Occoquan Watershed

Prince William County, Virginia

WSSI #25156.01

Study of Four Subwatersheds

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Disclaimer

This watershed study is a management tool for use in planning and prioritizing potential Capital Improvement Projects. While the information is based on actual observation in the field and believed to be accurate, all conceptual projects are subject to staff evaluation and prioritization based on multiple constraints such as time, resources, regulatory changes, and funding. This study is not designed, intended, or to be construed in any way, as a complete listing or comprehensive evaluation of all issues or needs within the area studied. This study does address many of the elements of the PWC Comprehensive Plan, Chapter 7, “Environment”. However, this study was not conducted to meet any regulatory requirement and is not a “Watershed Management Plan” in the regulatory sense. Cost estimates included are “order of magnitude” estimates based on the consultant’s expertise, experience, and judgment.

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1.0 Executive Summary

Prince William County Public Works, Watershed Management Branch of the Environmental Services Division, conducted a study of four subwatersheds (“subsheds”) within the portion of the Occoquan Watershed in Prince William County. The purpose of this subshed study was to provide guidance for Capital Improvement Projects (CIP) by using a combination of GIS data and field assessment techniques to prioritize and plan how impaired streams, Stormwater Management and Best Management Practice (SWM/BMP) Facilities, and other infrastructure can be improved and/or restored within the 4 selected subsheds.

The 4 subsheds of interest total over 3,100 acres, which is approximately 10 percent of the portion of the Occoquan Watershed in Prince William County. Initial GIS desktop screening provided helpful overall watershed information and is summarized in 13 watershed categorization maps. All four subsheds are predominately developed with a range in impervious cover from 37 to 72 percent, with Subshed 450 having the most impervious surfaces. Contiguous wetlands and streams do exist and many are protected with a forested buffer. Adjacent to these subsheds, Occoquan River is listed as an impaired 303(d) water for low dissolved oxygen, fecal coliform, and PCBs. In 2012, Hooes Run was added to the list of impaired waters for exceeding fecal coliform bacterium criteria for recreation water usage. Overall, the watershed characterization summary and maps show that while some surface waters and environmental resources within the subsheds are being protected, more efforts are required to protect the Occoquan River and the Chesapeake Bay.

This report provides a detailed summary of the initial desktop screening criteria, results of field assessments, and conceptual designs for 3 SWM/BMP retrofits projects and 6 stream restoration reaches. In summary, all 25 SWM/BMP Facilities in the 4 subsheds were visited, and 20 were successfully inspected. The goal of the site inspections was to identify general repair or retrofit opportunities that would significantly improve water quality or provide downstream channel protection. Four SWM/BMP Facilities (48, 454, 691, and 694) appeared to be in good operating condition, thus no retrofit or maintenance is required. Conceptual design plans were developed for three (SWM/BMP Facilities 28, 489, and 9026), as detailed within this report. The remaining facilities would benefit from some level of maintenance and/or retrofit, ranging from simple repairs to water treatment efficiency improvements. Detailed information on these maintenance opportunities is also provided within this report.

In addition, 26 streams, totaling over 6 miles, were field inspected and restoration needs and opportunities were prioritized. The Rapid Stream Assessment Technique (RSAT) was used for the assessment. Over 80 percent of the assessed stream reaches showed signs of degradation, mostly from urbanization of their respective subsheds, and would benefit from either full restoration or, at a minimum, from some “spot stabilization”. Therefore, those streams selected for conceptual plan development are those that would gain the most from restoration and/or stabilization, plus have sufficient construction access, buffer protection, and/or would provide benefits to impaired downstream waters. In addition, the selected streams are maintained by the County or a single entity. As a result, conceptual restoration designs are provided for 6 stream reaches (5, 6A, 9, 10, 12, and 20A), as detailed in this report.

Beyond the proposed full restoration opportunities, spot improvements were also identified and detailed. These improvements are primarily related to stabilizing exposed utilities in the stream channel, most likely from channel migration and downcutting. Two repairs require immediate attention where infrastructure (residential fence and retaining wall) adjacent to the channel is eroding (Reach 17B) and where a culvert wing wall and the exit ramp off Interstate 95 are being compromised (Reach 21).

In addition to the stream assessments used to prioritize restoration opportunities, a benthic macroinvertebrate assessment was conducted using Izaak Walton League of America's Save Our Streams (SOS) methodology on one assessed reach in each subshed. The stream with the highest ranking RSAT score was selected with the hypothesis that these reaches would provide the highest possible benthic assessment scores. The results of these assessments indicates that the SOS quality rating for 3 of the 4 subsheds was "Poor", with the stream in Subshed 448 ranking as "Fair".

Conceptual Plans include a narrative detailing existing conditions, design goals, design concepts, and future considerations. The plans also include existing condition photos, drainage area maps, and overall plan views of each site. SWM/BMP Facility Conceptual Plans also include a Curve Number summary table and a Conceptual Design Data Sheet that presents a summary of design options, highlighting the ones selected for the conceptual design. A supplement to the Stream Restoration Conceptual Plans is also provided. This supplement includes typical restoration approaches (e.g. design priorities), typical riffle with a reinforced bed, rock and wood stream structures that will provide both grade control and habitat benefits, and a planting detail.

Data for the conceptual plan cost estimates was obtained through numerous sources, including the PWC Unit Price List, contractor bids, and unit price lists from adjacent Counties. The estimated total cost for all SWM/BMP facility retrofits is $ 1,354,000 (range $235,000 to 600,000), with an average cost of $12,000 per pound of Total Phosphorous (TP).

The total estimated cost of the stream restoration projects is $7,110,000 (range $680,000 to $1,895,000), with an average cost of $12,500 per pound of TP. The average cost per linear foot for these projects is $870. Urban stream restoration costs in Northern Virginia generally range from $500 - $900 per linear foot due to the complexity of the design (e.g. amount of required rock, realignments, and utility crossings) and the ease of construction access and staging. The cost variability attributable to site specific conditions can be refined with detailed topographic surveys, tree surveys, and utility mapping. A summary of funding options from government, non-government, and private sources is provided as Appendix K.

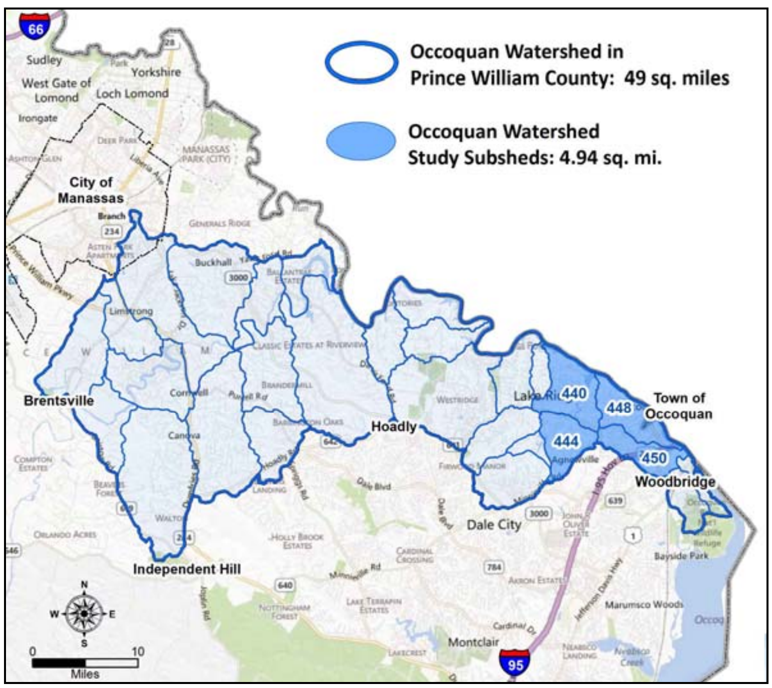
Beyond the recommended retrofits, restorations, and maintenance repairs, it is recommended that the County incorporate structural and non-structural Low Impact Development (LID) measures to help disconnect or reduce impervious cover, and reduce stormwater runoff from entering the County's waterways. The County should consider supplementing this watershed study with a study that focuses on identifying specific parcels for implementing these LID measures. The combination of the stream restoration and retrofit projects, along with LID measures, will assist the County in meeting the Chesapeake Bay TMDL nutrient load reduction requirements.

In addition, the County and Town of Occoquan (Town) should explore potential sources of the reported flooding problems in and near the Town. SWM/BMP retrofits are proposed upstream of the Town (SWM/BMP Facilities 28 and 9026). However, the receiving channel (Stream Reach 16) for Facility 28 that flows into the Town appeared stable during the stream site inspections, with no signs of frequent overbank flooding and received an RSAT score of 34 (good). Further investigation is therefore required in order to identify the cause of the reported flooding.

2.0 Project Description

Prince William County's Public Works Watershed Management Branch of the Environmental Services Division hired Wetland Studies and Solutions, Inc. (WSSI) to conduct this study of four subsheds within the portion of the Occoquan Watershed in Prince William County (Figure 2.1). The purpose of this subshed study was to provide guidance for CIP by using a combination of GIS data and field assessment techniques to prioritize and plan how impaired streams, SWM/BMP Facilities, and other infrastructure can be improved and/or restored within the four selected subsheds.

Figure 2.1 Occoquan Watershed and Subshed Study Area

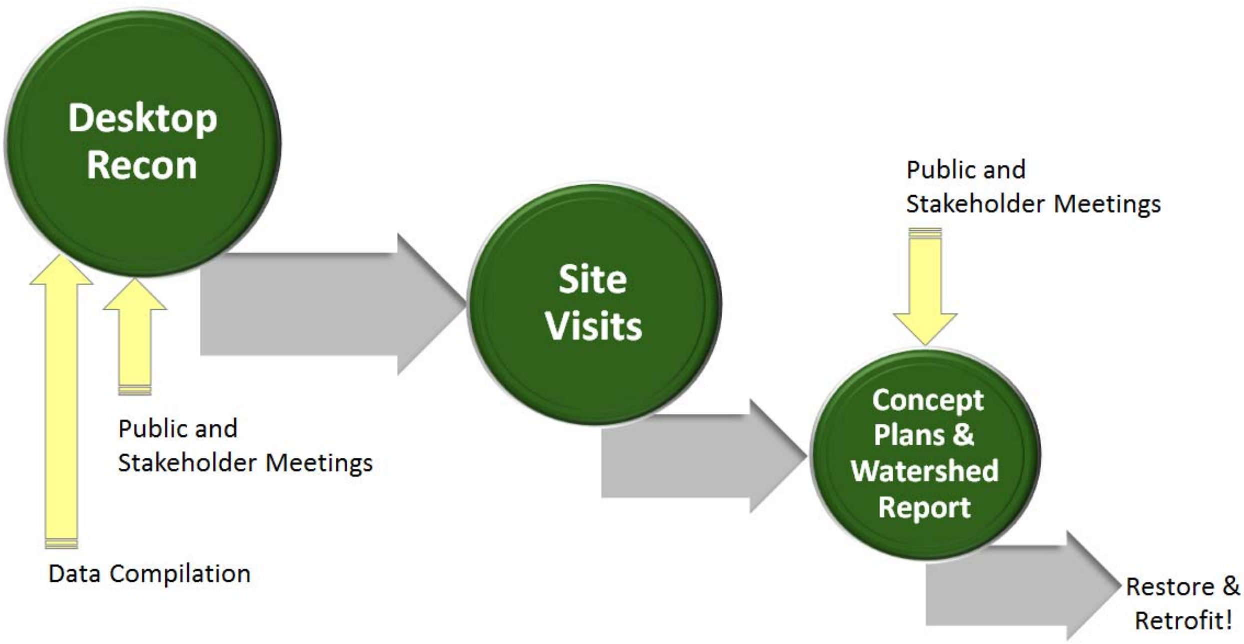


The four selected subsheds (Subsheds 440, 444, 448, and 450) were chosen in part due to flooding and stormwater problems in the Town of Occoquan (Appendix A, Exhibit 1). While these four subsheds surround the Town of Occoquan, resources within the Town limits were excluded from this study because they are outside of the jurisdiction of Prince William County.

Prior to initiating the subshed study process, Prince William County staff held a public meeting on April 1, 2013 inviting stakeholders to meet with staff, understand the scope of the study to be undertaken, and allow for public input into the process. During the public meeting, stakeholders identified several streams and SWM/BMP facilities that they recommended be studied during the inventory review. A final stakeholder meeting was held February 10, 2014. A list of attendees for both meetings is provided in Section 10.0 of this report.

Figure 2.2 illustrates the overall watershed study process. Upon initiating the study, a screening process was implemented that utilized desktop analysis of available GIS information to direct field inspection and assessment efforts of SWM/BMP facilities and stream reaches within the four subsheds. Following these field inspections, the facilities and streams were assigned a rank and prioritized for the development of facility retrofit or stream restoration conceptual plans. Proposed retrofit and restoration projects within the four selected subsheds were focused on publicly and Homeowner Association-maintained properties in an effort to minimize easement and land acquisition constraints. These proposed projects and other recommendations focus on solutions that address watershed degradation, including TMDLs and 303(d) listed impairments. Conceptual plans and cost estimates developed for the selected projects are included as part of this Watershed Study.

Figure 2.2 Overall Subshed Study Process



3.0 Watershed Characterization

This study consists of 4 subsheds within the Prince William County Occoquan watershed, designated as Subsheds 440, 444, 448, and 450. They comprise 3,163 acres, approximately 10 percent of the total Prince William County Occoquan watershed, and are concentrated in the eastern end, near or within the Interstate 95 corridor and surrounding the Town of Occoquan (Appendix A, Exhibit 1). These subsheds have undergone significant environmental changes since the settlement of Prince William County, transitioning from forests and agricultural fields to the mix of urban and suburban neighborhoods that are present today.

3.1 General Watershed Characteristics

In an effort to properly characterize each subshed, existing digital data was acquired from the County as recommended in the 2008 Prince William County Comprehensive Plan, Section EN7.1 (revised December 14, 2010) (Table 3.1). After the recommended data was evaluated, supplemental data from other available sources was acquired and integrated (Table 3.2). This supplemental data assisted in better understanding the overall environmental characteristics of this portion of the watershed and reduced data gaps and discrepancies in the existing County GIS data. The assimilated data is presented as 13 exhibits in Appendix B, Exhibit 1. A summary of the findings is presented below.

Table 3.1 Recommended GIS data for use in County Watershed Studies [1]

GIS Data [1]
Existing Impervious Surfaces
Stormwater Management Facilities
Water Quality Monitoring Stations
Forest Cover
Topography
Soils and Geologic Features
Floodplains
Maintenance Responsibility (Public/Private)
Land Use/Zoning
Sub-watershed Areas

[1] Per Prince William County 2008 Comprehensive Plan (revised December 14, 2010)
[2] All information acquired from Prince William County GIS data (April and March 2013)

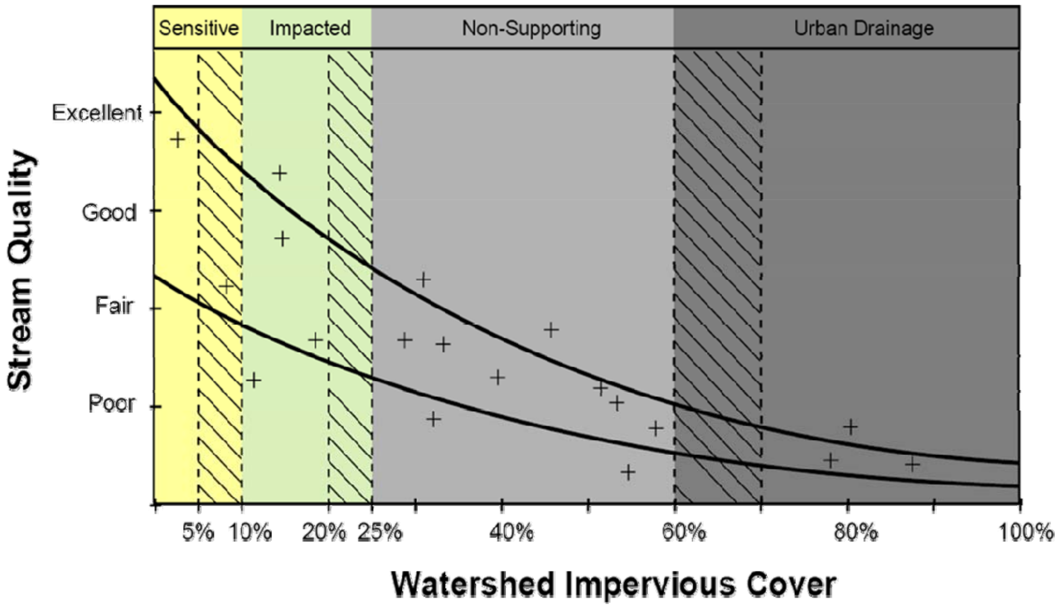
Table 3.2 Additional GIS Data used for the Study of 4 Subsheds within the Occoquan Watershed

Additional GIS Data	Source
County-mapped and Field-verified Wetlands and Streams	County, Wetland Studies and Solutions, Inc. (WSSI)
County-mapped and Field-verified Resource Protection Areas (RPA) Boundaries	County, WSSI
Northern Virginia Desktop Reconnaissance Wetlands and Streams with color-infrared	WSSI
WSSI stream flow determinations	WSSI
Hydrology (streams and water boundaries)	County
National Wetland Inventory (NWI) mapping	U.S. Fish and Wildlife Service (FWS)
Floodplains	Federal Emergency Management Agency
Soils (Hydrologic Soils Group, Hydric Soils, Highly Erodible Soils, Highly Permeable Soils)	National Resource Conservation Service, County
Sewer Lines	County
Stormwater Network	County
Environmental Monitoring Station Locations	Virginia Department of Environmental Quality, Occoquan Watershed Monitoring Laboratory
Trails	County
Total Maximum Daily Loads (TMDL) Locations	Virginia Department of Environmental Quality
Comprehensive Plan Areas	County
Watershed Boundaries	County, WSSI
Aerial Imagery	County, WSSI

3.1.1 Existing Impervious Cover

Impervious cover includes any alteration to the land that causes water to flow over the surface instead of infiltrating, or soaking into, the ground. These alterations include parking lots, roadways, sidewalks, and buildings, reflects the amount of development that has occurred. Studies show that streams exhibit signs of instability (downcutting, widening, and/or aggrading) and habitat degradation once the contributing watershed exceeds 10 percent imperviousness as shown in Figure 3.1.

Figure 3.1 Stream Quality vs. Percent Impervious Area



Adapted from Schueler, 2009

This degradation creates significant issues with transporting sediment through the stream network as evidenced by development of sediment bars in the channel and reduced riffle/pool sequencing. As stream banks erode, they become steep and devoid of vegetation, an indication that the stream has not reached equilibrium with the increased flows from its watershed and is still actively eroding. In addition, the increase in runoff volume may alter the effectiveness of SWM/BMP facilities if they were not initially designed for increased development within the drainage area. The facilities may also be adversely impacted from the increase in sediment from the upstream bank erosion.

In reviewing historic aerial photography, Subsheds 448 and 450 saw significant changes in the early 1960's with the development and completion of the Interstate 95 corridor. Subdivisions in Subsheds 440 and 444 were fully developed by the early 1980's. Current impervious area information was compiled from County GIS data and is summarized below in Table 3.3. A map is presented in Appendix B, Exhibit 2.

Table 3.3 Summary of Overall Impervious Cover

Subshed	Impervious Acreage	Watershed Acreage	Percent Impervious
440	187	977	19%
444	186	718	26%
448	230	818	28%
450	256	651	39%
Total Subsheds	**858**	**3,163**	**27%**

3.1.2 Comprehensive and Zoning Plans

Prince William County's Zoning Ordinance regulates land-use types, intensity of uses, building densities, parking, and other land development related issues. The Zoning Ordinance includes text and an associated map and is periodically updated by the County Board of Supervisors. It is a legally binding regulatory tool that is intended to complement the County's Comprehensive Plan. The County's Comprehensive Plan was adopted on March 18, 2008, and was last updated in July 2013. This plan provides guidance for future development by establishing the County's future vision, goals, and objectives. The Zoning and Comprehensive Plans specific to the subsheds of interest are provided as Appendix B, Exhibits 3 and 4, respectively.

These four subsheds are predominantly residential with various levels of density, from high density residential (apartment buildings) to single family residential on quarter and half-acre lots. Office, industrial, and general business zonings are also present, though primarily in Subshed 450 and the southeastern portion of Subshed 448 along Old Bridge Road and Interstate 95.

Comparing existing development (e.g. impervious areas) with that proposed in both the zoning and comprehensive plans assist in identifying areas within a watershed that may be developed in the future. This is essential in watershed planning, especially for stream restoration and SWM/BMP facility retrofits as increases in impervious cover increase the amount of stormwater runoff that leaves a site and enters the stream channel. This results in the need for increased channel sizes and/or larger stormwater treatment volumes. To compare the zoning and comprehensive plans with existing conditions, the percent of potential imperviousness was estimated using the Technical Release 55: Urban Hydrology for Small Watersheds (TR-55) design manual (NRCS 1986) as presented in Table 3.4.

Table 3.4 Zoning Districts and TR-55 Equivalency with Estimated Overall Impervious Cover

Zoning District	TR-55 Classification [1]	Imperviousness
Agricultural	Residential District: 2 acres	12%
General Business	Commercial and Business	85%
Heavy Industrial	Industrial	72%
Light Industrial	Industrial	72%
Mid-Rise Office	Commercial and Business	85%
Low-Rise Office	Commercial and Business	85%
Planned Mixed Residential	Residential District: 1/8 acres or less	65%
Residential Planned Community	Residential District: 1/8 acres or less	65%
16 Dwellings per 1 acre	Residential District: 1/8 acres or less	65%
6 Dwellings per 1 acre	Residential District: 1/8 acres or less	65%
Min. Lot Size - 10,000 sq. ft.	Residential District: 1/4 acres	38%
R-4 Cluster Development	Residential District: 1/4 acres	38%
Min. Lot Size - 20,000 sq. ft.	Residential District: 1/2 acres	25%
R-2 Cluster Development	Residential District: 1/2 acres	25%
1 Dwelling per 1 acre	Residential District: 1 acre	20%
City or Town	N/A	N/A

[1] NRCS 1986, Table 2-2a

For these four subsheds, the Comprehensive Plan and Zoning Map are primarily in agreement. Below is a brief description of potential changes in impervious areas within each subshed. A map highlighting the parcels areas of potentially higher imperviousness based on existing conditions, zoning, and comprehensive plans is provided as Appendix B, Exhibit 5.

Subshed 440. Both the Zoning and Comprehensive Plans classify a majority of this subshed as a Residential Planned Community, and the existing conditions reflect this classification. A significant difference between the maps is the buffered area surrounding Hooes Run. The Comprehensive Plan includes the 100-foot Resource Protection Area (RPA) buffer (Appendix B, Exhibit 6) within the Environmental Resource Classification, while the Zoning Map allocates only the open water of Hooes Run to the Agricultural District (see Section 3.1.3. for more information on RPAs). The residential development surrounding Hooes Run closely aligns with the Comprehensive Plan with almost all structures outside the RPA buffer.

The Comprehensive Plan also identifies a parcel of land north of Old Bridge Road between Oakwood Drive and Forest Hill Road as being publicly maintained. If assumed to become developed, the site impervious area could increase from less than 5 percent to over 85 percent. For purposes of determining the highest level of potential imperviousness, this parcel was assumed to be developed; however, the potential overall subshed imperviousness remains around 20 percent.

Subshed 444. Potential increases in impervious area within Subshed 444 are those areas zoned as agricultural, but classified as residential and business in the Comprehensive Plan along Minnieville Road and Omisol Roads. The undeveloped public land off Orleans Street is currently zoned as a Residential Planned Community, and identified as public land on the Comprehensive Plan. If developed into a school, or other community use, the site impervious area could increase to 85 percent. This parcel includes streams identified as Reaches 9 and 12 (Appendix B, Photos 31-34, 42-45) as part of the stream field reconnaissance study. Conceptual restoration designs are provided for both reaches in Appendix J.

Overall, the current site conditions closely align with the Comprehensive Plan, therefore the potential increase of the overall subshed imperviousness is minimal, from 26 to 29 percent. As with Subshed 440, the Comprehensive Plan includes the 100-foot RPA buffer around Hooes Run. However, the development in this area encroaches into the RPA in many areas. Though unlikely in the near future, the overall subshed imperviousness could decrease if infrastructure within the RPA is removed as land is redeveloped.

Subshed 448. This subshed includes the Town of Occoquan; however, only potential changes in imperviousness outside the Town are discussed herein since the Town was not included as part of this study. The largest potential increase in impervious area is a mostly undeveloped 24-acre parcel north of Old Bridge Road between Clipper Drive and Tanyard Hill that is primarily zoned agriculture, but the Comprehensive Plan designates it as Suburban Low Residential and Business. There are also a few business and office parcels along Old Bridge Road that could increase from current densities according to both the Zoning and Comprehensive Plans. The Comprehensive Plan also identifies a 17-acre parcel off Mariner Drive as public land. A portion of the site is already developed as a daycare facility. Developing the other portion of the parcel into a school, or other community use, would increase the parcel imperviousness up to approximately 70% (currently 20%). These combined areas could increase the overall subshed imperviousness from 28 to 34 percent.

A portion of the parcel between Tanyard Hill Road and Hall Street remains undeveloped, which matches the Comprehensive Plan's "environmental resource" designation. However, the Zoning Map identifies the area as Planned Mixed Use Residential, which therefore could increase the imperviousness.

The stream that runs parallel with Riverboat Drive and drains in the Occoquan River via Lake Richard (SWM/BMP Facility 5255, Appendix B, Photos 24-25) includes a 100-foot RPA buffer on the Comprehensive Plan, which is not on the Zoning Map. As with Subshed 444, the road and housing development encroaches into the RPA. Though unlikely in the near future, the overall subshed imperviousness could decrease if infrastructure within the RPA is removed as land is redeveloped.

Another point of interest is that many of the parcels surrounding the Town of Occoquan are zoned at a higher density, which closely aligns with existing conditions, than currently proposed in the Comprehensive Plan. This subshed may see a decrease in imperviousness if these areas are redeveloped to correspond more closely with the Comprehensive Plan.

Subshed 450. This subshed has the largest potential for an increase in imperviousness, from 39 to 47 percent. Most of the potential increases are near the Interstate 95 corridor in older residential developments (e.g. Devil's Reach Road and Occoquan Road south of Interstate 95) and under-developed parcels east of Annapolis Way.

In summary, new development within these four subsheds has the potential to increase impervious area within drainage areas of many streams. However, in the event a redevelopment within these subsheds is pursued that proposes to increase the amount of impervious area, state and county regulations are in-place to require that stormwater management be provided to offset any increases in stormwater runoff. In addition, adequate outfall regulations require that the downstream receiving water be able to withstand any increase in runoff rate or volume. Thus, any redevelopment project will be required to abide by these regulations and not adversely impact downstream waters. This is unlike early development of these subsheds prior to adoption of such regulations.

3.1.3 Forested and Resource Protection Areas (RPA)

All streams in the Occoquan Watershed drain into the Chesapeake Bay via the Occoquan River and the Potomac River. As a commitment to protect the Chesapeake Bay, Prince William County adopted the Chesapeake Bay Preservation Act (Bay Act) into its local ordinance in 1990, which provides a regulatory framework for protecting and improving waters that flow into the Chesapeake Bay. One component of the Bay Act is the protection of riparian buffers from encroaching urban development. Riparian buffers are vegetated, transitional boundaries between upland and water environments that generally consist of trees, shrubs, and grasses. These areas retard runoff and filter pollutants entering waterways and other sensitive environmental features and provide essential habitat for wildlife. Under the Prince William County Chesapeake Bay Preservation Ordinance, these buffers are called Resource Protection Areas (RPAs) and include tidal wetlands, non-tidal wetlands connected by surface flow and contiguous to tidal wetlands and water bodies with perennial flow, tidal shores, water bodies with perennial flow, and a 100-foot wide buffer adjacent to and landward of any of the previously listed components.

While the subsheds are essentially developed, numerous environmental resources are still present, including 1,587 acres of forested cover (50% of the four subsheds) and 486 acres of RPA (15% of the four subsheds). However, all four subsheds have encroachments within the RPA, including residential homes, roads, maintained utility easements, parking lots, and commercial buildings. A map showing the forested areas with the RPA boundary overlaid is provided as Appendix B, Exhibit 6.

3.1.4 Wetlands and Streams

Wetlands and streams play important roles in water quality, but are sensitive to disturbance. Within the four subsheds, there are nearly 92,400 linear feet of stream channel and approximately 15 acres of wetlands, not including the Occoquan Reservoir. As discussed in this report, over 34,700 linear feet of stream was assessed for this study, which represents over one-third of the total stream length in these subsheds (Appendix B, Exhibit 7).

3.1.5 Soil Series

Twenty-one different soils series are present in these subsheds, and range from silty loams to sandy loams. Soil series include the following: Albano silt loam, Baile loam, Buckhall loam, Comus loam, Delanco sandy loam, Dumfries sandy loam, Elioak Loam, Elsinboro sandy loam, Fairfax loam, Featherstone silt loam, Glenelg-Buckhall complex, Glenville loam, Hatboro-Codorus complex, Hoadly loam, Meadowville loam, Neabsco loam, Neabsco-Quantico complex, Occoquan sandy loam, Quantico sandy loam, Urban Land, and Watt silt loam. These soils have various characteristics that influence development potential, ecological features (such as wetlands and streams), and the ability to infiltrate and move water through the landscape. These features affect the approach to stormwater planning, flood management, and stream and wetland restoration within the watershed. These characteristics are discussed in the following sections.

3.1.6 Hydric and Non-Hydric Soils

Hydric soils are those that are formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper parts (USDA, 2010). Hence, these soils are often indicative of areas where naturally occurring wetlands, streams, or other water bodies may occur. Within these four subsheds there are approximately 221 acres of soils mapped as hydric or with hydric inclusions, with the remaining soils mapped as non-hydric soils. Non-hydric soils are typically more suitable for development or agricultural uses.

Though the soils in developed areas within these subsheds have been altered, it is still important to review the soil types and the various classifications to understand the limitations that may occur for certain retrofit and BMP implementations, such as infiltration. A map of the hydric and non-hydric soils is provided as Appendix B, Exhibit 8.

3.1.7 Hydrologic Soils Groups

Hydrologic soil groups are groupings of soils based on their physical and runoff characteristics. Four soils groups are defined by the Natural Resources Conservation Service (NRCS) and are labeled A through D (USDA, 2007). These groups are used in determining runoff coefficients which are used in various hydrologic calculations, for instance determining runoff volumes used to compute channel size for stream restoration projects and water quality treatment volumes for stormwater management facilities. Soils in Group A have the lowest runoff potential, while soils in Group D have the highest runoff potential. Within the four subsheds, the majority of the soils have been placed in Group B and Group D (Appendix B, Exhibit 9). Table 3.4 depicts the acreages for each Hydrologic Soil Group within each subshed.

Table 3.4 Summary of Hydrologic Soil Groups

Subshed	**A**		**B**		**C**		**D**	
	Acre	*%*	*Acre*	*%*	*Acre*	*%*	*Acre*	*%*
440	0	0	382	39	146	15	331	34
444	0	0	310	43	157	22	251	35
448	0	0	426	52	89	11	229	28
450	0	0	280	43	102	16	263	40
Total	**0**	**0**	**1,399**	**44**	**493**	**16**	**1,074**	**34**

3.1.8 Highly Erodible and Highly Permeable Soils

Soil erosion is a major cause of water quality degradation; therefore, mapping soils with high erosion potential is essential in watershed planning. Many factors, including rainfall intensity, steepness and length of slopes, vegetative cover, and management practices contribute to the potential for soils to erode. Additionally, there are inherent properties of soil that can influence its erosion potential, or the ease with which water can detach and transport soil particles downstream. These components are expressed as an erodibility index.

Erosion Index = R * K * L * S / T, where

R = rainfall and runoff
K = soil susceptibility to water erosion in the surface layer
LS = combined effects of slope length and steepness
T = soil loss tolerance

As defined by the PWC Comprehensive Plan (PWC, 2008), highly erodible soils are soils with an Erodibility Index of eight or higher. A map of highly erodible soils within these 4 subsheds is provided in Appendix B as Exhibit 10.

Soil permeability refers to the potential transmission of water through a soil profile, which can be helpful in reducing stormwater runoff and, in turn, soil erosion. Highly permeable soils have permeability equal to or greater than 6 inches of water movement per hour in any part of the soil profile to a depth of 72 inches (PWC, 2008). Identifying areas with high permeability rates is important during watershed planning as they have the potential to be utilized for infiltration facilities. A map of highly permeable soils within these 4 subsheds is provided in Appendix B as Exhibit 11.

Overall, highly erodible soils comprise almost half of all the mapped soils within these subsheds (Table 3.5), while in Subshed 450, it is approximately 72%. Only 18 acres of highly permeable soils are present in the subsheds, with none in Subshed 440.

Table 3.5 Summary of Highly Erodible Soils

Subshed	Highly Erodible Soils Acreage	Subshed Acreage	Percent
440	366	977	37%
444	324	718	45%
448	358	818	44%
450	466	651	72%
Total Subsheds	**1,514**	**3,163**	**48%**

3.1.9 FEMA and County Floodplains

A floodplain is the area adjacent to a channel, river, stream, or other water body that is susceptible to being inundated by water during storm events. According to PWC's Design and Construction Standards Manual (DCSM), the floodplain boundary is the land area in and adjacent to streams that are subject to inundation from the 100-year flood frequency event and has a drainage area greater than 100 acres (DCSM 2009, Section 730.03). Development within this boundary is typically restricted, and requires the developer to provide a floodplain study verifying that the elevation of the 100-year storm does not increase.

Floodplains help control downstream flooding, particularly when streams still have access to the floodplain, and provide critical habitat for various plants and animals. Development that encroaches into these floodplain areas are at risk of flood damage and have the potential to increase flood risks both upstream and downstream of such development. As a participating community in the National Flood Insurance Program (NFIP), Prince William County and FEMA have developed a Flood Insurance Study (FIS) and accompanying Flood Insurance Rate Maps (FIRMs) for the community to identify areas at risk of the 1 and 0.2 percent annual flood (the 100 and 500 year storms, respectively).

The FIS and FIRMs are updated on a countywide basis as needed and as funds permit. The most recent Prince William Countywide FIS became effective on January 5, 1995 (FEMA 1995) and is presented in Appendix B as Exhibits 12A – 12D. This study includes the Town of Occoquan. On August 23, 2013, FEMA published a preliminary study that only includes revisions to Potomac River coastal areas from results of a multi-state coastal storm surge study that was initiated in 2008 and completed in 2013. These proposed changes are along the Potomac River and do not affect the four-subshed study area, although the confluence of the Occoquan River south of Route 1 was included in the study.

Within these four subsheds, approximately 330 acres are mapped as FEMA floodplain and include areas adjacent to the Occoquan River and Hooes Run.

3.1.10 303(d) Impaired Waters and TMDL Status

Total Maximum Daily Loads (TMDLs) represent the maximum amount of pollutants that a water body can receive, while still maintaining certain assigned designated uses, such as fishable or swimmable conditions, as established by the Environmental Protection Agency (EPA) and other local authorities. TMDL studies identify the causes of any identified impairment(s) to water quality and establish the maximum daily load that will allow the water to meet quality standards. Section 303(d) of the Federal Clean Water Act requires each state to submit a list of these ‘impaired’ waters and provide a TMDL Priority List to the EPA.

According to the DEQ’s Draft 2012 305 (b) / 303 (d) Water Quality Assessment Integrated Report, the Occoquan Reservoir, two tributaries, and portions of the Occoquan River are categorized as impaired within the vicinity of the four subsheds (DEQ 2012). A summary of the impairments and the status of TMDL developments are presented in Appendix B, Exhibit 13. EPA typically classifies assessed and impaired sections one of five categories. DEQ has subdivided the categories even further, as described below:

EPA Category 1 All designated uses are supported, no use is threatened.

EPA Category 2 Available information indicates that some, but not all, designated uses are supported. DEQ divides this group into A, B, and C category to better explain what information is lacking.

EPA Category 3 There is insufficient information to make a use support determination. DEQ divides this group into A, B, C, and D categories to better explain data deficiencies.

EPA Category 4 Available information indicates at least one designated use is not being supported or is threatened, but a TMDL is not needed. This category is divided into three groups to clarify what a TMDL is not needed.

VA Category 4a A TMDL has already been prepared and has been approved or was established by EPA.

VA Category 4b A TMDL is not necessary because other required control measures are expected to restore water quality standard.

VA Category 4c The impairment is not caused by a specific pollutant that can be controlled through a TMDL

EPA Category 5 A TMDL is required as available information indicates that at least one designated use is not being supported, or is threatened. DEQ divides this group into A, B, C, D, F, and M categories to better explain data deficiencies. Below is a brief explanation of the category that applies to the impaired waters in and near the four subsheds.

VA Category 5a At least one water quality standard is not attained, and a TMDL is required.

In 2009 the EPA approved placing the dissolved oxygen impairment for the Occoquan Reservoir (305(b) # VAN-A24L-OCC01A02) into Category 4b with no TMDL required. It was determined the low dissolved oxygen levels are primarily from "unintended consequences of Fairfax Water's operation of the bubble diffusion aeration system at the reservoir's dam (DEQ 2012)" By replacing the equipment, it is expected that dissolved oxygen levels will meet water quality standards for aquatic life. According to the 2012 draft DEQ report dissolved oxygen levels in all other areas of the reservoir were above the required standards and reflect healthy conditions.

Insufficient data is available to determine if the Occoquan River is impaired between the upper and lower dams of the reservoir. However, since 2004, the portion of the Occoquan River immediately downstream of the lower dam to the first stream meander east of Gordon Boulevard has been categorized as Category 5a impairment for fecal coliform (305(b) # VAN-A25E_OCC05A02). As a Category 5a impairment, the state is required to prepare a TMDL report and submit to the EPA for approval. According to the 2012 draft DEQ report, the TMDL is scheduled for completion by 2016.

Beyond this point, the Occoquan River and the downstream waters of Belmont Bay are impaired and categorized as 4a for polychlorinated biphenyls (PCBs) (305(b) # VAN-A25E_OCC20A02, A25E_OCC04B08). A TMDL Report was prepared and approved by EPA in 2007 (Interstate 2007). During the 2012 assessments, the Occoquan River had not improved enough to be delisted for this impairment.

Virginia added Hooes Run to its impaired waters list for exceeding E. coli criterion for its designated use of recreation beginning at the outlet from Lake Omisol and continuing downstream to the beginning of the inundated waters of the Occoquan Reservoir near Old Bridge Road (305(b) # VAN-A24R_HOO01A02). A TMDL is scheduled for completion by 2024.

There are many impaired streams and water bodies surrounding this watershed study area including the Occoquan River upstream of the impoundment area for the Occoquan Reservoir (305(b) # VAN-A20E_OCC01A04) which is Category 4a impairment. A TMDL report was prepared in 2006 and approved by EPA in 2007. In addition, Mills Branch (305(b) # VAN-A25R_WLB01-A02) that drains into the Occoquan River north of the Town of Occoquan via Fairfax County is listed as 303(d) Category 5a for impaired waters for exceeding fecal coliform bacteria criterion for recreational uses. A TMDL is scheduled for completion in 2014.

3.1.11 Chesapeake Bay TMDL

Occoquan Subsheds 440, 444, 448, and 450 are located within the Chesapeake Bay watershed, and thus are included in the Bay TMDL Program. The Bay TMDL outlines nutrient allocations for Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Sediment (TSS) for the six Bay States and the District of Columbia within the Bay's 64,000 square mile watershed. Specific to Virginia, the loadings are limited to 5.36 Million lb/yr for TP, 53.42 Million lb/yr of TN, and 2,578.90 Million lb/yr of TSS. By establishing limits on these nutrients, the Chesapeake Bay TMDL seeks to improve dissolved oxygen, water clarity, and chlorophyll-*a* (a measure of algae) by 2025 with a goal of reducing load limits by 60 percent by 2017 within the Chesapeake Bay and its tidal tributaries. Reducing downstream movement of these nutrients and sediment within the four subsheds will help in meeting these goals, and stream restoration, stormwater management facility retrofits, and incorporation of low impact development (LID) infrastructure can make significant contributions.

As of May 2013, new allowable pollutant removal rates for urban stream restoration practices have been established (Schueler, 2013). There are now four protocols for defining these load reductions: (1) prevented sediment approach, (2) in-stream denitrification approach during base flow, (3) floodplain reconnection, and (4) dry channel Regenerative Stormwater Conveyance (RSC) as an upland stormwater retrofit. These new protocols represent an order of magnitude increase in allowed removal credit and provide the impetus for localities to shift resources toward urban stream restoration in order to more cost-effectively meet nutrient removal goals outlined in the Chesapeake Bay TMDL.

New protocols published in April 2012 outline removal rates for installation of new stormwater practices in areas currently not receiving any treatment and retrofits to existing practices through conversion, enhancement, or restoration (Schueler, 2012). Infrastructure ranges from runoff reduction (RR) practices (bioretention facilities, dry swales, infiltration facilities, permeable pavers, green roofs, etc.) to stormwater treatment (ST) facilities (e.g., wet ponds, constructed wetlands, filtering practices, wet swales, etc.). Removal rates for all these practices are determined using a rating curve based on the depth of runoff captured by impervious acres in inches.

As proposed in this watershed study, retrofitting older or poorly maintained stormwater facilities that were initially designed for peak quantity control can improve nutrient and sediment pollutant removal by increasing attenuation of runoff from smaller storm events. These types of retrofit projects can also provide additional downstream channel protection, remedy nuisance conditions, and improve flood control. In addition, the proposed stream restoration conceptual designs reduce pollutant and sediment loads by reducing bank erosion, adding geomorphic complexity with riffle/pool complexes, promoting denitrification during base flows, and increasing the flow path with reconnection to the floodplain during a wide range of storm events.

3.2 Summary

Overall, these series of maps show that the 4 subsheds are predominately developed and contiguous stream and wetland systems do exist that are typically protected within a forested buffer. The majority of soils are highly erodible, as is typical of coastal areas. These subsheds are included in the Bay TMDL program and in 2012 Hooes Run was classified as a 303(d) Category 5a impaired waters for exceeding fecal coliform bacteria criterion for recreational uses. Though outside the drainage boundaries of these four subsheds, both the Occoquan Reservoir and Mills Creek (Fairfax County) are classified as impaired and outfall into Occoquan River nearby. Taking efforts to protect and preserve the waters within these subsheds is a critical component to protecting Occoquan River and the Chesapeake Bay. This information was compiled and used in the desktop reconnaissance studies presented in the following sections.

4.0 Stormwater Inventory Approach and Results

On April 25, 2013, field reviews and assessments were conducted on all 25 SWM/BMP Facilities within the four subsheds. The goal of the assessments was to identify potential retrofit projects for CIP projects that address watershed degradation, specifically considering improvements relevant to TMDLs and stream protection.

Prior to the site visits, a list of the SWM/BMP facilities was developed based on a review of available GIS data, a public scoping meeting (held April 1, 2013), and aerial photography. Utilizing this information, the facilities were divided into three prioritization groups (Tier I, Tier II, and Tier III). Originally, site visits were planned for all Tier I and II facilities and select Tier III facilities. In the end, all 25 facilities were visited and 20 were successfully inspected. Of the five not inspected, three were central pond features within communities, one was inaccessible, and another was not a facility. Facilities 207 and 208 are the two large ponds in Tackett's Mill at Lake Ridge off Harbor Drive, and Facility 5255 is 'Lake Richard' in Westminster of Lake Ridge Assisted Living Community on Cathedral Drive. The gate to Facility 5355 was locked and a privacy fence prevented any visual inspection. Facility 457 is the culvert under Rolling Brook Drive with no signs of inundation. It is not a facility and there is little to no potential to convert into a SWM/BMP facility.

The initial desktop screening process used to rank and prioritize the facilities, the results of the field inspections, and the recommended retrofit projects are discussed in the following sections.

4.1 Desktop Reconnaissance Screening Process

A spreadsheet of the SWM/BMP Facilities within the four subsheds was provided by Prince William County staff on April 17, 2013. Using this list, along with compiled GIS data and aerial photography, the SWM/BMP Facilities were identified on a map and prioritized using criteria listed in Table 4.1 to determine which facilities where the most likely candidates for retrofit.

Table 4.1 Screening Criteria for the SWM/BMP Desktop Reconnaissance

Criteria	Most Desirable	Moderate	Least Desirable
Maintenance Responsibility	Publicly Maintained	HOA open space	Privately Maintained
Facility Type	Retention (dry) facilities	Detention (wet) facilities	Underground facilities
Facility Age	> 10 years	2 – 10 years	< 2 years
Outlet Control	No BMP, 10 year control only	No BMP, 2 and 10 year controls	0.5 inch + BMP + 2 and 10 year controls
Drainage Area	10 – 100 acres	1- 10 acres 100 - 500 acres	< 1 acre > 500 acres
Adjacent Land Uses	Open, Forested	Landscape	Residential
Percent Impervious	> 30%	10 – 30%	< 10%
Construction Accessibility	Short distances directly from public roads, few required easements		Long distances from public roads; access from private residences and/or multiple property owners

The categories in Table 4.1 and their Most Desirable/Least Desirable criteria were chosen as follows:

- Maintenance Responsibility: Publicly maintained facilities, along with facilities owned by Homeowner Associations that are County-maintained were most desirable due to reduced easement and land acquisition constraints. Facilities maintained by HOAs were considered more desirable than privately maintained facilities.
- **Facility Type**: Dry ponds were considered more desirable than wet ponds because retrofits to existing dry ponds typically provide more sediment and nutrient reduction than retrofits to existing wet ponds. Underground facilities were not evaluated as part of this study due to the constraints of visual field inspections.
- **Facility Age and Outlet Control**: Regulations for SWM/BMP facilities have changed dramatically over the years. As such, facilities that are more than 10 years old typically only provide flood control. Facilities designed within the last 2-10 years typically have an additional 2-year control. Water quality control using low flow or BMP orifices are more

prevalent in newer facilities, but may not be meeting current or proposed regulations. As such, newer facilities were still evaluated to insure controls were in place and operating correctly. Facilities with no BMP and only 10-year control were considered the highest priority as they have the most opportunity to provide significant water quality benefits and stream protection from a retrofit project.

- **Drainage Area**: It was initially predicted that there would be a higher benefit/cost ratio from facilities that treat between 10 and 100 acres with smaller facilities treating insufficient amount of land, and larger facilities being cost prohibitive. In review of the subsheds, four facilities have drainage areas less than 10 acres, with each treating a disproportionate amount of impervious areas. Five facilities have a drainage area greater than 100 acres, with all but one facility less than 150 acres. As a result, drainage area was not a driving factor in the initial desktop screening. However, the percent impervious cover was not correlated with the drainage area to evaluate which facilities treat the most impervious surface, thus maximizing the potential TMDL credit.
- **Adjacent Land Uses**: SWM/BMP retrofit projects that improve water quality typically increase the duration water is stored in the facility. With more frequent inundation, the plant and tree community changes and the general aesthetic will be altered. For these reasons, facilities protected with a forested buffer or located away from residences are more ideal than facilities in a landscaped or central residential area.
- **Percent Impervious**: Facilities treating more impervious area are considered more desirable for retrofitting because these facilities will qualify for more TMDL credit. However, they are typically exposed to more frequent inundation and litter/debris accumulation, and thus may require more maintenance.
- **Construction Accessibility**: Ease of access is important when considering potential projects. Facilities that are difficult or costly to access are less desirable.

Each of the 25 SWM/BMP facilities were ranked and assigned a priority Tier I, II, or III (<u>Appendix C</u>). Tier I facilities were County maintained, while Tier II facilities were privately owned, but maintained by the County. These two groups were considered the most desirable due to reduced easement and land acquisition constraints, and provided more County control over any future monitoring and maintenance. Other Tier II facilities included those that likely had no BMP controls and/or treated larger impervious surfaces. Tier III facilities were given the lowest priority for field visits and assessments. This group included newer facilities that already have BMP controls in-place as described in the County-provided spreadsheet as they have the least potential to benefit from a retrofit.

Based on the screening criteria, 3 Tier I facilities, 14 Tier II facilities, and 8 Tier III facilities were identified. Of the 25 identified facilities, all were visited and 20 were inspected. The approach to visiting the facilities started with the understanding that any facility – regardless of years in service or type of development in the watershed, may not be operating as originally designed and thus may provide water quality improvements with repairs or a retrofit. As a result, site visits were prioritized as described above, but every effort was made to visit all facilities.

4.2 Field Reconnaissance Methodology

All 25 facilities in the four subsheds were visited, and 20 were successfully inspected. Facilities 207 and 208 were only photo documented as they are combined water features incorporated into the center of the Tackett's Mill development. Facility 5255 was also only photo documented because the facility is Lake Richard located in the Westminster at Lake Ridge Assisted Living Community and did not appear to have any retrofit potential. An inspection of Facility 5355 on Directors Loop was not possible because the gate was locked and the facility was surrounded by privacy fence that prevented any visual examination.

The goal of the site inspections was to identify any general repair or retrofit opportunity that would significantly improve water quality or provide downstream channel protection. As a result, the following information was documented at each facility:

- Existing conditions (erosion, sediment accumulation, safety concerns, etc.);
- Discrepancies between field and base map information;
- Photo documentation of facility deficiencies and potential retrofit opportunities, including but not limited to:
    - Areas of short-circuiting
    - Potential for increasing dam height or excavating to increase volume,
    - Installation and /or modification of outlet structure to improve water quality treatment [1]
    - Modifications to provide better stream protection (and application of the Energy Balance Methodology)
    - Additional fringe wetlands or creating stormwater wetland systems
    - Addition of sediment forebays and/or micro pool outlets
    - Increasing drawdown times with constant head outlets
    - Conversion to lower maintenance outlet systems to reduce clogging

A map showing the location of each facility is included in Appendix C and a summary of site inspections is included in Appendix C, Table C.1. Representative photos are included in Appendix D.

4.3 Findings

Numerous potential retrofit opportunities and some needed maintenance repairs on the 20 facilities inspected were identified as summarized in Appendix C, Table C.1. After compiling the data, the proposed retrofit projects were ranked from “Very High” to “Low” with the former including facilities with the most potential for improved water quality treatment and downstream channel protection. The initial priority list was presented to County staff in a memorandum dated June 12, 2013 and a meeting was held on July 2, 2013. The result of those discussions is

[1] For purposes of this study, water quality treatment volume (Tv) is as defined in the draft *September 2012 Virginia Stormwater Management Handbook, Chapter 7.*

reflected in the final summary of recommended Action Items and Priority Ranking for Conceptual Plans in Table 4.2.

Table 4.2 SWM/BMP Facility Site Inspection Summary of Action Items and Priority Ranking for Conceptual Plans

Facility #	Subshed	Photo #	Suggested Maintenance	Potential Retrofit Opportunities	Conceptual Plan - Priority Ranking
489	440	4-7	Remove sediment and debris clogging culvert	Install riser; Add BMP control Increase pond storage through excavation	Very High
9026	448	26-29	Dredge facility	Modify/replace riser; Assess/Improve Tv detention (volume and drawdown)	Very High
28	448	13-16	Remove litter and debris at riser and ponding area; Unplug low flow orifice; Repair fence	Replace riser; Increase pond storage through excavation if available; Assess/Improve Tv detention (volume and drawdown)	Very High
465	450	51-53	None	Assess/Improve Tv detention (volume and drawdown); Protect downstream channel	Medium
5047	450	59-61	Confirm if a facility; Remove trees on dam	Considering adding riser with BMP Control	Medium
5707	450	69-71	Confirm if a facility; Repair failure at road crossing; Remove trees on dam; Repair perimeter fence	Consider adding riser with BMP Control	Medium
63	444	8-9	Remove vegetation covering riser	Increase pond storage through excavation; Assess/Improve Tv detention (volume and drawdown)	Low
163	450	33-37	Remove litter and overgrown vegetation; Remove trees on dam	Assess/Improve Tv detention (volume and drawdown)	Low
5153	450	62-65	Add County lock	Assess/Improve Tv detention (volume and drawdown)	Low

4.4 Discussion

Of the 20 SWM/BMP Facilities inspected, eight would benefit from some level of retrofit and/or maintenance (Table 4.2), seven require maintenance (Table 4.3 below), and five require no further action beyond continued monitoring. A discussion of these results is presented below.

4.4.1 Conceptual Plans

Based on the results of this study, the recommendation is made to develop conceptual plans for all three SWM/BMP Facilities that were prioritized as 'Very High' - SWM/BMP Facilities 489, 9026, and 28. All three SWM/BMP facilities are in good locations with reasonable construction access. Conceptual plans are discussed in Section 6.0 and presented in Appendix I. Appendix H highlights the locations of SWM/BMP facilities, along with streams recommended for restoration as part of the Stream Reconnaissance Study (Section 5.0 of this report) to illustrate spatial orientation of facilities and streams. Six facilities (465, 5047, 5707, 63, 163, and 5153) were given a lower priority for retrofit, hence conceptual plans are not provided as part of this study. However, these facilities could improve their existing treatment efficiency immediately through maintenance improvements.

SWM/BMP Facility 489 is in an ideal location within a power line easement and is isolated from residential areas. This facility appears to have the potential to be converted to treat additional water quality treatment volumes, thus maximizing potential TMDL credit. In addition, its receiving channel appears to be compromised and could benefit from increased storage within the facility. Note that this facility is in-line with Reach 5, which was assessed and is recommended for restoration as part of the Stream Reconnaissance Study (Section 5.0). Coordinating these two potential projects is recommended.

SWM/BMP Facility 9026 is also in a good location; it is bordered by two roads and is somewhat isolated from the adjacent business offices. This facility does not appear to be operating correctly with standing, stagnant water at the base of the riser evident during the site visit. Water quality treatment may be improved, along with a potential TMDL benefit, by excavating the facility and either modifying the existing riser or installing a new riser with a low flow orifice. The channel that drains parking lot runoff into the facility also appears to be actively eroding and may benefit from improvements. Any changes to increase storage to this facility may require installing a perimeter fence, where there currently is none. The management group for the business offices should be consulted before investing in these improvements as adding the fence and increasing the duration and frequency of inundation will change existing aesthetics.

SWM/BMP Facility 28 is another facility in a good location being surrounded by a dense forest and isolated from the nearby residential development. The riser is in disrepair and had a strong, foul odor. In addition, litter and debris has jammed the low flow perforations. This facility would benefit from a sediment forebay and additional pond storage, but space may be limited as the site appears to be on bedrock (outcrops are evident). At a minimum, a new riser with low flow orifice pipe may improve the facility aesthetics. The receiving channel for this facility was assessed and identified as Reach 15 as part of the Stream Reconnaissance Study, and was found to be relatively stable. Bringing the facility back to original design intent or improving it will help ensure downstream waters remain stable.

Six potential future retrofit projects are also proposed and presented in Table 4.2 for SWM/BMP Facilities 465, 5047, 5707, 63, 163, 5153 however, conceptual plans are not provided as they were prioritized lower than the three discussed above. **SWM/BMP Facility 465** does not require any maintenance, but a conceptual design could be developed to improve water quality treatment volume and drawdown.

Two streams (Reaches 20A and 20B) were assessed as part of the Stream Reconnaissance Study that actually overlapped with the area identified as **SWM/BMP Facility 5047**. The outlet to this “facility” is an approximately 48” culvert, and does not appear to be detaining water. Both reaches were noted as having signs of erosion and incision, along with highly mobile streambed material. Restoring the stream channel or dredging the ‘facility’ to detain more stormwater will aid existing and future maintenance of the downstream SWM/BMP Facility 201, which has significant sediment deposition. After review of the both site assessments and discussions with County staff, the decision was made to develop a conceptual plan for restoring the channel, and not retrofitting into a SWM/BMP Facility. More discussion is provided in Section 5.0.

SWM/BMP Facility 5707 is similar to 5047 in that the outlet to this “facility” is an approximately 48” culvert, and does not appear to be holding water. The stream running through the ‘facility’ appears to be perennial.

If **SWM/BMP Facilities 5707 or 5047** were previously approved and constructed as a SWM/BMP Facility, then retrofit activities would likely be considered a permittable activity. However, if a SWM/BMP Facility was never intended in these areas, then installing a facility in-line with what appears to be a perennial stream would be difficult to permit with the U.S. Army Corps of Engineers (COE) and Virginia Department of Environmental Quality (DEQ). As discussed above, the decision was made to restore the channels and to remove the facilities from the County database.

SWM/BMP Facilities 63, 163, and 5153 are ranked ‘Low’ for developing conceptual plans (Table 4.2). They all have the potential to increase water quality treatment and drawdown; however, further investigation is required to determine extent of potential benefits. As for maintenance, overgrown vegetation needs removed from the riser in **SWM/BMP Facility 63**, **SWM/BMP Facility 163** requires removal of overgrown vegetation and litter in the ponding area, and a county lock should be added to **SWM/BMP Facility 5153**.

4.4.2 Maintenance

An additional seven facilities were inspected and appeared to be in good operating condition, thus retrofits were not recommended. However, they require some level of maintenance ranging from simple repairs to water quality treatment improvements. A summary of recommended maintenance is provided in Table 4.3.

Table 4.3 Summary of Suggested Maintenance for SWM/BMP Facilities

Facility #	Photo #	Subshed	Suggested Maintenance
19	1-3	440	Remove debris accumulation at outlet structure; Assess Tv detention
632	10-12	444	Remove debris; Reinstall BMP plate
5147	21-23	448	Add County lock; remove trash and debris
92	30-32	450	Remove litter and debris; Investigate benefits of dredging
200	38-40	450	Remove overgrown vegetation, remove delta; Investigate benefits of dredging; Eliminate short-circuiting; Assess Tv detention
201	41-45	450	Remove overgrown vegetation and trees on dam; Remove debris on weir; Investigate benefits of dredging; Eliminate short-circuiting; Assess Tv detention
5400	66-68	450	Fix riser cap at upstream sediment trap

During consultation with the County, **SWM/BMP Facility 19** was removed from the Priority List (Table 4.2) because it was recently retrofitted with the box inlet and water quality storage volumes were maximized. However, it was added to the list of facilities that required maintenance as it would benefit from debris removal around the outlet structure.

SWM/BMP Facilities 200 and 201 were also removed from Priority List (Table 4.2) because of recent retrofit efforts, but the facilities do require maintenance. Both of these include a weir wall immediately upstream of double culverts. The capacity of both ponds appears to be compromised due to sediment accumulation and some short-circuiting. Water quality treatment will be improved by simply dredging the pond to provide additional storage, and, if necessary, increasing the weir height.

Suggested maintenance for **SWM/BMP Facility 92** includes dredging and litter removal. Upslope of SWM/BMP Facility 92 are Reaches 19B and 20A, and SWM/BMP Facilities 200, 201, 5047, and 5707 that were all assessed as part of the SWM/BMP and Stream Reconnaissance Studies. Of those assessed, only Reach 20A is proposed for restoration. However, the recommended maintenance to improve flow attenuation in SWM/BMP Facilities 200 and 201, along with restoration of Reach 20A will improve treatment quality and capacity of SWM/BMP Facility 92.

4.4.3 No Retrofit or Maintenance Required

The following five SWM/BMP Facilities were inspected and appeared to be in good operating condition, thus no retrofit or maintenance is required: **481, 454, 691, and 694**. However, the channels downstream of **SWM/BMP Facilities 691 and 694** showed signs of past erosion, but appeared stable during the site inspections. These downstream waters should continue to be monitored to ensure channels remain stable.

5.0 Stream Inventory Approach and Results

From April 15 to April 26, 2013, stream assessments were conducted on 20 streams within the four identified subsheds. As with the SWM/BMP facility assessments, the goal of these assessments was to also identify potential stream restoration projects for CIPs that address watershed degradation, specifically considering improvements relevant to TMDLs and stream protection.

Prior to the site visits, a list of streams were developed based on a review of available GIS data, a public scoping meeting (held April 1, 2013), and aerial photography. Utilizing this information, the streams were divided into three prioritization groups (Tier I, Tier II, and Tier III). Of the 92,375 linear feet of streams mapped in these four subsheds, 34,700 linear feet were field assessed as part of this study

The initial desktop screening process used to rank and prioritize the stream assessments, the results of the field assessments, the recommended stream restoration projects, and the results of the benthic macroinvertebrate assessments for the selected streams are discussed in the following sections.

5.1 Desktop Reconnaissance Screening Process

Streams within the four subsheds were identified and ranked based on the criteria listed in the Table 5.1.

Table 5.1 Screening Criteria for the Stream Restoration Project Desktop Reconnaissance

Criteria	Most Desirable	Moderate	Least Desirable
Maintenance Responsibility	Publicly maintained	HOA open space	Privately maintained
Adjacent Land Uses	Forested	Maintained	Developed
Available Forested Buffer	> 100 feet	25 – 100 feet	< 25 feet
Flow Type	Perennial	Intermittent	Ephemeral
Drainage Area	50 – 500 acres	25 – 50 acres 500 – 800 acres	< 25 acres > 800 acres
Estimated Restoration Length	> 1,000 feet	300 – 1,000 feet	< 300 feet
Existing Percent Impervious	> 15%	10 – 15%	< 5%
Highly Erodible Soils	Highly erodible soils in stream corridor		No highly erodible soils in the stream corridor
Construction Accessibility	Short distances directly from public roads, few required easements		Long, wooded, multiple easements from multiple property owners

These categories and their Most Desirable/Least Desirable criteria were chosen as follows:

- **Maintenance Responsibility**: Publicly maintained was most desirable, as it would include land that the County already has at its disposal. Reaches within a Homeowner Association or owned by a single entity are also desirable. The least desirable reaches are privately-maintained and/or span multiple owners.
- **Adjacent Land Uses**: Forested land allows for greater design flexibility, and provides a better long-term buffer.
- **Available Forested Buffer**: Larger widths (100 feet and greater) are preferred over smaller widths, again for design flexibility, water quality benefits, and pollution reduction.
- **Flow Type**: Perennial streams have a higher benefit/cost ratio when compared to intermittent or ephemeral streams.
- **Drainage Area**: Required disturbance for restoration of smaller headwater streams (less than 50 acres) may outweigh the benefits of the restoration (e.g. construction access, tree removal, etc.). Streams with drainage areas over 500 acres may be cost prohibitive to restore.
- **Restoration Length**: Streams in the 1,000 to 3,000 foot range are the most “manageable” for construction. Streams less than 1,000 feet have a smaller benefit/cost ratio.

- **Existing Percent Impervious**: Streams typically start showing signs of degradation when the impervious area within the watershed exceeds 5 - 10%. Streams with impervious areas over 15% tend to be the most damaged/unstable.
- **Highly Erodible Soils**: Streams on highly erodible soils tend to be more unstable.
- **Construction Accessibility**: Ease of access is important when considering potential projects. Streams that are difficult or costly to access are least desirable.

Using these criteria and available GIS data, 23 streams were selected for priority ranking and potential field review. Streams not included in the list of 23 streams were eliminated because the majority of their screening criteria were categorized as "Least Desirable".

Each of the 23 streams were ranked and assigned a priority Tier (Tier I, II, or III). Tier I streams had the greatest potential for restoration and are located on public property, thus were assigned highest priority for a site visit and stream assessment. Tier II streams also showed some potential for restoration, based on the reviewed GIS data, and would potentially be visited in the field and assessed. Tier III streams showed the least potential for restoration and were given the lowest priority for field visits and assessments. Tier III streams would only be visited if time and budget allowed.

Based on the screening criteria, 11 Tier I streams, 8 Tier II streams, and 4 Tier III streams were identified. Twenty of the 23 streams were visited and assessed in the field, including all Tier I and Tier II streams, and one Tier III stream.

5.2 Field Reconnaissance and Assessment Methodology

While there is a vast array of different types of stream assessment methodologies available, only one method, the Rapid Stream Assessment Technique (RSAT), was utilized for this watershed study. The RSAT method was utilized because it is intended to provide a "simple, rapid reconnaissance-level assessment of stream quality conditions," and because this methodology had previously been used in other watershed studies prepared for Prince William County. By utilizing the same methodology previously employed, it allows for quick "apples-to-apples" comparisons between studies.

The RSAT methodology requires evaluators to examine six categories: Channel Stability, Channel Scouring/Deposition, Physical Instream Habitat, Water Quality, Riparian Habitat Conditions, and Biological Indicators. Each category is given a general rating of Excellent, Good, Fair, or Poor, and then given a numeric score for each category. These scores are totaled and an overall descriptive category is assigned. In general, the evaluators attempted to score entire reaches of stream, without breaking the streams into smaller, separate reaches. In the event that stream reaches were divided into separate sections, these were done at logical stream restoration termini, such as culverts under roadway crossings. GPS locations at the upstream and downstream end of each reach were also recorded in order to check against GIS data. Accuracy of these GPS locations varied, depending on field conditions (forest cover, slopes, overhead power lines, etc.).

5.3 Findings

Of 23 total streams identified during the desktop screening process, 20 streams were assessed with the RSAT methodology. Six of these streams were broken into separate reaches. The stream reaches, and their RSAT scores, are provided in Table 5.2; descriptions of each stream reach are provided below. A map showing the location of each stream reach is included as Appendix E. Representative photos of each stream reach are included as Appendix F.

Table 5.2: Summary of Rapid Stream Assessment Technique (RSAT) Scores

Stream Number [1]	Drainage Area (ac)	RSAT Evaluation Category						Score [2]	
		Channel Stability	Channel Scouring/ Deposition	Physical Instream Habitat	Water Quality	Riparian Habitat Conditions	Biological Indicators	Total Score	Verbal Rating
2	83	5	4	4	5	4	3	25	Fair
3	75	5	6	5	8	5	1	30	Good
4	163	6	6	5	7	6	3	33	Good
5	115	1	3	3	4	4	1	16	Fair
6A	32	0	1	1	6	5	1	14	Poor
6B	78	6	4	4	6	4	2	26	Fair
7	158	2	3	5	4	5	4	23	Fair
8A	92	2	3	4	5	6	2	22	Fair
8B	61	1	2	3	4	5	1	16	Fair
9	80	1	3	4	4	4	2	18	Fair
10	50	2	2	2	2	3	1	12	Poor
11	2,021	6	6	5	3	4	4	28	Fair
12	48	1	2	1	3	5	1	13	Poor
15	171	7	6	6	5	5	5	34	Good
16	39	8	6	5	6	6	6	37	Good
17A	73	6	4	4	5	3	2	24	Fair
17B	66	4	3	3	6	2	2	20	Fair
18A	78	4	3	3	4	2	2	18	Fair
18B	74	3	4	3	3	3	1	17	Fair
19A	85	4	2	3	5	4	4	22	Fair
19B	251	2	2	1	6	0	2	13	Poor
20A	114	1	4	5	6	5	3	24	Fair
20B	100	4	2	3	6	5	3	23	Fair
21	390	2	3	4	4	2	1	16	Fair
22	63	5	5	4	4	1	1	20	Fair
23	621	1	4	5	3	6	3	22	Fair

[1] Streams 1, 13 and 14 were not assessed

[2] RSAT divides the verbal rankings as follows: Poor, <16; Fair, 16-29; Good, 30-41; and Excellent, 42-50

Stream Reach 1: This stream reach is a Tier III stream, and was not assessed in the field.

Stream Reach 2 (Appendix F, Photos 1 and 2): This stream reach showed moderate amounts of instability, with areas of actively eroding and incising banks, and a generally mobile streambed. The incision has affected a utility line crossing, undermining several support piers. The riparian habitat consists mostly of mature forest, with some encroachments by utilities and residential areas. Overall water quality appeared good, but lacked a diverse benthic community.

Stream Reach 3 (Appendix F, Photos 3 through 8): This stream reach also showed moderate amounts of instability, with areas of actively eroding and incising banks. However, the streambed appeared more stable, and with less recent deposition. The incision has affected several utility lines, exposing them to potential future failures. Water quality appeared high and the overall riparian area was well forested, with few encroachments. However, a diverse benthic community was absent, with only a few pollution-tolerant organisms present.

Stream Reach 4 (Appendix F, Photos 9 through 11): This stream was moderately stable, with most of the instability/erosion issues confined to stream bend areas, or areas around in-stream structures (such as a pier supporting a utility line crossing). Overall physical instream habitat was good, with a mature forested riparian buffer, but only a fair benthic community due to low diversity and high numbers of pollution-tolerant organisms.

Stream Reach 5 (Appendix F, Photos 12 through 17): This stream reach consists of the upstream portion of Stream Reach 4, west of Oakwood Drive. A portion of this stream is interrupted by stormwater management pond 489, located in a power line easement. This stream consists of a very unstable stream channel that is deeply incised and actively eroding, creating a mobile streambed that is aggrading in the area closest to SWM/BMP Facility 489. The riparian area has been compromised by adjacent development, and the benthic community is dominated by pollution-tolerant organisms. At least one utility line crosses this stream and has the potential to be compromised in the future if erosion continues.

Stream Reach 6A (Appendix F, Photos 18 through 21): This stream reach consists of the portion of stream 6 located east of Colby Drive. The pipe under Colby Drive has been blocked by sediment and debris, and is contributing to the aggradation at the downstream end of the reach. Overall, the channel is highly unstable with significant amounts of channel scouring and deposition. While the downstream portion appears to be aggrading, the upstream portion is deeply incised, exposing several utilities. The overall water quality appeared good; however the benthic community is highly degraded, likely linked to the overall stream degradation and habitat instability.

Stream Reach 6B (Appendix F, Photos 22 and 23): This stream reach consists of the portion of stream 6 located west of Colby Drive. While this reach is downstream of Reach 6A, it is in comparatively better condition, showing less overall incision and instability. However, it would appear that this reach is aggrading to some degree, due to the significant amount of sediment discharge from Reach 6A. There is also a large amount of accumulated sediments at the confluence of this stream with the Occoquan Reservoir. Overall water quality appears good; however there are a number of riparian area encroachments from development and utilities. The benthic community is poor, due to low diversity and high numbers of pollution-tolerant organisms.

Stream Reach 7 (Appendix F, Photos 24 and 25): This stream reach shows evidence of incision and stream bank instability throughout the assessed area. Instability is particularly noticeable in areas of stream bends. There is noticeable scouring and deposition occurring within the streambed, however, the riparian area is generally in good condition, and the benthic community is somewhat diverse, though dominated by pollution-tolerant organisms.

Stream Reach 8A (Appendix F, Photos 26 through 28): This stream consists of the portion of stream 8 located east of Oakwood Drive. This stream shows evidence of incision throughout the assessed reach, with evidence of deposition and a generally mobile substrate composition. A sewer manhole is present within the stream banks, and has the potential to be compromised in the future. An exposed sewer crossing of Hooes Run, near the confluence with Reach 8A, is being undermined and could be compromised in the future if this issue is not addressed.

Stream Reach 8B (Appendix F, Photos 29 and 30): This stream consists of the portion of stream 8 located west of Oakwood Drive. This stream showed evidence of erosion and incision throughout the majority of the assessed length, and had a number of exposed utility crossings that could be compromised in the future, if action is not taken. The uppermost portion of the reach was somewhat stable, being dominated by bedrock. The riparian area has been compromised by a wide, overhead electrical utility crossing and some adjacent development. The benthic community was generally low in population, and dominated by pollution-tolerant organisms.

Stream Reach 9 (Appendix F, Photos 31 through 34): This stream reach shows evidence of significant erosion throughout the majority of the reach, with some significant amounts of channel deposition. Instream habitat and water quality appears fair; however, the benthic community lacks diversity and is dominated by pollution-tolerant organisms. The riparian area has been heavily encroached upon by residential development in the upstream portion, but improves in the downstream portion. One partially exposed utility crossing was observed within this reach.

Stream Reach 10 (Appendix F, Photos 35 through 38): This stream reach shows evidence of significant erosion throughout the majority of the reach, with very high amounts of channel deposition. Nearly one-half of this stream reach is completely aggraded. Some exposed utility lines are present at the upstream end of the reach. Both water quality and instream habitat appear poor, which has resulted in a poorly populated, pollution-tolerant benthic community. The riparian area has been compromised by an overhead electrical utility and encroaching residential development.

Stream Reach 11 (Appendix F, Photos 39 through 41): This stream reach consists of a portion of Hooes Run. Overall, the channel appeared relatively stable, with little scouring and deposition. The water quality appeared only fair, while a portion of the riparian zone has been affected by an overhead electrical utility crossing and adjacent development. The benthic community was somewhat more diverse than in other assessed streams, but was still dominated by pollution-tolerant organisms. Several partially exposed utilities were also visible within this reach.

Stream Reach 12 (Appendix F, Photos 42 through 45): This stream reach is actively eroding and incising, with significant amounts of channel deposition. The lower portion of the stream is aggrading. Physical instream habitat is poor, resulting in a poor benthic community. The riparian condition is good, though any positive effect by this buffer is outweighed by other factors.

Stream Reach 13: This stream reach is a Tier III stream, and was not assessed in the field.

Stream Reach 14: This stream reach is a Tier III stream, and was not assessed in the field.

Stream Reach 15 (Appendix F, Photos 46 through 48): This stream reach is located downslope of a stormwater pond and flows into the Town of Occoquan. Assessment of this reach was stopped at Tanyard Hill Road, before crossing into the Town. This stream shows some localized areas of incision/erosion; however they are mostly concentrated at stream bends. The majority of the streambed consists of bedrock and large boulders, making it quite stable, with floodplain access. The riparian condition is good, with few encroachments. Instream habitat is stable, which helps to maintain a good benthic community with few pollution-tolerant organisms. Several utility crossings are visible along this stream, which show some evidence of undercutting.

Stream Reach 16 (Appendix F, Photos 49 and 50): This stream flows into Stream Reach 15 before reaching the Town of Occoquan. This stream shows some localized areas of incision/erosion; however they are mostly concentrated at stream bends. Bedrock is present throughout the stream reach, making it quite stable. The riparian condition is excellent, with only one encroachment from a single-family home. Instream habitat is stable, which helps to maintain a good benthic community with few pollution-tolerant organisms.

Stream Reach 17A (Appendix F, Photos 51 and 52): This stream reach characterizes the portion of Stream 17 located northeast of Gordon Boulevard (Route 123). This stream is relatively stable, but with localized areas of incision and active erosion, located mostly at stream bends. There is evidence of channel deposition, and the somewhat mobile streambed results in only fair instream habitat, and a pollution-tolerant benthic community. The riparian area is encroached upon by adjacent development throughout the reach. Several partially-exposed sanitary sewer manholes were present along the stream bank.

Stream Reach 17B (Appendix F, Photos 53 and 54): This stream reach characterizes the portion of Stream 17 located southwest of Gordon Boulevard. This stream is actively incising and eroding. A number of townhomes are immediately adjacent to the stream. The active migration of the stream channel appears to pose a threat to these properties. There is evidence of channel deposition, and the somewhat mobile streambed results in only fair instream habitat and a pollution-tolerant benthic community.

Stream Reach 18A (Appendix F, Photos 55 through 57): This stream reach characterizes the portion of Stream 18 located northeast of Gordon Boulevard. This stream is actively incising and eroding. One exposed utility crossing was noted, and a stormwater discharge pipe has been undercut, resulting in the loss of the headwall and first section of pipe. The riparian area has been encroached upon heavily by adjacent development, contributing to poor instream habitat and a pollution-tolerant benthic community.

Stream Reach 18B (Appendix F, Photos 58 through 60): This stream reach characterizes the portion of Stream 18 located southwest of Gordon Boulevard. This stream is actively incising and eroding, particularly in stream-bend areas. The streambed substrate is highly mobile and the riparian area has been encroached upon by adjacent development, contributing to poor instream habitat and a pollution-tolerant benthic community.

Stream Reach 19A (Appendix F, Photos 61 through 63): This stream reach characterizes the portion of Stream 19 located between Luca Station Road and Devils Reach Road. This stream is incised at the upstream and downstream ends, with significant aggradation in the middle portion. Some residential encroachment into the riparian area is affecting this stream. The mobile streambed contributes to only fair instream habitat, resulting in a benthic community that is somewhat diverse, but dominated by pollution-tolerant organisms.

Stream Reach 19B (Appendix F, Photos 64 through 66): This stream reach characterizes the portion of Stream 19 located between Devils Reach Road and Interstate 95. This stream has been significantly altered, with armoring along most of the left bank in order to protect Devils Reach Road. One partially exposed utility line was noted on this reach. The lower portion of the stream is affected by a stormwater basin, which appeared clogged during our site visit. Significant sedimentation throughout the reach results in overall poor instream habitat and a poor benthic community.

Stream Reach 20A (Appendix F, Photos 67 and 68): This stream reach characterizes the portion of Stream 20 located southeast of Tumbling Brook Drive. This channel is unstable throughout the reach with the exception of one area dominated by bedrock. The downstream portion of the assessed reach terminated at a fence for a stormwater pond. Overall, the streambed is mobile and the riparian area is reduced by adjacent residential development. The benthic community is generally pollution-tolerant.

Stream Reach 20B (Appendix F, Photos 69 and 70): This stream reach characterizes the portion of Stream 20 located northwest of Tumbling Brook Drive. The channel is more stable than Reach 20A, though still exhibits erosion and incision. A concrete channel feeds this stream, carrying runoff from Rolling Brook Drive. The streambed consists of highly mobile material, and generally poor instream habitat. Water quality appears good, and the riparian area shows few intrusions from adjacent development. The benthic community is generally pollution-tolerant.

Stream Reach 21 (Appendix F, Photos 71 through 74): This stream reach shows evidence of incision and stream bank instability throughout the assessed area. A number of exposed utilities are present throughout the reach, and the culvert at the downstream end of the reach (under the off-ramp for I-95) is being eroded behind the wingwall, compromising the ramp. Portions of the stream have been stabilized with rip-rap and gabion baskets. The supports for two pedestrian bridges have been affected by the active erosion of the stream channel. The riparian area has been compromised by adjacent residential and commercial development, I-95, and a playground. The benthic community is characterized by low population numbers and pollution-tolerant organisms.

Stream Reach 22 (Appendix F, Photos 75 through 77): This stream reach is a tributary to Stream 21, and has a generally stable stream bank with little scouring and deposition in the channel. Erosion is present, but mostly confined to stream bends. Physical instream habitat and water quality appear fair. The benthic community is characterized by low population numbers and pollution-tolerant organisms. Some portions of the channel have been altered by utility crossings and concrete channels carrying stormwater runoff.

Stream Reach 23 (Appendix F, Photos 78 through 80): This stream reach is the most downstream end of Streams 19, 20, 21, and 22, and ends at its confluence with the Occoquan River. This stream shows significant amounts of active erosion throughout. The overall riparian condition is good, and it appears that the erosion is likely due to the high amount of impervious surface in its watershed (21%). Several utility crossings are present across this stream, including one elevated sanitary sewer line. This sewer line has been armored with gabion baskets. Flooding over these baskets has resulted in erosion and a deep plunge pool on the downstream side. The benthic community exhibits low diversity and is dominated by pollution-tolerant organisms.

5.4 Discussion

The resulting RSAT scores for each assessed reach are summarized in Figure 5.1 and Table 5.3 and ranked according to score, from lowest score (poor quality streams) to highest score (excellent quality streams). The RSAT method divides the verbal rankings based on score, as follows: Poor, <16; Fair, 16-29; Good, 30-41; and Excellent, 42-50. Eighty-five (85) percent of the streams scored in the lower two RSAT rankings. No streams were ranked as ‘Excellent’ with the other streams as follows: 4 ‘Good’, 18 ‘Fair’, and 3 ‘Poor’ rankings, Conceptual stream restoration plans were developed for those identified in red on Figure 5.1.

Figure 5.1 Summary of Rapid Assessment Technique (RSAT) Scores by Subshed

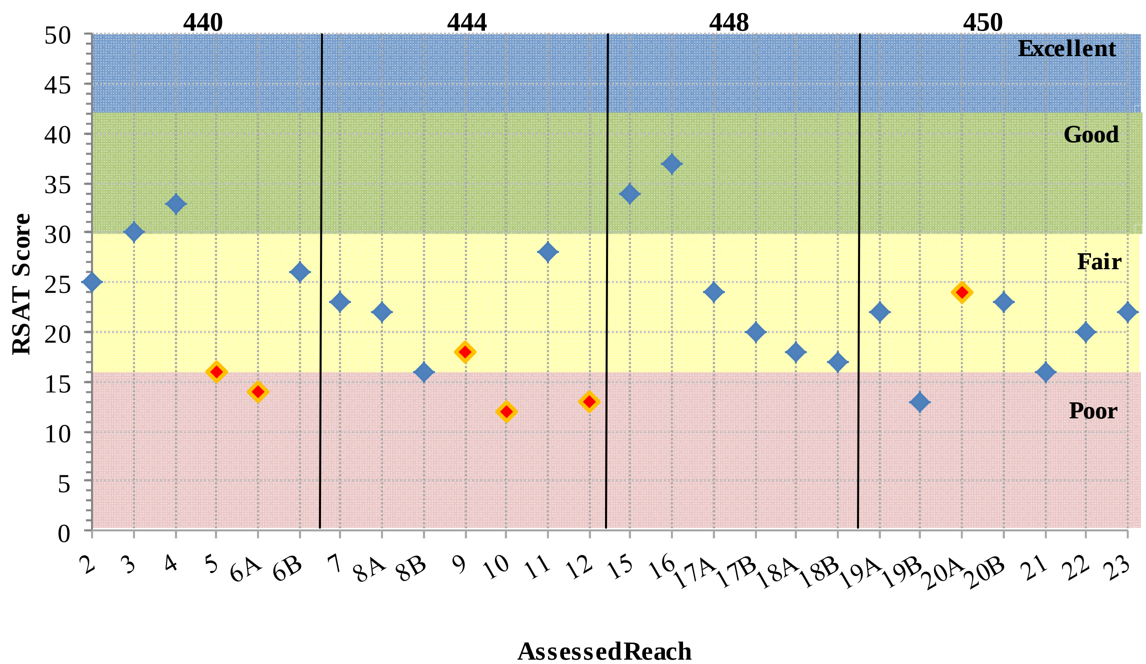


Table 5.3 Stream Assessment Summary and Priority Ranking for Conceptual Plans

Stream Number	**Subshed**	**Photo #**	**RSAT**		**Desktop Recon Tier**	**Overall Stream Rank**	**Selected Conceptual Plans**	**Maintenance Responsibility**
			Score	**Verbal**				
10	444	35-38	12	Poor	II	1	✓	HOA
12	444	42-45	13	Poor	I	2	✓	Public/HOA
6A	440	18-21	14	Poor	II	4	✓	HOA
5	440	12-17	16	Fair	II	5	✓	HOA
9	440	31-34	18	Fair	I	9		HOA
20A	450	67-68	24	Fair	II	19	✓	HOA
19B	450	64-66	13	Poor	I	3		Public/HOA
8B	440	29-30	16	Fair	II	6		HOA
21	450	71-74	16	Fair	I	7		VDOT R.O.W.
18B	448	58-60	17	Fair	II	8		Private
18A	448	55-57	18	Fair	II	10		Private
17B	448	53-54	20	Fair	I	11		Private
22	450	75-77	20	Fair	I	12		Mostly HOA
8A	440	26-28	22	Fair	II	13		HOA
19A	450	61-63	22	Fair	I	14		Public/HOA
23	450	78-80	22	Fair	II	15		Mostly Private
7	440	24-25	23	Fair	I	16		Public/HOA
20B	450	69-70	23	Fair	II	17		HOA
17A	450	51-52	24	Fair	I	18		Private
2	440	1-2	25	Fair	I	20		Mostly HOA
6B	440	22-23	26	Fair	II	21		HOA
11	444	39-41	28	Fair	III	22		Mostly HOA
3	440	3-8	30	Good	II	23	N/A	HOA
4	440	9-11	33	Good	I	24	N/A	HOA
15	448	46-48	34	Good	I	25	N/A	HOA
16	448	49-50	37	Good	I	26	N/A	Mostly HOA

5.4.1 Conceptual Plans

Overall, 22 of the 26 assessed stream reaches showed signs of degradation, mostly from urbanization of their respective watersheds, and would benefit from full restoration or spot stabilization. Therefore, those streams selected for developing conceptual plans are those that would gain the most from restoration and/or stabilization, plus have sufficient construction access, buffer protection after restoration, and/or provide benefits to impaired downstream waters. Thus, based on the results of this study, **the recommendation is made to develop conceptual plans for Stream Reaches 5, 6A, 9, 10, 12, and 20A**.

Appendix H is a map that highlights these streams, along with the SWM/BMP facilities recommended for retrofit as part of the SWM/BMP Facility Reconnaissance Study (Section 4.0 of this report) to illustrate spatial orientation of facilities and streams. Conceptual plans are discussed in Section 6.0 and presented in Appendix J. A location map and a design detail supplement are also provided in Appendix J. The supplement includes typical restoration approaches (e.g. design priorities), a typical riffle with a reinforced bed detail, rock and wood stream structures that will provide both grade control and habitat benefits, and a planting detail.

Streams 9 and 12 are a Tier I streams, while Streams 5, 6A, 10 and 20A are Tier II streams. Stream 5 and 6A are located in Subshed 440, Streams 9, 10 and 12 are located in Subshed 444, and Stream 20A is located in Subshed 450. All six streams occur on HOA land or Prince William County maintained land, which will make it easier to obtain easements to conduct the stream restoration work. All streams occur in an entirely or mostly (>70%) forested situation, with high percent impervious cover in their watersheds (21-36%) and drainage areas ranging from 50 – 115 acres. Restoration lengths exceed 1,000 feet, except Stream 10 at 940 feet.

Erosion from widening and downcutting of the channel in Stream 20A is the source of the sediment observed in SWM/BMP Facilities 200 and 201. Both facilities were recently retrofitted, but are already buried (see assessments provided in Section 4.3). This combined project will reestablish water quality and flood control storages, reduce erosive flows that are starting to impact Reach 19B, and greatly eliminate excessive sediment currently aggrading portions of Reach 19B and filling in SWM/BMP Facility 92. Therefore, approximately 250 acres within Subshed 450 would benefit from combining the restoration and SWM/BMP facility dredging projects, which is 136 additional acres with more than 35% impervious area.

Stream 5 was also given higher priority as restoration would improve the stream itself and directly benefit in-line SWM/BMP Facility 489.

Initially, Streams 6A, 10, 12, and 19B were identified as those that have the highest priority for stream restoration. However, Stream 19B was assigned a lower priority as Stream 20A and SWM/BMP Facilities 200 and 201 located upstream are likely the cause of the degradation and thus restoration would have little benefit until these upstream impairments are addressed. In addition, a significant portion of Stream 19B is contained within SWM/BMP Facility 92 and thus backwaters frequently; therefore, would not benefit as much as other streams from restoration. Though no conceptual restoration plan will be developed for Reach 19B, it should be noted that stabilization/restoration measures on 19B would benefit SWM/BMP Facility 92 and should be evaluated after proposed restoration and retrofit measures are completed upstream.

In addition to those streams rated as "Poor", other streams for which conceptual restoration plans could be developed include 8B (Subshed 444) and 21 (Subshed 450). Each of these streams has an RSAT score of 16, which is just above the "Poor" rating.

5.4.2 Maintenance and Spot Improvements

There are also opportunities for "spot improvements" on many of the streams that are not in the top ranking for concept plans. Appendix G includes a map identifying these areas. These include streams where there are exposed utilities (Streams 2, 3, 4, 5, 6A, 8A, 8B, 10, 11, 15, 17A, 18A, and 23) or dangerous/hazardous conditions (Stream 17B, eroding toward townhomes; Stream 21, eroding behind wingwall and exit ramp). Concept plans could be developed for "spot improvements" for any of these areas, if desired, and if time and budgetary constraints allow.

It should be noted that repairs to Streams 17B and 21 should be done immediately. Table 5.4 summarizes the various types of conditions observed that warrant such spot improvements, with a priority ranking for monitoring and maintenance. A number of these issues are proposed for repair as part of the concept plans noted in Section 6.0 (Streams 5, 6A and 10).

Table 5.4 Summary of Suggested Maintenance and Spot Improvements

Stream	Photo #	Subshed	Observed Conditions	Maintenance Priority [1]
2	2	440	Failing utility supports	Medium
3	4,5,7,8	440	Exposed utilities/failing supports	Low
3	6	440	Exposed utility	Medium
4	10	440	Eroding utility support	Low
5	12	440	Exposed utility	Low
6A	21	440	Exposed utility	Medium
8A	27,28	444	Exposed utilities	Low
8B	29	444	Exposed utility	Low
10	N/A	444	Exposed utility (cable/phone)	Low
11	40	444	Exposed utility	Low
15	48	448	Exposed utility	Low
17A	52	448	Exposed utility	Low
17B	54	448	Hazard; Eroding infrastructure on personal properties (e.g. fences and retaining walls)	High
18A	56	448	Failing outfall	Medium
18A	57	448	Exposed utility	Low
19B	64	450	Exposed utility	Low
21	72, 74	450	Hazard; Eroding wing wall and exit ramp; Exposed utilities	High
23	80	450	Exposed utility	Low

[1] Maintenance Priority Descriptions: Low: Monitor after major storm events; Medium: Monitor periodically and fix when funds are available; High: Fix immediately and monitor routinely

[2] Repairs will be included as part of restoration as proposed in Conceptual Plans (Appendix J).

Within Subshed 448 it was noted that four of the six assessed streams would benefit from some type of spot improvement (15, 17A, 17B, and 18A), though none were recommended for full stream restoration conceptual plans as they were limited in some manner (site access, maintenance responsibility, etc.) that precluded them from being selected. Reaches 16 and 18B would not benefit significantly from restoration activity as they are currently stable and protected with a forested buffer. However, the streams should be continually monitored, and efforts made to prevent increases in stormwater runoff within their respective watersheds.

Note that if spot improvements for stream stabilization on Stream 17B are pursued, it will be necessary to acquire easements for construction on private properties behind several townhomes, because the stream now encroaches into several of these properties.

5.5 Benthic Macroinvertebrate Assessment Methodology

Following the stream assessment scoring and ranking, the scope of this study called for benthic macroinvertebrate assessments to be conducted on four of the assessed streams, one in each subshed. In order to determine which streams should have benthic assessments conducted, WSSI ranked the RSAT scores by subshed, then chose the highest ranking stream in each subshed, with the hypothesis that these streams would yield the highest possible benthic assessment scores (which, based on the RSAT assessments, were not expected to be very high). Based on this method, WSSI identified the following streams: Stream Reach 4 (Subshed 440), Stream Reach 11 (Subshed 444), Stream Reach16 (Subshed 448), and Stream Reach 20A (Subshed 450).

The Izaak Walton League of America's Save Our Streams methodology was utilized in the field to give a general overview of the condition of the benthic macroinvertebrate community. This methodology calls for the assessors to take three samples from each stream and identify all aquatic organisms within the samples. The organisms are identified to Order level and assigned one of three categories: Sensitive, Less Sensitive, and Tolerant. A letter (A, B, or C) is used to identify the relative abundance of each Order found. The total number of Orders found is then multiplied by 3, 2, or 1 (depending on the Order's sensitivity), and the results are totaled for an Index Value.

5.6 Benthic Macroinvertebrate Assessment Findings

The benthic macroinvertebrate assessment field work took place from May 17, 2013 to May 21, 2013. The resulting Water Quality Ratings are provided in Table 5.5.

Table 5.5 Benthic Macroinvertebrate Assessment Water Quality Rating

Stream Number	SOS Index Value	SOS Water Quality Rating
4	4	Poor
11	10	Poor
16	12	Fair
20A	5	Poor

Stream Reach 4 is dominated by midge flies (pollution tolerant organisms), with lunged snails (tolerant) and crane flies (less sensitive) also present. Urban uses within the watershed (roadways and development) appear to have had the greatest influence on the benthic populations in this stream.

Stream Reach 11 is dominated by black flies (tolerant), and midge flies (tolerant), with fewer numbers of common net spinning caddisflies (less sensitive), and clams (less sensitive). Lunged snails (tolerant), aquatic worms (tolerant), and crane flies (less sensitive) are also present. Urban uses, housing development, and a power line appear to have had the greatest influence on the benthic populations in this stream.

Stream Reach 16 is dominated by scuds (less sensitive), and aquatic sowbugs (less sensitive), with fewer numbers of stoneflies (sensitive), aquatic worms (tolerant), and midge flies (tolerant). Mayflies (sensitive) are also present. Urban uses and development appear to have had the most influence on the benthic populations in this stream, though to a lesser degree than the other streams assessed.

Stream Reach 20A is dominated by midge flies (tolerant). Craneflies (less sensitive), aquatic worms (tolerant), and lunged snails (tolerant) are also present. Intensive urban uses and housing development appear to have had the greatest influence on the benthic populations in this stream.

An analysis of land use within the watershed of each stream reach indicates that each watershed is highly developed, with almost all reaches having greater than 20 percent impervious land cover. It has been documented that even at low levels of imperviousness (~5-10%); stream degradation can begin to occur, which includes macroinvertebrate diversity (Schueler, Fraley-McNeal, and Cappiella, 2009). Runoff from the highly impervious land within these watersheds typically produces a high volume and velocity of flowing water and sediment in the stream channels during storm events. As a result, epifaunal substrate/available cover within these streams becomes highly mobile and benthic macrofauna cannot easily colonize the available substrate (Debrey and Lockwood 1990) or get buried and killed by high sediment deposition (Wood and Armitage 1997). Stream restoration can allow the stream channels to be engineered to accommodate high volume flows to minimize future habitat degradation. It may be possible that benthic condition could increase over time if, in addition to in-stream restoration efforts, water quality enhancing measures are undertaken in the watersheds of the various restored streams.

It should be noted that, while none of the streams assessed are listed as 303(d) waters for benthic impairments, Stream Reach 11 (Hooes Run) is listed as impaired for recreation due to the presence of *E. coli* (DEQ, 2012) and is a Category 5 water (needing a TMDL study).

6.0 Capital Improvement Projects – Conceptual Designs

The conceptual design projects identified during the reconnaissance studies are presented herein will improve watershed conditions and can be implemented through the CIP Program. Retrofits to stormwater management facilities will help reduce quantity and improve quality of stormwater runoff. Stream restoration projects will improve stream bank stability, enhance in-stream habitat, protect and reconnect floodplain buffers, and reduce in-stream sediment and nutrient loads. Detailed conceptual plans are provided in Appendices I and J.

A design detail supplement is provided with the Conceptual Stream Restoration Plans in Appendix J. The supplement includes typical restoration approaches (e.g. design priorities), a typical riffle with a reinforced bed detail, rock and wood stream structures that will provide both grade control and habitat benefits, and a planting detail. Additional data is required before the stream alignments, grading, and structure locations can be confirmed. Therefore, this supplement provides typical design details that will likely be employed in the final restoration design plan.

7.0 Cost Estimates

Estimated costs for proposed conceptual designs are provided in Appendices I and J with the respective conceptual design. Cost data was obtained through numerous sources including Prince William County Unit Price List, contractor bids, general estimates, and unit price lists from adjacent counties. Below is a summary of the estimated costs and the estimated annual cost of removing a pound (lb) of Total Phosphorous (TP) (Schueler 2013, DCR 2011).

Facility 28	Estimated cost:	$ 600,000
	Cost per lb TP:	*$ 10,000*
Facility 489	Estimated cost:	$ 519,000
	Cost per lb TP:	*$ 8,000*
Facility 9026	Estimated cost:	$ 235,000
	Cost per lb TP:	*$ 18,000*
Reach 5	Estimated cost:	$ 1,441,000
	Cost per lb TP:	*$ 12,000*
Reach 6A	Estimated cost:	$ 677,000
	Cost per lb TP:	*$13,000*
Reach 9	Estimated cost:	$ 1,895,000
	Cost per lb TP:	*$ 12,000*
Reach 10	Estimated cost:	$ 1,361,000
	Cost per lb TP:	*$ 12,000*
Reach 12	Estimated cost:	$ 836,000
	Cost per lb TP:	*$ 13,000*
Reach 20A	Estimated cost:	$ 897,000
	Cost per lb TP:	*$ 13,000*

Estimated cost of all stormwater facility retrofits is $ 1,354,000 with an average $12,000 per pound of TP. Estimated cost of the stream restoration projects total $7,110,000 with an average $12,500 per pound of TP. The average cost per linear foot is $870 per linear foot. Urban stream restoration costs in Northern Virginia generally range from $500 - $900 per linear foot due to the complexity of the design (e.g. amount of required rock, realignments, and utility crossings) and the ease of construction access and staging. The cost variability attributable to site specific conditions can be refined with detailed topographic surveys, tree surveys, and utility mapping. Appendix K summarizes funding options from government, non-government, and private sources.

8.0 Recommendations

This section summarizes recommended structural projects that will improve watershed conditions and can be implemented through the County's CIP Program. In addition, a series of non-structural measures, including policy and land use recommendations, are presented that will complement the proposed structural improvements.

8.1 Retrofits to Stormwater Management Facilities

Of the over 20 SWM/BMP Facilities inspected as part of this watershed study, 12 were identified as potentially benefitting the most from a combination of maintenance and/or retrofits in an effort to improve water quality treatment. Three SWM/BMP Facilities (28, 489, and 9026) were developed into conceptual design plans that are included as Appendix I. A location map is provided in Appendix C. These recommended projects will improve water quality treatment in a combined 215 acres at an estimated cost of $1,354,000. Costs per pound of TP range from $8,000 and $18,000.

Six facilities (465, 5047, 5707, 63, 163, and 5153) were given a lower priority for retrofit, hence conceptual plans are not provided as part of this study. However, these facilities could improve their existing treatment efficiency immediately through maintenance improvements. An additional seven facilities (19, 632, 5147, 92, 200, 201, and 5400) were in good operating condition, but required some level of maintenance ranging from simple repairs to water quality treatment improvements. Refer to Sections 4.4 for detailed description of the maintenance needs and potential retrofit opportunities. A location map of SWM/BMP Facility locations is provided in Appendix C. The following summarizes the recommended repairs:

1. Minor maintenance
    a. Eight SWM/BMP Facilities require removal of debris and litter at the outfall structure:
    SWM/BMP Facilities 19, 63, 92, 163, 200, 201, 632, 5147
    b. Two are missing County locks:
    SWM/BMP Facilities 5153 and 5147
    c. One is missing its BMP plate on its outlet:
    SWM/BMP Facility 632
    d. One temporary sediment trap has a broken riser cap:
    SWM/BMP Facility 5400
    e. Perimeter fence is broken in multiple locations:
    SWM/BMP Facility 5707

2. Major maintenance
    a. Trees are growing on the dams of 4 SWM/BMP Facilities, all of which should be removed before any of the dams are compromised:
    SWM/BMP Facilities 163, 201, 5047, and 5707
    b. Five may benefit from dredging:

SWM/BMP Facilities 63, 92, 200, 201, and 9026

c. One requires a more permanent repair of an upstream roadway crossing that is washed out and is only temporarily stabilized with large boulders: SWM/BMP Facility 5707

d. Further investigation is required to determine opportunities to increase treatment volume detention, or opportunities to reduce runoff entering 10 facilities: SWM/BMP Facilities: 19, 63, 163, 200, 201, 465, 5047, 5153, 5153, and 5707

Beyond conceptual plans and proposed maintenance, the County should explore if SWM/BMP Facilities 5047 and 5707 are stormwater management facilities and either remove them from the County SWM/BMP Inventory or explore options for improving water quality and quantity treatment on the sites.

8.2 Stream Restoration Projects

Twenty streams, totaling almost 6 miles, within the 4 subsheds, were inspected with a majority of the reaches ranking as ‘Poor’ or ‘Fair’ under the RSAT method. This verifies that most of the streams in these subsheds are being adversely impacted from urban development in their drainage areas. Of the inspected reaches, 6 (5, 6A, 9, 10, 12, and 20A) were selected for the development of conceptual design plans (presented in Appendix J) A location map is provided in Appendix E. These reaches will gain the most from restoration and/or stabilization. They have sufficient construction access, buffer protection, and will benefit impaired downstream waters.

These recommended projects will restore 8,300 linear feet of stream channel at an estimated cost of $7,110,000. Cost per linear foot averages $870. However, it should be noted that other streams that were assessed would also benefit from restoration, stabilization, or other measures that would reduce stormwater runoff from entering the channels.

8.3 Repair and Monitor Exposed Utilities and Infrastructure

Exposed and compromised utilities were identified in 16 other reaches where spot stabilization measures should be explored. Of these, two (Reaches 17B and 21), pose the most hazardous conditions and require immediate stabilization. Section 5.4 summaries the maintenance priority of each exposed utility and a location map is provided in Appendix G.

8.4 Incorporate Structural and Non-Structural Low Impact Development Practices

Approximately 20 percent of the land in Subsheds 440, 444, and 448 and 60 percent in Subshed 450 is currently treated by local and/or regional SWM/BMP Facilities, leaving runoff from large portions of developed lands draining directly into the local streams without any stormwater treatment (e.g. primarily developments that drain into tributaries of Hooes Run or those adjacent to the Occoquan River). This is evidenced by the low RSAT rankings for most of the assessed streams as they show signs of degradation from the urban development. In addition, as noted from the stormwater facility inspections, many only provide quantity control during larger storm events and are not providing sufficient attenuation of the smaller, channel-forming storm events.

To help reduce impacts from development, the County should encourage the use of Low Impact Development (LID) infrastructure, such as bioswales, underground gravel detention, rain gardens, and permeable surfaces in an effort to reduce stormwater runoff. Not all technologies require a large footprint and can be installed in residential or commercial lots. County-owned facilities located within these four subsheds could serve as demonstration projects.

The County should also consider supplementing this watershed study with a study that focuses on identifying areas that could benefit from LID infrastructure and areas where impervious surfaces could be reduced. Reducing runoff from existing and new developments will slow down the current rate of stream degradation, reduce sediment and nutrients from washing downstream, and protect treatment efficiency of current infrastructure.

Though beyond the scope of this study, the County should explore, and play a role in implementing non-structural measures and policies that will prevent or reduce runoff from leaving sites, and that will complement the proposed CIP structural measures. The opportunities are numerous and could have a significant impact with these 4 subsheds, and the entire County.

Nonstructural measures encompass LID site development practices that minimize site disturbance, maintain natural drainage features, minimize turf grass and impervious surfaces, and utilize natural vegetation. Of particular interest, should be how redevelopment efforts around Old Bridge Road, Interstate 95, and other environmentally sensitive areas can be accomplished with reduced stormwater runoff. Other non-structural measures include public educational outreach, such, proper use of fertilizers, proper disposal of household hazardous waste, and onsite measures that reduce runoff. In addition, monitoring existing riparian areas and implementing County-wide invasive specifies management programs will help identify existing erosion issues.

8.5 Address Flooding Concerns in the Town of Occoquan

Further exploration is required by both the County and Town of Occoquan to determine potential sources for the reported flooding problems in the Town environs. Retrofits to SWM/BMP Facilities 28 and 9026 are proposed and they are upstream of the Town of Occoquan. However, it should be noted that the receiving channel for SWM/BMP Facility 28 (Stream Reach 15) flows into the Town and appeared stable during the site inspections with no signs of frequent overbank flows, and received an RSAT score of 34 (Good). Refer to the location map in Appendix H for SWM/BMP Facility and stream reach locations. Therefore, the proposed retrofits will likely improve facility aesthetics and downstream water quality, but will not resolve reported flooding problems.

The goal of the proposed assessment will be to determine the magnitude and frequency of the reported flooding events and whether the likely cause can be attributed to the volume of flow coming from the respective watersheds, a deficiency in the storm sewer network within the Town, a backwater issue related to flooding from the Occoquan River, or a combination of all three.

The assessment should include:

- Meeting with relevant stakeholders (e.g. County staff, elected officials, citizens that currently experience flooding, and staff from the Town);
- Review of development plans within the subsheds for both existing and proposed development;
- Field reconnaissance of the subsheds;
- GIS based analysis and hydrologic modeling of the contributing subsheds to assess flow rates;
- Review of available FEMA reports and the FIS for the Occoquan River;
- Field reconnaissance and field survey, as necessary, of the specific areas of reported flooding and related portions of the storm sewer system; and
- A summary overview of potential solutions and concepts should deficiencies be discovered.

9.0 References

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10.0 Stakeholder Meetings: List of Attendees

10.1 Initial Stakeholder Meeting

Date: April 1, 2013
Location: Prince William County Offices

Attendees

Clay Morris - *Prince William County (PWC)*
Charles Williamson - *PWC*
Michael Rolband - *Wetland Studies and Solutions - Inc. (WSSI)*
Ben Rosner - *WSSI*
Kelly Petrey - *WSSI*
Janet M. Doyle
Connie Moser
James Phelps
Kim Hosen
Bill Olson
Harry Wiggin
Jim White

Tom Burrell - *Lake Ridge Occoquan Coles Civic Association and the Planning, Environment, Land-Use, and Transportation Committee (LOCCA / PELT)*

10.2 Final Stakeholder Meeting

Date: February 10, 2014
Location: Prince William County Offices

Attendees

Clay Morris - *PWC*
Frank Graziano - *WSSI*
Ben Rosner - *WSSI*
Kelly Petrey - *WSSI*
Peter Rinkert - *County resident*
Tom Burrell - *LOCCA / PELT*
Kelly Jimenez - *PWSWCD*
Al Alborn - *Alborn Foundation*
Larry Mote - *MIDCO*
Bill Olson - *PWCA*
Henry Bibber - *Citizen*
Suzanne Dee - *George Mason University*
Earnie Porta - *Town of Occoquan Mayor*
Edward Cronin - *Office of Supervisor Mike May*
Colin Walthall - *Keep Prince William Beautiful*
Damir Grljevic - *Keep Prince William Beautiful*
Neil Nelson - *Prince William Trails and Streams*

Jim Gehlsen - *Prince William Soil and Water Conservation District (PWSWCD)*
Andy Gorecki - *Christopher Consultants / Northern Virginia Building Industry Association (NVBIA)*
Gayle Whitlock - *Lake Ridge Parks and Recreation Association, Inc.*
Jeff Irwin - *Prince William Conservation* Alliance (*PWCA)*