Stormwater Harvesting and Reuse in Montgomery County Parks

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Acronyms and Abbreviations

BMP	Best Management Practice
CWA	Clean Water Act
EPA	Environmental Protection Agency
ESD	Environmental Site Design
LID	Low Impact Development
MDE	Maryland Department of the Environment
NPDES	National Pollutant Discharge Elimination System
PALS	Partnership for Active Learning in Sustainability
PDS	Partial Duration Series
RWH	Rainwater Harvesting
SMS	Soil Moisture Sensor
WSSC	Washington Suburban Sanitary Commission

Executive Summary

Stormwater management is a vital practice that allows urban areas to mitigate negative water quality impacts associated with urban development. The Montgomery County Department of Parks seeks to increase their reuse of stormwater as part of its commitment to furthering sustainability practices within the parks system and to minimize their impact on the environment.

The project seeks to assist the Department of Parks by researching possible stormwater harvesting and filtration systems to implement in Cabin John Regional Park. This paper examines stormwater reuse for irrigation on Shirley Povich Field, a baseball field located northwest of the ice rink. The four objectives for this research project were as follows: (1) assess current stormwater flow and collection potential off of hardscape around Cabin John Regional Park, (2) analyze similar projects elsewhere to build the groundwork for developing a plan to harvest stormwater, (3) develop a generalized set of procedures that provide options for stormwater harvesting at different locations within Montgomery County Parks using the data gathered in in Objective 1, and (4) develop the most efficient and cost effective system to harvest and filter stormwater. This paper will provide suggestions on possible placement of a system, ways to store the collected stormwater, and other recommendations for components of a stormwater reuse system. The processes used to generate these plans for Cabin John are summarized in Appendix A so that they can be applied to other Montgomery County Parks locations.

This project comprises a number of fields related to environmental science and policy, scientific analysis of water quality, biological and ecological studies, topography analysis of the terrain of the park, the mechanics of stormwater management structures, economic analysis, and research of applicable policies and permitting processes associated with implementing such projects.

Based on the research findings, a rainwater collection and reuse system for irrigating Shirley Povich Field would not be a financially reasonable decision for Cabin John Regional Park due to the high upfront implementation costs, which include retrofitting required and a low return on investment. However, this type of system may be more cost effective at new parks where retrofitting would not be required. A more cost-effective way Cabin John Regional Park could reduce its water demand would be investing in a smart irrigation system with a soil moisture sensor that would reduce water use without the prohibitive retrofitting costs.

Introduction

Montgomery County Department of Parks has been innovative in its reuse of faucet water and installation of automatic faucets. Now, the Department of Parks and the Partnership for Action Learning in Sustainability (PALS) have tasked Team II Stormwater with researching and providing recommendations for a stormwater harvesting and reuse system that would help irrigate Shirley Povich Field, a baseball field within the Cabin John Regional Park, with captured stormwater runoff. This paper will also provide guidance for implementing similar stormwater harvesting systems at other parks within the Montgomery County Parks system.

This paper is informed by seven studies that review scientific literature, policy papers, and engineering design specifications covering the following topics: stormwater policy and permitting processes; stormwater quality, filtration, and treatment of contaminated stormwater; stormwater best management practices (BMPs), the effects of stormwater harvesting on downstream ecosystems; stormwater collection methods; and irrigation practices. These topics were researched with a focus on the potential to implement a stormwater capture and reuse system at Cabin John Regional Park. Case studies have found that implementing stormwater irrigation systems can be costly and are usually implemented on a smaller scale. This paper will examine if the costs of implementing a stormwater reuse and irrigation system outweigh the direct economic benefits to determine if this system is an economically sound method of reducing stormwater pollution and water use at Cabin John Regional Park.

Overarching Issue

The purpose of this research project is to research and analyze methods for implementing stormwater reuse systems at Montgomery County Parks. This case study will specifically discuss the process associated with implementing a new stormwater management system for Cabin John Regional Park. The system will collect stormwater runoff and reuse it for irrigation. These efforts may be replicated at other locations within the Montgomery Parks System.

A new stormwater management system requires many different actions. First, stormwater must be harvested from impervious surfaces, in this case, the roof of the ice rink's roof and surrounding parking lots. Next, the stormwater must be treated and filtered. After filtration, the water needs to be stored either underground or above ground. The water then needs to be distributed to the irrigation site. The impact of stormwater collection on stream ecosystems should also be considered. A cost benefit analysis will determine the viability of each component and the system as a whole.

Case Study Location

This case study focuses on rainwater harvesting for irrigation at Cabin John Regional Park (Figure 1). Cabin John is part of the Montgomery County Parks System, and is located in Rockville, Maryland, approximately six miles northwest of Washington D.C. Its two primary features are the Cabin John Ice Rink and Shirley Povich Field, a three-acre baseball field. The surrounding area is semi-urban with a small stretch of trees north of the rink and a larger forested area to the west. A small tributary stream, Cabin John Creek, runs north of the project location. This stream is part of the Potomac River tributary system. The park also consists of parking areas, tennis courts, soccer fields, baseball/softball fields, and a walking trail. The park is open to the public most days of the year.

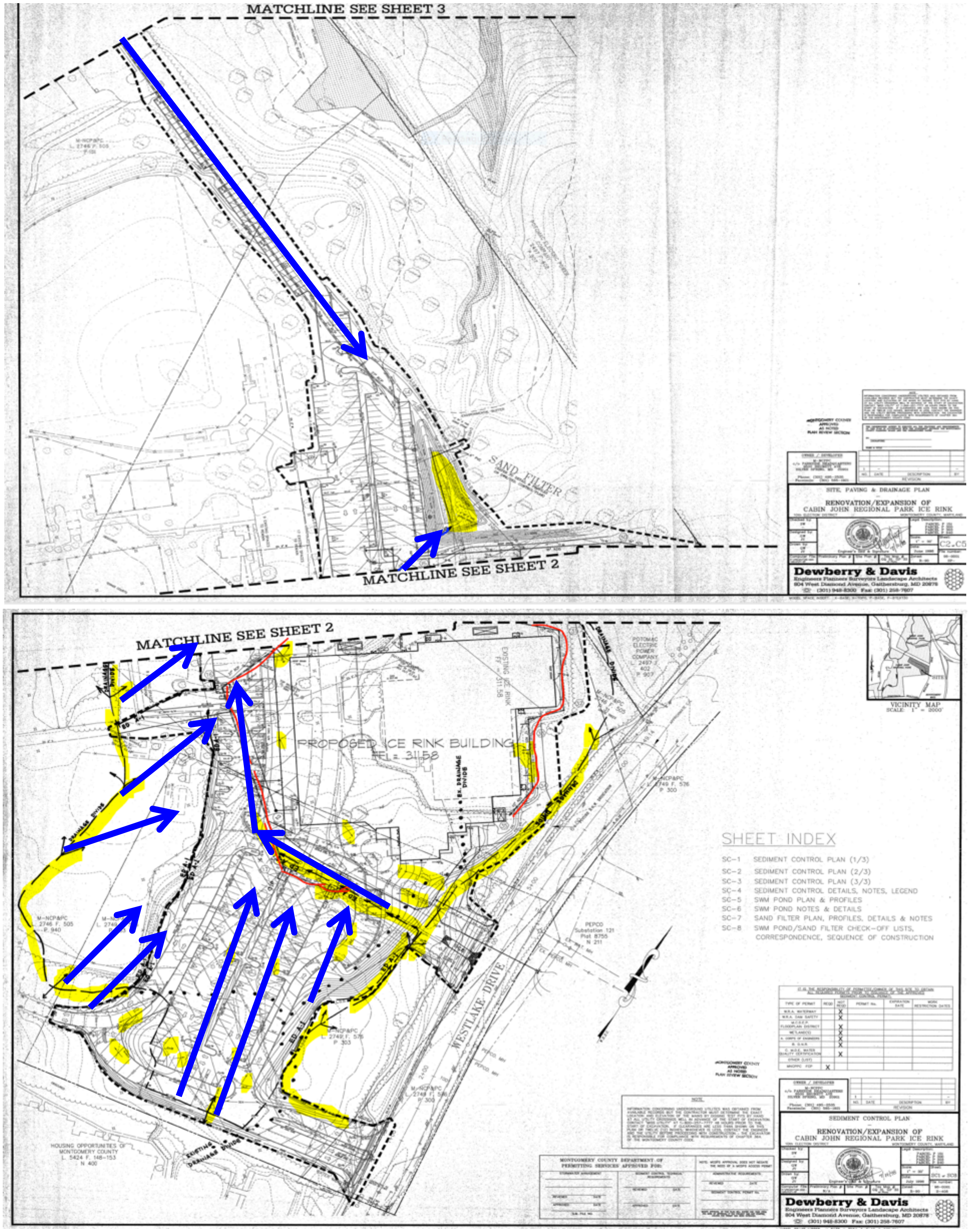
Figure 1: Google Earth Aerial Image of Project Area at Cabin John Regional Park (Cabin John Ice Rink, Shirley Povich Field, surrounding athletic fields, and Cabin John Creek)

Topography

The topography of Cabin John can be seen in Figures 2 and 3. The closely spaced lines indicate dramatic changes in elevation and show where water flows during a storm—from high to low points. Therefore, analyzing where these elevation changes are will determine stormwater drainage patterns. These topographical maps show a steep change in elevation in the park's southern parking lot (near the entrance) that slopes downward toward the ice rink. Similarly, the roads to the northwest of the ice rink also have a steep change in elevation sloping downward toward the ice rink.

Drainage/Runoff Patterns

The yellow arrows indicate concentrated flow patterns based on topography. At certain points, the stormwater will diverge based on the topography and some of it will not be captured. The blue arrows show the stormwater flows based on topography. Using these flow patterns, a location can be chosen that will capture a majority of stormwater runoff from hardscape. Based on this analysis of topography and drainage patterns, the area with the highest potential for capturing the highest quantity of stormwater is just north of the ice rink in a small, flat parking area near Shirley Povich Field. The areas from which stormwater would be collected (highlighted in blue) and the area of where stormwater collection potential is highest (highlighted in red) is shown in Figure 4.



Figures 2 and 3: Topographical map of Cabin John Regional Park with projected stormwater flow (blue arrows) (northern section: top, southern section: bottom)

Figure 4: Google Earth image with a projection of the area from which stormwater would be collected (blue) and area with the highest potential for stormwater runoff collection around Cabin John Ice Rink (red) based on topography analysis

Existing Stormwater Features

The area around the ice rink is already equipped with some stormwater management features. The most basic feature is a storm drain system underneath the parking lots, with three main entries into the system (Figure 5). The contents of these drains empty into a stormwater best management practice (BMP) structure located directly north of the rink (Figure 6). This feature is labeled as a bioretention pond, but its design more closely resembles a surface sand filter. Currently, stormwater that enters the drains underneath the parking lot is redirected into this filter before it flows into a stormwater retention pond downhill from the ice rink. The contents of the stormwater retention pond eventually infiltrate into the soil and flow into Cabin John Creek, a tributary to the Potomac River.

An additional stormwater feature at this location is rooftop disconnection on the ice rink itself (Figure 7). This BMP redirects rooftop runoff collected in the gutters away from impervious surfaces to reduce the amount of runoff. Some of these drains also empty into the surface sand filter near the rink. If a stormwater harvesting system were to be implemented at this location, it could be tied into these existing stormwater features.

Figure 5: Locations of existing stormwater drains near Cabin John Ice Rink

Figure 6: Existing stormwater BMP (surface sand filter) located north of Cabin John Ice Rink (left)
Figure 7: Rooftop disconnection located along the exterior of Cabin John Ice Rink (right)

Stormwater Collection Potential

Based on the topography analysis and runoff drainage patterns, the ideal location for stormwater collection near the ice rink would be the near the small, flat parking, lot southeast of Shirley Povich Field. This area is surrounded by impervious surfaces that are steeply sloped, which causes stormwater runoff to funnel into this area. The area itself is relatively flat and near Shirley Povich Field, an area that could be irrigated using collected stormwater. Furthermore, runoff from the ice rink roof flows into the existing stormwater BMP near this location. Currently, all runoff from these hardscape surfaces flows into this BMP near the ice rink. This stormwater flow could be redirected from the BMP outflow into a collection area or it could be redirected into a collection area and any overflow could be redirected to this BMP, which would filter the water and slow down the flow.

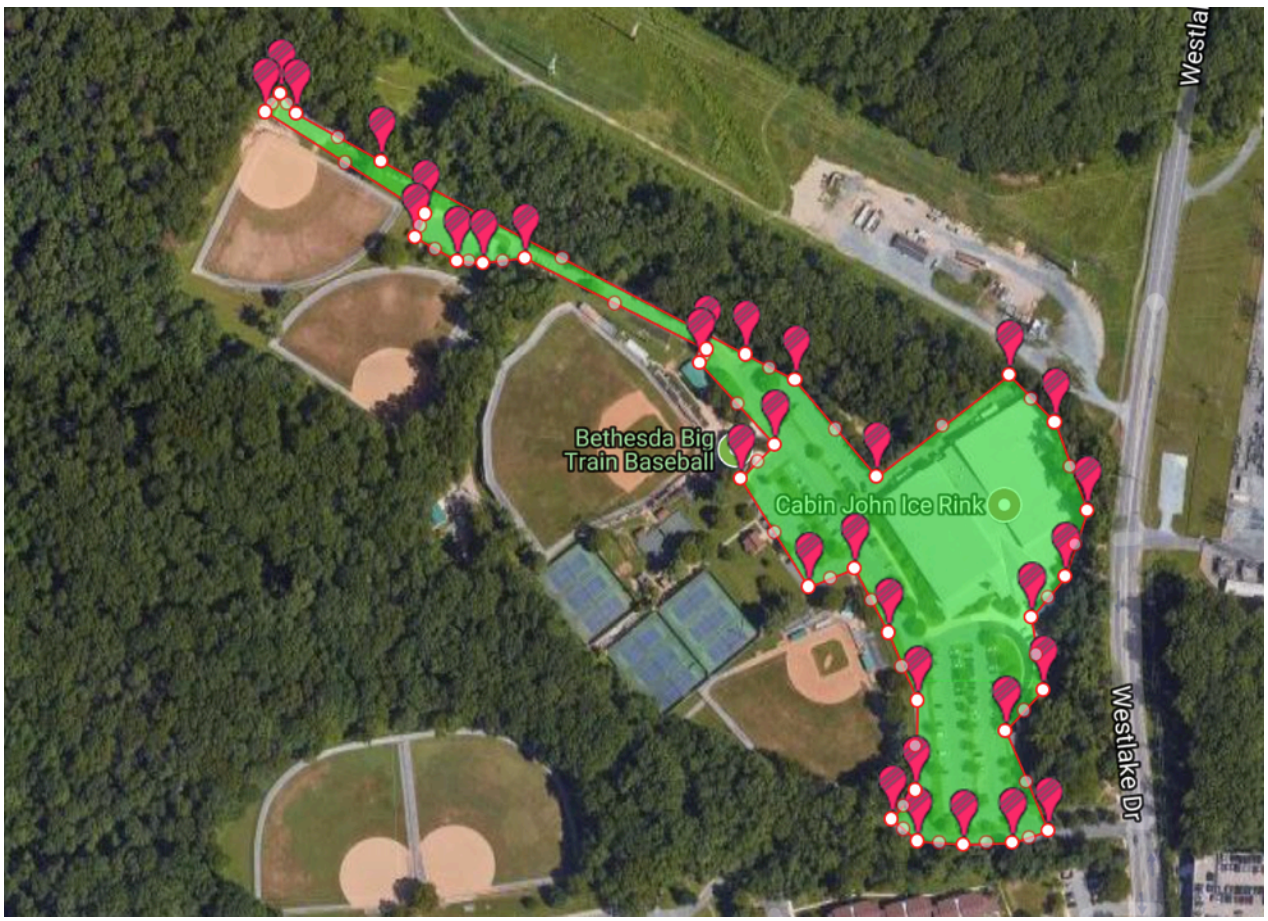


Figure 8: Impervious surface area from where stormwater runoff will be collected (Draftlogic, 2017)

After determining these flow patterns and an ideal point for stormwater collection, the next step is to calculate the amount of runoff generated from these surfaces. The Maryland Department of the

Environment (MDE) guidelines help calculate the anticipated amount of runoff per month for stormwater collection systems. The first dataset needed is average rainfall by month for Rockville, MD (US Climate Data, 2017). The second dataset needed is the area of hardscape from where stormwater will be collected. These values were calculated using a Google Maps tool shown in Figure 8 (Draftlogic, 2017). The total amount of hardscape from which stormwater could be collected was calculated to be approximately 315,000 square feet. However, this is only an estimate and a professional engineer should calculate the exact area. Also, note that Figure 9 shows the total area for hardscape and the rink roof. These values were also calculated separately to show the difference between collecting stormwater off all hardscape and collecting stormwater runoff from the roof alone (Table 1).

Using this data, the average monthly rainfall (inches) was converted to feet and multiplied by the area of the hardscape (square feet) from where stormwater will be collected. This generated the values for cubic feet of runoff per month, which was then converted to gallons per month of rainwater collected. MDE recommends assuming a five percent loss of stormwater, so these values for average runoff per month were reduced by five percent. The values of average monthly rain and average runoff for all hardscape and for just the rink roof are shown in Table 1.

Month	***Estimated Runoff from Hardscape (gal)***	***Estimated Runoff from Rink Roof (gal)***
Jan	624,927	169,837
Feb	527,924	143,475
Mar	727,527	197,721
Apr	595,080	161,726
May	815,204	221,549
Jun	697,680	189,610
Jul	727,527	197,721
Aug	690,218	187,582
Sep	762,971	207,354
Oct	624,927	169,837
Nov	639,851	173,893
Dec	595,080	161,726
Annual	8,028,917	2,182,030

Table 1: Estimated runoff for the hardscape around Cabin John Ice Rink and for the ice rink roof using MDE calculations for average monthly rainfall (MDE, 2012)

The amount of runoff can also be calculated by using partial duration series (PDS) estimates for Maryland (Figure 9). In a two-year storm, the average rainfall for Maryland is approximately 3.1 inches. Using this information, the area of hardscape where runoff would be collected can be multiplied by average amount of rainfall in a two-year period. This calculation was used to determine the peak flow around Cabin John Ice Rink and thus can be used in the design of a potential stormwater collection system.

*3.1(in of rainfall) *315,000(ft) (144) = 140,616,000 in^3 of rainfall per two-year rainfall.*

140,616,000 in^3 x 0.004326 in^3*/1 gallon = 608,305 gallon*s

These calculations give the maximum amount of stormwater runoff that can be collected for a two-year, 24-hour storm. Based on these calculations, the maximum that can be collected in this scenario is around 608,000 gallons.

For a typical Maryland rainstorm, the maximum rainfall for a one-year rainstorm of six hours should be used (Figure 9). Using this table and these assumptions, the maximum rainfall for a typical storm is 1.07 inches. If this value is multiplied this by the total hardscape area where stormwater will be collected (315,000 square feet) and converted from inches to cubic feet, the resulting value is approximately 200,000 gallons of water that could be collected.

PF tabular | PF graphical | Supplementary information | Print Page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.356 (0.323-0.392)	0.428 (0.387-0.470)	0.507 (0.460-0.559)	0.568 (0.512-0.624)	0.641 (0.576-0.707)	0.697 (0.622-0.760)	0.752 (0.668-0.832)	0.808 (0.710-0.895)	0.874 (0.762-0.977)	0.928 (0.802-1.04)
10-min	0.569 (0.516-0.628)	0.682 (0.619-0.751)	0.812 (0.730-0.895)	0.906 (0.818-0.998)	1.02 (0.917-1.13)	1.11 (0.991-1.23)	1.20 (1.06-1.32)	1.28 (1.13-1.42)	1.38 (1.21-1.55)	1.46 (1.26-1.64)
15-min	0.711 (0.645-0.782)	0.857 (0.778-0.944)	1.03 (0.931-1.13)	1.15 (1.04-1.26)	1.30 (1.16-1.43)	1.41 (1.26-1.55)	1.51 (1.34-1.67)	1.61 (1.42-1.79)	1.74 (1.52-1.95)	1.83 (1.59-2.06)
30-min	0.974 (0.884-1.07)	1.18 (1.07-1.30)	1.46 (1.32-1.61)	1.66 (1.50-1.83)	1.92 (1.72-2.12)	2.12 (1.89-2.34)	2.31 (2.05-2.56)	2.51 (2.21-2.79)	2.77 (2.41-3.10)	2.97 (2.57-3.34)
60-min	1.22 (1.10-1.34)	1.49 (1.35-1.64)	1.87 (1.70-2.06)	2.18 (1.95-2.38)	2.56 (2.29-2.82)	2.87 (2.58-3.17)	3.18 (2.83-3.53)	3.52 (3.10-3.91)	3.97 (3.46-4.44)	4.34 (3.75-4.87)
2-hr	1.42 (1.29-1.57)	1.73 (1.57-1.91)	2.19 (1.98-2.42)	2.55 (2.30-2.81)	3.06 (2.74-3.37)	3.47 (3.09-3.82)	3.90 (3.45-4.31)	4.36 (3.83-4.83)	5.00 (4.34-5.58)	5.53 (4.74-6.20)
3-hr	1.53 (1.39-1.70)	1.86 (1.69-2.06)	2.30 (2.13-2.61)	2.78 (2.48-3.05)	3.33 (2.96-3.67)	3.79 (3.36-4.10)	4.29 (3.77-4.75)	4.81 (4.19-5.35)	5.57 (4.79-6.22)	6.19 (5.26-6.95)
6-hr	1.07 (1.70-2.08)	2.27 (2.06-2.52)	2.87 (2.50-3.18)	3.36 (3.02-3.73)	4.09 (3.64-4.53)	4.71 (4.18-5.22)	5.38 (4.70-5.98)	6.11 (5.28-6.81)	7.18 (6.10-8.06)	8.08 (6.77-9.13)
12-hr	2.26 (2.03-2.51)	2.73 (2.45-3.08)	3.40 (3.10-3.89)	4.10 (3.65-4.60)	5.08 (4.46-5.67)	5.91 (5.15-6.62)	6.84 (5.90-7.65)	7.89 (6.70-8.89)	9.48 (7.88-10.8)	10.9 (8.86-12.4)
24-hr	2.63 (2.38-2.94)	3.18 (2.88-3.57)	4.12 (3.73-4.61)	4.93 (4.45-5.51)	6.17 (5.53-6.85)	7.27 (6.47-8.04)	8.51 (7.50-9.37)	9.91 (8.64-10.9)	12.1 (10.4-13.2)	13.9 (11.8-15.3)
2-day	3.04 (2.75-3.40)	3.69 (3.34-4.13)	4.76 (4.30-5.31)	5.68 (5.11-6.33)	7.06 (6.32-7.86)	8.27 (7.35-9.18)	9.62 (8.47-10.7)	11.1 (9.72-12.3)	13.4 (11.6-14.9)	15.4 (13.1-17.1)
3-day	3.22 (2.92-3.59)	3.90 (3.54-4.34)	5.01 (4.54-5.57)	5.98 (5.39-6.63)	7.40 (6.64-8.20)	8.65 (7.71-9.57)	10.0 (8.87-11.1)	11.6 (10.2-12.8)	13.9 (12.0-15.4)	15.9 (13.6-17.6)
4-day	3.39 (3.08-3.78)	4.10 (3.73-4.56)	5.26 (4.76-5.84)	6.25 (5.63-6.92)	7.74 (6.90-8.55)	9.03 (8.07-9.95)	10.6 (9.28-11.5)	12.0 (10.6-13.2)	14.4 (12.5-15.9)	16.5 (14.2-18.1)
7-day	3.93 (3.60-4.32)	4.73 (4.35-5.21)	5.99 (5.49-6.58)	7.08 (6.46-7.75)	8.66 (7.87-9.48)	10.0 (9.05-11.0)	11.5 (10.3-12.6)	13.2 (11.7-14.4)	15.7 (13.8-17.1)	17.8 (15.4-19.5)

Figure 9: partial duration series (PDS) precipitation estimates for Maryland, with the maximum rainfall for a typical storm highlighted (Prince Georges County Department of Permitting, Inspections, and Enforcement, 2016)

Water Quality

Once the values for expected amount of rainwater runoff are calculated, the next step is to consider the quality of the water collected. As of 2017, there are little to no water quality standards for non-potable stormwater reuse. Nonetheless, filtering the stormwater is still imperative if the water is to be reused for irrigation. Poor water quality would not only affect the grass on the baseball fields but also the irrigations system's piping and control valves with hardness and pH. Harder water and higher pH water is more likely to clog pipes. Microbial contaminants are also a concern as bacteria in the irrigation water could pose a human health risk. The primary pollutants and water quality concerns for the region are sediment and bio-contaminants like bacteria.

Stormwater and Water Quality Regulations

Research into the policies and permitting requirements was conducted to analyze regulations that would affect any stormwater systems implemented at Cabin John Regional Park. This analysis found that the primary policy regulating stormwater in the U.S. is the 1987 Amendment to the Clean Water Act, which introduced the National Pollutant Discharge Elimination System (NPDES) Stormwater Permitting Program. These NPDES permits only regulate stormwater generated from municipal separate storm sewer systems (MS4), construction, and industrial activities (Jones, 2015). However, stormwater runoff and other sources of non-point source pollution remain under-regulated when compared to point-source pollution (Copeland, 2016). In cases with any major construction or changes to stormwater management practices within Montgomery County Parks, the NPDES permit held by the Parks would need to be updated to comply with Clean Water Act regulations.

There are no specific federal, state, or local laws that regulate the quality of rainwater collected for non-potable uses such as landscape management (irrigation) and indoor uses (toilet flushing). However, filtering stormwater and monitoring for impaired water quality (abnormal pH, hardness, sediment content, presence of harmful bacteria, etc.) should be employed as a proactive measure to ensure that stormwater collection and distribution systems continue to run properly and do not have a harmful impact on the environment. Although the water is classified as non-potable, it will be used to water plants and will be in contact with people that use the irrigated fields. Therefore, the quality of the water harvested and used for irrigation should be monitored by a professional and corrective action taken if water quality has the potential to have a negative effect on plant or human life.

EPA guidelines for water reuse should be observed to ensure public protection and to maintain integrity of the water reuse system (Table 2). These recommendations are for urban public lands with unrestricted access, which includes parks and athletic fields. There are three forms of treatment recommended: secondary treatment, filtration, and disinfection. These practices are further defined as follows:

- Secondary treatment includes activated sludge processes, trickling filters, rotating biological contactors, and stabilization pond systems. Secondary treatment should produce effluent in which both the Biochemical Oxygen Demand and Soil Stabilization do not exceed 30 mg/l.

- Filtration includes passing wastewater through natural undisturbed soils or filter media such as sand and/or anthracite, or passing wastewater through microfilters or other membrane processes.
- Disinfection includes destruction, inactivation, or removal of pathogenic microorganisms by chemical, physical, or biological means. It may include chlorination, ozonation, other chemical disinfectants, UV, membrane processes, or other processes.

Furthermore, the EPA has established guidelines for levels of and monitoring frequencies for pH, BOD, turbidity (NTU), fecal coliform, and residual chlorine (Cl2). Although these are not required by law, ensuring that these parameters are met can help protect the human and environmental health where reclaimed water is used, and protect the integrity of the irrigation system itself so less maintenance is required. To meet these requirements, steps should be taken to assess current water quality of runoff at the location where a stormwater reuse system will be located and determine the level of treatment needed to meet or exceed EPA recommendations. If there are any anticipated changes in use or the addition of new pollution sources near runoff collection areas, these should be considered. It is typically a best practice to take these extra steps to ensure that any water to be reused meets or exceeds recommended levels.

Treatment	Reclaimed Water Quality	Monitoring Frequency	Setback Distances
Secondary Filtration Disinfection	pH = 6.0-9.0 ≤ 10 mg/L BOD ≤ 2 NTU No detectable fecal coliform /100 ml 1 mg/l Cl2 residual (min)	pH - weekly BOD - weekly Turbidity - continuous Fecal Coliform - daily Cl2 residual - continuous	50 ft to potable water supply wells Increased to 100 ft when located in porous media

Table 2: 2012 EPA Guidelines for Water Quality for Water Reuse on Public Lands with Unrestricted Access (EPA, 2012)

Water Quality Test

To assess the quality of stormwater runoff around the ice rink, a water quality test was performed on October 9, 2017 after a moderate rain event. The sample was collected from the outflow pipe at the existing surface sand filter, where most stormwater runoff from the impervious surfaces around the rink is discharged. The sample was taken where the water enters the surface sand filter. Thus, the sample had not yet been filtered. The results of the water quality test are shown in Table 3.

Stormwater Sample 10/9/17	
Contaminant	**Quantity Detected in Sample**
PO4	0.10 - 0. 250 ppm
Bacteria	Yes
Nitrates	0.00 ppm
Nitrites	0.10 ppm
Fe	0.10 ppm
Pb	0.00 ppm
Hardness	250 ppm
pH	8.00 -8.50
Cl	0.00 ppm
Cu	0.00 ppm
Pesticides	None detected

Table 3: Results of water quality testing for runoff at Cabin John Regional Park

Findings and Implications of Water Quality Test

There are several key pollutants in the water sample, which could have an adverse effect on the stormwater collection system. Water hardness is one of the main concerns for stormwater management systems. With a high hardness, the water will likely have a high amount of CaCO3+; calcite build up makes it more likely the irrigation system will clog. In addition to the amount of calcite and the sample's pH is also higher than normal. For irrigation, the water should have a pH around 7-7.5. With a high in pH, there is more likelihood that the water is basic, which can also result in hard water. Fixing the hardness problem should also change the pH. Generally, pH is more of a concern if the water is potable.

Finally, there are bacteria in the water sample. This is to be expected if wildlife is in the area. Bacteria may not be an issue in non-potable water but filtering the bacteria would also help keep the pipes clean and unclogged. The presence of bacteria at this site is not surprising, given that runoff in urban areas, especially from ground surfaces, comes in contact with much more mobilized pollutants including pet and wildlife waste. Initially, research was going to include additional water samples that could be used to quantify the exact types of bacteria present at this site. However, further investigation revealed this was not necessary for several reasons. Most importantly, standard treatments for bacteria in urban runoff are not contaminant specific. Additionally, conducting this type of specific analysis is difficult and better suited professionals. Given this information, combined with the lack of lab space, no further testing was done and instead research focused on a literature review to better understand treatment options for urban runoff.

Since this water is not being used for drinking, there are no established water quality standards. Furthermore, there is no specific permitting process that applies to collecting stormwater for non-potable use. Despite this, treating the collected stormwater would prevent the storage structure from becoming a breeding ground for bacteria.

Impacts of Stormwater Collection on Stream Ecosystems

Because this project is an initiative toward greater sustainability of Cabin John and other parks, it is important to consider the environmental implications of stormwater collection systems. In this case, setting aside environmental impacts during construction, a stormwater collection system can actually improve urban stream health.

Urban streams see higher than average runoff during storms. Additionally, urban waterways experience large influxes of pollutants, such as fertilizers, at levels that beyond that of pre-development streams. Water flow to streams should be restored to levels seen in pre-development streams if stream health is a concern. Urban streams, such as the one at Cabin John, will not experience a harmful decline in water supply because it already experiences a higher than natural level of water during storms. Capturing stormwater can be a component of maintaining lower stormwater flow to streams, which will help restore or maintain stream health (Walsh, et al. 2016).

Much of the damage to urban streams is caused by water flow over hard surfaces. A stormwater collection system could be part of the solution to reduce direct flow of water into streams, reducing concerning erosion and pollutant influx. In pre-development streams, the major pathways for stormwater are infiltration or groundwater recharge, not the groundwater flow over paved surfaces. Diverting storm runoff into collection for irrigation will help mitigate detrimental environmental damage to streams (Walsh et al 2016).

The pollutants that would usually be of concern, such as fertilizers and sediment, will be diverted through a filtration system and away from the stream, which should improve stream health (Mitchell, V et al. 2007). At a larger scale, diverting and filtering will also help improve the health of connected waterways and the Chesapeake Bay. Not only does capturing urban stormwater improve local sustainability and ecosystem health, but it also helps reduce criteria water contaminants in the Bay.

Stormwater System Design

This section is an overview of findings on specific design aspects of a stormwater system that could be implemented at Cabin John Regional Park. This system would need to collect and store stormwater from the impervious surfaces surrounding the ice rink and be able to treat the stormwater before it enters the main stormwater system. After these processes are completed, the main parts of this system would be composed of stormwater treatment, collection/storage, and irrigation.

Stormwater Management

Stormwater management helps reduce problems caused by high concentrations of impervious surfaces in urban development. These problems include downstream flooding, stream bank erosion, increased turbidity, habitat destruction, infrastructure damage, and contamination to water bodies (EPA, 2017). The goal of most stormwater policies is to mitigate negative water quality effects associated with urban development and return to the natural structures and functions of water regimes (Roy et al. 2008). Managing stormwater using green Infrastructure promotes infiltration, evapotranspiration, and captures and reuses stormwater to maintain or restore the natural hydrology (USEPA, 2017). Implementing green infrastructure includes using and/or installing best management practices (BMPs) and low-impact development (LID).

Examples of Stormwater Harvesting and Reuse in the United States

Stormwater runoff collection and use for small-scale irrigation has become common in the United States. However, most of these projects are at a residential or small commercial scale. The project at Cabin John would be at a much larger than most of the rainwater harvesting (RWH) systems currently in place in the U.S. However, RWH operations on this scale have some precedent. In June 2016, Upper Villa Park in Roseville, Minnesota completed a stormwater management project that combines stormwater collection and irrigation of a softball field. The project’s goal was to reduce nutrient loading and water usage for irrigating the softball field (SRF Consulting Group, 2017). It was and intensive project and required large-scale excavation project underneath the existing athletic field (Figure 10). Stormwater runoff was collected from hardscapes (a parking lot and nearby roofs). Runoff from the roadways first enters the filtration system. The collected water is then either diverted into the nearby waterway or flows into the sedimentation tank where it can then be drawn up by pumps into the irrigation system for the softball field (SRF Consulting Group, 2017). This project cost $1.2 million total and is expected to reduce stormwater flow by 2.55 million cubic feet and nutrient loading by 45 lbs. at the park each year (Johnson & Kelley, 2017). This project is similar to the one being investigated for Montgomery parks, and could serve as a model for the design.

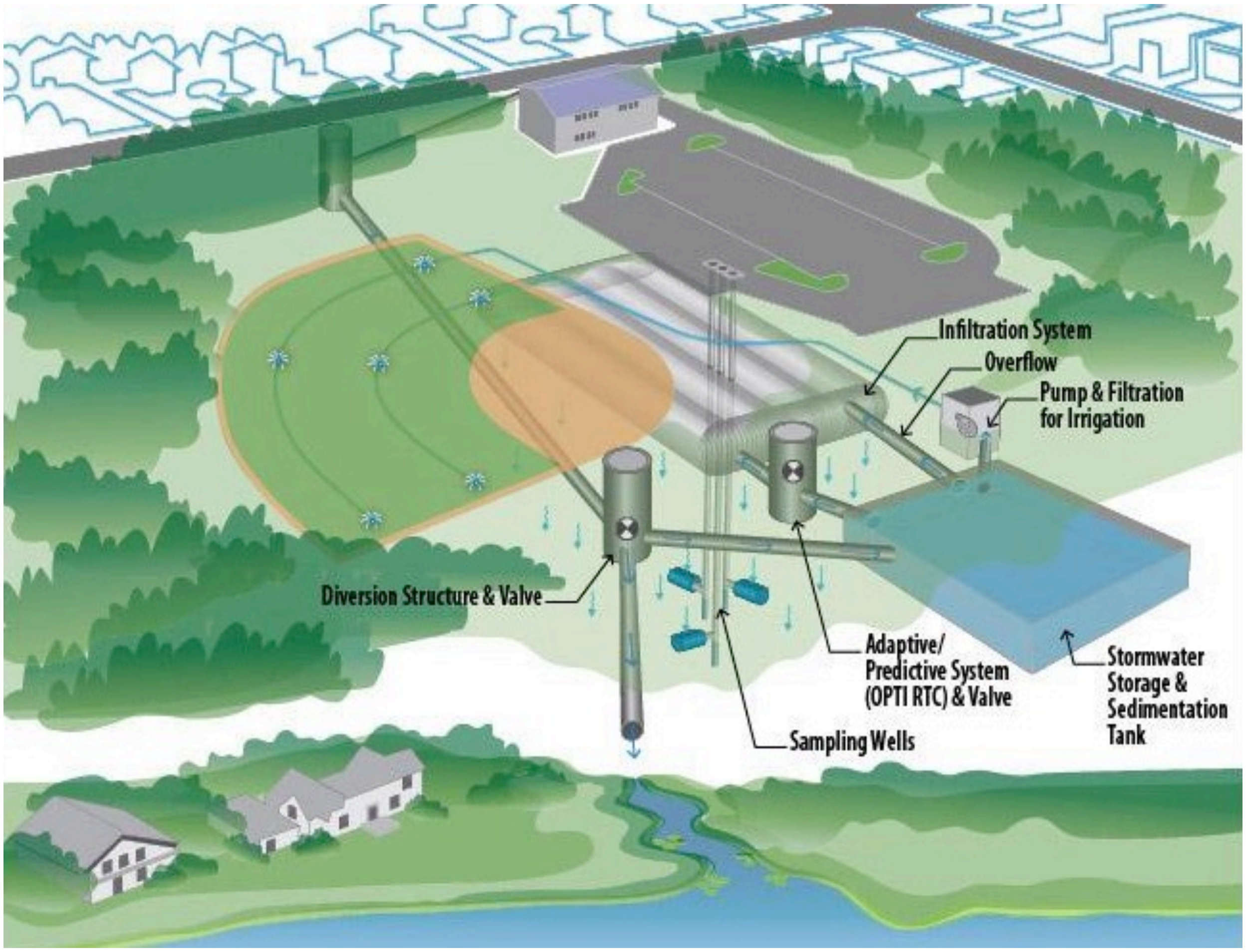


Figure 10: Diagram of stormwater harvesting and irrigation of a softball park in Upper Villa Park, MN. (SRF Consulting Group, Inc., 2016)

Stormwater Design Requirements

In the policy analysis of stormwater management regulations in Montgomery County, several regulate the design requirements for stormwater management structures. In Maryland, stormwater management primarily falls under the Maryland Stormwater Management Act of 2007, which requires that environmental site design (ESD) be implemented to the “maximum extent possible” to minimize the impact of development on water resources (Maryland, 2015). This law primarily dictates design requirements and approvals needed for stormwater management features. The implementation of any stormwater management practices or structure requires oversight by a professional engineer and State approval of all plans. In cases where earth disturbance is 5,000 square feet or more and 100 cubic yards or more, as may be required for an underground cistern, then a Sediment and Erosion Control Plan would be needed to comply with State regulations (Maryland Department of the Environment, 2017).

The County also has design requirements and permitting approvals for stormwater management structures. Plans for any stormwater management concepts, including stormwater harvesting, must be approved by the Montgomery County Department of Permitting Services. This application takes approximately six weeks to process and requires a $2,765 processing fee. The County also has construction requirements for underground cisterns used for stormwater collection to ensure safe access and servicing.

Stormwater Treatment

The three most common and effective treatment systems are wetlands, wet retention ponds and biofilters. According to the literature, biofilters are the most practical for urban areas, often the most aesthetically pleasing, and also equally as effective if not more effective at removing bacteria from urban stormwater runoff. The only downside of biofilters is that they are limited in the quantity of stormwater they can hold at one time (Jiang et al., 2015). The specifications for a particular biofiltration system (Contech's Filterra) are provided in Table 4 and a diagram of a typical biofilter is provided in Figure 11.

Pollutant	Median Removal Efficiency	Median Effluent Concentration (mg/L)	Third Party Reference Studies
Total Suspended Solids	86%	3.3	UVA 2006, Herrera 2009, Herrera 2014, NC State 2015
Total Phosphorus (TAPE)	70%	0.05	Herrera 2014, NC State 2015
Total Nitrogen	34%	0.54	NC State 2015
Total Copper	55%	0.004	UVA 2006, Herrera 2009
Dissolved Copper	43%	0.003	Herrera 2009
Total Zinc	56%	0.04	UVA 2006, Herrera 2009, NC State 2015
Dissolved Zinc	54%	0.1	Herrera 2009
Total Petroleum Hydrocarbons	87%	0.71	Herrera 2009

Table 4: Design Specs for a Biofiltration Unit (Contech, 2017)

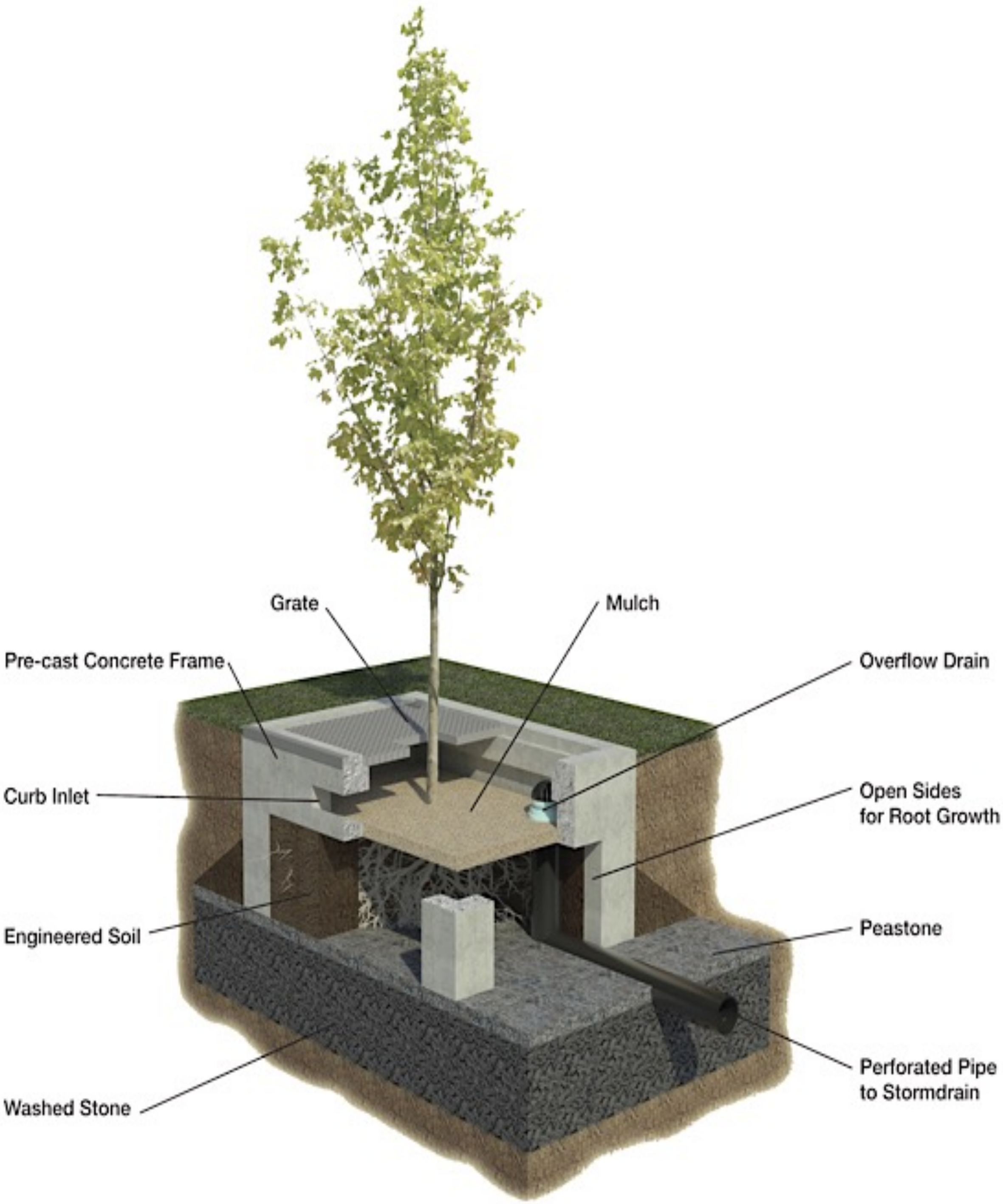


Figure 11: Diagram of a Biofiltration System (Nianic River Watershed, n.d.)

There are a few methods to mitigate high pH levels. Adding acids such as sulfuric hydrochloric or phosphoric acid into the irrigation system can lower the water's pH. These chemicals will not affect the pipes or the water quality of non-potable water. Adding an acid will lower the water's pH to be less saline and fewer free ions in the water. Another method is to "bury or mulch lateral [along the piping] whenever possible to reduce the temperature rise of the water." By lowering the water temperature, even with higher amounts of $CaCO3^{+}$ there would be less build up in the pipes (Schultheis et al., 2005).

The bacterial contaminants found in water are often due to organic compounds. To filter out these bio-contaminants, there are several organic filters that can be incorporated into the stormwater harvesting system. According to a number of academic sources, standard practice for biological oils are media filters and cartridge filters. Cartridge filters are generally simpler and can be easily cleaned by changing the cartridge when contaminated. Media filters on the other hand, can filter out contaminants and provide filtration for sediments. Finally, there are disk filters, which can filter out biological contaminants in addition to filtering out petroleum from cars.

Concerns about proper filtration of sediments in irrigation can be addressed by using a combination of different filter types. The simplest is a screen filter that can block larger sediment. The recommended standard is 150-micron screen filters. In addition to screen filters, media filters can also help mitigate sediment build up.

Implementation of BMPs

The design of a stormwater storage structure should incorporate BMPs for pre-treating stormwater before it enters the system. Considering how BMPs reduce pollution from urban runoff can be an added benefit of the system. A review of academic sources found many case studies that specifically looked at the effectiveness of BMPs in treating stormwater. Based on their results, one can determine the best BMPs for mitigating stormwater pollution.

Different BMPs can be applied in the urban environment to mitigate different pollutants. Stormwater BMPs can also be retrofitted to different stormwater systems. Two types of BMPs can be used to improve the effectiveness of a stormwater system—structural and nonstructural.

Nonstructural BMPs combine institutional and educational practices aimed at reducing stormwater pollution. They are not physical structures to treat polluted stormwater, but rather a way to handle stormwater pollution through behavioral change. Examples of nonstructural BMPs range from cutting off wastewater connections to enforcing ordinances designed to keep pollution transport in urban landscapes.

By contrast, structural BMPs are physical designs that enhance stormwater runoff quality by using avoidance and prevention methods in urban landscapes. These include infiltration basins, bioretention, and combined BMP systems. Figure 12 shows a combined BMP system and Figure 13 lists the components of specific structural BMPs. All of these should be considered when installing the stormwater system to mitigate polluted urban runoff.

An infiltration basin allows stormwater water to be stored temporarily and slowly released into the ground. It can remove up to 98% of the pollutants found in runoff. They also reduce the water volume and eliminate direct surface contact from storm runoff, which helps mitigate pollution.

One case study examined the effectiveness of a combined BMP system that used a planted gravel filter, a stormwater detention basin, and infiltration tank systems (Scholtz, 2008), which was used to treat parking lot runoff in the study area (Debusk, 2012). This system focused more on controlling water flow and evaporation than on capturing stormwater; it detains pretreated water. This process allowed for more infiltration and thus more pollution degradation than other systems in the case study. However, 50% of the stormwater runoff did evaporate, leaving only 50% to infiltrate.

If BMPs are to be included in Montgomery County Parks stormwater systems, such as the potential stormwater harvesting system at Cabin John, the Department will need to ensure that necessary operation and maintenance for is provided so that the structures and practices function properly.

Figure 12: The combined stormwater detention BMP during a heavy storm. This image shows the inflow to the infiltration cell, with the detention cell below it (Debusk 2011)

Object name	Object type	Description
Car park	(Sub-)catchment	Input of precipitation data; output of losses (evaporation and infiltration) and surface runoff (routed to gravel filter)
Gravel filter A	(Sub-)catchment	Input of precipitation data and surface runoff from car park; output of losses; runoff and groundwater flow
Gravel filter B	Simulated 'aquifer'	'Aquifer' beneath the sub-catchment gravel filter; input of simulated groundwater flow; outflow to storage unit
Detention tank	Storage unit	Storage of inflow; two outflows are associated with the tank: infiltration function and outflow tank (see below)
Infiltration function	Outlet	Flow regulator simulating infiltration with a head-discharge relationship
Outflow tank	Conduit	Link simulating the connection between overflow tank and gully pot system
Groundwater	Outfall	Terminal node for infiltration into soil

Figure 13: The different parts of a combined BMP stormwater system, the filtration methods used, its overall function (Debusk 2011)

Stormwater Storage

Case studies analyzing stormwater storage systems provided useful guidance for systems that could be implemented in Cabin John Park or in future stormwater harvesting projects in County parks. While it would have been ideal to analyze in place systems in the Northeastern U.S., information for this region was limited. But several case studies from Melbourne, Australia and one from Cross Plains, Wisconsin were analyzed for their suitability in Cabin John Park. Based on collected research, the two most suitable stormwater collection and storage systems for Cabin John were either bioretention or storm drain harvest and cistern storage.

Bioretention

Based on a case study published in *Renew: Technology for a Sustainable Future,* bioretention could be a good option for collecting and storing of stormwater at Cabin John Park for a few reasons. Though an underground system would require a good deal of initial construction at the site, the system would be hidden from park visitors. Also, a small retention pond already there would be an ideal location for a stormwater harvesting and storage system that would also consolidate filtration and harvesting into one system. Instead of a system for harvest and storage and another for filtration, this option consolidates the two. Finally, a bioretention filter is effective at removing microbial pollutants from stormwater, thus reducing the risk of bacterial contamination. Figure 14 depicts a bioretention system implemented in Melbourne, Australia. A similar system could be implemented at Cabin John Regional Park.

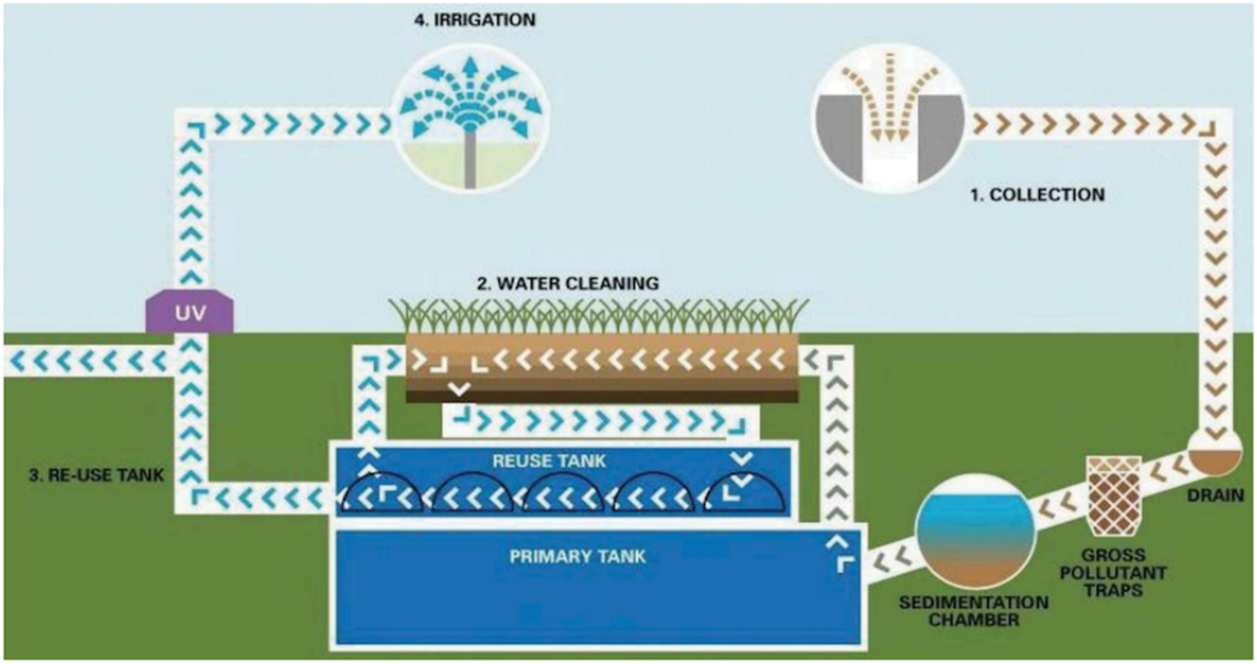


Figure 14: Diagram depicting a bioretention system implemented in Melbourne, Australia (Deed, 2012)

While there are many advantages to implementing a bioretention system, there are drawbacks. One of the biggest is the cost of retrofitting this system into the park's existing irrigation systems. The Melbourne case study was conducted one a site where no previous infrastructure was located. Implementing this system at Cabin John would require digging up a large portion of the park as well as redoing the irrigation system already in place. Another cost to consider is system maintenance, which is likely to be expensive. This system also requires a significant amount of electricity to operate both the filtration system and to pump the water from the filtration basin onto the baseball field. Another disadvantage of this system is it would most likely not be able to supply enough water to irrigate the baseball field every time irrigation is needed. Baseball fields require a lot of irrigation and this system would not be able to supply that demand, and that public water would still be needed for irrigation.

Storm Drain Harvest and Cistern Storage

The second case study was published by AECOM Australia in a report for a stormwater-harvesting device for Napier Park in Melbourne, Australia. Based on its findings, a storm drain harvest and cistern storage would also be a good option at Cabin John Park. A primary advantage of this type of system is there are already storm drains in place at Cabin John, which would mean the current drainage system can stay be used. However, stormwater collection technology would still need to be added. Another advantage of this system is its potential to use gravity rather than electricity to help move the water rather. Since water has to flow into the storm drains before harvesting, this could create enough pressure for this water to flow quickly into the irrigation system right after filtration. This option would most likely be cheaper than bioretention. Figure 15's diagram of Napier Park shows that the drainage catchment area must be larger than the area to be irrigated. This design component should be considered for any potential stormwater harvesting systems at Cabin John Park.

Figure 15: The layout of a storm drain harvest and cistern storage system shows the stormwater collection area and area to be irrigated using the harvested stormwater (AECOM Australia Pty Ltd., 2010).

Furthermore, MDE guidelines regulate the use of stormwater cisterns, and these guidelines would need to be considered if this method of stormwater storage were to be used at Cabin John (MDE, 2012). The MDE guidelines are:

- There must be sufficient dewatering of the tank in between rainfall events.
    - Full tank volume may be credited toward the ESD volume when there is enough demand to completely dewater the tank 72 hours after a rainfall event.
    - When the system cannot be completely dewatered, the available volume within the cistern in between storms is the storage that can be used for the ESD.
- The system may be combined with a down-gradient practice to dewater the tank.

- There must be stable discharge of flow dewatering from the system.

As with bioretention, this option also has disadvantages. It would be difficult to site the storage cistern. In the bioretention case study, storage could be placed under the current bioretention pond. In this case, the cistern would be harder to place. It could be underground, but it would be difficult to find a location with enough water pressure to easily irrigate the field. Another option would be to place the cistern above ground, which may be unsightly to park visitors. Another disadvantage is that this system may be more costly. Since the stormwater is coming directly off pavement, it will contain more harmful particles that would need to be filtered. Furthermore, as with the bioretention option, stormwater collected from the storm drains would may not be sufficient to irrigate the entire baseball field at the frequency needed. For this reason, the storm drain harvesting system would need to be supplemented with public water.

Irrigation Systems

The purpose of collecting and storing stormwater is to reuse it to irrigate Shirley Povich Field. Currently each of the park's baseball fields uses 68 pop-up sprinkler heads and takes roughly 10 hours to irrigate a whole field. This system is inefficient and uses large quantities of water. Redesigning the irrigation system would allow the fields to be watered faster, with fewer components, and less water.

Possible Irrigation Methods for Cabin John

There are a variety of options for commercial spray irrigation systems that the County could use at Cabin John Park. However, the style of irrigator best suited for watering the baseball field is a single point sprayer off the field, such as a gun-style irrigator. These irrigators can cover an entire field from a single point located off the field. This option does not require any piping or sprinkler heads to be dug into the ground of the field, which reduces installation costs. Traditional pop-up sprinklers can be damaged by players, or can injure players. Pop-up sprinklers also have significantly higher maintenance costs. When something in the system goes wrong, part of the field might have to be dug up to fix it, possibly during a time when the field needs to be used—a costly and cumbersome process. A single point sprayer, however, does not have these multiple points of possible failure, which makes diagnosing problems cheaper and easier. Furthermore, gun-style irrigators are not easily clogged by sediment in the system, especially compared to pop up sprinklers, which is important because stormwater contains an increased sediment load compared to potable water. As a result, filtering can be cheaper and less complex. Gun-style irrigators can be permanent fixtures in the ground, or portable on wheels with long hoses, allowing them to be moved easily between fields. Portable systems need fewer irrigators and reduce underground pipe costs. However, they do require the additional labor costs of someone moving the irrigator. One disadvantage of gun-style irrigators is that they require a high amount of pressure in the system, which requires a large and powerful pump. This leads to increased electricity costs. The Department of Parks must decide how much money they want to invest in underground piping and sprinkler heads.

An additional option that can dramatically cut water use is integrating a smart irrigation controller into the system. Smart irrigation systems can be added to whatever system the Department of Parks decides to implement at Cabin John. Instead of watering fields on a regularly timed schedule, smart irrigation systems adjust irrigation schedules based on weather and soil conditions. Soil moisture sensor (SMS) controllers irrigate based on soil moisture content and weather based controllers use local weather data to adjust irrigation schedules. A study done at the University of Florida comparing the use of soil moisture sensor irrigation controllers found that during wet weather, water savings ranged from 69% to 92% for three of four SMS brands tested and during dry weather conditions savings ranged from 28% to 83% (Dukes et al, 2008). If these results could be replicated at Cabin John Park, the Department of Parks could save water and money. These systems are not expensive to purchase, and the economic and environmental benefits are substantial.

A number of factors should be considered when designing the irrigation system. For example, the system cannot cause surface runoff. Determining if runoff will be generated requires expert analysis of topography, soil composition, grass type. The proper pump needs to be selected to meet the irrigator's pressure requirements and system plans should be reviewed by a licensed plumbing professional, certified irrigation designer, or professional engineer as part of the permitting process.

Integration of Stormwater Irrigation System into Existing System

Collected and stored stormwater will not be sufficient to meet the needs of the fields at Cabin John. As a result, the stormwater system should be connected to a make-up water supply system; in at Cabin John, this will be the municipal drinking water provided by WSSC. It may be possible to access the secondary supply by manually disconnecting from the harvest system storage and connecting to the secondary supply. This method, however, prevents the system from operating automatically, and requires additional labor costs of monitoring when stormwater supply runs out. Connecting the two systems will allow irrigation without interruption. A control panel can be added to help ease the process of controlling when reclaimed stormwater and when WSSC water will be used. The primary concern with make-up systems is that they typically require potable water to be brought into proximity with harvested stormwater, which introduces a risk of a cross-connection between the two supplies ("Design criteria for stormwater and rainwater harvest and use/reuse," 2017). This requires integrating backflow prevention into the system, usually in the form of an air gap. Table 5 explains the different components and design considerations required for an integrated irrigated system. Additionally, to prevent cross contamination, the pipes and supply lines need to be properly marked to distinguish between potable and reused water. As mentioned in the previous section, the automated make-up supply will require the expertise of an engineer to ensure proper integration.

Field Observations	**For some practices, field observations may be required to determine the design demand. For example, a washing station may require field observation of the time spent washing each vehicle.**
Air-gap	An air gap and other cross-connection requirements included in relevant building codes must be followed when combining potable and non-potable waters. An air gap physically separates two sections of pipe and is open to the atmosphere. The air gap must be located higher than the overflow drainage piping from the tank and the overflow drainage piping must remain free of blockage so that excess rainwater flows to the overflow system and does not back up and overflow at the air gap. Air gaps are not generally utilized or recommended in large outdoor storage tank applications due to freeze protection and loss of volume storage due to required air space.
Minimal make-up water storage	Stormwater management objectives must not be compromised if a secondary or makeup water supply is used. The design must provide adequate storage for the next design storm. Make-up systems must place a minimal amount of volume in the storage at any one time. Utilization of an air gap in a day tank is one option to address this issue.
Level Indicators	A float switch, pressure transducer, or level indicator typically triggers automatic make-up. The water elevation that triggers the make-up must be high enough to avoid running the pumps dry and must be lower than the passive drawdown orifice (if applicable). Float switches are preferred for critical operations including dry run protection and as fail-safe cut off when transferring water to a day tank. Level indicators can be used for informational levels and non-critical devices and are prone to failure in moist environments.
Wet Wells	An option for larger, underground storage tanks is to have a separate wet well at a lower elevation. This eliminates the storage of make-up water in the harvest storage tank.

Table 5: Design considerations for automated make-up water supply systems (Minnesota Pollution Control Agency, 2017)

Irrigation Demand at Cabin John Regional Park

An important step in designing a stormwater collection and reuse system for Cabin John Park is calculating irrigation demand for the area to be irrigated. This project focuses on irrigating Shirley Povich Field, which is approximately three acres. Specific data about the current quantity of water used to irrigate this field is unavailable. However, MDE provides guidelines and a formula for calculating average irrigation demand. The results of these calculations for three acres are shown in Table 6. The recommended formula for calculating the amount of water needed for irrigation is:

Equation 2: 43,560 sq. ft./acre x 1ft./12inch x 7.48 gal/cu. ft. x number of acres to be irrigated

Using this calculation, the amount of water needed to irrigate Shirley Povich Field would be approximately 81,500 gallons/week. To handle this demand, a cistern (or other stormwater storage feature) that could handle this demand would need to be at least 85,000 gallons.

The irrigation demand, and thus the size of the cistern needed, for this field can be reduced using smart irrigation technology, such as an SMS. Table 7 provides an estimation of reduced irrigation demand (low and high) using an SMS (Dukes et al., 2012) and shows the field's irrigation demand could be reduced to between 61,125 gallons and 24,450 gallons per week.

The size of the cistern could also be reduced if the stormwater harvesting and irrigation system is backed up with the WSSC water currently used for irrigation. MDE also provides recommendations for when irrigation begins and ends; usually the last week in April through the first week in October. Some irrigation may be required outside of these periods and steps should be taken to ensure that irrigation could take place during these periods. Furthermore, because irrigation is not usually needed between the end of October through the beginning of April, any stormwater collection system should be designed with overflow/bypass systems for periods when water is not needed or when the amount of stormwater flow is more than the system can handle.

Month	Avg. Rainfall (in)	Rainfall Collected (gal)	Irrigation (gal)	Grey Water (gal)	Total Demand (gal)
Jan	3.35	624,927	0	0	0
Feb	2.83	527,924	0	0	0
Mar	3.9	727,527	0	0	0
Apr	3.19	595,080	81,457	0	81,457
May	4.37	815,204	325,829	0	325,829
Jun	3.74	697,680	325,829	0	325,829
Jul	3.9	727,527	325,829	0	325,829
Aug	3.7	690,218	325,829	0	325,829
Sep	4.09	762,971	325,829	0	325,829
Oct	3.35	624,927	81,457	0	81,457
Nov	3.43	639,851	0	0	0
Dec	3.19	595,080	0	0	0
Annual	43.04	8,028,917	1,792,058	0	1,792,058

Table 6: Calculations for projected rainfall collection, irrigation demand, and storage in a 75,000-gallon cistern using parameters for Cabin John Regional Park, near Cabin John Ice Rink (MDE, 2012)

Month	Avg. Rainfall (in)	Runoff Generated (gal)	Irrigation Demand (gal)	Irrigation Demand w/ SMS (reduction 25%)	Irrigation Demand w/ SMS (reduction 70%)
Jan	3.35	624,927	0	0	0
Feb	2.83	527,924	0	0	0
Mar	3.9	727,527	0	0	0
Apr	3.19	595,080	81,457	61,0923	24,437
May	4.37	815,204	325,829	244,372	97,749
Jun	3.74	697,680	325,829	244,372	97,749
Jul	3.9	727,527	325,829	244,372	97,749
Aug	3.7	690,218	325,829	244,372	97,749
Sep	4.09	762,971	325,829	244,372	97,749
Oct	3.35	624,927	81,457	610,923	24,437
Nov	3.43	639,851	0	0	0
Dec	3.19	595,080	0	0	0
Annual	43.04	8,028,917	1,792,058	1,344,044	537,618

Table 7: Projected irrigation demand for baseball field at Cabin John Ice Rink using ranges of reduced irrigation demand through the use of an SMS (Dukes, 2012)

Costs and Benefit Analysis

Expected Costs

Using this paper's research and findings, a general cost estimate for a project that would capture and reuse stormwater at Cabin John Regional Park was generated. Using the parameters discussed, the cost estimate for this project is $346,000. The expected savings per year is approximately $1,700 ($34,000 in water savings over 20 years) using 2017 water rates (WSSC, 2017). A detailed breakdown of costs and their sources can be found in Appendix B (Table 9). These estimates are for the initial costs of the system, and do not take into account annual maintenance costs for system components. These costs are highly generalized and can be highly variable, so getting a cost estimated generated by a professional contractor is recommended for this project at Cabin John or any other County park where a stormwater system is proposed.

These costs were generated using three methods: using online search engines to find the commercial costs of various components, directly contacting companies and contractors familiar with this type of work or basing estimates on similar case studies for stormwater harvesting systems. One study by a professional engineer based in Virginia was used for many of these estimates, especially for the more specific parts that would be required for a stormwater harvesting system (Hicks, 2008). Note that any costs based on the Hicks study were adjusted for inflation using the Bureau of Labor Statistics inflation calculator (BLS, 2017).

The following sections briefly discuss the cost of each major component of a stormwater system that would be optimal for Cabin John Regional Park: reclaimed stormwater collection and storage, reclaimed stormwater distribution (to the irrigation system), water quality, irrigation, filtration/BMPs, other costs, and expected savings.

Reclaimed Stormwater Collection and Storage

The cost estimate for the purchase and operation of a cistern/stormwater storage system is for three 25,000-gallon fiberglass underground cisterns (75,000 gallons of storage). These cisterns are not typically sold in sizes larger than 50,000 gallons, so this cost estimate for 75,000 gallons of stormwater storage opted to estimate for three identical 25,000-gallon cisterns for easier of ordering, installation, and maintenance than two different sized cisterns. Fiberglass was chosen for its durability and suitability for underground storage. It has a longer lifespan than cisterns made of other materials, so will not need to be serviced or replaced as frequently as cisterns made of other materials.

Because the cistern will be underground, excavation costs are included. The costs of excavation were heavily based on the Hicks study. The amount of excavation needed was scaled from the size project in that study to this study, and the cost of excavation per cubic foot of soil was adjusted for inflation for a total of $5,840.

Other costs associated with stormwater storage included were first flush filters, a rainwater system controller (an easily accessible panel that allows for controlling releases or bypasses when needed), an overflow system for periods when the cisterns are full and can no longer take on water, and backflow prevention mechanisms (Hicks, 2008). These components and costs were all based on the Hicks study.

Reclaimed Stormwater Distribution

These costs and components are also based on the Hicks study. To ensure that water can be pumped from storage to irrigation points, control pumps are needed . Additionally, an easily accessed aboveground panel for managing the pumps will also be required to properly operate such a system.

Water Quality

These components are optional, but recommended based on the *2012 EPA Water Quality Guidelines*, which recommends continual monitoring of residual chlorine and turbidity (EPA, 2012). Furthermore, as stated previously, taking steps to properly maintain the system can reduce maintenance and repairs over the system's lifetime. Therefore, including continuous residual chlorine (Cl2) and turbidity monitors is recommended. The costs of testing equipment for other water quality measures, which don't require continuous monitoring, are not included in this estimate because Montgomery County Parks staff is equipped to test most water quality parameters.

Irrigation

The two main components of the irrigation system accounted for in this cost estimate are the irrigators and a soil moisture sensor. Based on this study's parameters, which require watering three acres of athletic field, only one irrigation point is needed for gun-style irrigator. This cost was derived from a case study in Centerville, Minnesota, where Stantec Consulting Services designed a stormwater reuse system to irrigate municipal ballfields (Statz, 2013). The soil moisture sensor is highly recommended for this project. It will increase the irrigation efficiency and thus allow for a smaller cistern size and decrease reliance on backup water systems. The sensor is relatively affordable and will likely generate high cost savings. Also, these components can be implemented independently of the stormwater reuse system and could save water without the high upfront costs of the stormwater reuse system, and likely be applicable to more parks. These components would cost less than $7,000 for one irrigator and an SMS.

Filtration/BMPs

To ensure that stormwater is filtered before entering the collection system, the use of BMPs and other filtration methods is recommended. Based on this paper's findings, 150-micron mesh filters, biofiltration, and infiltration trenches are the most effective ways to reduce the pollution associated with collecting stormwater off of roadways, sidewalks, and roofs. The mesh filters and bins (that hold the filters in place) are affordable. They can be placed within the system itself, before the water enters into the storage cistern. Biofiltration BMPs can be placed over each of the existing stormwater drains in the parking lots at Cabin John Ice Rink.

Other Costs

The other costs of this project include preparing the Concept Plan Application and the cost of Sediment Erosion Control. The Concept Plan Application (per the Montgomery County Department of Permitting Services webpage), is a one-time fee, but if the initial application is rejected, this fee must be repaid for every revised plan submitted. The cost of sediment and erosion control was derived from a 2011 study of stormwater management costs in Maryland (King and Hagan, 2011). These costs were adjusted for inflation using the BLS calculator (BLS, 2017).

Estimated Savings

The average annual savings for a stormwater reuse project at Cabin John that uses a 75,000-gallon cistern, given current rates for WSSC water, would be approximately $1,700 per year (WSSC, 2017). This gives a projected savings of about $34,000 over 20 years. A detailed breakdown of savings over a given year is provided in Appendix B (Table 10). Given that the total cost of installing the system is estimated to be around $350,000 (not accounting for maintenance costs), this project's return on investment is low.

However, the cost estimate only takes into account water that would be used in the cistern during periods when irrigation is needed (i.e. 75,000 gallons/week using MDE estimates for irrigation demand). Exact data for current water use for irrigating this field are unknown. Therefore, the savings could be greater than those predicted using these assumptions. To generate a 50% return on investment on a $400,000 stormwater system over 20 years, the system would need to save approximately $10,000 worth of water each year ($20,000 to pay for itself over 20 years). The current rate for WSSC water is $8.16 per 1,000 gallons, so to save $10,000 each year, the stormwater reuse system would need to save 12,255,000 gallons of water each year.

Based on these figures for costs and savings, this project would not be a financially rational decision at Cabin John Regional Park.

Summary of Findings

Using this paper's research and findings, a series of recommendations were developed that may be applied partially or in full to Cabin John Regional Park or other County parks. These findings are summarized in Table 8.

For stormwater collection, it would be best to collect runoff from all available hard surfaces around Cabin John Ice Rink, mainly the parking lot and roof (Figure 16). This stormwater naturally flows toward the small parking lot to the northwest of the ice rink, so this would be an ideal collection point.

Although there is no specific legal water quality standard, it is recommended that the water should have a pH of 7-7.5, hardness under 0.2 ppm, and chemical pollutants under 0.2ppm. This will generally protect the health of both the baseball field and the irrigation control valves.

To prevent damage to the collection system, a screen filter is recommended to prevent sediment from clogging the system. It is recommended to use multiple screen filters and a minimum of 150-micron mesh for best results.

Three common treatments for addressing microorganism contamination are wetland treatments, wet retention ponds, and biofilters. Of the three, biofilters are the most effective and practical for urban areas like Cabin John and other Montgomery parks. At Cabin John Regional Park, installing biofilters at the three main storm drains around the collection area would remove biocontaminants and other pollutants from stormwater harvested off roadways (Figure 16).

A stormwater BMP that could be included this system would be an Infiltration trench that would . slow down water flow so that it does not overload the cistern. However, including this structure is not necessary to run the system. It would be an extra measure that would enhance the quality of reused stormwater, but with BMPs already in the park and other filtration methods included in the stormwater system, it is not necessary to add more without researching their potential benefits. Therefore, constructing additional BMPs is not recommended.

The main concern with urban streams is large flows to the stream during storm events. Reducing the amount of runoff by collecting rainwater (in addition to reducing the amount of nonpoint source pollution from the runoff) may actually be beneficial to downstream ecosystems.

The best storage method is underground cisterns. Despite their high cost and required maintenance, underground cisterns provide large storage capacities without detracting from park aesthetics. Based on these findings and the expected irrigation demand, three 25,000-gallon underground fiberglass cisterns are recommended to store collected stormwater used for irrigation. These cisterns would be placed underneath the existing parking lot to the northwest of the ice rink (Figure 16). This process would require digging up the parking lot and replacing it once the cisterns are installed, which may be costly but is cheaper than placing the cisterns underneath the field or in the forested area near the surface sand filter.

At Cabin John, the irrigation system should be replaced with single-point gun-style irrigator. A smart irrigation system that uses SMS should be integrated into this system to reduce irrigation demand. Adding these components will generate large water savings, and they are versatile enough to be installed at nearly any County park. However, an irrigation system using reclaimed stormwater would need to be integrated into the existing WSSC water supply to ensure that irrigation demand can be met if the amount of collected stormwater is not sufficient.

Using these recommendations, a cost estimate of general component prices shows the initial cost of installation at approximately $346,000. Using estimates for cost savings due to reduced water use, the savings over 20 years would be $34,000. It is likely that the maintenance costs alone over this period would outweigh these savings.

Stormwater Structures	
Storage	75,000-gallon underground fiberglass cistern
Stormwater BMPs	Not required
Filtration	Multiple screen filters and a minimum of 150-micron mesh
Irrigation	Single-point gun-style irrigator and smart irrigation system with an SMS
Treatment	Biofiltration
Water Quality	
Standards	• pH of 7-7.5 • Hardness under 0.2 ppm • Chemical pollutants under 0.2 ppm • No measurable pathogens or fecal coliform
Water Quality Monitoring (daily/weekly)	Use existing equipment and staff
Water Quality Monitoring (continuous)	Continuous Cl2 Monitor and Continuous Turbidity Monitor
Other	
Impact on downstream ecosystems	Reducing the amount of runoff (in addition to reducing the amount of non-point source pollution from the runoff) may be beneficial to downstream ecosystems.

Table 8: Summary of the basic components needed for a stormwater reuse system at Cabin John Regional Park

Key:

Stormwater Runoff Collection

Pathway Stormwater Flow

Area to be Irrigated

Placement of Biofiltration

Flow of Water from Cistern to irrigation

Location of Underground Cistern

Existing Surface Sand Filter

Pathway of Overflow Water from Cistern

Figure 16: Potential layout for a stormwater harvesting and collection system at Cabin John Regional Park

Final Recommendations and Conclusion

Retrofitting Cabin John Regional Park with a stormwater capture/reuse system could benefit the park in many ways. This system could control overflow and runoff from storms, which would lessen pollution from runoff. Controlling the stormwater flow can also prevent erosion and protect surrounding ecosystems. Stormwater reuse also saves water by allowing the park to support irrigation with its own system instead of depending on WSSC. The options presented in the previous section outline the type of system appropriate for this park and the components for designing and operating such a system. If such a system is implemented, a professional engineer should oversee the design process.

Although this system would benefit Cabin John Regional Park in many ways, its costs are extremely high and the savings are very small. With an up-front cost of $350,000 and projected savings of only $34,000 over 20-years, there would be no significant return investment from installing this system. In a park that is already built, the costs of retrofitting the system are prohibitively high. However, installing such a system at a new park would eliminate the retrofitting costs and could make it a more cost-effective option.

Based on this paper's findings, the installation of a stormwater harvesting and reuse system to irrigate Shirley Povich Field at Cabin John Regional Park is not recommended. However, there are other methods to reduce water use at this park, specifically, replacing the irrigation system with a more efficient one and incorporating smart irrigation technology, such as a soil moisture sensor; this approach would also be a more cost-effective method to reduce water use at any Montgomery County park.

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Appendix A - Guidelines for Implementing Stormwater Harvesting and Reuse within Montgomery County Parks

This appendix outlines the general process for determining the suitability of and designing stormwater collection and reuse systems within Montgomery County parks. This process was derived from the steps taken to conduct a case study for a potential stormwater reuse system at Cabin John Regional Park. The steps are organized by the project's major components (e.g. "Determining the Location of a Stormwater Harvesting System," "Calculating Stormwater Runoff and Irrigation Demand," etc.) and step numbers (1, 2, 3…). This organization is for clarity and general organization only, and does not have to be followed exactly.

Note that these steps are highly generalized and should only be used to get an idea of the feasibility of a stormwater reuse system at a given County park. A professional engineer should always be consulted on decisions about suitability, location, design, and costs of any proposed stormwater system.

Determining the Location of a Stormwater Harvesting System

1. Select a park/portion of a park where a stormwater reuse system could be implemented.

2. These areas should have at least some hardscape and/or rooftops that generate stormwater runoff.

3. Selected areas should also have an area to be irrigated, such as an athletic field, garden, landscape feature, etc.

4. Select the priority area(s) for irrigation using reclaimed stormwater. A first option should be selected, as well as a few "back up" options in case the first choice is not a feasible location for a stormwater reuse system.

5. Analyze topography and drainage patterns (especially of hardscape) to determine where the stormwater naturally flows. Superimposing these drainage patterns on a topography map of the area is a useful tool in visualizing the existing stormwater flow.

6. Using the topography map, determine the locations where stormwater flows converge. These are the locations where most stormwater will naturally collect, and thus no additional steps will need to be taken to divert stormwater to a collection area.

7. Determine if there are any areas where the stormwater flow converges that are also near any locations that could be irrigated using the stormwater (the areas selected in Step 4).

    a. If areas to be irrigated selected in Step 4 don't have points of stormwater convergence, determine if any of these locations are in the path of natural stormwater flow (i.e. stormwater naturally flows towards it).

   b. If areas to be irrigated have no points of stormwater convergence or are not in the path of natural stormwater flow, a pump can be used to direct water flow from the collection point to the irrigation points. However, this method can be more costly and use more energy, so another option is to consider using another area that does meet these criteria.

Calculating Stormwater Runoff and Irrigation Demand

8. Once a location has been selected for the stormwater system, stormwater runoff and irrigation demand should be calculated.

9. Calculate the area of hardscape from which the stormwater will be collected. This drainage area should be based on the runoff/topography analysis conducted in Step 5.

   a. The area of hardscape from which stormwater will be harvested can be calculated using a professional engineer or surveyor. However, the Google Maps platform also provides tools that can be used for getting a general estimate the hardscape area.

10. Research rainfall data using sources such as NOAA databases, US Climate Data, etc. and get estimates for average rainfall per month of the area where the proposed stormwater system will be located.

11. To calculate the amount of stormwater runoff (assuming 5% of runoff is lost per MDE recommendation), MDE provides the following formula:

    a. Rainfall (inches) x Hardscape area (sq. ft.) x 0.95 x 7.48 gal/cu. ft. x 1 ft./12 inch. = gallons collected

12. Calculate the area to be irrigated; this should be done using the same method used for calculating the hardscape area in Step 9.

13. To calculate irrigation demand for the area to be irrigated (1 in/week per MDE recommendation), MDE provides the following formula:

    a. *43,560 sq. ft./acre x 1ft./12inch. X 7.48 gal/cu. ft. x number of acres to be irrigated*

    b. Irrigation demand may be less than the value calculated using the MDE formula if a SMS is used (studies show that irrigation demand can decrease by 25% - 70% when a SMS is used).

14. Using the values calculated for average runoff and irrigation demand, determine if the runoff generated will fulfill the demand for irrigation at the proposed site.

a. MDE recommends that the amount of runoff per month should be greater than or equal to the amount of irrigation demanded per month (note that the irrigation demand may be less if an SMS system is used).

b. It is preferable that the amount of runoff calculated is greater than the demand to account for periods of reduced rainfall.

c. If the amount of runoff is not sufficient to fulfill the irrigation demand, the stormwater irrigation system should be backed up with WSSC water supply. To be on the safe side, most irrigation systems that reuse stormwater should be backed up by water from a reliable water supply for periods of prolonged drought.

Analyzing Stormwater Quality and Selecting Appropriate BMPs and Treatment Methods

15. To determine what types of pre-treatment will be needed for stormwater entering the proposed system, conduct a water quality test of stormwater at the area where the system is proposed.

16. Some of the water quality criteria that should be tested for include:

    a. pH

    b. Sedimentation/turbidity

    c. Presence of contaminants/bacteria

    d. Hydrocarbons, oils, etc. (from automobiles)

    e. Pesticides

17. Using the findings of the water quality test, design a possible BMP layout for treating the stormwater. The following BMPs may be used to treat stormwater before it enters the stormwater harvesting system:

    a. Biofilters located at existing storm drains (if those storm drains will empty into stormwater storage)

    b. Infiltration trenches to intercept, filter, and slow the flow of stormwater runoff before entering the cistern

18. Additionally, filters should be placed at the inflow point of any stormwater storage device as an extra protection against stormwater pollution/contamination that may damage the stormwater system.

Selecting Locations for Stormwater Collection Area and Irrigation System

19. Select a collection method (either by an aboveground cistern, an underground cistern, or an underground cistern with bioretention).
    a. Underground cisterns tend to be the optimal choice for stormwater collection and storage because they are out of view and can be placed underneath existing hardscape.
    b. Include first flush filters and overflow pathways into any stormwater collection system so contaminated "first flush" of a rain event can bypass the system and so excess water can either bypass the system or be drained from the system.
    c. All systems should be designed to be drained in cases where the system may need servicing or for periods that do not require irrigation. They should also be equipped with safety features (ventilation, adequate entry points, etc.) for workers who may need to go inside the cistern to service it (confined space entry).
20. Calculate amount of storage needed. MDE recommends having a cistern that can hold enough water for one month of irrigation demand. If this size is not possible, using a cistern that can hold one-week worth of irrigation demand may be used (especially if a backup system that uses WSSC water is in place).
21. Using runoff estimates and irrigation demand to determine if an irrigation unit can act as a stand-alone or needs to be integrated into existing irrigation unit that uses WSSC water (would recommend integration in most cases to account for periods of limited rainfall).
    a. If integration into potable water sources (i.e. WSSC water lines) is needed, consult with Montgomery County Department of Health, WSSC, and a professional engineer to ensure that precautions are taken to ensure that reclaimed stormwater and potable water from WSSC are not mixed.
22. Select a location for the cistern/collection area. This is ideally close to the area to be irrigated and where stormwater will flow naturally.
    a. If underground stormwater pipes exist at the location in question, the cistern should be placed where the flow of stormwater through these pipes can be easily redirected to the cistern/collection area.
    b. The area selected should be relatively flat to reduce installation costs (i.e. no need for leveling, etc.)
    c. If an underground cistern is used, placing it underneath existing hardscape is the preferable placement, when possible.

d. If the collection storage area is uphill of the area to be irrigated, the system should be designed to use gravity to move water from the collection point to the irrigation area. Conversely, if the collection point is downhill from the area to be irrigated, pumping power is needed to move water from the collection point.

23. Once the cistern's location is chosen, the type of irrigator and number of irrigation points should be selected.

    a. Gun-style irrigation is typically a good choice for areas more than an acre. These can either be mobile or stationary, depending on field use and irrigation needs. Usually only one or two are needed because of their long range.

    b. Drip style irrigation can be used for small areas, such as planting beds and gardens.

Conducting a Cost-Benefit Analysis for the Proposed System

24. A professional consultant or engineer should conduct a cost estimate of the system based on the criteria chosen in the previous steps.

    a. The cost estimate in Appendix B can be used as a template for larger stormwater reuse projects.

    b. Cost savings can be calculated using the WSSC rates for 1,000 gallons of water x the irrigation demand of the location in questions. Table 10 in Appendix B may serve as an example.

25. Calculate the system's average projected savings per year and the system's total projected cost to determine the return on investment. A cost-effective system will have a return on investment of about 50% or more over 20 years.

    a. Maintenance costs for the system's various components should be taken into account in the cost benefit analysis. A professional engineer or consultant is conducting this assessment should be able to provide an estimate for annual maintenance costs for the system they design.

    b. Some manufacturers of stormwater systems also provide servicing for the equipment they install, so expected maintenance costs can also be provided by these entities. However, these costs vary depending on the company and typically do not take into account major repairs.

Consult Professionals and Submit Stormwater Concept Plan

26. A professional engineer must be hired to create the concept plan for a proposed stormwater system. They may be in-house engineers or contractors, as long as they possess the certifications required by state law.
    a. The engineer should ideally oversee the entire design process to ensure accuracy and that no major components are missed, costs are miscalculated, etc.
27. Once the concept plan is completed, it must be submitted to Montgomery County Department of Permitting Services for approval. This process usually takes about six weeks.
28. If the concept plan is approved, develop Sediment Erosion Control Plan (if applicable) and submit it for State approval.
29. Hire a team of qualified professionals to install the stormwater system. Ensure that a professional engineer oversees this process so the concept plan, sediment erosion control plan, and all other permitting process are followed.

Develop Maintenance Program for the Stormwater System

30. Once the final plan is approved and all components of the stormwater reuse system are clearly laid out, standard operating procedures (SOPs) should be drafted for all major components of the system (e.g. cistern servicing/confined space entry procedures, pipe maintenance, filter replacement, BMPs maintenance, irrigation system upkeep, etc.) These SOPs should be approved by the Montgomery County Department of Parks and followed by all personnel to ensure that the stormwater system functions properly and proper maintenance and servicing procedures are followed.

Appendix B - Detailed Cost Estimate Breakdown for a Stormwater Harvesting System at Cabin John Regional Park

Category	Component	Est. Price/Unit	Est. No.	Total Est. Cost	Source
Stormwater Collection and Storage					
	Fiberglass Underground Cisterns (75,000 gal)	$72,775	3	$218,325	http://www.rainharvest.com/rainflo-25-000-gallon-fiberglass-rainwater-system.asp
	First Flush Filter	$120	1	$120	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Rainwater System Controller	$700	1	$700	http://www.rainharvest.com/rainwater-system-controller.asp
	Excavation (per cubic yard)	$3	2,000	$5,840	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Overflow - 2 inch ball valve	$125	1	$125	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Overflow Piping 2 inch PVC	$23	10	$228	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Overflow - Cleanout Tee (2-inch)	$39	1	$39	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)

	Potable Supply - Bronze ball valve (3/4 inch)	$386	1	$386	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Potable Supply - 3/4 inch Copper Tubing	$15	100	$1,500	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Potable Supply - 3/4 inch Backflow Preventer	$335	1	$335	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Potable Supply - 3/4 inch Actuated Valve	$361	1	$361	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
Stormwater Distribution					
	Tank Pump (3/4 HP, 3 phase)	$623	1	$623	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Level Control (pump)	$97	2	$194	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Pump Panel	$2,026	1	$2,026	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Floating Intake	$299	1	$299	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)

	3/4 inch Copper Tubing	$14	1	$14	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
	Dayton Centrifugal Pump (model 4TU40)	$623	1	$623	https://www.rainharvest.com/more/MastersProjectRainHarvest_200805.pdf (Hicks, 2008)
Water Quality					
	Continuous Residual Chlorine Monitor	$3,570	1	$3,570	https://www.app4water.com/chlorine-monitor-111/
	Continuous Turbidity Monitor	$2,000	1	$2,000	http://refractometer.com/ptm-2000-turbidity-monitor/
Irrigation					
	Gun Style Irrigator	$6,000	1	$6,000	https://www.cleanenergyresourceteams.org/sites/default/files/Centerville_sw_reuse_5-21-13.pdf
	Irrigator Stand	$118	1	$118	https://www.rainfloirrigation.com/irrigation/sprinklers/big-guns
	Soil Moisture Sensor	$300	1	$300	https://www.hunterindustries.com/irrigation-product/sensors/soil-cliktm
Filtration/BMPs					
	Intake Filters (bin and screen)	$65	10	$650	https://www.hunterindustries.com/irrigation-product/sensors/soil-cliktm
	Biofilter Treatment (per acre)	$24,000	3	$72,000	http://www.conteches.com/Products/Stormwater-

					Management/Biofiltration-Bioretention/Filterra
Other Costs					
	Concept Plan Application Fee	$2,765	1	$2,765	https://permittingservices.montgomerycountymd.gov/DPS/pdf/ApplicationForStormwaterManagementConcept.pdf
	Sediment and Erosion Control	$27,000	1	$27,000	http://www.mwcog.org/asset.aspx?id=committee-documents/kl1fWF1d20111107094620.pdf
Total					**$346,141**

Table 9: Estimated costs of a stormwater reuse system for Cabin John Regional Park

Month	Gal/month	Thousands of Gal	$ /1,000 gal	Est. Savings	Est. Savings over 20 years
Jan	0	0	$0.00	$0.00	-------------------------------
Feb	0	0	$0.00	$0.00	-------------------------------
Mar	0	0	$0.00	$0.00	-------------------------------
Apr	75,000	75	$7.75	$82.75	-------------------------------
May	300,000	300	$8.16	$308.16	-------------------------------
Jun	300,000	300	$8.16	$308.16	-------------------------------
Jul	300,000	300	$8.16	$308.16	-------------------------------
Aug	300,000	300	$8.16	$308.16	-------------------------------
Sep	300,000	300	$8.16	$308.16	-------------------------------
Oct	75,000	75	$7.75	$82.75	-------------------------------
Nov	0	0	$0.00	$0.00	-------------------------------
Dec	0	0	$0.00	$0.00	-------------------------------
Annual				**$1,706**	**$34,126**

Table 10: Estimated cost savings from reusing stormwater for irrigation at Cabin John Regional Park (WSSC, 2017)