Quantico Creek Watershed Assessment Report

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EXECUTIVE SUMMARY

This report presents the findings of a rapid watershed assessment, performed by MACTEC Engineering & Consulting, Inc (MACTEC), provides management strategies to protect the Quantico Creek Watershed, its streams and tributaries, and the larger Potomac Watershed. In addition, this report presents alternatives for stormwater management and planning, including prioritization and cost opinions for capital improvement projects located within the Watershed.

The Quantico Creek Watershed is one of ten main watersheds located in Prince William County, Virginia. The Watershed covers approximately 25,600 acres (40 square miles), and includes the incorporated towns of Dumfries and Quantico, as well as Prince William Forest (National) Park and portions of the Marine Corps Base Quantico. The Watershed is made up of 21 smaller drainage basins, ranging in size from 58 acres to 3,800 acres.

This study included an assessment of the streams, tributaries, and open channels in six (6) representative drainage basins throughout the Quantico Creek Watershed. Given a limited budget and schedule, it was determined that a select number of subwatersheds could be used to identify major trends and impairments within the larger Quantico Creek Watershed, in order to provide a framework for future management decisions. The selection of subwatersheds was based upon the sampling methodology, amount of time allocated for field work, available field equipment, time of year, and other variables.

An assessment of existing stormwater basins was also conducted to identify potential retrofit opportunities that could enhance stormwater capture, storage, infiltration, pollutant removal, and ecological benefit. In addition to field data gathering, a series of meetings were held to identify problems and opportunities in the Quantico Creek Watershed.

The protocol for data collection in the Watershed's open channels followed the Rapid Stream Assessment Technique (RSAT), developed by J. Galli and the Metropolitan Washington Council of Governments (Galli, J. 1996). The RSAT method enables rapid assessment of current ecological condition and function, including both morphological (i.e. physical habitat/channel stability) and biological (macroinvertebrate) assessment, to provide a simplified, reconnaissance-level evaluation on a watershed-scale. The existing stormwater basins were evaluated and scored based upon basin type, basin structure, location and drainage area, and vegetation. Stormwater basins that received low scores were generally suitable for some type of retrofit or enhancement.

Based on analysis of the field data, 30 open channel problems and 16 stormwater basin maintenance and operations issues were identified. Recommendations were developed to address each of the identified problems, and the proposed improvements were assigned a priority number, or ranking in order of importance, and an opinion of probable design and construction cost. The total cost opinion for all 30 proposed open channel recommendations is $14,928,750.

The total cost opinion for all 16 proposed stormwater basin retrofits is $773,483. The combined total cost opinion for both open channel and basin retrofit projects is **$15,702,233**.

1.0 INTRODUCTION

The Quantico Creek Watershed is one of ten main watersheds located in Prince William County, Virginia. The Watershed covers approximately 25,600 acres (40 square miles), and includes the incorporated towns of Dumfries and Quantico, as well as Prince William Forest (National) Park and the Marine Corps Base Quantico. The main stem of Quantico Creek flows southeast, originating near the intersection of Aden Road (Route 646) and Joplin Road (Route 619), and emptying into the Potomac River just north of the Town of Quantico. The South Fork of Quantico Creek flows due east through Prince William Forest Park, before joining the main channel 4,300 feet upstream (west) of Interstate I-95. Figures 1-1 and 1-2 below provide an overview of the County, Watershed, and key property features.

The Quantico Creek Watershed extends as far west as Aden Road, north to Dumfries Road, south to Joplin Road, and east to the Potomac River. The Watershed is made up of 21 drainage basins, ranging in size from 58 acres to 3,800 acres. Land use throughout the Watershed is predominantly undeveloped/open lands (78%), with residential (18%) land use making up the second largest percentage of land cover.

The Quantico Creek Watershed has undergone dramatic changes during the past century, and is currently undergoing another recent transformation, as development pressures increase for residential and commercial properties near the Washington D.C. metropolitan area. This report presents the findings of a rapid watershed assessment, provides management strategies to protect Quantico Creek, its tributaries, and the larger Potomac Watershed, and presents alternatives for stormwater management and planning, including prioritization and cost opinions for capital improvement projects located within the Watershed.

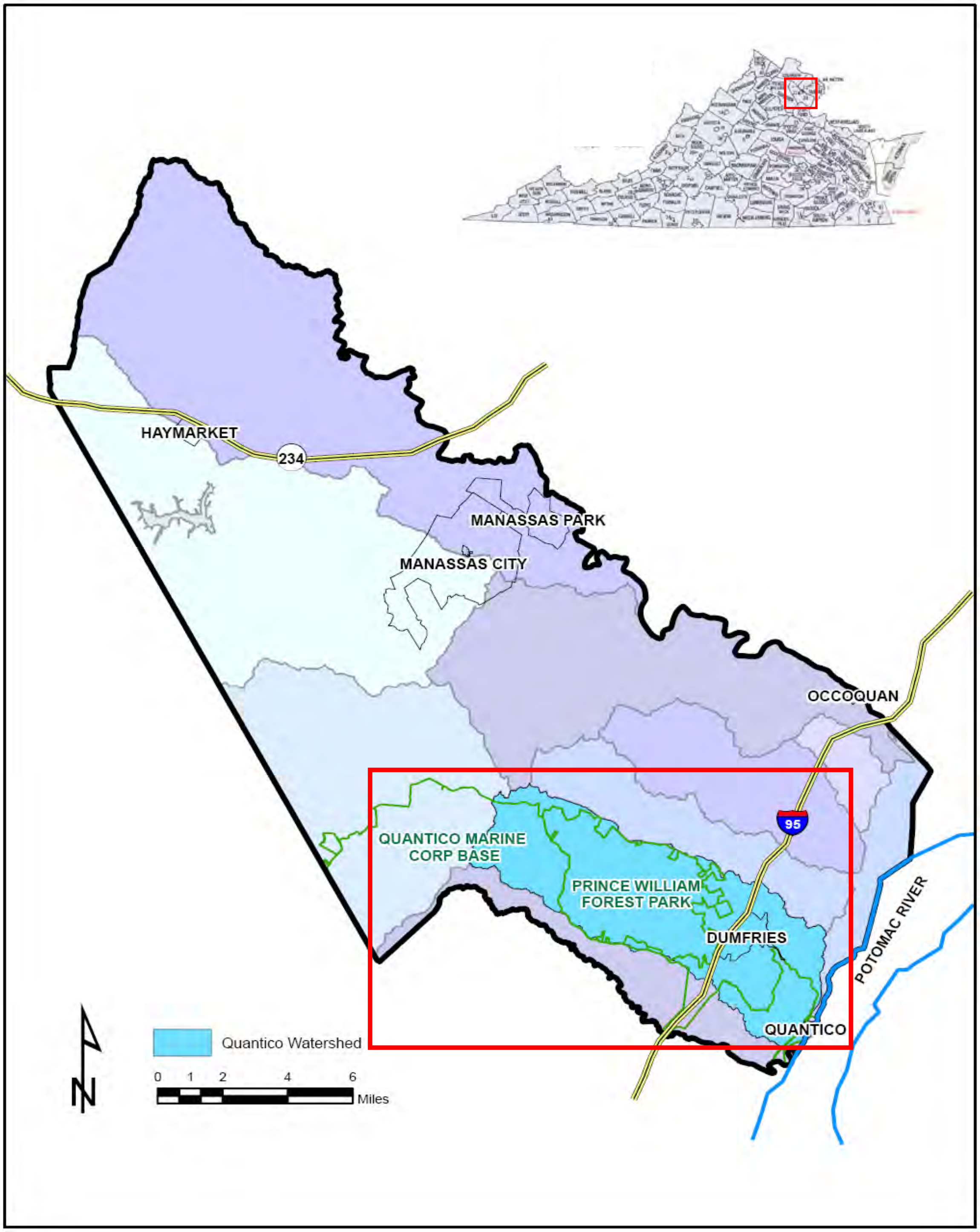

Figure 1-1: Overview of Prince William County and the Quantico Creek Watershed.

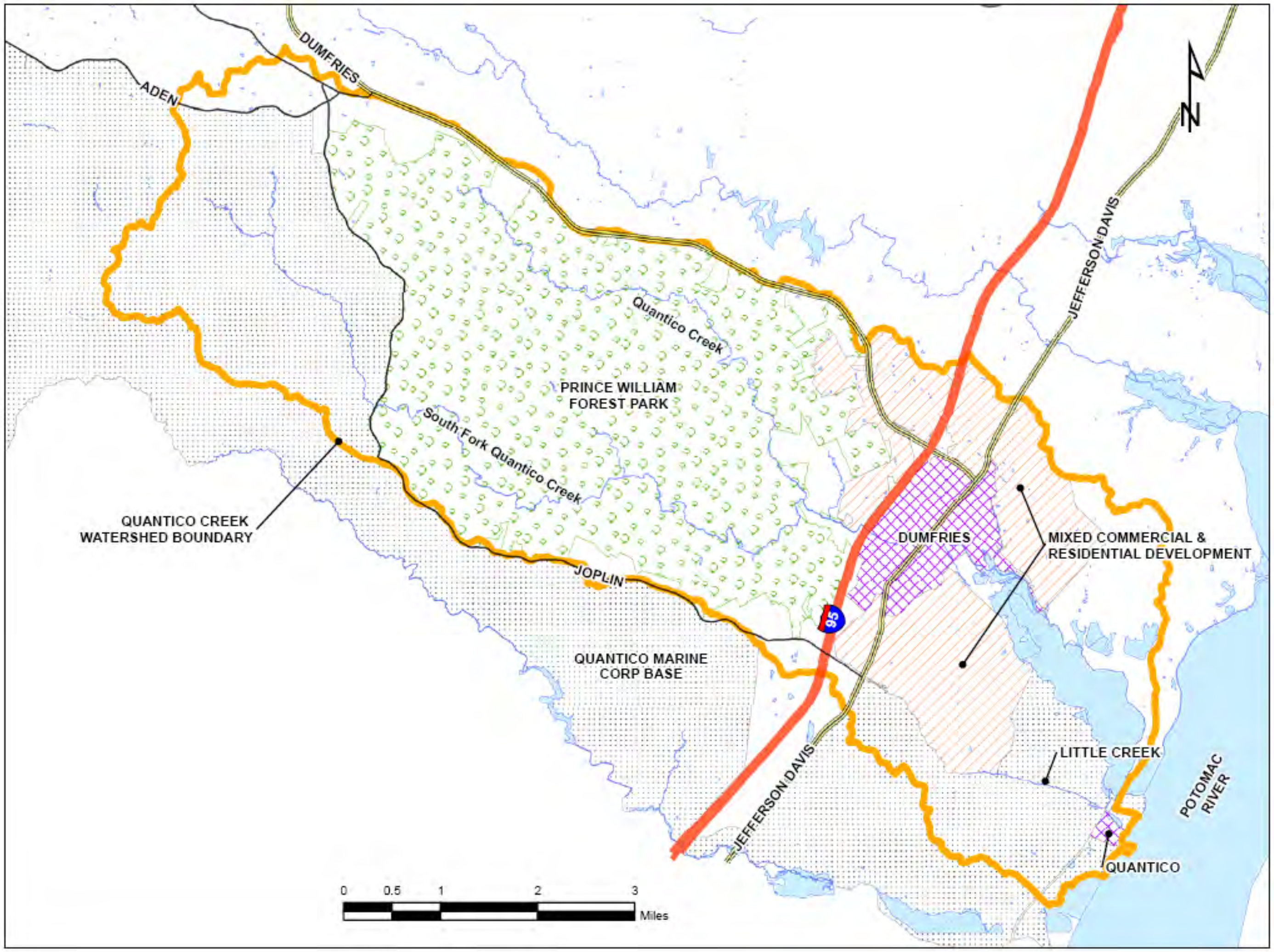

Figure 1-2: Overview of the Quantico Creek Watershed with Major Land Owners/Uses.

2.0 WATERSHED DESCRIPTION

The Quantico Creek Watershed covers an area of approximately 25,600 acres, draining to a Potomac River estuary near the Town of Quantico, Virginia. The Watershed is made up of 21 drainage basins, ranging in size from 58 acres to 3,800 acres. The headwaters of the Watershed begin approximately 430 feet above sea level, while Quantico Creek itself flows into the Potomac River at approximately sea level, with an average channel gradient of 0.005ft/ft (or 430ft of drop over approximately 86,000ft of channel).

The Quantico Creek Watershed is located on a geologic divide between the Piedmont physiographic province to the west and the Coastal Plain physiographic province to the east, known as the Quantico Syncline. This transitional divide, or fall line, is located along the Interstate 95 corridor, and marks a significant transition in geology and landform (discussed below in Section 2.2).

The upper and middle reaches of the Quantico Creek Watershed are located within the Piedmont Province, upstream of Interstate 95. The upper Watershed is largely undeveloped and somewhat rural in nature, with low density residential, open lands and agricultural land use. Portions of the Marine Base Quantico and Prince William Forest Park offer some permanent protection of higher quality, streams found throughout study Basin 615, South Fork of Quantico Creek.

The middle Watershed to the west of the I-95 corridor, including portions of study Basins 630 and 645, has experienced increased development in recent years, with newer residential neighborhoods and commercial development adjacent to I-95. However, large tracts of undeveloped woodland remain along hillsides and areas with steeper topographic relief.

The Coastal Plain Province is located east of Interstate 95, where Quantico Creek flows to the Potomac River and was heavily developed early in the previous centuries. The lower Watershed is influenced by the adjacent land uses associated with the Towns of Dumfries, Quantico, and Triangle. Depositional, multi-thread channels are common, due to a reduced slope, increased sediment load from eroding channels upstream, and the tidal influence of the Potomac River.

2.1 Climate

The climate of the Quantico Creek Watershed is characteristic of Modified Continental Climate. Average temperatures are around 56 degrees. The average annual precipitation is approximately 40 inches, with an increase in precipitation typically occurring during the summer months of July and August. Relative humidity can be high, due to the influence of the Chesapeake Bay and Atlantic Ocean.

2.2 Geology and Soils

The Quantico Creek Watershed is located along a northeast to southwest trending divide between the Piedmont Physiographic Province and the Atlantic Coastal Plain Physiographic Province, marking a significant transition in geology and landform. This Fall Line or Fall Zone is a transitional area where the softer, less consolidated rocks of the Coastal Plain to the east intersect with harder and more resistant metamorphic rocks to the west, forming an area of ridges, waterfalls and rapids. The Coastal Plain Province generally consists of unconsolidated sand, silt, and clay, formed from eroded sediments reworked by fluctuating sea levels and wave actions along the coastline. The Piedmont Province is an eastward sloping plateau characterized by moderate to very steep slopes formed by a combination of folding, faulting, uplift and erosion of the underlying metamorphic and sedimentary bedrock.

The upper two-thirds of the Quantico Creek Watershed is located within the Piedmont physiographic province and is underlain by crystalline and volcanic rocks of Cambrian to Ordovician Age belonging to the Quantico, Chopawamsic, Lunga Reservoir and Wissahickon Formations with other metamorphosed intrusive rocks characterized as amphibolites and felsic intrusives. The Wissahickon Formation is generally described as quartz gneiss with meta-graywacke, schist and meta-siltstone. The Lunga Reservoir Formation is generally a metasedimantary mélange resembling a granitic rock containing xenoliths and contains abundant quartz pebbles and mica schist. The Chopawamsic Formation includes primarily schist and granofels of low to medium metamorphic grade, with interbedded volcanigenic mafic and felsic sedimentary rocks, including flows of porphyritic and pyroclastic rocks, coarse breccias and greenstone. The Quantico Formation is generally described as black slate with interbedded metagraywacke, felsic tuff and greenschist.

Soils in this western two-thirds of the Watershed consist predominantly of Buckall-Glenelg-Occoquan complex, Gaila-Buckall-Occoquan complex, and Spriggs-Orenda-Minnieville complex. These soils are moderately deep to very deep, well-drained or somewhat excessively drained, with clayey or loamy subsoils. Soil along the main stem of Quantico Creek is primarily Hatboro-Codorus complex, with 0 to 2 percent slopes.

The lower portion of the Watershed, located in the Coastal Plain Province, includes sedimentary rocks and deposits of the Cretaceous, Tertiary and Quaternary Periods belonging to the Potomac Group and Aquia Formation with overlying Upland Deposits, Terrace Deposits and Alluvium. The Potomac Group is generally described as a quartz sand, clay, clayey sand and sandy silt with interbedded poorly preserved ferns and plant matter. The Aquia Formation is typically a glauconitic quartz sand with scattered quartz pebbles, shell material and clay. Upland deposits are generally a clayey quartz sand with quartz gravel while the Terrace Deposits include varying thicknesses of sand, silt and clay with pebble to cobble size well-rounded quartz. Alluvium is predominantly mud, sand and gravel formed in the flood plains of minor streams and marsh lands bordering tidal tributaries of the Potomac River. Soils in this Province are comprised of two major soils types; the Neabsco-Quantico-Dumfries complex and Dumfries-Lunt-Marr complex. These soils are very deep and well drained, with loamy or clayey subsoil.

This geology and soils discussion, while technical in nature, also directly relates to a number of watershed and hydrogeologic conditions that can be observed in the field. Essentially, there are two very distinct geologic areas (Piedmont and Coastal Plain) and each area has soils that are characteristic of the underlying geology. In the upper part of the watershed, the topography is steeper and there are often rock outcrops that affect stream grade. The sandy topsoils are typically porous and therefore droughty, slightly acidic with low buffering capacity, low in nutrients, and highly erodible. The subsoils typically have a higher clay content which is less porous and less erodible, and subsurface water tends to flow along this boundary. The lower portion of the watershed typically has less topographic relief, the geology is more buffered with lime, and the soils are very sandy and often erodible.

The geology and soils are a causative factor where changes in the watershed result in, for example, massive gully erosion in a short period of time. This break or transition in geology can also impact or drive recommendations, schedules, and costs. This geologic transition zone will also drive restoration where the selection of bank treatments, vegetation, and other materials will be different based on location in the watershed and the site geology.

2.3 History and Land Use

Prior to European settlement, much of the Quantico Creek Watershed was covered in forests of oak, hickory, and chestnut trees. Archeological evidence suggests that Archaic-period Native Americans hunted and camped in the area. However, permanent settlements within the Watershed were not likely established until the founding of Dumfries in the early 1700s, making it the oldest chartered town in Virginia. Dumfries was a thriving port town, until extensive land clearing along the surrounding hillsides for settlement and agriculture led to increased soil erosion and the generation of large volumes of sediment, which eventually deposited at the mouth of the port, making it inaccessible to commercial vessels.

In the early part of the 1900s, the Town of Quantico established new shipyards along the Potomac River, and the Marine Base Quantico was established to train Marines for combat in World War I. Development in and around the Towns of Quantico and Dumfries grew substantially through the 20th Century. As a result, direct alterations were made to Quantico Creek to accommodate new infrastructure, with a significant effect on the hydrologic regime and channel stability. Most notably, the construction of a sewage treatment facility resulted in the relocation and channelization of the lower portion of Quantico Creek, which likely aggravated bank erosion through the process of channel incision, or downcutting, as the stream adjusted to regain a stable gradient.

2.4 Current and Future Land Use

Prince William County is the third most populous jurisdiction in the State of Virginia (Prince William County Comprehensive Plan, 2008). The population has increased nearly 35% since 2000, and the County predicts nearly 50% additional growth over the next 20 years, due to its close proximity to the greater Washington D.C. metropolitan area.

The dominant land use in the Quantico Creek Watershed is forest and/or open lands, due in large part to the protection afforded by the Prince William Forest and portions of the Marine Base Quantico training grounds. However, residential, commercial, and industrial land uses are concentrated along the Interstate 95 corridor, in the eastern portion of the Watershed, and along Dumfries Road to the north, and several drainage basins (Basins 630, 645, 650 and 665) have significant areas of impervious surfaces, such as rooftops, roads, and parking lots.

The Prince William County 2008 Comprehensive Plan presents long-range land use planning, and designates residential, commercial, and industrial zoning based on the projected growth for the County. According to the Plan, long range land uses for the majority of the Quantico Creek Watershed do not diverge from present land uses and, therefore, will not have a change in impact on the watershed. However, a significant portion of Basins 670 and 675, in the lower portion of the Watershed, has a future long range land use designation of Suburban Residential Low (SRL); defined as areas of housing at a low suburban density, typically 1-4 dwellings per acre.

The significance of the impending development is the potential hydrologic effect it may have on the Watershed. It is well known that the conversion of open lands to land uses with greater impervious surface area can have dramatic effects on watershed hydrology and channel stability. Rooftops, concrete, pavement and compacted soils reduce infiltration, resulting in an increase in precipitation that is converted directly to stormwater runoff. This produces an increased volume and rate of delivery of runoff to nearby streams and tributaries. Alteration of the flow in magnitude, frequency and duration prompts receiving channels to erode in response to increased velocity and shear of the peak discharges.

However, new development projects can mitigate the influence of impervious surfaces by implementing stormwater best management practices (BMPs) to provide both water quantity and quality control. The *Prince William County Design and Construction Standards Manual* (2009) and the *Northern Virginia BMP Handbook* (1992) describe the requirements for all stormwater management techniques and best management practices (BMP's). These techniques are required to regulate the 2 and 10-year storm events, such that there is no increase in peak flows after development. Additionally, stormwater management ponds are to be designed so that they reduce the post-development flows from the 10-year storm event for the entire receiving watershed by twenty percent.

The design guidelines state that these techniques should not only be designed to reduce peak flows, but also to promote pollutant removal and water quality. The guides recommend a drawdown time of 30 to 48 hours for ponds; allowing for sediment and pollutants to settle out. With minor modifications, stormwater detention facilities could be converted into multipurpose facilities satisfying both water quantity and water quality needs. Along with water quality and quantity, these techniques should be constructed so that they preserve existing native vegetation and minimize impervious cover.

Some of these methods are described in subsequent sections of this report. In addition, recommendations for retrofitting existing stormwater basins to provide even greater benefit are discussed in Section 5.3.

Figure 2-1: Aerial Photograph Showing Land Use and New Development Near the Interstate I-95 Corridor (Basin 630).

2.5 Summary of Existing Data and Reports

Prince William County Stream Protection Strategy

The Prince William County Stream Protection Strategy (CH2M HILL, Williamsburg Environmental Group, and Michael Baker, 2004) included assessments of many streams and tributaries within Prince William County. The purpose of the assessment was to collect information on 1) Habitat Conditions, 2) Erosion, Buffer and Infrastructure Impacts, 3) General Stream Characteristics and 4) Biotic Integrity.

Data from this previous study was analyzed as part of the Quantico Creek Watershed Assessment, using the Prince William County Stream Assessment Viewer. A brief summary of the previous assessment results are presented below:

- There were two exposed sanitary line locations identified in Sub-basin 665 and two exposed pipe (possibly sanitary) locations in Sub-basin 690.

- A number of obstruction sites were noted in Basin 615, 630, and 665 consisting of beaver dams and /or woody debris jams. In addition, the metal sheet pile dam on Reach 690-A was identified in the previous study.

- A single, 10ft tall headcut (an indicator of channel incision) was previously identified in Basin 665, along Reach 665-I.

- There were two erosion sites identified in Basin 630 and four erosion sites in Basin 665.

- Four dump sites were identified in Bain 630.

Localized infrastructure and public safety problems such as those described in the previous report received the highest priority and are discussed in more detail in subsequent sections of this report. Erosion sites identified in the previous report appear to be part of a larger pattern of bank erosion, indicating systemic channel incision or widening. These problems are widespread throughout the Watershed, and are addressed on a reach-by-reach basis. Proposed recommendations, priority and cost opinions for erosion problems depend largely on the severity and extent of the problem.

Swans Creek Stabilization Study, MACTEC Engineering and Consulting, 2007.

A study was performed that looked at severe erosion and aggradation, associated with a subdivision located upstream on Swans Creek, and downstream of the intersection of Barrley Drive and New Cherry Hill Road. Severe headcutting and incision was identified as the primary driver behind widespread erosion problems. MACTEC performed a review of the existing conditions, and provided a series of solutions that would result in various levels of repair.

The problem resulted from the attempts of a developer to maximize developable land by excavating a ridge flat and pushing soil into adjacent ravines. The same developer installed a series of rock check dams in the ravine. The increased impervious surfaces from the development resulted in an increased volume and rate of stormwater runoff to the receiving stream, increasing the velocity and shear stress of peak flows, which eventually led to the failure of the check dams. The problem was aggravated by the highly erodible sandy soils that were liberated from the channel bed and banks through erosion, and subsequently deposited in downstream segments of Swans Creek. The Prince William County, Department of Public Works, Watershed Management Branch attempted to enforce subdivision development regulations, but the developer declared bankruptcy and left the State.

An important outcome of this study was the identification of the root cause of the problem, rather than focusing on its numerous symptoms, and the need for thorough planning, review, and enforcement of existing guidelines and regulations intended to protect the natural resources of the County.

Section 303(d)

Section 303(d) of the Clean Water Act requires states to develop a list of impaired waters, which fail to meet applicable water quality standards for their designated uses. States establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters included on the 303(d) list. The TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet state water quality standards. The TMDL program is mandated by the USEPA and administered by the Virginia Department of Environmental Quality (DEQ), who monitors more than 100 different pollutants, including sediment, metals, nutrients, and bacteria. Identifying sources and quantifying pollutant loads allow for the development of an implementation plan to provide recommendations for meeting the allowable load limits in the study watershed.

The 2006 list of impaired waters included a reach of Quantico Creek, from the confluence with the South Fork, just upstream from Interstate I-95, to the tidal waters of Quantico Bay. The listed impairment along this reach is fecal coliform bacteria. Fecal coliform is linked to human or animal waste, and can originate from combined sewer overflows in urban watersheds, agricultural/livestock operations in rural settings, and even wildlife. Sewage system updates, increased inspection of livestock facilities for illicit discharge, leash laws and pet-waste ordinances may reduce the various sources within the Watershed.

In addition, the Quantico Creek Estuary is listed as an impaired water, due to PCB contamination found in fish tissue samples. PCB contamination is thought to originate from the larger Potomac River system. Education on the presence of PCBs in the Quantico Creek Estuary is recommended to minimize potential human contact, ingestion and contamination.

3.0 DATA COLLECTION METHODOLOGY

The goals of the Quantico Creek Watershed Assessment include, but are not limited to, the following primary objectives:

- Assess the existing condition of the watershed for general physical, chemical, and biological characteristics
- Identify existing problems in the watershed and make recommendations
- Solicit input from the residents, communities, and land managers within the watershed
- Prioritize recommendations based on the magnitude, cost, construction sequence, and appropriate methods
- Present results that are technically accurate and acceptable for integration in land use decision making, grant applications, and in prioritizing fiscal investments
- Complete the study with the budget and schedule allotted

Data collection began with background data review and public comments, gained through a series of meetings with residents and project stakeholders, to identify existing or historic problems along Quantico Creek. Many of the comments were focused on siltation and invasive aquatic plant growth that impeded or prevented the use of watercraft, in the vicinity of the confluence with Quantico Creek and the Potomac River. Problems identified through the public comment process were then observed by MACTEC scientists and County administrators, and are included in the project recommendations.

The field reconnaissance portion of the watershed study was based on an assessment of selected subwatersheds and reaches of stream as an indicator of overall watershed health. Given a limited budget and schedule, it was determined that a select number of subwatersheds could be used to identify major trends and impairments within the larger Quantico Creek Watershed, in order to provide a framework for future management decisions. The selection of subwatersheds was based upon the sampling methodology, amount of time allocated for field work, available field equipment, time of year, and other variables. Subwatersheds were selected to represent the upper, middle, and lower watershed, including a number of stream reaches in Prince William Forest Park, which could be used as reference reaches for describing protected, high-quality stream within the Quantico Creek Watershed. An overview of the selected subwatersheds is shown below, in Figure 3-1.

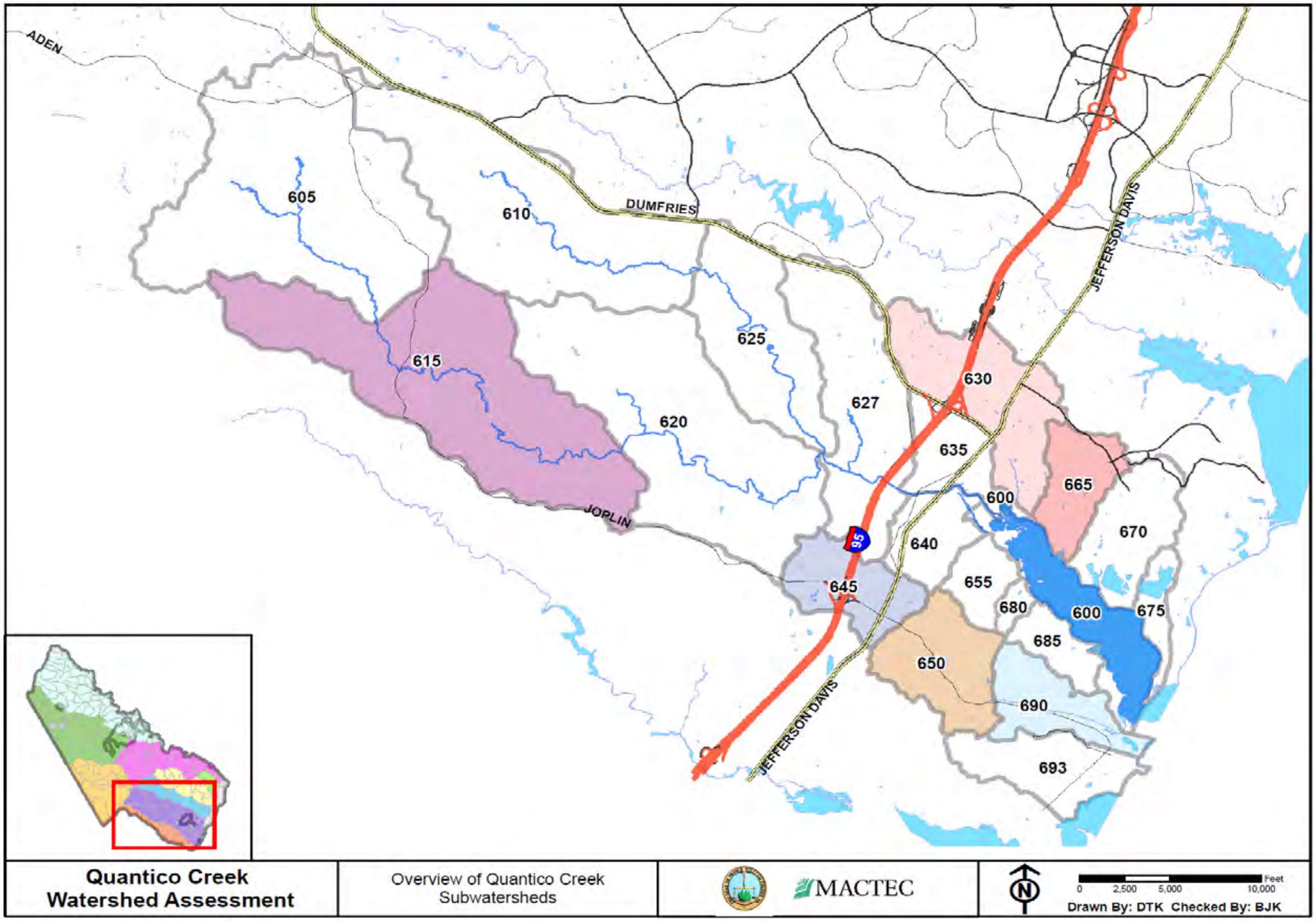

Figure 3-1: Overview of the Quantico Creek Watershed Subwatersheds.

Increasing impervious surface area, removal of riparian vegetation, herbicide and pesticide use, and other land practices manifest themselves as problems within the watershed. There are numerous methods for data collection, ranging from those that are extremely technical and costly, to those that are more qualitative and relatively inexpensive to evaluate these various impairments on a watershed-scale. The County selected a hybrid approach that collects and ranks data, based upon a widely used and accepted regional methodology. The protocol for field data collection followed the Rapid Stream Assessment Technique (RSAT), developed by J. Galli and the Metropolitan Washington Council of Governments. RSAT is essentially a blend of visual assessment methods, including the *USEPA Rapid Bioassessment Protocols* (Plafkin et al. 1989, Barbour et al. 1999) and the *USDA Water Quality Indicators Guide* (Terrell and Perfeti 1989).

As the name implies, the RSAT method enables rapid assessment of current ecological condition and function, including both morphological (i.e. physical habitat/channel stability) and biological (macroinvertebrate) assessment, to provide a simplified, reconnaissance-level evaluation of on a watershed-scale. The RSAT method is designed to be applied throughout a given watershed, with individual observations, or sample points, collected at 400 to 500-foot intervals.

Six evaluation categories are used to assess and score overall stream quality, including:

1. channel stability,
2. channel scouring or sediment deposition,
3. physical in-stream habitat,
4. water quality,
5. riparian habitat conditions, and
6. biological indicators.

Each of the six categories includes variables that are observed and recorded in the field, according to the descriptors in the RSAT manual, to assign a point value to each category. The six categories are weighted to greater emphasis on channel stability (less on riparian habitat). Scoring ranges from 0 and 50, with descriptive categories of poor, fair, good, and excellent. The maximum (best) possible RSAT score out of all six categories is 50 (Galli, J. 1996). Based on these scores, it is possible to arrive at conclusions regarding the source and magnitude of impacts to the watershed, which inform recommendations and proposed solutions.

An example of evaluation categories and scoring is shown below, in Figure 3-2.

RSAT Evaluation Category	**General Verbal Rating Categories and Associated Point Range**				
	Excellent	**Good**	**Fair**	**Poor**	**Points**
1. Channel Stability	9-11	6-8	3-5	0-2	7
2. Channel Scouring/Deposition	7-8	5-6	3-4	0-2	4
3. Physical Instream Habitat	7-8	5-6	3-4	0-2	6
4. Water Quality	7-8	5-6	3-4	0-2	6
5. Riparian Habitat Conditions	6-7	4-5	2-3	0-2	5
6. Biological Indicators	7-8	5-6	3-4	0-2	8
Total Points				**Total Score**	**36**
42-50 = Excellent					
30-41 = Good				**Verbal Ranking**	**Good**
16-29 =Fair					
< 16 = Poor					

Figure 3-2: Rapid Stream Assessment Technique (RSAT) Evaluation Categories and Scoring.

3.1 Channel Stability

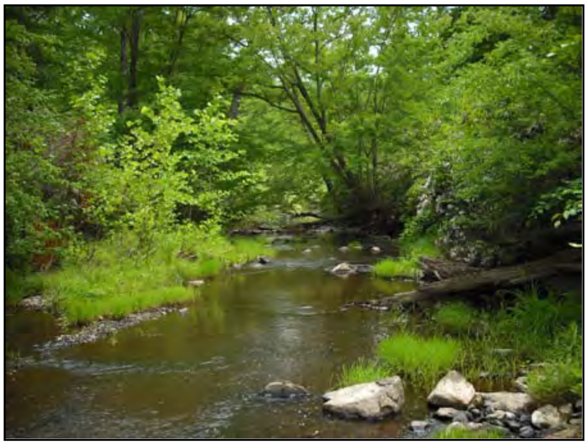

Figure 3-3: Comparison of Excellent Channel Stability (above) vs. Poor Channel Stability (below).

Channel stability is an evaluation of the geomorphic stability of the existing stream channel. This category provides general insight into the structural integrity of the channel and how it may potentially respond to future changes in the hydrologic regime. Channel stability is also the only category in the RSAT method that has a point value range of 0 to 11 (the others range from 0 to 8); an indicator of the weight and influence this category has over the remaining five categories in the assessment methodology.

An *Excellent* (11-9) channel stability score indicates stable streambanks (even at the outside of bends), with little or no evidence of bank sloughing or failure. Typically, vegetation plays a major role in maintaining an excellent channel stability rating, with the lower 1/3 of the bank comprised of either dense vegetation or resistant soils, and a root matrix of large, mature woody vegetation.

A *Good* (8-6) score indicates infrequent signs of sloughing or failure (71-80% of bank network stable) with some exposed tree roots and few recent tree falls.

A *Fair* (5-3) score is assigned to those reaches where only 50 to 70% of bank network is considered stable, with recent signs of sloughing or failure fairly common. As a result, exposed roots of young trees are common and the lower 1/3 of the bank has little vegetative reinforcement or is comprised of highly erodible material.

A *Poor* (2-0) channel stability score is reserved for reaches where less than 50% of the bank network is considered stable. Signs of sloughing or failure are frequently observed, stream bend areas are highly unstable, exposed tree roots are abundant, and the lower 1/3 of the bank is comprised of highly erodible material with little or no vegetative reinforcement.

3.2 Channel Scouring or Sediment Deposition

Channel scouring and sediment deposition is an evaluation of sediment load and transport ability, and often relates to uncontrolled runoff from developed areas. Other sources of problems are floodplain filling, undersized culverts, impoundments, or channelization.

An *Excellent* (8-7) score for channel scouring or sediment deposition indicates low rates of deposition, as evidenced by few sand or sediment deposits, few or relatively small point bars, riffles are less than 25% embedded, and a high number of deep pools.

A *Good* (6-5) score indicates low to moderate rates of deposition, as evidenced by relatively uncommon sand or sediment deposits, few point bars, riffles are less than 49% embedded, and a moderate number of deep pools.

A *Fair* (4-3) score is assigned to reaches where fresh sand deposits are common, point bars are moderately large and unstable, riffles are between 50 to 75% embedded, and deep pools are infrequent.

A *Poor* (2-0) channel scouring or sediment deposition score is reserved for reaches where fresh, large sand deposits are common, point bars are large and unstable with fresh sand present at most stream bends, riffles are more than75% embedded, and deep pools are few (if any).

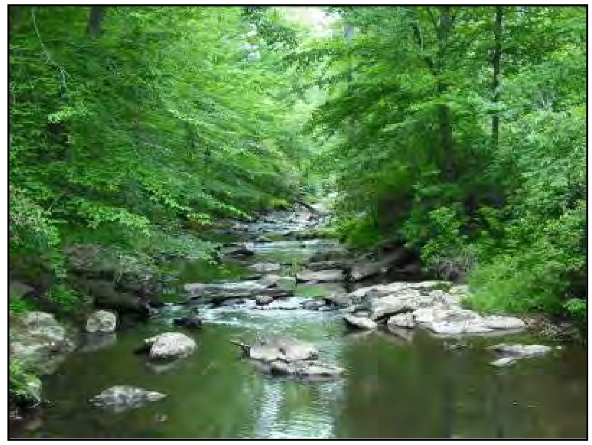

Figure 3-4: Comparison of Excellent Channel Scouring or Deposition reach (above) vs. Poor Channel Scouring or Deposition reach (below).

3.3 Physical In-stream Habitat

Physical in-stream habitat relates to the ability of the stream to provide basic physical requirements to support aquatic ecosystems, such as flow depth, water temperature, and channel substrate.

An *Excellent* (8-7) score for in-stream habitat indicates a wetted perimeter greater than 85% of the total channel width, the occurrence of riffles (greater than 8 inches deep), large pools, runs, and glides, and a channel substrate comprised largely of gravel, cobbles, and/or boulder materials. Excellent reaches show little or no evidence of channel alteration and/or bar formation, and have diverse flow depths and velocities throughout the reach. Overhead cover, or submerged habitat (such as rootwads or vegetative mats), provide shading and tend to keep summertime afternoon temperatures below 68 degrees Fahrenheit.

A *Good* (6-5) score indicates a wetted perimeter of 61% to 85% of the total channel width, a good mix of riffles, pools, runs, and glides, and a channel substrate comprised of gravel, cobbles, and/or rubble. Good reaches have a slight increase in bar formation with relatively diverse flow depths and velocities. A reduction in overhead cover or submerged habitat can maintain summertime afternoon temperatures between 68 and 75 degrees Farenheit.

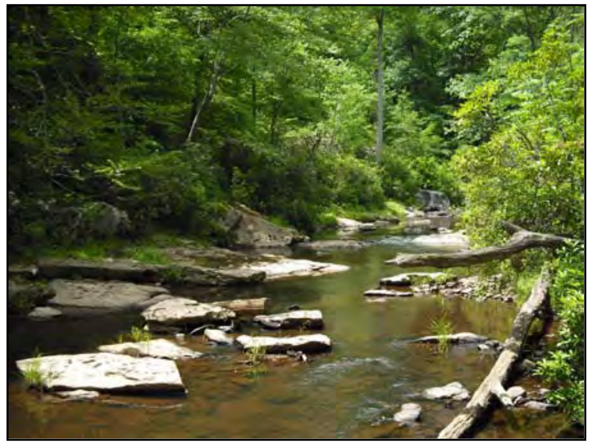

Figure 3-5: Comparison of Excellent Physical In-stream Habitat (above) vs. Poor Physical In-stream Habitat (below).

A *Fair* (4-3) score is assigned to reaches with a wetted perimeter between 40 and 60% of the total channel width. Riffles and runs dominate the reach, with few pools and a generally slow/shallow depth and velocity regime. Channel substrate is predominantly small cobble, gravel and sand, with increased bar formation, channel alteration and little or no overhead cover.

A *Poor* (2-0) in-stream habitat score is reserved for reaches with a wetted perimeter less than 40% of the total channel width, only one habitat type (usually runs) and flow regime, gravel and sand substrate, and a lack of cover or structure. Summertime afternoon temperatures in poor reaches often exceed 80 degrees Farenheit.

3.4 Water Quality

Water quality provides an estimate of aquatic habitat conditions, watershed disturbance, and corresponding point and nonpoint pollution loads. The RSAT methodology uses variables as indicators of water quality that have been found to have direct correlations to many of the other parameters, including turbidity, substrate fouling, and odors.

Figure 3-6: Comparison of Excellent Water Quality (above) vs. Poor Water Quality (below).

An *Excellent* (8-7) score for water quality indicates clear water, low Total Dissolved Solids, or TDS, (less than 50 mg/L), visibility down to 3ft or more, relatively little substrate fouling, and a lack of organic odors.

A *Good* (6-5) score indicates a slight increase in TDS (50-100 mg/L), visibility between 1.5 and 3ft, light substrate fouling, and a slight organic odor.

A *Fair* (4-3) score is assigned to increased levels of TDS, loss of clarity with visibility between 0.5 and 1.5ft, moderate levels substrate fouling, and/or an increase in organic odors.

A *Poor* (2-0) channel scouring or sediment deposition score is reserved for cloudy water with high TDS, visibility of less than 0.5ft, high levels of substrate fouling, and usually strong organic odors.

3.5 Riparian Habitat Conditions

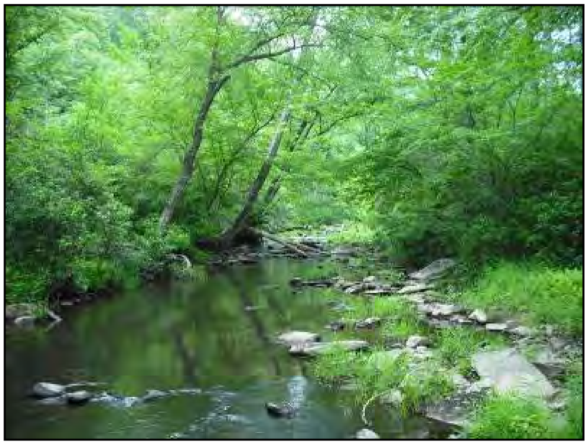

Figure 3-7: Comparison of Excellent Riparian Habitat Conditions (above) vs. Poor Riparian Habitat Conditions (below).

Riparian habitat condition is an evaluation of the aquatic and terrestrial habitat conditions, providing insight into stream energetic and temperature regime. Total possible scores for riparian habitat conditions range from 0 to 7, giving this category the least weight in the total scoring and evaluation.

An *Excellent* (7-6) score for riparian habitat conditions indicates a wide buffer area (greater than 200 feet) of mature forest along both banks, and more than 80% canopy cover (60% for the larger main stem reaches).

A *Good* (5-4) score indicates a forested buffer area, generally more than 100ft along both banks, and 60% to 79% canopy cover (45% to 59% for the larger main stem reaches).

A *Fair* (3-2) score indicates a riparian buffer area with localized gaps in the forest, and 50% to 60% canopy cover (30% to 44% for the larger main stem reaches).

A *Poor* (2-0) score is assigned to reaches where there is little riparian buffer area or woody vegetation, and less than 50% canopy cover (30% for the larger main stem reaches).

3.6 Biological Indicators

Figure 3-8: Comparison of Excellent Biological Indicator Species (above) vs. Poor Biological Indicator Species (below).

The biological indicators category is used to provide an overall indication of stream health and watershed disturbance based on key "indicator species". Aquatic macroinvertebrates spend a portion of their life cycles living in the water. Due to limited mobility, these organisms are unable to easily escape from detrimental or impaired conditions and are, therefore, indicative of overall water quality and habitat. Certain species of macroinvertebrates are indicators of either good or poor water quality, as well as the overall stream health.

An *Excellent* (8-7) score for biological indicators represents a diverse macroinvertebrate community, with moderate to high numbers of mayflies, stoneflies and caddisflies.

A *Good* (6-5) score for biological indicators represents good overall diveristy, with moderate to high numbers of mayflies and caddisflies, but no stoneflies present.

A *Fair* (4-3) score for biological indicators represents low to moderate numbers of more pollutant-tolerant species of caddisflies, midgeflies, snails, and aquatic worms.

A *Poor* (2-0) score for biological indicators represents poor diversity, with low populations of pollutant tolerant species, such as midgeflies, worms and snails.

3.7 Stormwater Basin Assessment

In addition to the streams and tributaries of the Quantico Creek Watershed, the assessment also included an evaluation of existing stormwater basins within the Watershed. The objective of the stormwater basin assessment is to identify basins that could be retrofitted to reduce runoff volumes, alleviate channel erosion and flooding, improve water quality, and provide aquatic and terrestrial habitat.

Basins were selected using the County's GIS database and best available aerial photographs. Preference for inclusion in the assessment was given, first, to basins that appeared to be dry or extended detention basins and, second, to those with a prevalence of adjacent impervious area and/or large contributing drainage areas. Lack of surrounding vegetation also influenced the selection of the basins included in this study, albeit to a lesser degree.

Existing basins were evaluated and scored based upon four main categories, including:

1. Basin type
2. Basin structures
3. Location and drainage area
4. Vegetation

Figure 3-9: Existing Stormwater Basin With No Permanent Pool and Lack of Internal Structure.

Like the RSAT protocol, each category in the stormwater basin assessment was assigned a range of possible scores, and each is weighted differently, with the greatest influence given to basin type and basin structures (10 points possible). Location and drainage area had the second greatest influence on the overall score (with 8 points possible), while vegetation had the least influence on overall score (with only 6 points possible). A low total score based upon this assessment indicates the greatest potential for retrofit, where a recommended retrofit would provide significant benefit to the Watershed, and/or where the potential return on investment is greatest. Conversely, a high score is indicative of poor retrofit potential, where the existing pond is already constructed to provide extended water control and/or ecological benefit, and the return on investment is low. Below is a brief description of each assessment category.

<u>Basin Type</u> – Basin type describes the overall design of the existing basin and typical storage strategy, such as dry detention, extended detention basin, retention pond or constructed wetland.

Preference for retrofit was given to dry detention basins, which tend to score very low in the Basin Type category (0-2). Basic dry basins provide no permanent pool and are typically designed for flood control, detaining stormwater for up to 12 hours, and drying out between storm events. Dry basins provide few water quality benefits and little protection for receiving streams.

Extended detention basins provided the second greatest opportunity for retrofit by basin type (with possible scores of 3-5). Extended detention is a variation of a dry basin, but typically provides upwards of 24-hour detention of runoff after a storm event, and usually contains some type of small, wet pond, although most of the basin dries out completely between storm events. Extended detention can provide sufficient storage time to allow pollutants (primarily sediment) to settle out of suspension.

Retention ponds provided only moderate opportunity (6-8) for retrofit. Retention ponds consist of a permanent pool of standing water. Runoff from each storm event enters the pond and displaces water stored in the pool from previous events. The pool also acts as a barrier to re-suspension of sediments and other pollutants removed during prior storms. Retention ponds tend to have a manicured turfgrass perimeter, providing an opportunity for vegetative enhancement.

Existing constructed wetlands provided very little opportunity for retrofit by basin type and, therefore, have very high scoring potential (9-10). Constructed wetlands are vegetated, shallow depressions that can provide excellent stormwater treatment ability. Runoff from each new storm displaces runoff from previous storms, with an extended residence time upwards of several days, allowing multiple pollutant removal processes to operate.

Figure 3-10: Existing Concrete Outlet Structure.

Basin Structures – The existing basin inlet(s), embankment, riser and outlet all present opportunities for retrofit to achieve more effective storage. Structure modifications can be a straight-forward and cost-effective approach to increase the basin's detention volume and draw down time, at great benefit to receiving streams, water quality, and the vegetative community within the pond. Restricting the orifice on an outlet structure, for example, can extend the drawdown time and increase storage volume for smaller storm events, such as the "first flush" or water quality storm.

Scoring for basin structures depended largely upon the design and function of existing inlets and outfall structures. Single stage outfall structures, designed only for large flood events, present the greatest opportunity for improvement (0-2 points). In contrast, multi-stage risers, with three or more possible inlets and outfalls, provided the lowest scoring potential (9-10). Points were also added or subtracted depending upon the outfall type, number of inlets, type and condition of energy dissipation, and the presence or absence of baffles, berms or grading that would influence the flow path and residence time of captured stormwater.

Location and Drainage Area – Location and drainage area is essential to the overall function and effectiveness of the existing basin and any proposed retrofit. Scoring depended upon the estimated storage volume, size of the basin relative to the contributing drainage area, general condition and land use of the surrounding area, and the location of the basin within its drainage area. Low storage volumes, large drainage areas, and adjacent commercial and/or industrial land uses, all score low and present good potential for retrofit (0-2 points). At the high end of the scale (6-8) are basins with sufficient storage volume, small drainage areas, and/or low impact or low density land uses, which typically provide little potential for improvement.

Vegetation – Existing vegetation within the basin can be an initial indicator of residence time and overall effectiveness of the basin. Enhancing the vegetative community within the basin provides an opportunity for the creation of wildlife habitat and water quality improvement. Re-introducing native riparian or wetland vegetation provides food and shelter for wildlife, and can enhance the removal of nutrients, metals, trash and debris from stormwater runoff. Basins with little more than manicured, turfgrass provide the greatest opportunity for retrofit (0-2). Unmowed vegetation, pioneer species, or a low-diversity mix of vegetation provide the second best opportunity for enhancement (3-4), while existing stands of mature woody vegetation or diverse plant communities are best left undisturbed (5-6).

Figure 3-11: Desirable Wetland Vegetation In An Existing Stormwater Basin.

4.0 ANALYSIS AND RESULTS

4.1 Public Participation

Two public meetings were held in the watershed on June 9, 2010. The first meeting was held in Dumfries at the Village Hall and the second meeting was held in at the Dr. A. J. Ferlazzo Building. Both meetings were well attended and there were similarities in the comments and concerns voiced by residents. Many of the comments focused on siltation and invasive aquatic plant growth that impeded or prevented the use of watercraft, in the vicinity of the confluence with Quantico Creek and the Potomac River. Problems identified through the public comment process were then observed by MACTEC scientists and County administrators, and are included in the project recommendations.

4.2 Open Channel Findings

The total RSAT score was used as an initial screening tool, to identify the overall condition of the channels that were assessed. Channel segments that were in *Excellent* or *Good* condition were noted, and *Fair* or *Poor* reaches of open channel that were in need of improvement were further scrutinized. Upon closer inspection of the data, three RSAT parameters were particularly useful in identifying problem areas: 1) Channel Stability, 2) Scour & Deposition, and 3) Physical Habitat. Low scores in each of these three parameters was generally indicative of rapidly incising and/or widening stream channels, with systemic channel bed or bank erosion, and a higher incidence of threatened property and infrastructure. Complete data sets of each RSAT data parameter by sample point location are included in Appendix C. Below is a summary of findings by drainage basin, beginning with an overview of basin characteristics, followed by a brief description of each problem area by reach.

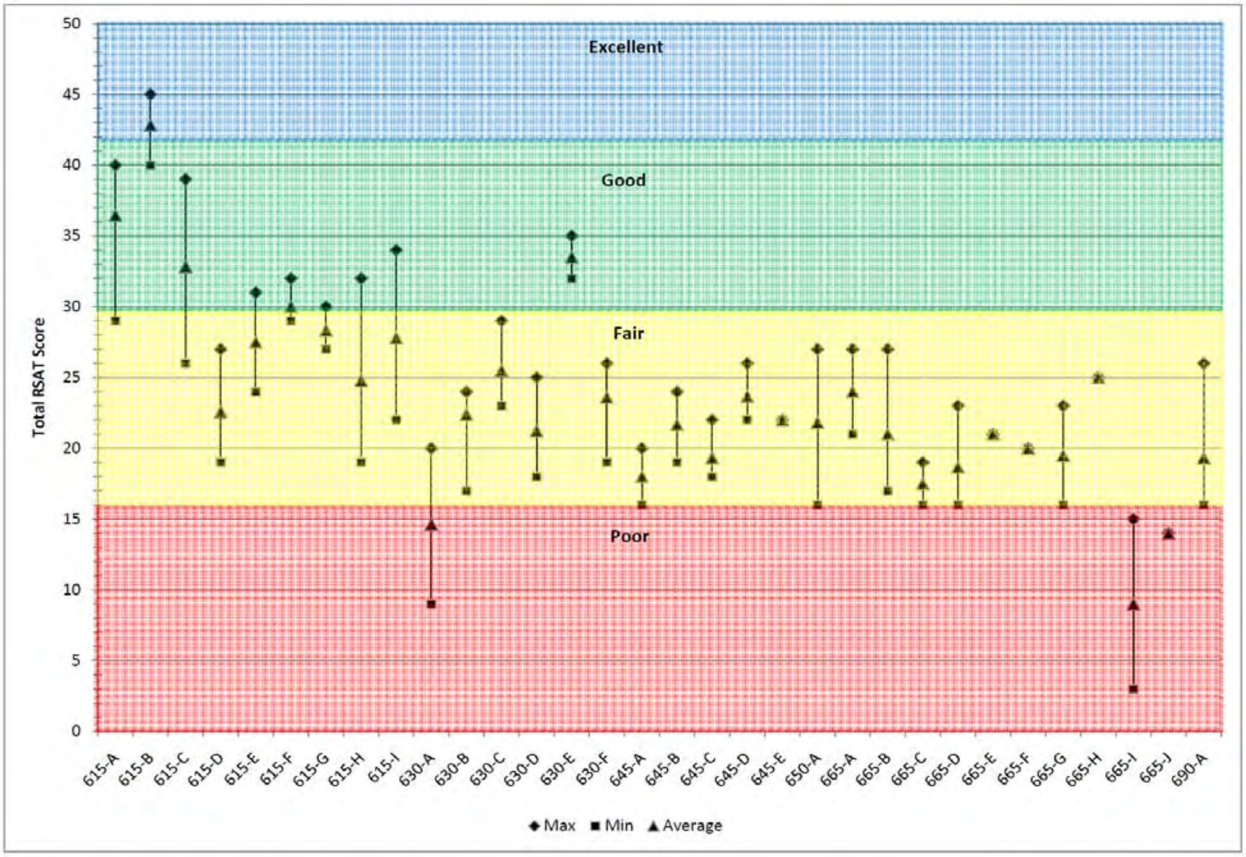

Figure 4-1: Maximum, Minimum and Average Total RSAT Scores by Reach.

Basin 615, South Fork of Quantico Creek

Basin 615 remains in a relatively undisturbed condition, with most of the basin located within the Prince William Forest Park boundaries. The uppermost portion lies within the Marine Base Quantico training grounds, and was inaccessible for this study. However, like much of the perimeter lands surrounding the Park, the upper portion of the Basin has scattered buildings and roadways. Open land is predominantly old fields or pasture, and riparian forest is common along most major tributaries to the South Fork of Quantico Creek.

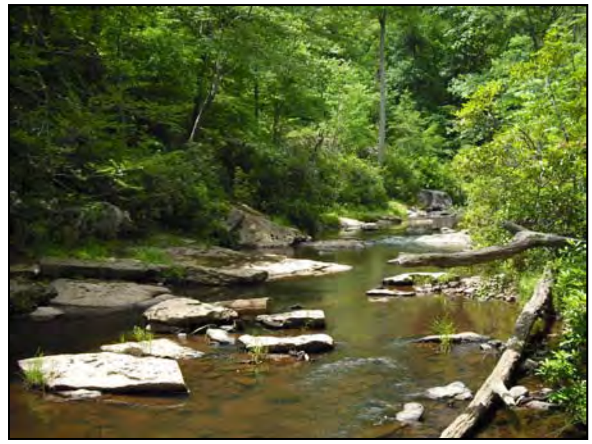

Figure 4-2: Relatively undisturbed reach of Basin 615, within Prince William Forest Park.

The main channel of the South Fork of Quantico Creek, flowing through the Park, is in nearly pristine condition, with little evidence of channel instability or bank erosion. Each of the RSAT parameters yielded scores in the *Excellent* or *Good* categories along the main stem. Reach 615-A begins at a marked transition in channel morphology, from the steeply-sloped, bedrock and boulder dominated reaches located immediately upstream, to a gentle, meandering channel composed of predominantly gravel and cobble substrate. Channel stability and scouring/deposition scores remain high ("good" category), with a slight increase in bank scouring, occurring opposite of gravel point bars. In-stream and riparian habitat are in excellent condition along this reach, corresponding with the rich diversity and large quantities of macroinvertebrates.

RSAT scores for the six tributaries in Basin 615 were considerably lower, due primarily to the lack of steady baseflow, increased embeddness of riffle material, a shallow riffle and run dominated morphology, and a lack of biological indicators. These low scores essentially indicate the headwater nature of these tributaries. Despite the slight impairment of the tributaries, no problem areas were identified for potential improvement.

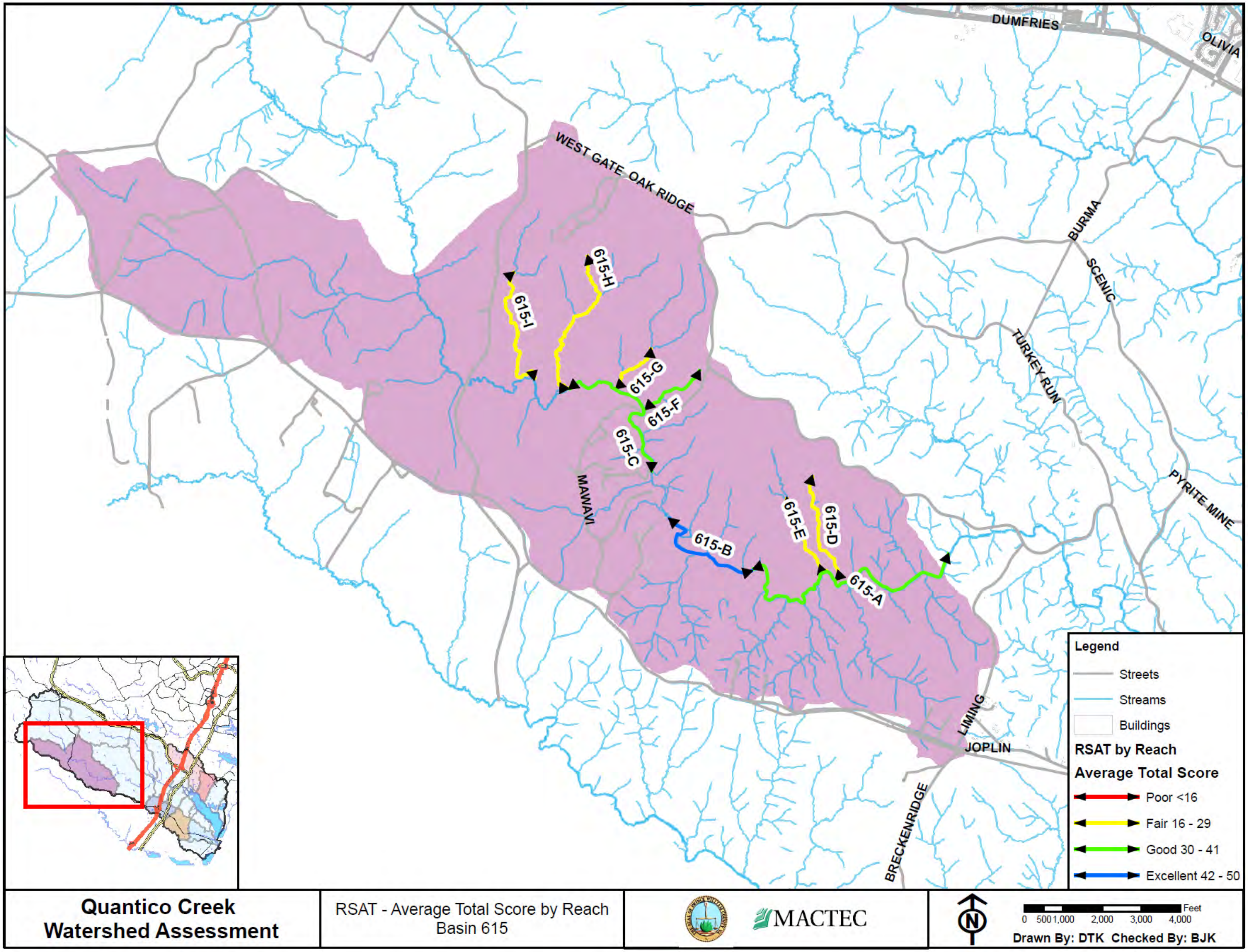

Figure 4-3: RSAT Average Total Score by Reach for Basin 615, South Fork of Quantico Creek.

Basin 630, Dewey's Creek

In contrast to Basin 615, the streams found in Basin 630 exemplify the effects of systemic channel incision and widening. Basin 630 is a developed watershed, dominated by newer subdivisions, with a significant increase in impervious surface area and loss of riparian forest cover. Reach 630-A (the main stem of Basin 630) is a poor quality stream, due mainly to widespread channel erosion, coupled with large amounts of sand and sediment deposition, and no available biological indicators. Similar conditions and channel morphology can be found along many of the tributaries, albeit to a somewhat lesser degree, with an increase in channel stability and decrease in deposition found in the upper reaches of the basin. For example, Reach 630-E is in particularly good condition, with excellent channel stability and scouring/deposition scores. Riparian habitat is also in excellent condition along this reach, illustrating the positive influence of a healthy and robust riparian forest. However, systemic erosion along Reaches 630-B and 630-D can be severe where incision has undermined sewer lines, pipe outfalls, and other infrastructure.

The following is a summary of the problem areas identified in Basin 630, by reach and location in NAD 83 Virginia State Plane coordinates:

- 630-A (11822962.95 - 6894168.06 to 11823033.98 - 6890886.59): Channel incision and widening along the lower portion of the basin, from Tulip Tree Place to Possum Point Road, has resulted in widespread, systemic bank erosion.
    - Removal of the riparian forest, encroachment on the stream corridor, and dumping of debris has left streambanks susceptible to overbank runoff, gully erosion and localized bank erosion, behind Skip's Auto Parts at the intersection of Jefferson Davis Highway and Old Stage Coach Road.
    - Sediment and debris (resulting from channel erosion upstream) has been deposited at the Possum Point Road culvert, severely restricting flow, reducing flood capacity, and posing a risk to public safety and infrastructure.

Figure 4-4: Deposition of sediment at Possum Point Road culvert, Reach 630-A.

- 630-B (11822467.88 - 6895752.49 to 11822940.41 - 6894169.88): Channel incision and widening has resulted in systemic streambank erosion, downstream from Jefferson Davis Highway to the upstream end of Reach 630-A.
    - A large woody debris jam, approximately 100 feet downstream from Jefferson Davis Highway, has resulted in localized bank erosion, which threatens to undermine an existing utility pole on the left descending (north) bank.
    - Channel incision along an unnamed tributary, south of Wayside Drive and west of Mountain Laurel Loop, has undermined an existing concrete pipe outfall and headwall along the left descending bank, creating a vertical drop of more than 8 feet.

Figure 4-5: Large woody debris jam responsible for localized bank erosion, Reach 630-B.

- 630-C (11820193.75 - 6897437.44 to 11822373.72 - 6895769.05): Localized bank erosion and subsequent deposition of coarse gravel and sediments threaten adjacent properties between Interstate I-95 and Jefferson Davis Highway.
    - Streambank erosion is particularly severe in the vicinity of the apartment/condominium complex at Briarwood and Interstate Drives.
    - Removal of riparian vegetation and loss of associated root mass has left the streambank vulnerable to continued erosion and mass wasting, along a temporary access road on the right descending bank, downstream of Interstate Drive to Dry Powder Circle.

Figure 4-6: Localized bank erosion occurring adjacent to deposition of coarse gravel, Reach 630-C.

Figure 4-7: Systemic erosion has exposed a sewer line, parallel to the stream, along Reach 630-D.

Figure 4-8: Moderate channel incision, slowed by *de facto* grade control, Reach 630-F.

- 630-D (11818042.79 - 6898816.70 to 11819766.46 - 6897648.47): Channel incision and widening has resulted in systemic streambank erosion, and exposure of a previously buried sewer line parallel to the stream, south of Four Seasons Drive to the culvert at Interstate I-95.
    - Illegal dumping of concrete rubble, tires and other debris (via an access road from Old Stage Road) has created and impoundment in the channel, interfering with the flow of water and sediment.

- 630-F (11822018.15 - 6900262.19 to 11821486.97 - 6896226.01): Moderate channel incision has been slowed by woody debris jams (that act as natural *de facto* grade control) and bank stabilization provided by a wide riparian forest buffer, from the upstream end of the reach at Telescope Lane, to the confluence with Reach 630-C near Dry Powder Circle.

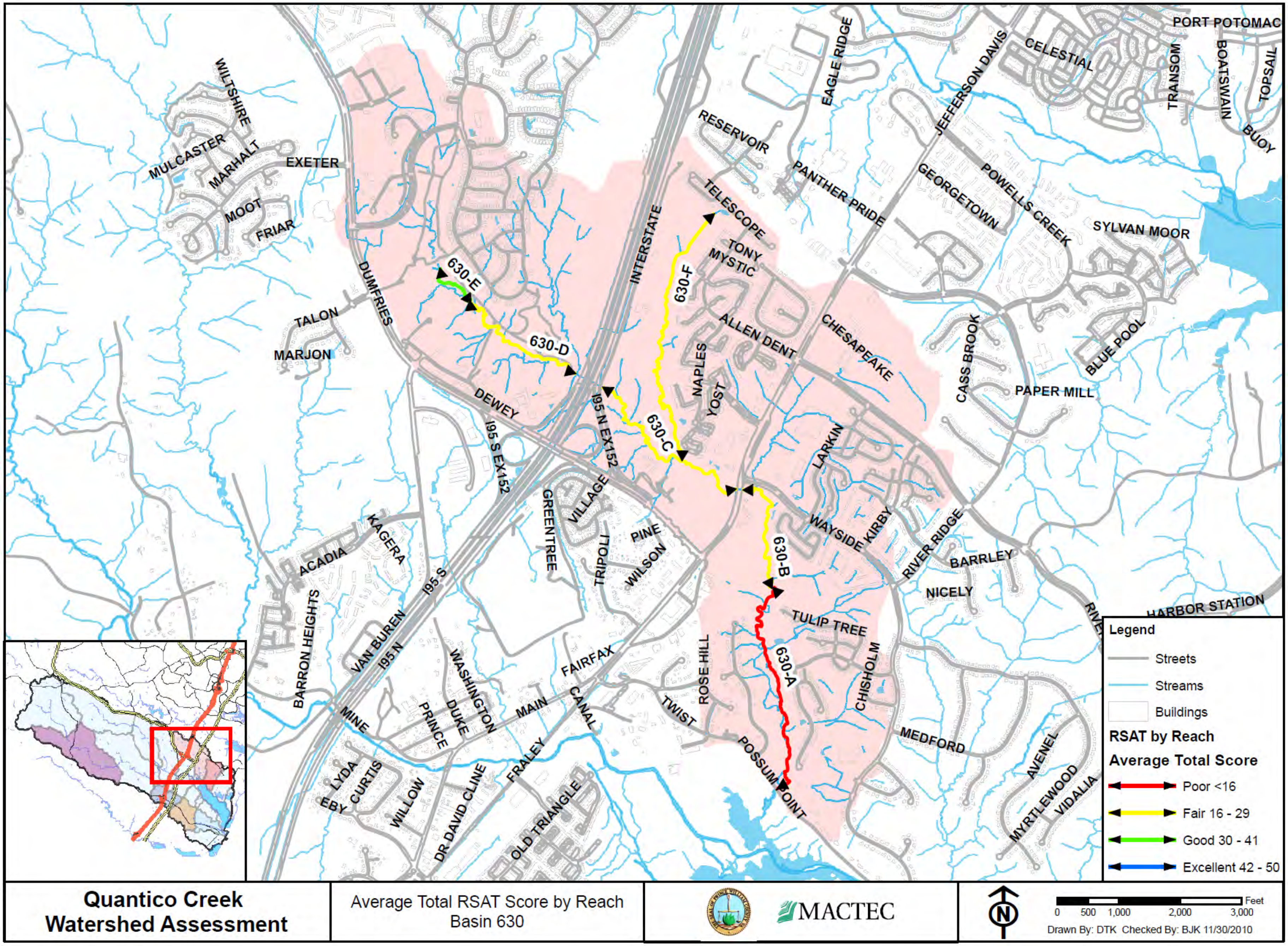

Figure 4-9: RSAT Average Total Score by Reach for Basin 630, Dewey's Creek.

Basin 645, Upper Little Creek

The streams and open channels in Basin 645 are in fair condition, as development pressures have resulted in channel encroachment and removal of riparian vegetation, followed by localized erosion in numerous locations. Bank erosion is particularly severe near Creek Road, where the riparian habitat is in poor condition, with only a narrow band of trees and very little woody vegetation to provide reinforcement of the sandy soils. Systemic bank erosion, due to channel incision, is limited mainly to Reach 645-D, between Park Entrance Road to Williams Road.

Figure 4-10: Removal of riparian forest along Creek Road, Reach 645-A.

The following is a summary of the problem areas identified in Basin 645, by reach and location in NAD 83 Virginia State Plane coordinates:

- 645-A (11814844.57 - 6885068.40 to 11815470.37 - 6884445.63): Removal of riparian forest and encroachment on the stream corridor has prompted localized bank erosion and mass wasting from Creek Road to the parking lot at First Assembly of God Church.

- 645-B (11814115.89 - 6886010.69 to 11814832.29 - 6885086.15): Removal of riparian forest and encroachment on the stream corridor continues upstream of Creek Road, to the culvert at Interstate I-95, accelerating localized streambank erosion.

Figure 4-11: Removal of riparian forest and encroachment on the stream corridor, Reach 645-B.

Figure 4-12: Removal of riparian forest and mowing to the top of bank, Reach 645-C.

Figure 4-13: Moderate channel incision near Park Entrance Road, Reach 645-D.

- 645-C (11812907.97 - 6887156.79 to 11813854.71 - 6886402.08): Removal of riparian forest, followed by mowing to the top of the streambank, has left the channel susceptible to localized bank erosion and prompted mass wasting, upstream from Interstate I-95 to Williams Road.

- 645-D (11812222.93 - 6888188.69 to 11812864.33 - 6887168.22: Moderate channel incision has been slowed by woody debris jams and bank stabilization provided by the existing riparian forest, from Park Entrance Road to Williams Road.

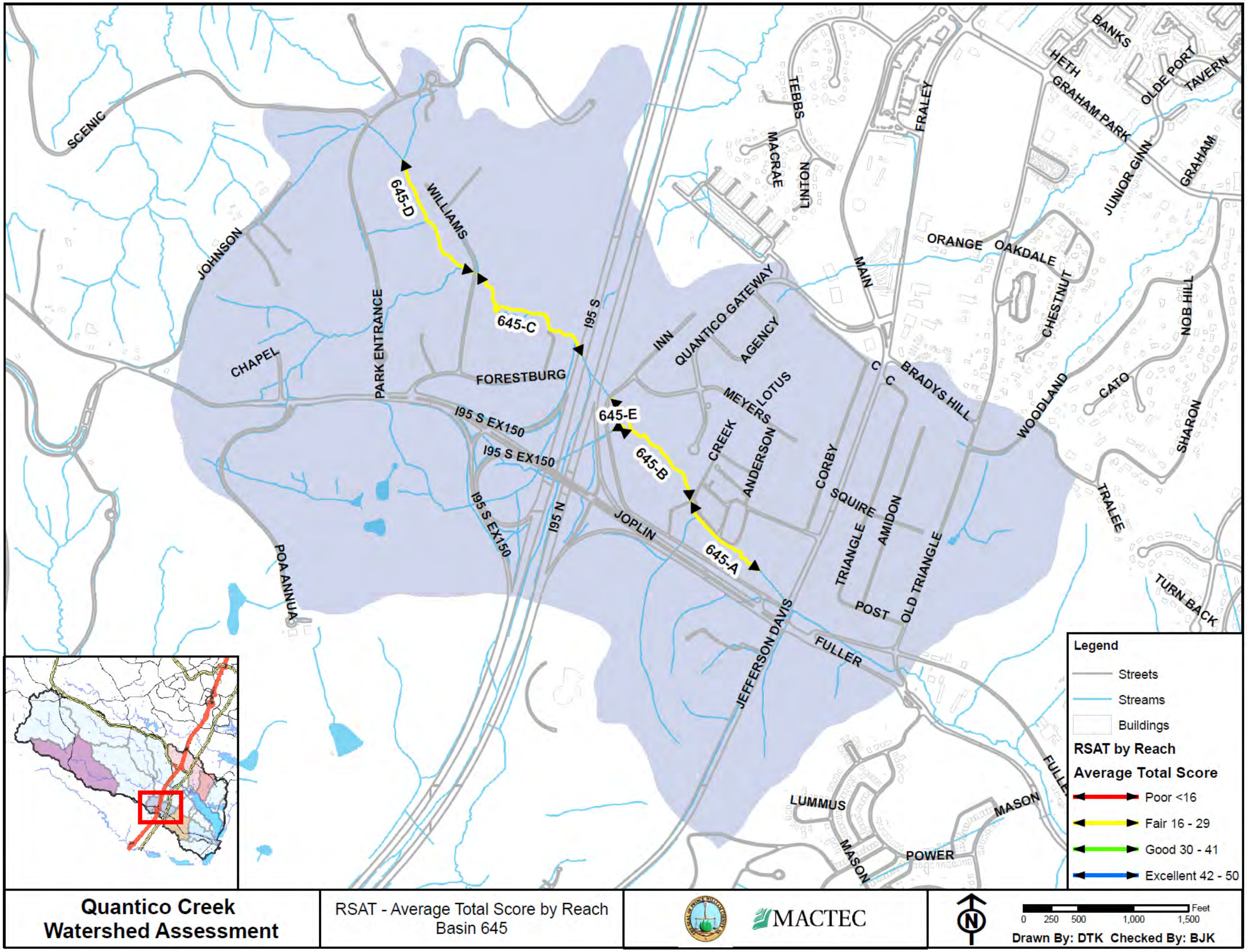

Figure 4-14: RSAT Average Total Score by Reach for Basin 645, Upper Little Creek.

Basin 650, Middle Little Creek

Basin 650 is comprised of a single reach (Reach 650-A), located almost entirely within the Marine Base Quantico, flowing between Fuller and Fuller Heights Roads, to Windsor. Reach 650-A is a fair quality stream, influenced by systemic channel widening. It is evident that the presence of streets and infrastructure in close proximity to the stream have limited its natural ability to meander through the former floodplain. Approximately 50% of the streambanks are experiencing sloughing or scour. Bank erosion is particularly severe on the outside of bends, in areas where riparian vegetation is sparse, and in the lower portion of the reach, through the Medal of Honor Golf Course, where fresh sand and gravel bars are common.

The following is a summary of the problem areas identified in Basin 650, by reach and location in NAD 83 Virginia State Plane coordinates:

- 650-A (11817805.92 - 6882818.38 to 11823028.71 - 6878665.37): Channel incision and widening has resulted in widespread, systemic streambank erosion and loss of property from Old Triangle Road to Windsor Road.
    - Removal of riparian forest, encroachment on the stream corridor, and dumping of rubble and debris have exacerbated erosion problems locally.
    - Fence lines and residential outbuildings have been undermined by ongoing bank erosion. Failure appears imminent behind properties along Fuller Heights Road, between Kerill and Lionsfield Roads, and again near Belleau Wood Drive.

Figure 4-15: Channel widening and streambank erosion near Fuller Road, Reach 650-A.

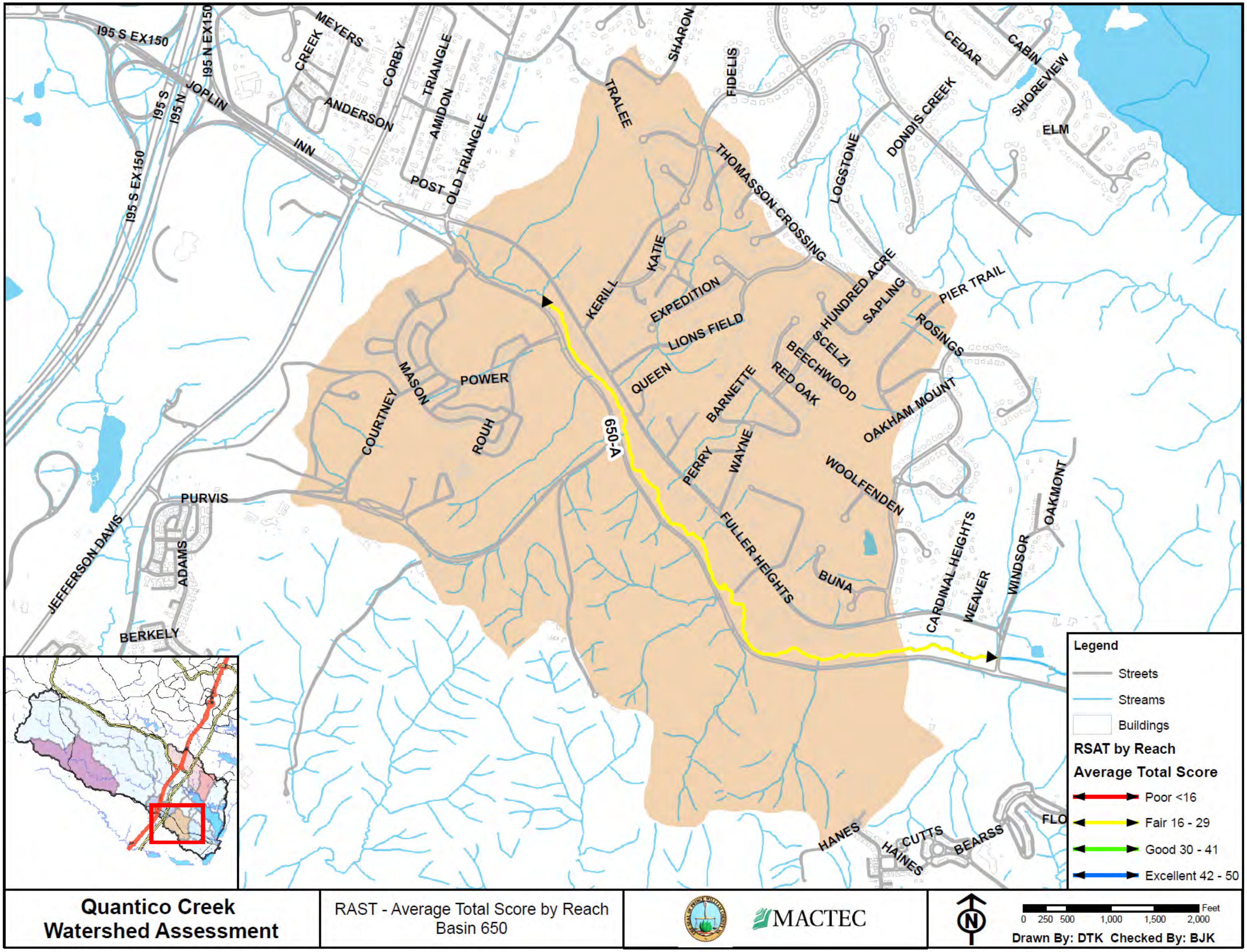

Figure 4-16: RSAT Average Total Score by Reach for Basin 650, Middle Little Creek.

Basin 665, Swans Creek

The main channel and tributaries in Basin 665 are, in some ways, typical of streams that are significantly influenced by urban stormwater runoff. The basin has been developed for residential land use. Channels in the upper portion of the basin continue to adjust to an increased volume and rate of runoff from impervious surfaces by eroding the bed and banks, while the sand and sediment liberated from the erosive process is deposited downstream, compromising instream habitat and biotic integrity. Riparian habitat remains in good or excellent condition throughout much of the basin, but habitat and biotic indicators are impaired, due to the uncontrolled erosion. Basin 665 has two of the lowest scoring reaches, Reach 665-I and Reach 665-J, due to the severe channel incision occurring unchecked, in the vicinity of River Heritage Boulevard and Barrley Drive. Farther downstream, deposition and channel widening has resulted in localized erosion problems and compromised infrastructure.

Figure 4-17: Channel incision and erosion near Crystal Downs Terrace, Reach 665-A.

Figure 4-18: Sedimentation of inline basin, east of Oyster Bay Court, Reach 665-B.

The following is a summary of the problem areas identified in Basin 665, by reach and location in NAD 83 Virginia State Plane coordinates:

- 665-A (11825862.93 - 6889065.09 to 11825727.90 - 6887811.99): Moderate channel incision has resulted in streambank erosion, between Swans Creek Lane and Crystal Downs Terrace. The extent and severity of erosion has been limited, due to influence of a wide riparian buffer.

- 665-B (11826427.47 - 6890793.80 to 11825862.93 - 6889065.09): Deposition and widening has prompted localized erosion between Desert Palm and Oyster Bay Courts.
    - Sedimentation of an inline basin, east of Oyster Bay Court, has clogged the outlet structure, resulting in a loss of sediment transport competency and capacity to downstream reaches.

- 665-C (11827538.98 - 6892250.56 to 11826427.47 - 6890793.80): Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest, between Medford Drive and Avenel Lane.

- 665-D (11825615.90 - 6891301.60 to 11825917.76 - 6889886.35): Channel incision and widening, has resulted in systemic streambank erosion, from Medford Drive to the confluence with Reach 665-B.
    - Removal of riparian forest and encroachment on the stream corridor, underneath the power lines, has exacerbated the erosion problems.
    - Channel incision has exposed a previously buried sewer line, approximately 500ft downstream from Medford Drive.

- 665-E (11825439.59 - 6892965.69 to 11825686.75 to 6891959.49): Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest, from Myrtlewood to Medford Drive.

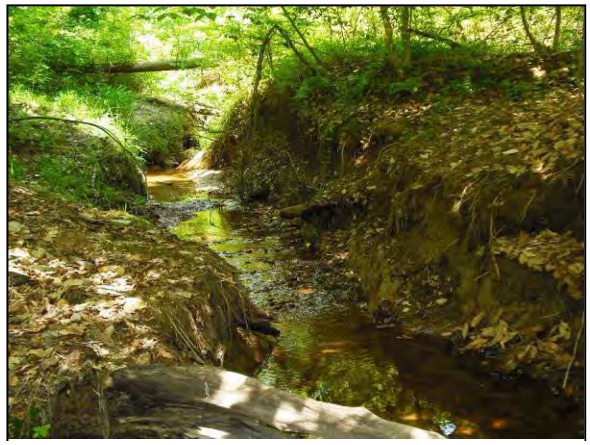

Figure 4-19: Channel incision and woody debris, near Myrtlewood Drive, Reach 665-C.

Figure 4-20: Removal of riparian forest underneath the power lines, along Reach 665-D.

Figure 4-21: Moderate channel incision, slowed by de facto grade control, Reach 665-E.

Figure 4-22: Channel incision and erosion downstream from Medford Drive, Reach 665-F.

Figure 4-23: Deposition and channel widening, from Myrtlewood to Medford Drive, Reach 665-G.

Figure 4-24: Deposition and channel widening, upstream from Myrtlewood Drive, Reach 665-H.

- 665-F (11826084.60 - 6891268.25 to 11825727.04 - 6890817.62): Channel incision has resulted in systemic streambank erosion, downstream from Medford Drive to the confluence with Reach 665-D.

- 665-G (11826556.02 - 6892575.31 to 11826178.21 - 6891604.06): Channel widening and subsequent deposition of silt and sediment has resulted in localized bank erosion and mass wasting, between Myrtlewood to Medford Drives.

  - 665-H (11827021.48 - 6893573.08 to 11826851.80 - 6892960.46): Channel widening and deposition of sediment, upstream of Myrtlewood Drive, has resulted in localized bank erosion.

- 665-I (11826523.69 - 6894458.21 to 11827021.47 - 6893573.15): Severe channel incision has resulted in systemic erosion, mass wasting, and imminent loss of property along the *Swan's Creek Reach*, downstream of Barrley Drive to the confluence with Reach 665-H. Near-vertical, eroded banks stand approximately 12ft high, posing a significant risk to public safety.

- 665-J (11828099.19 - 6893091.61 to 11826919.44 - 6893003.02): Severe channel incision, from River Heritage Boulevard to the confluence with Reach 665-H, has resulted in systemic erosion and loss of property.

Figure 4-25: Severe channel incision and imminent loss of property, Reach 665-I.

Figure 4-26: Severe channel incision and erosion, downstream of River Heritage Boulevard, Reach 665-J.

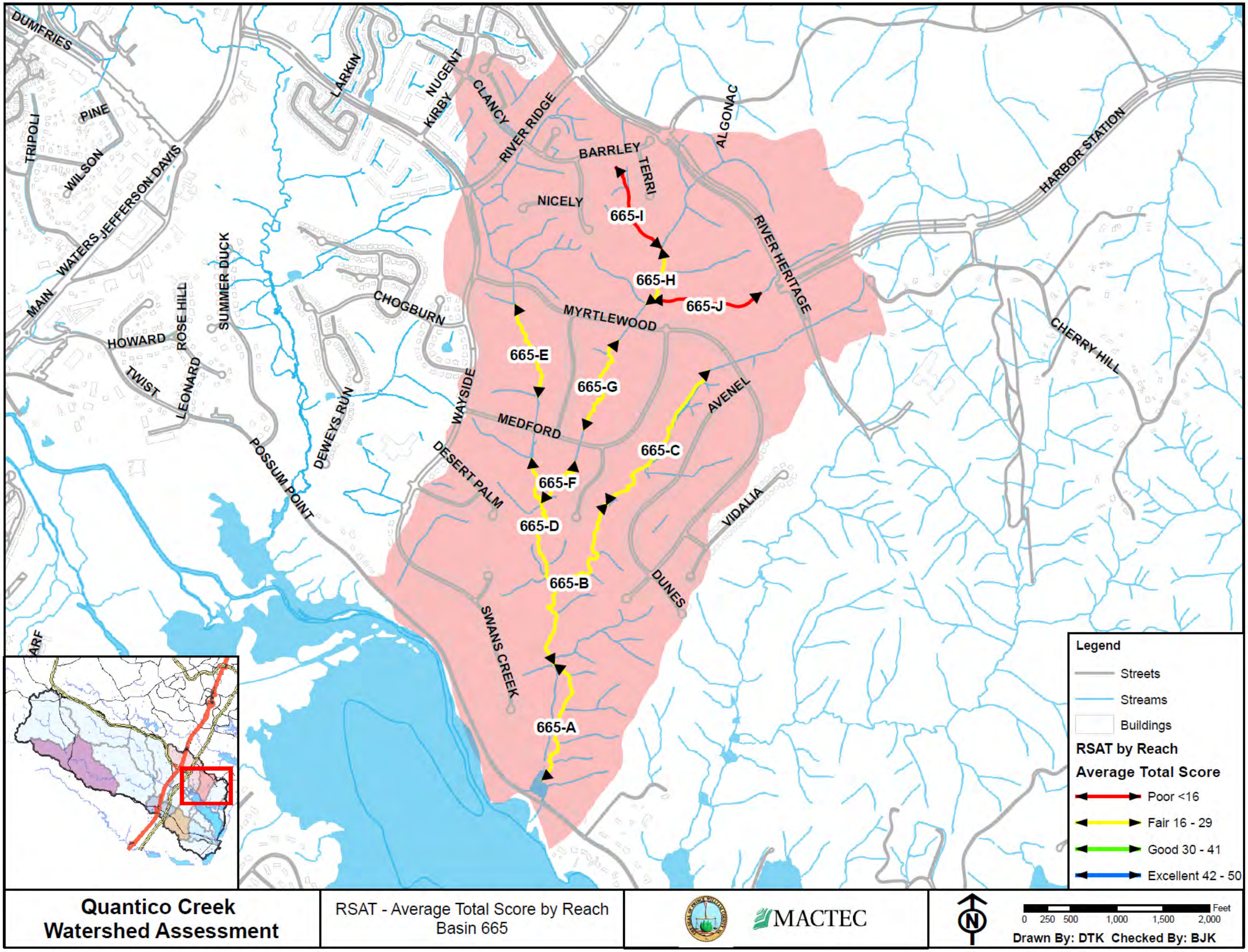

Figure 4-27: RSAT Average Total Score by Reach for Basin 665, Swans Creek.

Basin 690, Lower Little Creek

Basin 690 is comprised of a single reach (Reach 690-A), located entirely within the Marine Base Quantico, flowing east from Windsor to Geiger through the Medal of Honor Golf Course. Reach 690-A is a fair quality stream, influenced by systemic channel widening. The stream appears to have been channelized in some locations, and riparian buffers are largely absent where the manicured golf course greens encroach on the stream corridor. Approximately 50% of the streambanks are experiencing sloughing or scour. Bank erosion is particularly severe on the outside of bends, in areas where riparian vegetation is sparse, and where fresh sand and gravel bars are common. Riparian habitat is in fair condition, with only a narrow band of trees and woody vegetation through the golf course, and only 50% canopy coverage.

The following is a summary of the problem areas identified in Basin 690, by reach and location in NAD 83 Virginia State Plane coordinates:

- 690-A (11823030.51 - 6878665.26 to 11827315.24 - 6877563.49): Active channel widening, coupled with the loss of a riparian buffer zone and continued removal of woody vegetation (associated with golf course maintenance), has resulted in systemic streambank erosion from Windsor Road to Geiger Road.
    - A low head dam on the Medal of Honor Golf Course, near the intersection of Fuller Heights and Windsor Road, has impaired sediment transport, thereby exacerbating deposition and channel widening upstream of the dam.

Figure 4-28: Channel widening near the Medal of Honor Golf Course, Reach 690-A.

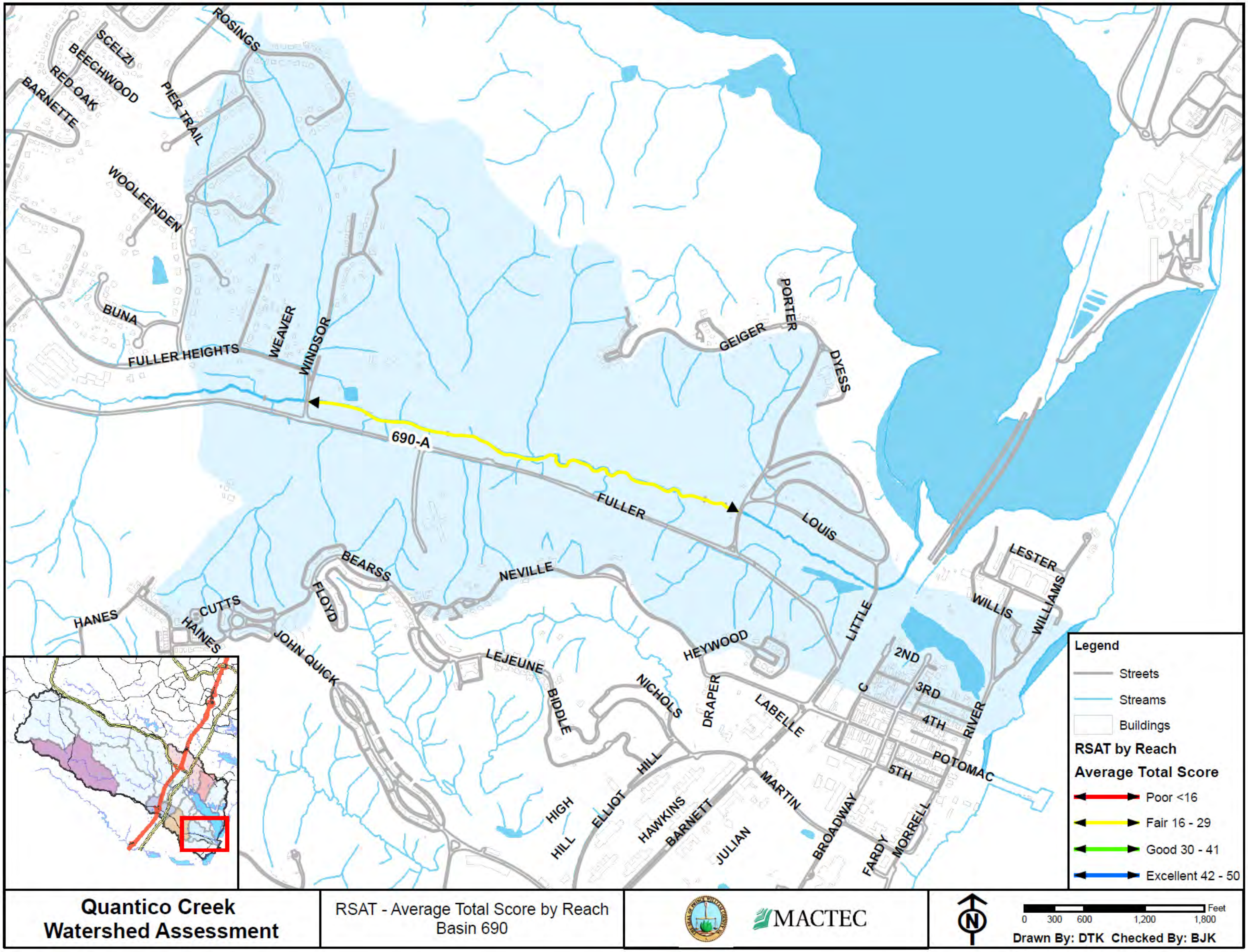

Figure 4-29: RSAT Average Total Score by Reach for Basin 690, Lower Little Creek.

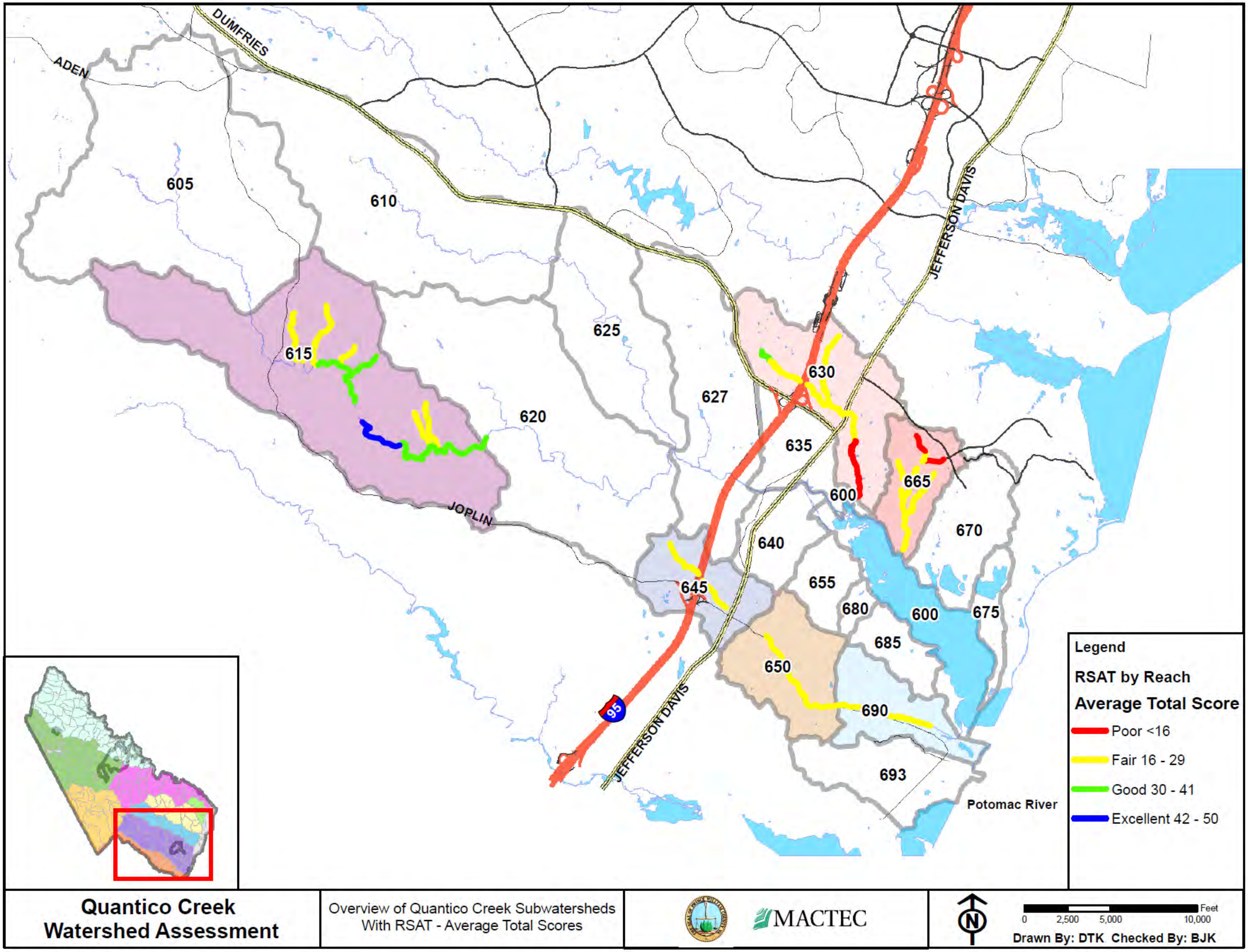

Figure 4-30: Overview of Quantico Creek Subwatersheds with RSAT Average Total Scores.

Table 4-1**:** Summary of Open Channel Problem Locations, Length and Description by Reach (part 1).

Reach	Location	Length (feet)	Problem Description
630-A	Tulip Tree Place to Possum Point Road	4360	Channel incision and widening along the lower portion of the basin has resulted in widespread, systemic bank erosion.
630-A	Possum Point Road	250	Sediment and debris (resulting from channel erosion upstream) has been deposited at the Possum Point Road culvert, severely restricting flow, reducing flood capacity, and posing a risk to public safety and infrastructure.
630-A	Skip's Auto Parts at the intersection of Jefferson Davis Highway and Old Stage Coach Road	250	Removal of the riparian forest, encroachment on the stream corridor, and dumping of debris has left streambanks susceptible to overbank runoff, gully erosion and localized bank erosion.
630-B	Jefferson Davis Highway to Reach 630-A	2310	Channel incision and widening has resulted in systemic streambank erosion.
630-B	Downstream from Jefferson Davis Highway,	100	A large woody debris jam has resulted in localized bank erosion, which threatens to undermine an existing utility pole on the left (north) bank.
630-B	South of Wayside Drive, west of Mountain Laurel Loop	200	Channel incision along an unnamed tributary has undermined an existing concrete pipe outfall and headwall along the left bank, creating a vertical drop of more than 8 feet.
630-C	Interstate I-95 and Jefferson Davis Highway	3790	Localized bank erosion and subsequent deposition of coarse gravel and sediments threaten adjacent properties.
630-C	Downstream of Interstate Drive to Dry Powder Circle.	1000	Removal of riparian vegetation and loss of associated root mass has left the streambank vulnerable to continued erosion and mass wasting, along a temporary access road.
630-D	North of Old Stage Road and west of Highway I-95	200	Illegal dumping of concrete rubble, tires and other debris (via an access road from Old Stage Road) has created and impoundment in the channel, interfering with the flow of water and sediment.
630-D	South of Four Seasons Drive to the culvert at Interstate I-95	2830	Channel incision and widening has resulted in systemic streambank erosion, and exposure of a previously buried sewer line parallel to the stream.
630-F	Telescope Lane to the confluence with Reach 630-C near Dry Powder Circle	5310	Moderate channel incision has been slowed by woody debris jams (that act as natural de facto grade control) and bank stabilization provided by a wide riparian forest buffer.
645-A	Creek Road to parking lot at First Assembly of God Church	950	Removal of riparian forest and encroachment on the stream corridor has prompted localized bank erosion and mass wasting.
645-B	I-95 to Creek Road	1270	Removal of riparian forest and encroachment on the stream corridor has prompted localized bank erosion and mass wasting.
645-C	Williams Road to I-95	1510	Removal of riparian forest, followed by mowing to the top of the streambank, has left the channel susceptible to localized bank erosion and prompted mass wasting.
645-D	Park Entrance Road to Williams Road	1280	Moderate channel incision has been slowed by woody debris jams and bank stabilization provided by the existing riparian forest.

Table 4-2: Summary of Open Channel Problem Locations, Length and Description by Reach (part 2).

Reach	Location	Length (feet)	Problem Description
650-A	Old Triangle Road to Windsor Road	8310	Channel incision and widening has resulted in widespread, systemic streambank erosion and loss of property .
665-A	Between Swans Creek Lane and Crystal Downs Terrace	1530	Moderate channel incision has resulted in streambank erosion. The extent and severity of erosion has been limited, due to influence of a wide riparian buffer
665-B	Between Desert Palm and Oyster Bay Courts	2430	Deposition and widening, resulting in localized bank erosion.
665-B	East of Oyster Bay Court	200	Deposition and widening has prompted localized erosion. Sedimentation of an inline basin, east of Oyster Bay Court, has clogged the outlet structure, resulting in a loss of sediment transport competency and capacity to downstream reaches.
665-C	Between Medford Drive and Avenel Lane	2080	Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest.
665-D	Medford Drive to the confluence with Reach 665-B	1740	Channel incision and widening, has resulted in systemic streambank erosion. Removal of riparian forest and encroachment on the stream corridor, underneath the power lines, has exacerbated the erosion problems.
665-E	Myrtlewood Drive to Medford Drive	1200	Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest.
665-F	Medford Drive to the confluence with Reach 665-D	800	Channel incision has resulted in systemic streambank erosion.
665-G	Myrtlewood Drive to Medford Drive	1230	Channel widening and subsequent deposition of silt and sediment has resulted in localized bank erosion and mass wasting.
665-H	Upstream from Myrtlewood Drive	700	Channel widening and deposition of sediment has resulted in localized bank erosion.
665-I	Downstream of Barrley Drive to the confluence with Reach 665-H	1100	Severe channel incision has resulted in systemic erosion, mass wasting, and imminent loss of property along the Swan's Creek Reach,. Near-vertical, eroded banks stand approximately 12ft high, posing a significant risk to public safety.
665-J	River Heritage Boulevard to the confluence with Reach 665-H	1250	Severe channel incision has resulted in systemic erosion and loss of property
690-A	Medal of Honor Golf Course, near intersection of Fuller Heights and Windsor Roads	100	A low head dam on the Medal of Honor Golf Course has impaired sediment transport, thereby exacerbating deposition and channel widening upstream of the dam.
690-A	Windsor Road to Geiger Road	4750	Active channel widening, coupled with the loss of a riparian buffer zone and continued removal of woody vegetation (associated with golf course maintenance), has resulted in systemic streambank erosion .

4.3 Existing Basin Findings

A key component of watershed management is the collection, storage, and treatment of stormwater before it is released and enters a receiving stream. Historically, little or no stormwater retention was required and, as a result, stormwater flow was conveyed quickly to receiving streams, resulting in rapid erosion, impaired water quality and frequent flooding. The towns of Dumfries and Quantico are examples of communities that were developed prior to an appreciation for the multiple benefits of retention and extended detention. In response to downstream flooding, zoning and building codes were adapted to capture runoff from subdivisions and developments, in order to maintain a pre-development discharge rate for specific storm events. These ponds are often rudimentary in design, and may only hold water for fixed periods, but provide little in the way of water quality improvement.

Stormwater regulations have changed significantly over the years and current Prince William County regulations require control of the 2 and 10-year storm events, such that there is no increase in peak flows after development. Additionally, stormwater management ponds are to be designed so that they reduce the post-development flows from the 10-year storm event for the entire receiving watershed by twenty percent. The current design guides also recommend a drawdown time of 30 to 48 hours for ponds, allowing for sediment and pollutants to settle out of suspension.

In addition, many communities have found that it can be cost-effective to retrofit existing stormwater basins to achieve the goals of a Watershed Action Plan. The goals of improving existing stormwater basins are many, including, but not limited to:

- increase the stormwater retention volume and detention time,
- decrease the discharge rate to reduce flooding and protect streams from erosive flows,
- capture the "first flush" of pollutant-laden runoff to filter and attenuate pollutants,
- increase groundwater infiltration and recharge,
- provide wildlife habitat and recreation amenities,
- increase site aesthetics and property values, and
- improve the quality of life for the residents of Prince William County.

It has been found that the reduction of peak flow and the increase of base flow can dramatically improve the health of adjacent streams. In some cases, reducing the discharge rates from stormwater basins can accelerate the "healing" of receiving streams, through the gradual processes of erosion, aggradation, and re-vegetation; a very cost-effective solution to existing erosion and sedimentation problems. Residences downstream often benefit, infrastructure typically requires less maintenance, estuaries do not silt in as rapidly, and water quality in the Potomac River and Chesapeake Bay is improved.

An evaluation of 24 existing stormwater basins within the Quantico Creek Watershed was conducted to identify stormwater management structures that could be retrofitted to improve stormwater capture and storage, alleviate channel erosion and flooding, improve water quality, and provide aquatic and terrestrial habitat. Stormwater basins with existing operational or maintenance problems and potential for retrofit were scored according to the method described in Section 3.7. The location of each stormwater basin is shown in Figure 4-15.

In general, many of the problems associated with the existing stormwater basins were due to a lack of internal structure, which is typically provided by engineered forebays, contouring, berms or varied microtopography on the pond bottom, that would otherwise provide an extended flow path from inlet to outlet, increasing residency time and pollutant attenuation. Other stormwater basins appeared to be too small to effectively manage the runoff volume from large drainage areas or significant impervious surfaces. In addition, many of the basins lack native wetland or riparian vegetation that plays a critical role in providing hydraulic roughness, stormwater filtration and pollutant attenuation, as well as providing wildlife habitat and enhanced site aesthetics.

Below is a summary of findings, with a brief description of existing problems identified at each stormwater basin, by FAC # and location in NAD 83 Virginia State Plane coordinates:

- FAC-473 (11,781,884.75 - 6,916,099.84): The existing wet pond captures runoff from a residential area, located near Keanon Ridge Court. The pond has excessive algae growth, indicative of possible nutrient and eutrophication problems. In addition, the pond appears to have insufficient storage volume to effectively manage stormwater runoff (given the permanent pool elevation, at the time of the assessment). Vegetation surrounding the pond consists mainly of manicured turfgrass, mowed to the edge of the bank, providing little or no filtration of stormwater runoff. The pond lacks a forebay, which would allow sediment (and adsorbed nutrients) to settle out of suspension, and has no visible multi-stage outlet for water level control.

Figure 4-31: Excessive algae growth, indicative of nutrient loading and eutrophication at FAC-473.

- FAC-5473 (11,785,626.94 - 6915704.77): The existing wet pond, located behind the Reconciliation Community Church (near the intersection of Bristow and Joplin Roads), has a single-stage, concrete weir overflow structure that appears to be ineffective at controlling varied flow events, including smaller, more frequent *water quality* and *channel protection* storm events. In addition, the pond appears to have nutrient and eutrophication problems, as evidenced by excessive algae growth. The pond lacks a forebay that could help alleviate sediment and nutrient loading issues.

Figure 4-32: A single-stage, concrete weir overflow structure at FAC-5473.

- FAC-558 (11,799,086.01 - 6,912,385.58): Located in the Ashland Subdivision, adjacent to Ashland Elementary School, the shallow stormwater swale, appears to provide adequate stormwater conveyance to an enclosed system (via grated inlet structures). Overland flow makes its way into an extended detention basin to the north of the school, parallel to Tinkling Springs Court. The basin is well vegetated and appears to provide adequate storage. However, the stormwater swales provide limited storage, infiltration, and treatment capacity.

Figure 4-33: A grated inlet structure at the downstream end of the shallow swale,

- FAC Unknown (11,807,827.86 - 6,906,664.61): The small, dry basin is located adjacent to Dumfries Road, near Forest Park High School (on Forest Park Drive). The basin lacks internal structure, berms or microtopography, and vegetation that would otherwise extend the flow path to the outlet structure, increase residency time of stormwater, and facilitate attenuation of pollutants from the adjacent roadway, prior to emptying into a tributary to Quantico Creek.

Figure 4-34: Dry basin lacking internal structure, microtopography and vegetation.

- FAC-5379 (11,813,906.27 - 6,904,455.33): The dry basin is located adjacent to Dumfries Road, near the intersection with Hide Away Drive. The basin lacks internal structure or microtopography, and vegetation that would otherwise extend the flow path, increase residency time, and facilitate attenuation of pollutants.

- FAC-5463 (11,821,375.13 - 6,895,208.36): The newly constructed wet pond is located northeast of the commuter parking lot, at the intersection of Dumfries Road and Jefferson Davis Highway. The pond appears to be designed to function as a wet pond, but lacks a permanent pool. In addition, the pond would benefit from a forebay, microtopography, and native vegetation. While the pond appears to have sufficient storage capacity, the inflow and outfall are no more than 50ft apart, given the lack of internal structure.

- FAC-5515 (11,817,985.29 - 6,897,922.17): The extended detention basin is located behind the Comfort Inn Hotel, off of Old Stage Road. The basin is well-vegetated, and appears to have sufficient storage to handle runoff from the adjacent parking, but lacks internal structure or microtopography that could extend the flow path and residency time of captured stormwater.

Figure 4-35: Dry basin lacking internal structure, microtopography and vegetation, FAC-5379

Figure 4-36: Newly constructed pond, with no permanent pool, and short flow path, FAC-5463

Figure 4-37: Vegetated basin, lacking internal structure and microtopography, FAC-5515.

Figure 4-38: Vegetated swale/dry basin experiencing rill and gully erosion, FAC-5122.

Figure 4-39: Wet pond in lacking forebay, microtopography, and vegetation, FAC-669.

Figure 4-40: Well-vegetated extended detention basin, with short flow path, FAC-5397.

- FAC-5122 (11,816,188.59 - 6,887,584.27): The vegetated swale/dry basin is located adjacent to the United Mine Workers of America office building at Main Street and Quantico Gateway Drive. The basin appears to provide adequate storage and infiltration. However, a lack of vegetation along the eastern slope (along Main Street) has contributed to significant rill and gully erosion around the perimeter of the structure.

- FAC-669 (11,818,957.76 - 6,886,549.65): The existing wet pond appears to have sufficient storage capacity, given the drainage area and surrounding residential land use of the Lionsfield Valley Subdivision. However, like many of the previously described bains, the pond would benefit greatly from a forebay at the two main inlet pipes, and additional berms or microtopography, and native vegetation between the inflow and outflow structures.

- FAC-5397 (11,815,616.93 - 6,885,998.48): Located adjacent to the East Gate Terrace Apartments, near the intersection of Locust Court and Meyers Road, the extended detention basin appears to have sufficient storage and is well-vegetated, but lacks internal structure or berms, resulting in a very short flow path between the basin inflow and outflow structures.

- FAC-5000 (11,819,312.05 - 6,881,979.55): The newly constructed wet pond is located southwest of Triangle Elementary School, off of Lionsfield Road. While the pond was still under construction or repair at the time of the assessment, it would benefit from the addition of a forebay, as well as native wetland or riparian vegetation, once the surrounding grounds have been stabilized and restored.

Figure 4-41: Newly constructed pond, lacking forebay and vegetation, FAC-5000.

- FAC-533 (11,824,556.22 - 6,890,630.52): The existing wet pond is located off of Deweys Run Lane, in the Hampstead Landing Subdivision. The pond appears to be functioning as designed, with sufficient storage, and an adjacent forested slope providing beneficial canopy cover and shading of the pond. However, like most of the wet ponds included in this study, FAC-533 lacks a forebay to capture sediment and debris flowing into the pond, which would reduce blockage of the existing weir and increase the ease of maintenance.

Figure 4-42: Wet pond lacking forebay, with adjacent forest cover, FAC-533.

- FAC-5462 (11,830,690.33 - 6,911,341.69): Located near the intersection of Jefferson Davis Highway and Rippon Landing Road, stormwater runoff is conveyed to the existing pond via overland flow and steep-gradient swales, which provide limited intermediate storage or retention. While the pond is well-vegetated, it lacks internal structure, typically provided by berms or varied microtopography.

Figure 4-43: Steep gradient, riprap swales leading to the existing wet pond, FAC-5462.

Figure 4-44: Extended detention basin with dense vegetative growth, FAC-505.

- FAC-505 (11,823,442.12 - 6,891,980.19): The extended detention basin is located in the Wayside Village Subdivision, east of Wayside Drive and south of Azalea Sands Lane. The basin is densely vegetated; so much so, that inflow and outflow structures are barely visible. While the existing vegetation may provide sufficient roughness, sediment capture, and pollutant attenuation capability, the basin could benefit from additional internal structure, berms or microtopography.

Figure 4-45: Existing wet pond, lacking forebay and native vegetation, FAC-Unknown.

- FAC Unknown (11,826,322.66 - 6,889,258.44): The existing wet pond is located in a newly constructed subdivision, at the intersection of Myrtlewood Drive and Crystal Downs Terrace. The pond lacks a forebay and native wetland or riparian vegetation that could alleviate the siltation problem, already observed at the inflow to the pond.

Figure 4-46: Pond with adequate storage capacity, lacking native vegetation, FAC-9025.

- FAC-9025 (11,822,984.77 - 6,886,161.29): The existing wet pond is located north of Kerill Road, in the Graham Park Shores Subdivision. The pond is the largest of the basins included in the assessment, and appears to have adequate storage for runoff from the surrounding residential area. The pond is well-designed, with high aesthetic value, but could benefit from native wetland vegetation around the perimeter of the pond to increase pollutant attenuation capability and provide habitat.

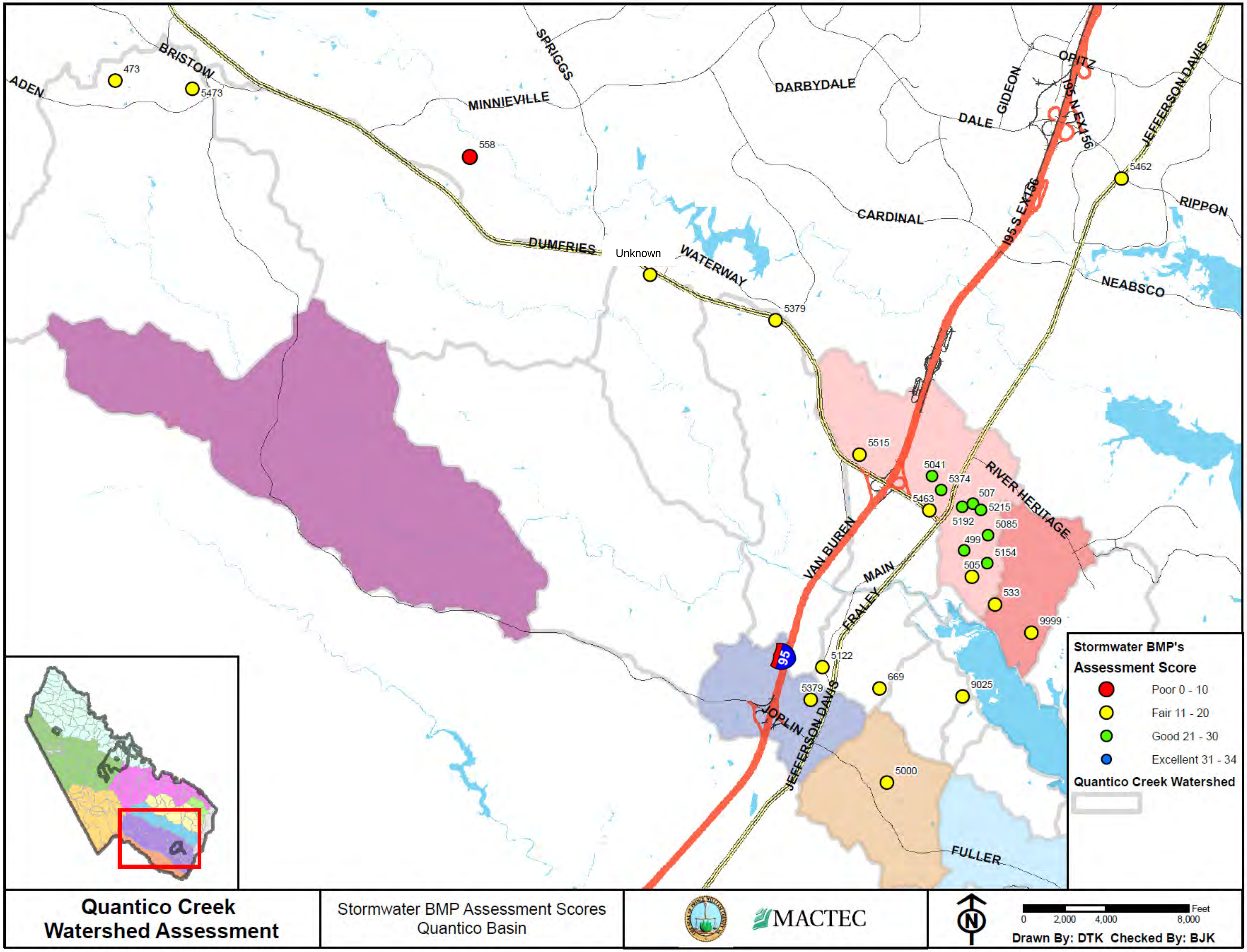

Figure 4-47: Stormwater BMP Assessment Scores.

Table 4-3: Summary of Existing Stormwater Basin Problem Locations, Length and Description by Drainage Basin (part 1).

Basin	Location (FAC #)	Problem Description
605	473	The pond has excessive algae growth, indicative of possible nutrient and eutrophication problems. In addition, the pond appears to have insufficient storage volume to effectively manage stormwater runoff (given the permanent pool elevation, at the time of the assessment). Vegetation surrounding the pond consists mainly of manicured turfgrass, mowed to the edge of the bank, providing little or no filtration of stormwater runoff. The pond lacks a forebay, which would allow sediment (and adsorbed nutrients) to settle out of suspension, and has no visible multi-stage outlet for water level control.
605	5473	The existing wet pond has a single-stage, concrete weir overflow structure that appears to be ineffective at controlling varied flow events, including smaller, more frequent water quality and channel protection storm events. In addition, the pond appears to have nutrient and eutrophication problems, as evidenced by excessive algae growth. The pond lacks a forebay that could help alleviate sediment and nutrient loading issues.
610	558	The shallow stormwater swale, appears to provide adequate stormwater conveyance to an enclosed system (via grated inlet structures). However, the stormwater swales provide limited storage, infiltration, and treatment capacity.
625	Unknown	The basin lacks internal structure, berms or microtopography, and vegetation that would otherwise extend the flow path to the outlet structure, increase residency time of stormwater, and facilitate attenuation of pollutants from the adjacent roadway, prior to emptying into a tributary to Quantico Creek.
627	5379	The basin lacks internal structure or microtopography, and vegetation that would otherwise extend the flow path, increase residency time, and facilitate attenuation of pollutants.
630	5463	The pond appears to be designed to function as a wet pond, but lacks a permanent pool. In addition, the pond would benefit from a forebay, microtopography, and native vegetation. While the pond appears to have sufficient storage capacity, the inflow and outfall are no more than 50ft apart, given the lack of internal structure.
630	5515	The basin is well-vegetated, and appears to have sufficient storage to handle runoff from the adjacent parking, but lacks internal structure or microtopography that could extend the flow path and residency time of captured stormwater.
630	505	The basin is densely vegetated; so much so, that inflow and outflow structures are barely visible. While the existing vegetation may provide sufficient roughness, sediment capture, and pollutant attenuation capability, the basin could benefit from additional internal structure, berms or microtopography.

Table 4-4: Summary of Existing Stormwater Basin Problem Locations, Length and Description by Drainage Basin (part 2).

Basin	Location (FAC #)	Problem Description
640	5122	The basin appears to provide adequate storage and infiltration. However, a lack of vegetation along the eastern slope (along Main Street) has contributed to significant rill and gully erosion around the perimeter of the structure.
640	669	The pond would benefit greatly from a forebay at the two main inlet pipes, and additional berms or microtopography, and native vegetation between the inflow and outflow structures.
645	5379	The extended detention basin appears to have sufficient storage and is well-vegetated, but lacks internal structure or berms, resulting in a very short flow path between the basin inflow and outflow structures.
650	5000	While the pond was still under construction or repair at the time of the assessment, it would benefit from the addition of a forebay, as well as native wetland or riparian vegetation, once the surrounding grounds have been stabilized and restored.
665	533	The pond appears to be functioning as designed, with sufficient storage, and an adjacent forested slope providing beneficial canopy cover and shading of the pond. However, like most of the wet ponds included in this study, FAC-533 lacks a forebay to capture sediment and debris flowing into the pond, which would reduce blockage of the existing weir and increase the ease of maintenance.
665	9999	The pond lacks a forebay and native wetland or riparian vegetation that could alleviate the siltation problem, already observed at the inflow to the pond.
680	9025	The pond is the largest of the basins included in the assessment, and appears to have adequate storage for runoff from the surrounding residential area. The pond is well-designed, with high aesthetic value, but could benefit from native wetland vegetation around the perimeter of the pond to increase pollutant attenuation capability and provide habitat.
NA	5462	Stormwater runoff is conveyed to the existing pond via overland flow and steep-gradient swales, which provide limited intermediate storage or retention. While the pond is well-vegetated, it lacks internal structure, typically provided by berms or varied microtopography.

5.0 RECOMMENDATIONS

A number of recommendations were developed for the Quantico Creek Watershed, based on the results of the data collection and analysis. Each of these recommendations is presented below, in one of three categories; 1) General Recommendations, 2) Open Channel Recommendations, and 3) Existing Basin Recommendations.

General Recommendations are strategies that apply watershed-wide, to improve overall Watershed health and stability. Open Channel Recommendations are reach-specific improvements, focused on improving channel stability, flood prevention, and protection of public health, property and infrastructure. Existing Basin Recommendations are proposed retrofit solutions for existing stormwater basins, intended to address design deficiencies or maintenance issues and to improve the performance of existing stormwater infrastructure.

5.1 General Recommendations

A successful Watershed Action Plan includes both structural and non-structural techniques to minimize stormwater runoff, increase its interception, storage and infiltration, and improve stream stability and ecological health. In addition to site-specific interventions and improvements, described in subsequent sections of this report, we recommend the following general strategies that may be implemented throughout the Watershed, regardless of drainage basin and location.

Quantico Bay

As a part of the public comment process, meetings were held that identified problems along Quantico Creek, and in the vicinity of the confluence with Quantico Creek and the Potomac River. Problems included siltation and invasive aquatic plant growth that impeded or prevented the use of watercraft in this area. Residents were particularly concerned with the need to dredge this segment of the river to restore recreational and commercial use and improve the quality of life for the residents affected.

Figure 5-1: Silt-laden backwater and invasive vegetation near the mouth of Quantico Bay.

Implementing the recommendations outlined in this section of Watershed Plan will reduce the quantity of sediment generated in the eroding reaches of Quantico Creek. The benefits of any dredging will be lost quickly if the Open Channel Recommendations are not implemented first. Once substantial portions of the plan have been implemented and measured sediment load has decreased significantly, then it is recommended that a dredging and invasive species removal plan is carried out. It is preferable that this dredging occur as part of a larger program within the river, and that the costs are shared with State and Federal governments.

Invasive Vegetation Removal and Control

A multi-faceted approach is needed for success in removing and controlling the spread of invasive vegetation. Measures that have been shown to work throughout the country include:

- Educate Property Owners - Provide programs that educate property owners about what to plant and what plants to remove from their property. Programs could include brochures, providing plant identification keys, equipment lending program, and technical assistance. Recommendations for plantings and sources of plant material will also benefit the owners and provide incentives the nurseries.

- Implementing an Invasive Species Removal Program - This program should occur as a part of all maintenance and restoration activities in the Watershed. Anytime that work is performed, in conjunction with the stream or riparian area, invasive plant removal and replanting should be carried out. In addition to the County performing this work, watershed groups, civic groups, and other volunteer groups should be encouraged to assist with these activities, in order to educate and encourage stewardship of the areas natural resources. Grants are often available through State and Federal programs to assist with costs.

- Implementing Native Species Planting Programs - A healthy riparian forest can often compete against, and discourage the spread, of invasive vegetation. Implementing a program that educates property owners about the value of native plants, encourages them to plant them, and provides sources for materials will improve the stream banks, riparian zone, and watershed over time.

Figure 5-2: Growth of native grasses, following the removal of invasive bush honeysuckle.

- Discourage the Use of Invasive plants, Modify Nursery Stock - Work with local nurseries to modify or diversify the plants that are sold. Encourage the stocking of native plants, shrubs, and trees. Provide brochures to customers identifying native species, ornamental attributes, and wildlife value. Discourage the sales of invasive plant species such as wisteria, privet, ornamental pears, honeysuckle, purple loosestrife, and many others.

Riparian Management

Riparian management includes methods to preserve and restore the quality of riparian areas, in order to capitalize on the ecological services that healthy riparian forests can provide, including channel stabilization, erosion prevention, stormwater filtration, pollutant removal, sediment storage, wildlife habitat, and enhanced aesthetics. Major impairments to the existing riparian area adjacent to Quantico Creek and the South Branch are forest clearing, fragmentation, encroachment, and the spread of invasive plant species.

For all new development, all streams and wetlands are identified on the site plan and there is a structure in place to protect these areas that is enforced by the state and federal government. What this enforcement lacks is the ability to protect a buffer around these areas. It is recommended that the County implement a water resource protection buffer requirement within the zoning and building rules. These buffers would be based on an area along the stream or wetland, the width would be based on topography, stream size, land use, and other variables. The other factor is the quality of the buffer. The buffer should be free of invasive plants and contain a healthy ground cover, shrub and tree layer, all consisting of native vegetation. The County could implement incentives for the improvement of the riparian zone as part of the development.

In areas where riparian corridor impairment is particularly severe, we recommend an active reforestation program, designed to maximize ecological benefit by creating a mature and self-sustaining native plant community. In other areas, an education program for residents may be sufficient to alleviate riparian zone clearing, mowing, or illegal dumping by raising awareness of the resource and its associated benefits. Natural regeneration is a passive management approach that is simple and effective, allowing native vegetation to re-grow, just by stopping clearing and mowing operations.

Figure 5-3: Interpretive signage promoting watershed awareness.

Education

Continued educational opportunities are key to promoting stewardship and citizen action, including:

- Signage to identify streams and watersheds - Signage within the Watershed is a cost-effective approach to make residents aware of the Watershed in which they live. This awareness is part of a program that promotes ownership of the Watershed, the stream, wildlife, and water quality.

- Educational Materials - Brochures and emails can be incorporated into a program to increase citizen awareness. Some programs target school children with simple educational brochures that encourage classroom and home discussion. A program of sending brochures along with water and sewer bills has generally been found to be less-effective. Televised programs on the community access channel has been found to be effective if well-targeted and re-run at key times. There are communities across the country that hold competitions for advertisements that have resulted in some very creative educational opportunities at little or no cost.

- Watershed Awareness Programs - Begin with townhall-style meetings that present the Watershed assessment and identify problems. Residents are invited to bring pictures and discuss problems that affect them directly. There were several meetings associated with this Watershed Plan that sought this type of input. However, specialized programs can include "watershed walks" where professionals tour streams and yards, meet with the landowners, and make recommendations for measures to improve the stream, banks, riparian zone, and floodplain.

- Watershed Groups- The County should encourage the initiation of Watershed Groups. These groups would be comprised of volunteers that would implement projects the clean and restore streams and portions of watersheds. Functions of the groups would be watershed ownership, education, assistance with enforcement, monitoring, invasive plant removal, and native plant installation. These groups could work with other existing civic groups such as Boy Scouts, Girl Scouts, gardening clubs, and others to implement projects. The County would provide annual financial support and recognition.

<u>Erosion and Sediment Control Enforcement</u>

Inspection and enforcement of existing erosion and sediment control measures is performed by the Prince William County Department of Public Works, Environmental Services Division. Current staff are responsible for all aspects of stormwater management for the entire county, and enforcement is only one of numerous responsibilities. Based on comments received at the public meetings, held at the initiation of the Plan, there are a number of residents that feel inspection and enforcement measures are not as stringent as they need to be.

The prevention of impacts to the Watershed is a cost-effective approach, when compared to the cost of repairing a damaged or degraded stream, dredging a retention basin filled-in with sediment, or replacing an eroded road culvert. It is difficult to quantify the benefit of erosion and sediment control enforcement because there is rarely a direct correlation between the action and the effect, as the impacts happen over time and generally occur upstream or downstream of the initial impact. This Watershed Plan, in many ways, helps to quantify the need for increased inspection and enforcement because a portion of the recommendations arise directly from this issue.

The need for municipal financial austerity can be outweighed, due to the need to protect municipal infrastructure, maintain property values and taxes, and comply with state and federal regulations. Therefore, we recommend that the County consider the addition of staff or retain the services of a company that specializes in erosion and sediment control measures, in order to provide additional inspection and enforcement capacity.

Discharge Prevention

During the field survey, it was noted that there are pipes of unknown origin discharging to Quantico Creek and its tributaries. In several cases, it was obvious that swimming pool overflow was being discharged, which can have a negative effect on the biological integrity of the receiving stream. In a few locations, the water in the stream appeared gray and cloudy, typically an indicator of anaerobic conditions associated with effluent or septic drainage. This could be coming from a failed septic system, an illegal discharge, or a broken sewer service or trunk line.

Therefore, it is recommended that a dry weather inspection program be implemented throughout the Watershed to identify problems. This program would not necessarily be a permanent one, but one that occurs once every few years, typically in August after at least a week or more of little or no precipitation.

On-site Stormwater Capture and Storage

Many communities are implementing additional development requirements, model ordinances, or discounted stormwater fees for on-site capture and use of stormwater. This approach is one of the requirements for LEED certification of a project and, in many cases, the period of return for these measures can be short. The implementation of some or all of these approaches would prevent future impacts to streams that are currently in good condition, and possibly prevent the condition of impacted streams from becoming worse. Given the amount of developable land and the pressures to grow in this region, the approach would help to maintain property values, protect infrastructure, and improve water quality throughout the County.

Stormwater storage measures in the watershed should be implemented before implementing stream restoration or infrastructure replacement if possible. Reducing the peak flow in a watershed may negate or reduce the need to implement repairs downstream.

Regional Detention Facilities

The watershed was analyzed for the potential of a regional stormwater facility that would retain stormwater runoff, restore base flow, and provide recreation opportunities. No obvious candidate locations were observed. Likely locations for a facility of this type would be in the upper watershed in headwater locations, on a large parcel of land (more than 5 acres), where topography is gentle to reduce dam size and maximize storage, and preferably on property owned by the County.

5.2 Open Channel Recommendations

The following section summarizes major problems and proposed solutions identified in the open channel portion of our rapid watershed assessment. A total of 30 open channel recommendations have been identified. Each of these recommendations is strongly influenced by the geomorphic condition of the stream, as evidenced by the Channel Stability, Channel Scouring and Sediment Deposition, and Physical In-stream Habitat scores obtained through the RSAT protocol. Many of the Open Channel recommendations described below are specifically designed to mitigate the effects of channel incision and widening.

In general, the open channel recommendations tend to fall into one of seven categories of improvement: 1) Infrastructure Repair or Relocation, 2) Debris Removal, 3) Channel Restoration, 4) Enhancement, 5) Riparian Buffer Restoration, and 6) Preservation and Monitoring.

Infrastructure Repair or Relocation (1) refers specifically to those projects that involve repair directly to existing infrastructure, such as a pipe outfall, culvert or utility pole. Often, infrastructure repairs require some form of restoration or enhancement of the adjacent stream channel following disturbance associated with construction. In lieu of repair, some projects may demand relocation of existing infrastructure altogether, to avoid future conflicts with the existing stream or floodway.

Debris Removal (2) includes the excavation and disposal of dumped garbage, debris, or rubble that impairs or inhibits the function of a stream or riparian zone. While debris removal is typically completed in conjunction with a larger restoration or enhancement efforts, it can be implemented as a relatively inexpensive, "stand-alone" project with immediate benefits.

Figure 5-4: Example of a channel restoration project, using regrading, fabric and plants.

Channel Restoration (3) consists of a combination of grading to establish stable channel dimensions, application of bank treatments, and installation of in-stream structures. Bank treatments are used to stabilize and protect eroding streambanks. There are a number of bank treatments available for restoration, including, but not limited to, those included in this report. Each type of bank treatment has specific applications and limitations. For this report, preferred bank treatments were selected based upon design objectives, applicability to site conditions, cost per linear foot of treatment, and design life or longevity. These include fabric and plant slopes, live fascines or brush mattress, rock toe with joint planting, and gravel or earth wraps. Other factors considered in the selection process are the difficulty or ease of installation, habitat value, and site aesthetics.

- Fabric and plant consists of erosion control blanket, or coir fabric, installed over re-graded streambanks and planted. It is recommended for low stress areas where slopes are no greater than 2H:1V and flow velocities do not exceed 3 to 4fps. It is a relatively inexpensive bank treatment, relying on the temporary protection of biodegradable fabric, while vegetation becomes well established.

- Live fascines or brush mattress consists of layered mats or bundles of live woody cuttings, secured in place by ties and stakes, and used in combination with fabric and plant bank treatment. Live fascines and brush mattress provide significant habitat improvement in degraded reaches, but are typically used to stabilize streambanks in reaches with moderate hydraulic stresses. While labor-intensive to install, these treatments do not require the use of heavy machinery and, therefore, minimize disturbance to the surrounding environment.

- Rock toe with joints planting is proposed for high stress areas along the outside of meander bends. This type of bank treatment consists of rock installed along the toe of the streambank, with live woody cuttings planted in joints or openings between rocks to provide additional root-reinforcement of the streambank and to "soften" the appearance for high-visibility areas. Although slightly more expensive per linear foot than brush mattresses or live fascines, rock toe can provide streambank protection for higher shear stress and velocities. In addition, joint plantings of plugs or livestakes installed in the voids between rocks can provide habitat benefits similar to that of other vegetative treatments.

Figure 5-5: Rock toe bank treatment and in-stream structures downstream of bridge.

- Gravel or earth wraps are used for high stress areas where steep gradient banks are required, due to a narrow corridor, adjacent infrastructure, or other site constraints. Gravel or earth wraps are constructed as layers, or lifts, of gravel or compacted soil encapsulated in geotextile. The installation process is more complicated when compared to the use of rock toe and, therefore, usually more expensive.

In-stream structures are used to control channel gradient, restore sediment transport competency, direct flow, dissipate energy, and provide in-stream habitat. All in-stream structures are designed to maximize design life and to remain stable over a range of flows. In-stream structures selected for the proposed restoration reaches include stilling basins, rock riffles, and wing deflectors. Given the potential for relatively high velocity (greater than 10fps) and shear stress during large flood events, particularly at culvert outfalls and at meander bends, it is presumed that in-stream structures will be constructed of large riprap, 12 to 24 inches in diameter.

- Stilling basins are designed to dissipate energy at the outfall of a culvert or channel, prior to release to a receiving stream. Stilling basins are typically used in tandem with rock riffles to imitate the function of a stable, step-pool channel, which dissipate energy through a series of small steps or cascades.

- Rock riffles are constructed of large cobbles, extending across the stream channel and trenched into the streambed. These structures control bed scouring by reducing the energy grade and creating a hard point, capable of resisting the advance of channel incision. Rock riffles are proposed for restoration reaches throughout the Quantico Creek Watershed, located at intervals of approximately 5 to 7 channel widths. The excavated depth of both riffles and pools is contingent upon the location and depth of buried utilities.

Figure 5-6: Typical rock riffle for energy dissipation and grade stabilization.

- Wing deflectors are rock structures, triangular in shape, that extend out from the streambank toward the center of the channel. They are designed to redirect or turn flows away from the bank, constrict the channel and produce a local acceleration of flow. Wing deflectors are ideally suited for culverts that have deposition or sedimentation related problems, such as the crossing at Possum Point Road. When used in combination with a trash rack or debris catch, installed at the culvert inlet, these structures assist in directing debris through the culvert to prevent blockage during flood flows, thereby reducing long-term maintenance requirements. Wing deflectors can enhance aquatic habitat by providing heterogeneity in channel cross section and flow, and by promoting the formation of pools.

Enhancement (4) recommendations are assigned to those reaches that are experiencing a lesser degree of channel erosion, than those requiring full-scale channel restoration. Enhancement projects require much less grading and excavation to achieve a stable channel shape, less robust bank treatments due to lower hydraulic stresses, and fewer in-stream structures. Enhancement projects typically call for stabilizing the streambanks in their original configuration or shape, with fabric and plant bank treatments, and flow deflection structures, such as rock weirs or wing deflectors, to reduce near-bank stresses in strategic locations.

Riparian Buffer Restoration (5) includes removal of any invasive vegetation (if present), followed by seeding, straw application for temporary ground cover, and planting of 1 to 5 gallon container plants at a recommended density of 1200 stems per acre. Buffer restoration is intended to restore the native riparian plant communities that will filter stormwater runoff, provide pollutant attenuation, mechanically reinforce streambank soils, provide canopy cover, and a myriad of other ecological services.

Preservation and Monitoring (6) is recommended for channel reaches that are surrounded by a wide riparian buffer zone, but appear to be undergoing some minor channel adjustments. Preservation and monitoring includes the purchase of a minimum 100ft buffer zone along the stream, permanent preservation with a deed restriction or conservation easement, and a minimum of 5 years of monitoring.

Below is a summary of open channel recommendations by Basin and Reach. Project prioritization and cost opinions are described in detail in Sections 5.4 and 5.5.

Basin 615, South Fork of Quantico Creek

Due to the relatively undisturbed condition and remote location, there are no open channel recommendations for Basin 615.

Basin 630, Dewey's Creek

- 630-A: Restore more than 4300ft of stream, from Tulip Tree Place to Possum Point Road, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 14 rock riffles for permanent grade stabilization.
    - Remove debris and rubble from the streambanks behind Skip's Auto Parts (at the intersection of Jefferson Davis Highway and Old Stage Coach Road) and restore the riparian buffer zone with seed, straw and container plants (at a planting density of up to 1200 stems/acre) along 250 linear feet of channel. Establish a conservation easement, or permanent deed restriction area, to protect the buffer zone to a minimum of 100ft from the channel.
    - Repair or retrofit the culvert at Possum Point Road with up to 4 rock weirs or wing deflectors and a floating trash rack to focus the flow, enhance sediment transport, trap woody debris, and prevent siltation of the culverts.
- 630-B: Restore more than 2300ft of stream, from Jefferson Davis Highway to Tulip Tree Place, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 6 rock riffles for permanent grade stabilization.

  - Relocate an undermined utility pole along the left descending (north) bank, remove a large woody debris jam, and restore approximately 100 feet of eroded streambank downstream from Jefferson Davis Highway.
  - Stabilize 200ft of tributary, south of Wayside Drive and west of Mountain Laurel Loop, using fabric and plant bank treatment with rock toe, and replace the undermined pipe outfall and headwall.
- 630-C: Enhance nearly 3800ft of degraded stream, from Interstate 1-95 to Jefferson Davis Highway, using fabric and plant bank treatment and up to 12 rock weirs or wing deflectors to reduce bank scouring.
  - Restore the riparian buffer zone with seed, straw and container plants (at a planting density of up to 1200 stems/acre) along 1000 linear feet of channel, downstream of Interstate Drive to Dry Powder Circle. Establish a conservation easement, or permanent deed restriction area, to protect the buffer zone to a minimum of 100ft from the channel.
- 630-D: Realign and restore more than 2800ft of stream channel, along the sewer line south of Four Seasons Drive to the culvert at Interstate I-95, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 7 rock riffles for permanent grade stabilization.
  - Remove dumped rubble, tires and other debris, creating an impoundment near the access road from Old Stage Road, prior to restoration.
- 630-F: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 5300ft of stream, from the upstream end of the reach at Telescope Lane, to the confluence with Reach 630-C near Dry Powder Circle.

<u>Basin 645, Upper Little Creek</u>

- 645-A: Enhance approximately 950ft of degraded stream, from Creek Road to the parking lot at First Assembly of God Church, using fabric and plant bank treatment and up to 3 rock weirs or wing deflectors to reduce bank scouring.
- 645-B: Enhance nearly 1300ft of degraded stream, upstream from Creek Road to the culvert at Interstate I-95, using fabric and plant bank treatment and up to 4 rock weirs or wing deflectors.
- 645-C: Enhance approximately 1500ft of degraded stream, upstream from Interstate I-95 to Williams Road, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.
- 645-D: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along nearly 1300ft of stream, from Park Entrance Road to Williams Road.

Basin 650, Middle Little Creek

650-A: Restore approximately 8300ft of stream, from Old Triangle Road to Windsor Road, using fabric and plant bank treatment, rock toe, and gravel or earth wraps to stabilize eroding streambanks, and up to 22 rock riffles for permanent grade stabilization.

Basin 665, Swans Creek

- 665-A: Enhance more than 1500ft of degraded stream, between Swans Creek Lane and Crystal Downs Terrace, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.
- 665-B: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2400ft of stream, between Desert Palm and Oyster Bay Courts.
    - Remove and dispose of sediment, retrofit existing inline structure with multi-stage outlet, and enhance 200ft of degraded stream east of Oyster Bay Court using fabric and plant bank treatment and 2 rock weirs or wing deflectors.
- 665-C: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2000ft of stream, between Medford Drive and Avenel Lane.
- 665-D: Restore more than 1700ft of stream, from Medford Drive to the confluence with Reach 665-B, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 5 rock riffles for permanent grade stabilization.
- 665-E: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along 1200ft of stream, from Myrtlewood to Medford Drive.
- 665-F: Restore 800ft of stream, from Medford to the confluence with Reach 665-D, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and 2 rock riffles for permanent grade stabilization.
- 665-G: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 1230ft of stream, between Myrtlewood to Medford Drives.
- 665-H: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along 700ft of stream, upstream of Myrtlewood Drive.
- 665-I: Restore 1100ft of stream, along the *Swan's Creek Reach*, downstream of Barrley Drive to the confluence with Reach 665-H, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.

- 665-J: Restore approximately 1250ft of stream, from River Heritage Boulevard to the confluence with Reach 665-H, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.

Basin 690, Lower Little Creek

- 690-A: Restore approximately 4750ft of stream, from Windsor Road to Geiger Road, using fabric and plant bank treatment, rock toe, and gravel wraps to stabilize eroding streambanks, and up to 12 rock riffles for permanent grade stabilization.
    - Remove the low head dam at the Medal of Honor Golf Course, restore up to 100ft of streambank using fabric and plant bank treatment and 2 rock weirs or wing deflectors to restore sediment transport competency and to alleviate deposition and widening upstream.

Table 5-1: Summary of Proposed Open Channel Improvement Projects (part 1).

Reach	Improvement ID	Location	Length (feet)	Project Type	Problem Description	Proposed Improvement Projects
630-A	630-A-1	Tulip Tree Place to Possum Point Road	4360	Stream restoration	Channel incision and widening along the lower portion of the basin has resulted in widespread, systemic bank erosion.	Restore more than 4300ft of stream, from Tulip Tree Place to Possum Point Road, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 14 rock riffles for permanent grade stabilization.
630-A	630-A-2	Possum Point Road	250	Infrastructure repair or relocation	Sediment and debris (resulting from channel erosion upstream) has been deposited at the Possum Point Road culvert, severely restricting flow, reducing flood capacity, and posing a risk to public safety and infrastructure.	Remove debris and rubble from the streambanks behind Skip's Auto Parts and restore the riparian buffer zone with seed, straw and container plants. Establish a conservation easement, or permanent deed restriction area, to protect 100ft buffer zone.
630-A	630-A-3	Skip's Auto Parts at the intersection of Jefferson Davis Highway and Old Stage Coach Road	250	Debris removal/ Riparian buffer restoration	Removal of the riparian forest, encroachment on the stream corridor, and dumping of debris has left streambanks susceptible to overbank runoff, gully erosion and localized bank erosion.	Removal of dumped materials, repair of localized bank erosion, and restoration and protection of riparian corridor with permanent deed restriction or conservation easement.
630-B	630-B-1	Jefferson Davis Highway to Reach 630-A	2310	Stream restoration	Channel incision and widening has resulted in systemic streambank erosion.	Restore more than 2300ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 6 rock riffles for permanent grade stabilization.
630-B	630-B-2	Downstream from Jefferson Davis Highway,	100	Infrastructure repair or relocation	A large woody debris jam has resulted in localized bank erosion, which threatens to undermine an existing utility pole on the left (north) bank.	Relocate an undermined utility pole along the left (north) bank, remove a large woody debris jam, and restore approximately 100 feet of eroded streambank.
630-B	630-B-3	South of Wayside Drive, west of Mountain Laurel Loop	200	Infrastructure repair or relocation	Channel incision along an unnamed tributary has undermined an existing concrete pipe outfall and headwall along the left bank, creating a vertical drop of more than 8 feet.	Stabilize 200ft of tributary, using fabric and plant bank treatment with rock toe, and replace the undermined pipe outfall and headwall.
630-C	630-C-1	Interstate I-95 and Jefferson Davis Highway	3790	Stream enhancement	Localized bank erosion and subsequent deposition of coarse gravel and sediments threaten adjacent properties.	Enhance nearly 3800ft of degraded stream using fabric and plant bank treatment and up to 12 rock weirs or wing deflectors to reduce bank scouring.
630-C	630-C-2	Downstream of Interstate Drive to Dry Powder Circle.	1000	Riparian buffer restoration	Removal of riparian vegetation and loss of associated root mass has left the streambank vulnerable to continued erosion and mass wasting, along a temporary access road.	Restore the riparian buffer zone with seed, straw and container plants along 1000 linear feet of channel. Establish a conservation easement, or permanent deed restriction area, to protect the buffer zone to a minimum of 100ft from the channel.
630-D	630-D-1	North of Old Stage Road and west of Highway I-95	200	Debris removal	Illegal dumping of concrete rubble, tires and other debris (via an access road from Old Stage Road) has created and impoundment in the channel, interfering with the flow of water and sediment.	Remove dumped rubble, tires and other debris, creating an impoundment near the access road from Old Stage Road, prior to restoration.
630-D	630-D-2	South of Four Seasons Drive to the culvert at Interstate I-95	2830	Stream restoration	Channel incision and widening has resulted in systemic streambank erosion, and exposure of a previously buried sewer line parallel to the stream.	Realign and restore more than 2800ft of stream channel along an exposed sewer line, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 7 rock riffles for permanent grade stabilization.
630-F	630-F-1	Telescope Lane to the confluence with Reach 630-C near Dry Powder Circle	5310	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams (that act as natural de facto grade control) and bank stabilization provided by a wide riparian forest buffer.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 5300ft of stream.
645-A	645-A-1	Creek Road to parking lot at First Assembly of God Church	950	Stream enhancement	Removal of riparian forest and encroachment on the stream corridor has prompted localized bank erosion and mass wasting.	Enhance approximately 950ft of degraded stream, using fabric and plant bank treatment and up to 3 rock weirs or wing deflectors.
645-B	645-B-1	I-95 to Creek Road	1270	Stream enhancement	Removal of riparian forest and encroachment on the stream corridor has prompted localized bank erosion and mass wasting.	Enhance approximately 1300ft of degraded stream, using fabric and plant bank treatment and up to 4 rock weirs or wing deflectors.
645-C	645-C-1	Williams Road to I-95	1510	Stream enhancement	Removal of riparian forest, followed by mowing to the top of the streambank, has left the channel susceptible to localized bank erosion and prompted mass wasting.	Enhance approximately 1500ft of degraded stream, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.
645-D	645-D-1	Park Entrance Road to Williams Road	1280	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams and bank stabilization provided by the existing riparian forest.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along nearly 1300ft of stream.

Table 5-2: Summary of Proposed Open Channel Improvement Projects (part 2).

Reach	Improvement ID	Location	Length (feet)	Project Type	Problem Description	Proposed Improvement Projects
650-A	650-A-1	Old Triangle Road to Windsor Road	8310	Stream restoration	Channel incision and widening has resulted in widespread, systemic streambank erosion and loss of property .	Restore approximately 8300ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 22 rock riffles for permanent grade stabilization
665-A	665-A-1	Between Swans Creek Lane and Crystal Downs Terrace	1530	Stream enhancement	Moderate channel incision has resulted in streambank erosion. The extent and severity of erosion has been limited, due to influence of a wide riparian buffer	Enhance more than 1500ft of degraded stream, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.
665-B	665-B-1	Between Desert Palm and Oyster Bay Courts	2430	Preservation and monitoring	Deposition and widening, resulting in localized bank erosion.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2400ft of stream.
665-B	665-B-2	East of Oyster Bay Court	200	Infrastructure repair or relocation	Deposition and widening has prompted localized erosion. Sedimentation of an inline basin, east of Oyster Bay Court, has clogged the outlet structure, resulting in a loss of sediment transport competency and capacity to downstream reaches.	Remove and dispose of sediment, retrofit existing inline structure with multi-stage outlet, and enhance 200ft of degraded stream east of Oyster Bay Court using fabric and plant bank treatment and 2 rock weirs or wing deflectors.
665-C	665-C-1	Between Medford Drive and Avenel Lane	2080	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2000ft of stream.
665-D	665-D-1	Medford Drive to the confluence with Reach 665-B	1740	Stream restoration	Channel incision and widening, has resulted in systemic streambank erosion. Removal of riparian forest and encroachment on the stream corridor, underneath the power lines, has exacerbated the erosion problems.	Restore more than 1700ft of stream, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 5 rock riffles for permanent grade stabilization.
665-E	665-E-1	Myrtlewood Drive to Medford Drive	1200	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement.
665-F	665-F-1	Medford Drive to the confluence with Reach 665-D	800	Stream restoration	Channel incision has resulted in systemic streambank erosion.	Restore 800ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and 2 rock riffles for permanent grade stabilization.
665-G	665-G-1	Myrtlewood Drive to Medford Drive	1230	Preservation and monitoring	Channel widening and subsequent deposition of silt and sediment has resulted in localized bank erosion and mass wasting.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 1230ft of stream.
665-H	665-H-1	Upstream from Myrtlewood Drive	700	Preservation and monitoring	Channel widening and deposition of sediment has resulted in localized bank erosion.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along 700ft of stream.
665-I	665-I-1	Downstream of Barrley Drive to the confluence with Reach 665-H	1100	Stream restoration	Severe channel incision has resulted in systemic erosion, mass wasting, and imminent loss of property along the Swan's Creek Reach,. Near-vertical, eroded banks stand approximately 12ft high, posing a significant risk to public safety.	Restore 1100ft of stream, along the Swan's Creek Reach, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.
665-J	665-J-1	River Heritage Boulevard to the confluence with Reach 665-H	1250	Stream restoration	Severe channel incision has resulted in systemic erosion and loss of property.	Restore approximately 1250ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.
690-A	960-A-1	Medal of Honor Golf Course, near Fuller Heights and Windsor Roads	100	Stream restoration - Low head dam removal	A low head dam on the Medal of Honor Golf Course has impaired sediment transport, thereby exacerbating deposition and channel widening upstream of the dam.	Remove the low head dam at the Medal of Honor Golf Course, restore up to 100ft of streambank using fabric and plant bank treatment and 2 rock weirs or wing deflectors to restore sediment transport competency and to alleviate deposition and widening upstream.
690-A	690-A-2	Windsor Road to Geiger Road	4750	Stream restoration	Active channel widening, coupled with the loss of a riparian buffer zone and continued removal of woody vegetation (associated with golf course maintenance), has resulted in systemic streambank erosion.	Restore approximately 4750ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 12 rock riffles for permanent grade stabilization.

5.3 Existing Basin Recommendations

The evaluation of existing stormwater basins within the Watershed identified 16 stormwater basins that could be retrofitted to reduce runoff volumes, alleviate channel erosion and flooding, improve water quality, and provide aquatic and terrestrial habitat. Existing basins were evaluated and scored based upon the four categories of 1) basin type, 2) structure, 3) location/drainage area, and 4) vegetation.

Below is a brief description of each retrofit recommendation by drainage basin. Project prioritization and cost opinions are described in detail in Sections 5.4 and 5.5.

- FAC-473: It appears that the existing pond has insufficient storage for the given volume of stormwater runoff directed to the basin. Additional storage can be gained by raising the height of the embankment with clean fill, and retrofitting the existing outfall with a multi-stage riser. In addition, we recommend adding a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables, and constructing earth or rock berms along the pond bottom to lengthen the flow path from the proposed forebay to the new outlet structure. This will encourage settling of sediment and attenuation of nutrients. Once all structural work has been completed, revegetate the pond with native wetland species.

Figure 5-7: Example of pond forebay, designed for capture of sediment and debris.

- FAC-5473: The pond appears to have nutrient and eutrophication problems, as evidenced by excessive algae growth. We recommend the addition of a forebay at the main entry point to the pond to alleviate sediment and nutrient loading issues. Furthermore, the existing concrete weir overflow structure appears to be ineffective at controlling varied flow events. While the existing structure can remain in place, we recommend retrofitting the outfall with a multi-stage riser.

- FAC-558: While the existing stormwater swales provide limited storage, infiltration, and treatment capacity, they can be retrofitted to perform as infiltration features by excavating the swale bottom (to a minimum depth of 3ft) and constructing an infiltration trench with gravel backfill and amended planting substrate. Add low rock check dams to encourage storage and infiltration. Revegetate the swale with native riparian species to provide additional hydraulic roughness.

- FAC Unknown: The existing dry basin lacks internal structure, microtopography, and vegetation that would extend the flow path and increase the residency time of stormwater runoff from the adjacent roadway. Regrade the bottom of the basin to lengthen the flow path from inlet to outlet, and revegetate with native riparian species to facilitate pollutant attenuation.

- FAC-5379: The dry basin is located adjacent to Dumfries Road, near the intersection with Hide Away Drive. The basin lacks internal structure or microtopography, and vegetation that would otherwise extend the flow path, increase residency time, and facilitate attenuation of pollutants.

- FAC-5463: The newly constructed wet pond appears to have sufficient storage capacity, but lacks of internal structure, with a very short flow path from inflow to outfall. Construct a forebay at the main entry point to the pond and add berms along the pond bottom to lengthen the flow path from the proposed forebay to the outfall structure. Once structural work is complete, revegetate the pond with native wetland and riparian species to increase hydraulic roughness, encourage settling of suspended sediments, and provide pollutant attenuation.

Figure 5-8: Example of pond microtopography, designed to lengthen the flow path.

- FAC-5515: The extended detention basin lacks internal structure or microtopography that could extend the flow path and residency time of captured stormwater. Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native wetland and riparian species.

- FAC-5122: The vegetated swale/dry basin appears to provide adequate storage and infiltration. However, we recommend regrading the side slopes around the basin, add topsoil and amendments, seed with mesic prairie species, and install erosion control blanket to prevent rill and gully erosion around the perimeter of the structure.

- FAC-669: The existing wet pond appears to have sufficient storage capacity, but would benefit from a forebay at the two main inlet pipes, additional berms or microtopography, and native vegetation between the inflow and outflow structures. Construct a forebay at the main entry point to the pond, coupled with additional berms along the pond bottom to lengthen the flow path from the proposed forebay to the outlet structure. Revegetate the pond with native wetland species.

- FAC-5397: The extended detention basin appears to have sufficient storage and is well-vegetated, but lacks internal structure or berms, resulting in a very short flow path between the basin inflow and outflow structures. Regrade the dry basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native riparian species.

- FAC-5000: While the pond was still under construction or repair at the time of the assessment, it would benefit from the addition of a forebay, as well as native wetland or riparian vegetation, once the surrounding grounds have been stabilized and restored. Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Revegetate the pond with native wetland species.

- FAC-533: The existing wet pond appears to be functioning as designed, with sufficient storage, but lacks a forebay to capture sediment and debris flowing into the pond. Construct a forebay at the main entry point to the pond to reduce blockage of the existing weir and increase the ease of maintenance. Revegetate the pond with native wetland species.

- FAC-5462: The pond is well-vegetated, but lacks internal structure, typically provided by berms or varied microtopography. Add berms along the pond bottom to lengthen the flow path from the inflow to the outlet structure. In addition, add low rock check dams and revegetate with upland trees and shrubs to encourage storage and infiltration along steep gradient swales leading to the pond.

Figure 5-9: Native wetland vegetation, planted along the perimeter of a detention pond.

- FAC-505: The extended detention basin is densely vegetated, but could benefit from additional internal structure, berms or microtopography. Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate within the area of disturbance with native wetland and riparian species.

- FAC-Unknown (9999): The existing wet pond lacks a forebay and native wetland vegetation that could alleviate siltation problems. Construct a forebay at the main entry point to the pond and revegetate with native wetland species.

- FAC-9025: The existing wet pond is the largest of the basins included in the assessment, and appears to have adequate storage for runoff from the surrounding residential area. While the pond is well-designed, it could benefit from the addition of native wetland vegetation around the perimeter of the pond to increase pollutant attenuation capability and provide habitat.

Table 5-3: Summary of Existing Stormwater Basin Proposed Improvement Projects**.**

Basin	Location (FAC #)	Problem Description	Proposed Retrofit
605	473	The pond has excessive algae growth, indicative of possible nutrient and eutrophication problems. In addition, the pond appears to have insufficient storage volume to effectively manage stormwater runoff (given the permanent pool elevation, at the time of the assessment). Vegetation surrounding the pond consists mainly of manicured turfgrass, mowed to the edge of the bank, providing little or no filtration of stormwater runoff. The pond lacks a forebay, which would allow sediment (and adsorbed nutrients) to settle out of suspension, and has no visible multi-stage outlet for water level control.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables, and retrofit the existing outfall structure with a multi-stage riser. Raise the embankment height to provide additional storage, and add berms along the pond bottom to lengthen the flow path from the proposed forebay to the outlet structure. Once structural work is complete, revegetate the pond with native wetland species.
605	5473	The existing wet pond has a single-stage, concrete weir overflow structure that appears to be ineffective at controlling varied flow events, including smaller, more frequent water quality and channel protection storm events. In addition, the pond appears to have nutrient and eutrophication problems, as evidenced by excessive algae growth. The pond lacks a forebay that could help alleviate sediment and nutrient loading issues.	Construct a forebay at the main entry point to the stormwater pond to capture silt, sediment, debris and floatables. The existing concrete weir overflow structure may remain in place, but retrofit the outfall structure with a multi-stage riser.
610	558	The shallow stormwater swale, appears to provide adequate stormwater conveyance to an enclosed system (via grated inlet structures). However, the stormwater swales provide limited storage, infiltration, and treatment capacity.	Excavate the swale bottom to a minimum depth of 3ft and construct an infiltration trench with gravel backfill and amended planting substrate. Add low rock check dams to encourage storage and infiltration. Revegetate the swale with native riparian species.
625	Unknown	The basin lacks internal structure, berms or microtopography, and vegetation that would otherwise extend the flow path to the outlet structure, increase residency time of stormwater, and facilitate attenuation of pollutants from the adjacent roadway, prior to emptying into a tributary to Quantico Creek.	Regrade the dry basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native riparian species.
627	5379	The basin lacks internal structure or microtopography, and vegetation that would otherwise extend the flow path, increase residency time, and facilitate attenuation of pollutants.	Regrade the dry basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native riparian species.
630	5463	The pond appears to be designed to function as a wet pond, but lacks a permanent pool. In addition, the pond would benefit from a forebay, microtopography, and native vegetation. While the pond appears to have sufficient storage capacity, the inflow and outfall are no more than 50ft apart, given the lack of internal structure.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Add berms along the pond bottom to lengthen the flow path from the proposed forebay to the outfall structure. Once structural work is complete, revegetate the pond with native wetland and riparian species.
630	5515	The basin is well-vegetated, and appears to have sufficient storage to handle runoff from the adjacent parking, but lacks internal structure or microtopography that could extend the flow path and residency time of captured stormwater.	Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native wetland and riparian species.
630	505	The basin is densely vegetated; so much so, that inflow and outflow structures are barely visible. While the existing vegetation may provide sufficient roughness, sediment capture, and pollutant attenuation capability, the basin could benefit from additional internal structure, berms or microtopography.	Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native wetland and riparian species.
640	5122	The basin appears to provide adequate storage and infiltration. However, a lack of vegetation along the eastern slope (along Main Street) has contributed to significant rill and gully erosion around the perimeter of the structure.	Regrade the side slopes around the basin, add topsoil and amendments, seed with mesic prairie species, and install erosion control blanket.
640	669	The pond would benefit greatly from a forebay at the two main inlet pipes, and additional berms or microtopography, and native vegetation between the inflow and outflow structures.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Add berms along the pond bottom to lengthen the flow path from the proposed forebay to the outlet structure, and revegetate the pond with native wetland species.
645	5379	The extended detention basin appears to have sufficient storage and is well-vegetated, but lacks internal structure or berms, resulting in a very short flow path between the basin inflow and outflow structures.	Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native wetland and riparian species.
650	5000	While the pond was still under construction or repair at the time of the assessment, it would benefit from the addition of a forebay, as well as native wetland or riparian vegetation, once the surrounding grounds have been stabilized and restored.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Revegetate the pond with native wetland species.
665	533	The pond appears to be functioning as designed, with sufficient storage, and an adjacent forested slope providing beneficial canopy cover and shading of the pond. However, like most of the wet ponds included in this study, FAC-533 lacks a forebay to capture sediment and debris flowing into the pond, which would reduce blockage of the existing weir and increase the ease of maintenance.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Revegetate the pond with native wetland species.
665	9999	The pond lacks a forebay and native wetland or riparian vegetation that could alleviate the siltation problem, already observed at the inflow to the pond.	Construct a forebay at the main entry point to the pond, and revegetate with native wetland species.
680	9025	The pond is the largest of the basins included in the assessment, and appears to have adequate storage for runoff from the surrounding residential area. The pond is well-designed, with high aesthetic value, but could benefit from native wetland vegetation around the perimeter of the pond to increase pollutant attenuation capability and provide habitat.	Revegetate with native wetland species.
NA	5462	Stormwater runoff is conveyed to the existing pond via overland flow and steep-gradient swales, which provide limited intermediate storage or retention. While the pond is well-vegetated, it lacks internal structure, typically provided by berms or varied microtopography.	Add berms along the pond bottom to lengthen the flow path from the inflow to the outlet structure. In addition, add low rock check dams and revegetate with upland trees and shrubs to encourage storage and infiltration along steep gradient swales leading to the pond.

5.4 Project Prioritization

Each open channel recommendation was prioritized based on the following project categories:

Priority 1

Priority 1 projects represent those reaches of stream that pose an immediate threat to public health, safety, property or infrastructure. These sites exhibit evidence of accelerated erosion, mass wasting, or flooding. Delay in the design and construction of Priority 1 projects could result in significant increase in cost and/or loss of property. Therefore, Priority 1 projects should be repaired as soon as possible.

Priority 1 projects include:

- 630-A: Restore more than 4300ft of stream, from Tulip Tree Place to Possum Point Road, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 14 rock riffles for permanent grade stabilization.
    - Repair or retrofit the culvert at Possum Point Road with up to 4 rock weirs or wing deflectors and a floating trash rack to focus the flow, enhance sediment transport, trap woody debris, and prevent siltation of the culverts.
- 630-D: Realign and restore more than 2800ft of stream channel, along the sewer line south of Four Seasons Drive to the culvert at Interstate I-95, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 7 rock riffles for permanent grade stabilization.
- 665-I: Restore 1100ft of stream, along the *Swan's Creek Reach*, downstream of Barrley Drive to the confluence with Reach 665-H, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.
- 665-J: Restore approximately 1250ft of stream, from River Heritage Boulevard to the confluence with Reach 665-H, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.

Priority 2

Priority 2 projects are systemic in nature and are characterized by unstable channel conditions, such as channel incision or widening. While they may not pose an immediate threat to property or infrastructure, Priority 2 reaches often influence conditions elsewhere in the Watershed. For example, an actively incising Priority 2 reach will continue to downcut, eroding the channel bed and banks, liberating large volumes of sediment and increasing sedimentation downstream. These projects should be constructed after all Priority 1 projects have been completed, and as soon as funding allows.

Priority 2 projects include:

- 630-A: Remove debris and rubble from the streambanks behind Skip's Auto Parts (at the intersection of Jefferson Davis Highway and Old Stage Coach Road) and restore the riparian buffer zone with seed, straw and container plants (at a planting density of up to 1200 stems/acre) along 250 linear feet of channel. Establish a conservation easement, or permanent deed restriction area, to protect the buffer zone to a minimum of 100ft from the channel.
- 630-B: Restore more than 2300ft of stream, from Jefferson Davis Highway to Tulip Tree Place, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 6 rock riffles for permanent grade stabilization.
- 650-A: Restore approximately 8300ft of stream, from Old Triangle Road to Windsor Road, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 22 rock riffles for permanent grade stabilization.
- 665-B: Remove and dispose of sediment, retrofit existing inline structure with multi-stage outlet, and enhance 200ft of degraded stream east of Oyster Bay Court using fabric and plant bank treatment and 2 rock weirs or wing deflectors.
- 665-D: Restore more than 1700ft of stream, from Medford Drive to the confluence with Reach 665-B, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 5 rock riffles for permanent grade stabilization.
- 665-F: Restore 800ft of stream, from Medford to the confluence with Reach 665-D, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and 2 rock riffles for permanent grade stabilization.
- 690-A: Restore approximately 4750ft of stream, from Windsor Road to Geiger Road, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 12 rock riffles for permanent grade stabilization.

<u>Priority 3</u>
These projects include both repair of systemic channel adjustments, as well as localized repairs to open channels or adjacent infrastructure. However, because of location in the Watershed or robust channel conditions, propagation of the problem is proceeding relatively slowly. These problems are distinct from the two previous categories in that the cause is local rather than systemic. Examples of this type of problem include overbank drainage, removal of riparian corridor, and debris dumping.

Priority 3 projects include:

- 630-C: Enhance nearly 3800ft of degraded stream using fabric and plant bank treatment and up to 12 rock weirs or wing deflectors to reduce bank scouring.

- 645-A: Enhance approximately 950ft of degraded stream, from Creek Road to the parking lot at First Assembly of God Church, using fabric and plant bank treatment and up to 3 rock weirs or wing deflectors to reduce bank scouring.
- 645-B: Enhance nearly 1300ft of degraded stream, upstream from Creek Road to the culvert at Interstate I-95, using fabric and plant bank treatment and up to 4 rock weirs or wing deflectors.
- 645-C: Enhance approximately 1500ft of degraded stream, upstream from Interstate I-95 to Williams Road, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.
- 665-A: Enhance more than 1500ft of degraded stream, between Swans Creek Lane and Crystal Downs Terrace, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.
- 690-A: Remove the low head dam at the Medal of Honor Golf Course, restore up to 100ft of streambank using fabric and plant bank treatment and 2 rock weirs or wing deflectors to restore sediment transport competency and to alleviate deposition and widening upstream.

<u>Priority 4</u>
Preservation: These are opportunities to protect the higher quality reaches of Quantico Creek. In addition to the aesthetic, water quality, and habitat benefits, protecting the better-functioning reaches provide a reference point for reclaiming the damaged areas. Moreover, the presence of self-managing reaches buffers some of the effects of stream degradation.

Priority 4 projects include:

- 630-B: Relocate an undermined utility pole along the left descending (north) bank, remove a large woody debris jam, and restore approximately 100 feet of eroded streambank downstream from Jefferson Davis Highway.
- 630-B: Stabilize 200ft of tributary, south of Wayside Drive and west of Mountain Laurel Loop, using fabric and plant bank treatment with rock toe, and replace the undermined pipe outfall and headwall.
- 630-C: Restore the riparian buffer zone with seed, straw and container plants (at a planting density of up to 1200 stems/acre) along 1000 linear feet of channel, downstream of Interstate Drive to Dry Powder Circle. Establish a conservation easement, or permanent deed restriction area, to protect the buffer zone to a minimum of 100ft from the channel.
- 630-D: Remove dumped rubble, tires and other debris, creating an impoundment near the access road from Old Stage Road, prior to restoration.
- 630-F: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 5300ft of stream, from the upstream end of the reach at Telescope Lane, to the confluence with Reach 630-C near Dry Powder Circle.

- 645-D: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along nearly 1300ft of stream, from Park Entrance Road to Williams Road.
- 665-B: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2400ft of stream, between Desert Palm and Oyster Bay Courts.
- 665-C: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2000ft of stream, between Medford Drive and Avenel Lane.
- 665-E: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along 1200ft of stream, from Myrtlewood to Medford Drive.
- 665-G: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 1230ft of stream, between Myrtlewood to Medford Drives.
- 665-H: Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along 700ft of stream, upstream of Myrtlewood Drive.

Stormwater Basin Retrofits

Stormwater basin retrofit projects were not included in the prioritization scheme described above. Instead, the proposed retrofit projects were ranked according to their assessment score. Order of project implementation is based solely upon this score. However, in contrast to the open channel recommendations, the stormwater basin retrofit projects could also be implemented independently, according to cost, since individual retrofit projects are unlikely to have the same degree of influence elsewhere in the Watershed as, for example, a rapidly incising channel would.

5.5 Opinion of Probable Cost

Opinions of probable construction costs were developed based on estimates of cost per linear foot, per acre, or by unit cost of proposed structures, which vary by project type. Design costs were estimated to be approximately 25% of the total construction budget, including preparation of plans and specifications, construction oversight and post-construction monitoring.

The total cost opinion for all 30 of the proposed open channel recommendations is $14,928,750. Improvements in Basin 630 represent more than 30% of the total cost. Basin 655 represents more than 20% of the total cost. However, the most expensive of any single recommendation is the restoration of more than 8,000ft of open channel along Reach 650-A to address ongoing channel incision and widening. The total cost opinion for all 16 of the proposed stormwater basin retrofits is $773,483. Tables 4-5a, 4-5b, and 4-5c below presents a summary table of each recommendation, priority and cost opinion.

Table 5-4: Summary of Project Priority and Cost Opinion for Proposed Open Channel Improvement Projects by Reach (part 1).

Priority	Reach	Improvement ID	Location	Length (feet)	Project Type	Problem Description	Proposed Improvement Projects	Opinion of Probable Cost: Design	Opinion of Probable Cost: Construction
1	630-A	630-A-1	Tulip Tree Place to Possum Point Road	4360	Stream restoration	Channel incision and widening along the lower portion of the basin has resulted in widespread, systemic bank erosion.	Restore more than 4300ft of stream, from Tulip Tree Place to Possum Point Road, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 14 rock riffles for permanent grade stabilization.	$ 327,000.00	$ 1,308,000.00
1	630-A	630-A-2	Possum Point Road	250	Infrastructure repair or relocation	Sediment and debris (resulting from channel erosion upstream) has been deposited at the Possum Point Road culvert, severely restricting flow, reducing flood capacity, and posing a risk to public safety and infrastructure.	Remove debris and rubble from the streambanks behind Skip's Auto Parts and restore the riparian buffer zone with seed, straw and container plants along 250 linear feet of channel. Establish a conservation easement, or permanent deed restriction area, to protect the buffer zone to a minimum of 100ft from the channel.	$ 18,750.00	$ 75,000.00
2	630-A	630-A-3	Skip's Auto Parts at the intersection of Jefferson Davis Highway and Old Stage Coach Road	250	Debris removal/Riparian buffer restoration	Removal of the riparian forest, encroachment on the stream corridor, and dumping of debris has left streambanks susceptible to overbank runoff, gully erosion and localized bank erosion.	Removal of dumped materials, repair of localized bank erosion, and restoration and protection of riparian corridor with permanent deed restriction or conservation easement.	$ 12,500.00	$ 50,000.00
2	630-B	630-B-1	Jefferson Davis Highway to Reach 630-A	2310	Stream restoration	Channel incision and widening has resulted in systemic streambank erosion.	Restore more than 2300ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 6 rock riffles for permanent grade stabilization.	$ 173,250.00	$ 693,000.00
4	630-B	630-B-2	Downstream from Jefferson Davis Highway,	100	Infrastructure repair or relocation	A large woody debris jam has resulted in localized bank erosion, which threatens to undermine an existing utility pole on the left (north) bank.	Relocate an undermined utility pole along the left (north) bank, remove a large woody debris jam, and restore approximately 100 feet of eroded streambank.	$ 7,500.00	$ 30,000.00
4	630-B	630-B-3	South of Wayside Drive, west of Mountain Laurel Loop	200	Infrastructure repair or relocation	Channel incision along an unnamed tributary has undermined an existing concrete pipe outfall and headwall along the left bank, creating a vertical drop of more than 8 feet.	Stabilize 200ft of tributary, using fabric and plant bank treatment with rock toe, and replace the undermined pipe outfall and headwall.	$ 15,000.00	$ 60,000.00
3	630-C	630-C-1	Interstate I-95 and Jefferson Davis Highway	3790	Stream enhancement	Localized bank erosion and subsequent deposition of coarse gravel and sediments threaten adjacent properties.	Enhance nearly 3800ft of degraded stream using fabric and plant bank treatment and up to 12 rock weirs or wing deflectors to reduce bank scouring.	$ 189,500.00	$ 758,000.00
4	630-C	630-C-2	Downstream of Interstate Drive to Dry Powder Circle.	1000	Riparian buffer restoration	Removal of riparian vegetation and loss of associated root mass has left the streambank vulnerable to continued erosion and mass wasting, along a temporary access road.	Restore the riparian buffer zone with seed, straw and container plants along 1000 linear feet of channel. Establish a conservation easement, or permanent deed restriction area, to protect the buffer zone to a minimum of 100ft from the channel.	$ 25,000.00	$ 100,000.00
4	630-D	630-D-1	North of Old Stage Road and west of Highway I-95	200	Debris removal	Illegal dumping of concrete rubble, tires and other debris (via an access road from Old Stage Road) has created and impoundment in the channel, interfering with the flow of water and sediment.	Remove dumped rubble, tires and other debris, creating an impoundment near the access road from Old Stage Road, prior to restoration.	$ 10,000.00	$ 40,000.00
1	630-D	630-D-2	South of Four Seasons Drive to the culvert at Interstate I-95	2830	Stream restoration	Channel incision and widening has resulted in systemic streambank erosion, and exposure of a previously buried sewer line parallel to the stream.	Realign and restore more than 2800ft of stream channel along an exposed sewer line, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 7 rock riffles for permanent grade stabilization.	$ 212,250.00	$ 849,000.00
4	630-F	630-F-1	Telescope Lane to the confluence with Reach 630-C near Dry Powder Circle	5310	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams (that act as natural de facto grade control) and bank stabilization provided by a wide riparian forest buffer.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 5300ft of stream.	$ 132,750.00	$ 531,000.00
3	645-A	645-A-1	Creek Road to parking lot at First Assembly of God Church	950	Stream enhancement	Removal of riparian forest and encroachment on the stream corridor has prompted localized bank erosion and mass wasting.	Enhance approximately 950ft of degraded stream, using fabric and plant bank treatment and up to 3 rock weirs or wing deflectors.	$ 47,500.00	$ 190,000.00
3	645-B	645-B-1	I-95 to Creek Road	1270	Stream enhancement	Removal of riparian forest and encroachment on the stream corridor has prompted localized bank erosion and mass wasting.	Enhance approximately 1300ft of degraded stream, using fabric and plant bank treatment and up to 4 rock weirs or wing deflectors.	$ 63,500.00	$ 254,000.00
3	645-C	645-C-1	Williams Road to I-95	1510	Stream enhancement	Removal of riparian forest, followed by mowing to the top of the streambank, has left the channel susceptible to localized bank erosion and prompted mass wasting.	Enhance approximately 1500ft of degraded stream, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.	$ 75,500.00	$ 302,000.00
4	645-D	645-D-1	Park Entrance Road to Williams Road	1280	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams and bank stabilization provided by the existing riparian forest.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along nearly 1300ft of stream.	$ 32,000.00	$ 128,000.00

Table 5-5: Summary of Project Priority and Cost Opinion for Proposed Open Channel Improvement Projects by Reach (part 2).

Priority	Reach	Improvement ID	Location	Length (feet)	Project Type	Problem Description	Proposed Improvement Projects	Opinion of Probable Cost	
								Design	Construction
2	650-A	650-A-1	Old Triangle Road to Windsor Road	8310	Stream restoration	Channel incision and widening has resulted in widespread, systemic streambank erosion and loss of property .	Restore approximately 8300ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 22 rock riffles for permanent grade stabilization	$ 623,250.00	$ 2,493,000.00
3	665-A	665-A-1	Between Swans Creek Lane and Crystal Downs Terrace	1530	Stream enhancement	Moderate channel incision has resulted in streambank erosion. The extent and severity of erosion has been limited, due to influence of a wide riparian buffer	Enhance more than 1500ft of degraded stream, using fabric and plant bank treatment and up to 5 rock weirs or wing deflectors.	$ 76,500.00	$ 306,000.00
4	665-B	665-B-1	Between Desert Palm and Oyster Bay Courts	2430	Preservation and monitoring	Deposition and widening, resulting in localized bank erosion.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2400ft of stream.	$ 60,750.00	$ 243,000.00
2	665-B	665-B-2	East of Oyster Bay Court	200	Infrastructure repair or relocation	Deposition and widening has prompted localized erosion. Sedimentation of an inline basin, east of Oyster Bay Court, has clogged the outlet structure, resulting in a loss of sediment transport competency and capacity to downstream reaches.	Remove and dispose of sediment, retrofit existing inline structure with multi-stage outlet, and enhance 200ft of degraded stream east of Oyster Bay Court using fabric and plant bank treatment and 2 rock weirs or wing deflectors.	$ 15,000.00	$ 60,000.00
4	665-C	665-C-1	Between Medford Drive and Avenel Lane	2080	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 2000ft of stream.	$ 52,000.00	$ 208,000.00
2	665-D	665-D-1	Medford Drive to the confluence with Reach 665-B	1740	Stream restoration	Channel incision and widening, has resulted in systemic streambank erosion. Removal of riparian forest and encroachment on the stream corridor, underneath the power lines, has exacerbated the erosion problems.	Restore more than 1700ft of stream, using fabric and plant bank treatment with live fascines or brush mattress to provide immediate vegetative cover, and up to 5 rock riffles for permanent grade stabilization.	$ 130,500.00	$ 522,000.00
4	665-E	665-E-1	Myrtlewood Drive to Medford Drive	1200	Preservation and monitoring	Moderate channel incision has been slowed by woody debris jams and bank stabilization, provided by the existing riparian forest.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along 1200ft of stream.	$ 30,000.00	$ 120,000.00
2	665-F	665-F-1	Medford Drive to the confluence with Reach 665-D	800	Stream restoration	Channel incision has resulted in systemic streambank erosion.	Restore 800ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and 2 rock riffles for permanent grade stabilization.	$ 60,000.00	$ 240,000.00
4	665-G	665-G-1	Myrtlewood Drive to Medford Drive	1230	Preservation and monitoring	Channel widening and subsequent deposition of silt and sediment has resulted in localized bank erosion and mass wasting.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along more than 1230ft of stream.	$ 30,750.00	$ 123,000.00
4	665-H	665-H-1	Upstream from Myrtlewood Drive	700	Preservation and monitoring	Channel widening and deposition of sediment has resulted in localized bank erosion.	Purchase, preserve and monitor the existing riparian corridor with a permanent deed restriction or conservation easement, along 700ft of stream.	$ 17,500.00	$ 70,000.00
1	665-I	665-I-1	Downstream of Barrley Drive to the confluence with Reach 665-H	1100	Stream restoration	Severe channel incision has resulted in systemic erosion, mass wasting, and imminent loss of property along the Swan's Creek Reach,. Near-vertical, eroded banks stand approximately 12ft high, posing a significant risk to public safety.	Restore 1100ft of stream, along the Swan's Creek Reach, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.	$ 82,500.00	$ 330,000.00
1	665-J	665-J-1	River Heritage Boulevard to the confluence with Reach 665-H	1250	Stream restoration	Severe channel incision has resulted in systemic erosion and loss of property	Restore approximately 1250ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 3 rock riffles for permanent grade stabilization.	$ 93,750.00	$ 375,000.00
3	690-A	960-A-1	Medal of Honor Golf Course, near intersection of Fuller Heights and Windsor Roads	100	Stream restoration - Low head dam removal	A low head dam on the Medal of Honor Golf Course has impaired sediment transport, thereby exacerbating deposition and channel widening upstream of the dam.	Remove the low head dam at the Medal of Honor Golf Course, restore up to 100ft of streambank using fabric and plant bank treatment and 2 rock weirs or wing deflectors to restore sediment transport competency and to alleviate deposition and widening upstream	$ 15,000.00	$ 60,000.00
2	690-A	690-A-2	Windsor Road to Geiger Road	4750	Stream restoration	Active channel widening, coupled with the loss of a riparian buffer zone and continued removal of woody vegetation (associated with golf course maintenance), has resulted in systemic streambank erosion .	Restore approximately 4750ft of stream, using fabric and plant bank treatment with rock toe to stabilize eroding streambanks, and up to 12 rock riffles for permanent grade stabilization.	$ 356,250.00	$ 1,425,000.00
								$ 2,985,750.00	**$ 11,943,000.00**
							TOTAL COST OF DESIGN AND CONSTRUCTION		**$ 14,928,750.00**

Table 5-6: Summary of Project Priority and Cost Opinion for Existing Stormwater Basin Improvement Projects by Basin and Location.

Basin	Location (FAC #)	Assessment Score	Problem Description	Proposed Retrofit	Opinion of Probable Cost Design	Construction
605	473	17	The pond has excessive algae growth, indicative of possible nutrient and eutrophication problems. In addition, the pond appears to have insufficient storage volume to effectively manage stormwater runoff (given the permanent pool elevation, at the time of the assessment). Vegetation surrounding the pond consists mainly of manicured turfgrass, mowed to the edge of the bank, providing little or no filtration of stormwater runoff. The pond lacks a forebay, which would allow sediment (and adsorbed nutrients) to settle out of suspension, and has no visible multi-stage outlet for water level control.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables, and retrofit the existing outfall structure with a multi-stage riser. Raise the embankment height to provide additional storage, and add berms along the pond bottom to lengthen the flow path from the proposed forebay to the outlet structure. Once structural work is complete, revegetate the pond with native wetland species.	$ 8,277	$ 33,110
605	5473	20	The existing wet pond has a single-stage, concrete weir overflow structure that appears to be ineffective at controlling varied flow events, including smaller, more frequent water quality and channel protection storm events. In addition, the pond appears to have nutrient and eutrophication problems, as evidenced by excessive algae growth. The pond lacks a forebay that could help alleviate sediment and nutrient loading issues.	Construct a forebay at the main entry point to the stormwater pond to capture silt, sediment, debris and floatables. The existing concrete weir overflow structure may remain in place, but retrofit the outfall structure with a multi-stage riser.	$ 3,939	$ 15,754
610	558	8	The shallow stormwater swale, appears to provide adequate stormwater conveyance to an enclosed system (via grated inlet structures). However, the stormwater swales provide limited storage, infiltration, and treatment capacity.	Excavate the swale bottom to a minimum depth of 3ft and construct an infiltration trench with gravel backfill and amended planting substrate. Add low rock check dams to encourage storage and infiltration. Revegetate the swale with native riparian species.	$ 3,706	$ 14,824
625	Unknown	12	The basin lacks internal structure, berms or microtopography, and vegetation that would otherwise extend the flow path to the outlet structure, increase residency time of stormwater, and facilitate attenuation of pollutants from the adjacent roadway, prior to emptying into a tributary to Quantico Creek.	Regrade the dry basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native riparian species.	$ 5,338	$ 21,351
627	5379	14	The basin lacks internal structure or microtopography, and vegetation that would otherwise extend the flow path, increase residency time, and facilitate attenuation of pollutants.	Regrade the dry basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native riparian species.	$ 1,606	$ 6,422
630	5463	14	The pond appears to be designed to function as a wet pond, but lacks a permanent pool. In addition, the pond would benefit from a forebay, microtopography, and native vegetation. While the pond appears to have sufficient storage capacity, the inflow and outfall are no more than 50ft apart, given the lack of internal structure.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Add berms along the pond bottom to lengthen the flow path from the proposed forebay to the outfall structure. Once structural work is complete, revegetate the pond with native wetland and riparian species.	$ 1,093	$ 4,373
630	5515	16	The basin is well-vegetated, and appears to have sufficient storage to handle runoff from the adjacent parking, but lacks internal structure or microtopography that could extend the flow path and residency time of captured stormwater.	Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native wetland and riparian species.	$ 3,233	$ 12,930
630	505	18	The basin is densely vegetated; so much so, that inflow and outflow structures are barely visible. While the existing vegetation may provide sufficient roughness, sediment capture, and pollutant attenuation capability, the basin could benefit from additional internal structure, berms or microtopography.	Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native wetland and riparian species.	$ 6,827	$ 27,307
640	5122	18	The basin appears to provide adequate storage and infiltration. However, a lack of vegetation along the eastern slope (along Main Street) has contributed to significant rill and gully erosion around the perimeter of the structure.	Regrade the side slopes around the basin, add topsoil and amendments, seed with mesic prairie species, and install erosion control blanket.	$ 2,871	$ 11,484
640	669	18	The pond would benefit greatly from a forebay at the two main inlet pipes, and additional berms or microtopography, and native vegetation between the inflow and outflow structures.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Add berms along the pond bottom to lengthen the flow path from the proposed forebay to the outlet structure, and revegetate the pond with native wetland species.	$ 3,840	$ 15,359
645	5379	16	The extended detention basin appears to have sufficient storage and is well-vegetated, but lacks internal structure or berms, resulting in a very short flow path between the basin inflow and outflow structures.	Add berms along the detention basin bottom to lengthen the flow path from inlet to outlet, and revegetate with native wetland and riparian species.	$ 2,092	$ 8,369
650	5000	15	While the pond was still under construction or repair at the time of the assessment, it would benefit from the addition of a forebay, as well as native wetland or riparian vegetation, once the surrounding grounds have been stabilized and restored.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Revegetate the pond with native wetland species.	$ 3,263	$ 13,051
665	533	18	The pond appears to be functioning as designed, with sufficient storage, and an adjacent forested slope providing beneficial canopy cover and shading of the pond. However, like most of the wet ponds included in this study, FAC-533 lacks a forebay to capture sediment and debris flowing into the pond, which would reduce blockage of the existing weir and increase the ease of maintenance.	Construct a forebay at the main entry point to the pond to capture silt, sediment, debris and floatables. Revegetate the pond with native wetland species.	$ 6,228	$ 24,914
665	9999	14	The pond lacks a forebay and native wetland or riparian vegetation that could alleviate the siltation problem, already observed at the inflow to the pond.	Construct a forebay at the main entry point to the pond, and revegetate with native wetland species.	$ 870	$ 3,479
680	9025	18	The pond is the largest of the basins included in the assessment, and appears to have adequate storage for runoff from the surrounding residential area. The pond is well-designed, with high aesthetic value, but could benefit from native wetland vegetation around the perimeter of the pond to increase pollutant attenuation capability and provide habitat.	Revegetate with native wetland species.	$ 21,109	$ 84,438
NA	5462	20	Stormwater runoff is conveyed to the existing pond via overland flow and steep-gradient swales, which provide limited intermediate storage or retention. While the pond is well-vegetated, it lacks internal structure, typically provided by berms or varied microtopography.	Add berms along the pond bottom to lengthen the flow path from the inflow to the outlet structure. In addition, add low rock check dams and revegetate with upland trees and shrubs to encourage storage and infiltration along steep gradient swales leading to the pond.	$ 8,893	$ 35,572
					$ 83,184	**$ 690,299**
				TOTAL COST OF DESIGN AND CONSTRUCTION		**$ 773,483**