CABIN JOHN CREEK

WATERSHED ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

FINAL REPORT

ENVIRONMENTAL MANAGEMENT DIVISION

DEPARTMENT OF PUBLIC WORKS

CITY OF ROCKVILLE, MARYLAND

Approved July 18, 2011

Center for Watershed Protection

KCI Technologies, Inc.

CABIN JOHN CREEK

WATERSHED ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

FINAL REPORT

APPROVED JULY 18, 2011

Rockville Maryland

Prepared By:

Environmental Management Division
Department of Public Works
City of Rockville
111 Maryland Avenue
Rockville, Maryland 20850

Consultant Services by:

KCI Technologies, Inc.
936 Ridgebrook Road
Sparks, Maryland 21152

KCI TECHNOLOGIES

Center for Watershed Protection
8390 Main Street, 2nd Floor
Ellicott City, MD 21043

CENTER FOR WATERSHED PROTECTION

Acknowledgements

The Cabin John Creek Watershed Management Plan was initiated by the City of Rockville Department of Public Works, Environmental Management Division. The Project Team consisted of the following City staff and consultants:

CITY OF ROCKVILLE STAFF

Heather Gewandter, Department of Public Works
Michael Critzer, Department of Recreation and Parks
Dianne Fasolina, Department of Recreation and Parks
Mark Kibiloski, Department of Recreation and Parks
John Scabis, P.E., Department of Public Works
Lise Soukup, P.E., Project Manager, Department of Public Works
Jim Woods, P.E., Department of Public Works

KCI TECHNOLOGIES, INC.

Susanna Brown
Ryan Burdette, P.E.
Manasa Damera
Nate Drescher
Bill Frost, P.E., Project Manager
Colin Hill
Jackie Krayenvenger, P.E.
Bill Medina
Mandy O'Shea
Mike Pieper
Andrea Poling

CENTER FOR WATERSHED PROTECTION

Kelly Collins
Greg Hoffmann, P.E.
Julie Schneider, Subcontract Manager
Lori Lilly

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES (SEPARATE VOLUME)

1 EXECUTIVE SUMMARY

INTRODUCTION / BACKGROUND

The City of Rockville, as an active steward of the environment, is responsible for watershed management within the City limits. The City oversees stormwater and sediment control regulations for new and redevelopment, maintains and repairs public stormwater management facilities and storm drains, and designs and constructs Capital Improvement Program projects for stormwater management facilities and stream restoration. The City works with private owners and commercial operators to protect water quality from illicit discharges and offers education and outreach programs to promote sustainable practices. It also evaluates watershed policies, monitors stream and stormwater facility conditions, and administers the City's Stormwater Management Fund that supports staffing, consultants and contractor services, and other watershed program elements.

The City's watershed management program is regulated by Maryland Department of Environment under a National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit. This permit is part of a national watershed protection program administered through U.S. Environmental Protection Agency under the Clean Water Act. The permit, renewable every five years, requires Rockville to implement effective programs that reduce water-borne pollutants from construction sites, municipal activities, and commercial and residential properties. The permit makes the City responsible for the quality of the runoff discharged from public storm drains into streams, and for the stream conditions themselves. Throughout the Chesapeake Bay, MS4 permits are moving towards numeric stream quality standards that will hold municipalities to even higher levels of watershed protection. The City's already-extensive efforts must expand to balance the existing effects of urban development with more effective watershed improvements.

As part of this comprehensive effort, the City's Department of Public Works (DPW) has completed an update to the 1996 Cabin John Creek Watershed Management Plan. The new assessment and recommendations will help the City prioritize CIP projects and programmatic activities over the next ten years.

Rockville is situated at the headwaters of Cabin John Creek. The stream starts near the City's center and flows south to enter Montgomery County at Route I-270 and Montrose Road, then to its confluence with the Potomac River near Glen Echo. The overall Cabin John Creek watershed at the Potomac River drains 25 square miles (16,022 acres); the portion within the City is 3.6 square miles (2,281 acres). It encompasses part of downtown Rockville, including City Hall, County buildings and the District Courthouse; most of the commercial area along Rockville Pike, the I-270 corridor near Tower Oaks, and residential communities, including Potomac Woods, North Farm, Hungerford, and New Mark Commons, and Woodmont Country Club. The new watershed study covers the portion of the Cabin John Creek watershed located within the City limits. It divides the watershed into the same seven sub-watersheds that were used in the 1996 study to allow comparisons of watershed and stream conditions over time.

The new study's findings and recommendations were evaluated by City staff from DPW's Environmental Management and Engineering Divisions, the Department of Recreation and Parks, and the Watershed Protection sub-committee of the Commission on the Environment. They were also presented in two public meetings.

FINDINGS / WATERSHED CONDITION

LAND USE ANALYSIS AND STORMWATER MANAGEMENT CAPACITY

The Cabin John watershed is significantly urbanized, but not by a single type of land use. About a third of the area consists of open space, which includes parks and golf course areas; another third is residential, and the last third is a mix of commercial and institutional uses and roadways. Overall, the watershed is about 32% impervious.

Studies have shown that impacts on aquatic life begin to occur at 10% impervious and significant degradation is found at around 25%. At 32% imperviousness, Rockville's Cabin John Creek watershed is characterized by fair to poor water quality, unstable channels, and limited diversity in aquatic life. Small changes in land use or watershed controls do not measurably affect water quality at this level of imperviousness, so restoration is needed on a widespread basis to produce significant improvements.

Tree canopy helps to counteract the impact of impervious areas. A study by the Maryland Department of Natural Resources found that tree canopy covers approximately 44% of the City, exceeding the American Forests goal of 40% in all three of the City's watersheds.

Half of the watershed's area drains to some form of stormwater management (SWM) system. These tend to be either small facilities on commercial sites or larger public SWM facilities that treat mixed residential and commercial areas. Many facilities were built under outdated standards that are not effective at reducing stream erosion or trapping pollutants. Based on recommendations from the 1996 Cabin John Creek Watershed Management Plan, the City has retrofitted, or modernized, the largest public SWM ponds in the watershed to provide at least partial water quality and channel protection controls. The City is now enforcing proper maintenance of private SWM systems, as well as reducing a maintenance backlog on public facilities, so they will perform as originally designed.

WATER QUALITY IMPAIRMENTS

The State of Maryland has listed Cabin John Creek and its tributaries, collectively, as an impaired water body. Pollutants of concern include nutrients (nitrogen and phosphorus), sediment, fecal bacteria, and adverse impacts to biologic communities. Subsequent State analysis identified high storm flow rates and sediment loads, but not nutrients, as the primary stressors on the stream biological communities.

The State's designation triggers a Clean Water Act requirement to undertake a Total Maximum Daily Load (TMDL) assessment. A TMDL is an investigation into the causes and corrective actions needed to restored the impaired water body to health. To date, a TMDL was performed for fecal coliform bacteria (2007). Another one for sediment (total suspended solids) is pending. These TMDLs will require the City and Montgomery County to develop implementation plans that reduce these pollutants.

STREAM ASSESSMENT

Aquatic habitat assessment, water quality sampling, and stream channels measurements were performed. Almost all of the streams in the watershed are identified as having poor quality habitat, and none have highly rated habitat. The poor physical conditions are related to active erosion and sedimentation, channelization and disturbed riparian (i.e., near-stream) buffer impacts where streams abutted residential lots.

The channel assessment shows active head cuts (an incised eroded channel working back upstream to a storm drain outfall) in smaller headwater streams. Larger streams exhibit deeply incised stream channels and eroded banks, with large sediment loads moving with every storm. Although most development occurred in this watershed 20-50 years ago, many of the streams are still actively eroding.

This is typical of urbanized watersheds due to geomorphic shaping processes. Streams are very dynamic. They constantly change channel shape, capacity, and depth in response to storm flow patterns. After imperviousness is created by development, urban stream channels expand over decades to accommodate the higher storm flows. The lack of effective stormwater controls in older areas further contributes to the channel instability.

RECOMMENDATIONS

Although urbanized streams generally cannot be restored to the aquatic diversity and stability found in forested low-impervious areas, they can be made healthier. In Rockville, watershed management goals are more ambitious than simply meeting State permit requirements. They are intended to achieve cleaner water, more stable habitat, and less adverse man-made impacts. Healthier streams cause less damage to adjacent properties and City infrastructure, support a wider diversity and number of fish and aquatic insects, and deliver cleaner water to the Potomac River and the Chesapeake Bay. They also enhance the beauty and use of the stream valleys for all City residents.

This plan recommends watershed improvements in three categories: stormwater management retrofits, stream restoration, and operational programs.

Stormwater Management

Water quality-based stormwater controls help improve all sizes of streams, and these benefits continue downstream to the Chesapeake Bay. For this reason, water quality improvements are the highest priority for the recommended stormwater projects. Water quantity-based stormwater management to reduce downstream channel erosion is less effective in an already developed watershed, so it is a secondary goal. Unless most or all of the contributing drainage area is controlled, adding quantity controls has little correlation with stream stability.

The recommended projects, shown in Table A and Figure A, each involve retrofits or improvements to existing City-owned stormwater management dry ponds or wet ponds. No suitable locations were found to create new facilities.

Three concepts recommend engineering modifications to update outdated stormwater management designs and/or replace aging pipes; these are recommended as future CIP projects. The other three concepts recommend major maintenance on existing ponds constructed or expanded as a result of the 1996 Cabin John Creek Watershed Management Plan. These wet ponds need extensive sediment removal (i.e., dredging) to restore their original volume and maintain their pollutant removal effectiveness, but are already optimally designed for maximum water quality benefits.

TABLE A: RECOMMENDED STORMWATER MANAGEMENT PROJECTS

Sub-watershed	Current Site ID	Name and SWM Type	Final Recommendation	Priority
Bogley Branch	R-02	Potomac Woods Wetland Marsh Pond	Program for major maintenance. Remove accumulated sediment, dredge pond to restore original storage volume, adjust forebay berm, and replant wetland areas.	High
Bogley Branch	R-08	Locks Pond Court Wet Pond	Program for major maintenance. Remove accumulated sediment, dredge pond to restore original storage volume.	High

TABLE A: RECOMMENDED STORMWATER MANAGEMENT PROJECTS

Sub-watershed	Current Site ID	Name and SWM Type	Final Recommendation	Priority
Upper Cabin John	R-23	Hungerford-Stoneridge Wetland Marsh Pond	Program for major maintenance. Remove accumulated sediment, dredge pond to restore original storage volume, adjust forebay berm, and replant wetland areas. Forebay dredging (high priority) may be done separately from main pool dredging.	High-Medium (may be done in two stages)
Seven Locks Tributary	R-12a	Montgomery County Detention Center Wet Pond	CIP retrofit and repair project. Replace corrugated metal pipe control structure, replace low flow pipes, stabilize inflow channels, provide accessible forebays, and adjust controls to provide for 1" water quality volume and channel protection volume or to current standards.	Medium
Bogley Branch	R-03	Arlive Ct. Dry Pond	CIP retrofit project. Convert dry pond to sand filter to provide water quality treatment.	Low
Lower Cabin John	R-19b	North Farm Dry Pond	CIP retrofit project. Convert dry pond to sand filter to provide water quality treatment.	Low

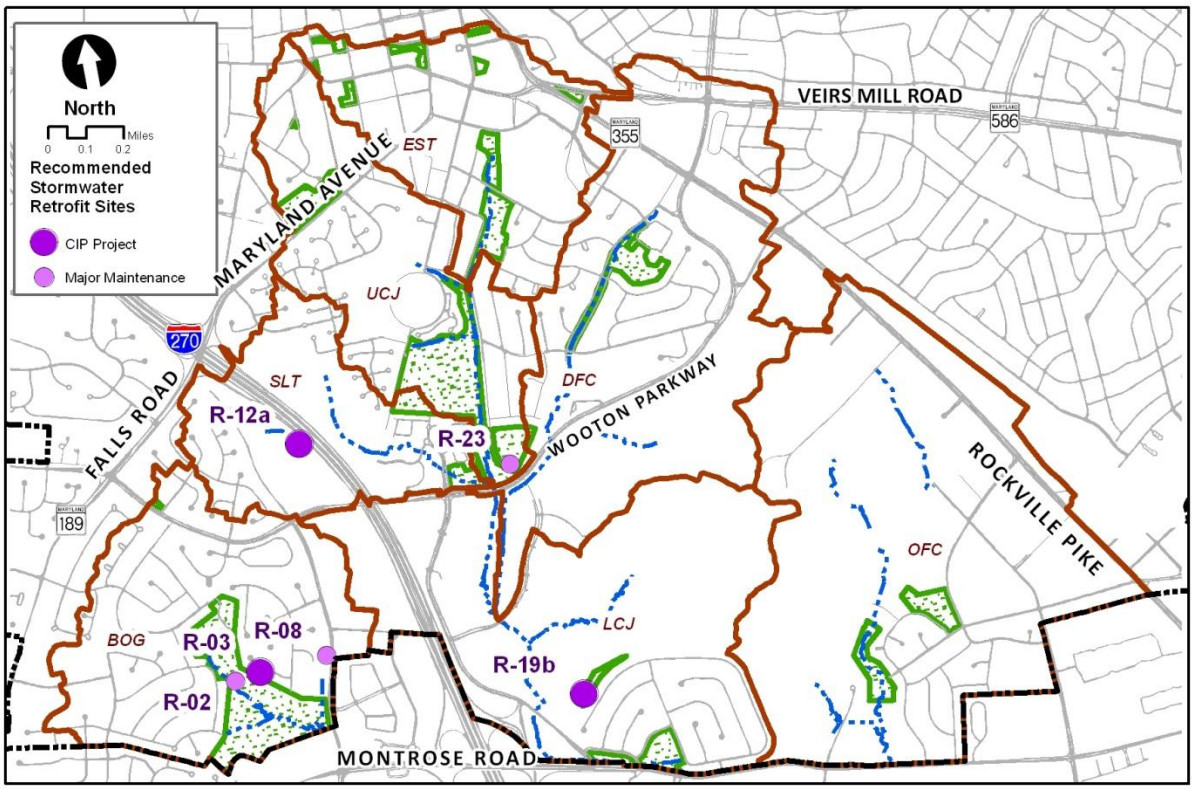


FIGURE A: RECOMMENDED STORMWATER MANAGEMENT PROJECTS

STREAM RESTORATION

Rockville's stream restoration measures focus on reducing bank erosion and sediment loadings from within the channel itself. They use rocks, bank shaping, and native plantings to create stable channels

and good aquatic habitat. These projects are designed to safely convey both small and large storm flows and accommodate debris loads from uncontrolled drainage areas.

Restoration concepts were developed for streams on City land where moderate to severe erosion or storm drain outfall damage was observed during the initial stream assessment. These concepts generally fall into two types of projects: traditional stream restoration for larger streams to armor or protect eroded banks, and a new technique for stabilizing smaller streams and storm drain outfall channels called regenerative stream conveyance (RSC). This method creates a filter of stone, sand, and woodchips in the channel that stops widening/downcutting and may also offer some water quality benefits.

Based on current conditions, seven CIP stream restoration projects are recommended. Four other stream segments will be monitored for worsening conditions between now and the next Cabin John Creek assessment. Table B and Figure B show the stream reaches involved in these recommendations.

TABLE B: RECOMMENDED STREAM RESTORATION PROJECTS

Sub-watershed	Current Site ID	Location	Final Recommendation	Priority
Old Farm Creek	R-80S	Old Farm Creek in Montrose Park at Rollins Ave.	CIP project – storm drain outfall repair, spot stream restoration and removal of debris	High
Upper Cabin John	R-68S	Stream at Dogwood Park – from Waddington Lane to Cabin John Pkwy.	CIP project – outfall RSC or stream restoration	High
Elwood Smith Tributary	R-66S	Outfall below Mt. Vernon Place to pedestrian bridge at Elwood Smith Recreation Center	CIP project - storm drain outfall repair; CMP culvert replacement	High
Bogley Branch	R-62S	Potomac Woods Park at Derbyshire Road	CIP project – outfall RSC or stream stabilization	Medium
Dawson Farm Creek	R-70S	Cabin John Creek mainstem – east branch	CIP project – stream restoration; sediment/debris removal from culverts under Wootton Pkwy.	Medium
Lower Cabin John	R-72S	Cabin John Creek mainstem – west branch	CIP project – stream restoration	Medium
Lower Cabin John	R-73S	Outfall channel from Tower Oaks Blvd. to mainstem south of Preserve Pkwy.	CIP project – removal of old dry pond dam/barrel and outfall RSC or stream stabilization	Medium

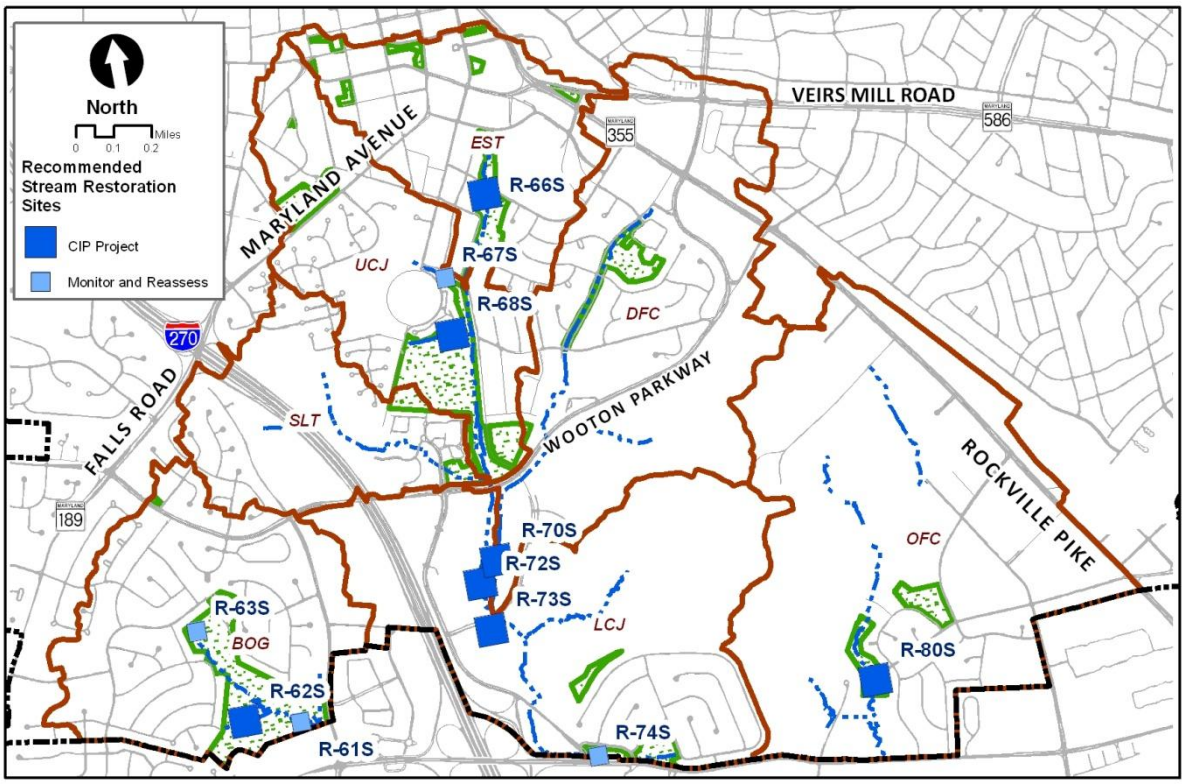


FIGURE B: RECOMMENDED STREAM RESTORATION PROJECTS

OPERATIONAL PROGRAMS

Two upland reconnaissance surveys were conducted during the study: the Neighborhood Source Assessment (NSA), which evaluated typical residential community behaviors affecting water quality, and Hotspot Site Investigation (HSI, which identified illicit discharges or other housekeeping concerns on commercial/institutional sites. Based on these assessments and other findings from the watershed assessment field work, several measures are highly recommended for implementation across the watershed. The operational program recommendations are organized into the following categories: ongoing monitoring and assessment; enforcement; outreach; maintenance; and incentives.

Ongoing Monitoring and Assessment

- Develop a water quality monitoring protocol to track pollutants targeted by TMDLs (nutrients, sediment or suspended solids, bacteria, etc.). This should include a city-wide plan identifying what parameters, where, when and how often. In addition, this protocol should identify the best way to monitor the success of SWM retrofits and stream restorations by identifying before and after monitoring techniques.
- Implement monitoring protocol. More monitoring data is needed to accurately identify pollution sources as well as to effectively evaluate programmatic success. The City should use monitoring results to make adjustments in program or project implementation as needed.
- Assess the feasibility of increasing frequency of street sweeping or storm drain inlet cleaning. (Debris, leaves, yard clippings, organic material, or trash was observed in common areas and street gutters in 26 of the 32 NSAs.) Further investigation is needed to identify the most cost-effective measures, best street sweeper equipment for water quality improvements, and ideal

frequency for residential and for non-residential streets. Also evaluate if source controls at storm drain inlets is more economical than trash/grit control at storm drain outfalls.

Enforcement

- Continue to conduct immediate investigation and enforcement for potential illicit discharges, using the Water Quality Ordinance.
- Increase compliance inspection and enforcement along Rockville Pike to reduce poor dumpster and trash management practices, using the Property Code regulations.
- Work with Woodmont Country Club and the Montgomery County Seven Locks Maintenance Yard to improve the water quality of runoff leaving their sites through better housekeeping practices and site management.

Outreach

- Conduct a lawn care education effort to reduce fertilizer use, and encourage proper disposal of yard debris, grass clippings and pet waste. (Sixteen of 32 NSAs had over 20 percent of the lawns showing high maintenance practices and some of the NSAs were observed with 100 percent of the lawns with high maintenance.)
- Expand the City's Rainscapes program to promote increased implementation of conservation landscaping in order to increase onsite runoff retention. Consider adding rain gardens or soil amendments to the Rainscapes program.
- Promote Rainscapes rebate program for tree planting in residential lots. This can be a lower priority because all but five of the NSAs had more than 20 percent of the lot devoted to landscaping as opposed to turf cover. All but four of the NSAs had more than 30 percent of the lot covered by tree canopy
- Promote the City's volunteer storm drain marking program. Stenciling was observed in only one of the NSAs.

Maintenance

- Develop an inspection and maintenance program to keep major culverts clear of sediment and vegetation.
- Continue to develop and refine a SWM maintenance program. Take into consideration SWM design, placement (what areas are draining to the facility) and age.

Incentives

- Consider expanding Rainscapes rebate program to encourage voluntary implementation of Environmental Site Design (ESD) practices on institutional and commercial properties to reduce runoff and improve water quality.

RECOMMENDATION COSTS

The preliminary cost of the recommended stormwater management and stream restoration projects is estimated at $5,015,000. This includes design and construction capital costs, and major maintenance work for pond dredging. Costs for recommended non-structural program changes cannot be fully quantified at this time. Some costs will be for contractor/consultant services or rebate programs, and some are for increased staffing to improve enforcement, maintenance or outreach services. Although they will add additional costs, these may be implemented City-wide since it is expected that similar issues exist in the City's other watersheds.

2 INTRODUCTION

Clean, healthy streams are important to Rockville—not just to protect people and to preserve the quality of our open spaces, but also to protect the water for the plants, insects, and other animals that call city streams home.

As in many urban areas, the health of city streams and waterways is threatened. This is due largely to the increased pollutants generated by human activities and the increased amount of impervious surfaces that funnel unfiltered runoff to streams. As Rockville's population grows, so does the amount of contaminants, such as fertilizers, pesticides, sediments, and pet waste, conveyed through the storm drain system into the community's streams.

2.1 WATERSHEDS

A watershed is the land area from which all water, and everything carried by that water, flows or drains into a common river, lake, ocean, or other body of water. A watershed can be very large; for example, the Potomac River collects water from thousands of square miles; or very small, such as a 20-acre watershed that drains into a pond. The City of Rockville contains part of three watersheds: Cabin John Creek, Watts Branch, and Rock Creek. All of Rockville's watersheds are part of the greater Potomac River Basin, which itself drains into the Chesapeake Bay.

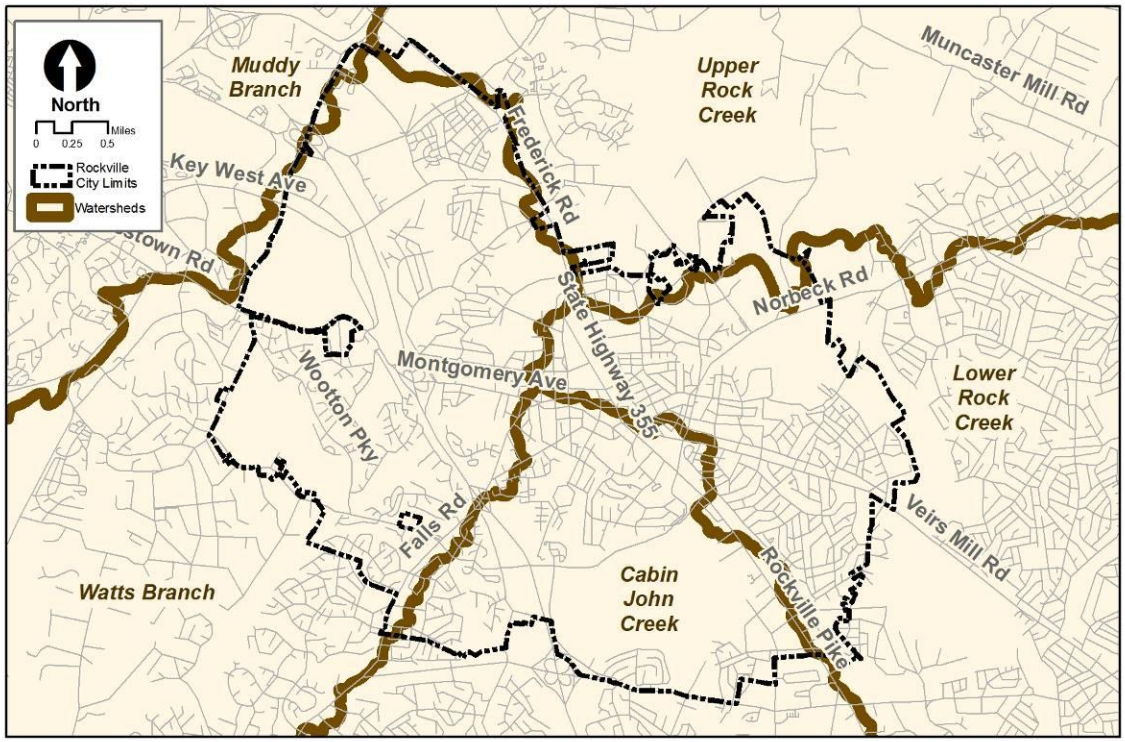


FIGURE 1: CITY OF ROCKVILLE WATERSHEDS

2.2 CABIN JOHN CREEK WATERSHED ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

The 2011 Cabin John Creek Watershed Assessment and Management Recommendations provides an in-depth look at the watershed's health and identifies steps the City can take to restore and protect this resource. Over a 14 month period, the City's consultant team, headed by KCI Technologies, Inc. and

assisted by the Center for Watershed Protection, rated the physical health of the stream habitat, sampled the water to provide contamination, measured stream bank erosion over time and identified likely sources of pollution from upland areas of the watershed. Based on the data collected and in consultation with City staff, recommendations for Capital Improvement Program (CIP) projects and stormwater operational programs were identified. These projects and programs are intended to mitigate the effects of urban runoff and to protect the watershed from further deterioration. The objectives are to stop or reduce potential contamination as close to its source as possible, to maximize stormwater management using current treatment standards, and to stabilize and restore stream channels for better water quality and aquatic habitat.

The headwaters of the Cabin John Creek watershed originate in the southern portion of the City of Rockville, Maryland and flow south into Montgomery County, Maryland to its confluence with the Potomac River near the towns of Cabin John and Glen Echo. The overall Cabin John Creek watershed drains 25 square miles (16,022 acres). The portion within the City (Figure 2) is 3.6 square miles (2,281 acres). This plan is targeted to the City of Rockville's portion of the watershed and unless noted, all further reference to the Cabin John Creek watershed refers to the City's 3.6 square miles.

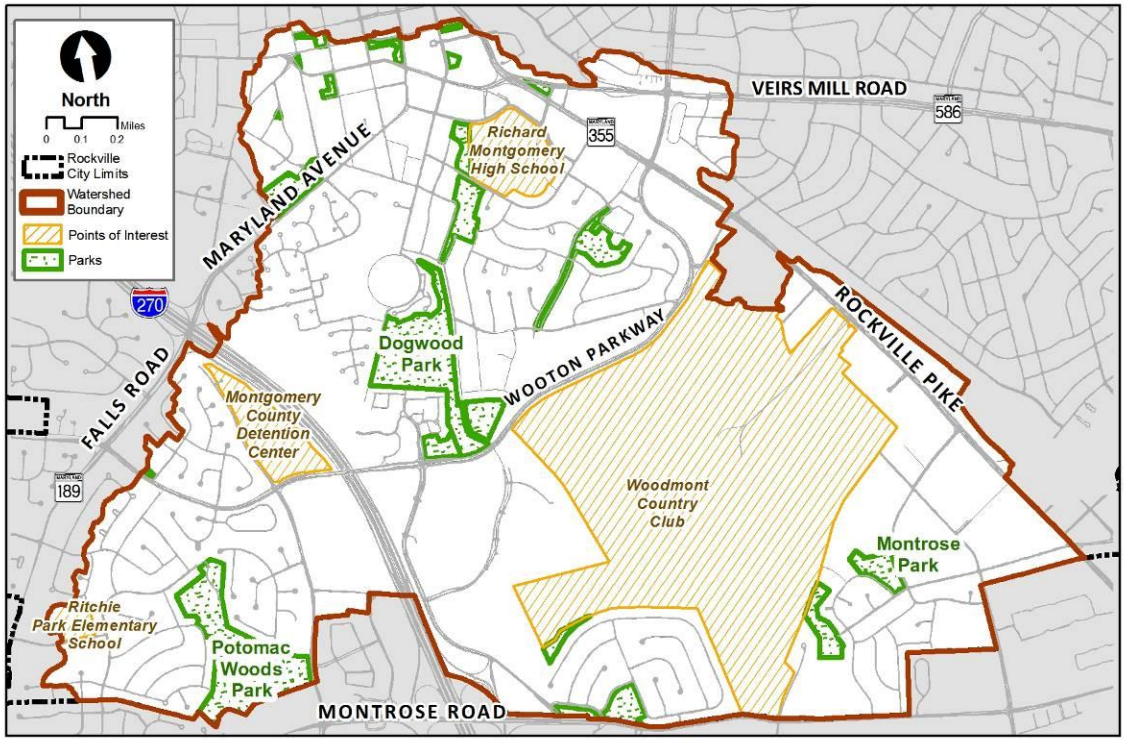


FIGURE 2: CABIN JOHN CREEK WITHIN ROCKVILLE

Figure 3 shows that the existing land use in the watershed is a heterogeneous mix of open space and water (35 percent), residential areas (32 percent), commercial/institutional/industrial uses (17 percent) and transportation (17 percent). The Woodmont Country Club and several parks are located within the watershed. Parks range in type from regional parks with picnic areas and play fields (Dogwood Park, Potomac Woods Park, Dawson Farm Park, and Elwood Smith Park) to green space associated with buildings (Beall-Dawson House & Park), and small urban parks (James Monroe Park). In addition, several schools and City and County institutional uses, like office buildings, detention centers and maintenance facilities, are located within the watershed.

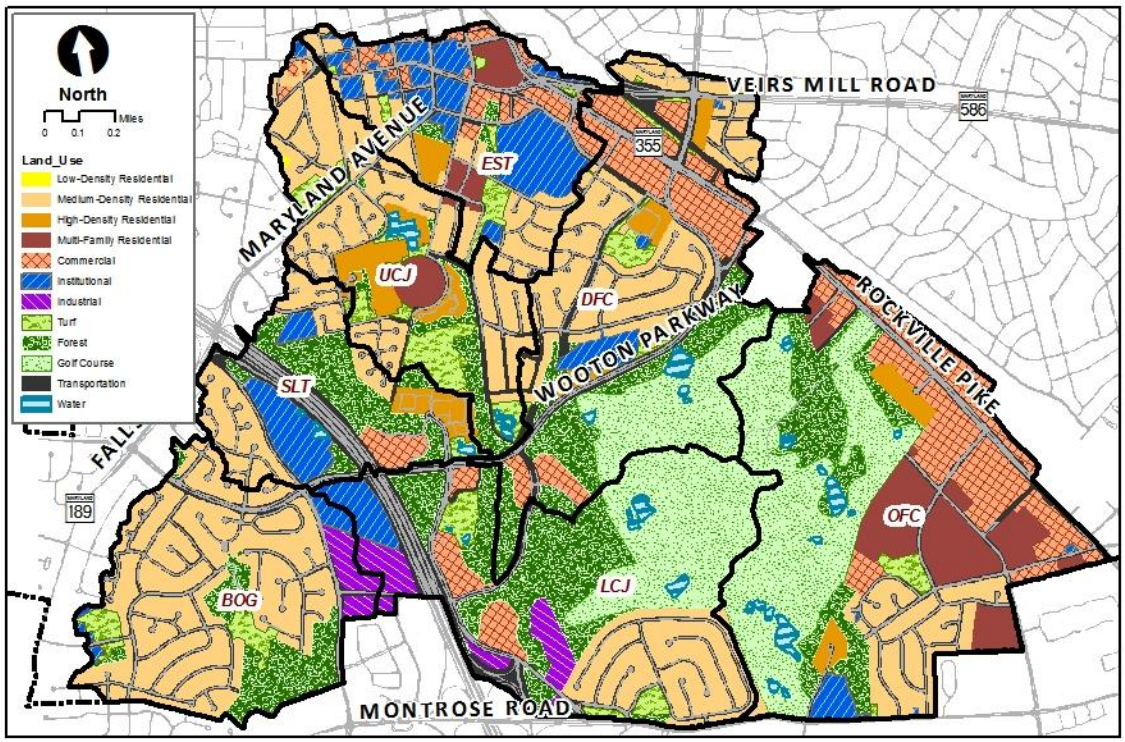


FIGURE 3: EXISTING LAND USE

2.3 URBAN LANDSCAPES IMPACT ON THE WATERSHED

Before any development occurred, much of the rain and melting snow soaked into the soil. Water that did not soak into the soil evaporated, was absorbed by plants or traveled slowly over land to streams, wetlands, and ultimately the Chesapeake Bay.

Urban development increased the amount of impervious surface, which prevents or inhibits the infiltration of rainwater into the earth. Impervious surface, such as buildings, paved roads and parking lots, and even highly compacted soil or gravel, causes stormwater to "run off" into storm drain pipes and streams. As the water runs over land, it picks up pollutants like oil, fertilizer, pesticides, pet waste, and sediment. Without effective water quality treatment, these pollutants impact a stream's water quality. In addition to debris and other pollutants entering storm drains, the fast-flowing water causes stream banks to continually erode for decades, dumping more sediment into waterways.

Impervious area was estimated for the Cabin John Creek watershed by using GIS and aerial photography. The estimated total area of impervious surface is 736 acres out of the total area of 2,281 acres, or, approximately 32 percent of the watershed.

2.4 CITY RESPONSIBILITY TO STREAM HEALTH

As Stated in the Mayor and Council's 2010 Vision:

> "Rockville is a 'Green City' in all areas…Rockville continues to be the regional leader in stormwater management and energy conservation, not only for City facilities, but also for residential and commercial properties. It does this through education and innovative programs, incentives, and regulation where appropriate."

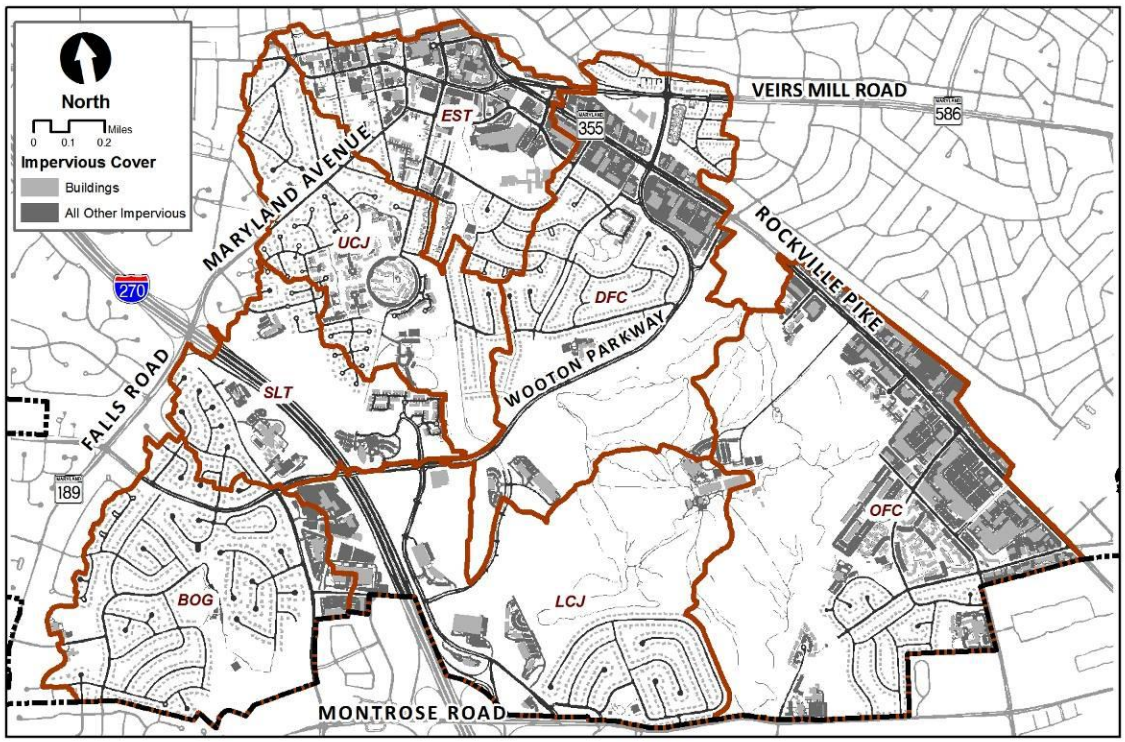


FIGURE 4: IMPERVIOUS COVER

Rockville created the first stormwater management program in Maryland in 1978 to address flood control. In 1982 the State of Maryland followed suit by requiring local jurisdictions to adopt local ordinances for the control of stormwater generated by development. These early programs focused on preventing floods from larger storms but did little to protect water quality in streams. Throughout the following decades, stormwater management techniques evolved to better protect water quality, with Rockville's program frequently leading the way. Today, the City's comprehensive program includes extensive watershed protection and restoration planning, enforcement of water quality protection ordinances, Capital Improvement Program projects, outreach and education, monitoring, and infrastructure inspection and maintenance.

The City is not only driven by a stewardship ethic but also has strong Federal and State stormwater management regulatory requirements to follow. Most notably, both the Clean Water Act's (CWA) Total Maximum Daily Load (TMDL) program and National Pollutant Discharge Elimination System (NPDES) permit, which are administered through U.S. EPA and Maryland's Department of the Environment, are part of the City's regulatory environment.

When streams, lakes, and other bodies of water are impaired, a TMDL or "pollution diet" is created. The TMDL restricts the amount of contamination that is allowed to flow into that water body. Specific industrial activity, including water or wastewater treatment plants, municipal maintenance yards, and certain commercial businesses like swimming pools, may be regulated through NPDES permits issued for that property. For nonpoint source discharges from a shared storm drain network, such as the City of Rockville, these pollution restrictions are administered through an NPDES Municipal Separate Storm Sewer Systems (MS4) permit.

All the stream miles in the Cabin John Creek watershed have been identified by the State as degraded, based on water quality sampling of benthic macroinvertebrates or fish indices of biological impairment.

In response, Maryland Department of the Environment has issued TMDLs for Cabin John Creek watershed for nutrients, total suspended solids (TSS), fecal bacteria, and chlorides and sulfates. In addition to these Cabin John Creek specific contaminants, the entire Chesapeake Bay has Bay-wide TMDLs for sediments, nitrogen, and phosphorus.

Requirements to reduce these target pollutants are outlined in the City's NPDES permit. Due to the population size, Rockville is designated as a Phase II NPDES MS4 community. Under its current NPDES permit and anticipated future permits, the City is committed to carrying out activities that will reduce TMDL target contaminants. One aim of this watershed assessment is to recommend CIP projects and programmatic solutions that will reduce these pollutants. This helps the City fulfill the intent of its own Water Quality Protection Ordinance as well as NPDES permit requirements.

2.5 REPORT ORGANIZATION

The 2011 Cabin John Watershed Assessment and Management Recommendations lays out a snapshot of current stream health, investigates pollution sources, and recommends methods to protect and restore stream resources. It also summarizes past water quality investigations and watershed improvements made since the City's 1996 Cabin John Creek Management Plan. The report is organized as follows:

- Detailed description of the Cabin John Creek watershed
- Overview of previous water quality monitoring data
- Data gathering methodology
- Study results organized by sub-watershed
- Recommendations and conclusions

2.6 OVERVIEW OF THE CABIN JOHN CREEK WATERSHED

The City of Rockville was founded in the mid-1700s as a small hamlet near the current Town Center. The City has thrived and is now an important suburb of Washington DC. The City is almost entirely built-out and is characterized as a mix of residential communities, commercial and industrial corridors, extensive transportation networks, and strategically placed parks, golf courses, and forested areas. Some of the oldest and densest development in the City occurred within the Cabin John Creek watershed and, as a result, the stream's water quality, flow path, and channel characteristics have changed substantially.

Cabin John Creek flows from its headwaters in Rockville, through Montgomery County to the Potomac River. The watershed is 25 square miles in area, with major tributaries that include Bogley Branch, Booze Creek, Buck Branch, Congressional Branch, Ken Branch, Old Farm Branch, Snakeden Branch, and Thomas Branch.

The watershed lies entirely in the Piedmont physiographic province, which has a characteristic terrain of low rolling hills. Average annual precipitation is 39 inches of rain and 17 inches of snow. Figure 5 shows the watershed boundary in relation to the City.

Several major transportation corridors within the watershed include I-270, which connects to the Capital Beltway (I-495) to the south and I-70 in Frederick to the north. Maryland Route 355 (Rockville Pike) is a major north-south road and commercial shopping corridor. The Rockville portion of the watershed is generally bordered by Rockville Pike to the east, Maryland Route 189 (Falls Road) to the west and Montrose road to the south. In addition, the Metrorail Red Line runs along the eastern edge of the watershed.

Several parks are located within the watershed ranging from regional parks with picnic areas and active recreation areas (Dogwood Park, Potomac Woods Park, Dawson Farm Park, and Elwood Smith Park) to open space associated with historic buildings and/or statues (Beall-Dawson House & Park), and small

urban parks (James Monroe Park) (Table 1). These parks comprise 137 acres (5.9 percent) of the watershed. One private golf course, Woodmont Country Club (458 acres), is located in the southeastern corner of the watershed located between Wootton Parkway to the north and Montrose Road to the south. In addition, several schools are located within the watershed, which collectively add to the open space.

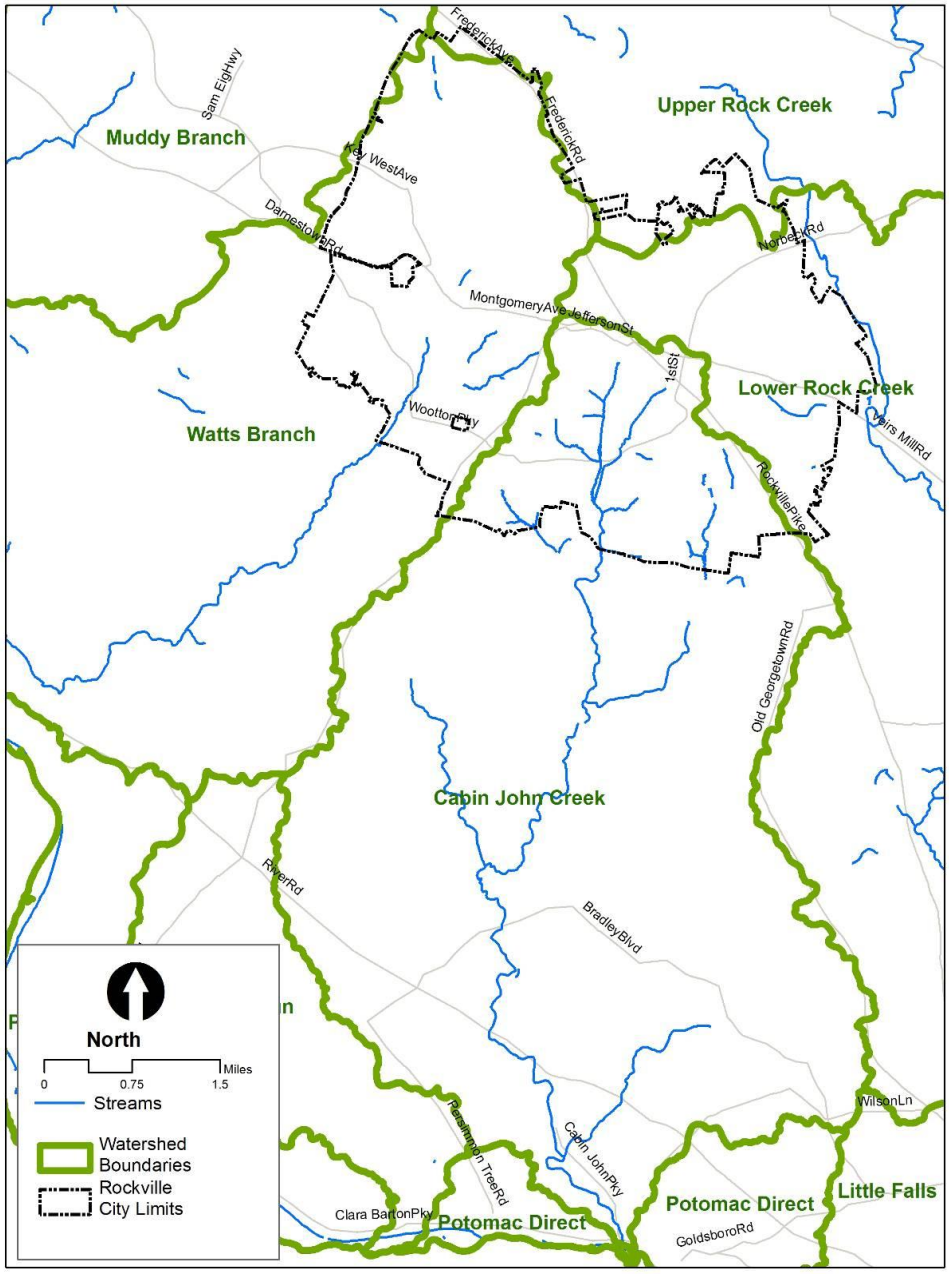


FIGURE 5: CABIN JOHN CREEK WATERSHED

TABLE 1: CITY PARKS IN THE WATERSHED

Name	Acres
Beall-Dawson House & Park	0.43
Courthouse Square Park	1.46
Dawson Farm Park	9.33
Dogwood Park	39.93
Elwood Smith Park	10.87
Friends Park	0.15
Grandin Avenue Park	0.20
Jacquilin Trells Williams Park	0.98
James Monroe Park	0.59
Karn Park	0.11
Montrose Park	5.69
Montrose Woods Park	6.00
Monument Park	6.61
North Farm Park	5.41
Open Space (North Farm)	1.75
Open Space (SWM) (Tower Oaks, North Farm)	5.32
Orchard Ridge Park	0.33
Potomac Woods Park	40.75
Promenade Park	0.35
Veterans Park	0.87
Total	137.16
Percent of Watershed	5.9%

2.7 SUB-WATERSHEDS

This Plan divides the watershed into seven sub-watersheds: Bogley Branch, Dawson Farm Creek, Elwood Smith Tributary, Lower Cabin John Creek, Old Farm Creek, Seven Locks Tributary, and Upper Cabin John Creek. A summary of each sub-watershed is provided in Table 2. Their boundaries are shown in Figure 6.

TABLE 2: SUMMARY SUB-WATERSHED DATA

Sub-watershed	Sub-watershed Code	Drainage Area (acres)	Streams (mi)
Bogley Branch	BOG	287	1.06
Dawson Farm Creek	DFC	412	1.79
Elwood Smith Tributary	EST	213	0.48
Lower Cabin John Creek	LCJ	401	2.11
Old Farm Creek	OFC	543	2.46
Seven Locks Tributary	SLT	182	0.74
Upper Cabin John Creek	UCJ	243	1.58
Total		2,281	10.22

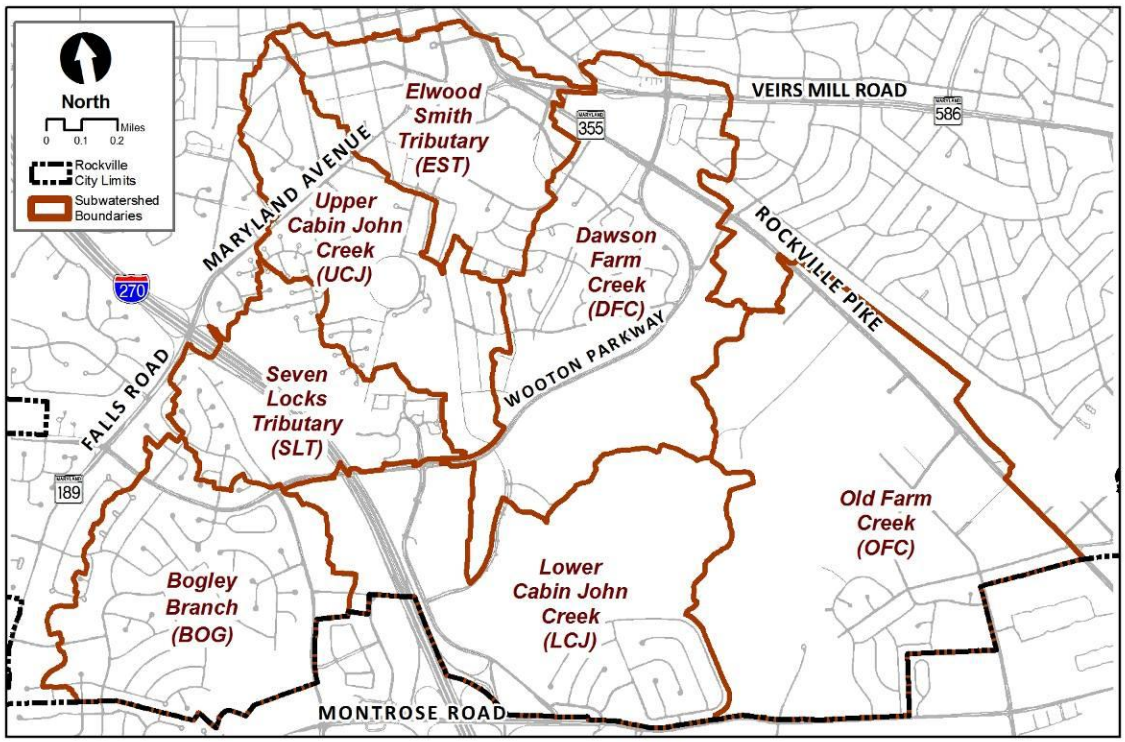


FIGURE 6: CABIN JOHN CREEK SUB-WATERSHEDS

2.8 LAND USE AND IMPERVIOUS AREA

A watershed may have multiple land uses. Each potentially can contribute different impacts on water quality and habitat. For example, a forested watershed produces relatively few pollutants. It has capacity to absorb much of the rainfall volume and slow the flow of water into streams. Conversely, a more developed watershed that includes roads, rooftops, and parking lots will generate a greater volume of stormwater with a higher concentration of pollutants. More of this runoff will reach the stream system because there is less vegetated area to infiltrate, evaporate or transpire the runoff, and because storm drainage systems for developed areas are designed to efficiently move runoff from impervious areas to streams.

2.8.1 LAND USE

The land use in the Cabin John watershed consists of open space (35 percent), residential areas (32 percent), commercial/ institutional/ industrial uses (17 percent), and transportation (17 percent). Watershed land use is shown in Figure 3 and described in Table 3.

The Woodmont Country Club makes up a significant portion of three sub-watersheds: Old Farm Creek, Lower Cabin John, and Dawson Farm Creek. Forested areas within and around the golf course property contribute to a high percentage of open space in these sub-watersheds as well. Dogwood Park in Upper Cabin John and Potomac Woods Park in Bogley Branch are also large contiguous areas of open space.

The great majority of residential area is medium-density single-family detached housing (roughly 1/4 acre lots), distributed through every sub-watershed. Smaller areas of townhouse and apartment housing are found adjacent to the Rockville Pike corridor and the central business district in downtown Rockville.

The watershed is home to several City and County institutional uses, including office buildings, a detention center, maintenance facilities, and judicial buildings, primarily in the Elwood Smith Tributary and Seven Locks Tributary sub-watersheds. Commercial and industrial uses are focused along the Rockville Pike corridor, the center of Rockville, and to a lesser extent along I-270. As a result, Dawson Farm Creek and Old Farm Creek sub-watersheds also have a high proportion of commercial land use.

The categories of Turf, Forest, Golf Course, and Water shown in Table 3 are all different types of open space. Lawn or tree canopy associated with residential areas is included in residential land and is not part of these categories. Parks in the watershed are not classified as a separate land use. Instead, the recreational areas and forest within the parks were classified as Turf and Forest. Woodmont Golf Course has been classified in two of these land uses: Golf Course for the areas in turf, and Forest for the areas covered with tree canopy. This breakdown better reflects the effect that vegetative cover has on both volume and quality of runoff.

TABLE 3: EXISTING LAND USE, CABIN JOHN WATERSHED

Land Use	Acres	Percent of the Watershed	Impervious Area	Percent Impervious Within the Land Use	Percent Impervious of the Watershed
Turf in Open Space	88	4%	9	11%	0.4%
Forest	334	15%	3	1%	0.1%
Managed Turf on Golf Course	338	15%	23	7%	1.0%
Water	22	1%	0.0	0%	0.0%
SUBTOTAL OPEN SPACE	**782**	**35%**	**35**	**4%**	**1.5%**
Medium-Density Residential	550	24%	162	30%	7.1%
High-Density Residential	72	3%	34	48%	1.5%
Multi-Family Residential	103	5%	61	59%	2.6%
SUBTOTAL RESIDENTIAL	**725**	**32%**	**257**	**35%**	**11.2%**
Institutional	132	6%	62	47%	2.7%
Commercial	211	9%	165	78%	7.2%
Industrial	39	2%	26	67%	1.1%
Transportation	391	17%	191	49%	8.4%
TOTAL	**2,280**	**100%**	**736**	**32%**	**32.3%**

2.8.2 IMPERVIOUS AREA

The overall imperviousness of the Rockville portion of the Cabin John Creek watershed is 32 percent, which is consistent with the impervious coverage in the City's other two watersheds. This means that about 1/3 of the Cabin John Creek watershed is hardscape (i.e., impervious) that prevents runoff from soaking into the ground. Impervious area was estimated for the Cabin John Creek watershed from GIS layers of the following features:

- Streets
- Parking Lots
- Buildings
- Driveways
- Trails and footpaths

Driveway areas were estimated using the assumption that each multi-family detached property had a driveway of approximately 60 ft x 20 ft, an average size from samples measured in the watershed. Sidewalk areas adjacent to streets were not included in the calculation.

The estimated total of 736 acres of impervious surfaces is fairly evenly distributed among streets, buildings, and parking lots, with a minor amount in driveways, as shown in Table 4 and Figure 4.

TABLE 4: IMPERVIOUS SURFACES IN CABIN JOHN CREEK

Impervious Type	Acres	% of Watershed
Streets	199	8.7%
Parking Lots / Trails	243	10.7%
Buildings	225	9.9%
Driveways	69	3.0%
Total	736	32.3%

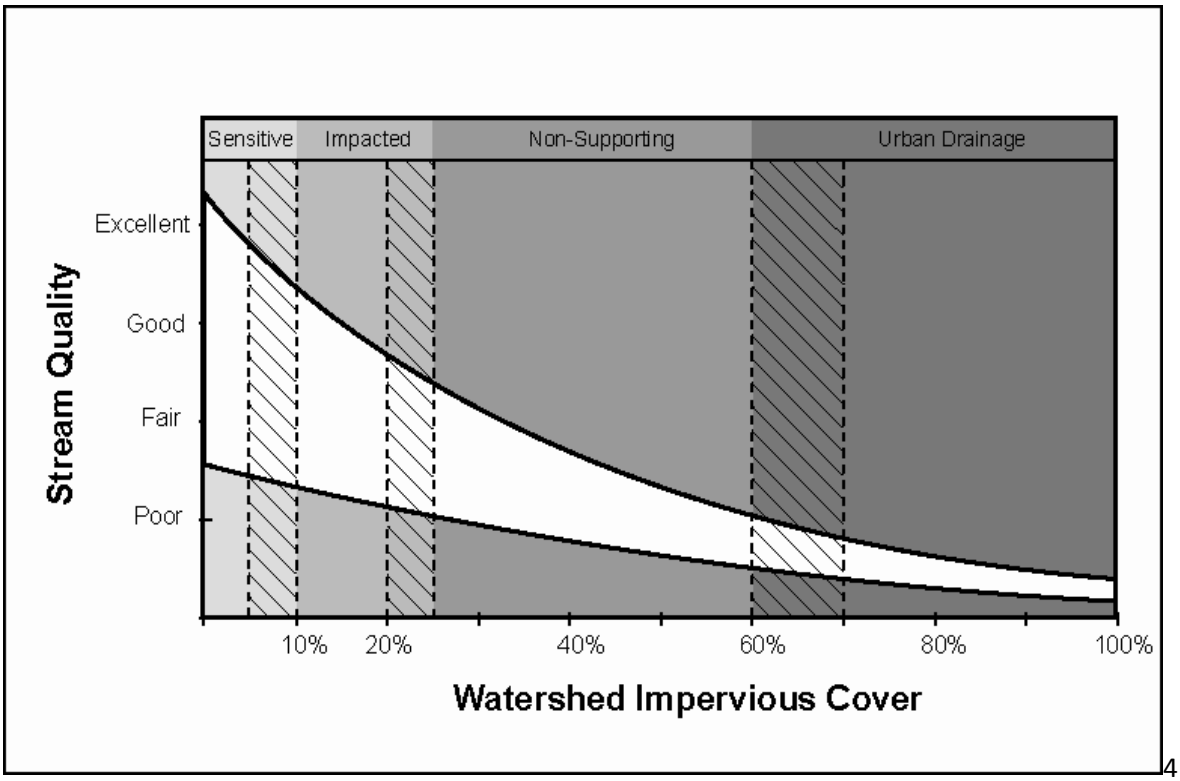
Table 5 shows that Elwood Smith Tributary, at 48.6 percent impervious, has the highest imperviousness of this watershed; it drains part of the town center of Rockville. Old Farm Creek, at 35.0 percent is the second most impervious sub-watershed, draining a heavily commercial area adjacent to Rockville Pike. The other sub-watersheds are all within a few percent of 30 percent with the exception of Lower Cabin John, which has several large forested areas along with a substantial portion of Woodmont Country Club within its boundaries.

TABLE 5: IMPERVIOUS AREA BY SUB-WATERSHED

Sub-watershed	Area (ac)	Impervious Area (ac)	Percent Impervious
Bogley Branch	287	87	30.3%
Dawson Farm Creek	412	132	32.1%
Elwood Smith Tributary	213	103	48.6%
Lower Cabin John Creek	401	95	23.8%
Old Farm Creek	543	190	35.0%
Seven Locks Tributary	182	57	31.0%
Upper Cabin John Creek	243	72	29.5%
Total	2,281	736	32.3%

The percentage of impervious cover is directly related to the level of urban stream degradation. Although lawn, grass play fields, and golf courses are considered vegetated open space, soils in these areas tend to be more compacted than natural, forested areas, so they do not infiltrate runoff as efficiently. They often have high pollutant loads from pesticide and fertilizer applications, and uncollected pet waste. These areas are not included in the impervious calculations below, but they do have a negative impact on water quality.

Research shows that, as impervious cover in a watershed increases, there is a decline in water quality, and in diversity and abundance of aquatic and terrestrial life (Schueler et al., 2009). This relationship is demonstrated in the impervious cover model in Figure 7. This relationship is represented as a 'cone' that indicates a stronger relationship as impervious cover increases. At low levels of impervious cover, other watershed metrics such as forest cover, road density, and riparian buffers influence stream health. Studies used to develop the impervious cover model measured stream quality based on a variety of indicators such as the number of aquatic insect species, stream temperature, channel stability, aquatic habitat, wetland plant density, and fish communities.



[4]

FIGURE 7: IMPERVIOUS COVER MODEL (SCHUELER ET AL. 2009)

Based on the research compiled, the following general categories were developed to classify and predict stream quality in terms of impervious cover represented by bands in Figure 7:

- Sensitive – watersheds with less than 10 percent impervious cover are referred to as sensitive, and typically have high quality streams with stable channels, good habitat conditions, and good to high water quality. Sensitive watersheds are susceptible to environmental degradation with urbanization and increases in impervious cover.
- Impacted – watersheds with between 10 and 25 percent impervious cover show clear signs of degradation such as erosion, channel widening, and decline in stream habitat. Stream restoration to a somewhat natural functioning system is still possible in these watersheds.
- Non-supporting – watersheds with between 25 and 60 percent of impervious cover are characterized by fair to poor water quality, unstable channels, severe erosion, and the inability to support aquatic life and provide habitat. Many streams in this category are typically piped or channelized. This category has a wide range for impervious cover, which means that small changes in land use typically do not measurably affect water quality, either positively or negatively. Watershed interventions must occur on a comprehensive scale to lead to demonstrable improvements.
- Urban drainage – in watersheds where impervious cover exceeds 60 percent, a watershed is classified as severely damaged, which means that most of the natural open stream system is has been converted to man-made concrete or riprapped channels, or piped into underground storm drains.

In terms of the Impervious Cover Model, the Cabin John Creek watershed, at 32 percent impervious cover, falls within the low end of the Non-Supporting category which is typical for urban watersheds.

2.9 *CITY PLANNING AND STORMWATER INFRASTRUCTURE*

Emphasized throughout multiple City planning documents is the concept of reducing impervious surface, establishing contiguous green space and providing open space within walking distance to all Rockville residents. While these green and/or open spaces are used for multiple purposes, they provide the City opportunity to locate stormwater management facilities and perform needed stream restoration work.

- *Parks, Recreation and Open Space Plan*

The City has a long-range policy document, the *Parks, Recreation and Open Space (PROS) Plan* that sets goals and objectives for parks and recreation in the City for the next 20 years (City of Rockville, 2009a). The PROS plan emphasizes connectivity of trails and greenways for recreation, to improve walkability and neighborhood connections, and to reduce the need for vehicle use. In addition, the PROS plan aims to:

  - Limit natural resource consumption, reduce pollution sources, avoid adverse environmental impacts, and reduce impervious surfaces;
  - Use sustainable maintenance practices at all parks and facilities;
  - Develop an open space plan to assess and unite the greenways, connections, and potential open spaces in the City under a single vision;
  - Partner with neighborhoods to create interconnecting spaces or "greenways" and formalize this as a program; and
  - Acquire 25-30 acres of PROS land within the Rockville Pike Neighborhood Plan area by 2030.

- *Comprehensive Master Plan*

The City Comprehensive Master Plan (Rockville, 2002) recommends maintenance of a near 50-50 balance between passive open space and active park areas with recreational amenities. In 2010, the City added a Water Resources Element to the Comprehensive Master Plan, which describes the framework for all of the City's water resources protection programs and policies.

- *City Zoning Code*

The City zoning code was updated as of March, 2009 to include a new zoning district, the Park Zone, with the purpose of providing and maintaining open space areas within the City.

- *City Code Chapter 5, Buildings and Building Regulations*

Chapter 5 of the City Code was updated in 2010 to add a new article titled "Green Building Regulations" that improves the efficiency and environmental quality of buildings and homes.

- *Rockville Pike Redevelopment Plan*

The Rockville Pike Redevelopment plan includes multiple elements, such as greening the Pike through tree planting and landscaping. New development will need to provide 15 percent open space (5 percent must be onsite open space and 10 percent can be fee-in-lieu). Additional opportunities, such as green roofs on commercial buildings, are encouraged.

- *City Code Chapter 19 and Regulations for Stormwater Management and Erosion and Sediment Control*

The sections dealing with stormwater management requirements in City Code Chapter 19 and the City's regulations were updated in 2010 to adopt the State's 2009 regulations for Environmental Site Design-based practices for stormwater management on new development and redevelopment.

These laws and regulations also contain rules for erosion and sediment control during construction. Finally, they include details regarding the City's stormwater management utility fee, an ongoing funding mechanism applicable to all property owners.

- *City Water Quality Protection Ordinance*

The City's 2007 Water Quality Protection Ordinance protects surface and groundwater by specifying prohibited discharges, such as oil or excessive sediment, to the storm drain. It also establishes a duty to report and cleanup these discharges, and clarifies the City's ability to conduct inspections and enforce the ordinance. The City may use this enforcement mechanism to work with private owners to mitigate onsite activities and property management issues that may harm stream quality.

Additional information on municipal policies and programs related to watershed management is provided in Appendix B.

2.9.1 STORMWATER MANAGEMENT

The City's stormwater management infrastructure performs an essential role in mitigating the effects of development on streams and surrounding environmentally sensitive areas. Stormwater management practices are required for both new development and for redevelopment projects. In addition to these private resources, the City constructs and maintains public stormwater management (SWM) facilities and an extensive storm drain system. Rockville's stormwater system consists of more than 2,560 storm drain inlets, nearly 400 private and 140 public SWM facilities, and approximately 100 linear miles of public storm drain pipe.

The stormwater management infrastructure is designed to collect and slow down stormwater runoff in order to allow time to separate out pollutants that are taken up as rain passes over impervious surfaces. SWM facilities, such as wet ponds and sand filters, act as a repository for these pollutants as they separate from the stormwater, collecting contaminants before they enter the City's streams. The storm drain network and SWM facilities also act to reduce the velocity of runoff as it enters the streams. This reduction in stormwater's speed helps to protect receiving streams from erosion.

The City's stormwater management budget is funded to support regional stormwater facilities that treat runoff from multiple properties and public roads. These are considered public SWM facilities. The City usually takes over ownership and maintenance of SWM facilities built by developers to serve residential communities, since these facilities control runoff from public streets in the neighborhood. However, the City does not construct or maintain SWM facilities on private property that only manage that site's runoff, such as on a shopping center. Private SWM facilities are built and maintained by individual owners through development regulations. Similarly, the City maintains the public storm drainage system in streets and parks, but does not manage storm drains on private property.

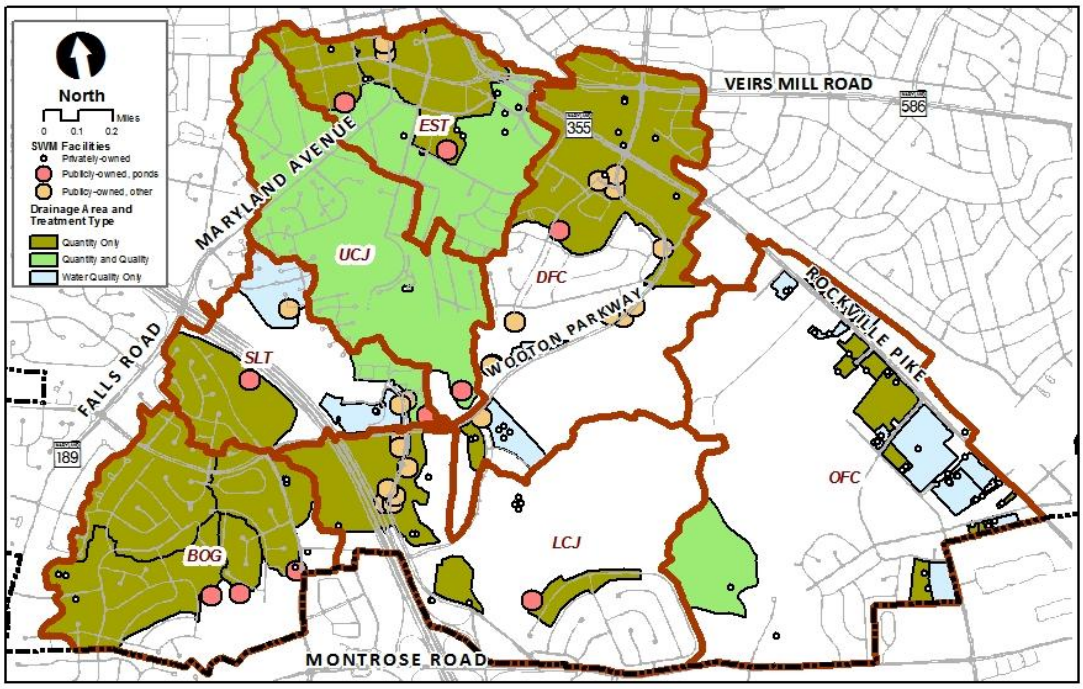
Although 51 percent of the watershed drains to some type of stormwater management facility, much of this acreage goes to ineffective facilities built under outdated treatment standards. The other 49 percent of the watershed has no stormwater treatment since it was built before stormwater management was required. The City retrofits, or modernizes, older public stormwater management facilities to maximize effective treatment for these under-controlled areas, as well as to install new stormwater treatment for drainage areas that developed prior to stormwater management requirements.

An analysis of the stormwater facility GIS layer (current as of 2004) provided by the City shows that there are approximately 108 public and 30 private stormwater facilities located in the Cabin John Creek watershed. While the various types of sand filters and underground detention are the most frequently

found methods, ponds treat the majority of the managed drainage area. Twelve percent of the systems are ponds providing various levels of water quantity and/or quality control that capture 89 percent of the treated area. Twenty percent of the systems are water quality sand filters that capture 4 percent of the treated area. Forty percent of the systems are water quality underground facilities that capture another 4 percent of the treated area.

Some SWM systems are in series; individual water quality facilities may drain in turn to a SWM pond downstream. A summary of these facilities is provided in Table 6 and shown in Figure 8, and more information describing them can be found in Appendix C. Table 6 also describes the function of each of these types of systems. "QN" refers to systems designed for quantity control only. These are generally designed to reduce the peak rate of runoff (the highest rate of flow) from a developed area down to the flow that existed prior to development. Systems flagged as "WQ" are generally newer, and were designed to reduce runoff pollution. A few types are coded "WQ-QN" and are designed to reduce both peak flows and pollutants.

Drainage areas, as shown in Figure 8, were delineated for the largest and most significant SWM facilities, which happened to be ponds. Together, these ponds result in a total drainage area treated for either quantity or quality of 1,055 acres, or 46 percent of the watershed. An additional area of commercial and high-density residential development along the Rockville Pike corridor in Old Farm Creek has also been treated during development or redevelopment. These facilities, along with other scattered smaller sites, were delineated by assuming that the entire parcel containing the facility was treated. The resulting delineation was a variety of stormwater controls treating an area of approximately 110 acres within these individual parcels. In cases where the sites were very small, the facility type was not recorded, or the location of the facility was not clearly marked, no drainage areas were delineated. These included the privately-owned bioretention facilities.



Note: Drainage areas may be partial coverage or outdated treatment practices.

Figure 8: SWM Facilities and Drainage Areas

TABLE 6: SUMMARY OF STORMWATER TREATMENT PRACTICES IN THE WATERSHED

Stormwater Treatment Practice	Quantity / Quality	# of Private	# of Public	Total	Drainage Area (ac)
Bioretention for quality control	WQ	3	0	3	N/A
Filtration practice	WQ	12	0	12	8
Infiltration trench for quality only	WQ	7	1	8	29
Oil grit separator	WQ	1	17	18	N/A
Pond-quantity only	QN	6	7	13	403
Pond-wet quantity control	QN	0	1	1	222
Pond-wet w/ quality and extended detention	WQ-QN	1	1	2	58
Pond-wetland and extended detention	WQ-QN	0	1	1	351
Proprietary sediment separator	WQ	8	0	8	13
Sand filter / bioretention	WQ	1	0	1	N/A
Sand filter-quantity	QN	1	0	1	N/A
Sand filter-surface	WQ	13	1	14	16
Sand filter-underground	WQ	12	0	12	33
Stormceptor	WQ	5	0	5	N/A
Underground detention	QN	19	2	21	25
Underground detention sand filter surface	WQ-QN	2	0	2	N/A
Underground practice	QN	4	0	4	4
Unknown practice		9	2	11	N/A
Vegetated swale	WQ	1	0	1	1
Watershed Total		105	33	138	1165

2.9.2 1996 Cabin John Creek Watershed Management Plan

The City adopted its first watershed study for Cabin John Creek in 1996. It included an inventory of stream conditions using the Rapid Stream Assessment Technique (RSAT); a conceptual analysis of stormwater management retrofit sites; a list of stream restoration needs, fish passage barriers; and wetland and riparian reforestation opportunities. The City implemented many of the high priority projects recommended in this plan over the next ten years, as shown below.

TABLE 7: IMPLEMENTED PROJECTS FROM 1996 CABIN JOHN CREEK MANAGEMENT PLAN

Stormwater Management	Stream Restoration	Fish Passage Barrier Removal
Mt. Vernon wetland marsh pond	Elwood Smith Tributary – E. Lynfield Dr.	Wootton Pkwy. culverts on Middle Cabin John Creek and Dawson Farm Creek branches
Hungerford Swim Center wetland marsh	Bogley Branch – below ball field	Seven Locks Tributary – above Tower Oaks Development east of I-270
Villages at Tower Oaks wet pond		Bogley Branch – below ball field
Potomac Woods wetland marsh (combination of #1 and #2 in 1996 study)		Elwood Smith Tributary – Cabin John Pkwy culvert at E. Lynfield Dr.
Locks Pond Court dry pond retrofit		

3 WATERSHED CHARACTERISTICS

3.1 NATURAL RESOURCES

3.1.1 SOILS

Soil erosion and sedimentation play a major role in overall stream health. Although erosion is a natural process, human activities, such as construction and agriculture, can greatly increase the rate of erosion.

Sedimentation occurs when water carrying eroded soil particles slows enough to allow the particles to settle out and cover the channel bottom. Sedimentation can reduce storage volume in stormwater ponds and clog streams. Sediment can affect the physical, chemical, and biological water quality, and overall ecology of the receiving stream. Smaller particles, such as clays, can stay suspended in the water for very long periods, contributing to water turbidity or reduced clarity. Chronic suspended solids can also inhibit plant growth. Sedimentation can destroy fish spawning beds by smothering benthic invertebrates and submerged aquatic vegetation, which destroys essential foods and habitat for fish species. Additionally, sediment can carry organic matter such as animal wastes, nutrients, chemicals, and pesticides that may be toxic to aquatic plants and animals.

Soil erodibility is an estimate of a soil's ability to resist erosion, based on the physical characteristics of each soil type. Generally, soils with higher infiltration rates are less susceptible to erosion. Sand, sandy loam, and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils.

Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups (HSG) based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C, and D. A soils generally are sandy with high infiltration rates and have the least runoff potential. D soils have high clay content with low infiltration, so they generate the most runoff. Once impervious area is created, the underlying soils are blocked from infiltration (except for porous paving systems, which are designed to pass runoff through the paving into the soils underneath). Urban soil complex areas are soils disturbed during past development; these areas generally have low infiltration rates due to previous compaction and mass grading, regardless of their original soil type, and are thus classified as D soils.

In general, the soils in the watershed, shown in Figure 9, tend to be well drained in the upland areas and poorly drained along the stream corridors. The Rockville Pike corridor along the eastern edge of the watershed has extensive areas of urban soil complex where heavy commercial development has paved over the land, or stripped and compacted the soil during construction.

Along with the importance in determining runoff potential, understanding soil characteristics is also critical to managing stormwater. Some small-scale SWM facility designs, for example, are dependent on soil infiltration and need to be sited within A or B soil types.

3.1.2 CANOPY COVER

Urban tree canopy (UTC) is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Trees and forests reduce stormwater runoff by capturing and storing rainfall in the canopy, and releasing water into the atmosphere through evapotranspiration. In addition, tree roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil. This helps to replenish our groundwater supply and maintain streamflow during dry periods. Wooded floodplains also help to slow down and temporarily store runoff, further promoting infiltration and decreasing downstream erosion. Trees and forests reduce pollutants by taking up nutrients from soils and water through their roots, and by transforming pollutants into less harmful substances. (CWP/USFS, 2008)

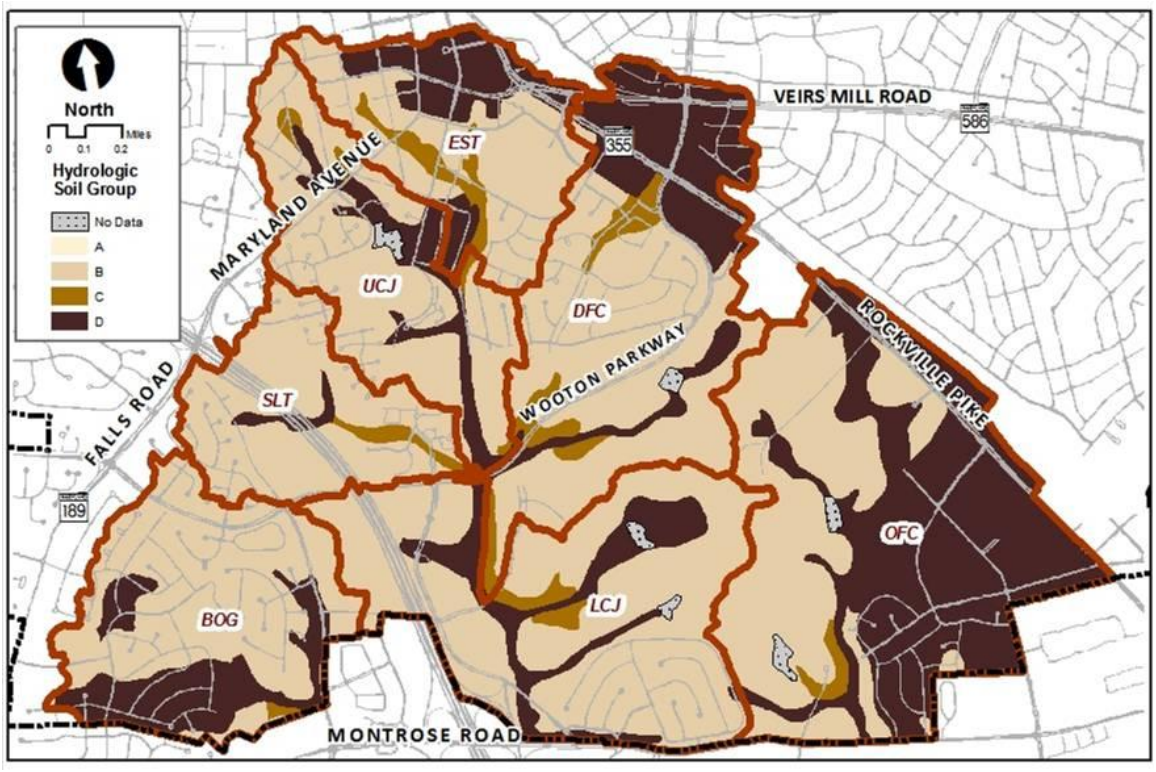


FIGURE 9: HYDROLOGIC SOIL GROUPS

UTC also reduces the urban heat island effect, reduces heating/cooling costs, lowers air temperatures, reduces air pollution, increases property values, provides aquatic and wildlife habitat, and provides aesthetic and community benefits.

The existing urban tree canopy (UTC) in the City was estimated based on aerial imagery to be approximately 3,744 acres or 44 percent of the City (MD DNR, 2009), shown in Figure 10. The City has the potential to increase UTC by an additional 3,177 acres or 37 percent of the City. The location of potential UTC in the City includes non-canopy vegetation, exposed soil, and some paved surfaces that could be modified to increase tree cover. American Forests recommends 40 percent cover for most metropolitan areas, and a number of communities have already adopted this as a goal. Across the United States, tree canopy cover currently falls below this standard, averaging 27 percent in urban areas and 33 percent in metropolitan areas (Dwyer and Nowak, 2000). Based on this, the City has high urban tree canopy coverage.

The highest percentage of possible UTC is on residential parcels. Right-of-ways are well-covered by UTC (37 percent) but room does exist to expand street tree plantings. Although data regarding the City portion of the Cabin John watershed is not called out specifically in the 2009 DNR report, the report does State that tree canopy in the three major sub-watersheds that fall within Rockville exceed 40 percent.

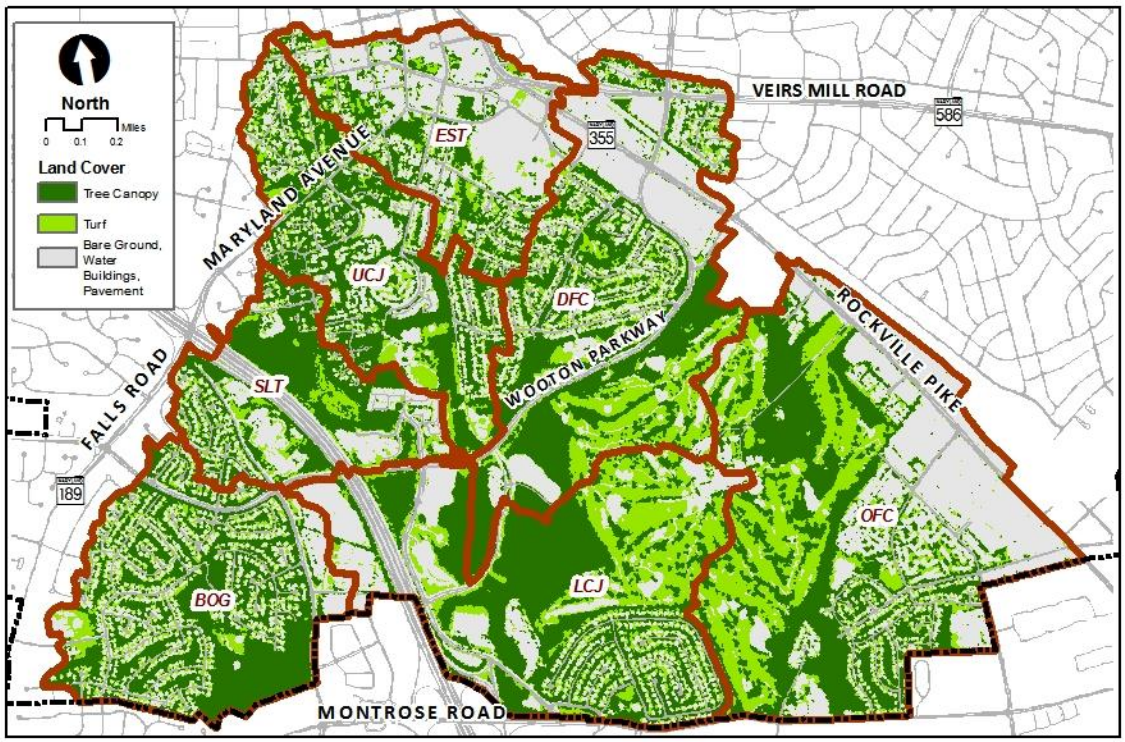


FIGURE 10: URBAN TREE CANOPY

3.1.3 WETLANDS

Protecting wetlands is critical to watershed health due to the important functions they provide including improving water quality by removing pollutants, minimizing flood damage by slowing and storing floodwaters, and providing habitat for birds and wildlife (Strommen et al., 2007). Wetlands function like sponges, storing runoff and releasing it slowly. This process slows the water's erosive potential, reduces flood heights, and allows for ground water recharge.

Only 44.4 acres (1.9 percent) of the watershed is comprised of wetlands according to the 1989 National Wetland Inventory (NWI). Low levels of wetlands are consistent with urbanized areas developed in the 1940s through the 1970s, before policies and regulations for wetland preservation became widespread. Of these wetlands, the dominant type consists of freshwater forested/shrub wetland (1.24 percent) located along the mainstem stream banks. Other types of wetlands consist of freshwater ponds and freshwater emergent wetlands, or wetlands characterized by erect, rooted, herbaceous plants (Table 7).

TABLE 7: WETLAND COVERAGE IN THE WATERSHED

Wetland Type	Acres	% of Watershed
Freshwater Emergent Wetland	0.6	0.03%
Freshwater Forested/Shrub Wetland	28.5	1.24%
Freshwater Pond	15.3	0.66%
Total	44.4	1.90%

3.2 WATER QUALITY

3.2.1 HISTORICAL WATER QUALITY MONITORING

From 1995 to 2008, a series of water quality monitoring activities were performed throughout the Cabin John Creek watershed, including portions outside the City. The monitoring events informed regulatory

activity including the Clean Water Act's impairment designation for several pollutants and resulting Total Maximum Daily Loads (TMDLs).

All of the data in this section was collected from sites located within Montgomery County, MD. Unless otherwise noted, the data represent conditions for the entire Cabin John Creek watershed, including those portions outside of the City.

Montgomery County Monitoring

Montgomery County Department of Environmental Protection (MCDEP) staff assessed biological conditions over time at a station just downstream of the City on the Cabin John Creek mainstem (CJCJ202) and a station on a Cabin John tributary downstream of the City (CJOF202). These sampling sites are shown in Figure 11. The procedures used were developed by MCDEP staff in 1995 with guidance by EPA and were based on EPA's Rapid Bioassessment Protocols. In 2001, Montgomery County revised its methods to directly compare to those of the Maryland Department of Natural Resources (MD DNR) Maryland Biological Stream Survey (MBSS).

In general these protocols are designed to rate the level of impairment of a stream, using stream habitat, fish, and benthic species as an indication of water quality and stream health. The technique is based on comparing habitat, water quality, and biological measures of a given stream with an expected State stream reference condition that would exist in the same type of stream in the absence of human disturbance. Investigators evaluate a given stream using a predetermined set of parameters and the stream is rated based on the parameter condition as compared to the reference stream. The stream is then given a rating ranging from optimal to good to fair to poor. Comparing these ratings over time helps identify stream impact trends and may help to evaluate the effectiveness of a stormwater program. The County's results at these two sites (Table 8 and
TABLE 9) rated stream habitat as generally in good condition, fish species as fair to good condition, and benthic diversity as poor condition. All MCDEP data for these sites are provided in Appendix D.

TABLE 8: MONITORING DATA STATION CJCJ202

Year	Habitat	Fish	Benthic
1996	Good	Good	Poor
2003	Good	Fair	Poor
2008	Good	Good	Poor

TABLE 9: MONITORING DATA STATION CJOF202

Year	Habitat	Fish	Benthic
1995	Good	Fair	No data
2003	No data	No data	No data
2008	No data	No data	No data

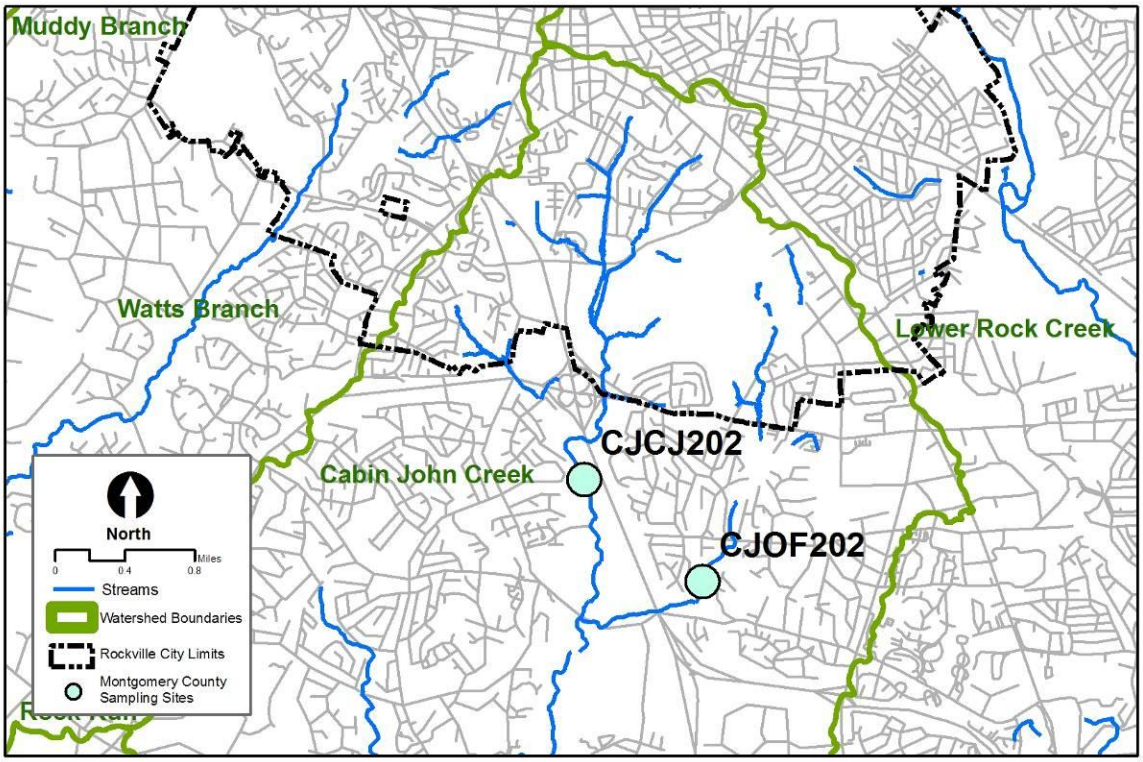


FIGURE 11: MONTGOMERY COUNTY SAMPLING SITES DOWNSTREAM OF ROCKVILLE

State of Maryland Monitoring

Maryland performed a series of monitoring events in order to fulfill Clean Water Act, Section 303(d) requirements. All states are required (under 303(d) of the Clean Water Act) to maintain and update a list of impaired and threatened waters (stream segments) and submit the list to the US EPA for approval every two years. This list is then used to develop total maximum daily loads (TMDLs), which is a detailed investigation into the causes and solutions for the impairment.

The State performed two data gathering efforts. Eight sites were sampled between 1995-1997 and again in 2000-2004. A biological stress identification (BSID) investigation was performed in 2009. All the stream miles in the Cabin John Creek watershed were determined to be degraded because the benthic and/or fish indices of biological impairment rated in the very poor to poor category.

The BSID (MDE, 2009a) analysis was conducted to determine the predominant cause of the degraded condition. Data suggest that biological communities in the Cabin John Creek watershed have been strongly influenced by urban land uses. These are degraded by altered hydrology, impaired aquatic habitat impaired by sedimentation and scour, and elevated levels of sulfates, chlorides and conductivity. These inorganic pollutants are found in 95 percent of the stream miles with very poor to poor biological conditions. The BSID analysis did not identify any nutrient stressors.

The BSID report recognized that stressors can act either independently or together in a variety of complex causal scenarios (e.g., eutrophication, urbanization, habitat modification). Also, uncertainties in the analysis can also occur from limitations in the data.

3.2.2 *Impaired Waters*

TMDLs must be undertaken for every stream listed as impaired on the 303(d) list of the Clean Water Act. As described in the Code for Maryland Regulations (COMAR) Surface Water Use Designation, Cabin John Creek is a Use I-P. Use I-P is defined as water contact recreation, protection of nontidal warmwater aquatic life, and public water supply, meaning that streams in the watershed should be able to support these identified uses. Since the impairments preclude meeting these designated uses, the State performed a thorough analysis of the sources of impairment and the creation of a restoration plan designed to allow the stream to achieve its designated uses.

In 1996, the Cabin John Creek watershed was identified as impaired by nutrients, suspended sediments, fecal bacteria and evidence of impacts to biological communities (MDE, 1996). In 2006, a TMDL for fecal bacteria was completed (MDE, 2006). In 2008, the 303(d) listing was refined: phosphorus was identified as the specific impairing pollutant. In 2010, the watershed also was listed as impaired for chlorides, sulfates, and total suspended solids (TSS) (MDE 2010). A TMDL for the TSS listing has been submitted by MDE and is awaiting EPA approval. Table 10 provides a summary of water quality impairments for the Cabin John Creek watershed.

TABLE 10: WATER QUALITY IMPAIRMENTS (MDE, 2009B AND MDE, 2010)

Year First Listed	Impairment	Listing	Designated Use
2010	Chlorides and Sulfates	303 (d) List[1]	Aquatic life and wildlife
2002	Fecal coliform	TMDL completed in 2008	Water contact sports
1996	TSS	303 (d) List [2]	Aquatic life and wildlife
Not Available	Total phosphorus and Dissolved Oxygen	N/A[3]	Aquatic life and wildlife

[1] This listing replaces the 1996 biological listing. The biological stress identification indicated that chlorides and sulfates are a major stressor affecting biological integrity in this watershed.

[2] A TMDL is expected to be developed in the next two years (2010-2012). A draft TMDL was submitted to EPA in September 2010.

[3] Categorized by MDE as attaining some standards but insufficient data exists to assess completely.

4 METHODOLOGY

4.1 SUB-WATERSHED ASSESSMENT

4.1.1 INTRODUCTION

The seven sub-watersheds in Cabin John Creek were individually assessed to develop a detailed understanding of the current condition. Four types of assessments were conducted, which are described in the following sections.

- Stream assessment on all perennial streams, to assess aquatic habitat, erosion and deposition, and water quality
- Water quality sampling at specific sites, to obtain laboratory tested results for pollutants, such as nutrients, bacteria, and sediment
- Geomorphic assessment at specific sites, to further assess stability, predict future changes, and develop general restoration approaches
- Upland reconnaissance, at a sample of neighborhoods and commercial areas, to assess pollution-producing activities in the watershed and help identify improvement measures

4.1.2 STREAM ASSESSMENT

The current condition of the streams in the Cabin John Creek watershed was assessed by field crews in March and April 2010. Field crews conducted stream assessments using the Center for Watershed Protection's Unified Stream Assessment (USA) methods (Center, 2004). The USA was developed as a method to rapidly evaluate conditions in urban streams by walking stream corridors, characterizing physical features, and identifying opportunities for restoration. Field crews evaluated ten miles of perennial stream channels. Sample data collection sheets are provided in Appendix E.

Information was collected digitally with subjective ratings for channel alteration, stream buffer condition, erosion, exposed utility pipes, outfalls and illicit discharges, fish barriers, construction activity, trash dumping, and any other unusual conditions. In addition, each stream reach was assessed for overall habitat condition. This assessment has been used to compare the relative stability of stream reaches and help to identify causes of poor stream habitat and water quality that may be improved through specific restoration actions. The consultants also conducted an Illicit Discharge Detection and Elimination (IDDE) assessment for outfalls adjacent to stream channels.

Habitat

Habitat is a measure of a stream's ability to support a healthy aquatic community. As such, it incorporates all aspects of a channel's physical and chemical characteristics. Physical habitat assessments evaluate conditions such as the width of baseflow compared to the entire channel, the size of material on the streambed (sand, gravel, cobble, etc,), presence and type of algae, water clarity, bank and bed erosion, and buffer vegetation. Habitat parameters are classified as optimal, suboptimal, marginal, or poor condition.

- Optimal: More than 70 percent of the reach consists of stable habitat suitable for aquatic insects and fish cover: there is a mix of snags, submerged logs, undercut banks, cobble or other stable materials. Stream banks are stable, 90 percent of the buffer consists of native vegetation. The stream is not entrenched and high flows can enter floodplain.
- Suboptimal: 40 percent to 70 percent of the reach consists of stable habitat conditions, described above. The remainder of the reach is adequate to support existing populations. 70 to

90 percent of the streambank surfaces are covered by native vegetation, some disruption is evident. There are isolated occurrences of bank failure.

- Marginal: The reach has from 20 percent to 40 percent stable habitat; channel bottom material is frequently disturbed by high flows, stream banks have patches of bare soil, past downcutting is evident and the stream is actively widening. The stream is deeply entrenched and flows cannot enter the floodplain.
- Poor: Less than 20 percent of the reach has stable habitat, channel bottom material is unsuitable for aquatic insects. Disruption of streambank vegetation is significant. The channel is actively downcutting and erosion is contributing a significant amount of sediment. The stream is deeply entrenched and flows cannot enter the floodplain.

Channel Dynamics

Stream erosion is part of natural channel migration, where streams meander, widen, and narrow in order to reach a stable equilibrium. Urbanization changes stream flows, increasing the amount of water and creating flashier flows. Changes such as this can cause a stream to be unstable, as it tries to adjust its banks to the change in flows. Channel dynamics, or changes in stream channels, are described by these five terms:

- Stable: the channel is in balance between erosion and deposition
- Aggrading: the streambed is raised up by deposits of sediment carried from upstream
- Bed erosion: the streambed erodes and the channel becomes deeper, or incised
- Bank erosion: the stream banks erode and the channel becomes wider
- Head cutting: bed erosion moves upstream at nick points (waterfalls)

4.1.3 Water Quality Sampling

Water Quality Standards

MDE has established water quality criteria that define impairment for several of the above parameters for each designated Stream Use Classification. These standards are listed in COMAR 26.08.02.01-.03 - Water Quality (COMAR, 2010). The Maryland COMAR criteria represent conditions of surface waters that are protective of aquatic life and recreational uses. The streams in the Cabin John Creek watershed are classified as Use I-P, with acceptable standards as follows:

- pH - 6.5 to 8.5
- DO - may not be less than 5 mg/l at any time
- Turbidity - maximum of 150 Nephelometric Turbidity Units (NTUs) and maximum monthly average of 50 NTU
- Temperature - maximum of 90°F (32°C) or ambient temperature of the surface water, whichever is greater

In order to compare in situ results to water quality standards, DO in situ readings in percent were converted to mg/L using tables available online from the USGS (USGS, 2010). The conversion was done assuming atmospheric pressure of 760 mm and fresh water, based on correction factors of less than 1 percent at the measured conductivity values.

There are no regulated criteria for nutrients (nitrogen and phosphorus) or TSS concentrations. There is no current standard for fecal coliform, as MDE has phased out its use as an indicator, substituting *Enterococci* and *E. coli*, but has not established new standards. The US Environmental Protection Agency (EPA) has developed nutrient guidelines for each of 14 ecoregions in the United States (EPA, 2000). The

Cabin John Creek watershed lies in Aggregate Ecoregion IX, the Southeastern Temperate Forested Plains and Hills. More specifically, it is part of the Level III Ecoregion 64: Northern Piedmont. Guidelines for nutrients have been taken from this source. Guidelines for TSS and fecal coliforms are determined from the sources noted in Table 11, below. The EPA guidelines represent levels measured in reference streams that should limit eutrophication—the adverse effects of algae growth and reduced DO that occur in water bodies with excess nutrient inputs.

While not providing criteria or guidelines, the University of Maryland Appalachian Laboratory published an analysis of Maryland Biological Stream Survey (MBSS) results for over 2,000 surveys across the State, focusing on correlations between water quality and biological health (Morgan et al., 2006). The analysis identified critical values for nutrients, conductivity, and chloride above which biological integrity was degraded. These critical values were similar to the EPA Ecoregion 64 levels. The critical value of conductivity for benthic macroinvertebrates has been included in Table 11 for purposes of comparison with data collected during this study. Other critical values are shown for reference.

TABLE 11: STATE AND FEDERAL WATER QUALITY GUIDELINES (EPA, 2000)

Parameter (mg/L, except as noted)	Level III Ecoregion 64	Other Source	Reference
TP	0.040	0.043	EPA Recommended Criteria (EPA 822-B-00-019) Morgan et al., 2006
TN	1.295	1.3	EPA Recommended Criteria (EPA 822-B-00-019) Morgan et al., 2006
TKN	0.3	--	EPA Recommended Criteria (EPA 822-B-00-019)
$NO_2 + NO_3$	0.995	0.865	EPA Recommended Criteria (EPA 822-B-00-019) Morgan et al., 2006
Turbidity *(NTU)*	2.825	--	EPA Recommended Criteria (EPA 822-B-00-019)
Conductivity		247	Morgan et al., 2006
pH		6.5 to 8.5	COMAR 26.08.02.01-.03 - Water Quality
DO		5.0	COMAR 26.08.02.01-.03 - Water Quality
TSS		500	1972 305(a) Report to Congress (EPA 440/9-74-001)
Fecal coliforms *(MPN/100ml)*		400	No longer listed in COMAR. previous standard for Fecal coliforms was applied to allow for comparisons

Sampling Protocols

Two types of water quality sampling, in situ and snapshot monitoring, were performed during the study. In situ sampling consisted of measurements taken directly in the stream on the sampling day with a handheld probe for a limited number of parameters. Snapshot monitoring consisted of a single "grab sample" of stream water taken from each site on specific dates and analyzed in a laboratory. Detailed results of the in-situ water quality and snapshot water quality results are discussed in the sub-watershed write-ups in Section 4.

In-Situ.

In-situ water quality sampling locations (Figure 12) were selected by the field crew leader and were generally located at the downstream end of each assessment reach and at each grab sample location. In-situ data was collected at the time of the stream assessment in March and April 2010, and again during the grab sampling in September 2010. A multi-probe meter (YSI, Inc.) was used to collect the parameters listed below at both the in-situ and grab sampling sites. These are commonly measured parameters that rarely exceed established water quality standards under typical urban runoff conditions. Dissolved oxygen or pH may spike outside of acceptable limits in cases of illicit dumping or

sanitary sewer overflows, and construction sediment or heavy rains eroding streams may cause high turbidity readings.

- Temperature (degrees Celsius, °C)
- Conductivity (microSiemans per centimeter, µS/cm)
- Dissolved Oxygen (DO, percent saturation)
- Turbidity (NTU)
- pH (standard pH units)

Snapshot Water Quality Sampling.

Snapshot sampling consisted of collecting water quality samples that were analyzed by a contract laboratory. Two rounds of sampling were conducted in April and September 2010. Sites were selected to characterize the sub-watershed conditions. Since monitoring is typically performed at the outlet of each sub-watershed, this required seven sampling locations in Cabin John Creek. In discussions with City staff, the grab sample at the outlet of Lower Cabin John was determined to be less valuable than adding an extra sampling station to Old Farm Creek, which had two different types of land use. This provided one sample to capture golf course streamflow, and one to capture baseflow from the major storm drain outfall draining much of the development along Rockville Pike. The outlet sampling station for Bogley Branch was located downstream of the City limits in order to capture flow from the Seven Locks Road storm drain collecting about one-quarter of the flow from the City's portion of the sub-watershed.

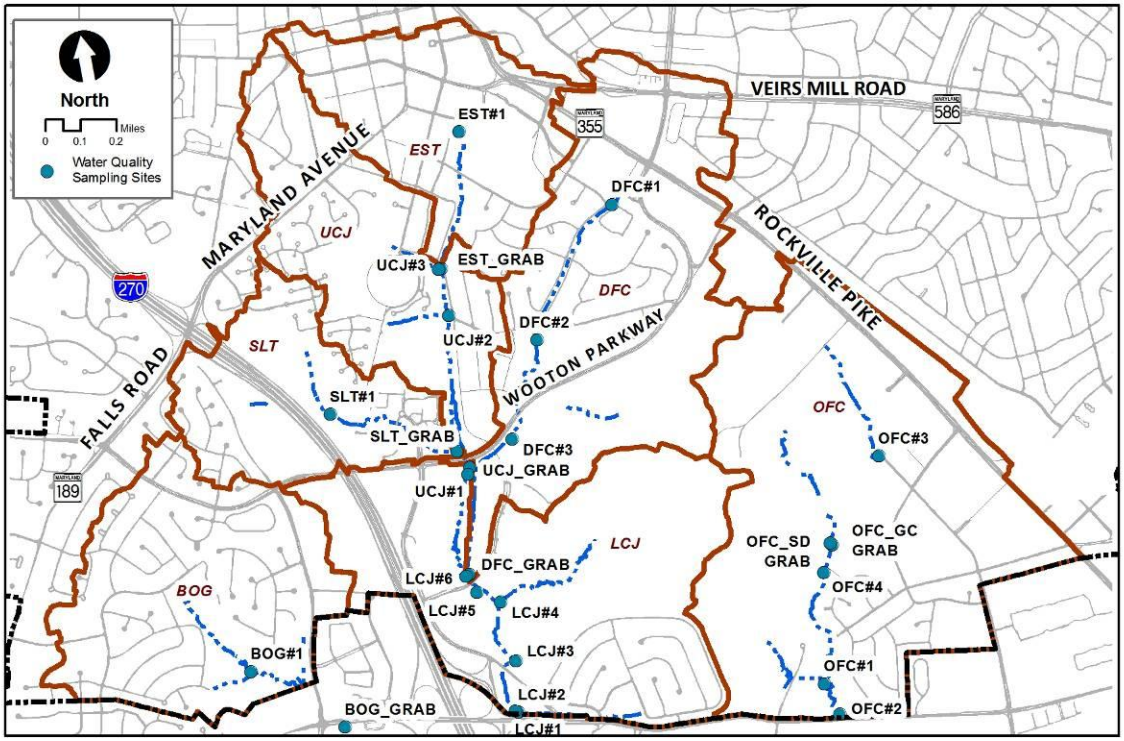


FIGURE 12: WATER QUALITY SAMPLING LOCATIONS

Grab samples were tested for both the in situ parameters listed above and the following ones, which are the focus of Chesapeake Bay restoration plans.

- Total Suspended Solids (TSS, mg/L)
- Total Phosphorus (TP, mg/L)
- Total Nitrogen (TN, mg/L)

- Total Kjeldahl Nitrogen (TKN, mg/L)
- Nitrate+Nitrite (mg/L)
- Fecal Coliforms (most probable number/100mL)

Based on National Airport rainfall records (US NCDC, 2011) antecedent rainfall for the September sampling was drier than the April sampling. In September, there were 17 days with no significant rainfall prior to sampling, whereas there was a measurable event 3 days earlier than the April sampling. Total precipitation for the 30 days prior to sampling was 1.99 inches for April and 2.73 inches for September. Both months were drier than the long term averages of 2.77 and 3.79 inches, respectively. Lower rainfall prior to the September sampling period led to lower baseflow for that sampling event. As a result, one station (Seven Locks Tributary) that had been sampled in April was reported dry and did not have a September grab sample. In general, the September grab samples appeared to have high concentrations for most parameters than the April samples, which are attributed to the lower flows and the same inputs of pollutants.

4.1.4 Geomorphic Assessments

Geomorphology is the study of how landforms change under processes associated with running water. Studies can be conducted at the large scale of mountain ranges and river systems, down to changes in the smallest headwater streams, such as those found in Rockville.

Geomorphic assessments of smaller urban streams are focused on determining their stability. During the USA stream assessment, geomorphology was described by visual observations of bed and bank erosion. For this more detailed assessment, physical measurements of channels were made in order to classify the streams by a method developed by Rosgen (1996). The classification system is useful for assessing stream condition, predicting future changes, and developing general restoration approaches. Figure 13 shows how a stream's shape can adjust based on changes in flows or sediment load. The E4 and C4 channels are stable, and represent a healthy stream type. The G4 channel is one where stream bed erosion is taking place and the stream is downcutting. When it is deeply incised, the banks collapse and the stream widens to an F4 channel, which continues to be unstable. The channel is reestablished well below the adjacent floodplain, causing continued channel erosion in large storm events. The watershed also suffers from the degradation of decades of bank erosion. Urban streams in the Piedmont area of Maryland typically are G or F class streams in the Rosgen system.

Geomorphic assessments were performed in April in six of the seven sub-watersheds. Physical measurements of the channel were surveyed including a cross-section, profile, and pebble count. The stream cross-sections, bed and bank material data and profile was analyzed using the Reference Reach Spreadsheet Version 4.3L developed and maintained by the Ohio Department of Natural Resources (ODNR, 2010) to determine a Rosgen Level II classification for each cross-section reach. Rosgen channel types are dependent on a combination of factors including entrenchment, width/depth ratio, planform and channel slope. The Level II assessment means that field measurements were used to determine the stream classification. Field data sheets are provided in Appendix F.

All the reaches assessed were classified as Rosgen type F4. This channel type is gravel dominated, entrenched, meandering, and deeply incised in gentle terrain. F-type channels are typical of streams, particularly in urbanized areas, where the flow regime has changed so that high flows become more frequent and the existing channel responds first by downcutting and then by widening. Since this type of channel is deeply incised, floodplain access is lost and stream bank erosion rates can be very high. F4 channels typically exhibit riffle/pool bed features and have high width/depth ratios. Central and transverse bars are common as well as depositional features such as point bars.

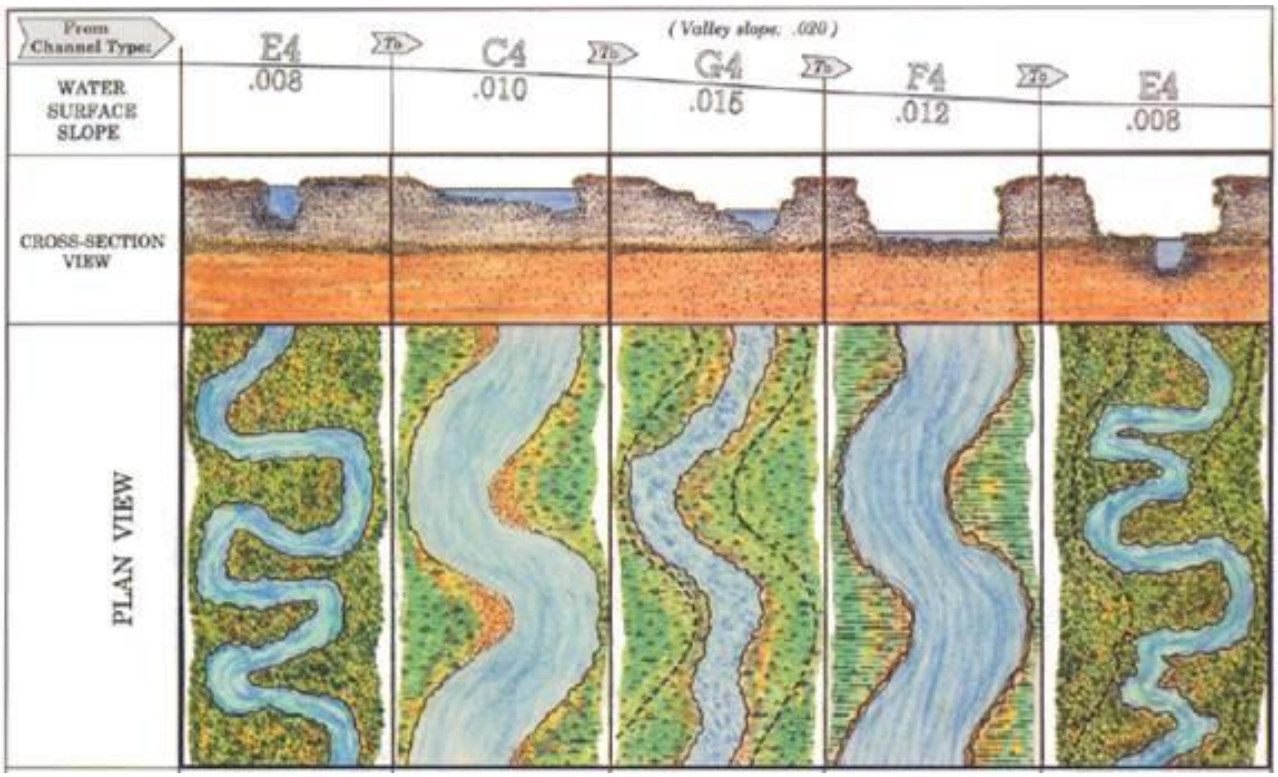


FIGURE 13: GEOMORPHIC CHANGE IN FIVE STAGES (ROSGEN, 1996)

4.1.5 UPLAND RECONNAISSANCE

Urban watershed restoration has traditionally focused on the stream corridor, with less attention paid to upland areas where neighborhoods and businesses are located. These upland areas, however, are important in watershed restoration, since they contribute storm water pollutants to the stream corridor. The Unified Sub-watershed and Site Reconnaissance (USSR) is designed to assess these upland areas for behaviors that can potentially influence water quality and to identify promising restoration project opportunities.

Two elements of the USSR were conducted in the field: the Hotspot Site Investigation and Neighborhood Source Assessment. Both evaluate pollution-producing behaviors and restoration potential in upland areas of the Cabin John Creek watershed. The USSR is a "windshield survey" where field crews drive streets in the watershed to determine specific pollution sources and identify areas outside the stream corridor where pollution prevention possibilities exist. The goal of the USSR is to quickly identify behaviors and sources that are contributing pollutants to the stream, and recommend methods to reduce these pollutant loads through actions like additional source controls, outreach to change current practices, or improved municipal maintenance operations. Keeping the pollutants out of the storm drains and streams is a much cheaper control strategy than treated polluted runoff in downstream stormwater facilities. Additional information on the USSR is found in Wright et al. (2005). Field data sheets and tables showing the results of this assessment are provided in Appendix G.

Hotspot Site Investigation Assessment

The Hotspot Site Investigation (HSI) is used to evaluate commercial, industrial, municipal and transport-related sites that have a high potential to contribute contaminated runoff to the storm drain system or directly to receiving waters. Potential pollutants that can be generated from hotspot sites include nutrients, pesticides, fuels, toxic chemicals, bacteria, road salt, trace metals, and sediments. Hotspots

may be regulated, that is, subject to State or Federal regulation, or unregulated. Common hotspot operations that may be found in a watershed include commercial laundry facilities, restaurants, swimming pools, public works yards, scrap yards, hospitals, golf courses, and schools.

At hotspot sites, field crews look specifically at vehicle operations, outdoor materials storage, waste management, building conditions, turf and landscaping, and stormwater/storm drain infrastructure to evaluate potential pollution sources. Based on observations at the site, field crews may recommend enforcement measures, follow-up inspections, illicit discharge investigations, retrofits, or pollution prevention planning and education.

The overall pollution prevention potential for each hotspot site is assessed based on observed sources of pollution and the potential of the site to generate pollutants that would likely enter the storm drain network. A hotspot designation criterion set forth in Wright et al. (2005) was used to determine the status of each site based on field crew observations. Sites are classified into four hotspot severity categories:

- Low – no observed pollutant; few to no potential sources
- Potential– no observed pollution; some potential sources present
- Confirmed– pollution observed; many potential sources
- Severe– multiple polluting activities directly observed

Neighborhood Source Assessment

Neighborhoods are an important focus for watershed restoration. Each residential neighborhood has a distinctive character, in terms of its age, lot size, tree cover, drainage, lawn size, general upkeep, and resident awareness. In addition, residents may copy their neighbors in lawn and garden practices, stewardship, and involvement in restoration efforts. These unique characteristics directly influence the ability to widely implement restoration practices, such as on-site retrofits, neighborhood source controls, and better stewardship.

The neighborhood is the fundamental unit for residential source control. Residential pollution sources can only be assessed neighborhood by neighborhood within a sub-watershed. The residential behaviors that contribute to storm water quality problems can be systematically assessed by the Neighborhood Source Assessment (NSA). The NSA was conducted in the watershed to evaluate pollution source areas, stewardship behaviors, and restoration opportunities within individual residential areas.

Neighborhoods were visually assessed in five general categories. Characterization involved age, lot size, and degree of infill or remodeling. Yard and lawn condition assessed landscaping types (lawn vs. mulched beds), tree cover, level of lawn maintenance and fertilizer usage, and general upkeep. A rating of 'high level of lawn maintenance' indicated use of fertilizer/weed control, frequent mowing to keep grass under 2", or evidence of watering, all of which have environmental impacts. Driveways, sidewalks, and street gutters were rated on condition, drainage, and presence of debris or litter. The assessment assumes closed-section streets (i.e., those with curb, gutter and storm drain inlets in the gutters) transport more pollutants than open-section streets that allow runoff to drain from the paved road into a grassed swale before entering the storm drain system. Rooftop downspout pipes were categorized as draining directly to storm drains, onto impervious areas such as driveways or patios, or were 'disconnected' by draining to vegetated areas that filter runoff before it enters the drainage system. Common areas and parking lots around townhouse or condominium communities were assessed for evidence of resident stewardship (i.e., storm drain stenciling, pet waste management signage, etc.).

Each site was assigned a pollution severity rating of "severe," "high," "moderate," or "low," using a set of benchmarks set forth in Wright et al. (2005). Pollution severity is an index of the amount of nonpoint

source pollution a neighborhood is likely generating based on easily observable features (i.e. lawn care practices, drainage patterns, oil stains, etc.). A restoration potential rating of high, moderate or low was also assigned to each neighborhood. Restoration potential is a measure of how feasible onsite retrofits, such as bioretention or swales, or behavior changes, such as installation of rain barrels or change in fertilizer use, would be based on space, number of opportunities, presence of a strong homeowner association (HOA), and similar factors.

Field crews assessed 15 potential hotspots and 32 residential neighborhoods within the Cabin John Creek watershed using USSR methods. Identification of potential or confirmed hotspots (HSI) and residential pollution-producing behaviors (NSA) was the primary focus of this effort. Results of the HSI/NSA assessments are presented in the sub-watershed write-ups.

4.2 WATER QUALITY IMPROVEMENT ASSESSMENTS

Rockville evaluates opportunities to improve water quality and reduce stream erosion. This evaluation occurs not only through the City's watershed studies done on roughly a ten-year cycle, but also in ongoing staff assessments as stream problems develop, watershed goals are refined, or other City projects are planned. This study assessed three types of potential improvements to watershed health: expansion or addition of stormwater management, restoration of streams or storm drain outfall channels, and non-structural programs focused on changing behaviors, landscape conditions, and property maintenance enforcement.

A wide variety of potential projects were identified using computer mapping, desktop analysis, and initial field survey information. Structural stormwater and stream projects determined to be feasible and effective were carried forward to concept design that included a sketch of the proposed improvement, the project pros and cons, construction issues, and a rough cost estimate. The concept plans for these projects are included in Appendix A. After additional field visits and discussions, a final list of recommended projects was developed.

Potential non-structural program changes were proposed based on the recommendations and data collection during the upland reconnaissance and field assessment. Non-structural programs do not involve engineering design and construction.

It is very important that stormwater management and stream restoration designs are developed as close to construction of the project as possible. Changing national and state standards, advancement in techniques, and changing watershed conditions often lead to design modifications between early concepts and final design. Some projects recommended in this plan may take ten years to implement. For these reasons, the recommended projects have been described very conceptually. Each project will be individually considered through the City's CIP process, and the concept refined as needed. As each project begins its final design phase, the City will conduct community involvement and outreach to inform residents of any proposed changes, and will gather more detailed site information.

4.2.1 STORMWATER MANAGEMENT PROJECTS

Stormwater management projects that either upgrade outdated stormwater treatment facilities or install new facilities are called retrofits.

This study evaluated potential stormwater structural improvements using the following process:

1. A desktop assessment of available mapping data to identify 72 potential candidate sites
2. Review of candidates to select most promising sites for concept evaluation

3. Field assessment to evaluate site constraints and choose an appropriate SWM improvement technique for the site
4. Concept preparation to assess design feasibility and site constraints
5. Staff field visits with the completed concepts to review the recommendations and assess any cost-effective alternatives

Desktop Assessment

The desktop assessment analyzed GIS mapping for topography, streams, storm drainage, known utilities, parcel ownership, and aerial photography to find feasible locations to intercept and treat runoff. Pond retrofits included adding storage volume, converting dry ponds to wet ponds, revising outlet characteristics to trade quantity storage for water quality, or adding internal design features to increase pollutant removal. Parking lot and street retrofits include a mix of treatment alternatives for water quality treatment, such as pervious paving, bioretention, sand filters, or swales. Sites included islands, medians, or perimeter areas, as well as reducing paving width in cul-de-sacs or wider residential streets.

Selection for Concept Evaluation

The possible SWM improvements identified in the desktop assessment were screened using the following decision-making criteria. The inventory of 72 stormwater candidate projects was reduced to 11 sites suitable for field assessment as future City SWM retrofit projects. Projects dropped from further investigation included:

- Pond and other SWM sites determined to be infeasible due to limited space, poor access or other technical issues;
- ESD or other onsite SWM sites on privately-owned land, including County government or public school property, that have the potential to be installed through commercial redevelopment. The City's SWM budget presumes that SWM opportunities on privately owned land will occur primarily through SWM redevelopment regulations rather than public funding;
- ESD retrofits for City streets or parking lots were deferred due to the current high cost of ESD construction and maintenance per treated impervious acre. These projects may become viable as DPW gains more ESD experience and other traditional SWM opportunities are exhausted. ESD measures may also be implemented to meet SWM requirements for other City projects, such as sidewalk and alley improvements which create relatively small impervious areas suitable to ESD;
- All suggested improvements within or directly serving drainage from the private property of Woodmont Country Club were also dropped from implementation by the City. The City will continue to work with the Country Club to update onsite ponds to meet current SWM standards through the City's stormwater ordinance (City Code Chapter 19) and regulations that govern SWM requirements for redevelopment. The City will also explore using the Water Quality Ordinance to enhance treatment opportunities and reduce pollutant export from the Country Club; and
- Storm drain outfall sites were moved from the stormwater retrofit list to the stream restoration list to utilize in-channel filtration/stabilization techniques. Storm drain outfalls typically are in or adjacent to stream channels and wetlands, where traditional SWM facilities cause greater disturbance to natural resources. Permitting is often difficult in these cases. In-channel methods have smaller footprints that can be adjusted to better fit the site constraints.

Field Assessment

The eleven candidate sites for SWM retrofits were visited to visually assess the existing embankment, riser, and adjacent and downstream areas, and consider available treatment options. Opportunities were considered for enlarging facilities by adding volume through excavation or raising the embankment height, if needed.

Potential constraints were noted for all sites, including the following information:

Adjacent land use: Impacts to adjacent land owners are variable but depend to a large extent on how successfully the stormwater system fits the site. Considerations include aesthetic features and landscaping, safety issues in residential areas, or loss of parking area in commercial areas.

Construction access: The ability to move construction equipment to the site and to perform the work safely once there is an important consideration. Access constraints include physical factors such as steep slopes and soft ground which could cause difficulty bringing in construction equipment and supplies.

Utility conflicts: Utilities may preclude or complicate construction if located on or adjacent to the site. In many cases, they can be relocated as part of the project, but at an additional cost. In addition to checking the GIS utility layers for known underground utilities at or near a proposed project, evidence of existing utilities at the project site was noted, such as fire hydrants, sewer manholes, cable, power, and telephone connections, and gas pipeline markers.

Permitting factors: The sites and access paths were assessed for potential difficulties with U.S. Army Corps of Engineers or Maryland Department of the Environment wetland or waterway construction permitting. All City construction projects also are subject to the City's Forest Preservation Ordinance requirements. If work would be required on an existing pond embankment, the potential for a dam safety permit was noted, regardless of the pond size, dam condition, or recommended retrofit technique.

Concept Design

SWM design steps began with delineating the drainage area to the sites and hydrologic computations to develop proposed treatment storage volume, which provided a target for the retrofit concept design. Calculations of water quality volume (WQv) and channel protection volume (CPv) were made according to the guidelines in the 2000 Maryland Stormwater Manual.

For pond retrofits, the design process itself was an iterative approach of working with existing grading, taken from topographic mapping, and outflow parameters to develop the best design to accomplish the retrofit goals. If site constraints prevent achieving 100 percent of water quality treatment for a retrofit, the amount of WQv treatment that can be provided is indicated.

The resulting concept plan includes a rough cost estimate based on Rockville Department of Public Works' Standard Prices for Cost Estimating-2010, and discussions of constraints, benefits and construction issues.

The final SWM projects, which are presented for each concept in the Sub-watershed Plans section, took into consideration forestry and park impacts, community use, and watershed goals and practicality.

4.2.2 STREAM RESTORATION

Potential stream or storm drain outfall improvements were evaluated using a slightly different process from the SWM evaluation:

1. Field assessment during the initial stream walks to document problems

2. A desktop assessment to identify high-priority stream reach or storm drain outfall sites for restoration and stabilization
3. Selection of sites for concept evaluation
4. Concept preparation to identify extent, method and level of restoration
5. Site visits to confirm priority and extent of recommended restoration

Field Assessment

Field assessment of stream stability issues, site constraints and feasibility was done as part of the initial stream assessment walks in the early part of the study.

Desktop Assessment

The desktop assessment for stream restoration sites consisted of a review of the field data and photos from the stream assessment, with particular emphasis on notes regarding improvements. Twenty stream reaches or storm drain outfall sites were identified.

Selection for Concept Evaluation

Projects were evaluated based on the erosion severity, public ownership of the site, and potential for restoration. Sites were assigned to two project types, Stream Stabilization/Restoration or Regenerative Stream Conveyance, based on the drainage area, size of channel, and number of storm drain outfalls entering the reach.

Stream Stabilization/Restoration: General stream restoration projects involved reconstruction of the stream channel (channel re-alignment, spot stabilization, or armoring), and could also include related storm drain outfall repairs. Sites included channels with large drainage area (>60 acres) undergoing active bed or bank erosion, active headcuts, sites where earlier armoring such as gabion baskets or rip-rap appeared to be failing, and eroded or failing isolated storm drain outfalls.

Regenerative Stream Conveyance: Stabilization projects at or below some storm drain outfalls were conceptually designed as Regenerative Stream Conveyance (RSC), a relatively new technique first developed for Anne Arundel County, Maryland. RSC stabilizes an eroded or downcut channel and also filters the channel's storm flows through layers of carefully placed sand, woodchips, rocks and boulders. The technique is expected to advance in the next years and may become approved by the State as a stormwater management treatment system. These sites included smaller stream channels with 1-3 storm drain outfalls and less than 60 acres drainage area that were identified as eroding during the field assessment.

One site (R-66S) needed limited storm drain spot repairs that did not warrant a concept design, but the work will be included in future CIP projects. Several other sites (R-75S, R77S) were not considered for concept design because they are on private property, and the City's stormwater program does not support spending public funds on private stream restoration at this time.

Concept Design

Concepts for stream restoration consisted of a description of the problems found during the assessment and proposed improvements for stabilizing or restoring the stream. Improvements included items such as debris removal, regrading, hard armoring such as stone toe protection and imbricated rip rap, natural channel restoration, outfall reconstruction, and buffer restoration. Rough quantities were estimated for inclusion in the project cost estimate, and unit costs were applied based on Rockville Department of Public Works' Standard Prices for Cost Estimating-2010.

Concept designs for RSC projects focused on designing the riffle-pool sequence based on existing channel slopes and channel dimensions. Since a sand filter is an integral part of the RSC approach, hydrologic computations and calculations of water quality volume (WQv) were made similarly to those described for SWM design. The design provided an estimate of the overall length of RSC channel to be constructed, which was used along with an average cost per linear foot (LF) to develop the cost estimate.

Eleven stream/storm drain outfall concepts were prepared, and are included in Appendix A. These were further evaluated after additional field visits, and final City recommendations are presented in the Sub-watershed Plans section.

4.2.3 Non-Structural Measures

Recommendations for non-structural measures for the general community were based on the NSA reconnaissance findings. The NSA evaluation chart shown in Table 12 lists behaviors with watershed impacts and action thresholds. Where the surveyed neighborhood met the specified action level, the consultant team recommended the targeted outreach, enforcement, or education activity to improve watershed stewardship. For example, when Item B5 showed that on average, less than 40 percent of the lot area in a neighborhood was covered with tree canopy, the NSA toolkit recommends working with property owners to plant more trees. The NSA assessment team also could add comments about particular measures they felt would be appropriate at each site.

Most of these non-structural measures could be carried out City-wide, rather than on a watershed-specific basis. The recommendations in the plan represent a smaller group of measures that were frequently identified for the assessed Cabin John Creek neighborhoods.

TABLE 12: POTENTIAL NON-STRUCTURAL MEASURES

NSA Item	Observation	Threshold	Recommendation
A3	% of infill and redevelopment	> 5%	E/SC inspection/enforcement
B3	% of lot with mulched beds or landscaping	< 25%	Landscape outreach to improve infiltration, evapotranspiration
B5	% of lot with forest canopy	< 40%	Tree planting
B7	% of neighborhood with high maintenance lawns	> 20%	Lawn care outreach
B8	% of lots with swimming pools	> 10%	Outreach for pool cleaning/discharging
B9	% of lots with junk or trash in yards	> 25%	Solid waste enforcement
C3	% of sidewalks with pet waste	> 25%	Pet waste outreach
C4	Curb and gutter - trash, litter, debris, leaves	> 20%	Street sweeping
D1	Downspouts directly connected to storm drains	> 25%	Downspout disconnection or rain barrels
D5	Lawn area down gradient of downspout	> 25%	Rain garden
E1	Storm drain inlets marked or stenciled	< 10%	Storm drain marking
E3	Common open space - pet waste observed	> 25%	Pet waste outreach
E3	Common open space - trash / litter / dumping	> 25%	Volunteer cleanup, enforcement

5 FINDINGS AND RECOMMENDATIONS

The findings and recommendations are divided into several sections. First is a brief discussion of common issues found throughout the watershed and general recommended actions. Next, the seven sub-watersheds are discussed in detail. Each sub-watershed section is organized as follows:

- Land use and impervious area description
- Existing SWM facilities
- Stream assessment, including water quality sampling results
- HIS and NSA assessments
- Summary of sub-watershed issues and goals
- Table of candidate sites for SWM and stream improvements
- Concept descriptions and recommendations for SWM and stream improvements

Finally, a status summary is given for unbuilt SWM projects that were recommended in the 1996 Cabin John Creek Watershed Management Plan. The summary table describes the original project proposal, and the re-assessment and new final recommendation for each site.

5.1 GENERAL WATERSHED FINDINGS AND RECOMMENDATIONS

In general, conditions in the City's Cabin John Creek are typical of urbanized watersheds. The streams continue to show evidence of impairment from extensive upland development and numerous pollution sources. Numerous SWM retrofits and stream restoration projects recommended in the 1996 Cabin John Creek Watershed Management Plan were implemented in the past 15 years, and they have improved the affected stream reaches. The stream stabilization projects have checked bank erosion in those reaches, and the SWM facilities continually trap large amounts of trash and sediment. However, a large part of the watershed is not managed by these projects and continues to degrade the downstream water quality.

5.1.1 HOTSPOT INVENTORY - GENERAL FINDINGS

Many HSI assessments across the sub-watersheds noted problems with uncovered or overflowing dumpsters, especially on the commercial sites with food establishments. The City's Code Enforcement Division has been informed of this and will increase enforcement of the City's Property Code regulations concerning dumpster maintenance, especially along the Rockville Pike corridor where multiple infractions were found.

Site-specific concerns about possible illicit discharges found during the field work were investigated by City staff in 2010. Enforcement action was taken at two sites and the owners complied with directions to eliminate illicit connections or dumping into storm drains.

General pollution problems exist at the Seven Locks Maintenance Yard for the County's Department of Transportation's Division of Highway Services. This site drains into the Bogley Branch and Lower Cabin John Creek sub-watersheds. The City should coordinate with County DOT to ensure that the County fulfills best management practices as required in its NPDES Industrial Discharge permit for the site, and provides any needed site maintenance to reduce sediment loads. The City also maintains the public Locks Pond SWM pond, which receives storm drain runoff from the front part of the County maintenance yard. The County's facility manager should be instructed to contact City Department of Public Works in the event of a spill or sediment discharge from this site since it may be at least partially contained in the City's Locks Pond Court SWM pond or Tower Oaks Wetland Marsh Pond.

The Woodmont Country Club also contributed to erosion, sedimentation and eutrophication problems in the several sub-watersheds it drains into (Dawson Farm Creek, Lower Cabin John, and Old Farm Creek). Currently, the Country Club has limited need for redevelopment permits that would trigger the City's stormwater management requirements. As the City further defines its obligations to manage nonpoint source runoff under its NPDES MS4 permit, the City and the Country Club will need to discuss feasible site management improvements that reduce nutrient and sediment loads. The City's Water Quality Ordinance may be helpful in framing this discussion.

5.1.2 Water Quality sampling results

The two events of stream snapshot monitoring and in-situ sampling were not enough to indicate trends for water quality problems or causes. Since sampling was done outside of rain events, the data cannot be correlated to typical urban runoff effects. Indeed, unusual spikes at given locations, such as the September sampling date turbidity readings at BOG #1 and BOG-GRAB locations, may be due to an illicit discharge from a contractor or property owner in the drainage area. These discharges are difficult to track down and to prevent. The City may wish to consider a more comprehensive monitoring program for parameters of concern as NPDES permit requirements focus more heavily on meeting TMDLs. If patterns of repeat offences can be identified, the City can better focus its enforcement efforts.

Bacterial counts were very high on the September grab sampling date. Based on the locations across the watersheds, there is no detectable land use pattern or stream dynamic to explain these readings, other than high water temperature which can lead to high bacteria counts. Possible explanations include leaking sanitary sewers or sewer overflows (which City records ruled out as a cause), high loads of either pet waste or urban wildlife scat, or an illicit discharge source such as a septic cleaning truck. Further sampling is needed before considering any action on bacteria controls.

5.1.3 ESD Recommendations for City Projects

ESD opportunities were identified in nearly every sub-watershed. As of 2010, ESD is required by State and City law as the first choice for SWM treatment, so both City and private projects that trigger SWM regulations will have to explore ESD measures. Therefore, the Cabin John Creek plan assumes that some of the suggested ESD on private property will occur in the course of redevelopment.

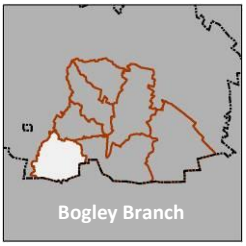
The City is in the early stages of approving and inspecting ESD measures. Before the City proceeds with numerous ESD projects, it is desirable to gain more experience with technical specifications, maintenance needs, and retrofitting the features into an existing streetscape and storm drainage system. Currently, ESD costs per treated impervious acre are quite high compared to traditional SWM methods, so the City will need to consider how to fund ESD construction and maintenance in its overall retrofit strategy. Many of the public ESD candidate sites identified in this study were for City streets or cul-de-sacs. The City will explore partnering pilot ESD projects with sidewalk or other localized City improvements that might fit the micro-drainage scale of ESD.

5.1.4 Non-Native Invasive Vegetation Control

Non-native invasive vegetation was found throughout the stream valleys across the watershed. These plants tend to out-compete native species, displacing the normal herbaceous plants and shrubs found in natural areas. The non-native plants harm the ecosystem's biodiversity by blocking native species from the ecosystem; these invasive plants often form a mono-culture. The invasives are also foreign to birds and animals, so they do not provide good food or shelter sources for wildlife. The City has a limited budget through the Department of Recreation and Parks to address elimination of invasive species. However, the City has not yet established a process to systematically eliminate a given invasive species, nor set priorities on which species or locations to first focus on. Although the City partners invasive

plant control with other projects (for instance, requiring SWM retrofit or stream restoration projects to remove and control invasive plants within the project's limits of disturbance for a five-year period), this is too sporadic and spread out to succeed in eliminating any specific species. The City would benefit from employing more systematic decision-making against at least one or two non-native invasive plant species.

5.2 BOGLEY BRANCH



Bogley Branch flows south from Stratton Drive through Potomac Woods Park into Montgomery County, north of Montrose Road. The sub-watershed consists primarily of the residential community of Potomac Woods, with small commercial and institutional areas on the eastern edge. The original headwaters of Bogley Branch are piped upstream of Lancaster/Stratton Drive. The upstream portion of the main channel flows adjacent to a residential street and homes, but the majority of the channel is well-buffered by forested park land in Potomac Woods Park.

5.2.1 LAND USE AND IMPERVIOUS AREA

Bogley Branch sub-watershed is 287 acres with 53 percent of the area made up of medium-density residential development, 21 percent transportation (roadways primarily associated with residential communities) and 14 percent forested. Total impervious cover is 30 percent, with 10 percent of the total impervious area used for transportation. Wootton Parkway bisects the extreme northern portion of the sub-watershed and Seven Locks Road runs along the eastern edge where the sub-watershed's only industrial area is also located. This is the only sub-watershed in the Cabin John watershed without a substantial commercial area. A summary of the land use and imperviousness within the Bogley Branch sub-watershed is provided in Table 13.

TABLE 13: BOGLEY BRANCH LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Turf in Open Space	14	5%	1	7%	0%
Forest	42	15%	0	0%	0%
Managed Turf on Golf Course	0	0%	0	0%	0%
Water	0	0%	0	0%	0%
SUBTOTAL OPEN SPACE	**55**	**19%**	**2**	**4%**	**1%**
Medium-Density Residential	152	53%	42	28%	15%
High-Density Residential	0	0%	0	0%	0%
Multi-Family Residential	0	0%	0	0%	0%
SUBTOTAL RESIDENTIAL	**152**	**53%**	**42**	**28%**	**15%**
Institutional	7	2%	4	57%	1%
Commercial	0	0%	0	0%	0%
Industrial	13	5%	9	69%	3%
Transportation	59	21%	30	51%	10%
TOTAL	**287**	**100%**	**87**	**30%**	**30%**

5.2.2 *Existing Stormwater Management Facilities*

There are three public and eight private stormwater management facilities on record in the Bogley Branch sub-watershed (see Table 14). Public facilities include one older dry pond, Arlive Court, and two wet ponds, Locks Pond Court and Potomac Woods, both retrofitted in the late 1990s to provide partial water quality and quantity control. These facilities currently treat 56 acres of impervious cover, or about 65 percent of the impervious area in Bogley Branch. The wet ponds are undersized by current standards because of limited space.

TABLE 14: BOGLEY BRANCH STORMWATER MANAGEMENT FACILITIES

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Public			
Dry Pond, Quantity Control Only	1	19	6
Wet Pond, Quality and Quantity Control	2	124	32
Total Public	**3**	**138**	**36**
Private			
Dry Pond, Quality Control Only	1	N/A	N/A
Sand Filter	1	N/A	N/A
Stormceptor	2	N/A	N/A
Underground Detention	1	N/A	N/A
Underground Detention/Sand Filter	2	N/A	N/A
Unknown	1	N/A	N/A
Total Private	**8**	**N/A**	**N/A**

5.2.3 *Stream Assessment*

1994 Conditions

Major stream problems during the 1994 assessment (MWCOG, 1994) included severe channel erosion in the lower third of the stream, high riffle embeddedness, moderate to high sand-silt bedload and high levels of channel widening. The macroinvertebrate community had fair diversity and poor fish diversity with only two fish species observed, blacknose dace and northern creek chub. The culvert at Seven Locks Road and Montrose Road posed a barrier to upstream fish migration.

2010 Conditions

The mainstem of Bogley Branch was broken up into three unique assessment reaches based on habitat conditions (Reaches 001, 004, and 006). There are also three tributaries draining into the mainstem of Bogley Branch (Reaches 002, 003 and 005). Detailed reach write-ups are included in Appendix H.

FIGURE 14: RIP-RAP ARMORING (REACH BOG-004)

Generally, the streams in the mainstem of the Bogley Branch sub-watershed are degraded with moderate to severe erosion occurring along outer meanders. There are many areas where outer meanders have been patched with imbricated rip-rap walls. These areas (reaches BOG-004 to BOG-001) were stabilized by the City in 1998. Reaches where the armoring is in good condition are experiencing less erosion than those areas where meanders haven't been armored or where the armoring is beginning to fail. Habitat conditions along the mainstem reaches are in the high-marginal to low-suboptimal range with riffles and pools as the dominant habitat available, however, there are several areas where fish passage is not possible (specifically along Reach 006) due to weirs and culverts.

Tributaries draining to the mainstem reaches are generally stable with the exception of Reach 005 which is experiencing severe erosion and active headcutting along the entire reach. Low flow, shallow depth and poor habitat make the tributary reaches unsuitable as fish habitat.

FIGURE 15: SEVERE BANK EROSION (REACH BOG-005)

Geomorphic Assessment.

The geomorphic assessment was performed on Reach 001 in the Bogley Branch sub-watershed just upstream of the City limits above Seven Locks Road. This reach is in transition from a C4 channel type at the downstream end to an F4 channel type at the upstream end. The C4 type is characterized as more stable with lower gradient and having good floodplain access.

Floodplain access was noted at the start of the assessed reach. Moderate to severe erosion was noted on outside meanders and large gravel dominated point bars were prevalent on inside meanders. One rock vane and one imbricated stone wall were noted at the most upstream portion of the assessed reach; however, no other stream restoration, stabilization, or bank armoring was present.

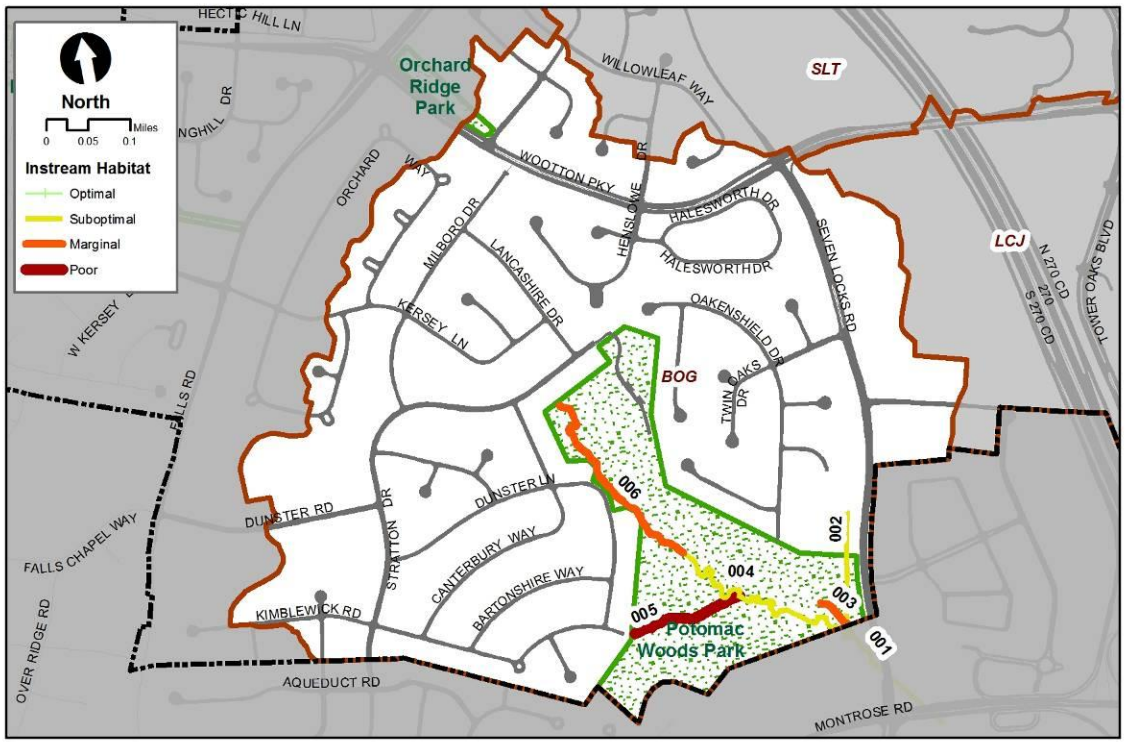


FIGURE 16: BOGLEY BRANCH HABITAT ASSESSMENT

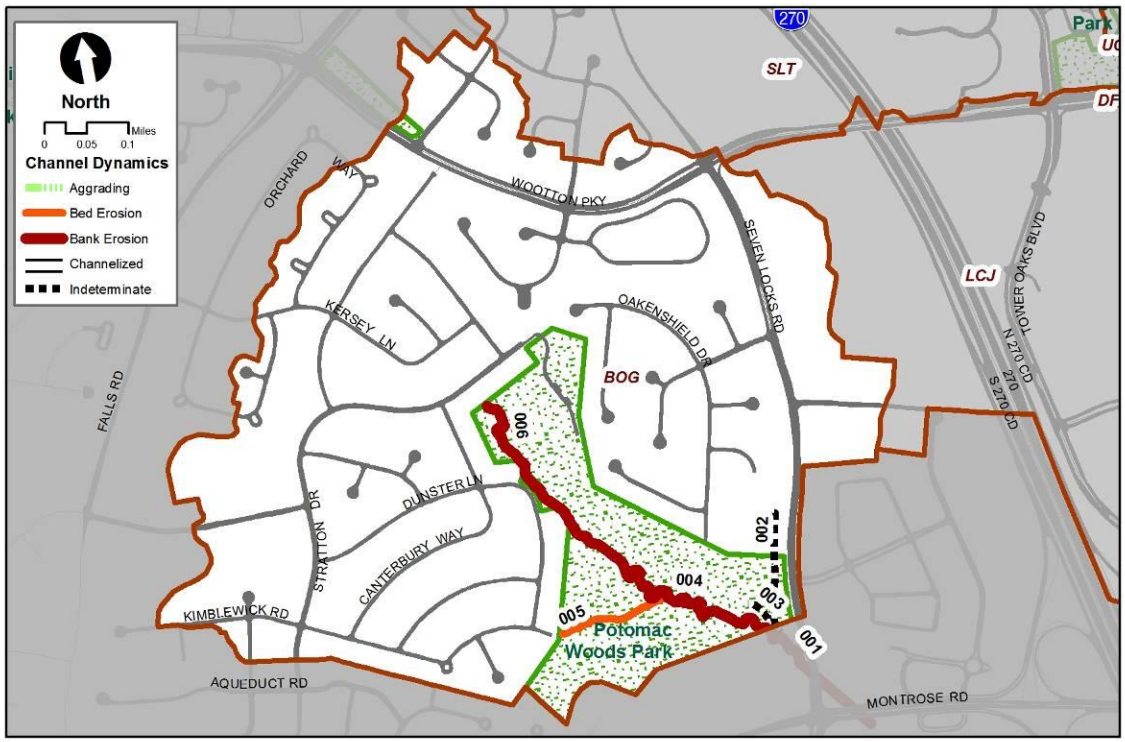


FIGURE 17: BOGLEY BRANCH CHANNEL DYNAMICS ASSESSMENT

Water Quality.

For the Spring sampling, In-situ and water quality grab samples taken in the Bogley Branch sub-watershed did not indicate any parameters outside of COMAR standards. Nutrient levels were within the EPA acceptable range with the exception of nitrite-nitrate; however conductivity was higher than the reference level for both samples. Summer sampling showed high levels of turbidity and conductivity at both sites, with fecal coliform counts over 24,000. Conductivity levels are higher for this sample because during the lower baseflow conditions the dissolved solids were more concentrated. It is not clear why bacteria counts are high, as there are many variables. High flows of urban runoff, low flows inducing high temperatures, and increased wildlife could all be a factor. Results of water quality measurements are shown in Table 15. Values higher than the reference range are shown in bold.

TABLE 15: BOGLEY BRANCH WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
Reference			247	5.0	2.825	6.5-8.5	500	0.04	1.295	0.3	0.995	400
BOG#1	Apr-10	16.3	311.6	**0.01**	1.33	7.7	---	---	---	---	---	---
BOG#1	Sep-10	18.9	**261.3**	6.2	**50.50**	7.67	---	---	---	---	---	---
BOG GRAB	Apr-10	16.1	**324.2**	8.7	1.83	8.3	<1	0.02	1.1	<0.5	**1.10**	<3
BOG GRAB	Sep-10	18.1	**339.1**	8.6	**5.47**	7.87	19	**0.13**	0.83	<0.5	0.83	**>= 24000**

5.2.4 HSI / NSA Assessment

One hotspot site and five neighborhoods were assessed in Bogley Branch, with a portion of a sixth neighborhood which will be discussed in the section on the Seven Locks Tributary.

The single hotspot site (H-102) assessed under Bogley Branch sub-watershed was a commercial area with several restaurants, a shopping center, and a fitness center, which was rated as low severity. No vehicle maintenance or outdoor material storage activities were identified. Waste management was the primary source of potential pollutants. Dumpster lids were open at the site and dumpsters were overflowing (Figure 18); however, the overall site was related low severity. The back part of this commercial area is in the Lower Cabin John sub-watershed.

Another hotspot site, the Seven Locks Maintenance Yard for the Highway Services Division of the Montgomery County Department of Transportation, also drains to both Bogley Branch and Lower Cabin John sub-watersheds. Its HSI assessment is included under the Lower Cabin John section. The maintenance yard was a confirmed hotspot for leaking vehicles, overflowing dumpsters and poor parking lot condition.

FIGURE 18: OVERFLOWING DUMPSTERS (H-102)

The five neighborhoods surveyed in Bogley Branch all consisted of single-family detached structures on 1/4 to 1/3 acre lots, classified as medium-density residential land use. They were well established areas constructed primarily in the 1960s, 1970s, and 1980s. Very little infill or redevelopment was observed. Lawns in all the NSAs were characterized as having medium- or high-maintenance, indicating higher rates of fertilizer or pesticide use that can impact stream quality. Downspouts were 80 percent disconnected (i.e., discharging onto vegetated areas instead of paving) in the two newer neighborhoods, and 35 – 50 percent disconnected in the three older areas. Some roof drainage was connected directly or indirectly to the storm drain system. Parking lot and street stormwater is conveyed through curb and gutter, then to inlets, and finally to a closed storm drain system. No inlet stenciling or marking was observed.

FIGURE 19: EXCESSIVELY WIDE CUL-DE-SAC (N-101); DOWNSPOUT INDIRECTLY CONNECTED TO THE STORM DRAIN (N-102)

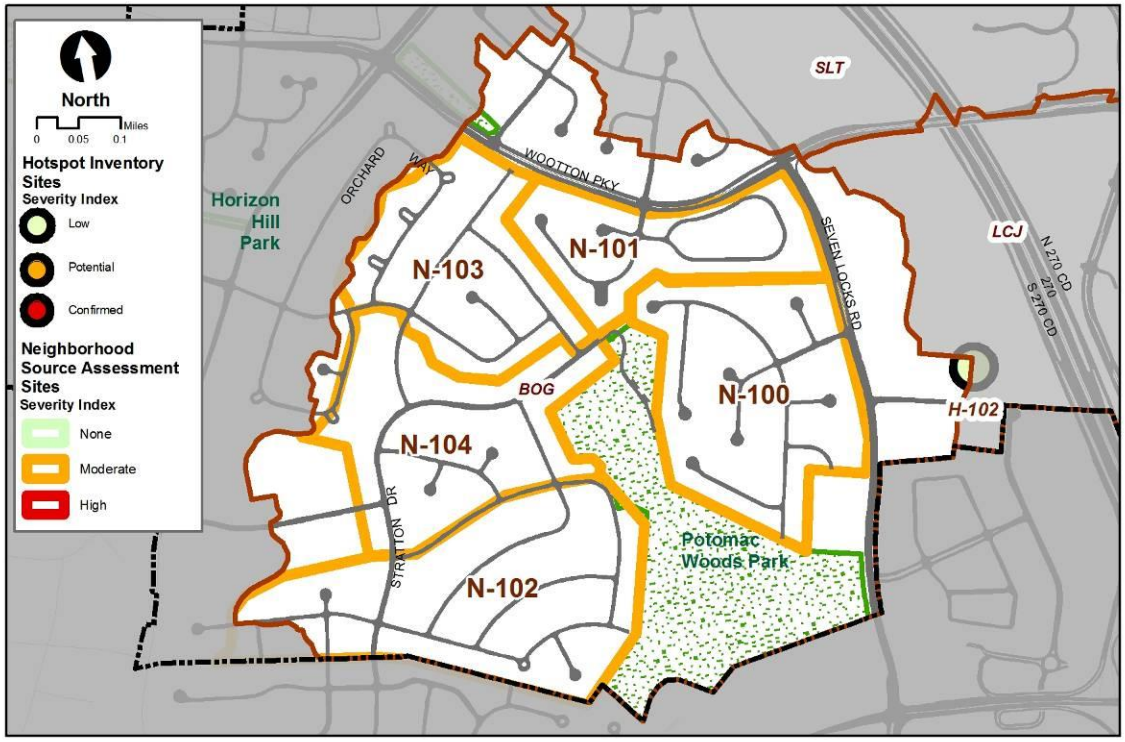


FIGURE 20: BOGLEY BRANCH NSA/HSI RESULTS

5.2.5 Summary of Problems

Streams

- Reach 005 is experiencing severe erosion with active headcutting due to a 24-inch storm drain outfall located at the end of Derbyshire Road;
- The portion of Reach 001 within the City limits is over-widened with moderate to severe erosion on outside channel meanders and large depositional features;

- Reach 006 has three fish blockages: one at the tennis court trail crossing, one at a gabion weir that diverts flow from the channel into the City's offline Potomac Woods SWM Pond, and the third at a park trail stream crossing near Dunster Lane. The stream buffer is narrow and contains many invasive species in the reach bounded by Dunster Lane on one side and the Potomac Woods SWM Pond and adjacent trail and ball field on the other side. This is a common situation in urban stream corridors where development occurred before stream buffer setbacks were standard.

Water Quality

- Baseflow nitrate-nitrite grab sample readings were 10 percent higher than the maximum recommended level;
- Older residential areas in the sub-watershed do not have SWM treatment.

HSI/NSA

- The commercial site (H-102) was rated with low severity for pollution potential. The Montgomery County Seven Locks Maintenance Yard is a confirmed hotspot for vehicle maintenance and solid waste practices, and sediment from poorly maintained paving;
- Approximately 70 percent of the lawns in the sub-watershed were flagged with high management status. High turbidity and nutrients, along with observations of algae in the streams are indicators of excess phosphorus and nitrogen;
- Two neighborhoods (N-102, N-103) were candidates for outreach for downspout disconnection and rain gardens. The others had a significant amount of roof drainage already disconnected.

5.2.6 Sub-watershed Restoration Goals

- Implement SWM retrofits and stream restoration projects recommended for the sub-watershed. Recommended SWM projects are R-02, R-03, and R-08, all of which will improve water quality;
- RSC site R-62S is recommended for stream restoration, and also may provide SWM benefits.
- Target residential neighborhoods for outreach for lower impact lawn care measures. An outreach program to encourage soil testing and reduced fertilizer use on City lawns could help improve water quality;
- Work with Montgomery County to ensure the Seven Locks Maintenance Yard is not violating the City's Water Quality Protection Ordinance and to implement a more effective Stormwater Pollution Prevention Plan. Ask for inspection reports on the facility to be copied to the City, and for notice of any spills or sediment discharges.

5.2.7 CANDIDATE SITES FOR IMPROVEMENTS

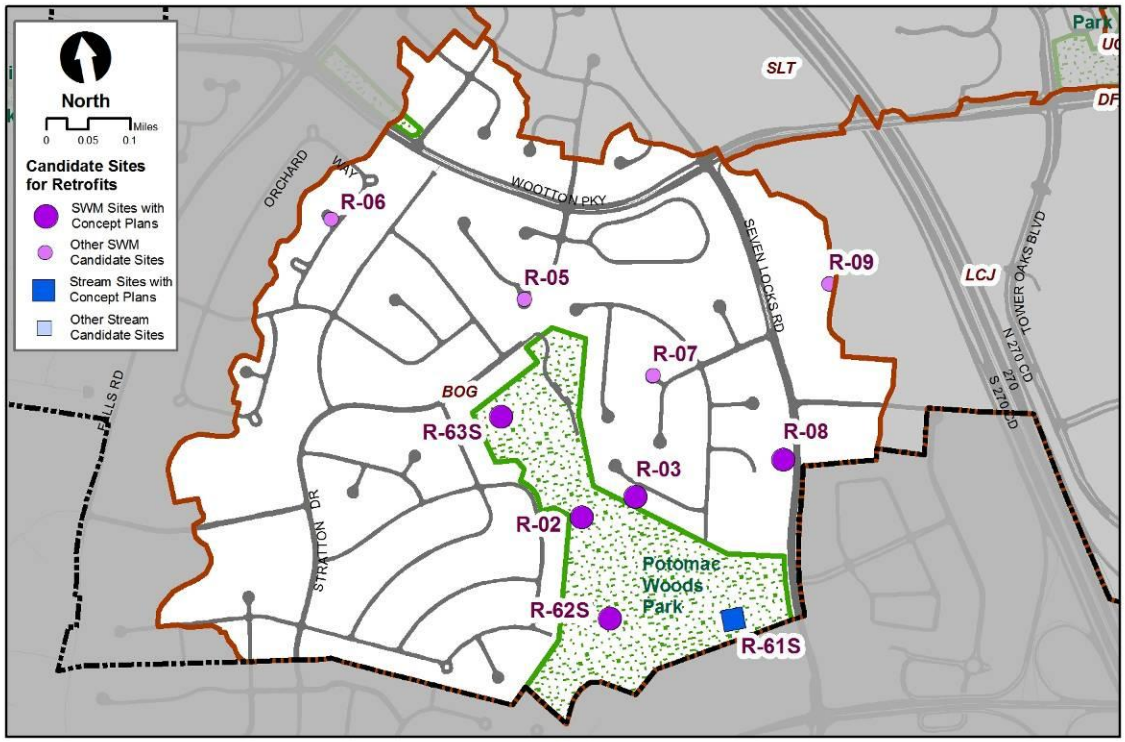


FIGURE 21: BOGLEY BRANCH, CANDIDATE SITES FOR IMPROVEMENTS:

TABLE 16: BOGLEY BRANCH CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-02		**Potomac Woods**	**Existing Pond**	**City**	**Improve water quality treatment at pond**	**Pond Retrofit**	**Perform field assessment for concept**
R-03		**Arlive Ct 77-01002**	**Existing Pond**	**City**	**Improve water quality treatment at pond**	**Pond Retrofit**	**Perform field assessment for concept**
R-05		Henslowe Dr.	Street Retrofit	City	Cul-de-sac site identified during NSA assessment (N-101); impervious cover removal or on-site treatment	Public ESD - defer until City has more experience	Feasible for IC removal or creating onsite treatment; however, not a significant amount of treated area for the cost.
R-06		Orchard Way	Street Retrofit	City	Cul-de-sac site identified during NSA assessment (N-103); impervious cover removal or on-site treatment	Public ESD - defer until City has more experience	Small amount of treated area for the cost, no underdrain feasible.
R-07		Twin Oaks Dr.	Street Retrofit	City	Cul-de-sac site identified during NSA assessment (N-100); impervious cover removal and on-site pond retrofit opportunity	Public ESD - defer until City has more experience	Center of cul-de-sac too small for on-site treatment system.
R-08		**Locks Pond Ct 77-01027**	**Existing Pond**	**City**	**improve water quality treatment in pond**	**Pond Retrofit**	**Perform field assessment for concept**
R-09		1201 Seven Locks Rd.	Parking Lot	Private	treat parking lot with on-site or storage pond retrofits	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-61S		**Bogley Branch Mainstem**	**Stream Restoration**	**City**	**Stream restoration primarily on outside meanders, some erosion on straight sections as well**	**Stream restoration**	**Develop concept plan based on field work during stream assessment**

TABLE 16: BOGLEY BRANCH CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-62S	**96-12**	**Potomac Woods Park –Derbyshire Rd. (1996 study - Potomac Woods #3- West)**	**Outfall**	**City**	**1996 proposal for new pond. Current proposal - RSC or stream restoration.**	**RSC**	**Develop concept plan based on field work during stream assessment**
R-63S		**Potomac Woods Park- Stratton Dr.**	**Outfall**	**City**	**RSC, Outfall Stabilization, Stream Restoration of short length of stream**	**RSC**	**Develop concept plan based on field work during stream assessment**

Concept plans were prepared for bolded projects

5.2.8 FIELD ASSESSMENT AND CONCEPT DESIGN

R-02 Potomac Woods Wetland Marsh Pond Retrofit This wetland marsh pond, located between the stream and the ball field in the park, was built in 1999 to provide partial water quality control for the first ¼" runoff, and partial quantity control (roughly a 40 percent attenuation of the 1-year storm with a 12-hour extended detention period). Due to compromises to save trees and provide recreation use, it is undersized for the drainage area, which contributes to maintenance problems and reduced effectiveness.

Major maintenance is recommended to restore the pond's functionality. This project will be pursued through the City's stormwater facility maintenance contract. The project will remove accumulated sediment from the forebay and main pond area, re-establish the wetland marsh, and may regrade the basin to extend time between routine dredging and better maintain wetland functions. No change to the pond function is planned at this time. Coordination with the Department of Recreation and Parks and the surrounding neighbors will occur before the maintenance work is scheduled.

If pond performance does not improve with major dredging work, the City may re-evaluate other facility improvements through the CIP in the future to improve pond lifespan between dredging, to address mosquito concerns, and to expand water quality volume. Any changes to the pond area will be discussed with the community, the Department of Recreation and Parks, and State/Federal wetland permitting agencies before proceeding with a redesign.

R-03 Arlive Court Pond Retrofit This project is an existing dry pond built in 1977 that is located between Arlive Court and the baseball field at Potomac Woods Park. The pond was designed to treat runoff from the upstream 14-acre medium density residential area for 10-year water quantity control. Water quantity control is no longer a priority because of the small pond's placement at the lower end of a much larger watershed. Since the pond outfalls into a long culvert under the ball field that discharges directly into a second-order stream, this pond is of little value in preventing stream erosion and does not contribute to water quality goals. The existing dry pond is currently in good condition, and does not need major maintenance at this time.

The proposed project consists of converting this site from a dry detention basin to an offline surface sand filter to provide water quality. However, the resulting sand filter would be substantially undersized according to current standards and may present maintenance problems. This is recommended for a future SWM retrofit, but will be postponed in the CIP schedule pending SWM treatment advances.

Any retrofit should focus on maximizing water quality treatment. Staff will re-evaluate this project if new SWM treatment methods (filtration or otherwise) for drainage areas between 5-30 acres that fit the available storage space become available, or when the corrugated metal pipe control structure requires replacement. Coordination with the Department of Recreation and Parks and the surrounding neighbors will occur at time of design.

R-08 Locks Pond Court Pond Retrofit This project is an existing wet pond located at the end of Locks Pond Court adjacent to Seven Locks Road. This facility was originally built in 1977 to treat 46 acres of residential, institutional, and industrial land use. It was modified by the City in the mid-1990s to provide partial water quality control and 1-year extended detention control for water quantity. The retrofit improved water quality control by adding a forebay and micropool and replaced the CMP riser with the concrete weir wall.

This facility is undersized for the drainage area and receives a heavy grit load from office/Montgomery County Seven Locks Maintenance Yard sites on Seven Locks Road. Retrofit potential is limited by available space and storage depths, so no modification of the control structure or pond expansion is

proposed. Water quantity control in this facility has limited benefits because the pond discharges into a long storm drain owned by Montgomery County before it reaches an open channel far down in the watershed and outside of the City.

Major maintenance is recommended to restore the pond's functionality. Work will include dredging the forebay and main pond basin to restore the pond volume, and removal of any trees from the impoundment that were not part of the original project. No change to the pond function is planned at this time. The work will be done through the City's stormwater facility maintenance contract. Coordination with the surrounding neighbors will occur before the maintenance work is scheduled.

R-61S Bogley Branch Mainstem Stream Restoration The project site is an existing stream section of Bogley Branch mainstem in Potomac Woods Park, and is located northwest of the intersection of Seven Locks Road and Montrose Road, behind the Maryland State Police Department building. Parts of this forested stream reach have been stabilized with rip-rap, with some spot areas behind the riprap that are destabilizing.

This project is not recommended for CIP inclusion at this time. Erosion appears minor to moderate, and no significant issues are present. Since the City limits are roughly 300 linear feet upstream of Seven Locks Road, Montgomery County would need to participate in any restoration for this segment. Staff recommends that this reach be monitored for worsening erosion and re-assessed in the next study.

R-62S Potomac Woods Stream Restoration – Derbyshire Road The existing stream channel is located entirely within Potomac Woods Park, and receives drainage from Derbyshire Road's residential land with no stormwater quantity or quality controls. This reach shows moderate erosion, and has a single storm drain outfall at the head of the channel. The mainstem channel at the downstream confluence was stabilized in 2000.

The proposed project will install a regenerative stream conveyance (RSC) channel that uses aquatic pools, riffle grade controls, native vegetation, and sand/woodchip filters to attenuate and treat small stormflows and pass larger storms safely. The proposed channel is approximately 720 feet long with a 30 foot elevation drop over this distance. Access along stream is easier from the south side of channel, which has fewer large trees. Coordination with the Department of Recreation and Parks and the surrounding neighbors will occur at time of design.

R-63S Potomac Woods Park Stream Restoration The existing 644 linear foot stream channel is located entirely within a forested section of Potomac Woods Park between Stratton Drive and Dunster Lane. This channel was previously stabilized in spots with imbricated riprap in 2000 and the majority appears to be stable, although there are a few meander bends showing moderate erosion.

This project is not recommended for CIP inclusion at this time. Erosion appears moderate, and the existing stabilization appears to be in good condition. Staff recommends that this reach be monitored for new erosion or failing stabilization and re-assessed in the next study. Staff should also monitor the storm drain outfall at Stratton Drive, which may need stabilization before the receiving channel does.

5.3 DAWSON FARM CREEK

The headwaters of the Dawson Farm Creek sub-watershed originate in the commercial corridor along Rockville Pike (MD 355), flow along Ritchie Parkway through Dawson Park, and under Wootton Parkway south to join the Lower Cabin John Creek main stem at Preserve Parkway. A small tributary, Woodmont Country Club Tributary No. 1, joins the creek just south of Wootton Parkway.

5.3.1 LAND USE AND IMPERVIOUS AREA

Over a quarter (28 percent) of this 412 acre sub-watershed is in residential land use, with the majority developed as medium-density residential communities. Transportation makes up another 21 percent of the watershed and includes neighborhood roads, Wootton Parkway and Rockville Pike. Portions of the golf course for the Woodmont County Club make up another 16 percent of the total area. Commercial areas located along the northeastern edge of the sub-watershed and forested areas adjacent to the Woodmont Country Club each make up 15 percent of the sub-watershed. The overall impervious cover is 32 percent. A summary of the land use and imperviousness within the Dawson Farm Creek sub-watershed is provided in Table 17.

TABLE 17: DAWSON FARM CREEK LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Turf in Open Space	10	2%	1	10%	0%
Forest	60	15%	0	0%	0%
Managed Turf on Golf Course	67	16%	4	6%	1%
Water	4	1%	0	0%	0%
SUBTOTAL OPEN SPACE	**141**	**34%**	**5**	**4%**	**1%**
Medium-Density Residential	99	24%	33	33%	8%
High-Density Residential	14	3%	6	43%	1%
Multi-Family Residential	1	0%	0	0%	0%
SUBTOTAL RESIDENTIAL	**114**	**28%**	**39**	**34%**	**9%**
Institutional	13	3%	3	23%	1%
Commercial	60	15%	49	82%	12%
Industrial	0	0%	0	0%	0%
Transportation	85	21%	37	44%	9%
TOTAL	**412**	**100%**	**132**	**32%**	**32%**

5.3.2 STORMWATER MANAGEMENT

As shown on Table 18, there are 12 public and 14 private stormwater management facilities in the Dawson Farm Creek sub-watershed. Major public facilities include Dawson Farm Park dry pond, which drains 165 acres, and the Curtis Place sand filter. The Dawson Farm Park pond is very outdated and undersized for the large drainage area, so it does not provide adequate stormwater management treatment under current standards. The public and private systems treat at least 86 acres, or about 65

percent, of the sub-watershed impervious area. However, this is misleading because most of this control is attributed to the Dawson Farm Park dry pond.

TABLE 18: DAWSON FARM CREEK STORMWATER MANAGEMENT FACILITIES

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Public			
Oil/Grit Separator	8		
Dry Pond, Quantity Control Only	1	165	75
Sand Filter	1	3	1
Underground Detention	2		
Total Public	**12**	**168**	**76**
Private			
Bioretention, Quality Control	1	N/A	N/A
Dry Pond, Quality Control Only	1	N/A	N/A
Sand Filter	4	4	1
Sand Filter, Underground	3	11	5
Stormceptor	1	N/A	N/A
Underground Detention	4	4	2
Total Private	**14**	**>19**	**>8**

5.3.3 Stream Assessment

1994 Conditions

Stream problems observed in 1994 included high embeddedness, loss of aquatic habitat due to stream channelization, and high baseflow turbidity in the lower stream reaches. The low to moderate quality macroinvertebrate diversity and biomass appeared to increase in the downstream direction. Two fish barriers were noted at Wootton Parkway and the lower Woodmont Country Club Tributary No. 1 pond. Just south of Wootton Parkway, 1000 linear feet of stream channel was realigned with rip-rap and gabion baskets. Despite these stream problems, overall the stream network was relatively stable.

2010 Conditions

The mainstem stream in Dawson Farm Creek was divided into five unique assessment reaches based on habitat conditions (Reaches 001, 002, 003, 004, and 005). One tributary also drains to the mainstem channel within Dawson Farm Creek. This tributary was broken up into three unique assessment reaches (Reaches 006, 010, and 011). All tributary reaches lie completely within the Woodmont Country Club property.

The mainstem reaches for the Dawson Farm Creek sub-watershed can generally be characterized as incising with erosion occurring along the outsides of meanders. Gravel and sand point bars are common throughout the mainstem with areas of bedrock and exposed clay substrate. Eroded sediment is filling in available pools. Many of the reaches in this sub-watershed are constrained by existing infrastructure. There are large areas of channel straightening and stabilization, specifically along Reach 003, paralleling Wootton Parkway.

FIGURE 22: INCISED CHANNEL WITH GRAVEL POINT BARS (REACH DFC-002)

Along this reach, areas where sedimentation has occurred are beginning to colonize with thick grasses and scattered trees helping to create a more natural channel. Much of the buffer is heavily forested along Preserve Parkway although there are areas where the buffer is narrow with many invasive species, specifically between Brice Road and West Edmonston Drive. Habitat along the mainstem ranges from the mid-marginal to the mid-suboptimal range with riffles and pools as the dominant habitats. Impediments to fish passage are found along Reach 003, where designed low flow channels have filled with sediment and at the culvert under West Edmonston Drive along Reach 005. No buffer encroachment from residents was observed.

Reaches that are tributaries to the mainstem of Dawson Farm Creek are heavily impacted by practices at the Woodmont Country Club. Stream channels are generally stable with localized areas of erosion along outside meanders. Habitat is in the poor to low marginal range due to the amount of algae covering the channel bed and the lack of a sufficient riparian buffer. Along Reach 010, which lies between two fairways, all vegetation has been removed with the exception of several trees and it appears that herbicides have been applied along the stream banks to inhibit growth.

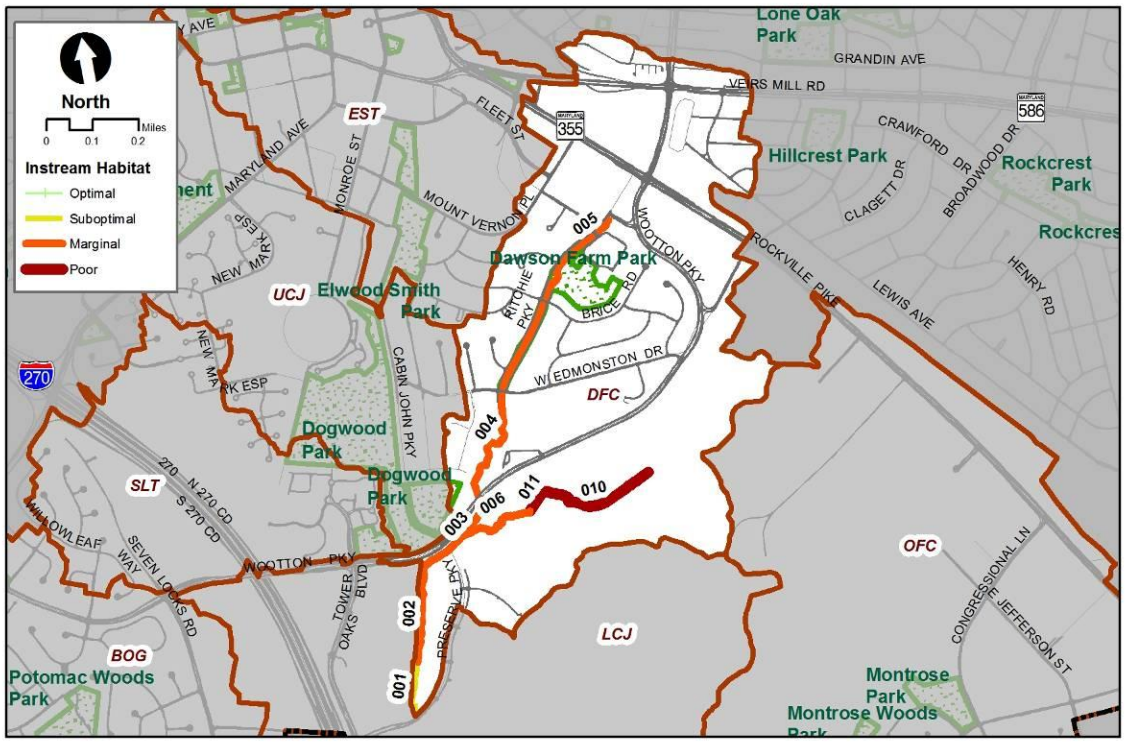


FIGURE 23: DAWSON FARM CREEK HABITAT ASSESSMENT

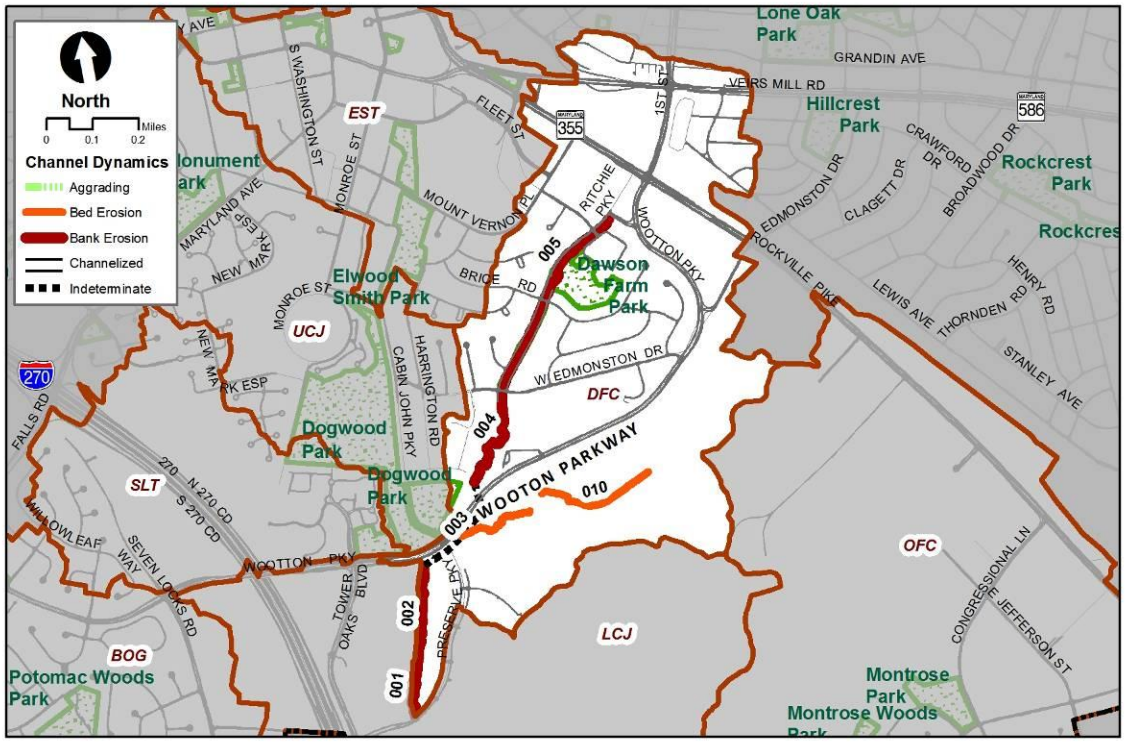


FIGURE 24: DAWSON FARM CREEK CHANNEL DYNAMICS ASSESSMENT

Geomorphic Assessment.

A geomorphic assessment was performed on Reach 002 in the Dawson Farm Creek sub-watershed, which is the eastern tributary between Wootton Parkway and Preserve Parkway. Severe erosion was very common throughout the assessed reach and many of the pools in the reach were being filled with coarse sand and small gravel. Large gravel and sand point bars were prevalent on inside meanders. This reach was mostly straight with only a few minor meanders. No stream restoration, stabilization, or bank armoring was present in the assessed reach.

Water Quality.

In-situ and water quality grab samples taken in the Dawson Farm Creek sub-watershed did not indicate pH or DO outside of COMAR standards. Conductivity levels were elevated, especially at stations located just downstream of a commercial center along Rockville Pike (DFC#1) and just downstream of a large residential area (DFC#2). The summer sampling showed high conductivity everywhere, which may have been a function of low rainfall in the weeks prior to sampling, as lower baseflow causes dissolved solids to become more concentrated. Nitrate+nitrite was high in both seasons but still within the acceptable limit. Phosphorus was high in the summer sample, and bacteria levels were extremely high. Results of water quality measurements are shown in Table 19. Values higher than the reference range are shown in bold.

TABLE 19: DAWSON FARM CREEK WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
Reference			247	5.0	2.825	6.5-8.5	500	0.04	1.295	0.3	0.995	400
DFC#1	Apr-10	14.5	**661.0**	9.0	1.26	7.5	---	---	---	---	---	---
DFC#1	Sep-10	18.9	**589.0**	7.6	1.00	7.71	---	---	---	---	---	---
DFC#2	Apr-10	14.6	**600.2**	9.0	2.02	8.0	---	---	---	---	---	---
DFC#2	Sep-10	18.2	**586.0**	8.2	1.18	7.80	---	---	---	---	---	---
DFC#3	Apr-10	15.4	243.0	9.6	**11.50**	8.1	---	---	---	---	---	---
DFC#3	Sep-10	17.8	**485.0**	7.6	1.06	7.45	---	---	---	---	---	---
DFC GRAB	Apr-10	13.3	**441.4**	9.5	2.46	8.1	<1	0.03	0.98	<0.5	0.98	43
DFC GRAB	Sep-10	18.5	**490.6**	8.6	0.91	7.86	<1	**0.08**	0.89	<0.5	0.89	**>= 24000**

5.3.4 HSI/NSA INVESTIGATION

Six hotspot sites and eight neighborhoods were assessed in Dawson Farm Creek. Five of the six hotspot sites were commercial areas and the sixth was an institutional use. The only hotspot activity noted was related to waste management, there were no vehicle operations or materials handling at any of the sites. Problems with waste management were noted at most of the sites, with either overflowing dumpsters or loose trash. A potential illicit discharge was found at site H-306, and evidence of discharging washwater into storm drains was seen at site H-308. Site H-300 was rated as a confirmed hotspot and all the others were rated low severity.

FIGURE 25: EVIDENCE OF WASHWATER DUMPING INTO STORMDRAIN SYSTEM (H-308)

The eight neighborhoods assessed in Dawson Farm Creek were not uniform for type of housing, lot size, or age. They ranged from older houses built in the 1950s to townhouse developments less than 10 years old.

The single-family detached neighborhoods were all constructed with lots 1/4 acre or smaller. The multi-family dwellings are townhouses on less than 1/8 acre. Very little active construction was observed. Lawn care practices varied widely, with newer developments typically showing a larger percentage of high-maintenance lawns, which may indicate higher rates of fertilizer or pesticide use, which impacts stream water quality. Lawn care in the older neighborhoods was generally medium-maintenance, which is less detrimental to stream health.

Tree canopy on private lots was lower in this sub-watershed than others, with all of the neighborhoods assessed at less than 40 percent coverage, which is a target recommended by American Forests.

With one exception, downspouts were more disconnected in the older neighborhoods. Stormwater was conveyed through curb and gutter to inlets. No inlet stenciling or marking was observed. All the areas except one were rated moderate for both pollution potential and restoration opportunities.

FIGURE 26: TYPICAL NEIGHBORHOOD CONDITIONS (N-129)

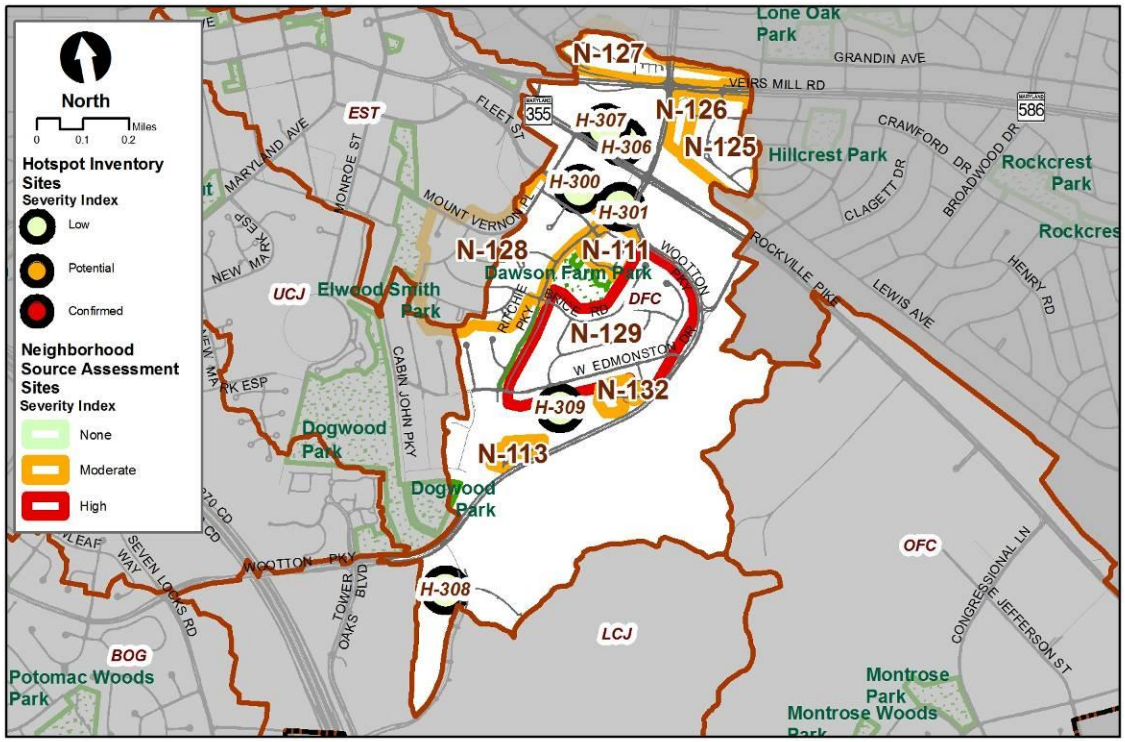


FIGURE 27: DAWSON FARM CREEK NSA / HSI RESULTS

5.3.5 Summary of Problems

Streams

- Reach 001 is experiencing moderate erosion with bank scalloping. This reach is trying to over-widen; however, many large trees are preventing the channel from becoming sinuous. The

channel becomes increasingly incised from the downstream end of the reach to the upstream end;
- Reach 002 is very straight with only occasional meanders and is severely incised and eroded. Large gravel point bars are common, pools are filling up with sand and gravel, and large areas of clay are exposed;
- The culverts under Preserve Parkway and Wootton Parkway were both designed with low flow channels to help facilitate fish passage; however, sedimentation is blocking or filling up these channels in both culverts on Reach 003;
- Reach 004 is experiencing moderate erosion on outside meander bends with a complete fish blockage at the stream culvert under West Edmonston Drive.;
- Reach 006 stream banks become more steep and eroded in a downstream to upstream direction especially on outside meanders. The upstream portion of this reach is eroded and incised with no floodplain access. Algae were prevalent throughout this reach, especially at the Woodmont Country Club outfall;
- Reach 010 parallels two fairways and is heavily impacted by the Woodmont Country Club, with excessive algae found throughout this reach. All vegetation, with the exception of several trees, has been removed along most of this reach and it appears that herbicides are being applied along the stream banks to inhibit growth.

Water Quality

- Nitrate+nitrite were high but still within the acceptable limit. One turbidity sample (DFC#3) was very high. Conductivity, which is a measure of dissolved solids, was high in all the summer samples.

HSI/NSA

- Potential illicit discharge behind 804 Rockville Pike. (Site ID: HSI-306);
- Dumping of trash and barrels behind the building at 736 Rockville Pike (Site ID: HSI-307);
- There is a general lack of trash maintenance along the entire length of the east side of Rockville Pike through the sub-watershed;
- The sub-watershed contains high-density residential areas with high management lawns, which may indicate higher rates of fertilizer or pesticide use, which can impact on stream water quality.

5.3.6 Sub-watershed Restoration Goals

- Restore the actively eroding stream at site R-70S as identified in the stream assessment.
- Target residential neighborhoods for outreach and education for lower impact lawn care measures. An outreach program to encourage soil testing and reduced fertilizer use on City lawns could help improve water quality;
- Target residential areas with low tree canopy, particularly the medium-density neighborhoods, for outreach for tree planting;
- Continue to inspect and enforce the City's Property Maintenance Code for litter, trash, and dumpster maintenance for commercial properties in the sub-watershed;
- Explore methods of course maintenance with Woodmont Country Club that could provide lower impacts to the sub-watershed.

5.3.7 CANDIDATE SITES FOR IMPROVEMENTS

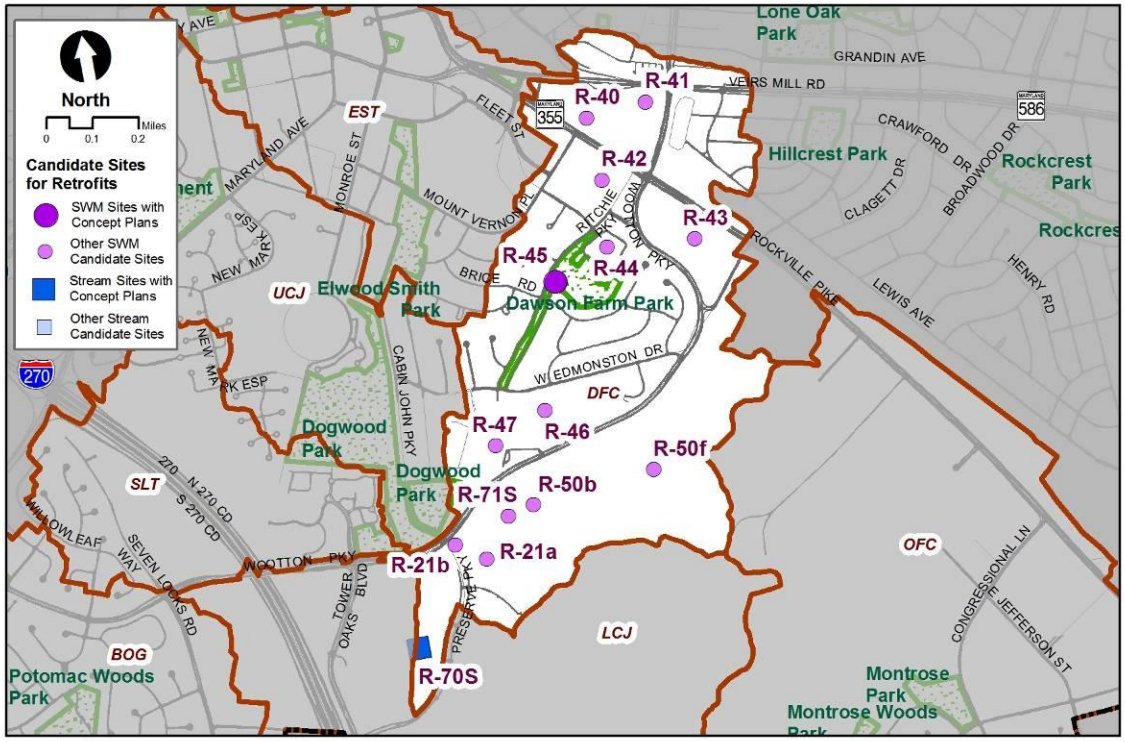


FIGURE 28: DAWSON FARM CREEK, CANDIDATE SITES FOR IMPROVEMENTS

TABLE 20: DAWSON FARM CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-21a		1 Preserve Pkwy	Parking Lot	Private	Provide on-site treatment and rooftop disconnection	Encourage through redevelopment SWM requirements	Already treated by underground sand filter- onsite SWM meets MDE 2000 SWM requirements. Retrofits on privately owned property were low priority
R-21b		1 Preserve Pkwy	Existing Pond	Private	Improve water quality treatment	Encourage through redevelopment SWM requirements	Onsite SWM meets MDE 2000 SWM requirements. Retrofits on privately owned commercial property were low priority
R-40		718 Rockville Pike	Parking Lot	Private	Site has existing sand filter and underground detention. Provide additional on-site treatment	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-41		Wootton Pkwy and Veirs Mill Rd	Parking Lot	Private	Site has underground detention and sand filter. Provide additional on-site treatment opportunity	Encourage through redevelopment SWM requirements	Onsite SWM meets MDE 2000 SWM requirements. Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-42		765 Rockville Pike	Parking Lot	Private	Site identified during HSI assessment. Dry swale retrofit opportunity along sidewalk. Sand filter located at site.	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-43		815 Rockville Pike	Parking Lot	Private	Stormceptor on site. Provide additional on-site pond retrofit	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority

TABLE 20: DAWSON FARM CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-44		Jefferson Square	Parking Lot	Private	Provide on-site opportunity at condominium apartment complex	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property were low priority
R-45	**96-08**	**Dawson Farm Park 8501017**	**Existing Dry Pond**	**City**	**Field assess for feasibility of adding water quality treatment to in-stream quantity control, may sacrifice higher storms to treat smaller storms and account for baseflow. 100-year flooding, trash and floatables should be considered.**	**Pond Retrofit**	**Perform field assessment**
R-46		Hungerford ES	Parking Lot	County	Institutional Site. Provide on-site and educational opportunity, rooftop disconnection	Implement through redevelopment process	Retrofits on County-owned property that could be installed with redevelopment are low priority
R-47		Wootton Oaks	Storm Drain Outfall	Private	Provide RSC and storage opportunity at outfall and on-site quality treatment at townhouse complex	No action	Onsite SWM (sand filter) provides ½" water quality control. Privately-owned. Insufficient space between outfall and stream for off-line storage
R-50b		Woodmont Country Club	Existing Pond	Private	Enhance water quality treatment at existing pond	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action	

TABLE 20: DAWSON FARM CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-50f		Woodmont Country Club	Existing Pond	Private	Enhance water quality treatment at existing pond	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action	
R-70S		**DFC Mainstem-south of Wootton Pkwy, west of Preserve Pkwy**	**Stream Restoration**	**City**	**Stream restoration, very incised, over-widening, severe erosion**	**Stream restoration**	**Develop concept plan based on field work during stream assessment**
R-71S	96-09	Wootton Parkway (1996 Watershed Plan – site of proposed new pond in mainstem of Dawson Farm Creek owned by City)	Stream Restoration	Private	1996-Proposed in-stream gabion weirs/culvert pond retrofit in a perennial stream. Not feasible due to permit issues, flooding hazards. Potential RSC and spot stabilization on side tributary where stream is eroded on meanders and downcutting.	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action	

Concept Plans were prepared for bolded projects

5.3.8 Field Assessment and Concept Design

R-45 Dawson Farm Park Pond Retrofit The existing in-stream dry detention pond is located in Dawson Park along Ritchie Parkway. The gabion weir control structure provides temporary storage of flood volumes that overtop the existing stream channel during extreme flooding events. The pond receives runoff from 165 acres of commercial, medium density residential, and roadway areas upstream. The stream channel / pond outflow is directed to a culvert that flows underneath Ritchie Parkway downstream. This facility does not meet current SWM standards for either quality or quantity control.

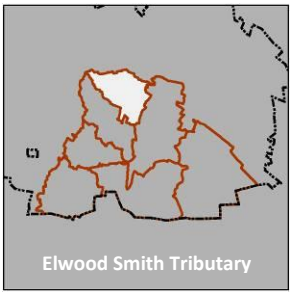
The concept considered creating a shallow wetland adjacent to the stream, but it would provide less than 20 percent of the water quality requirement. At this time, there is no appropriate SWM treatment technology that fits the large drainage area and available space in the park. The elevations of storm drain culverts and adjacent Ritchie Parkway during flooding are further impediments to a retrofit. This project is not recommended.

R-70S Dawson Farm Creek Stream Restoration The project site is located in a forested area behind Clyde's Tower Oaks Lodge west of Preserve Parkway and south of Wootton Parkway. This is the east branch of the two parallel mainstem reaches in this stream valley, and the parcel is owned by the City of Rockville. The stream reach has experienced moderate-severe bank erosion, widening, aggradation and downcutting of the channel bottom.

This project is recommended for stream restoration through the CIP. The total length of channel bank to be restored is approximately 1400 feet. Also, storm drain maintenance is needed to remove excess sediment and vegetation from the twin box culvert under Wootton Parkway and the outfall channel upstream of this reach (between Wootton Pkwy and the eastern end of Preserve Pkwy.) The storm drain maintenance work may be done separately from the stream restoration CIP project.

Staff recommends that this reach continue to be monitored for worsening conditions, and programmed into the CIP after more severe erosion problems have been addressed at Dogwood Park, Montrose Woods Park, and Mt. Vernon Place. Coordination with the Department of Recreation and Parks and any commercial properties affected by access/staging issues will occur at time of design. (Note: R-70S, R-72S, and R-73S stream restoration may be designed and constructed at the same time since they are located adjacent to each other.)

5.4 ELWOOD SMITH TRIBUTARY



This sub-watershed drains a portion of the City Town Center. It is estimated that approximately 1/3 of the stream network has been piped (upstream of Fleet Street). The stream flows from Fleet Street to where it joins with the Upper Cabin John Creek mainstem at Cabin John Parkway.

5.4.1 LAND USE AND IMPERVIOUS AREA

Institutional land uses (primarily government buildings and a school) make up 30 percent of this 213-acre sub-watershed,. Transportation makes up another 22 percent and includes the intersection of Rockville Pike (MD 355) and Veirs Mill Road (MD 28). The combined large amount of commercial, institutional, and multi-family residential areas contributes to a high impervious cover of 49 percent, the highest of any of the seven sub-watersheds in the Cabin John watershed. A summary of the land use within the Elwood Smith Tributary sub-watershed is provided in Table 21.

TABLE 21: ELWOOD SMITH TRIBUTARY LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Turf in Open Space	10	5%	0	0%	0%
Forest	6	3%	0	0%	0%
Managed Turf on Golf Course	0	0%	0	0%	0%
Water	0	0%	0	0%	0%
SUBTOTAL OPEN SPACE	**16**	**8%**	**1**	**6%**	**0%**
Medium-Density Residential	42	20%	13	31%	6%
High-Density Residential	6	3%	3	50%	1%
Multi-Family Residential	14	7%	10	71%	5%
SUBTOTAL RESIDENTIAL	**63**	**30%**	**26**	**41%**	**12%**
Institutional	63	30%	30	48%	14%
Commercial	25	12%	19	76%	9%
Industrial	0	0%	0	0%	0%
Transportation	46	22%	28	61%	13%
TOTAL	**213**	**100%**	**104**	**49%**	**49%**

5.4.2 STORMWATER MANAGEMENT

There are 4 public and 17 private stormwater management facilities in the Elwood Smith Tributary sub-watershed (see Table 22). The upper part of this sub-watershed is treated by the Rockville Heights dry pond and the Mount Vernon wet pond, both public facilities. This entire sub-watershed drains into the Upper Cabin John Creek sub-watershed, where the combined streamflow is treated by an off-line facility, Stoneridge Marsh.

TABLE 22: ELWOOD SMITH TRIBUTARY STORMWATER MANAGEMENT FACILITIES

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Public			
Oil/Grit Separator	2		
Wetland Pond, Extended Detention	1	117	45
Dry Pond, Quantity Control Only	2	96	52
Total Public	**4**	**213**	**97**
Private			
Bioretention, Quality Control	1	N/A	N/A
Flow Splitter	1	N/A	N/A
Infiltration Trench	4	N/A	N/A
Dry Pond, Quality Control Only	2	N/A	N/A
Sand Filter	2	N/A	N/A
Sand Filter/Bioretention, Quality Control	1	N/A	N/A
Sand Filter, Quantity Control Only	1	N/A	N/A
Sand Filter, Underground	1	N/A	N/A
Stormceptor	1	N/A	N/A
Total Private	**14**	**N/A**	**N/A**

5.4.3 Stream Assessment

1994 Conditions

Stream impacts noted in 1994 included channel erosion, riffle embeddedness, impaired aquatic habitat, poor canopy cover, riparian buffer width, and an impaired macroinvertebrate community. Two fish barriers were noted at the culverts at Mt Vernon Place and Cabin John Parkway. Channel erosion was noted along Elwood Smith Park and East Lynfield Road where riparian vegetation consisted of grass.

2010 Conditions

The streams in the Elwood Smith Tributary sub-watershed were divided into three unique assessment reaches based on habitat characteristics (Reaches 001, 002, and 003).

Generally, streams in the Elwood Smith Tributary sub-watershed are relatively stable with sections of active erosion. The overall assessment of the reach was that the active widening was the dominant process. Several outside meanders on Reach 001 have been armored and are in stable condition. Riparian buffer width varies along the length of the channel from good to poor and invasive species are prevalent. Stream habitat is in the mid-marginal to low-suboptimal range and the culvert at the downstream end of the mainstem (under Cabin John Parkway) is a fish blockage for all upstream reaches.

FIGURE 29: STREAMBANK ARMORING (REACH EST-001)

Geomorphic Assessment.

There was no geomorphic assessment performed in this sub-watershed because much of the reach has been straightened and armored with rip-rap. Geomorphic measurements will not provide useful information regarding the potential changes in the channel to justify the level of effort required.

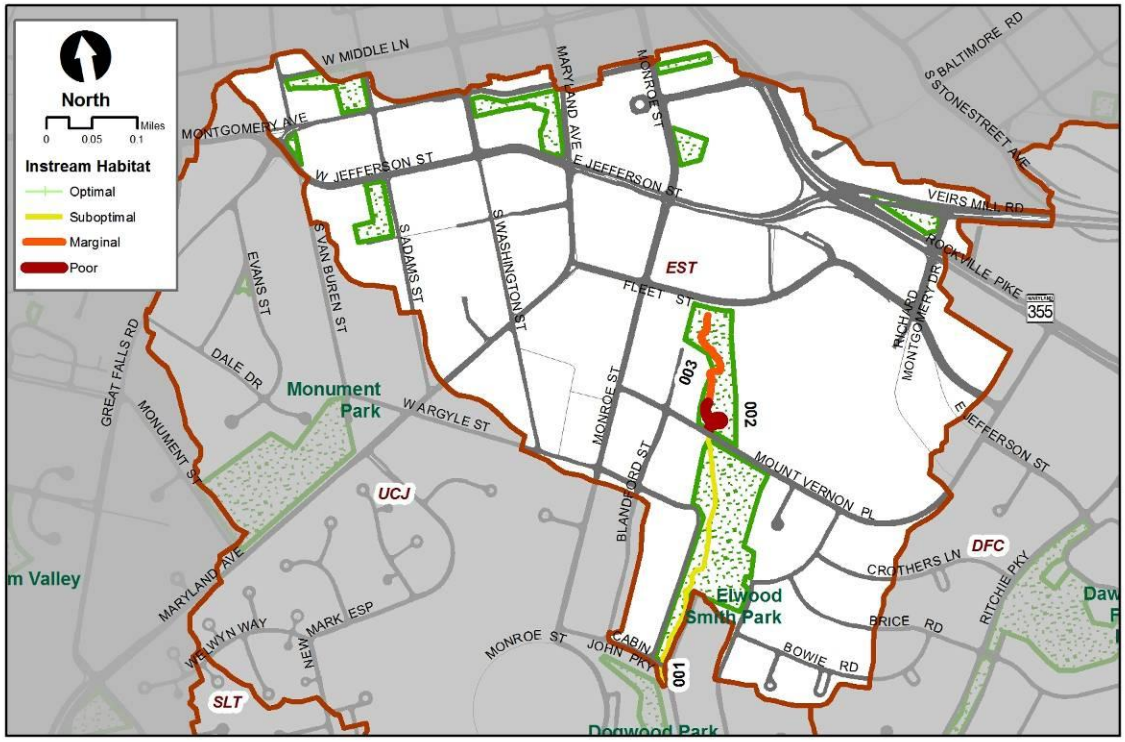


FIGURE 30: ELWOOD SMITH TRIBUTARY HABITAT ASSESSMENT

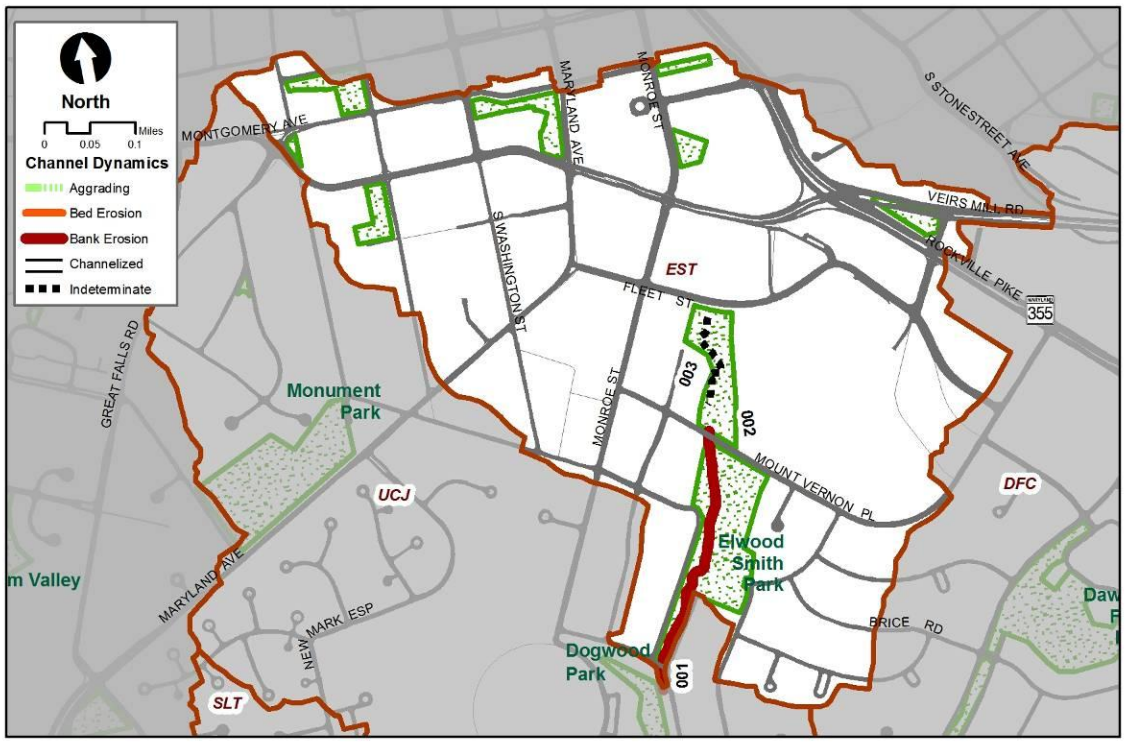


FIGURE 31: ELWOOD SMITH TRIBUTARY CHANNEL DYNAMICS

Water Quality.

In-situ and water quality grab samples taken in the Elwood Smith Tributary sub-watershed did not indicate either pH or DO outside of COMAR standards. Conductivity was much higher than the reference level at both the in-situ site located at the headwaters and at the grab sampling site at the downstream end for both sampling dates. Both nitrogen and phosphorus levels were higher than acceptable ranges. Nitrate is a component of TN, and was high enough that TN also exceeded the recommended limit. The grab sample for turbidity also exceeded EPA's recommended limit in the spring sample, but not the summer. The summer bacteria level was extremely high. Results of water quality measurements are shown in Table 23. Values higher than the reference range are shown in bold.

TABLE 23: ELWOOD SMITH TRIBUTARY WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
Reference			247	5.0	2.825	6.5-8.5	500	0.04	1.295	0.3	0.995	400
EST#1	Apr-10	15.9	**1189.0**	9.0	1.62	7.8	---	---	---	---	---	---
EST#1	Sep-10	19.2	**1205.0**	7.5	1.05	7.61	---	---	---	---	---	---
EST GRAB	Apr-10	17.7	**724.0**	9.2	**3.98**	7.7	2	**0.08**	**1.5**	<0.5	**1.50**	240
EST GRAB	Sep-10	18.5	**959.0**	8.2	0.56	7.40	<1	**0.32**	**1.7**	<0.5	**1.7**	**>= 24000**

5.4.4 HSI/NSA Investigation

There were no hotspot sites and only one residential area assessed in this sub-watershed. While the residential area consisted of a mix of single-family detached and multi-family structures, built from the 1920s to the 1980s, the area assessed (N-120) was a uniform neighborhood of duplexes built in the

1950s. Lawn care practices were not a significant pollutant source, being primarily low maintenance. There was some evidence of trash and litter, and tree canopy was relatively low (less than 40 percent).

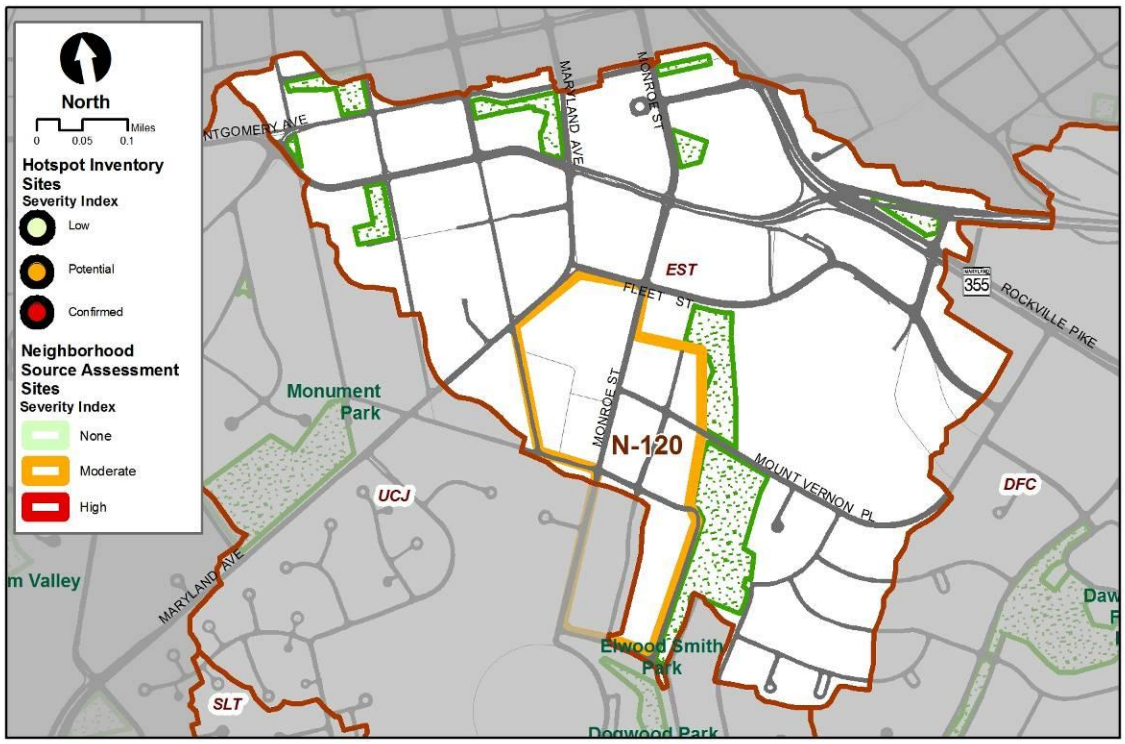


FIGURE 32: ELWOOD SMITH TRIBUTARY, NSA / HSI RESULTS

5.4.5 Summary of Problems

Streams

- The downstream end of Mt. Vernon Place culvert is severely eroded with a large scour hole that is beginning to undermine the concrete outlet structure (at Site R-66S);
- Both banks of Reach 001 have either extensive invasive vegetation or too narrow of a buffer. Within the recreational portion of Elwood Smith Park, mowing is occurring to the stream bank. At the upstream end of Reach 001 next to a baseball field, overland flow from the field is eroding the stream bank slope;
- Reach 003 riparian buffers are mostly intact; however, significant invasive vegetation was found behind residences along Blandford Street. The buffer along a pedestrian trail near Richard Montgomery High School is very narrow in places.

Water Quality

- The baseflow grab sample exceeded the recommended nutrient levels for nitrate+nitrite and TN. Turbidity was also high.

HSI/NSA

- There are no hotspot recommendations in the sub-watershed;
- The amount of tree canopy was low (Site N-120).

5.4.6 *Sub-watershed Restoration Goals*

- Protect the vulnerable storm drain outfall area at Site R-66S identified in the stream assessment. Repairing site R-66S would address some problems in Reach 001;
- Identify water quality retrofit measures that could be implemented to treat runoff from areas with either no treatment or only quantity treatment. Pond retrofit sites R-29, R-36, and R-39 would convert quantity control facilities to water quality. New ponds R-35 and R-81 could provide quality control, as would the other sites listed as parking lot or street retrofits;
- Target the residential area with low tree canopy for outreach for tree planting.

5.4.7 *Candidate Sites for Improvements*

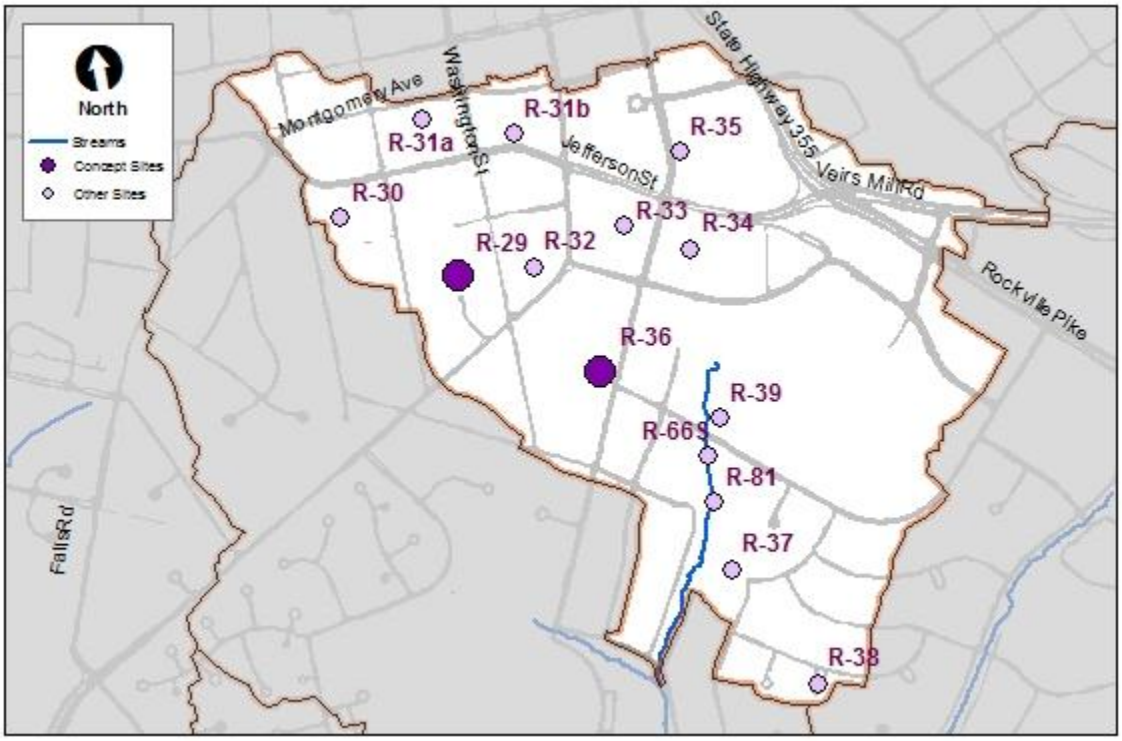


FIGURE 33: ELWOOD SMITH TRIBUTARY, CANDIDATE SITES FOR IMPROVEMENTS

TABLE 24: ELWOOD SMITH TRIBUTARY CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-29	**96-03**	**Rockville Heights**	**Existing Pond**	**City**	**Add water quality/ extended detention to dry pond. Retrofit constrained since this pond was created to solve a flooding problem at S. Washington St. & Maryland Ave.**	**Pond Retrofit**	**Perform field assessment**
R-30		Jacqueline Trellis Williams Park	Parking Lot	Public	Park land. Provide on-site and educational opportunity	Public ESD - defer until City has more experience	Not a lot of treated area for the cost, no underdrain feasible.
R-31a		50 W. Montgomery Avenue	Parking Lot	County/Private	Small portion of areas is County -owned. Provide on-site pond retrofit opportunity	Encourage through redevelopment SWM requirements	Retrofits on County-owned or private property that could be installed with redevelopment are low priority
R-31b		District Courthouse	Parking Lot	County/State	County -owned. Oil grit separators on site. Provide additional on-site pond retrofit opportunity	Encourage through redevelopment SWM requirements	Retrofits on County-owned property that could be installed with redevelopment are low priority. No space for pond.
R-32		City Hall	Parking Lot	City	Provide on-site opportunity	Public ESD - defer until City has more experience	Not a lot of treated area for the cost.
R-33		Council Office Bldg.	Office/Parking Garage	Public	Provide on-site retrofit opportunity, rooftop disconnection.	No action	Insufficient space at edges of parking garage for either on-site systems or disconnection
R-34		200 Monroe St.	Parking Lot	County	Provide on-site opportunity	Encourage through redevelopment SWM requirements	Retrofits on County-owned property that could be installed with redevelopment are low priority

TABLE 24: ELWOOD SMITH TRIBUTARY CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-35		Veteran's Park	New Pond	City	Park land. Improve water quality treatment	No action	Pocket park not large enough to dedicate space to new SWM facility.
R-36		**Lynn Manor Dr.-Monroe St.**	**Existing Pond**	**Private (Courthouse Walk HOA)**	**Improve water quality treatment**	**Pond Retrofit**	**Perform field assessment**
R-37		Elwood Smith Rec Center	Parking Lot	City	Park land. Provide on-site treatment and educational opportunity at parking lot and possible storage for storm drain system at outfall.	Public ESD - defer until City has more experience	Feasible for creating onsite treatment; however, not a significant amount of treated area for the cost. No space for treatment between outfall and stream.
R-38		Bowie Rd.	Street Retrofit	City	Cul-de-sac sites identified during NSA assessment (N-128). Provide opportunity to reduce impervious cover and on-site treatment.	Public ESD - defer until City has more experience	Not a lot of treated area for the cost, no underdrain feasible.
R-39		Mt. Vernon Pond	Existing Wet Pond	City	Park land. Provide opportunity to improve water quality treatment	No action	Retrofitted in early 2000s for maximum water quality and 1-year extended detention; no further retrofit feasible.
R-66S		Outfall / Culvert / Stream below Mt. Vernon Pl.	Stream Restoration	City	Proposed project would stabilize large outfall/culvert structure and downstream channel.	Stream restoration; storm drain repair	Potential for stream restoration project, lower priority since stream channel is fairly stable. Outfall needs repair**. (No concept prepared, but project is recommended for repairs)**

TABLE 24: ELWOOD SMITH TRIBUTARY CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-81	96-02	Elwood Smith	New Pond proposed in 1996 Watershed Plan	City	Proposed in-stream facility has permit issues, will require removal of a recreation area, large amount of excavation. Two upstream SWM facilities are already in place to treat the same drainage area.	No action	1996 proposed project is no longer necessary

Concept plans were prepared for bolded projects

5.4.8 Field Assessment and Concept Design

R-29 Rockville Heights Pond Retrofit This facility is an existing dry pond with a 30-acre drainage area, built in 1981 between Church Street and Leland Street. The pond is currently used to mitigate 2-year to 10-year storm drain surcharges and flooding of South Washington Street and Maryland Avenue. It has no baseflow.

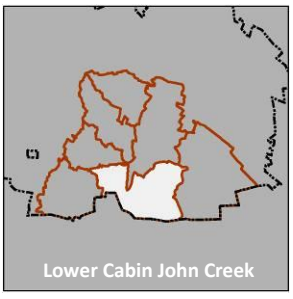
Improvements considered included an option to convert the existing quantity basin to an in-line modified sand filter. Current sand filter designs are not appropriate for a drainage area of this size, so the project is not recommended. The City may re-evaluate this pond for a water quality retrofit in the future as SWM treatment technology advances.

R-36 Lynn Manor Drive Pond Retrofit This facility is a well-maintained existing dry detention basin located between Lynn Manor Drive and Monroe Street with a small 6-acre drainage area. It is privately owned and apparently used as open space area by the Courthouse Walk Homeowners Association. Based on visual inspection of the riser structure, the facility is designed to provide water quantity management; likely for the 2-year and 10-year design storm. Recommendations involve converting the dry pond to an in-line modified sand filter to provide water quality treatment.

This project is not recommended at this time since the retrofit benefits are outweighed by the cost for the conversion, and the pond is in private ownership with a homeowners association.

R-66S Stream Restoration This stream channel lies completely within Elwood Smith Park, between Mt. Vernon Place and Cabin John Parkway. The downstream end of Mt. Vernon Place culvert is severely eroded with a large scour hole that is beginning to undermine the concrete end wall and apron at the pipe outlet. Channel stability in this reach was moderately stable with only a few isolated areas of bank erosion due to channel widening. The rest of channel through Elwood Smith Park was previously stabilized with riprap and is in good condition.
This storm drain rehabilitation project is recommended to be implemented through the CIP. The project will repair the concrete end wall and apron at the Mt. Vernon Place outfall to protect the culverts from erosion and structural failure. This storm drain repair may be paired with lining/replacement of the corrugated metal pipe culvert on the same reach at the Elwood Smith Recreation Center's pedestrian bridge. Stream buffer management and repair schedule will be discussed with the Department of Recreation and Parks and the surrounding neighbors at time of design. (Note: no concept was prepared for this project since it is primarily storm drain structure repair.)

5.5 LOWER CABIN JOHN CREEK



The Lower Cabin John Creek sub-watershed extends from Wootton Parkway downstream to Montrose Road. The channel is the continuation of the mainstem from Upper Cabin John Creek, and is the west branch of the two channels between Wootton Pkwy and Preserve Pkwy. Three tributaries feed into this sub-watershed, Golf Course Tributary #2 from Woodmont Country Club, a partially piped stream north of Farm Haven Drive, and North Farm Park Tributary just north of Montrose Road.

5.5.1 Land Use and Impervious Area

Half of the land use in this 401 acre sub-watershed is in open space as the Woodmont Country Club (26 percent) and forest (23 percent) use. Single-family residential and transportation make up another 29 percent of the total. Transportation includes Interstate I-270, Tower Oaks Boulevard and roads associated with the residential areas. There are also industrial, institutional and commercial areas

scattered throughout the sub-watershed resulting in a total impervious cover of 24 percent. Montgomery County operates a vehicle maintenance yard on the southeast corner of Seven Locks Road and Wootton Parkway. A summary of the land use and imperviousness is provided in Table 25.

TABLE 25: LOWER CABIN JOHN CREEK LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Turf in Open Space	13	3%	1	8%	0%
Forest	93	23%	0	0%	0%
Managed Turf on Golf Course	106	26%	10	9%	2%
Water	4	1%	0	0%	0%
SUBTOTAL OPEN SPACE	**215**	**54%**	**11**	**5%**	**3%**
Medium-Density Residential	63	16%	18	29%	4%
High-Density Residential	0	0%	0	0%	0%
Multi-Family Residential	0	0%	0	0%	0%
SUBTOTAL RESIDENTIAL	**63**	**16%**	**18**	**29%**	**4%**
Institutional	14	3%	9	64%	2%
Commercial	21	5%	10	48%	2%
Industrial	26	6%	17	65%	4%
Transportation	62	15%	30	48%	7%
TOTAL	**401**	**100%**	**95**	**24%**	**24%**

5.5.2 Stormwater Management

As shown on Table 26, there are 9 public and 11 private stormwater management facilities in the Lower Cabin John Creek sub-watershed. The public facilities include the North Farm dry pond behind Farm Haven Drive and the Tower Oaks Wetland Marsh, which was not yet converted to final stormwater management from sediment control conditions as of 2011. They also include seven oil/grit separators along Tower Oaks Boulevard. They provide treatment for more than 40 percent of the impervious area in the sub-watershed.

TABLE 26: LOWER CABIN JOHN CREEK STORMWATER MANAGEMENT FACILITIES

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Public			
Oil/Grit Separator	7	N/A	N/A
Pond-wetland, extended detention (under construction)	1	66	29
Dry Pond, Quantity Control Only	1	13	3
Underground Sand Filter	1	N/A	N/A
Total Public	**10**	**>79**	**>32**
Private		N/A	N/A

Dry Pond, Quality Control Only	1	9	5
Sand Filter	3	N/A	N/A
Sand Filter, Underground	2	N/A	N/A
Proprietary Sediment Separator	1	N/A	N/A
Underground Detention	4	N/A	N/A
Total Private	**11**	**>9**	**>5**

5.5.3 STREAM ASSESSMENT

1994 Conditions

This stream reach was found to have major stream problems that include high riffle embeddedness, and a high sand-silt bedload. In-stream habitat and water quality were rated as fair with moderate macroinvertebrate and fish diversity. Six fish species were noted upstream of the confluence with Dawson Farm Creek while pollutant tolerant blacknose dace were noted downstream. In addition, moderate-severe channel erosion was noted upstream of Dawson Farm Creek confluence while moderate channel erosion was noted downstream of this point. Fish barriers include the Tower Oaks Boulevard culvert and two log jams.

2010 Conditions

The mainstem channel of the Lower Cabin John sub-watershed was broken up into two unique assessment reaches (Reaches 001 and 003) based on habitat. Five distinct tributaries also drain to the mainstem channel within Lower Cabin John (Reaches 002, 004, 005, 006 and 007).

The mainstem reaches of the sub-watershed are moderately eroded and actively widening. There are areas of severe erosion along several outer meanders with sediment deposition in the form of gravel and sand bars on inner meanders. In addition to this natural erosion, human impacts on Reach 001 are severe. A person was encountered during the field work using a shovel to cut off existing meanders thus straightening the channel. This disturbance has occurred along approximately 700 feet of the reach. (City staff were not able to find this person after the report of his illegal activities.) Habitat for the mainstem reaches are in the low-suboptimal to high-marginal range with areas of heavy algae. Riffles and pools are the dominant habitat.

FIGURE 34: GRAVEL POINT BAR AND WIDENING CHANNEL (REACH LCJ-001)

Reaches that are tributaries to the mainstem in the sub-watershed are moderately to severely eroded with many areas of channel restoration and spot stabilization. Headcutting was noted on several channels. The riparian buffer along many reaches is narrow with extensive invasive species. Habitat was primarily in the poor range due to erosion, low flow and water quality. The water quality for several reaches is being impacted by landscaping practices at the Woodmont Country Club.

Geomorphic Assessment.

A geomorphic assessment was performed on Reach 001 of the Lower Cabin John Creek sub-watershed. Based on the surveyed information, this reach was identified as an F4 channel. The assessed reach is sinuous and overwidened with moderate to severe erosion on outside meanders. Large point bars with sand and gravel were prevalent. The channel is entrenched and overwidened with no apparent floodplain access even during high flow events. A resident is excavating portions of this surveyed reach with a shovel, effectively shortening meanders and creating a single long riffle instead of a riffle/pool morphology. This channel appears unstable and is moving large amounts of sediment during high flow events. No stream restoration, stabilization, or bank armoring was present in the assessed reach.

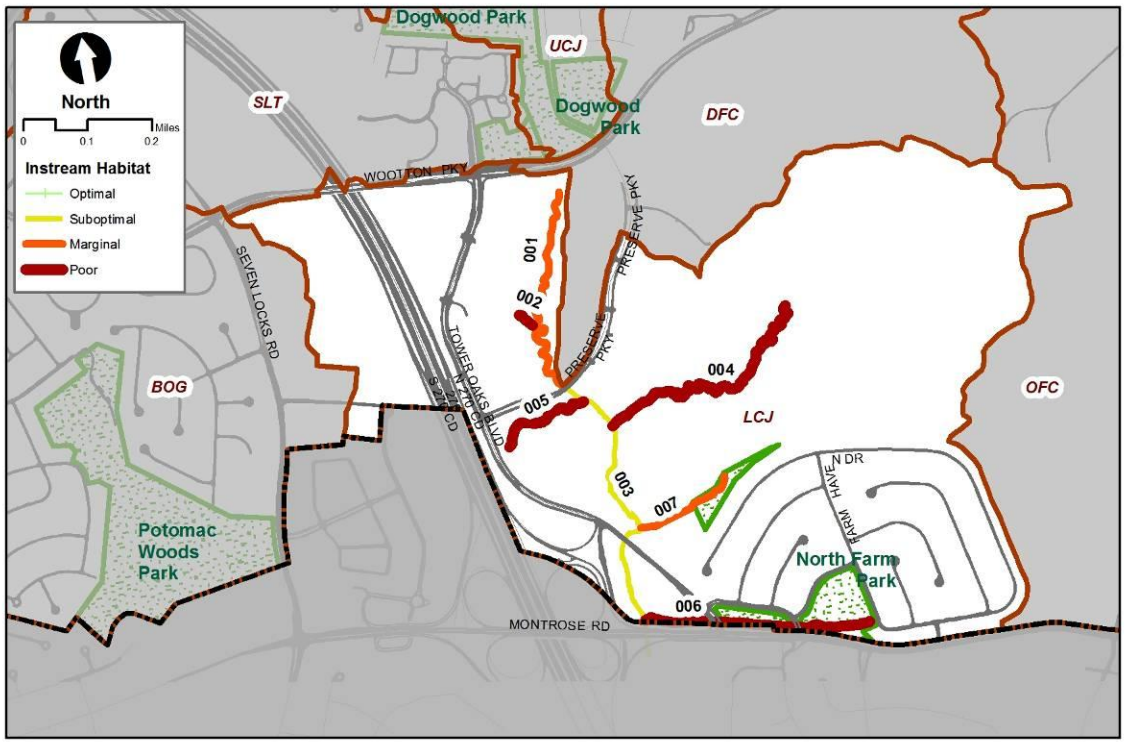


FIGURE 35: LOWER CABIN JOHN HABITAT ASSESSMENT

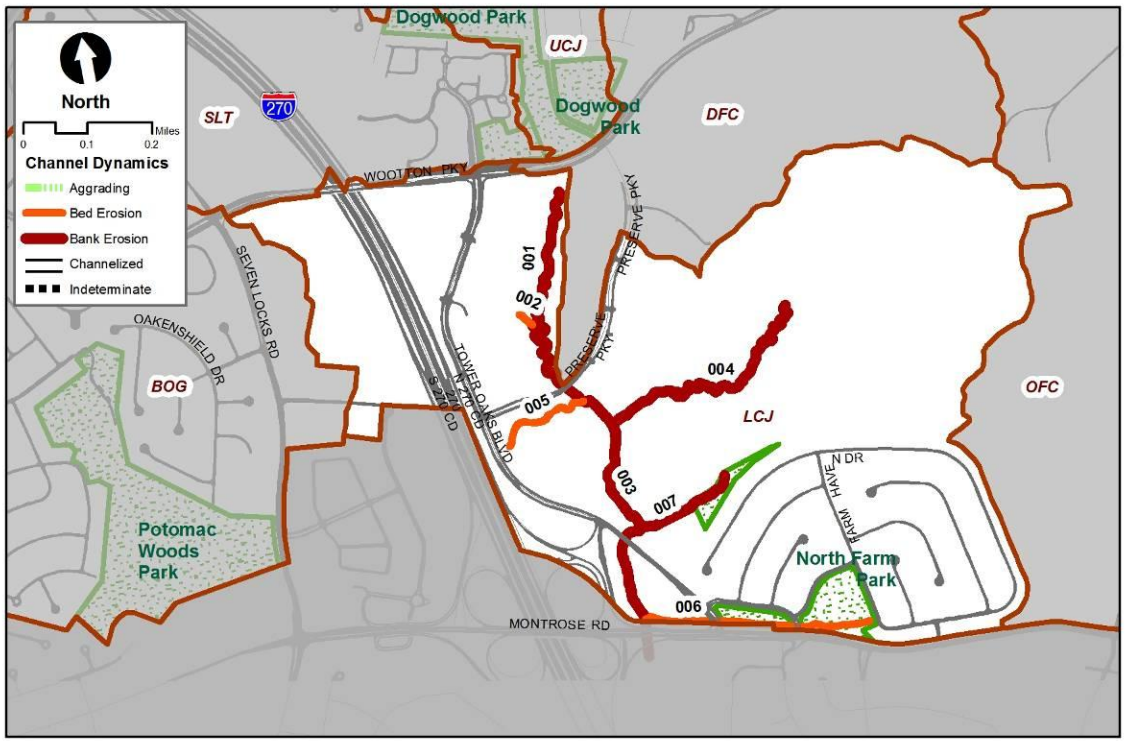


FIGURE 36: LOWER CABIN JOHN CHANNEL DYNAMICS ASSESSMENT

Water Quality.

In-situ sampling completed in the Lower Cabin John Creek sub-watershed did not indicate that pH or DO were outside of COMAR standards. As with other sub-watersheds, conductivity levels were elevated on most tributaries. The lowest conductance was reported on Reach 004, which is well-buffered by forest and does not receive large inputs from commercial or residential properties. This reach was dry during the summer sampling. Turbidity was higher than the standard for several of the samples during both sampling dates. There were no grab samples collected in this sub-watershed. Results of water quality measurements are shown in Table 27. Values higher than the reference range are shown in bold.

TABLE 27: LOWER CABIN JOHN CREEK WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
Reference			247	5.0	2.825	6.5-8.5	500	0.04	1.295	0.3	0.995	400
LCJ#1	Apr-10	13.2	**539.0**	9.5	**3.06**	7.8	---	---	---	---	---	---
LCJ#1	Sep-10	18.6	**587.0**	7.8	1.22	7.37	---	---	---	---	---	---
LCJ#2	Apr-10	12.7	**522.0**	8.6	2.03	7.6	---	---	---	---	---	---
LCJ#2	Sep-10	16.4	**460.9**	7.4	1.16	7.46	---	---	---	---	---	---
LCJ#3	Apr-10	12.3	225.7	9.7	**2.91**	7.7	---	---	---	---	---	---
LCJ#3	Sep-10	17.5	232.2	7.0	**6.75**	7.56	---	---	---	---	---	---
LCJ#4	Apr-10	13.8	172.2	9.1	**5.76**	7.9	---	---	---	---	---	---
LCJ#4	Sep-10	DRY					---	---	---	---	---	---

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
LCJ#5	Apr-10	12.1	**1185.0**	10	1.16	7.6	---	---	---	---	---	---
LCJ#5	Sep-10	17.4	**1430.0**	7.4	0.76	7.32	---	---	---	---	---	---
LCJ#6	Apr-10	14.2	**720.0**	8.9	**8.48**	7.7	---	---	---	---	---	---

5.5.4 HSI/NSA Investigation

Much of the land use in Lower Cabin John Creek remains as open space or golf course. Two hotspot sites were investigated, along with two neighborhoods making up all of the residential area.

The two hotspots were the Woodmont Country Club facilities (H-104) and the Montgomery County Seven Locks Maintenance Yard vehicle facility (H-101). The Country Club facilities included vehicle operations for golf cart fueling, repair and washing, material storage, (soil and mulch) and waste management. This site was rated a potential hotspot for severity.

Potential pollution sources for the vehicle shop included vehicle operations (repair, fueling, washing, and storage), outdoor gravel storage, and waste materials, garbage and construction materials, and the physical plant. Vehicles were stored outside, and leaks were observed. Dumpsters were overflowing. One parking lot was in poor enough condition to be contributing sediment when it rains. Severity was rated as confirmed.

The two NSA sites were part of the North Farm subdivision, a single-family detached development on 1/4 acre lots built in the late 1970s and 1980s. Very little infill or redevelopment was noted. All the lawns were maintained with either high or medium management status. A large percentage of the downspouts were disconnected from impervious surfaces. Some rain garden potential was noted in each neighborhood for treatment of rooftop, driveway and sidewalk runoff. Stormwater is conveyed through curb, gutter, inlets, and pipes, and a portion of the neighborhood is treated by an existing dry pond. They were both rated moderate for pollution potential.

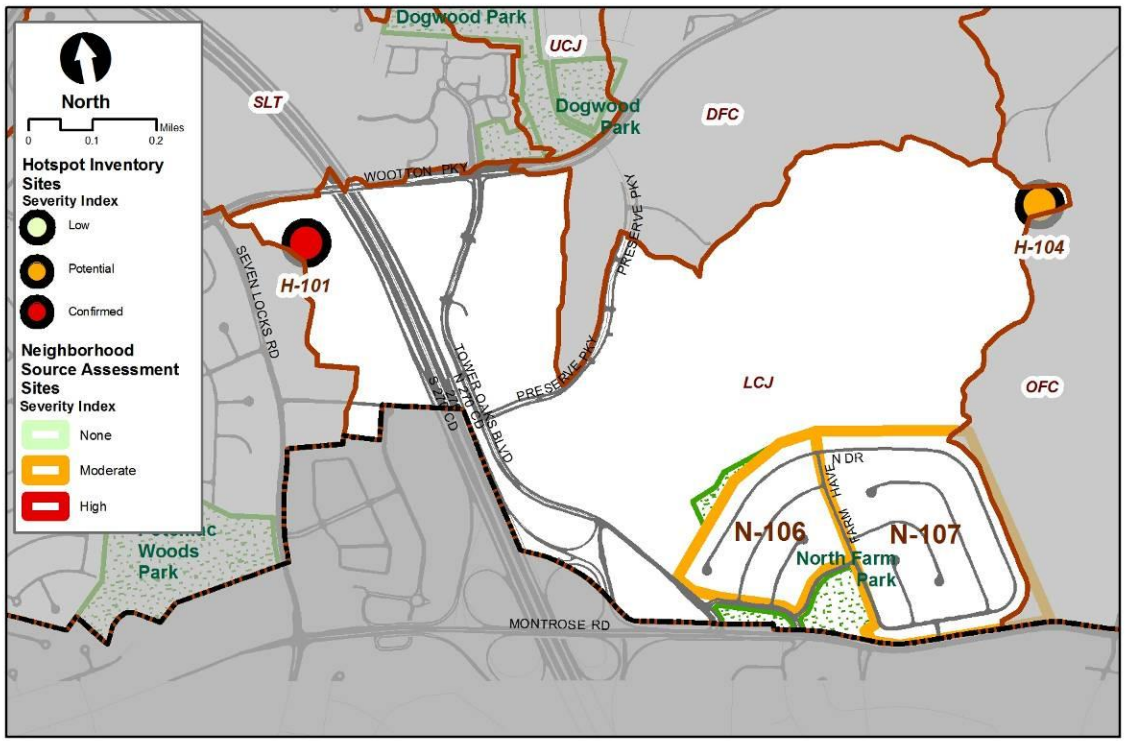


FIGURE 37: LOWER CABIN JOHN NSA / HSI RESULTS

5.5.5 Summary of Problems

Streams

- Reach 001 is sinuous and unstable with over-widening in many places. Large gravel and sand bars have formed on the inside meanders of the channel;
- Reach 002 is not stabilized and is severely eroded where the silt fence ends from the recent stormwater management facility project of Tower Oaks Wetland Marsh (still operating under sediment control);
- The downstream portion of Reach 003 is buffered well on both sides; however, moderate erosion is occurring due to channel widening. Severe erosion in the form of headcutting was found near an outfall draining the Montrose Road I-270 interchange ramps. Erosion has exposed a sewer manhole and pipe within the stream channel (Reach 005) near a GEICO warehouse off of Tower Oaks Boulevard;
- The upstream and middle portions of Reach 004 tend to be highly sinuous and eroded. It appears this channel is widening and is beginning to downcut from the lower portion of the reach to the upper portion of the reach. The water quality in this reach appeared to be impacted by Woodmont Country Club;
- The downstream portion of Reach 005 was ineffectively stabilized when Preserve Pkwy was built in the early 2000s. Most of the riprap from this past stabilization has washed away, allowing erosion and headcutting to occur. The middle and upstream portions are severely eroded and entrenched. Active downcutting and headcutting are occurring in several areas with significant losses of bed and bank materials;

- The downstream portion of Reach 006 is incised, eroded and straight. The buffer along the downstream portion of this reach has been partially removed due to overhead power lines above the channel;
- The downstream section of Reach 007 has moderate erosion from the confluence with the Lower Cabin John mainstem to the gabion baskets found below the culvert running under a commercial business park along Tower Oaks Boulevard.

Water Quality

- Runoff from older single-family detached residential neighborhoods is not treated with SWM facilities;
- There were no grab samples for nutrient testing taken in this sub-watershed.

HSI/NSA

- Site H-101, the Seven Locks Light Vehicle Shop, was a confirmed hotspot for vehicle repair and storage issues, including observed leaks. Waste management was also a concern;
- The Woodmont Country Club (H-104) was identified as a potential hotspot due to outdoor material storage of soil, mulch, and grass clippings, uncovered fueling area, high-maintenance turf management, and golf cart maintenance areas;
- The newer section of North Farm (Site N-107) had low tree canopy coverage and high management lawns. Both situations can lead to higher rates of runoff and pollutant loading from excess fertilizer or pesticide use.

5.5.6 Sub-watershed Restoration Goals

- Restore actively eroding streams and protect vulnerable areas identified in the stream assessment. Stream restoration sites R-72S through R-76S address this goal;
- Identify water quality retrofit measures that could be implemented to treat runoff from areas with either no treatment or only quantity treatment. Pond retrofit sites R-16b, R-16c, R-19b, and R-50c would add quality control to existing quantity treatment. New pond site R-16d and the parking lot retrofit sites could provide quality control where it does not currently exist. The RSC project sites R-73S, R-74S, and R-75S would also provide filtration for smaller runoff events;
- Target residential neighborhoods for outreach and education for lower impact lawn care measures;
- Work with Montgomery County to ensure the Seven Locks Maintenance Yard is not violating the City's Water Quality Protection Ordinance and to implement a more effective Stormwater Pollution Prevention Plan. Ask for inspection reports on the facility to be copied to the City, and for notice of any spills or sediment discharges;
- Explore methods of course maintenance with Woodmont Country Club that could provide lower impacts to the sub-watershed. During the field assessment, Woodmont staff expressed interest in greening efforts and pollution prevention practices as the golf course is seeking Audubon certification.

5.5.7 CANDIDATE SITES FOR IMPROVEMENT

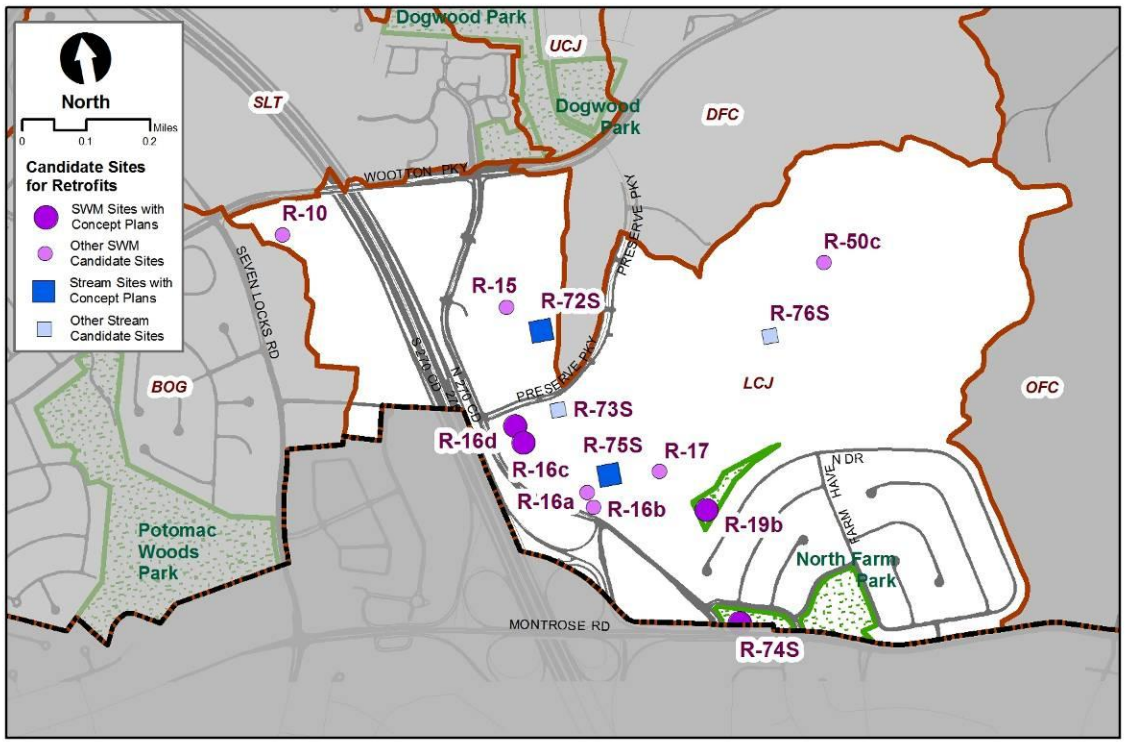


FIGURE 38: LOWER CABIN JOHN, CANDIDATE SITES FOR IMPROVEMENTS

TABLE 28: LOWER CABIN JOHN CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-10		Montgomery County Maintenance Yard	Parking lot and municipal maintenance	County	Provide on-site pond retrofit opportunity. Site has Stormceptor	Outreach-enforcement through Water Quality Ordinance	City's Tower Oaks Wetland Marsh is downstream and can provide quality and quantity controls. Work with County to implement more effective best management practices on operations.
R-15		Boston Property Office/parking garage	Existing Pond	Private	Site has surface sand filter and underground pipe storage built in early 2000s.	Encourage through redevelopment SWM requirements	Onsite SWM meets MDE 2000 SWM requirements.
R-16a		GEICO site	Parking Lot	Private	Provide on-site opportunity, rooftop disconnection	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-16b		1976-01201	Existing Pond	Private	Provide opportunity to improve water quality treatment	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-16c and R-16d		**SE corner of Tower Oaks Blvd/Preserve Pkwy – next to GEICO**	**Existing Pond**	**City**	**Proposed new extended detention pond at Tower Oaks Blvd and Preserve Pkwy to treat runoff from adjacent storm drains and I-270.**	**Pond Retrofit**	**Perform field assessment on these two adjacent parcels owned by City.**
R-17			Parking Lot	Private	Provide on-site opportunity at apartment complex	Encourage through redevelopment SWM requirements	Retrofits on privately owned property were low priority

TABLE 28: LOWER CABIN JOHN CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-19b	**96-14**	**North Farm 77-01020 – dry pond behind Farm Haven Dr.**	**Existing Pond**	**City**	**Proposed project was to convert dry detention pond to extended detention pond, may sacrifice higher storms to treat smaller storms. Drainage area too large for ESD, too small for wet pond. Investigate other in-pond water quality alternatives**	**Pond Retrofit**	**Perform field assessment**
R-50c		Wet pond due west from clubhouse	Existing Pond	Woodmont Country Club	Provide opportunities to enhance water quality treatment at existing pond	No action	This pond was retrofit by Country Club in mid-2000s to meet MDE 2000 SWM requirements. No further retrofit needed at this time.
R-72S		**LCJ Mainstem**	**Stream Restoration**	**City**	**Stream restoration, Buffer restoration, overwidened, incised, impacts from residents**	**Stream restoration**	**Develop concept plan based on field work during stream assessment**
R-73S		**LCJ Tributary**	**Stream Restoration**	**City**	**RSC, Stream restoration, very eroded, large headcut area in upstream portion**	**RSC**	**Potential for stream restoration project – use as replacement for R-16c/ R-16d SWM concept.**
R-74S		**North Farm Park Tributary**	**3 Storm Drain Outfalls and Channel**	**City**	**RSC, Stream restoration upstream, New in-stream facility downstream, buffer restoration.**	**RSC**	**Develop concept plan based on field work during stream assessment**
R-75S		LCJ Mainstem between GEICO site and Tower Oaks Blvd	Stream Restoration	Private	Erosion affecting sewer, stream restoration, outfall stabilization, RSC, overwidened	RSC	Develop concept plan based on field work during stream assessment; low priority because channel is private

TABLE 28: LOWER CABIN JOHN CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-76S		Woodmont CC LCJ Tributary (downstream of R-50 pond)	Stream Restoration	Private	RSC, stream restoration, outfall stabilization, very sinuous and eroded	Encourage through redevelopment SWM requirements	Retrofits related to Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action

Concept Plans were prepared for bolded projects

5.5.8 FIELD ASSESSMENT AND CONCEPT DESIGN

R-16C GEICO Pond Retrofit, and R-16D Tower Oaks / Preserve Parkway New Pond Concept plans, included in Appendix A, were developed for these two abutting sites that proposed enlarging the existing dry pond and converting it into an extended detention pond with micropools. Due to high cost and tree impacts, this project was replaced with a more beneficial and cost-effective stream restoration project (see description below for site R-73S) using the RSC method.

R-19B North Farm Pond Retrofit. This is an existing dry pond with a 13-acre drainage area built in 1978 and located behind a residential area on Farm Haven Court. Although DPW records are incomplete, the pond likely provides quantity management of the 2-year and 10-year storm events, but it does not provide any water quality treatment. The existing dry pond is currently in good condition, and does not need major maintenance at this time.

This project is recommended through the CIP for a conversion to a facility that maximizes water quality treatment. Water quantity control is not a priority because of the small pond's placement in a much larger watershed. Final design will be postponed in the CIP schedule pending SWM treatment advancements. The City will re-evaluate this project when new SWM treatment methods (filtration or otherwise) for drainage areas between 5-30 acres that fit the available storage space become available, or when the corrugated metal pipe control structure requires replacement. Coordination with the Department of Recreation and Parks and the surrounding neighbors will occur at time of design.

R72S Lower Cabin John Creek Stream Restoration The project site is a reach of the Lower Cabin John Mainstem located in the forested area east of Tower Oaks Boulevard and south of Wootton Parkway. This is the west branch of the two parallel branches of Cabin John Creek in this stream valley. Spot stabilization has been placed around Preserve Parkway's crossing. Although this parcel is privately owned as of 2011, it is in the process of being dedicated to the City as public park land. Channel widening, downcutting, and moderate bank erosion was observed throughout the main channel.

This project is recommended for stream stabilization through the CIP. The total length of channel bank to be restored is approximately 1,230 feet. Staff recommends that this reach continue to be monitored for worsening conditions, and programmed into CIP after more severe erosion problems have been addressed at Dogwood Park, Montrose Woods Park, and Mt. Vernon Place. Storm drain maintenance is also needed for the culverts on this tributary at Wootton Parkway and Preserve Parkway to remove accumulated sediment and vegetation at the outlets. Coordination with the Department of Recreation and Parks and any commercial properties affected by access/staging issues will occur at time of design. (Note: R-70S, R-72S and R-73S should be designed and constructed at the same time since they are adjacent to each other.)

R73S Stream Restoration (Supersedes SWM concepts for R-16C and R-16D) This storm drain outfall channel located directly downstream of the 48 inch culvert under Tower Oaks Boulevard south of the western end of Preserve Parkway is actively incising and headcutting with moderate to severe erosion. The channel has high loadings of sediment and trash from nearby I-270 and the upstream drainage area. There is an existing dry SWM pond adjacent to this channel that controls roughly 3 acres of drainage area from the GEICO property. The pond's corrugated metal riser and barrel through the dam have deteriorated, and the pond provides no benefit to either water quality or channel erosion protection. Both the outfall channel and the dry pond are owned by the City.

This project is recommended for stream stabilization/RSC through the CIP. The project will begin at the Tower Oaks Boulevard culvert endwall and extend downstream to the confluence with mainstem Cabin John Creek, a distance of about 930 feet. As part of the project, the existing dry pond will be

decommissioned (i.e., have the failed corrugated metal pipe riser and pond barrel removed and the dam partially breached) to integrate the flow from the GEICO site into the new RSC system.

Staff recommends that this reach continue to be monitored for worsening conditions, and programmed into CIP after more severe erosion problems have been addressed at Dogwood Park, Montrose Woods Park, and Mt. Vernon Place. Coordination with the Department of Recreation and Parks and GEICO will occur at time of design. (Note: R-70S, R-72S, and R-73S may be designed and constructed at the same time since they are located adjacent to each other.)

R74S North Farm Park Stream Restoration The project site is located entirely within North Farm Park. The 520 linear foot stream channel is incised with moderate to severe erosion occurring throughout and areas of narrow buffer. The upstream portion of the channel has been lined with rip rap boulders. The downstream portion of the channel is natural with 8 foot slightly eroded banks.

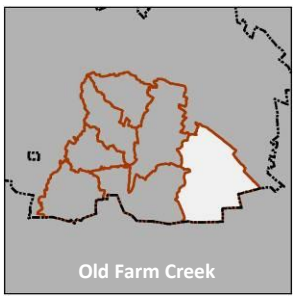
This project is not recommended for stream restoration due to much of the channel either being stable or previously protected with riprap that is still in good condition. Also, several storm drains emerge into this channel, giving it a large drainage area with four substantial storm drain outfalls. More experience is needed with the RSC technique before using it on this high-volume channel.

This reach shows slight erosion and has few bends. The upstream end by tennis courts was previously stabilized with rip-rap and appears stable. The middle section near playground & basketball courts is moderately eroded in spots. There currently is deposition of unconsolidated sediment and concrete washoff or road grit on banks in the middle section, but removal would cause more sedimentation than taking no action. Although the channel is poorly aligned with the culvert headwall under North Farm Drive, there is little scour/erosion here. The lower reach between North Farm Drive and Tower Oaks Blvd. is very stable. Staff recommends that this reach be monitored for worsening erosion and re-assessed in the next study.

R75S Lower Cabin John Creek Stream Restoration This project is located on the Lower Cabin John Mainstem located south of Preserve Parkway and upstream of Tower Oaks Boulevard. Channel widening, downcutting, and bank erosion was observed throughout 1,150 linear feet of stream channel. An existing City sanitary sewer pipe crosses the stream channel near the north limit of the project reach. Bank erosion in this area has exposed pipes and manhole boxes, which have created obstructions in the channel leading to further degradation of the surrounding area. This sewer was lined by the City in 2010 to protect against infiltration and inflow, but the pipe and manholes were left exposed.

This project is not recommended for inclusion in the SWM CIP because the stream is on private commercial property, which the City SWM program does not financially support at this time. The City may consider this as part of a Sanitary Sewer CIP project to protect the sewer pipe against further exposure and possible damage.

5.6 OLD FARM CREEK



This sub-watershed is bound along the east by Rockville Pike (MD 355) and to the south by Montrose Road. The headwaters originate within the Woodmont Country Club near Rockville Pike. West of East Jefferson Street, a section of the stream is piped before it flows south into Montgomery County near Montrose Road.

5.6.1 LAND USE AND IMPERVIOUS AREA

The land use in this 545-acre sub-watershed is primarily golf course (30 percent of the sub-watershed); commercial areas make up another 17 percent and forest 12 percent. This sub-watershed has the

highest percentage of commercial and high-density residential land use in the Cabin John Creek watershed, but that is balanced by the low impervious area of the golf course, which leads to an average impervious cover of 35 percent (5 percent transportation). A summary of the land use and imperviousness within the Old Farm Creek sub-watershed is provided in Table 29.

TABLE 29: OLD FARM CREEK LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Turf in Open Space	6	1%	1	17%	0%
Forest	67	12%	2	3%	0%
Managed Turf on Golf Course	165	30%	9	5%	2%
Water	9	2%	0	0%	0%
SUBTOTAL OPEN SPACE	**248**	**46%**	**11**	**4%**	**2%**
Medium-Density Residential	53	10%	15	28%	3%
High-Density Residential	13	2%	6	46%	1%
Multi-Family Residential	77	14%	44	57%	8%
SUBTOTAL RESIDENTIAL	**142**	**26%**	**65**	**46%**	**12%**
Institutional	9	2%	5	56%	1%
Commercial	95	17%	82	86%	15%
Industrial	0	0%	0	0%	0%
Transportation	50	9%	27	54%	5%
TOTAL	**545**	**100%**	**190**	**35%**	**35%**

5.6.2 Stormwater Management

There are 52 private stormwater management facilities in the Old Farm Creek sub-watershed and no public facilities (see Table 30). Most of the private facilities are in the commercial areas adjacent to Rockville Pike and serve single parcels or parts of developments. Approximately 67 impervious acres in this area are treated with a mix of quantity and quality controls, or 35 percent of the impervious area. The wet pond is on Woodmont Country Club where it treats a 40-acre drainage area, but only 1 impervious acre, in the center of the Country Club.

TABLE 30: OLD FARM CREEK STORMWATER MANAGEMENT FACILITIES

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Private			
Oil/Grit Separator	2	0	0
Bioretention, Quality Control	1	N/A	N/A
Filter	9	8	7
Infiltration Trench	4	7	6
Infiltration Trench, Quality And Quantity Control/ Stormceptor	1	N/A	N/A
Dry Pond, Quality Control Only	1	2	2
Wet Pond, Quality Control And Extended Detention	1	40	1
Sand Filter, Underground	4	23	20
Proprietary Sediment Separator	7	13	11

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Stormceptor	1	N/A	N/A
Underground Detention	10	21	17
Underground Practice	4	5	2
Vegetated Swale	1	1	1
Unknown	6	N/A	N/A
Total Private	**52**	**119**	**67**

5.6.3 STREAM ASSESSMENT

1994 Conditions

Major stream problems in 1994 included high riffle embeddedness, loss of stream habitat through piping, and moderate to high sand-silt bedload in the lower stream reaches. Macroinvertebrate diversity was fair with a low number of individuals present and six fish species were observed. An eight foot diameter pipe, 1,000 feet long, was noted as a fish barrier.

2010 Conditions

The mainstem channel of the Old Farm Creek sub-watershed was broken up into two unique assessment reaches (Reaches 015 and 016) based on habitat characteristics. There are multiple tributary channels to the mainstem.

FIGURE 39: DEBRIS JAM CONTRIBUTING TO EROSION (REACH OFC-015)

In general, the mainstem channel in the Old Farm Creek sub-watershed is experiencing minor to moderate erosion on outer meander bends. There are portions of the channel with bedrock substrate where only minor erosion is occurring and areas that have been stabilized and straightened. The riparian buffer along the downstream portions of the mainstem is intact while the buffer in the upstream portions is narrow with only a few scattered trees. Habitat quality is in the low-marginal to low-suboptimal range with riffles and pools as the dominant habitat. One section of Reach 015 opposite Rollins Avenue has severe erosion, apparently caused by abandoned loose large-diameter concrete pipe

left in the stream channel and an adjacent failing 21" storm drain outfall. These are directing streamflows to the opposite (west) bank which is very steep and has a City playground at the top of the tall bank. The erosion needs to be arrested to keep more of the bank from being undercut, which may threaten the playground.

Tributaries to the mainstem in the sub-watershed are affected by the Woodmont Country Club. These channels are also experiencing erosion along outer meanders except where restoration or spot bank stabilization has occurred. Buffers are generally narrow or absent along many of the tributary reaches and habitat quality ranges from poor to marginal range with low flow, sections of stream bed covered with gabion baskets or reno mattresses to protect utility crossings against erosion, and poor water quality degrading available habitat.

Geomorphic Assessment.

A geomorphic assessment was performed on Reach 015 in the Old Farm Creek sub-watershed. Based on the surveyed information, this reach was identified as an F4 channel. Although the assessed reach was classified as such, this reach differed from other F4 classified channels in the Cabin John watershed. This reach has low sinuosity and appeared mostly stable with only moderate erosion on one outside meander. Despite this stability, the channel is entrenched and overwidened with little floodplain access. Several bedrock outcrops were present in the channel bed and large gravel and small cobbles made up the substrate in the channel, which increases overall stability. Gravel and cobble bars were present, but were relatively small features within the channel. Riffles and runs dominated the reach as the channel had relatively steep slopes.

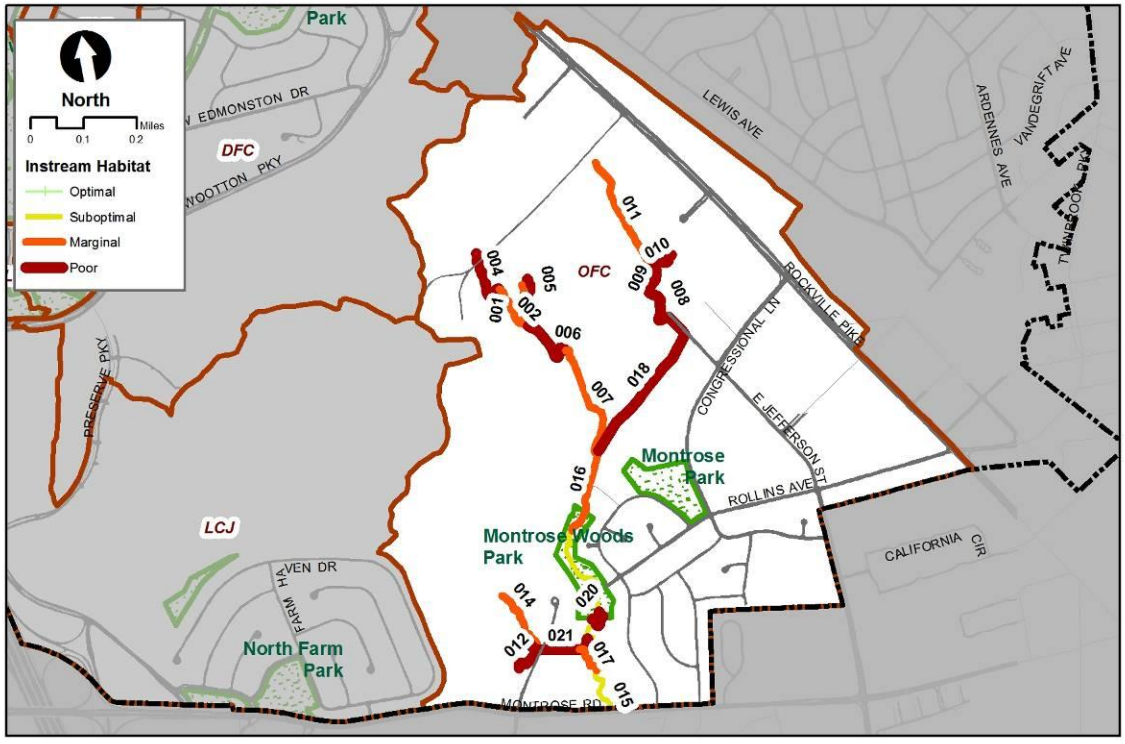


FIGURE 40: OLD FARM CREEK HABITAT ASSESSMENT

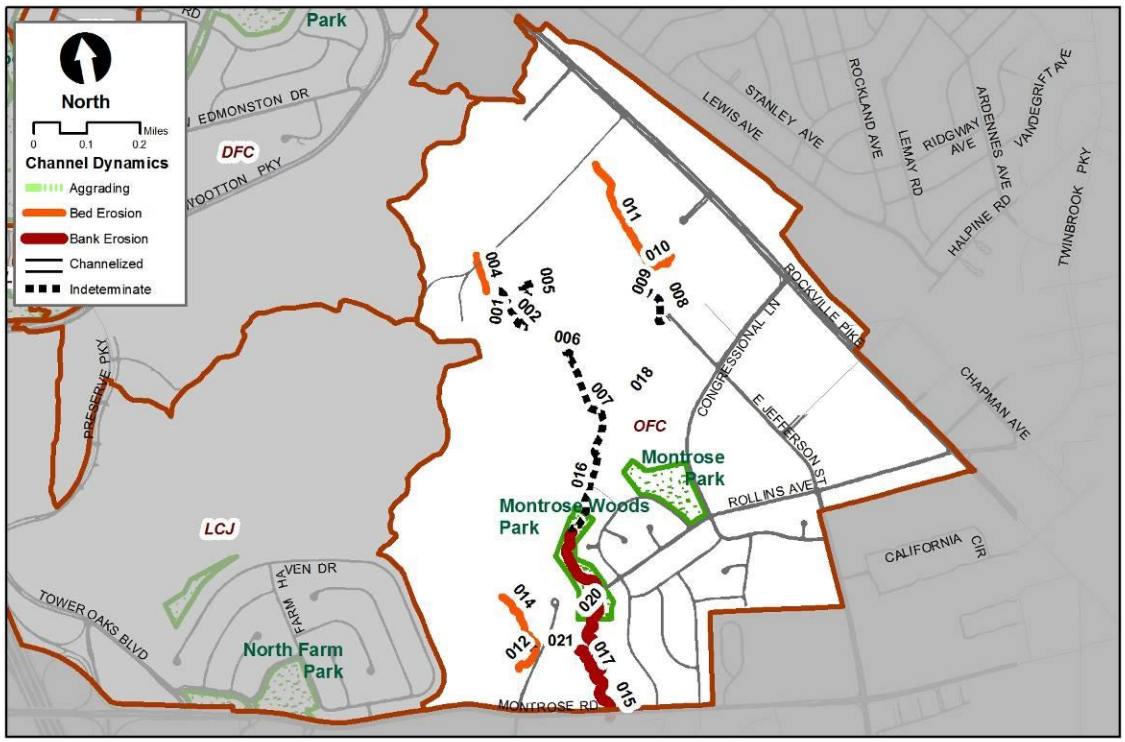


FIGURE 41: OLD FARM CREEK CHANNEL DYNAMICS ASSESSMENT

Water Quality.

In-situ and water quality grab samples taken in the Old Farm Creek sub-watershed did not indicate either pH or DO to be outside of COMAR standards. Conductivity levels were elevated during both sampling dates, especially along reaches draining commercial land uses (OFC#3 and OFC_SD GRAB). Nutrient levels were elevated in both grab samples. These were taken at a point where baseflow from the Rockville Pike corridor (OFC_SD) could be compared with flow from the golf course (OFC_GC). The results showed that nutrient and fecal coliform concentrations were higher from the urbanized area than from the golf course. The storm drain sample (OFC-SD) was higher than the recommended levels for fecal coliform, nitrate+nitrite, TN and TP for both sampling dates. The golf course sample was higher for TKN and TN. Results of water quality measurements are shown in Table 31. Values higher than the reference range are shown in bold.

TABLE 31: OLD FARM CREEK WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
Reference			247	5.0	2.825	6.5-8.5	500	0.04	1.295	0.3	0.995	400
OFC#1	Apr-10	13.5	**336.9**	8.7	1.80	7.8	---	---	---	---	---	---
OFC#1	Sep-10	18.5	**406.9**	8.0	1.68	7.69	---	---	---	---	---	---
OFC#2	Apr-10	12.1	193.3	8.7	**4.96**	7.8	---	---	---	---	---	---
OFC#2	Sep-10	17.5	175.9	6.8	**7.35**	7.62	---	---	---	---	---	---
OFC#3	Apr-10	16.9	**544.0**	4.8	**4.99**	7.6	---	---	---	---	---	---
OFC#3	Sep-10	21.7	**592.0**	7.7	**4.43**	7.69	---	---	---	---	---	---
OFC#4	Apr-10	15.4	**270.3**	9.0	**10.60**	8.0	---	---	---	---	---	---
OFC#4	Sep-10	19.5	**272.6**	6.6	**80.80**	7.74	---	---	---	---	---	---
OFC GC	Apr-10	15.8	163.2	7.9	**7.23**	7.6	1	0.04	**1.5**	**1.0**	0.49	4

TABLE 31: OLD FARM CREEK WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
GRAB												
OFC GC GRAB	Sep-10	DRY										
OFC SD GRAB	Apr-10	14.8	**521.0**	8.6	**3.69**	7.6	<1	**0.06**	**1.9**	**0.9**	**1.0**	460
OFC SD GRAB	Sep-10	20.2	**571.0**	8.2	2.78	7.74	4	**0.32**	**1.3**	<0.5	**1.3**	**>= 24000**

5.6.4 HSI/NSA INVESTIGATION

Approximately half of the area of the Old Farm Creek watershed is made up of a portion of Woodmont Country Club. The remainder of the sub-watershed is developed with intense land uses including commercial activities in the Rockville Pike corridor and a number of housing developments, both multi-family and medium density single-family uses. Four hotspot sites and six neighborhoods were assessed.

Two of the four HSI sites were restaurants. The only potential pollution source at these sites (H-302, H-303) was waste management. Both had issues with dumpster management (Figure 42), but they were rated low severity overall.

The other two sites were a muffler repair shop (H-304) and an auto repair facility (H-305). H-304 had potential pollution sources from vehicle repairs and waste management. It was rated as a potential hotspot for severity. Pollution sources noted at H-305 included vehicle repairs, outdoor storage of car parts, tires, and liquids, and evidence of washwater dumping. It was rated confirmed for severity.

FIGURE 42: OVERFLOWING GREASE TRAP (H-302).

The two single-family detached areas that were assessed were both part of the Montrose community and were adjacent to each other in the lower part of the watershed at the City line. Houses were built on 1/4 acre lots in the early 1960s. No evidence of infill or redevelopment was seen. Lawns were maintained well, but were not high-management status. Stormwater was conveyed through curb, gutter, inlets, and storm drains, and there did not appear to be any existing stormwater management facilities. None of the storm drain inlets were stenciled.

The four multi-family areas were situated throughout the watershed and were a mix of townhouses built in the 1980s, garden apartments and high-rise apartments built in the 1960s. All storm drainage was conveyed through curb, gutter, inlets, and storm drains. No inlets were stenciled. Lawns and common areas were well maintained, and no trash or pet waste was observed. Tree canopy was less than optimum at all the sites, which is to be expected for the higher density developments. However, it could be improved at the single-family residential areas N-108 and N-110. The newer developments were treated with stormwater management facilities. All six areas were rated with low or moderate severity for pollutants.

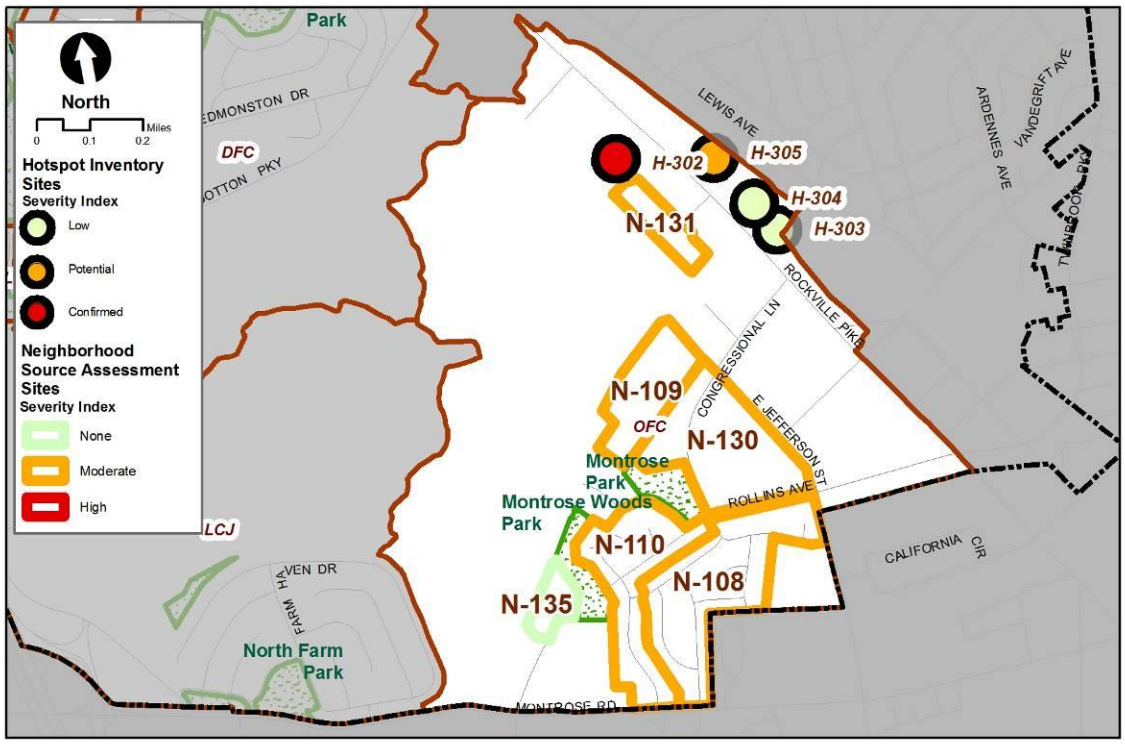


FIGURE 43: OLD FARM CREEK NSA / HSI RESULTS

5.6.5 Summary of Problems

Streams

- The downstream portion of Reach 015 has moderate erosion occurring on meander bends and in straight sections due to channel widening. Several log and debris obstructions were found in the downstream portion of the channel that may be causing the channel to create overflow channels during high flows. The channel and floodplain become steep and narrow in this area and the stream is eroding the valley walls;
- Reach 002 was found to contain a significant amount of algae with several seeps entering the channel. The upstream portion was severely eroded and incised due to an unstabilized lake outfall where riprap has been placed in the channel and has failed;
- The culvert under the Woodmont Country Club entrance road on Reach 004 has a significant amount of downstream scour creating a large pool full of algae;
- Reach 007 has been altered significantly by Woodmont Country Club. The middle portion of the reach is a culvert which flows underneath a fairway and then into a pond. Several seep areas are present at the top of this reach with large amounts of algae;

- Reach 008 is a highly disturbed reach on the Woodmont Country Club property. The riparian buffer consists of mowed grass to the banks of the channel along the entire each. The downstream portion of the channel has been channelized with riprap bed and banks;
- The middle and upstream portions of Reach 011 on Woodmont Country Club had moderate to severe erosion on both outside meanders and straight sections. The upstream portion is incised and the eroded banks are beginning to headcut where concentrated overland flow is present. This section was previously stabilized by the Country Club in the late 1990s, but has deteriorated again;
- An old pipe was found crossing the upstream portion of Reach 012 on Woodmont Country Club. The unidentified pipe was in poor condition and is causing scour and a headcut to form.

Water Quality

- Baseflow grab samples were above the recommended limit for nitrate+nitrite, TKN, TN, TP, and fecal coliform at one or both of the sampling locations;
- The Montrose development was apparently constructed before SWM regulations and its runoff is not treated.

HSI/NSA

- Potential dumping of washwater into storm drain and overflowing grease trap near wetlands at 1319 Rockville Pike (HSI-302). The City took enforcement action under the Water Quality Protection Ordinance on this site, which has been remediated;
- There are overflowing trash and recycling containers at 1488 Rockville Pike (HSI-303);
- There are outdoor materials stored at a garage at 1400 Rockville Pike that should be contained or covered (HIS-305);
- There is a general lack of trash maintenance along the entire length of the east side of Rockville Pike through the sub-watershed;
- Site N-109 (Congressional Towers) has a very large amount of impervious cover with high volumes of runoff impacting adjacent stream. In this same location, dumpsters on the parking lot are present with no setback from stream.

5.6.6 Sub-watershed Restoration Goals

- Restore the actively eroding stream and protect vulnerable areas identified in the stream assessment at site R-80S;
- Continue to inspect and enforce the City's Property Management Code regarding litter, trash, and dumpster maintenance for commercial properties in the sub-watershed;
- Establish a dry weather illicit discharge investigation protocol at the outfalls that drain the commercial areas along Rockville Pike to identify any non-stormwater discharges that should be eliminated;
- Include the single-family residential areas in a program of outreach to plant trees on privately-owned yards;
- Explore methods of course maintenance with Woodmont Country Club that could provide lower impacts to the sub-watershed.

5.6.7 CANDIDATE SITES FOR IMPROVEMENT

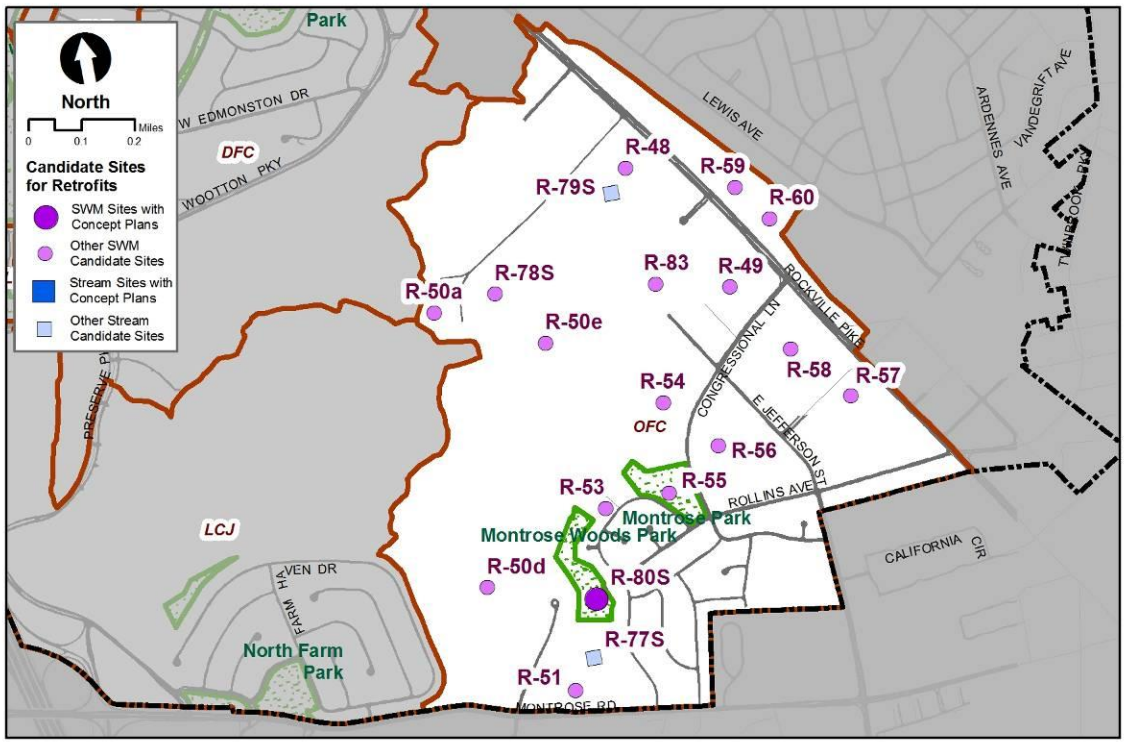


FIGURE 44: OLD FARM CREEK, CANDIDATE SITES FOR IMPROVEMENTS

TABLE 32: OLD FARM CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-48		1319 Rockville Pike	Parking Lot	Private	Provide on-site retrofits, rooftop disconnection	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-49		1501 Rockville Pike	Parking Lot	Private	Site has vegetated swale, underground detention, and oil/grit separator. Provide additional on-site opportunity	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-50a		Woodmont Country Club	Parking Lot / clubhouse	Private	Golf Course Clubhouse. Provide on-site pond retrofit opportunity, rooftop disconnection	Encourage through redevelopment SWM requirements	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action
R-50d		Woodmont Country Club	Existing Pond	Private	Provide opportunities to enhance water quality treatment at existing pond	Encourage through redevelopment SWM requirements	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action
R-50e		Woodmont Country Club	Existing Pond	Private	Location is along stream. Provide opportunities to enhance water quality treatment at existing pond	Encourage through redevelopment SWM requirements	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action
R-51		St. Elizabeth's Catholic Church/School	Parking Lot	Private	Existing bioretention on site	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority

TABLE 32: OLD FARM CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-53		Private Swim Club	Parking Lot	Private	Onsite SWM built in early 2000s.	Encourage through redevelopment SWM requirements	Onsite SWM meets MDE 2000 SWM requirements.
R-54		Congressional Towers Apartments	Parking Lot	Private	Site identified during NSA. Provide on-site pond retrofits, rooftop disconnection	Encourage through redevelopment SWM requirements	Site is feasible based on flow and underdrain potential; however retrofits on privately-owned property that could be installed with redevelopment are low priority
R-55		Montrose Park	Conveyance System	Public	Park Land. Provide on-site and demonstration opportunity.	No action	Insufficient space to implement retrofits without major impact to recreational facilities
R-56		200 Congressional Lane	Conveyance System	Private	Site identified during NSA (N-130). Retrofit concrete channel for on-site storage.	Encourage through redevelopment SWM requirements	Retrofits on privately owned property were low priority
R-57		1701 Rockville Pike	Parking Lot	Private	Provide on-site treatment opportunity, rooftop disconnection	Encourage through redevelopment SWM requirements	Already treated by filtration systems. Retrofits on privately owned property were low priority
R-58		1601 Rockville Pike	Parking Lot	Private	Site has underground sand filter. Provide additional on-site pond retrofit opportunity.	Encourage through redevelopment SWM requirements	Already treated by underground sand filter. Retrofits on privately owned property were low priority
R-59		1450 Rockville Pike	Parking Lot	Private	Provide on-site pond retrofit opportunity, rooftop disconnection	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority

TABLE 32: OLD FARM CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-60		1488 Rockville Pike	Parking Lot	Private	Provide on-site pond retrofit opportunity, rooftop disconnection	Encourage through redevelopment SWM requirements	Retrofits on privately owned commercial property that could be installed with redevelopment are low priority
R-77S		OFC Mainstem – St. Elizabeth's Catholic Church/School	Stream Restoration	Private	Stream restoration, obstruction removal	Encourage through redevelopment SWM requirements	Retrofits on privately owned property were low priority
R-78S		Woodmont Country Club tributary	Existing Pond	Private	Provide opportunities to enhance water quality treatment at existing pond, stabilize outlet channel	Encourage through redevelopment SWM requirements	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action
R-79S		Woodmont CC Channel/Outfall	Stream Restoration	Private	Outfall stabilization, buffer restoration, stream restoration	Encourage through redevelopment SWM requirements	Retrofits in Woodmont Country Club deferred to redevelopment review or Water Quality Ordinance action
R-80S	**96-16**	**Montrose Woods Park- (1996 Watershed Plan pond site for Montrose Woods Park)**	**Stream restoration**	**City**	**1996 proposed pond retrofit would be placed in a perennial stream channel. Constraints include permit issues, loss of park area and tree, steep slopes and little storage. Now recommended to fix channel and outfall erosion at this site to repair severe bank erosion in park and remove concrete debris.**	**Stream restoration, storm drain outfall repair**	**Develop concept plan based on field work during stream assessment**

TABLE 32: OLD FARM CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-83	96-15	Woodmont Country Club – 1996 Watershed Plan – pond retrofit proposal	Existing Pond	Private	Proposed pond retrofit is on private property with no storage potential currently. Most golf course ponds were not designed to be SWM ponds. Pond is currently an in-stream wet pond.	No action	Proposed project is no longer feasible

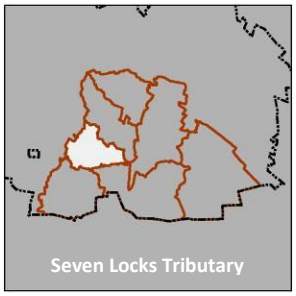
Concept plans were prepared for bolded projects

5.6.8 *Field Assessment and Concept Design*

R-80S Montrose Park Stream Restoration The existing stream channel located between Rollins Avenue and Tildenwood Drive is undergoing severe bank erosion; and a 21" storm drain outfall is damaged with several sections of concrete pipe laying in the channel. This project is entirely located within Montrose Park and is characterized by steep, forested slopes. The mainstem's severe erosion is approximately 100 feet long with a bare-dirt bank height of roughly 20 feet adjacent to a playground located next to Tildenwood Drive.

This project is recommended for immediate stream stabilization and storm drain repair through the CIP. Proposed restoration for this project includes stabilizing the existing stream channel with imbricated stone walls, regrading existing valley wall slopes, and replacing the storm drain outfall, as well as removing loose pipes from the stream bed that are exacerbating the erosion. Until implementation, DPW should monitor this site for further erosion that would threaten the City playground. Partial access to the stream is available across a sanitary sewer access path from Rollins Avenue that was last used by the City in 2010. Coordination with the Department of Recreation and Parks, Chadsberry Homeowners Association, and the surrounding neighbors will occur at time of design.

5.7 SEVEN LOCKS TRIBUTARY



The tributary drains from west to east from Potomac Valley Road through forested land to where it joins the Lower Cabin John Creek main stem at Wootton Parkway. A small tributary that drains the Montgomery County Detention Center runs under I-270 from the west.

5.7.1 *Land Use and Impervious Area*

This sub-watershed is the smallest of the seven at 182 acres. Forest, transportation, and medium-density residential land uses are fairly evenly represented in the sub-watershed, with I-270 bisecting the sub-watershed and making up the bulk of the transportation land use. With the County Detention Center adjacent to I-270, the institutional land use makes up the next largest percentage. Overall, the sub-watershed is 31 percent impervious (12 percent transportation). Additional development is eventually expected through Reaches 005 and 006 in the middle of the sub-watershed on the east side of I-270. A summary of the land use and imperviousness within the Seven Locks Tributary sub-watershed is provided in Table 33.

TABLE 33: SEVEN LOCKS TRIBUTARY LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Turf in Open Space	3	2%	0	0%	0%
Forest	47	26%	0	0%	0%
Managed Turf on Golf Course	0	0%	0	0%	0%
Water	2	1%	0	0%	0%
SUBTOTAL OPEN SPACE	**51**	**28%**	**0**	**0%**	**0%**
Medium-Density Residential	39	21%	12	31%	7%
High-Density Residential	13	7%	7	54%	4%
Multi-Family Residential	0	0%	0	0%	0%
SUBTOTAL RESIDENTIAL	**52**	**29%**	**20**	**38%**	**11%**

TABLE 33: SEVEN LOCKS TRIBUTARY LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Institutional	26	14%	11	42%	6%
Commercial	9	5%	5	56%	3%
Industrial	0	0%	0	0%	0%
Transportation	45	25%	21	47%	12%
TOTAL	**182**	**100%**	**56**	**31%**	**31%**

5.7.2 Stormwater Management

There are 5 public and 3 private stormwater management facilities in the Seven Locks Tributary sub-watershed (see Table 34). The sub-watershed's most substantial treatment is from publicly-owned facilities treating the Montgomery County Detention Center and the Villages at Tower Oaks townhouses. These are both wet extended detention ponds that provide at least ½" water quality treatment. The other significant treatment system is public facility 93-1201, an infiltration/underground storage system treating Don Mills court. Smaller privately-owned systems also provide treatment at a site level. Overall, these systems treat more than 70 percent of the impervious area in the sub-watershed, although Don Mills Court is not designed for current water quality standards.

TABLE 34: SEVEN LOCKS TRIBUTARY STORMWATER MANAGEMENT FACILITIES

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Public			
Infiltration Trench	1	23	6
Dry Pond, Quality Control Only	1	57	18
Wet Pond, Quality Control and Extended Detention	2	18	7
Oil Grit Separators	2	N/A	N/A
Total Public	**5**	**98**	**31**
Private			
Sand Filter	3	12	5
Total Private	**3**	**12**	**5**

5.7.3 Stream Assessment

1994 Conditions

Problems observed in the field in 1994 included high riffle embeddedness, loss of aquatic habitat associated with stream channelization and poor stream shading. Stream bank stability and in-stream habitat was rated as good despite having low macroinvertebrate diversity. Along Tower Oaks Boulevard, three fish barriers were noted in addition to 400 feet of stream channelization.

2010 Conditions

The mainstem streams in the Seven Locks Tributary sub-watershed were broken up into five unique assessment reaches (Reaches 001, 002, 003, 004, and 005) based on habitat. An additional tributary to the mainstem (Reach 006) was also assessed.

Many areas along the mainstem have been stabilized with bed elevations controlled by in-stream gabion weirs and high flows attenuated by an in-stream stormwater management pond at the downstream end next to Wootton Parkway (Villages of Tower Oaks wet pond). These practices appear to have provided some protection against severe erosion. Many areas that have not received stabilization are experiencing severe bank erosion and bed incision. Stream buffers are generally good throughout the sub-watershed but there are many invasive species present. Habitat ranges from the poor to low-suboptimal range with areas lacking natural habitat (Reach 001) and heavy algae and trash (on Reach 005).

FIGURE 45: IN-STREAM GABION WEIR (REACH SLT-005)

The tributary to the mainstem (Reach SLT-006) was experiencing low flows and may not be a perennial channel. This reach is stable along the downstream end, with offline depressions adjacent to the reach and a gabion weir controlling the bed elevation. The offline depressions were an attempt by a developer in the 1990s to create wetland habitat as part of a State permitting requirement. These palustrine wetland areas have not been maintained, and are silting in but still providing some shallow depression storage in the floodplain. Habitat for this reach is poor with low flow and erosion adversely affecting habitat quality.

Geomorphic Assessment.

A geomorphic assessment was performed on Reach 004 of the Seven Locks Tributary sub-watershed. Based on the surveyed information, this reach was identified as a Rosgen F4 type channel. Moderate to severe erosion was very common throughout the assessed reach and many of the pools in the reach were being filled with coarse sand and small gravels. Cobble and large gravel point bars were common on inside meanders. The assessed reach was sinuous with no stream restoration, stabilization, or bank armoring present.

Water Quality.

In-situ and water quality grab samples taken in the Seven Locks Tributary sub-watershed did not indicate that either pH or DO was outside of COMAR standards. Conductivity was high at both the upstream in-situ sampling site and the downstream grab sample site. These high levels may be a result of runoff from I-270. Nitrate+nitrite concentrations were at acceptable levels, but TKN was high and TP was at the limit. Turbidity was also high for both the in situ and grab samples. Results of water quality measurements are shown in Table 35. Values higher than the reference range are shown in bold. Both sites were dry during the second sampling date in September, when there was very little rainfall in the weeks prior to sampling.

TABLE 35: SEVEN LOCKS TRIBUTARY WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
Reference			247	5.0	2.825	6.5-8.5	500	0.04	1.295	0.3	0.995	400
SLT#1	Apr-10	15.9	**1532.0**	7.9	**5.02**	7.9	---	---	---	---	---	---
SLT#1	Sep-10	DRY					---	---	---	---	---	---
SLT GRAB	Apr-10	15.3	**1026.0**	9.9	**6.33**	8.1	4	0.04	1.2	**0.9**	0.26	<3
SLT GRAB	Sep-10	DRY					---	---	---	---	---	---

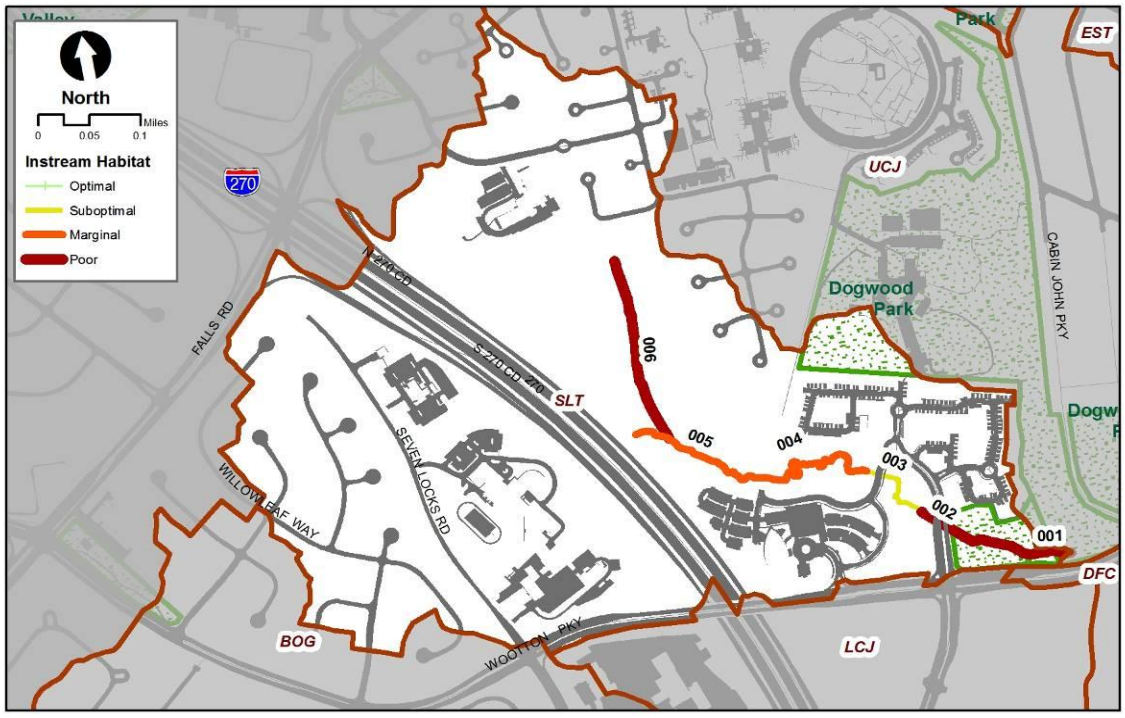


FIGURE 46: SEVEN LOCKS TRIBUTARY HABITAT ASSESSMENT

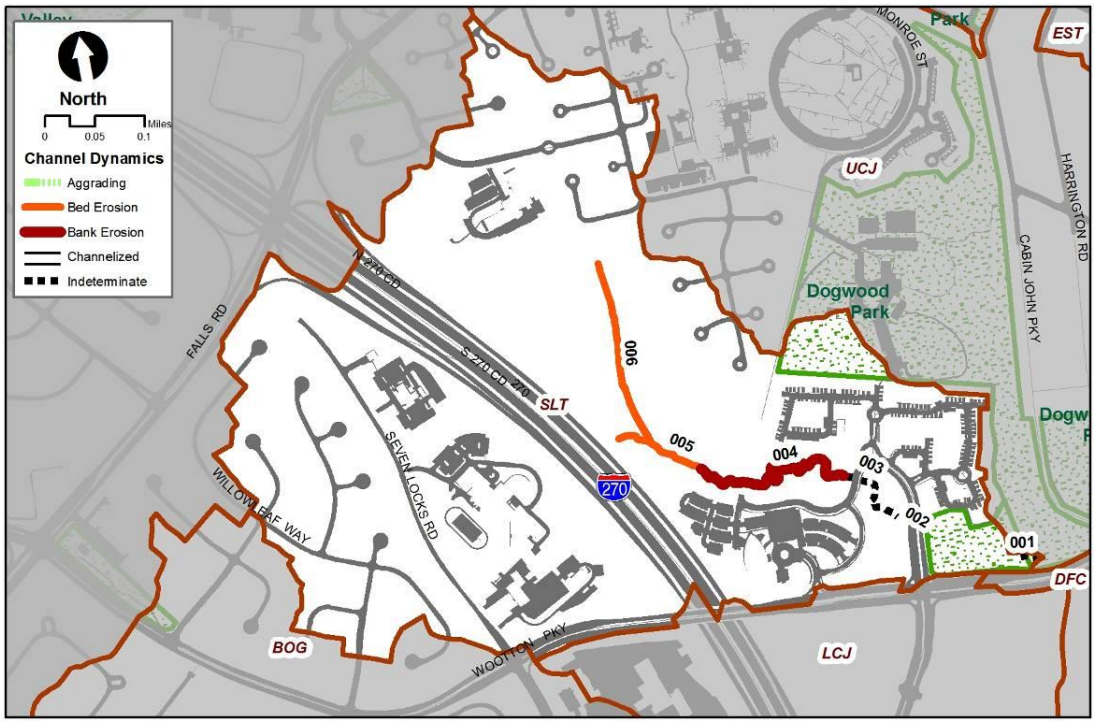


FIGURE 47: SEVEN LOCKS TRIBUTARY CHANNEL DYNAMICS ASSESSMENT

5.7.4 HSI/NSA INVESTIGATION

Two hotspots and three neighborhood sites were assessed in this watershed. Both hotspot sites were owned and maintained by Montgomery County. H-103 is a general maintenance facility for government operations and H-100 is the Montgomery County police headquarters and detention center. The only hotspot activities at the County detention facility were related to waste management, with uncovered and overflowing dumpsters. It was rated low severity. H-103 had potential sources from outdoor storage of building materials, waste management of garbage and construction materials. Materials stored without cover or secondary containment can easily spill or overflow during rain events. Dumpsters were uncovered and paint cans, gravel, and other materials were stored in the open. This site was rated as confirmed.

FIGURE 48: PARKING LOT IN NEED OF REPLACEMENT (H-101).


FIGURE 49: IMPROPERLY STORED OUTDOOR MATERIALS (H-103)

Two single-family detached areas and one townhouse development were assessed. Both single-family areas were part of adjacent watersheds as well, but were assessed here. Falls Ridge (N-105) is on the border between Seven Locks and Bogley Branch, and New Market Commons (N-118) is also contained in Upper Cabin John. Both consist of houses on 1/4 acre lots, built in the 1980s and late 1960s respectively. The townhouse development, Wootton Oaks (N-136), was built in the 1990s on lots smaller than 1/8 acre. All three areas had similar characteristics, with a significant percentage of high-maintenance turf, and about half of the downspouts disconnected. Curb, gutter, and storm drains conveyed stormwater to treatment systems in all of the areas. All three were rated moderate for pollution severity.


FIGURE 50: POTENTIAL HIGH MAINTENANCE LAWN (N-105)

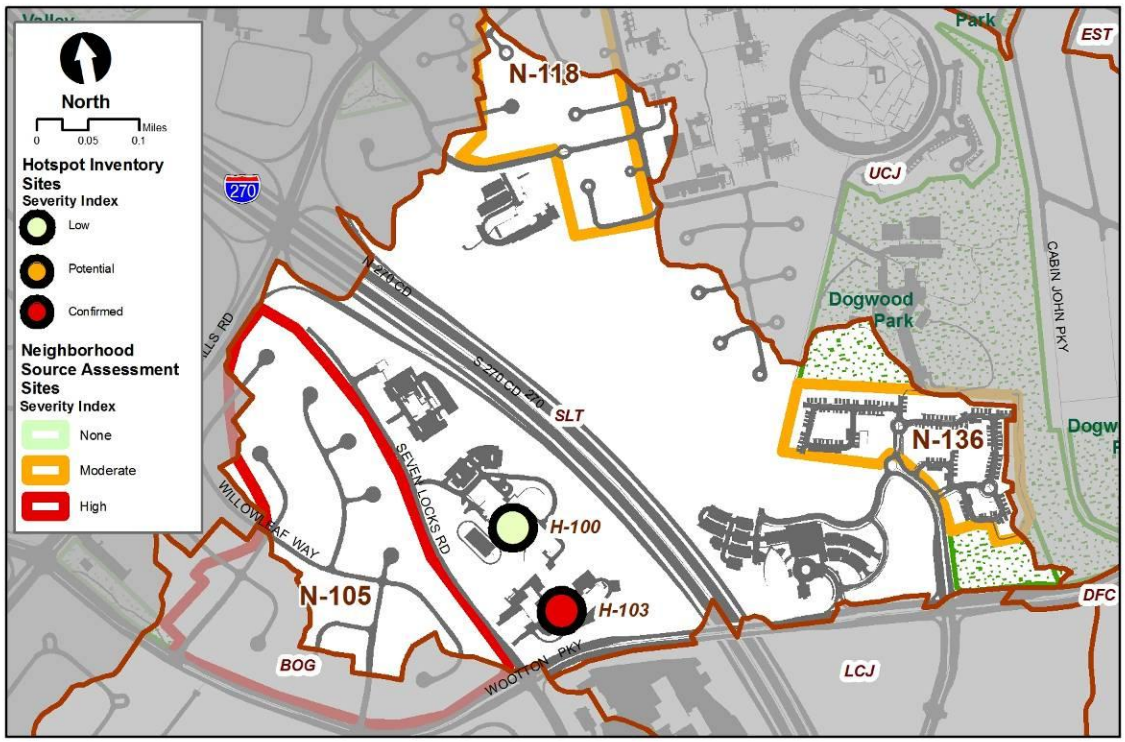


FIGURE 51: SEVEN LOCKS TRIBUTARY NSA / HSI RESULTS

5.7.5 Summary of Problems

Streams

- The downstream portion of Reach 004 between Tower Oaks Flagship building and Grand Oak Way is sinuous, eroded, and incised. In particular, severe erosion is occurring on the outer meanders and especially where the channel is flowing along a valley wall. Active downcutting of the stream channel is occurring downstream of a culvert at the end of Tower Oaks Drive;
- The riparian buffer at the top of Reach 005 had extensive invasive species that are adversely affecting the forest. A large amount of brown algae and trash are adversely affecting the overall habitat. This tributary receives drainage from the Montgomery County Detention Center SWM pond, a portion of I-270, and the man-made wetland depressions, as well as tributary SLT-006. The large areas of shallow ponding in the wetlands and the SWM pond may lead to eutrophication in the runoff flowing through this tributary;
- On Reach 006, the channel between the culvert and the storm drain outfall near Don Mills Court is straight and beginning to erode. Above this eroded section are areas of riprap and a gabion weir in the channel. Flow appears to be going around this weir and onto the floodplain. The weir is holding the upstream bed elevation to the storm drain outfall; however, overland flow around the weir may begin to erode back to the stream channel.

Water Quality

- Both the in situ and grab sample of baseflow showed higher than recommended turbidity, and the grab sample was high in TKN;

HSI/NSA

- The County maintenance facility at Seven Locks Road (H-103) was a confirmed hotspot for waste management and materials stored outdoors, including paint cans and containers stored without cover;
- High maintenance lawn care was identified in all neighborhoods.

5.7.6 Sub-watershed Restoration Goals

- Restore actively eroding streams and protect vulnerable areas identified in the stream assessment. Sites R-64S and R-65S could help meet this goal;
- Identify water quality retrofit measures that could be implemented to treat runoff from areas with only quantity control. Pond retrofits at sites R-12a and R-22 would provide additional quality control, as would the parking lot retrofits listed;
- Target residential neighborhoods for outreach and education for lower impact lawn care measures. An outreach program to encourage soil testing and reduced fertilizer use on City lawns could help improve water quality;
- Meet with staff at the County maintenance facility to discuss stormwater problems and work with them to implement a more effective Stormwater Pollution Prevention Plan.

5.7.7 Candidate Sites for Improvement

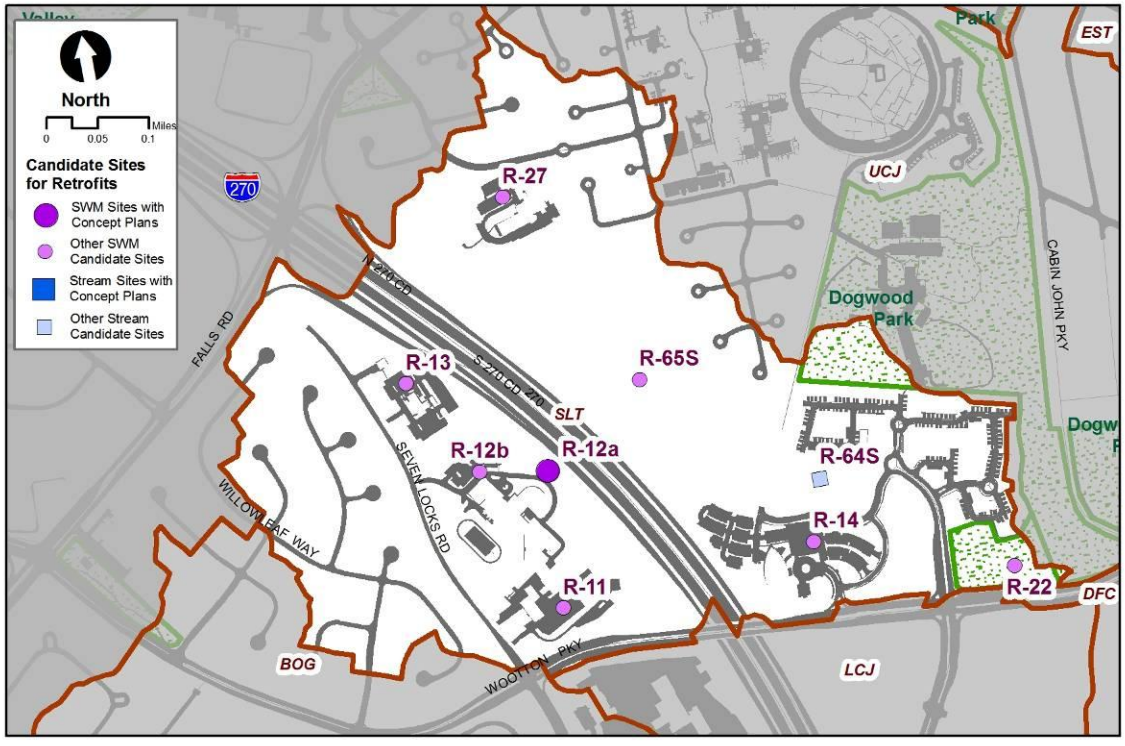


FIGURE 52: SEVEN LOCKS TRIBUTARY, CANDIDATE SITES FOR IMPROVEMENTS

TABLE 36: SEVEN LOCKS TRIBUTARY CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-11		Montgomery Co Detention Crenter	Parking Lot	County	County -owned property; provide on-site pond retrofit opportunity	No action	Drains to County Detention Center pond, see R-12a
R-12a		**Montgomery Co Detention Center**	**Existing Pond**	**City (has easement to pond on County land)**	**Provide opportunity to improve water quality treatment**	**Pond Retrofit**	**Perform field assessment**
R-12b		Montgomery Co Detention Center	Parking Lot	County	Provide on-site opportunities, roof disconnection, and impervious cover removal on North Seven Locks Rd	Encourage through redevelopment SWM requirements	Drains to County Detention Center pond, see R-12a
R-13		Montgomery County Police Sub-station	Parking Lot	County	Provide on-site pond retrofit opportunity	No action	Drains to County Detention Center pond, see R-12a
R-14		Tower Oaks Flagship bldg	Parking Lot	Private	Provide on-site opportunity at facility	Encourage through redevelopment SWM requirements	Already treated by sand filter with at least ½" quality control. Retrofits on privately owned property were low priority
R-22		Villages of Tower Oaks pond	Existing Pond	City	extended detention wet pond on park land. Close to stream. Provide opportunity to improve water quality treatment at pond	No action	Meets MDE 2000 SWM requirements – no retrofit needed.
R-27		1235 Potomac Valley Rd.	Parking Lot	Private	Provide on-site and educational opportunity	Encourage through redevelopment SWM requirements	Not a lot of treated area for the cost, no underdrain feasible, privately owned.

TABLE 36: SEVEN LOCKS TRIBUTARY CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-64S		Seven Locks Mainstem – between Tower Oaks Flagship Bldg. and Villages of Tower Oaks.	Stream Restoration	Private	Stream Restoration, channel is headcutting, severe meander erosion at one spot	Encourage through redevelopment SWM requirements	Retrofits on privately owned property were low priority
R-65S	96-07	Seven Locks/ Detention Center Tributary (east of I-270)	New Pond	Private	1996 study proposed in-stream pond. Now Infeasible. Consider stream restoration / wetland enhancement.	Encourage through redevelopment SWM requirements	Retrofits on privately owned property were low priority. These reaches are on property slated for development in the future, which will provide an opportunity for restoration.

Concept plans were prepared for bolded projects

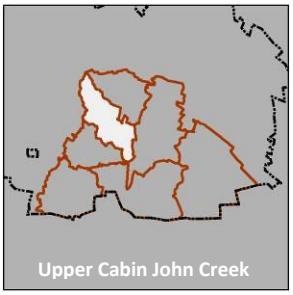
5.7.8 *Field Assessment and Concept Design*

R-12a Montgomery County Detention Center Pond Retrofit This wet pond facility is located between the County Detention Center and I-270. Although it is on the Detention Center property, it is in an easement to the City, who has maintenance and operation responsibility. The two-celled wet pond, draining 57 acres of residential, streets and institutional land, was built in 1987 to provide partial water quality control for the first ½" of runoff, and 10-year post-development /2 year pre-development water quantity control.

This project is recommended for a SWM retrofit through the CIP due to the large drainage area and available storage volume in the existing pond, which makes the retrofit relatively cost-effective. The facility needs repairs to replace the control structure and low-flow piping that is at the end of its lifecycle. The control structure will also be redesigned to meet current water quality and quantity control standards, which is feasible within the footprint of the existing pond. Work will also include dredging accumulated sediment and inflow channel improvements to create sediment forebays.

This project will require extensive coordination with Montgomery County Detention Center and State Highway Administration.

5.8 UPPER CABIN JOHN CREEK



The stream runs from the Maryland Avenue area downstream to Wootton Parkway and includes the Dogwood Park Tributary which is located just south of Waddington Lane where it flows east to join the Upper Cabin John Creek mainstem. It includes some or all of the communities of New Mark Commons, Fireside Apartments, Waddington Circle, and Hungerford.

5.8.1 *Land Use and Impervious Area*

Medium-density residential land use makes up 42 percent of the total 243 acres in the Upper Cabin John Creek sub-watershed. Transportation makes up the next largest percentage of sub-watershed area at 18 percent, primarily in residential streets and Maryland Avenue, which crosses the northern portion of the sub-watershed. There is considerable open space in turf, forest cover, and golf course uses, making up a combined 34 percent. The sub-watershed is 30 percent impervious, with 7 percent represented by roadways.

A summary of the land use and imperviousness within the Upper Cabin John Creek sub-watershed is provided in Table 37.

TABLE 37: UPPER CABIN JOHN CREEK SUB-WATERSHED LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
Turf in Open Space	32	13%	5	16%	2%
Forest	20	8%	0	0%	0%
Managed Turf on Golf Course	26	11%	12	46%	5%
Water	4	2%	0	0%	0%
SUBTOTAL OPEN SPACE	**82**	**34%**	**18**	**22%**	**7%**
Medium-Density Residential	101	42%	17	17%	7%

TABLE 37: UPPER CABIN JOHN CREEK SUB-WATERSHED LAND USE AND IMPERVIOUS AREA

Land Use	Drainage Area (acres)	Percent of the Sub-Watershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Sub-Watershed
High-Density Residential	1	0%	1	100%	0%
Multi-Family Residential	11	5%	8	73%	3%
SUBTOTAL RESIDENTIAL	**114**	**47%**	**35**	**31%**	**14%**
Institutional	1	0%	0	0%	0%
Commercial	2	1%	0	0%	0%
Industrial	0	0%	0	0%	0%
Transportation	44	18%	18	41%	7%
TOTAL	**243**	**100%**	**72**	**30%**	**30%**

5.8.2 Stormwater Management

Table 38 lists the 1 public and 2 private stormwater management facilities in the Upper Cabin John Creek Tributary sub-watershed. The entire watershed is treated by the Hungerford-Stoneridge Wetland Marsh off-line facility. A low-flow diversion pipe in the Cabin John mainstem adjacent to the Leverton Rd/Cabin John Pkwy intersection directs flows from smaller storms from the stream into the marsh pond where the runoff is treated, detained, and released at a slower rate to return the runoff at a non-erosive rate back to Cabin John Creek. Due to its interception of runoff from the mainstem, the Stoneridge Marsh captures runoff from the entire drainage area upstream of the diversion structure, so it treats the commingled runoff from Elwood Smith Tributary sub-watershed and Upper Cabin John Creek sub-watershed. This facility provides 0.5" of water quality treatment (through a combination of wet pool and extended detention storage) for the entire watershed, and provides 12-hour extended detention for quantity control of roughly the 6-month storm. This qualifies as partial treatment under the 2000 State standards, and is all that the available space allows for.

TABLE 38: UPPER CABIN JOHN CREEK STORMWATER MANAGEMENT FACILITIES

Structure Type	Number of Facilities	Treated Area (ac)	Impervious Area Treated (ac)
Public			
Wetland Pond, Extended Detention	1	237	59
Total Public	**1**	**237**	**59**
Private			
Sand Filter, Underground	2	N/A	N/A
Total Private	**2**	**>0**	**>0**

5.8.3 Stream Assessment

1994 Conditions

In 1994 this sub-watershed was characterized by low bank stability, high riffle embeddedness, and poor riffle substrate quality despite a diversity of macroinvertebrate and fish communities (six fish species

observed). Stream bank erosion was identified downstream of the Leverton Road/Cabin John Parkway area.

The Dogwood Park Tributary was assessed separately and exhibited poor bank stability, extreme riffle embeddedness, poor riffle substrate material composition, and a lack of adequate pool habitat that explained the poor macroinvertebrate community.

2010 Conditions

The mainstem channel of the Upper Cabin John Creek sub-watershed was divided into two unique assessment reaches (Reaches 001 and 005) based on habitat. Seven tributaries also drain to the mainstem channel within Upper Cabin John (Reaches 002, 003, 004, 007, 008, 009, and 010).

FIGURE 53: OVERWIDENED CHANNEL, WITH GRAVEL DEPOSITION (REACH UCJ-005)

The mainstem channel in the sub-watershed is generally overwidened with depositional features common on the downstream end. Erosion is occurring on both outside meanders and straight sections of the reach. Areas where stabilization has occurred appear to be in good condition leaving localized areas of moderate to severe erosion. Riparian buffers are intact but are dominated by mowed grass along at least one bank, especially along Cabin John Parkway and through Dogwood Park. Invasive species are prevalent. Habitat is in the suboptimal range with several habitat types present. Many fish were observed in the downstream portions of the reach and barriers to fish passage were noted, including a blocked low flow channel in the culvert under Wootton Parkway designed to facilitate fish passage.

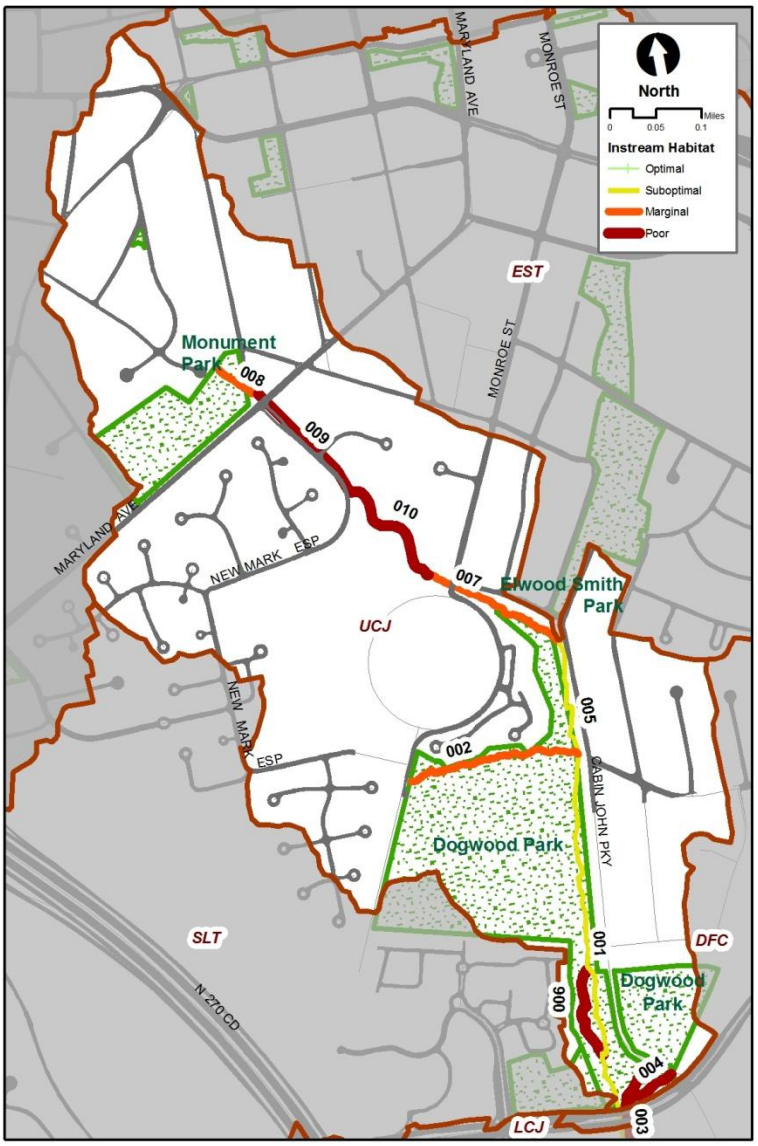


FIGURE 54: UPPER CABIN JOHN HABITAT ASSESSMENT

Tributary channels to the mainstem range from a good quality wetland (Reach 004) to piped reaches and trapezoidal channels. In general, channels are eroding and overwidened. Reach 002, specifically, is very unstable and experiencing extensive bank and bed erosion. Stream buffers through park areas are generally adequate but with areas where mowed grass is the dominant vegetation. Invasive species are prevalent, especially along Cabin John Parkway. Habitat ranged from poor to mid-marginal with areas of erosion, lack of habitat and algae negatively impacting habitat quality.

Geomorphic Assessment. A geomorphic assessment was performed on Reach 005 of the Upper Cabin John Creek sub-watershed. Based on the surveyed information, this reach was identified as a Rosgen type F4 channel. This reach differed from other F4 channels in the Cabin John watershed with very low sinuosity and appeared mostly stable with only minor erosion. Despite this stability, the channel is entrenched with no floodplain access. Several rock vanes and an occasional boulder/root wad restoration are present within the assessed reach and may be responsible for the stability. The riffle/pool morphology of this channel has been altered by the rock vane restoration in some areas.

Portions of the channel between rock vanes have become long, shallow runs instead of riffles or pools. Gravel dominated the substrate in the channel and some gravel point bars were present in the channel.

Water Quality. In-situ and water quality grab samples taken in the Upper Cabin John Creek sub-watershed did not indicate that either DO or pH was outside of COMAR standards for either sampling event. Conductivity levels were elevated along the mainstem reaches, with the highest level at the downstream end of the sub-watershed. While the Spring baseflow sample for nitrate+nitrite was within acceptable levels, TKN was high, which caused TN to be elevated. The reverse was true in the September sample. Turbidity was also high in both the grab and in situ samples during both seasons. The September sample also showed elevated levels of phosphorus and bacteria. Results of water quality measurements are shown in Table 39. Values higher than the reference range are shown in bold.

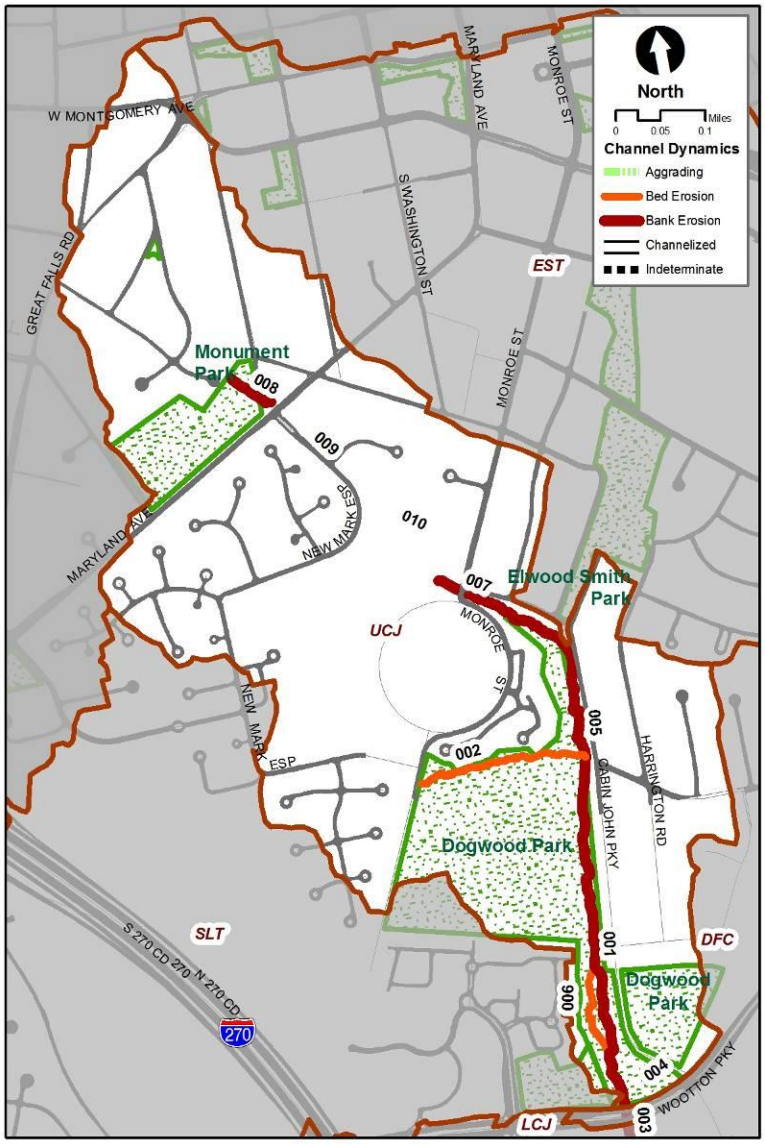


FIGURE 55: UPPER CABIN JOHN CHANNEL DYNAMICS ASSESSMENT

TABLE 39: UPPER CABIN JOHN CREEK WATER QUALITY – IN-SITU AND GRAB SAMPLES

Site ID	Sample Date	Temp (°C)	Cond (µS/cm)	DO (mg/L)	Turb (NTU)	pH	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	Fecal Coliform
Reference			247	5.0	2.825	6.5-8.5	500	0.04	1.295	0.3	0.995	400
UCJ#1	Apr-10	16.9	**695.0**	7.7	**5.15**	7.8	---	---	---	---	---	---
UCJ#1	Sep-10	18.3	**691.0**	7.1	**3.85**	7.53	---	---	---	---	---	---
UCJ#2	Apr-10	15.2	**305.5**	9.5	0.90	7.8	---	---	---	---	---	---
UCJ#2	Sep-10	DRY					---	---	---	---	---	---
UCJ#3	Apr-10	18.2	**717.0**	9.1	1.22	7.5	---	---	---	---	---	---
UCJ#3	Sep-10	17.4	**302.1**	7.3	0.58	7.91	---	---	---	---	---	---
UCJ_GRAB	Apr-10	16.9	**722.0**	8.6	**4.43**	7.8	3	0.03	**1.6**	**0.7**	0.88	23
UCJ_GRAB	Sep-10	18.3	**685.0**	7.7	0.42	7.52	<1	**0.31**	**1.5**	<0.5	**1.5**	**4600**

5.8.4 HSI/NSA INVESTIGATION

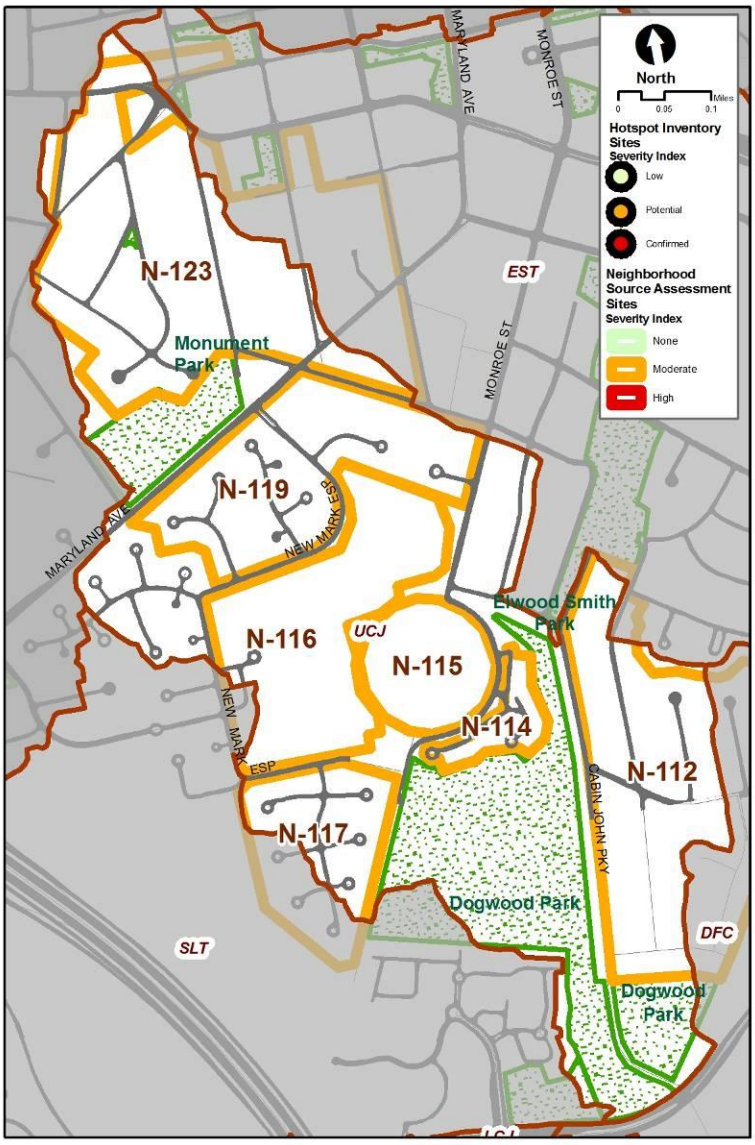


FIGURE 56: UPPER CABIN JOHN NSA / HSI RESULTS

Six residential areas were assessed in Upper Cabin John Creek. No hotspot sites were investigated because there is so little commercial or institutional land coverage. The residential areas consisted of a mix of single-family and multi-family developments at a variety of densities, built from the 1940s to the 1990s, with most of the development occurring in the 1960s and 1970s. Pollutant-causing behaviors and potential actions also varied widely across the different areas. Tree canopy was over 40 percent in all the single-family areas. Lawn care practices were primarily medium intensity, with lower impact on streams. Downspouts were over 40 percent disconnected in all neighborhoods except N-114. There were invasive species noted in Dogwood Park, adjacent to the neighborhood.

SUMMARY OF PROBLEMS

Streams

- Reach 001 is moderately unstable with erosion occurring on outside meanders and straight sections. Overwidening and large gravel and cobble deposits were common. The culvert under Wootton Parkway was designed to have a low flow channel to help facilitate fish passage. However, sedimentation is blocking this channel to the point that vegetation has grown up inside one of the culvert cells under Wootton Parkway;
- Reach 002, Dogwood Park tributary, is very unstable with severe erosion and evidence of active widening and downcutting. Significant losses of bank and bed materials have occurred and will continue to occur until the waterway is restored;
- Reach 007, which runs next to Cabin John Parkway between Monroe St. and E. Lynfield Dr., is overwidened and incised with moderate to severe erosion on outside meanders. The riparian buffer along Cabin John Parkway was narrow and mostly made up of invasive species. In some cases, grass was mowed up to the stream bank;
- The Dogwood Park stream buffer between the stream channel and Cabin John Parkway is planted in grass with the immediate overbank covered in invasive vegetation. This area would benefit from the Department of Recreation and Parks conducting non-native plant removal and tree planting. The 100-year floodplain should be reconfirmed beforehand to make sure the increase in overbank roughness from changing the turf to woods will not raise floodplain elevations for the houses along Cabin John Parkway. This area is known for flooding in high storm events. (Site ID: N-112).

Water Quality

- TKN and TN were higher than the recommended level for the baseflow grab sample, and turbidity was high for both the grab sample and one in situ sample. TP and TN were both high in the Summer sample.

HSI/NSA

- There were no HSI assessments in this sub-watershed;
- Invasive species were identified in Dogwood Park adjacent to Hungerford (Site N-112);
- Dumpsters were left uncovered at the Fireside apartment complex (N-115).

5.8.5 SUB-WATERSHED RESTORATION GOALS

- Restore actively eroding streams and protect vulnerable areas identified in the stream assessment. Three candidate sites for stream restoration were found: R-67S, R-68S, and R-69S.
- Identify water quality retrofit measures that could be implemented to treat runoff from areas with only quantity control. Candidate sites include pond retrofits R-23 and R-82, and parking lot and street retrofits R-24 and R-26;
- Invasive species removal, tree planting, downspout disconnection, and rain gardens were among the actions identified that neighbors can take to improve water quality in the sub-watershed. The Department of Recreation and Parks may also choose to expand the natural wooded stream buffer along Cabin John Parkway;
- Clean out accumulated sediment and vegetation from culvert system under Wootton Parkway to restore conveyance capacity in large storms and reduce available sediment load.

5.8.6 *CANDIDATE SITES FOR IMPROVEMENT*

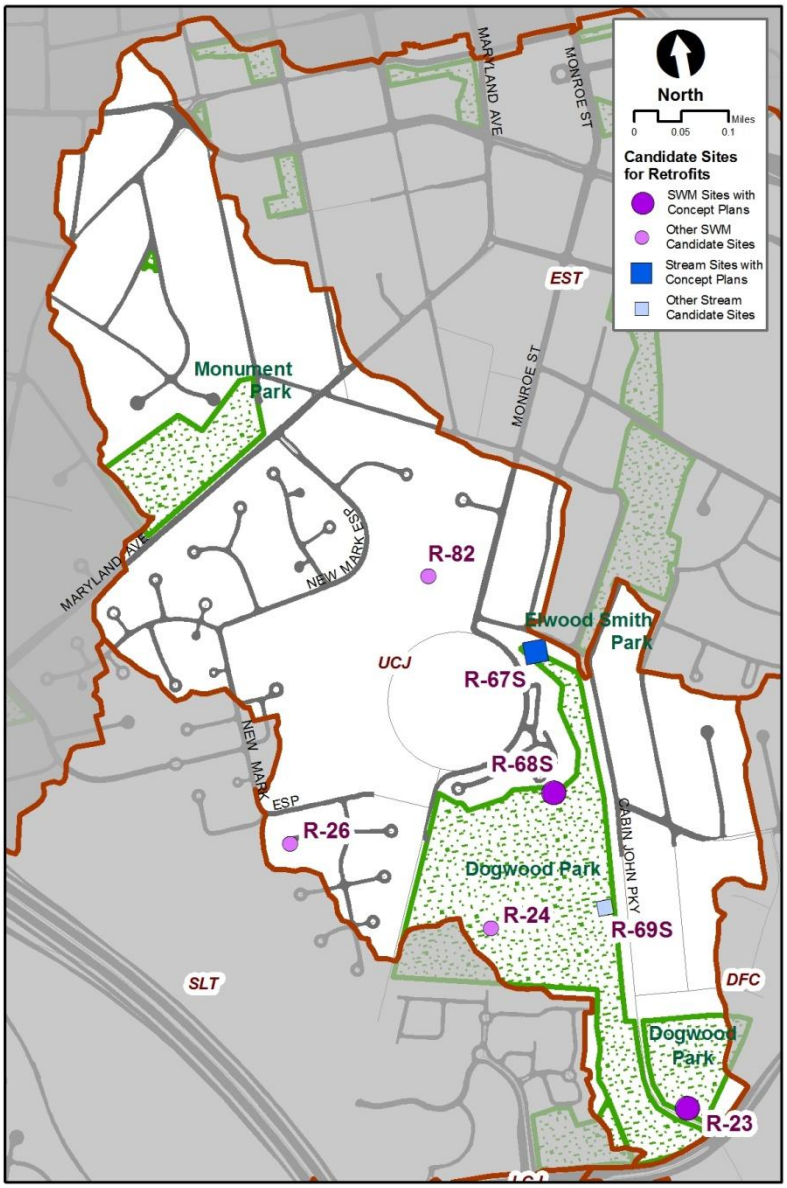


FIGURE 57: UPPER CABIN JOHN, CANDIDATE SITES FOR IMPROVEMENTS

TABLE 40: UPPER CABIN JOHN CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-23		**Hungerford-Stoneridge Marsh, 98-1055**	**Existing wetland marsh extended detention Pond**	**City**	**Extended detention wetland on park land. Located near stream. Provide opportunity to improve water quality treatment**	**Pond Maintenance**	**Perform field assessment. Original design maximized water quality storage volume and extended detention volume, so retrofit potential is low. Pond needs major dredging of entire pond bottom.**
R-24		Dogwood Park – 1996 Watershed Plan proposed pond	Parking Lot	City	Park land. Provide on-site pond retrofit opportunity. 1996 Plan proposed new pond on ball field.	Replaced with adjacent stream restoration project (R-68S)	Pond still not considered feasible – major recreation impacts, and unlikely to obtain significant % of storage goals. Replace with stream stabilization project (See R-68S)
R-26		Farsta Ct.	Street Retrofit	City	Cul-de-sac site identified during NSA assessment (N-117). Provide impervious cover removal and on-site pond retrofit opportunity	Public ESD - defer until City has more experience	Not a lot of treated area for the cost, no underdrain feasible, privately owned.
R-67S		**UCJ Mainstem**	**Stream Restoration**	**City**	**Spot stream restoration, outfall stabilization, invasive vegetation removal, buffer restoration**	**Stream restoration**	**Develop concept plan based on field work during stream assessment**
R-68S	**96-06**	**Dogwood Park**	**Replacement stream concept in lieu of stormwater concept R-24.**	**City**	**Proposed facility will require removal of a baseball field and park area, large amount of excavation, and relocating existing storm drain networks. Original 1996 plan now unbuildable, RSC, outfall stabilization is better approach at the site.**	**RSC**	**Develop concept plan based on field work during stream assessment**

TABLE 40: UPPER CABIN JOHN CREEK CANDIDATE SITES

Site ID	1996 Plan ID	Facility ID / Location	Candidate Type	Ownership	Desktop Assessment	Recommended Next Steps	Notes
R-69S		UCJ Mainstem, Dogwood Park	Stream Restoration	City	Stream restoration in downstream portion	Recommend to City Forestry Division	No in-stream work needed; revised to buffer reforestation only
R-82	96-05	New Mark Commons	Existing Pond (1996 Watershed Plan proposed retrofit)	Private	Site is a private in-stream wet pond with adjacent condominiums	No action	Proposed project is still not feasible, given private pond ownership and floodplain constraints for adjacent houses.

Concept plans were prepared for bolded projects

5.8.7 FIELD ASSESSMENT AND CONCEPT DESIGN

R-23 Hungerford / Stoneridge Pond Retrofit This facility is a wetland marsh built in 1998 located in a park at the end of Cabin John Parkway. The pond receives runoff from an in-stream flow splitter. Under existing conditions, the permanent wet storage within the facility is satisfying approximately 45 percent of the water quality volume. The pond treats the first ½" of runoff over entire 351-acre drainage area, and provides 12-hour extended detention for approximately the 6-month storm (1.75" runoff), which was all that available storage would allow.

The existing forebay volume may be undersized to current standards. The pond has accumulated at least one foot or more of sediment across the entire basin, which has caused the wetland marsh areas to lose proper depth and therefore shifted the planted zones to more upland species. This has disrupted the nutrient uptake as well as reduced storage volume, so the pond is not performing as designed.

This project is recommended for major maintenance through the City's stormwater facility maintenance contract. The project will remove accumulated sediment across the forebay and main pond area, re-establish the wetland plants, and may regrade the basin to extend time between routine dredging and better maintain wetland functions. No change to the pond function is planned at this time. Coordination with the Department of Recreation and Parks and the surrounding neighbors will occur before the maintenance work is scheduled.

R-67S UCJ Mainstem Stream Restoration**:** This proposed project site is a section of the Upper Cabin John Mainstem stream channel located in a partially forested area within a residential community adjacent to Cabin John Parkway. An existing aesthetic pond at New Mark Commons, which is not a SWM facility, is located just upstream of the channel. Areas of the stream embankment along Cabin John Parkway and along the outside banks at meandering sections have are moderately eroded with incised bank slopes.

This project is not recommended for implementation due to the stream showing only slight-moderate erosion. Gabions installed in 1997 are still stable. The City will monitor this reach and re-assess it in the next study.

R-68S Dogwood Park Stream Restoration This 980 linear foot stream channel is located entirely within Dogwood Park adjacent to the Waddington Circle townhouses. The channel has three storm drain outfalls that contribute to its severe erosion, widening and downcutting. An 85 foot eroded side channel with a 5 foot deep headcut has developed below a storm drain outfall from Dogwood Park leading to this stream.

This severely eroded stream is recommended for an RSC-based stream restoration through the CIP. The regenerative stream conveyance technique may be feasible here, and should be considered at the design stage as an alternative to traditional stream stabilization. Access will start at Monroe Street and can utilize an area for half the stream length that was cleared in 2010 for a sewer blockage.

The top of stream bank on the northern side is very close horizontally & vertically to the adjacent townhouses in Waddington Circle. At design, the stream improvements should be analyzed to ensure the hydraulics effects do not increase the floodplain boundary and further impact the townhouse lots. If this is an issue, traditional stream restoration may be used in place of RSC. Coordination with the Department of Recreation and Parks and the Waddington Park Townhouse Association will occur at time of design.

5.9 STATUS OF 1996 WATERSHED PLAN RECOMMENDATIONS

The eleven unconstructed sites proposed in the City's 1996 management plan for Cabin John Creek were reviewed as part of the retrofit assessment for this plan. Feasible projects were identified for three of

the sites. Table 41 shows the results of the assessment for these sites. The site ID for the current plan is provided, along with the recommendation from the original plan, and notes on the original proposed retrofit and the current concept design. The final recommendation from this 2010 management plan is shown in the last column.

TABLE 41: DISPOSITION OF RETROFIT SITES FROM 1996 PLAN

1996 Plan	Facility ID	Current Plan ID	Original 1996 Proposal	Owner	2010 Study Notes	Final Recommen-dation in 2010
96-02	Elwood Smith	R-81	New Pond	City	Two facilities (Mt. Vernon Pond, Richard Montgomery HS) have been constructed and treat the same area. No concept developed.	No action
96-03	Rockville Heights	R-29	Existing Pond	City	Concept plan developed for conversion to in-line modified sand filter, but rejected due to large drainage area and flood control priority, which make current SWM methods infeasible.	No action - reassess as technology advances
96-05	New Mark Commons	R-82	Existing Pond	Private	Proposed project is no longer feasible. Site is a private wet pond with adjacent condominiums. No room for water surface fluctuations. No concept developed.	No action
96-06	Dogwood Park	R-68S	New Pond	City	Original proposal would require removal of a baseball field and park area, large amount of excavation, and relocating existing storm drain networks. Original plan is now unbuildable. Changed to stream stabilization project. A concept plan was developed.	Stream Stabilization CIP project - high priority
96-07	Seven Locks/ Detention Center Tributary (East of I-270)	R-65S	New Pond	Private	Original proposal would require removal of a forest and intermittent stream channel (permit issues). Site is also in private ownership.	Encourage through redevelopment SWM requirements.
96-08	Dawson Farm 8501017	R-45	Existing Pond	City	Concept plan developed for a shallow wetland to provide water quality treatment in the form of wet storage. Took all available open space at park; road flooding issues, still undersized for drainage area.	No action - reassess as technology advances
96-09	Wootton Parkway	R-71S	New Pond	City	Original proposal involved placement of in-stream gabion weirs/culvert pond retrofit in the mainstem channel. This is infeasible due to low available storage volume and high maintenance problems. A new pond on a wooded side tributary from Woodmont Country Club was considered, but rejected. This would be better treated in open areas on Woodmont CC.	Encourage through redevelopment SWM requirements
96-12	Potomac Woods #3 (West) – Derbyshire	R-62S	New Pond	City	Original pond proposal for 96-12 would require extensive excavation, forest removal, and intermittent stream channel removal. Instead, stream stabilization concept plan developed for	Stream Stabilization CIP project medium priority

TABLE 41: DISPOSITION OF RETROFIT SITES FROM 1996 PLAN

1996 Plan	Facility ID	Current Plan ID	Original 1996 Proposal	Owner	2010 Study Notes	Final Recommen-dation in 2010
	Road				RSC (Regenerative Stream Conveyance).	
96-14	North Farm 77-01020	R-19b	Existing Pond	City	Original retrofit proposal was to convert dry pond to shallow wetland marsh. Drainage area & baseflow not compatible with marsh concept. New concept plan developed for conversion to sand filter.	SWM CIP retrofit - medium priority
96-15	Woodmont Country Club	R-83	Existing Pond	Private	Proposed project is no longer feasible. Golf course pond was not designed to pond standards. No concept developed.	No action
96-16	Montrose Park-Alternatives	R-80S	Stream Restoration	City	Original dry pond retrofit proposal would be placed in a perennial stream channel. Constraints include permit issues, steep wooded stream valley, and loss of park area. Developed concept plan for stabilization of failed storm drain outfall and stream channel.	Stream stabilization CIP project - high priority

6 LESSONS LEARNED

Through implementation of the 1996 Plan recommendations and completion of this 2010 watershed analysis, the City identified a number of lessons learned that should be considered when implementing stormwater management CIP and operational activities in the future.

Design/Construction

- Federal and State standards for stream protection and water quality control are changing rapidly and new technology to meet these standards is being developed. Because of this, the City should not invest in detailed designs during the watershed analysis. Instead, the watershed analysis should identify locations for improvements based on the assessments performed and provide preliminary ideas on possible techniques. At the time of design, City staff should evaluate options for design refinements and engage the community about the design options.
- Some of the City's stormwater management facilities have been significantly undersized for their drainage areas due to space constraints with woods, recreation areas, etc. This has the potential to lead to increased facility maintenance needs and greatly reduced water quality treatment capacity. The City will continue to evaluate each project's merits vs. constraints, but should try to avoid undersizing facilities, particularly in the wet storage and pre-treatment areas. Where it is unavoidable, the City will need to plan for higher maintenance costs, and consider adding more stringent and costly pre-treatment systems.

Facility Maintenance

- Completed construction of a SWM facility is just the beginning. SWM facilities need to be inspected and maintained/repaired on a routine basis. Maintenance requirements and lifecycle costs need to be considered when SWM facility retrofits are being designed.
- A relatively small investment has the potential to greatly reduce maintenance costs while maintaining water quality treatment standards. Previously retrofitted facilities should be evaluated for design modifications that reduce maintenance costs (such as improved trash racks or low-flow pipe designs, hardier replacement wetland plants, deeper wetland marsh areas), even if the overall control rates for treating water quality or limiting stream erosion are current.
- It is important to perform recommended preventative maintenance on SWM facilities because it is likely to lengthen the facility's life-cycle. For example, filter-based facilities (such as sand filters and bioretention) are particularly prone to clogging if neglected, and may require expensive replacement of the entire filter layer years earlier than planned.

Future Project Planning

- The City implemented a number of SWM retrofits recommended in the 1996 Cabin John Creek Watershed Management Plan and sites for traditional, large-scale SWM facilities are harder to find. This is especially true because large-scale SWM facilities are often only appropriate on City-owned land, which meets multiple needs including recreation and forest preservation. To meet expected NPDES permit requirements, the City will need to explore new techniques and opportunities beyond construction or retrofitting of SWM facilities. The City will continue to balance the watershed benefits from various SWM and stream projects against competing needs to preserve forests, wetlands, recreation areas, and to integrate the watershed improvements with other City objectives.

- Environmental site design (ESD) stormwater management techniques will have a greater role in the City's stormwater management program in the future. The State or Maryland is requiring the increased use of ESD. In addition, ESD may become the only viable option as we run out of space for larger-scale retrofits. These features typically are used to treat a small drainage area. Currently, they cost more to construct and maintain (per acre treated) than traditional SWM structures. While we anticipate these costs will fall as ESD use increases, for now, additional funding may be needed to construct and maintain these types of facilities.

7 RECOMMENDATIONS

Taking into consideration the findings of this watershed analysis, the lessons learned from implementing the projects suggested in the 1996 Plan and regulatory requirements placed upon the City through its NPDES permit, staff identified the following action recommendations. These recommendations do have budgetary impacts and the cost of implementation has been estimated. In order to move forward on implementation, the City will need to make decisions on whether to increase the overall budget or slow down or reprioritize implementation of current CIP projects and operational programs.

The recommendations are grouped into three categories: stormwater management, stream restoration, and operational programs. Implementing the recommendations outlined in this section is key to addressing the issues identified during this assessment. In addition, the City should consider implementing the programmatic recommendations City-wide. While action will begin within the Cabin John Creek Watershed, it is believed that similar findings will result from watershed assessments throughout the City.

The stormwater management and stream restoration projects are ranked in high, medium, and low priority based on the current conditions in the field. Please note that stormwater management and stream conditions are subject to change over the 10-15 year expected implementation City staff will annually assess planned projects and adjust their order based on variables such as trends in downstream erosion, maintenance history and expected life for stormwater facilities, nearby existing or planned City facilities that would be affected, and target watershed protection goals in the City's NPDES permit.

7.1.1 STORMWATER MANAGEMENT

Table 42 and Figure 58 summarize the recommendations for stormwater management in the Watershed Management Plan. Eleven concept plans were developed for stormwater retrofits as a result of the candidate site review and field investigation. Six projects were selected for action, all of which are existing public SWM facilities. Three of these will involve significant engineering modifications to the facility, and will be designed and constructed through the City's Capital Improvements Program (CIP). The other three projects require substantial maintenance but are already designed to meet current SWM standards. This work will be programmed through the annual Operations budget for SWM maintenance.

The recommended priority reflects the relative benefits to the watershed, based on the project's drainage area size and expected improvements to SWM water quality and/or quantity controls. For the operational maintenance projects, the priority also reflects the current condition (as of 2010) and effectiveness of the facility before dredging. Priority may shift, subject to changing conditions in the facilities, SWM treatment methodology, alignment with other City projects, available funding, etc.

TABLE 42: STORMWATER MANAGEMENT RECOMMENDATIONS

Subwater-shed	Current Site ID	Name and SWM Type	Final Recommendation	Priority
Bogley Branch	R-02	Potomac Woods Wetland Marsh Pond	Program for major maintenance. Remove accumulated sediment, dredge pond to restore original storage volume, adjust forebay berm, and replant wetland areas.	High
Bogley Branch	R-08	Locks Pond Ct. Wet Pond	Program for major maintenance. Remove accumulated sediment, dredge pond to restore original storage volume.	High

TABLE 42: STORMWATER MANAGEMENT RECOMMENDATIONS

Subwater-shed	Current Site ID	Name and SWM Type	Final Recommendation	Priority
Upper Cabin John	R-23	Hungerford-Stoneridge Wetland Marsh Pond	Program for major maintenance. Remove accumulated sediment, dredge pond to restore original storage volume, adjust forebay berm, and replant wetland areas. Forebay dredging (high priority) may be done separately from main pool dredging.	High-Medium (may be done in two stages)
Seven Locks Tributary	R-12a	Montgomery County Detention Center Wet Pond	CIP retrofit and repair project. Replace corrugated metal pipe control structure, replace low flow pipes, stabilize inflow channels, provide accessible forebays, and adjust controls to provide for 1" water quality volume and channel protection volume or to current standards.	Medium
Bogley Branch	R-03	Arlive Ct. Dry Pond	CIP retrofit project. Convert dry pond to sand filter to provide water quality treatment.	Low
Lower Cabin John	R-19b	North Farm Dry Pond	CIP retrofit project. Convert dry pond to sand filter to provide water quality treatment.	Low

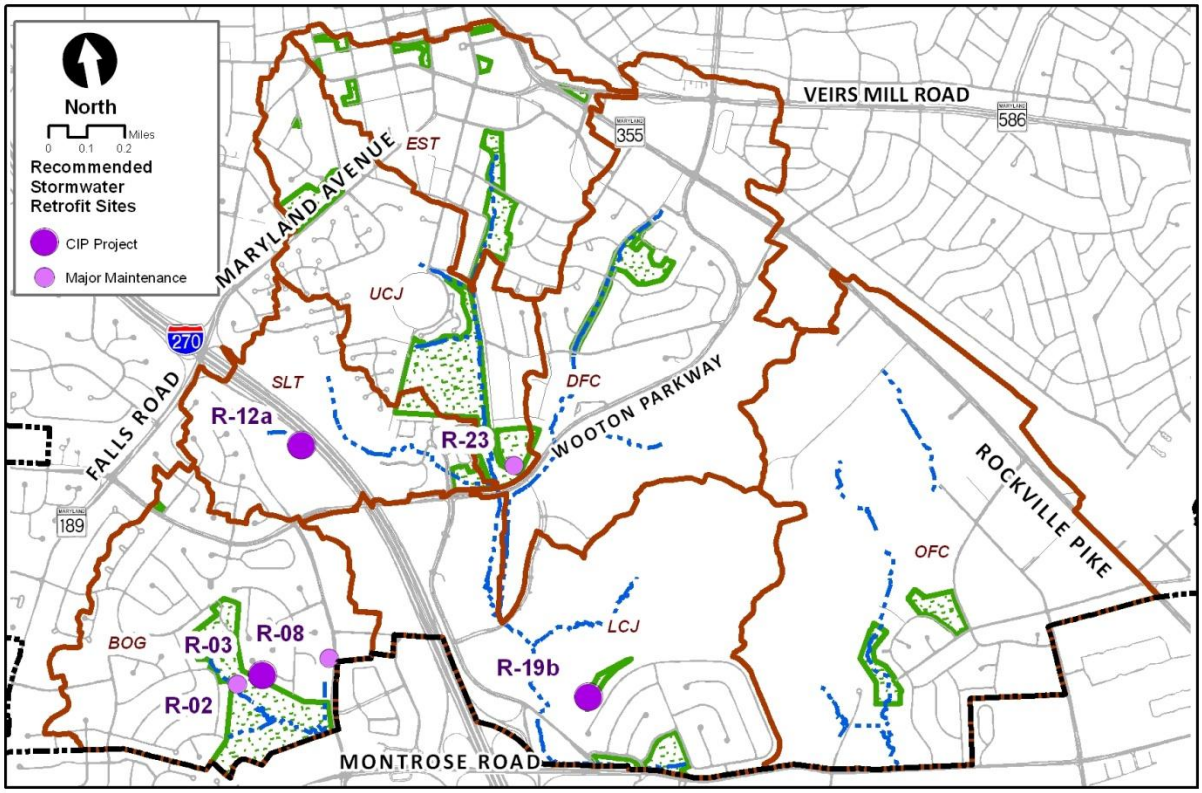


FIGURE 58: RECOMMENDED SWM RETROFIT SITES

7.1.2 *Stream Restoration*

Recommended projects for stream restoration are shown in Table 43 and Figure 59. Twelve concept plans resulted from the selection of candidate sites and review of field data.

The concepts include:

- Conventional stream restoration projects to repair eroded banks, redirect flow away from the banks, and improve habitat. This uses large rock, bank regrading, and plantings to stabilize larger stream channels;
- Regenerative stream conveyance (RSC) projects that use an in-channel filter system of rocks, sand, and woodchips to stabilize channels as well as provide water quality filtration for smaller, more frequent flows. This relatively new technique is appropriate for smaller streams with less than 75 acres of drainage area, or for storm drain outfall channels. As the RSC technique evolves in the future, the City will consider this and other small-channel stabilization methods;
- Storm drain/culvert outfall repairs or replacement for failing structures.

Seven projects are recommended for Capital Improvement Program implementation. The recommended priority is based on current (as of 2010) conditions, potential for damage to nearby infrastructure, and potential for additional downcutting/widening. Because urbanized stream erosion may change quickly due to storm action, debris blockages, and natural geomorphic conditions, City staff will monitor these locations for signs of active or accelerating degradation to reassess the order of priority. The City will also monitor several other stream reaches that are not now planned for stream improvements, but were flagged during the study with some unstable areas. These are listed in Table 44.

TABLE 43: STREAM RESTORATION RECOMMENDATIONS

Subwater-shed	Current Site ID	Location	Final Recommendation	Priority
Old Farm Creek	R-80S	Old Farm Creek in Montrose Park at Rollins Ave.	CIP project – storm drain outfall repair, spot stream restoration and removal of debris	High
Upper Cabin John	R-68S	Stream at Dogwood Park – from Waddington Ln. to Cabin John Pkwy.	CIP project – outfall RSC or stream restoration	High
Elwood Smith Tributary	R-66S	Outfall below Mt. Vernon Place to pedestrian bridge at Elwood Smith Rec. Center	CIP project - storm drain outfall repair; CMP culvert replacement	High
Bogley Branch	R-62S	Potomac Woods Park at Derbyshire Rd.	CIP project – outfall RSC or stream stabilization	Medium
Dawson Farm Creek	R-70S	Cabin John Creek mainstem – east branch	CIP project – stream restoration; sediment/debris removal from culverts under Wootton Pkwy.	Medium
Lower Cabin John	R-72S	Cabin John Creek mainstem – west branch	CIP project – stream restoration; sediment/debris removal from culverts under Wootton Pkwy.	Medium

Subwater-shed	Current Site ID	Location	Final Recommendation	Priority
Lower Cabin John	R-73S	Outfall channel from Tower Oaks Blvd. to mainstem south of Preserve Pkwy.	CIP project – removal of old dry pond dam/barrel and outfall RSC or stream stabilization	Medium

TABLE 44: STREAM SEGMENTS TO BE MONITORED

Subwater-shed	Current Site ID	Location	Notes
Bogley Branch	R-63S	Potomac Woods Park between Stratton Drive and Dunster Lane	Channel previously stabilized in spots with imbricated riprap in 2000. Mostly stable, but few bends with moderate erosion. Monitor the storm drain outfall at Stratton Drive and channel for worsening conditions.
Bogley Branch	R-61S	Bogley Branch mainstem in Potomac Woods Park upstream of Seven Locks Road behind the Maryland State Police Department building	Wooded stream reach with some riprapped sections. Some spots are showing scour behind the riprap. One sewer crossing protected with stone. Low banks, channel is mostly stable. Monitor for worsening erosion.
Upper Cabin John	R-67S	Cabin John mainstem adjacent to Cabin John Pkwy between Monroe St. and W. Lynfield Dr.	Stream is immediately adjacent to street, and was straightened and channelized for road construction. Gabions were installed in 1997 at W. Lynfield Dr./Cabin John Pkwy and are still stable. Moderate spot erosion, but no signs of accelerated conditions. Monitor annually for worsening erosion, especially at gabions for road stability.
Lower Cabin John	R-74S	North Farm Creek between Montrose Road and North Farm Drive/Farm Pond Ln.	Channel has several large storm drain outfalls and large drainage area. Upstream portion of channel by tennis courts is stabilized with riprap in good condition. Reach shows slight erosion and has few bends. Middle section near playground & basketball courts has moderate spot erosion, with deposition of apparent dumped concrete or road grit. Channel is poorly aligned with the culvert headwall under North Farm Drive, but shows little scour/erosion. The lower reach between North Farm Drive and Tower Oaks Blvd. is very stable. Monitor middle section for worsening erosion or repeated deposited materials.

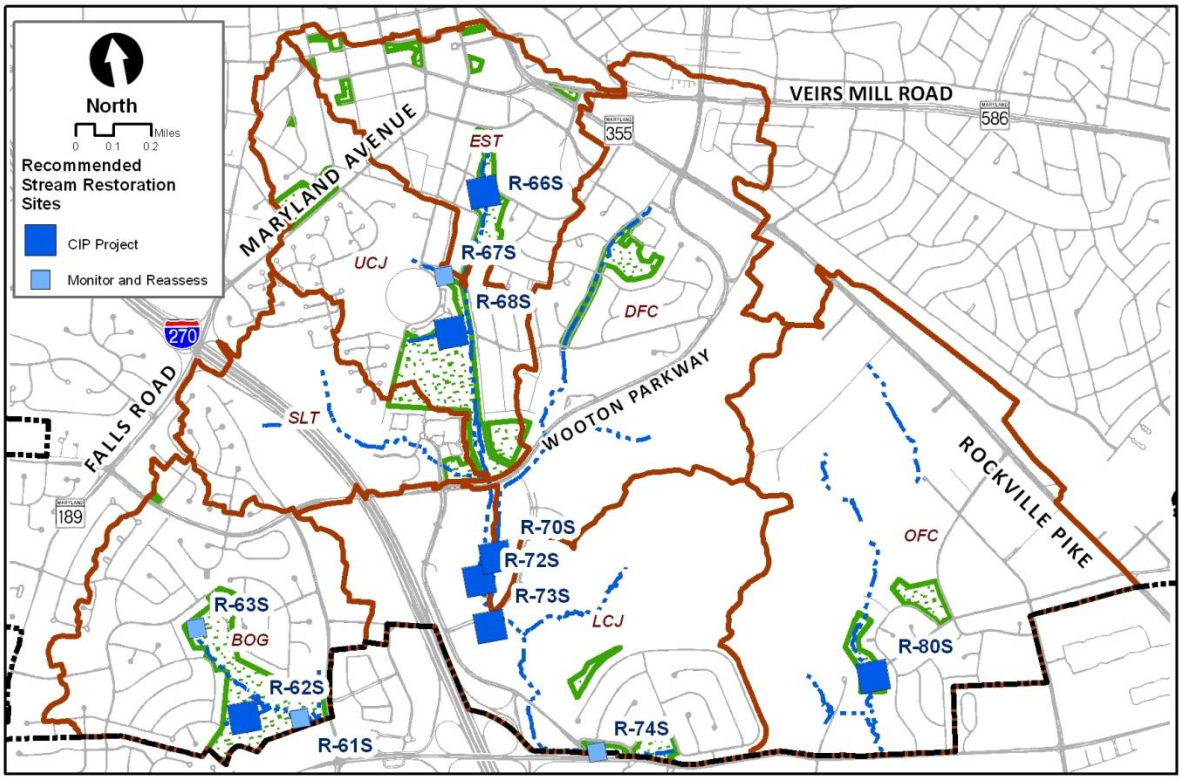


FIGURE 59: RECOMMENDED STREAM RESTORATION SITES

7.1.3 Operational Programs

The operational program recommendations are organized into the following categories: on-going monitoring and assessment; enforcement; outreach; maintenance; and incentives. While city staff can take on a small portion of these programmatic actions with current resources, implementing the majority on a large-scale will require either reprioritization of existing resources or increased investment if staff and/or funding. These impacts are outlined in the cost section below.

Ongoing Monitoring and Assessment

- Develop a water quality monitoring protocol to track pollutants targeted by TMDLs (nutrients, sediment or suspended solids, bacteria, etc.). This should include a city-wide plan identifying what parameters, where, when and how often. In addition, this protocol should identify the best way to monitor the success of SWM retrofits and stream restorations by identifying before and after monitoring techniques.
- Implement monitoring protocol. More monitoring data is needed to accurately identify pollution sources as well as to effectively evaluate programmatic success. The City should use monitoring results to make adjustments in program or project implementation as needed.
- Assess the feasibility of increasing frequency of street sweeping or storm drain inlet cleaning. (Debris, leaves, yard clippings, organic material, or trash was observed in common areas and street gutters in 26 of the 32 NSAs.) Further investigation is needed to identify the most cost-effective measures, best street sweeper equipment for water quality improvements, and ideal

frequency for residential and for non-residential streets. Also evaluate if source controls at storm drain inlets is more economical than trash/grit control at storm drain outfalls.

Enforcement

- Continue to conduct immediate investigation and enforcement for potential illicit discharges, using the Water Quality Ordinance.
- Increase compliance inspection and enforcement along Rockville Pike to reduce poor dumpster and trash management practices, using the Property Code regulations.
- Work with Woodmont Country Club and the Montgomery County Seven Locks Maintenance Yard to improve the water quality of runoff leaving their sites through better housekeeping practices and site management.

Outreach

- Conduct a lawn care education effort to reduce fertilizer use, and encourage proper disposal of yard debris, grass clippings and pet waste. (Sixteen of 32 NSAs had over 20 percent of the lawns showing high maintenance and some of the NSAs were observed with 100 percent of the lawns with high maintenance.)
- Expand the City's Rainscapes program to promote increased implementation of conservation landscaping in order to increase onsite runoff retention. Consider adding rain gardens or soil amendments to the Rainscapes program.
- Promote Rainscapes rebate program for tree planting in residential lots. This can be a lower priority because all but five of the NSAs had more than 20 percent of the lot devoted to landscaping as opposed to turf cover. All but four of the NSAs had more than 30 percent of the lot covered by tree canopy
- Promote the City's volunteer storm drain marking program. Stenciling was observed in only one of the NSAs.

Maintenance

- Develop an inspection and maintenance program to keep major culverts clear of sediment and vegetation.
- Continue to develop and refine a SWM maintenance program. Take into consideration SWM design, placement (what areas are draining to the facility) and age.

Incentives

- Consider expanding Rainscapes rebate program to encourage voluntary implementation of Environmental Site Design (ESD) practices on institutional and commercial properties to reduce runoff and improve water quality.

7.2 RECOMMENDATION COSTS AND BENEFITS

7.2.1 COST ESTIMATES

The preliminary cost estimate of all of the recommended stormwater management and stream restoration projects is approximately $5,015,000. CIP projects are broken down into design/permitting/inspection costs and construction costs, and include contingency costs due to the very conceptual designs. SWM CIP projects were based on City 2010 unit costs for construction. CIP stream project estimates are based on the Department of Public Works stream restoration unit costs projected for design in FY 2013 and construction in FY 2015. For SWM projects planned for major maintenance (Potomac Woods Wetland Marsh, Locks Pond, and Hungerford-Stoneridge Wetland Marsh), estimates were based on current (FY 2011) unit costs from the City's SWM Maintenance contract. Table 45 and Table 46 below summarize the preliminary cost estimates. Once the project

schedules are determined, these estimates will be updated in the CIP or Operations budgets to account for future cost of inflation.

TABLE 45: SWM RETROFIT CIP COST ESTIMATE

Site #	Site Name	CIP Design/ Permitting/ Inspection Costs	CIP Construction Costs	Non-CIP Major Maintenance Costs	Total Estimated Cost
R-03	Arlive Court Pond Retrofit	$36,000	$120,000		$156,000
R-19b	North Farm Pond Retrofit	$36,000	$120,000		$156,000
R-12a	Montgomery County Detention Center Pond Retrofit	$86,000	$462,000		$548,000
R-02	Potomac Woods Wetland Marsh Pond			$59,000	$59,000.00
R-08	Locks Pond Court Pond			$33,000	$33,000.00
R-23	Hungerford-Stoneridge Wetland Marsh Pond			$421,000	$421,000.00
	TOTAL	**$158,000**	**$702,000**	**$513,000**	**$1,373,000**

TABLE 46: STREAM RESTORATION CIP COST ESTIMATE

Site #	Site Name	CIP Design/ Permitting/ Inspection Costs	CIP Construction Costs	Total Estimated Cost
R-62S	Potomac Woods #3 Stream Restoration	$65,000	$349,000	$414,000
R-66S	Elwood Smith Park Stream Restoration	$5,000	$24,000	$29,000
R-68S	Dogwood Park Stream Restoration	$89,000	$480,000	$569,000
R-70S	Dawson Farm Creek Stream Restoration	$153,000	$825,000	$978,000
R-72S	Lower Cabin John Creek Stream Restoration	$171,000	$922,000	$1,093,000
R-73S	Tributary to Cabin John Creek Stream Restoration	$68,000	$414,000	$482,000
R-80S	Montrose Park Stream Restoration	$19,000	$58,000	$77,000
	TOTAL	**$570,000**	**$3,072,000**	**$3,642,000**

Costs of the non-structural recommendations will also impact the SWM Fund budget, but need more investigation to fully quantify. These are likely to be applied City-wide since the operational changes are equally applicable to all of the City's three watersheds. Table 47 lists the main programmatic recommendations and their estimated annual costs.

TABLE 47: OPERATIONAL COSTS AND STAFFING ESTIMATES

Recommendation	Current Annual Cost/Staffing	Projected Annual Cost/Staffing	Notes
Increased Street Sweeping	$30,000	$90,000	City-wide residential sweeping currently done twice a year; recommended for 6 times a year
Increased staffing for outreach/education	0.8 FTE	1.8 FTE	Increase staff to support new initiatives, additional Rainscapes approvals/inspections, research on effective resident/operational practices
Increased Rainscapes rebate funding	$10,000	$20,000	If rebates are added for structural ESD on residential or non-residential sites, annual costs would be at least $50,000+
Implement targeted water quality monitoring for both for SWM facilities and streams	$10,000 for pre/post CIP project, when required	To Be Determined	Better evaluate the effectiveness of watershed improvements and programmatic changes and link these to regulatory pollution limits
Increased inspection/ maintenance for storm drain culverts	As-needed basis based on complaints	To Be Determined	Remove unconsolidated sediment and vegetation from road culverts and immediately downstream to prevent out-of-bank flooding and reduce unconsolidated sediment

(Note – current and proposed operational costs represent City-wide spending, and are not limited to Cabin John watershed.)

7.2.2 Watershed Benefits

As Chesapeake Bay restoration efforts have shown, it is difficult to condense the entwined impacts of development, weather, and natural ecosystems into a cause-and-effect model. Without long-term stream monitoring of dry and wet-weather flowrates and water chemistry, agencies cannot numerically prove the pollutant reductions associated with BMP implementation. It is expected that TMDLs and other numeric yardsticks increasingly will be applied by the Federal and State regulators to measure progress towards the Chesapeake Bay Agreements.

There is also a lack of standardization in quantifying the effects of stormwater management facilities, stream restoration, and especially non-structural changes from ESD, education and other small-scale measures. New, more refined tools are needed to account for incremental benefits of many individual watershed improvements over time.

For now, spreadsheet models are the best method to evaluate watersheds in the absence of years of continuous water quality monitoring data. To develop these models, researches have averaged the pollutant reduction efficiency for groups of SWM facilities. For example, dry ponds mostly trap only loose trash and sandy grit, but wet ponds can retain up to 80 percent of the total suspended sediment loads. Additionally, armored streambanks improve water quality by reducing the sediment loads that

would have washed from the banks. To try and characterize the benefits received through implementation of the recommendations in this report, the Watershed Treatment Model was utilized.

Results of WTM Modeling

Pollutant loads were estimated using the Watershed Treatment Model (Caraco, 2010). The model allows for assessment of primary loads from urban land runoff, along with secondary sources such as active construction, managed turf, channel erosion, and point sources. It is a spreadsheet model that uses average loading factors for nutrients, sediment, and other pollutants to reflect the contributions from land use, vegetative cover, and development influences. The model then assesses the changes that best management practices like SWM or watershed education can make when applied to these pollution loads. Two scenarios were modeled for the City's Cabin John watershed: existing conditions, and proposed conditions with implementation of this study's recommendations. Printouts of model input/output spreadsheets are provided in Appendix I.

The overall benefits in pollutant load reductions come to approximately a 5 percent reduction in nitrogen and phosphorus throughout the watershed. This is primarily because of the limited opportunities to add more water quality treatment to the watershed beyond what exists now. The model shows that the proposed plan would have a more significant effect on sediment, reducing it by 10 percent from the total existing load from all sources.

Additional benefits to an active stormwater management program Include:

- Bank stabilization preventing tree loss in City parks and protecting private property
- Less trash and loose sediment in our City streams
- Improved local aquatic habitat
- Aesthetic benefits to the community and wildlife habitat through maintained SWM facilities
- Protection of City infrastructure including sewer and storm drain pipes

GLOSSARY

A

Armor-in-Place: Restoration technique intended to help stream banks withstand high flows from altered hydrology. "Armor" can consist of hard elements such as concrete, rip rap, or rock, or natural materials such as fiber logs or root wads. This technique is usually used when site constraints limit other restoration options.

B

Baseflow: The portion of stream flow that is not from runoff, resulting from seepage of groundwater into a channel. Also called dry weather flow.

Berm: A ridge of earth formed to direct or control the flow of surface water.

Bioengineering: Stream restoration techniques which use plants and living materials in preference to rock to stabilize eroding streams or to redirect flow to improve habitat.

Bioretention: A water quality practice that uses landscaping and soils to collect and treat urban stormwater runoff. Water is collected in shallow depressions in the ground and allowed to slowly filter through a layer of filter media and soil, while plants take up water and nutrients.

Build-out: The total potential land development area based on current and future land development and zoning plans.

Buffer: A vegetated, natural area adjacent to shorelines, wetlands, or streams. See also, *Resource Protection Area* and *Riparian Buffer*.

C

Channel: A natural or manmade waterway.

Confluence: The point where two or more streams join to create a combined, larger stream.

Control Structure: See *Riser*

D

Daylighting: A stream restoration technique which involves demolition and removal of a section of storm sewer and reconstructing a natural stream channel in its place, restoring the stream flow to "daylight".

Deposition: The process in which particles (e.g., silt, sand, gravel) in the water settle to the stream bottom. Too much deposition can create a thick layer of particles on the stream bottom causing a loss of habitat and spawning areas for *aquatic* insects and fish. Stream bank erosion is a common source for the particles.

Detention: The temporary storage of stormwater runoff used to control peak runoff amounts and provide time for the gradual settling of pollutants.

Dewatering Device: A component of a stormwater pond which can be opened up to drain the pond completely dry for maintenance.

Discharge: The volume of water that passes a given location within a given period of time, usually expressed for stream flow and stormwater in cubic feet per second. In the NPDES program, a discharge is the flow from a regulated facility, or in the case of municipalities like Rockville, from public storm drain outfalls.

Disconnected Impervious Area: Impervious area which drains to a pervious area. It is considered disconnected from the storm drain system because the flow can infiltrate and evaporate. A roof where the downspouts flow on to a lawn is disconnected.

Dissolved Oxygen (DO): The amount of oxygen that is present in water**.** An adequate supply of oxygen is necessary to support life in a body of water. Measuring the amount of dissolved oxygen in water provides a means of determining the water quality.

Drainage: The flow of surface water or *groundwater* from a land area.

Drainage Area: The area of land draining to a single outlet point.

Dry Pond: See *Detention Basin*.

Detention Basin: A stormwater management pond that temporarily holds runoff and slowly releases it to a downstream stormwater system. Since a detention basin holds runoff only temporarily, it is normally dry during periods of no rainfall. (Also called a *Dry Pond*.)

Dwelling Unit: A residential building or part of a building intended for use as a complete, independent living facility.

E

Ecosystem: All of the organisms in an ecological community and their environment that together function as a unit.

Effluent: Water that flows from a sewage or industrial treatment plant after it has been treated.

Embankment: The structure, typically of earth or concrete, which is designed to hold back water in a stormwater pond.

Endwall: A structure at the point where a free-flowing stream enters or discharges from a pipe or culvert. The endwall protects the pipe end from erosion and guides the flow in or out.

Ephemeral: A stream with no baseflow which flows only periodically or occasionally, usually during and immediately after precipitation.

Environmental Site Design (ESD): A suite of stormwater management techniques that reduces the stormwater impacts from new development or redevelopment, which combines site design and onsite treatment techniques. Site design can include reducing the amount of *impervious surfaces* and designing the site to take advantage of the natural conditions can reduce the amount of runoff produced by a development area. Onsite treatments include techniques such as vegetated swales and *bioretention* filters or basins to reduce runoff rates and promote *infiltration*.

Erosion: The wearing away of the land surface by running water, wind, ice, or other geological agents. In streams, erosion is the removal of soil from the stream banks or streambed by rapid flows.

Eutrophication: The process of over-enrichment of water bodies by nutrients, often resulting in excess algae. Decaying algae or other organic matter reduces dissolved oxygen in streams and the Bay.

Evapotranspiration: The loss of water to the atmosphere from the earth's surface by both evaporation and by *transpiration* through plants.

Extended Detention: Additional depth in a stormwater pond (usually 2 to 3 feet) above the permanent pool or dry bottom to increase holding time and sedimentation. The additional storage is used for improving water quality or reducing flooding or peak discharges that can cause downstream channel erosion.

F

Fecal Coliform Bacteria: A group of bacterial organisms that live in the intestinal tracts of humans and animals. The presence of fecal coliform bacteria indicates excrement sources from humans, pets or wildlife are present in the environment.

Filter Strips: A vegetated area that treats *sheet flow* and/or interflow by removing sediment and other pollutants. The area may be grass-covered, forested or of mixed vegetative cover (e.g., wildflower meadow).

Fish Passage: Unobstructed movement of fish within the stream system. Fish require the ability to move between various habitat types and during migration.

Flashy: A description of stream flow that varies widely and rapidly between very low baseflow and significantly higher flows in wet weather.

Floatables: Trash, debris, and other large pollutants that tend to float on the surface of streams, lakes, and ponds, and which are not removed by sedimentation, filtration, or other processes in most stormwater management facilities.

Flood limit: Those land areas in and adjacent to streams subject to continuous or periodic inundation from flood events. A 100-year flood limit is an area with a 1 percent chance of inundation in any given year. Differs from a floodplain.

Floodplain: An ecosystem adjacent to a stream which undergoes fairly frequent inundation during high flows when the stream overtops its banks.

Forebay: A small storage area near the inlet of a stormwater pond to trap incoming sediment where it can be removed easily before it can accumulate in the pond.

G

Gabion: A wire basket or cage that is filled with rock, used to stabilize stream banks, change flow patterns, or prevent erosion.

Geographic Information System (GIS): A computer system for mapping and spatial analysis.

Geomorphology: The study of physical landforms and the processes that shape and change them. In this study, it refers to the study of fluvial (rivers and streams) geomorphology.

Grade Control (Streams): A method of stream restoration intended to halt and repair incision by adjusting the slope of the stream through a series of step pools, riffles and pools, or other constructed features.

Groundwater: Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturated zone is called the water table.

H

Habitat (Aquatic): A measurable description of the features of a stream which are necessary for insects, fish, and other creatures to thrive, including depth, flow, velocity, substrate, substrate size, and riparian cover.

Head Cut: A type of incision in a streambed consisting of a sudden change in elevation from upstream to downstream, similar to a waterfall. High flows erode the upstream channel at a headcut, resulting in the erosion and incision migrating upstream.

Headwater: The source of a stream or watercourse.

Hydraulics: The physical science and technology of the stationary and active behavior of fluids.

Hydrology: The science dealing with the distribution and movement of water, including the hydrologic cycle of rainfall, runoff, groundwater flow, surface water flow, and evaporation.

I

Illicit Discharge: To dump, spill, convey, or otherwise release pollutants to the City's waterways, storm drain system, or groundwater in violation of the City Code. Illicit discharges are regulated by the City's Water Quality Protection Ordinance.

Incised (Stream): A channel which has cut downward through its bed, becoming disconnected from its floodplain. High flows which previously overtopped the stream banks and dissipated energy in the floodplain stay within the banks of an incised channel, increasing erosion.

Impervious Surface: A surface composed of any material that impedes or prevents *infiltration* of water into the soil. Impervious surfaces include roofs, buildings, streets, and parking areas. Also called impervious cover.

Infill: A residential development that has occurred near, or within, an already established neighborhood.

Inflow: The source of flow into a stormwater pond. Usually a pipe or man-made channel.

Infiltration: The process by which water drains into the ground. Some of this water will remain in the shallow soil layer, where it will gradually move through the soil and subsurface material. Eventually, it might enter a stream by seepage out of a stream bank or it may penetrate deeper, recharging *groundwater aquifers*.

Infiltration Facility: A stormwater management facility that temporarily stores runoff so it can be absorbed into the surrounding soil. Since an infiltration facility confines runoff only temporarily, it is normally dry during periods of no rainfall. Infiltration ponds, infiltration trenches, infiltration dry wells, and porous pavement are considered infiltration facilities.

Invert: The lowest elevation of a feature in the drainage network: the bottom of a pond, the bottom of a manhole or pipe, the lowest part of a control structure,

L

Land Development: A man-made change to, or construction on, the land surface.

Land Use: Describes the type of activity on the land such as commercial or residential. The City zoning requirements dictates the type of land use allowed for a given area.

Low-flow Channel: In a stormwater pond, the low-flow channel guides baseflow through the pond during dry periods. Older designs used straight channels made with concrete; newer designs use meandering paths in natural soils, frequently planted with wetland vegetation.

M

Marsh: A wetland area, periodically inundated with water.

Meander: A stream bend or series of stream bends. Erosion is frequently found on the outer banks of meander bends because they take the force of the flow as it turns.

Median (Parking lot): A small unpaved area in the middle of a parking lot. Most designs use raised medians with curbs. LID techniques can use depressed medians for stormwater treatment.

Micropool: A small permanent pool in a larger stormwater pond system, usually at the pond outlet to provide additional settling of pollutants.

Mitigation: To make a development scenario less harmful than the original plan; or to provide a habitat in another more conducive, larger, or better-suited area, typically in a different location from the original.

Municipal Separate Storm Sewer System (MS4) Permit: An NPDES (National Pollutant Discharge Elimination System) permit issued to municipalities requiring the reduction in pollutants contributing to the discharges from the municipality's storm drain outfalls.

N

National Pollutant Discharge Elimination System (NPDES): The national program for issuing, modifying, monitoring, and enforcing permits under Sections 402 of the Clean Water Act. The NPDES permits regulate wastewater and stormwater discharges to the waters of the United States, and are administered by the Maryland Department of the Environment.

Nested Channel: A stream restoration technique for incised and overwidened streams which mimics a natural, recovered stream by constructing a small, low-flow channel with an adjacent floodplain bench, all within the existing channel.

Nitrogen: A chemical element that occurs naturally as a gas and makes up 78 percent of the atmosphere. Combined with oxygen as nitrate, it is required by plants for growth and is found in most fertilizers. Too much nitrogen in the water can cause *eutrophication* and result in excess algal blooms, reducing the amount of oxygen available to aquatic life. *Total Nitrogen* refers to all nitrogen compounds forms: nitrate, nitrite, ammonia, and organic nitrogen.

Nutrient: A substance that provides food or nourishment. In the aquatic environment, nutrients refer to compounds of phosphorus, nitrogen, and potassium that contribute to *eutrophication*.

O

Open Space: A portion of a development site that is permanently set aside for public or private use and will not be developed. The space may be used for recreation, or may be reserved to protect or buffer natural areas.

Outfall: Defined in the *NPDES* program as the point where discharge from a regulated system flows into waters of the United States.

Outlet: The point at which water flows from one water body to another, such as a stream or river to a lake or larger river.

Overwidened (Stream): A stream with a channel cross-section which has eroded and become wider over time. Low flows become very shallow and provide poorer habitat.

P

Peak Discharge: The maximum flow rate at a given location during a rainfall event. Peak discharge is a primary design factor for the design of stormwater runoff facilities such as pipe systems, storm inlets and culverts, and swales.

Perennial Streams: A body of water that normally flows year-round, supporting a variety of aquatic life.

Pervious: Any material that allows for the passage of liquid through it. Any surface area that allows *infiltration*.

Phosphorus: An element found in fertilizers and soil that can contribute to the *eutrophication* of water bodies. *Total Phosphorus* refers to all phosphorus compounds forms: orthophosphorus and both dissolved and particulate organic and inorganic phosphorus.

Plunge Pool: A small pond located at either a stormwater outfall or an inflow to a stormwater pond, designed to dissipate the energy of high-speed flows.

Pollutant: Any substance introduced to water that degrades its physical, chemical, or biological quality.

Pollutant Loading: The rate at which a pollutant enters a surface water or *groundwater* system. This is typically determined by water quality modeling and expressed in terms such as pounds per acre, per year.

Pollution Prevention: Any activity intended to reduce or eliminate stormwater pollution by reducing the amount of runoff, or by reducing the opportunity for stormwater to wash off and transport pollutants downstream.

Pool: The reach of a stream between two *riffles*; a small and relatively deep body of quiet water in a stream or river. Natural streams often consist of a succession of pools and riffles.

Post-Development: Refers to conditions that exist after completion of a land development activity on a specific site or tract of land.

Pre-Development: Refers to the conditions that exist at the time that plans for land development of a tract of land are approved by the plan approval authority.

Pre-Treatment: A component of a stormwater management facility located upstream of the main storage area. It is designed to trap trash and coarse sediment at the inflow point to increase the facility's effectiveness and maintenance life.

Q

Quantity Control: *Stormwater management facilities* designed to reduce *post-development peak discharge* to the peak *discharge* that occurred in the *pre-development* conditions, or to reduce the amount of runoff.

Quality Controls: *Stormwater management facilities* designed to remove *pollutants* from *runoff* and improve water quality.

R

Rain Barrel: A storage container connected to a roof downspout, typically including a hose attachment to allow for capture and reuse of rooftop runoff.

Rain Garden: A landscaped depressed area that allows stormwater from impervious areas, typically roofs and driveways, to pond temporarily before infiltrating and being taken up by vegetation.

Reach: General term used to describe a length of stream.

Recharge: The downward movement of water through the soil into *groundwater*; for example, rainfall that seeps into a groundwater aquifer.

Redevelopment: The substantial alteration, rehabilitation, or rebuilding of a property for residential, commercial, industrial, or other purposes.

Regenerative Stream Conveyance: A stabilization technique for storm drain outfalls or small streams. A filter of large stone, sand and woodchips is installed along a downcut channel to control bank erosion and provide some water quality treatment.

Regional Ponds: Larger stormwater management facilities designed to treat the runoff from drainage areas of 100 to 300 acres.

Regrade: A stream restoration technique for incised or over-widened channels which involves excavation and fill to change the cross-section of the stream banks from an easily eroded, usually vertical, form, to a more stable, usually sloping, shape.

Retention Basin: A stormwater management pond that permanently stores water for the purpose of improving water quality. It is normally wet, even during periods without rainfall. Also called a *Wet Pond*.

Retrofit: The modification of stormwater management systems to improve water quality or to change characteristics of peak discharge control by adding storage, changing outflow characteristics, or adding water quality treatments such as pools, meanders, wetland plantings, or other features.

Riparian Buffer: Strips of grass, shrubs, and/or trees along the banks of rivers and streams that filter polluted runoff. These buffers provide a transition zone between water and human land use. Buffers are also complex ecosystems that provide habitat and improve the stream communities they shelter.

Riprap: A protective layer of large stones placed on a streambank to prevent erosion.

Riffle: A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle/Run: Streams that are generally characterized by a high slope (gradient), and a mixture of riffle and run habitat.

Riser: A pipe or structure used to control the discharge rate from a stormwater management pond.

Runoff: The portion of precipitation, snowmelt, or irrigation water that flows off the land into surface waters instead of *infiltrating*.

Run: A segment of stream length that is characterized by moderate depths, smooth flowing water at a moderate pace. A run is intermediate between a *riffle* and a *pool*.

S

Sand Filter: A stormwater management facility consisting of a large, flat area which collects stormwater in a shallow pond and allows it to slowly percolate through a sand bed to remove sediment and pollutants. Usually has an underdrain to collect and convey the filtered stormwater.

Sanitary Sewer: The pipe network that carries domestic and industrial wastewater to a treatment plant.

Scour: Removal of sediment from the streambed and banks caused by fast moving water. See also *Erosion*.

Sedimentation (Treatment): In a water treatment context, sedimentation refers to a pollutant removal method in which pollutants are removed by gravity as sediment settles out of the water column. An example of a *best management practice* using sedimentation is a *detention pond/wet pond*.

Sedimentation (Streams): See *Deposition*

Sheet Flow: Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Sinuous: Sinuosity describes how a stream or river turns back and forth across the land as it flows downstream. A stream with many tight meanders for its length is more sinuous than one with shallow bends.

Stakeholder: Stakeholders include groups of people within the watershed (e.g., residents, businesses, industry, local government agencies, and community groups). Stakeholders may have environmental interests or other interests that affect choices for watershed management.

Storm Drain: A man-made drainage system of street or yard inlets and pipes that carries rain/snow runoff from developed areas to the stream. In Rockville and Montgomery County, storm drain pipes are completely separate from sanitary sewers that carry wastewater.

Stormwater: Surface water flow that results from rainfall.

Stormwater Management (SWM) Facility: A structure, such as a pond, that controls the quantity and quality of stormwater runoff.

Stormwater Outfall: A single location, pipe discharge, or outlet structure that releases stormwater into a stream, river, or pond.

Stormwater Ponds: A depression or dammed area with an outlet device that controls stormwater outflow. Stormwater ponds retain water from upstream areas, thereby reducing peak flows downstream. In the City of Rockville, stormwater ponds are either dry (*dry pond*) or contain a permanent pool of water (*wet pond*) and are typically designed to control the peak runoff rate for selected storm events.

Stormwater Wetlands: Areas intentionally designed to emulate the water quality improvement function of wetlands for the primary purpose of removing pollutants from stormwater.

Stream Restoration: The reestablishment of the structure and function of a stream, as closely as possible to its pre-existing condition.

Substrate: The material forming the bottom of a stream channel. Channel materials are generally broken into categories (listed smallest to largest) such as clay, silt, sand, gravel, cobble and boulder.

Sub-watershed: A smaller subsection of a larger *watershed*, often delineated to describe a particular tributary to a larger water body.

Suspended solids: Particles that are suspended in and carried by the water. The term includes sand, mud, and clay particles as well as solids in wastewater.

Swale: A natural depression or wide shallow ditch used to temporarily store, route, or filter runoff.

T

Toe Protection (Streams): A stream restoration technique to provide erosion protection for the bottom of the streambank. Typically constructed of stone and tied into a regraded and re-vegetated bank.

Total Kjeldahl Nitrogen (TKN): A measure of two forms of nitrogen: ammonia and organic nitrogen. Total Nitrogen (TN) equals TKN plus nitrite plus nitrate.

Transpiration: The process by which water vapor escapes from living plants and enters the atmosphere. Studies have shown that about 10 percent of the moisture found in the atmosphere is released by plants through transpiration.

Tree Canopy Cover: The area directly beneath the crown and within the drip line of a tree.

Turbidity: Turbidity is an indicator of the amount of solid particles suspended in water. High turbidity typically is associated with runoff from construction sites, which may make water cloudy or opaque.

U

Underdrain: A series of perforated pipes installed under a filtration treatment system which collects filtered water and conveys it to a storm sewer or stream. May be installed in infiltration systems to divert high flows.

W

Waters of the United States: Lakes, rivers, streams, tidewater, wetlands, and other water bodies protected under the Clean Water Act (33 U.S.C.1252). Also see the definition set for in 40 CFR 230.3(s).

Watershed: An area of land that drains directly, or through tributary streams, into a particular river or water body. A watershed includes its associated groundwater. Elevated landforms, such as ridges or even roads can serve as watershed divides.

Weir: A section of a riser which limits the discharge from a stormwater pond to the level determined by the design.

Wetlands: Areas where the soil or substrate is saturated with water during at least a part of the growing season. These saturated conditions determine the types of plants and animals that live in these areas.

Wet Pond: See *Retention Basin*

8 ACRONYMS

BMP	Best Management Practice
BSID	Biological Stress Identification
CIP	Capital Improvement Plan
CMP	Corrugated Metal Pipe
CN	Runoff Curve Number
COMAR	Code of Maryland Regulations
CPv	Channel Protection Volume
DCIA	Directly Connected Impervious Area
DNR	Maryland Department of Natural Resources
DO	Dissolved Oxygen
DRP	City of Rockville Department of Recreation and Parks
DPW	City of Rockville Department of Public Works
ESD	Environmental Site Design
EPA	US Environmental Protection Agency
E/SC	Erosion and Sediment Control
FEMA	US Federal Emergency Management Agency
GIS	Geographic Information System
HOA	Homeowners Association
HSG	Hydrologic Soil Group
HSI	Hotspot Site Investigation
MBSS	Maryland Biological Stream Survey
MDE	Maryland Department of the Environment
MCDEP	Montgomery County Department of Environmental Protection
MS4	Municipal Separate Storm Sewer System
MWCOG	Metropolitan Washington Council of Governments
NO2	Nitrite
NO3	Nitrate
NPDES	National Pollutant Discharge Elimination System
NRCS	US Natural Resources Conservation Service
NSA	Neighborhood Source Assessment
NTU	Nephelometric Turbidity Units
NWI	National Wetland Inventory
PROS	Parks, Recreation, and Open Space Plan
RSAT	Rapid Stream Assessment Technique
RSC	Regenerative Stream Conveyance

ROW	Right of Way
SHA	Maryland State Highway Administration
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic Data
SWM	Stormwater Management
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USA	Unified Stream Assessment
USACE	U.S. Army Corps of Engineers
USSR	Unified Sub-watershed and Site Reconnaissance
UTC	Urban Tree Canopy
WQ	Water Quality
WQv	Water Quality Volume
WSSC	Washington Suburban Sanitary Commission
WTM	Watershed Treatment Model

9 REFERENCES

Caraco, Deb. 2010. Watershed Treatment Model (WTM), 2010 User's Guide – Draft. Center for Watershed Protection, Ellicott City, MD.

Center for Watershed Protection, 2004. Unified Stream Assessment: A User's Manual, Version 1.0. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection and US Forest Service, 2008. "Reducing Stormwater Runoff", Watershed Forestry Guide. http://www.forestsforwatersheds.org/reduce-stormwater/ Accessed March 31, 2011.

City of Rockville, 2002. Comprehensive Master Plan http://www.rockvillemd.gov/masterplan/index.html#masterplan

City of Rockville, 2009. Parks, Recreation and Open Space Plan. Rockville, MD.

Code of Maryland Regulations (COMAR), 2010. Online website http://www.dsd.State.md.us/comar/comar.aspx

Dwyer, John F., and David. J. Nowak, 2000. "A National Assessment of the Urban Forest: An Overview", in Proceedings of the Society of American Foresters 1999 Convention, Portland, Oregon.

Maryland Department of the Environment, 1996. Integrated Report of Surface Water Quality in Maryland.

Maryland Department of the Environment ,2006. Total Maximum Daily Loads of Fecal Bacteria for the Non-tidal Cabin John Creek Basin in Montgomery County, Maryland. MDE, Baltimore, MD.

Maryland Department of the Environment, 2010. Draft Integrated Report of Surface Water Quality in Maryland. http://www.mde.State.md.us/Programs/WaterPrograms /TMDL/Pub_Notice /draft_2010_IR_for_pubnotice.asp

Maryland Department of the Environment, 2009a. Watershed Report for Biological Impairment of the Cabin John Creek Basin in Montgomery County, MD: Biological Stressor Identification Analysis Results and Interpretation.

Maryland Department of the Environment, 2009b. Maryland's Searchable Integrated Report Database Combined 303(d)/305(b) list. http://www.mde.State.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/2008_303d_search/index.asp

Maryland Department of the Environment, 2008. Integrated Report of Surface Water Quality in Maryland. http://www.mde.maryland.gov/assets/document/2008_IR_Parts_A_thru_E(1).pdf

Maryland Department of Natural Resources, 2009. A Report on the City of Rockville's Existing and Possible Urban Tree Canopy.

Metropolitan Washington Council of Governments, 1994. Upper Cabin John Creek Watershed Management Study. Prepared for the City of Rockville Department of Public Works Stormwater Management Division.

Ohio Department of Natural Resources , 2010. Division of Soil and Water Resources – Stream Morphology. 2010. STREAM Modules. http://www.dnr.State.oh.us/soilandwater/water/streammorphology/default/tabid/9188/Default.aspx

Rosgen, Dave, 1996. Applied River Morphology, Wildland Hydrology, Pagosa Springs, CO.

Schueler, T., Fraley-McNeal, L., and K. Cappiella, 2009. Is Impervious Cover Still Important? Review of Recent Research. Journal of Hydrologic Engineering 14(4): 309-315.

Strommen, B., Cappiella, K., Hirschman, D., and J. Tasillo, 2007. A Local Ordinance to Protect Wetland Functions. Article 4 in the Wetlands and Watershed Article Series. Center for Watershed Protection. Ellicott City, Maryland.

U.S. Geological Survey, 2010. Dissolved Oxygen Saturation Tables. Available online at http://water.usgs.gov/software/DOTABLES/

U.S. Environmental Protection Agency, 2000. Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria - Rivers and Streams in Nutrient Ecoregion IX. EPA 822-B-00-019. Office of Water; Washington D.C.

U.S. National Climatic Data Center, 2011. Preliminary Monthly Climate Data. http://www.nws.noaa.gov/climate/index.php?wfo=lwx,.

Wright, T., C. Swann, K. Cappiella, T. Schueler, 2005. *Unified Sub-watershed and Site Reconnaissance: A User's Manual-Version 2.0*. Manual 11 in the Urban Sub-watershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.