine; other disinfectants can be used
[4] MR: Measured reported only

Table 5.2
NSF/ANSI Standard 350-1.

Resuse Category and Description	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring
Urban Reuse			
Unrestricted: the use of reclaimed water in nonpotable applications in municipal settings where public access is not restricted	Secondary Filtration Disinfection	pH: 6.0-9.0 10 mg/l BOD 2 NTU No detectable fecal coliform /100 ml 1 mg/l Cl_2 residual (min.)	pH: weekly BOD: weekly Turbidity: continuous Fecal coliform: daily Cl_2 residual: continuous

Table 5.3
2012 EPA Guidelines for Water Reuse.

Chapter 6: Cost of Implementation

Introduction to Determining Cost-savings and Return on Investment of a Greywater System

The purpose of this chapter is to conduct a quantitative assessment to calculate the respective cost-savings a greywater system will bring in the new Damascus ice rink facility in Montgomery County by observing the current water usage costs in the Cabin John ice rink facility. The final result will be to establish the return on investment of a greywater system. This will be determined by examining greywater implementation costs-savings through algebraic equations which will use current water usage amounts in the Cabin John ice rink shavings and its restroom facilities as variables. In addition, a literature review will also consider possible indirect savings that a greywater system generates due to environmental and social savings and benefits. The expectation is to present the cost-savings of implementing a greywater system which will lead to a return on investment in a matter of years. Although an investment to buy a greywater system, the monetary, environmental, and social benefits it will provide to Montgomery County will far exceed the upfront costs. Annually, Montgomery County Department of Parks can save an average of $4,201.36 in its water costs in the newly constructed Damascus facility by installing two Aqua2use model GTWS1200 greywater systems, one for the ice rink and one for the bathroom facilities. The return on investment for buying each greywater system is 5.66 years. These numbers are significant, for as more greywater systems are bought, the more savings Montgomery County will see every year over time.

How to Calculate the Cost-savings and Return on Investment of a Greywater System through a Quantitative Assessment

The algebraic equations used in Table 6.1 were initially inspired by an empirical study that looked at the cost-savings greywater systems bring to commercial facilities (Memon et al 2005). Similar variables to the ones expressed in the methods section of this chapter were used, however, the variables were altered to be site specific to the Cabin John facility, rather than an extremely large commercial facility overall. The equations were derived by starting at what PALS staff eventually wanted to identify, the cost-savings resulting from the use of a greywater system and the return on investment of buying a system.

To find out how much the reused water would be able to save Montgomery County, it is assumed a greywater system can run with total efficiency, for the average or minimum water used each day in the Cabin John facility is 6.84 Kgal (W_d). This amount of water should be more than the amount of water a greywater system can cycle each day (G), assuming the number of systems purchased (N) is sufficiently few, which is shown in Equation (1).

$$W_d > N*G \quad (1)$$

The savings a greywater system can bring to Montgomery County (S) can be calculated from information that is readily available, such as the number of greywater systems desired to be purchased (N), the amount of water a greywater system can cycle each day (G), the days of the year Cabin John facility is open (D), and the average cost per Kgal of water bought from the water utility company (C_{Kgal}), which was found from a Cabin John water bill, which is shown in Equation (2).

$$S = N*G*D*C_{Kgal} \quad (2)$$

Now that the savings have been calculated, the initial cost of implementing a greywater system (C_{init}) must be determined, as shown in Equation (3). The price of a greywater system (C_{GS}) is known, but must be multiplied by the number of systems to be purchased (N).

$$C_{init} = N*C_{GS} \quad (3)$$

The time for a return on investment in years (T_{ret}) can now be calculated, defined by the amount of time it will take the savings to meet the initial cost, as expressed in Equation (4).

$$T_{ret} = C_{init} / S \quad (4)$$

The cost to install and setup the greywater systems (C_{setup}) and the cost of annual maintenance needed for the greywater systems (C_{ma}) cannot be estimated at the current time. Equation (5) is noted so that these costs can be accounted for in the years to come, which will impact the years it will take to see a return on investment of the systems (T_{ret}).

$$T_{ret} = (C_{init} + C_{setup})/(S - C_{ma}) \quad (5)$$

Variable	Representation	Value, if known
C_{Kgal}	=average cost per Kgal of water from the utility company	$19.29
G	=greywater system output/day	0.30 Kgal
C_{GS}	=cost per greywater filtration system	$11,900.00
S	=annual savings from greywater usage in years	-
T_{ret}	=time for return on investment in years	-
C_{ma}	=cost of annual maintenance to greywater system	(!)
C_{setup}	=cost to install and setup the greywater system	(!)
C_{init}	=initial cost of implementing the greywater system	-
N	=number of greywater systems	2
D	=days of the year	363
W_d	=average or minimum water used each day	6.84 Kgal

Number	Equation
1	Given: $W_d > N*G$
2	$S = N*G*D*C_{Kgal}$ [dollars/year]
3	$C_{init} = N*C_{GS}$ [dollars]
4	$T_{ret} = C_{init} / S$ (years)(!!)
5	If C_{setup} and C_{ma} are significant, then $T_{ret} = (C_{init} + C_{setup})/(S - C_{ma})$

(!) This value cannot be estimated at the current time, but can be factored in once known.

(!!) Then, the investment will be returned at approximately the same time regardless of the number of systems purchased, provided the systems are all operating at capacity.
$T_{ret} = G*D*C_{Kgal} / C_{GS}$

Table 6.1

A quantitative assessment to determine the cost-savings and return on investment of a greywater system.

1) Given: $W_d > N*G$
$6.84 \text{ Kgal} > 2*0.30 \text{ Kgal}$
$6.84 \text{ Kgal} > 0.60 \text{ Kgal}$

2) $S = N*G*D*C_{Kgal}$ [dollars/year]
$S = 2*0.30 \text{ Kgal}*363*\$19.29$
$S = \$4,201.36$

3) $C_{init} = N*C_{GS}$ [dollars]
$C_{init} = 2*\$11,900.00$
$C_{init} = \$23,800.00$

4) $T_{ret} = C_{init} / S$ [years](!!)
$T_{ret} = \$23,800.00/\$4,201.36$
$T_{ret} = 5.66$ years

5) $T_{ret} = (C_{init} + C_{setup})/(S - C_{ma})$

Explanation of the Quantitative Assessment

The rinks and bathrooms in Cabin John facility use water that can potentially be recycled into greywater by the shavings and flushings of all bathroom appliances. Corresponding to the assigned numbers of the equations listed in the above Table 6.1: (1) this total amount, the possible greywater, will presumably always be very large, as the average amount of water used on a daily basis in the facility is 6.86 Kgal (James Poore, personal communication, October 13, 2017). One Aqua2use model GTWS1200 greywater system has a capacity, or output, of 300 gallons per day, or 0.30 Kgal (Greywater Action 2017). As long as the possible greywater produced is greater than the amount a greywater system can hold, it can be assumed that the greywater system is working at maximum capacity. It is also assumed that all water produced by the greywater system will be reused immediately for the rinks or bathrooms.

As more systems are bought, there may be a worry of whether the systems can be used to maximum efficiency. For example, if there are three greywater systems just for the ice shavings pit of the ice rink, and if the pit is only filled once per day, then, since the pit can hold 750 gallons (0.75 Kgal), that is how much greywater will be produced, and not the maximum 0.90 Kgal (3 * 0.30 Kgal) that the three greywater systems can filter (James Poore, personal communication, October 13, 2017). Therefore, assume the new Damascus facility produces more greywater than each greywater system can treat daily. The reason this assumption is made is because the average amount of water used every day in Cabin John is 6.86 Kgal while a single Aqua2use greywater system can only treat 0.30 Kgal per day. This amount of 6.86 Kgal of water is so high that even the capacity of filtration of multiple greywater systems should not come close to the water produced by the ice rinks and bathrooms (James Poore, personal communication, October 13, 2017). Thus, the annual savings at the new facility is simply the number of systems there is * 0.30 Kgal * 363 days a year * the cost per Kgal of water (Jason Schoenfeld, personal communication, October 13, 2017). Cabin John facility is open 363 days of the year, as it is closed on Christmas Day and Thanksgiving (Montgomery Parks 2017).

The cost of a typical commercial-sized Aqua2use greywater system is $11,900.00 (Greywater Action 2017). The average cost of water used every day at Cabin John facility was determined to be $18.11/Kgal. However, the cost of the rate of water every year is slowly increasing . Therefore, the most recent cost of water for Cabin John has been used as the water/Kgal value, which is $19.29/Kgal (James Poore, personal communication, October 13, 2017). (2) If two greywater systems are purchased, one for the bathroom facilities (for sink, toilet, urinal, and shower water) and one for the ice rink shavings, the annual savings will amount to roughly 2 systems * 0.30 Kgal * 363 days of the year * $19.29 = $4,201.36 per year. (3) The installation costs for two greywater systems amounts to 2 * $11,900.00 = $23,800.00. (4) Thus, the systems will pay for themselves in $23,800.00/$4,201.36 = 5.66 years (Jason Schoenfeld, personal communication, October 13, 2017). Not accounting for maintenance and setup costs, it will take 5.66 years to see a return on investment on each greywater system.

Indirect Savings and Benefits Brought by Greywater Systems

Implementing a greywater system clearly brings many direct financial savings to Montgomery County. Despite the cost-savings primarily being financial, other savings and benefits that should be considered when implementing a greywater system are environmental savings and social savings. From an environmental savings standpoint, by using greywater in the Damascus facility, the local community water system will extremely benefit. There will be a relieved stress on water resources, as groundwater and reservoirs can recharge their water supply more quickly as a result of lower water withdrawals from local rivers due to the decreased dependency on potable water. In addition to reducing the pressure on local water systems, Montgomery County will save money on energy costs as they are reducing the energy it takes to transport their wastewater to a treatment facility. By treating water in house with a greywater system, water can be piped from the shower straight to the toilet to meet flushing needs without having to be transported all the way to a treatment facility (Munoz 2006). This not only saves Montgomery County money on energy savings, but it also reduces its carbon footprint. With reduced energy consumption in the Damascus facility, less carbon emissions are released into the atmosphere which in return reduces its carbon footprint. Less carbon emissions also equates to improved air quality in the area surrounding the ice rink (Adeyeye 2013).

A concern of park's staff is the public's perception of greywater, and whether or not a negative outlook of implementing a greywater system will affect the Damascus ice rink's use. A greywater system is a positive addition to the Montgomery County community, as it brings many social benefits. These benefits can include providing the community with aesthetic improvements on-site due to increased green space. With more streamflow and water in the local system around the Damascus facility due to less pumping of potable water, more grass, trees, shrubs, or other vegetation can flourish. Not only does improved green space provide the Damascus facility aesthetic enhancements, but it can also increase or enhance local recreational opportunities outside of the building (NASEM 2016). Added local green space and improved local riparian systems from decreased pumping of water by instead using greywater allows Montgomery County the ability to add a park, community garden, playground, public seating area, or public plaza outside of the Damascus facility if park's staff wishes (EPA 2017). Another social benefit that a greywater system will bring to the community is increased public education associated to using local resources and encouraging sustainability. The Damascus ice rink facility will be a community center for Montgomery County; park's staff can educate the public on the importance of recycling water and using sustainable practices at the facility by explaining what greywater is and how the system functions. Through this education, the public can become more aware of where their water comes from and the benefits of using recycled water (NASEM 2016).

Chapter 7: Final Recommendations and Remarks

The culmination of our research is a final recommendation describing the greywater systems that can be implemented at the Cabin John and Wheaton ice rink facilities, as well as a new ice rink in Damascus.

At the existing facilities in Cabin John and Wheaton, we recommend using the ice shavings for irrigation rather than resurfacing of the rinks or toilet flushing. This is largely due to the cost and feasibility of retrofitting these facilities. The amount of concrete at these locations is extensive, bringing the cost of construction up. Removing concrete floors and walls would require the facility to close during the retrofitting process, further increasing costs. The treatment of ice shavings would require construction of a large annex to house the treatment and storage apparatus, as well as retrofitting all existing plumbing. Irrigation would require the least amount of construction, and the treatment of the greywater can be done with the stormwater contained in the underground cisterns, which is the most cost-effective treatment method.

Before reusing water containing potential paint products, however, a water quality test of shaved ice must be completed. Several water quality tests were researched, but no labs for ocytylphonoxylpolyethoxythanol were identified as feasible over the course of the study period. If it is found that the water is not free of this compound, then an implementable method of extraction needs to exist. From the literature available, two main methods of ocytylphonoxylpolyethoxythanol removal were identified, microdialysis and sludge formation, though these will be difficult to implement on a large scale. There have also been some health concerns voiced from WSSC with regards to using greywater to resurface the ice rinks, due to the ease of spread of contamination through dermal, eye, and mouth contact, as well as high humidity and constant inhalation on the ice rinks.

The free-standing restroom facilities throughout Montgomery County Parks should be implemented with a filtration system to use sink water for toilet flushing. This would require adding a filter, such as the Aqua2use, to existing plumbing in the corridor between the men’s and women’s restrooms. This is a relatively easy process that requires little construction and is both cost-effective and environmentally beneficial.

At the new facility in Damascus, we recommend capturing greywater from ice shavings and restroom sinks to be used for toilet flushing.

Installing two Aqua2use greywater systems in the new Damascus facility will significantly save Montgomery County money in the long-term, as the annual savings the county can expect is $4,201.36. The return on investment of each greywater system purchased will take 5.66 years. The quantitative assessment shows that the amount of time it will take to see a return on investment is independent of the number of greywater systems implemented, if each system can run at or near maximum capacity. Therefore, the facility will be able to save more money annually with each system purchased. It is also important to note that because the greywater savings come directly from the cost of water, savings will increase proportionally with any change in the price of water from the utility company. If many systems can be purchased and run optimally, long-term savings increase directly. For an extreme example, ten systems are still half the approximate daily water usage, and would reliably be able to provide as much as $21,000.00 in savings annually combined from the use of ten systems.

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