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BUS RAPID TRANSIT IN MONTGOMERY COUNTY

MD 355 BRT Corridor Planning Study

Stormwater Management Technical Report

May 2019

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1 Introduction

The Montgomery County Department of Transportation (MCDOT) is preparing a *Corridor Summary Report* for Phase 2 of the MD 355 Bus Rapid Transit (BRT) Planning Study. The project is evaluating detailed concepts for providing enhanced transit service along MD 355 from Bethesda to Clarksburg in Montgomery County, Maryland.

As part of this study, three Build Alternatives were developed that would include varying degrees of potential roadway widening in the median and along the outside of the roadway. As part of the process to establish conceptual construction cost estimates and limits of disturbance (LOD), preliminary stormwater management facilities have been identified for the Build Alternatives A, B, and C.

The purpose of this Stormwater Management Technical Report is to discuss the stormwater quality and quantity requirements for the three Build Alternatives, the approach used to satisfy those requirements through Best Management Practices (BMPs), and the methodology used to select and place BMPs. This report also documents the findings of the attempts to meet the stormwater management requirements within the study area.

2 Approach

Stormwater management plays a critical role in transportation projects since they often add impervious surface. Drainage design standards strive to remove stormwater runoff from the impervious surfaces to maintain a safe facility, while stormwater management standards require that the volumes of runoff and rate of discharge maintain the existing water quality. When older facility designs do not meet current stormwater management standards, additional treatment is desired where practicable. In short, the goal is to remove detrimental nutrients from the increased stormwater runoff and release it at safe velocities and flow rates into the natural receiving system.

The MD 355 BRT project is no exception. With a 22-mile long corridor of proposed linear roadway work, stormwater management BMPs would be needed to prevent the impact of additional impervious surface on adjacent downstream waterways. It is important to have a thorough evaluation of the study area's existing and proposed conditions to understand the different stormwater management requirements that accompany each Build Alternative.

Analyzing existing and proposed stormwater conditions within the study area and the impacts on the watershed included the following actions:

- Identifying major watershed boundaries and the sub-watershed limits within them.
- Identifying Points of Interest (POIs) and Limits of Interest (LOIs) and their associated drainage areas.
    - POIs are defined by the point where runoff leaves the existing right-of-way in a concentrated channel or pipe.

  - LOIs are defined by the area where sheet flow leaves the right-of-way but is not captured by a POI.
- Determining the size, land cover, hydrologic soil groups, and time of concentration (Tc) for each drainage area.
- Identifying the Limits of Disturbance (LOD) for each Build Alternative based on proposed work.
- Calculating stormwater quality requirements for Impervious Area Receiving Treatment (IART) and calculating stormwater runoff volume requirements for Environmental Site Design (ESDv) and Overbank Flood Protection Volume (Qp) based on MDE guidelines.
- For documentation purposes, noting if waivers or variances are recommended based on Maryland Stormwater Management Guidelines.

Through investigation, it was determined that there are four major watersheds in the study area; the Potomac River, Rock Creek, Cabin John Creek, and Seneca Creek. These four watersheds influenced the division of the drainage portion of the project into four sections (Sections 1-4), which differ from the seven geographic segments used to describe the alternatives in the *Alternatives Technical Report*. Within the four watersheds are nine sub-watersheds; Little Falls, Lower Rock Creek, Cabin John Creek, Watts Branch, Upper Rock Creek, Muddy Branch, Lower Great Seneca Creek, Middle Great Seneca Creek, and Little Seneca Creek. There are 146 POIs and LOIs within the sub-watersheds for each Build Alternative across all Sections 1 through 4.

From the derived information, water quality and quantity requirements were calculated for each POI / LOI in each of the three Build Alternatives. Requirements are shown in detail for Alternatives A, B, and C in **Appendices B**, **C**, and **D,** respectively.

- Analysis has been completed for Alternative A, which includes mixed traffic operations, minor widening at queue jump locations, and new BRT stations.

- Analysis has been completed for Alternative B, which includes roadway widening to include new dedicated median lanes where feasible and new BRT stations.

- Analysis has been completed for Alternative C, which includes roadway widening to include new dedicated curb lanes where feasible and new BRT stations. Requirements for Alternative C used the analysis for Alternative B with a 30% reduction to water quality requirements, since the amount of widening needed was more than 30% less than Alternative B.

The scope of work and broader impact of Build Alternatives A, B and C, are discussed in length in the *Corridor Summary Report*.

3 Data

Topographical information for the study area is a compilation of Montgomery County GIS files and project flown contours from recent aerial data. The flown topography is restricted to the project corridor and was supplemented with GIS contours to encompass the larger area necessary to define existing watershed and drainage area boundaries. GIS and aerial derived contours are shown at two-foot intervals. Existing and proposed drainage area maps that are found in **Appendix A.1** only show GIS contours, to avoid confusion and clutter on the drawings. There is no spot grade information available, so drainage area divisions are approximate but not exact.

Soil information was gathered from the Natural Resources Conservation Service (NRCS) Web Soil Survey for Maryland. The information used from the survey was a mapping of hydrologic soil groups and their boundaries. Soils in the study area were mostly groups B and D with limited areas of group C.

No formal utility survey has been conducted so storm sewer data was compiled manually from Montgomery County GIS files and supplemented with aerial and street view images from Google Earth. This approximate storm sewer representation is considered reasonable for this preliminary stage of the design. Other than the storm sewer network, no underground utility information is known or shown.

4 Methodology

4.1 Stormwater Management Requirements

This project is a Montgomery County managed project that would occur predominately on property that is or will become Maryland Department of Transportation State Highway Administration (MDOT SHA) right-of-way or easements. Stormwater management requirements for the proposed MD 355 BRT Planning Study and existing roadways being reconstructed for the project will conform to the Maryland Department of the Environment (MDE) 2000 Stormwater Design Manual and Montgomery County Code Chapter 19 entitled Erosion, Sediment Control and Stormwater Management, unless specified otherwise. For this preliminary study, the requirements that impose stricter stormwater management have been followed, which is generally Montgomery County stormwater management requirements. The review and approving authority for the stormwater management designs is assumed to be the Montgomery County Department of Permitting Services (DPS), which has stricter guidelines than MDE. If the approving authority changes as design progresses, this assumption would be revised, and guidance would be updated as needed.

As a County project, new and existing impervious areas are treated similarly for stormwater management and all impervious area within the LOD shall be considered Impervious Area Requiring Treatment (IART). Stormwater management would be implemented to manage runoff for the project within the LOD for water quality and quantity control. Stormwater management for the proposed alignment for water quality would be provided using environmental site design (ESD) to the maximum extent practicable (MEP). Stormwater quantity management would be provided for the one-year storm (ESDv) for the entire alignment and for the ten-year storm where flooding problems or inadequate drainage conveyance are identified by the County within the Project Area.

BMPs to meet stormwater management requirements within the Practice Area were selected by use of the following general discipline goals and practices:

GOALS

- Full water quality management of all new and disturbed impervious areas has been managed as feasible.
- ESD has been used to the maximum extent practicable (MEP) within the right-of-way.
- Post development for the net increase of all IART has been managed to meet existing conditions.
- Runoff from the proposed new IART will be treated to a P_E = one inch or larger as practicable.
- Where on-site management is unfeasible, off-site stormwater BMP opportunities within the same sub-watershed have been identified.

PRACTICES

- TR-55, which uses the Natural Resources Conservation Service (NRCS) unit hydrograph method, with Type II rainfall distribution, has been used to determine volume and peak flows at each POI and LOI; see note (a) below.
- Site characterization data for analyses used: existing Montgomery County GIS shapefiles for land use, impervious surfaces, and storm sewer systems; recent aerial data to adjust land use discrepancies as appropriate; project flown topography from recent aerial data; and the NRCS Web Soil Survey for Maryland.
- POIs / LOIs will remain the same for existing and proposed conditions as no grading is proposed and the roads are curbed so changes to road conditions will continue to drain to the existing storm sewer system outfalls. However, the drainage area for each may have shifted in the proposed drainage area map due to changes in runoff pathways caused by proposed stormwater management facilities.
- Alternative BMPs have been implemented if necessary that include non-ESD practices in the right-of-way, off-site BMPs or the purchase of pollutant reduction credits.
- Impacts to adjacent private properties have been minimized as feasible; where significant impacts occur, efforts have been made to place stormwater management on the entirety of one or a few properties rather than major impacts to many properties.

Note (a): Maryland and Montgomery County now use the most recent rainfall distribution information available through NOAA Atlas 14 and, in WinTR-55, NOAA Atlas Type C distribution. The Urban Hydrology for Small Watersheds, Technical Release No. 55 (TR-55) released June 1986 provides graphical tools (such as Figure 6-1, Approximate detention basin routing for rainfall types I, IA, II and III) to size BMPs using stormwater volume detention. These tools were not updated using NOAA Type C distribution data. As an economical planning tool, this study used the NRCS Type II rainfall distribution for Montgomery County that is contained in WinTR-55 and the graphical sizing tools in the TR-55 manual. Both TR-55 and the Type II distribution are anticipated to oversize rather than undersize the volume of stormwater that is needed to manage runoff from the project. Thus, this is a conservative approach towards identifying the necessary storage volume and footprint of BMPs to manage stormwater runoff for the project.

As stated in Montgomery County Code, Section 19-24, (a) (3), "[t]he MEP standard is met when channel stability is maintained, pre-development groundwater recharge is replicated, nonpoint source pollution is minimized, and structural stormwater management practices are used only when absolutely necessary." This guidance has been used to determine if ESD practices can practicably meet on-site stormwater management requirements before alternative BMPs are considered. Projects can use specific stream or wetland restoration measures to meet stormwater management requirements if the Director of DPS grants a waiver. Projects can also use alternative stormwater management measures that include on-site structural BMPs and off-site structural BMPs / retrofits or ESD to provide water quality treatment.

As a planning level study, hydrologic analysis focused on compliance at the POI / LOI and not further downstream. Detailed design that is to follow as a separate project(s) would be responsible for identifying ESD and structural practices that maintain downstream channel stability, replicate pre-development groundwater recharge, minimize nonpoint source pollution, and address the impact of hydrograph timing modifications.

An initial LOD was assumed in order to calculate the water quality volume requirements and the ESDv. This LOD was based on preliminary roadway improvements but did not include all bicycle and pedestrian amenities, grading impacts, and accommodation for construction. When the design was completed it was determined that the final LOD was approximately 30% larger than the initial assumed LOD. Therefore, a 30 percent increase was applied to the initial LOD to more accurately represent the requirements.

The maps in **Appendices B, C,** and **D** show the final LOD for construction of each alternative, including maintenance of traffic, and shows the complete impacts of the project but is not precisely represented in the requirements. Creating the roadway design and the stormwater management plan was a synchronous and sometimes iterative process which made it difficult to have a plan view LOD that exactly matched the LOD area used in the requirement calculations.

The right-of-way in the requirements was expanded only in areas where proposed work went beyond the existing right-of-way; it too was expanded by 30 percent. If there was no right-of-way present within an area, the edge of road pavement was offset by five feet and used as the right-of-way within the requirements.

In the requirement tables found in **Section 5 of the Appendices**, a POI or LOI is listed as having "No Impacts" in the Proposed Conditions columns when there is no work being done in that POI or LOI. While no work is proposed, treatment provided in that POI / LOI can be used to compensate for ESDv or IART deficits in other POIs of the same sub-watershed. Montgomery County does not require quantity management unless the area is flood prone or the local systems are affected. It was assumed that stormwater quantity management is necessary if the outfall is located on private property and the amount of new impervious area is greater than 0.20 acres.

Stormwater quality requirements for each POI should be satisfied within the POI. If that is not possible, then it should be satisfied in a POI of the same sub-watershed. Stormwater quantity requirements must be met within their respective POI, no compensation can be found in neighboring POIs of the same sub-watershed. If compensation was unable to be found in another POI of the same sub-watershed a variance or waiver is noted.

MDE guidelines dictate that stormwater quality deficits need a variance while stormwater quantity deficits require a waiver.

4.2 Stormwater Management Facility Design

Stormwater management design has been based on the criteria specified in the following design documents:

- Maryland Stormwater Management Guidelines for State and Federal Projects: February 2015 and associated Technical Memoranda
- Maryland State Highway Administration Sediment and Stormwater Guidelines and Procedures: November 24, 2015 and associated Technical Memoranda
- Maryland Stormwater Design Manual, Volumes I & II (October 2000, Revised May 2009) and related supplements and design guidance
- MDE, Stormwater Design Guidance: Rainwater Harvesting
- MDE, Stormwater Design Guidance: Submerged Gravel Wetlands
- MDE, Stormwater Design Guidance: Environmental Site Design Redevelopment Examples
- MDE, Stormwater Design Guidance: Addressing Quantity Control Requirements
- MDE, Stormwater Design Guidance
- Montgomery County Stormwater Management design requirements based on Chapter 19 of Montgomery County Code

4.2.1 BMP Sizing Criteria

- BMPs within the MD 355 right-of-way were sized according to the Maryland 2000 Stormwater Design Manual.
- Off-site BMPs that will be located on Montgomery County property followed Montgomery County Standards and were sized according to DPS criteria. Though tailored to criteria established by the County, these designs meet the Maryland 2000 Stormwater Design Manual.
- Underground storage (Silva Cell or similar) was calculated assuming a 37.5 percent volume capacity. A depth of four feet has been assumed for all underground storage facilities.
- Planter Boxes were sized based on accepted criteria used during the Purple Line Project preliminary design analysis.
- For all underground facilities, the BMP size was determined by using the calculated treatment design volume multiplied by 1.10 to account for construction offsets and post-construction operation and maintenance required in the field.

- For all graded, surface facilities, the BMP size was determined by using the calculated treatment design volume multiplied by 1.25 to account for grading and outfalls.
- All surface facilities assumed a six-inch depth for water surface ponding.
- All infiltration practices assumed a 24-inch Biosoil Mixture depth.
- Underground sand filters were sized for the maximum of one-acre drainage area as the base assumption and will provide a standard size based on the Montgomery County Separator Sand Filter (MCSSF) Detail.

4.2.2 Determining the Effective Impervious Area Treated

Filtering BMPs within MDOT SHA right-of-way were sized by calculating the effective ESDv using the Surface Storage Volume Tables for Bioretention, Bioswales, Rain Gardens, and Landscape Infiltration (MDE32012). This approach considers the treatment area when determining the effective impervious area treated and excludes the forebay area. This approach is only accepted by MDE for MDOT SHA projects that use their Biosoil Mixture specifications.

The Maryland 2000 Stormwater Design Manual allows for the calculation of ESDv based on total surface storage volume provided, which can include forebay and treatment area storage. Because of the limited space along the MD 355 corridor, proposed BMPs often have forebays sized according to pretreatment design standards, but then have inadequate space available to size a treatment area that meets the P_E target of treating one inch of precipitation runoff. In these cases, both the MDOT SHA approach and the MDE approach are calculated to determine which provides credit for the larger ESDv. For offsite BMPs, the ESDv approach developed by Montgomery County, is used. This follows the MDE approach for surface storage in forebay and treatment areas.

Once ESDv is determined, the equivalent P_E is calculated for each BMP. The ESD and Alternative BMP design parameters shown in **Table 4-1** have been used to design the stormwater management facilities with all BMPs designed to meet MDE's guidelines.

Table 4-1: ESD and Alternative BMP Design Guidelines

Stormwater Management Practice	Drainage Area (DA) (SF)	Minimum Surface Area (A_f) % of DA	Surface Storage Depth (Inches)	Design Dimension for Project			Notes
				Width* (LF)	Filter Thickness Inches	Gravel & Underdrain Thickness Inches	
Grass swale	<43,560	2% for swale bottom	See notes	4 for swale bottom	NA	12	Bottom slope 4% or less; Bottom width 2 to 8 feet; Max flow depth for ESDv treatment is 4 inches; Setback at least 10 feet from structures or use impermeable liner; Channel side slopes 3:1 (W:H) or shallower; Max velocity of 1 fps; Min freeboard of 6 in. at 10-yr, 24-hr storm event
Bioswale					24		
Submerged gravel wetlands	>43,560	NA	6	6	24	N/A	Pretreat 10% of total ESDv; Storage volume to assume gravel porosity of 40%
Bioretention	Max. 10 acres	2%	6	TBD	30	18	Up to 3-acre DA is considered as ESD
Micro-bioretention	<20,000	2%	6	6	24	12	A railing is required if the ponding depth exceeds 4.43 inches; Underdrain shall not intercept groundwater
Tree Planter Box, or similar		0.45%		N/A			
Silva Cell planter, or similar	<20,000	N/A	6	6	16.7, 30.9 or 43	N/A	Storage volume is 94% of surface storage and 37.5% of subsurface aggregate volume
Underground Sand Filter	<43,560	See County Standard Detail			36	N/A	Sized for the maximum of 1-acre drainage area as the base assumption

* The width of the design practice is 72 inches (6 feet) unless specified otherwise at a specific site location.

Existing stormwater management facilities affected by the proposed MD 355 BRT alignment would be replaced volumetrically based on their original design functionality as per MDE or local agency standards that have jurisdiction of the existing facilities. Existing stormwater management facilities being retrofitted to jointly provide stormwater management for the MD 355 BRT project and its original functionality would be designed to provide the original design storage volume in addition to storage for the MD 355 BRT project.

When ESD facilities cannot be incorporated or cannot achieve full treatment, the following facilities have been used:

- Water Quality Inlets: Maximum runoff that can be treated is limited to one inch.
- High Flow Media: The proprietary method increases the media flow rate to optimize the runoff volume treated and reduce the footprint required in urban applications. MDE has approved treatment of one inch of runoff for ESD facilities with high flow media. A 91-square foot high-flow media surface area can treat 20,000 square feet of drainage area.

Structural BMPs would need to be considered in locations where ESD devices are not feasible. For example, quantity management can be provided by underground detention chambers or retrofitting existing surface ponds. The underground detention chambers have been sized to occupy no more than one travel lane width for maintenance reasons.

Drainage area boundaries have been revised in the Proposed Drainage Area Maps found in **Appendices B.1, C.1, and D.1** due to altered runoff pathways caused by the proposed stormwater management facilities and buildings to be removed to accommodate the proposed roadway alignments.

5 Findings

5.1 Stormwater Management Requirements

Stormwater requirements for ESDv, IART and Qp10, as discussed in **Chapter 2,** are shown in greater detail in **Section B.6, C.6, and D.6 of the Appendices**. A summary of the requirements for each Build Alternative are found in **Section B.5, C.5, and D.5 of the Appendices** broken down by section and sub-watershed.

5.2 BMP Placement Approach

Stormwater management facilities throughout the project corridor and adjacent drainage areas were placed using the following assumptions:

- BMPs were proposed within the sidewalk or roadway only when realignment work already was proposed. Consequently, no demolition or relocation of existing sidewalks or roadways was proposed solely for stormwater management purposes.
- No BMPs were proposed on federal property.
- Urban areas like Bethesda offered limited or no room for BMP placement because of lack of open space and lack of proposed work in the area.
- BMPs were proposed within the project corridor first before considering offsite BMPs.

- Major impacts to residential properties were avoided where possible.
- Areas of open spaces within the right-of-way were a priority for BMP placement.
- Linear BMPs required an immediate inlet downstream to receive overflow from higher than design storms.
- Work to the existing storm drain system due to BMP placement was minimized.
- Stormwater quality requirements were satisfied within each POI to the MEP, with BMPs proposed in adjacent POIs within the same sub-watershed if a deficit remained.
- Stormwater quantity requirements are to be met within their respective POI to the MEP.
- When stormwater requirements cannot be met, stormwater quality deficits need a variance while stormwater quantity deficits need a waiver according to MDE guidelines.
- Areas with steep slopes were avoided when BMP installation would require excessive grading and / or retaining walls.
- Areas of dense forest were avoided. Selection of individual trees for removal occurred in other situations on a case-by-case basis.

5.3 BMP Selection

Numerous BMP types were considered for stormwater treatment, as discussed in **Chapter 4**, but only six were used in the conceptual design phase for various reasons. The reasons for using these six practices and criteria for their placement are provided below.

5.3.1 Planter Boxes (Bioretention)

Planter Boxes have vertical side slopes which reduces the grading / LOD impact of the practice and they can be placed in open spaces with a minimum open width of six feet (assuming a bottom width of four feet). Because of their small footprint and linear nature Planter Boxes were utilized both onsite and offsite.

Some of the considerations used to place and size Planter Boxes include the following:

- Sufficient linear open space was needed for the forebay and treatment areas.
- A storm drain was needed immediately downstream for surface overflow and underdrain connection.
- The design used one inlet at the forebay to route flow into the system and one outlet for overflow.
- Runoff that drained from sidewalks to the practice was ignored in ESDv and IART calculations because this flow would not follow the full flow path through the forebay to the treatment area.
- P_E and ESDv calculations used forebay and treatment surface areas in calculating water quality credit.
- Curbs cuts were used to direct runoff to the practice.

5.3.2 Bioswales

Bioswales are a linear practice, with multiple inlet points, preferably from sheet flow, to the treatment area that can operate in an open area as wide as 20 feet (assuming an eight-foot wide buffer on each side for grading and minimum bottom width of four feet). Bioswales require mild slopes and an outfall point, usually a yard inlet. Unlike planter boxes, bioswales have graded side slopes at four horizontal to one vertical (4:1) allowing them to be deeper and offer more storage volume.

5.3.3 Pervious Pavement

Pervious Pavement has been proposed in several sidewalk areas across all alternatives because it supports pedestrian traffic and stormwater management. Because of the need for infiltration into the subsoils, it was not considered in areas with hydrologic soil group D soils. The drainage area to the Pervious Pavement for quality calculations was limited to the surface area of the facility.

5.3.4 Microbioretention and Bioretention

In situations where suitable amounts of open space were available, bioretention or microbioretention was the preferred facility. Bioretention basins offer good treatment credit, are aesthetically pleasing, and are relatively easy to maintain.

5.3.5 Underground Water Quality Structures

Underground facilities used for stormwater quality treatment have been designed as concrete structures with a seven-foot minimum width, a height of six feet and a five-foot buffer on all sides for maintenance access. The facility is assumed to be a Rainstore3 type of facility (or similar) and guidelines from that product line were used in sizing and crediting. In areas where underground facilities were proposed, it was assumed that there were either no underground utilities or that they could be easily relocated. Facilities were placed at least 15 feet away from other structures.

Facilities were mainly placed under parking lots, open areas, and dedicated bus lanes in Alternative B. With the exception of the bus lanes, facilities were not placed under roadways.

5.3.6 Water Quantity

Stormwater quantity requirements were satisfied where possible by either an underground detention structure or a retrofit expansion of an existing management pond.

Underground quantity structures were designed to be a large concrete detention structure placed in areas adjacent to the existing storm sewer network and away from roadway travel lanes. These units were used throughout the Project Area in POIs that had quantity management requirements. Opportunities to use ponds and surface BMPs were limited due to a lack of open space and strict criteria of meeting quantity objectives within the POI.

Retrofit expansion of an existing pond has been proposed in POI 302 for Alternatives B and C. There is an existing wet pond at Bohrer Park in Gaithersburg located within POI 302. An expansion of the pond could be proposed, totaling 12,000 sf of additional surface area around the western perimeter of the pond with an assumed depth of one foot. However, this pond retrofit has not been incorporated into the final LOD shown on the maps because of lack of information about the facility and uncertainty as to whether this retrofit is permissible.

6 Summary

Meeting stormwater requirements for MD 355 BRT may be a challenge depending on the Build Alternative implemented. The findings of this stormwater management study are provided below by Build Alternative. Each Build Alternative included a 30% increase in the LOD to account for the footprint of the stormwater BMPs.

6.1 Alternative A

The requirements for Alternative A were satisfied for every sub-watershed except for Little Falls (located in Bethesda) because of the urban nature of the area, as previously discussed in **Section 5.2**. To satisfy the requirements of Alternative A, 68 BMPs would be included throughout the study area.

Table 6-1 provides values by section and sub-watershed for the following:

- Stormwater requirements created by the proposed MD 355 BRT study area.
- Stormwater treatment that is proposed.
- Stormwater quality and quantity credits earned by the proposed treatment practices. Negative values indicate a deficit in meeting the stormwater requirements.

Table 6-1: Summary of Stormwater Management Findings for Alternative A

		SWM Requirements*				Treatment Provided			Credit/Debit		
Section	Sub Watershed	WQv (ESDv min.) (cf)	ESDv (cf)	IART (ac)	Qp (cf)	ESDv (cf)	IAT (ac)	Qp (cf)	ESDv (cf)	IAT (ac)	Qp (cf)
Section 1	Little Falls	533	1,012	0.15	0	0	0.00	0	-1,012	-0.15	0
	Lower Rock Creek	9,962	18,470	2.79	68,066	23,339	3.04	69,100	4,869	0.25	1,034
Section 2	Cabin John Creek	2,633	4,741	0.74	0	8,867	1.55	0	4,126	0.81	0
	Lower Rock Creek	3,203	5,758	0.90	0	7,021	1.27	0	1,263	0.37	0
	Watts Branch	4,354	8,983	1.23	0	11,120	1.29	36,840	2,137	0.06	36,840
	Upper Rock Creek	4,253	8,547	1.20	23,192	9,633	1.22	24,000	1,086	0.02	808
	Muddy Branch	0	0	0.00	0	0	0.00	0	0	0.00	0
Section 3	Muddy Branch	449	951	0.12	0	13,120	1.39	0	12,169	1.27	0
	Lower Great Seneca Creek	1,026	1,847	0.29	0	5,689	0.55	0	3,842	0.26	0
	Middle Great Seneca Creek	2,908	5,631	0.82	0	31,242	4.72	0	25,611	3.90	0
	Little Seneca Creek	2,546	4,769	0.72	0	5,480	0.86	0	711	0.14	0
Section 4	Little Seneca Creek	1,750	3,256	0.50	0	4,177	0.51	0	921	0.01	0

* SWM Requirements were based on a 30% increase in the LOD
Note: For more detailed information pertaining to the requirements and treatment provided refer to **Appendix B.6**
IAT is impervious area treated by the stormwater BMPs proposed
WQv is water quality volume to be treated for a rainfall depth of 1 inch

6.2 Alternative B

Alternative B would include the greatest amount of proposed impervious area, including roadway and sidewalk widening and a median bus lane. Consequently, it includes the greatest requirements for stormwater quality and quantity, approximately eight times larger than those for Alternative A. The LOD is larger for Alternative B, which presents more areas for BMP installation, specifically under the dedicated bus lane. Water quality requirements were met for all but three sub-watersheds, and one other sub-watershed has an unmet requirement for water quantity. 280 BMPs have been proposed for Alternative B. **Table 6-2** provides a summary of stormwater management findings for Alternative B.

Table 6-2: Summary of Stormwater Management Findings for Alternative B

		SWM Requirements*				Treatment Provided			Credit/Debit		
Section	Sub Watershed	WQv (ESDv min.) (cf)	ESDv (cf)	IART (ac)	Qp (cf)	ESDv (cf)	IAT (ac)	Qp (cf)	ESDv (cf)	IAT (ac)	Qp (cf)
Section 1	Little Falls	495	941	0.14	0	0	0.00	0	-941	-0.14	0
	Lower Rock Creek	37,815	69,488	10.30	71,722	71,476	10.49	73,600	1,988	0.19	1,878
Section 2	Cabin John Creek	74,609	134,485	20.13	0	135,778	19.67	1,500	1,293	-0.46	1,500
	Lower Rock Creek	18,902	34,022	5.18	0	38,155	5.70	0	4,133	0.52	0
	Watts Branch	14,411	23,409	3.85	2,435	33,398	4.10	2,700	9,989	0.25	265
	Upper Rock Creek	28,437	55,832	7.55	23,192	59,649	9.45	30,800	3,817	1.90	7,608
	Muddy Branch	3,647	6,803	0.95	0	8,566	1.01	0	1,763	0.06	0
Section 3	Muddy Branch	24,113	50,405	6.34	97,962	59,222	6.58	30,700	8,817	0.24	-67,262
	Lower Great Seneca Creek	12,369	22,264	2.98	0	34,690	3.74	0	12,426	0.76	0
	Middle Great Seneca Creek	66,176	129,580	17.60	11,979	144,923	17.01	12,000	15,343	-0.59	21
	Little Seneca Creek	1,246	2,242	0.36	0	3,602	0.49	0	1,360	0.13	0
Section 4	Little Seneca Creek	1,547	2,345	0.43	0	4,630	0.44	0	2,285	0.01	0

* SWM Requirements were based on a 30% increase in the LOD
Note: For more detailed information pertaining to the requirements and treatment provided refer to **Appendix C.6**
IAT is impervious area treated by the stormwater BMPs proposed
WQv is water quality volume to be treated for a rainfall depth of 1 inch

6.3 Alternative C

Detailed requirements were not developed for Alternative C. It was developed using a 30 percent decrease in the the LOD and impervious area of Alternative B. The study team considers this approach to be reasonable, though it may potentially overestimate the stormwater requirements and potentially underestimate the area of the LOD. As a result, meeting the potentially greater than necessary requirements proved challenging within a smaller LOD than Alternative B.

Six sub-watersheds have water quality debts remaining for both ESDv and IART, and one sub-watershed had a debt remaining for water quantity. Because the requirements for Alternative C are estimates and were not developed in the same way as Alternatives A and B, the deficits may not be an ideal representation of the SWM requirements. 173 BMPs have been proposed for Alternative C. **Table 6-3** provides a summary of stormwater management findings for Alternative C.

Table 6-3: Summary of Stormwater Management Findings for Alternative C

Section	Sub Watershed	SWM Requirements*				Treatment Provided			Credit/Debit		
		WQv (ESDv min.) (cf)	ESDv (cf)	IART (ac)	Qp (cf)	ESDv (cf)	IAT (ac)	Qp (cf)	ESDv (cf)	IAT (ac)	Qp (cf)
Section 1	Little Falls	347	659	0.10		0	0.00	0	-659	-0.10	0
	Lower Rock Creek	26,527	48,926	7.23	48,980	52,357	7.37	68,400	3,431	0.14	19,420
Section 2	Cabin John Creek	51,057	91,978	13.76	1,016	89,001	11.15	1,500	-2,977	-2.61	484
	Lower Rock Creek	13,808	24,850	3.79	0	26,884	3.81	0	2,034	0.02	0
	Watts Branch	10,082	16,432	2.70	1,705	13,451	1.61	2,700	-2,981	-1.09	996
	Upper Rock Creek	19,893	39,061	5.29	15,175	50,916	6.00	22,000	11,855	0.72	6,825
	Muddy Branch	2,545	4,698	0.67	0	0	0.00	0	-4,698	-0.67	0
Section 3	Muddy Branch	16,872	35,741	4.44	68,988	58,348	6.41	30,700	22,608	1.97	-38,288
	Lower Great Seneca Creek	8,854	15,937	2.14	0	7,595	0.78	0	-8,342	-1.36	0
	Middle Great Seneca Creek	46,135	90,311	12.27	8,332	58,231	7.42	12,000	-32,079	-4.85	3,668
	Little Seneca Creek	872	1,569	0.25	0	3,602	0.49	0	2,033	0.24	0
Section 4	Little Seneca Creek	1,083	1,642	0.30	0	5,369	0.51	0	3,728	0.21	0

* SWM Requirements for Alternative C were based on Alternative B. The LOD was increased by 30% to compensate for SWM BMPs, but requirements were decreased by 30% due to the reduction in pavement quantities compared to Alternative B. Existing Drainage Areas were used and no shifts were considered within the Drainage Areas.

Note: For more detailed information pertaining to the requirements and treatment provided refer to **Appendix D.6**

IAT is impervious area treated by the stormwater BMPs proposed

WQv is water quality volume to be treated for a rainfall depth of 1 inch

6.4 Conclusion

This report focused on the stormwater management that would be required to address the redeveloped and new impervious areas for three of the Build Alternatives being evaluated. Stormwater management practices are to be implemented wherever road impervious area is altered. The objective is to manage stormwater so that proposed changes do not increase environmental impacts beyond current conditions and, ideally, reduce the impacts. Stormwater quantity refers to the volume of runoff and peak discharges. Stormwater quantity, especially the peak discharges, are to be managed within the POIs and LOIs. Stormwater quality is to be managed within POIs and LOIs but can be managed with off-site practices within the same sub-watershed. Stormwater quality is to use ESD practices to the MEP, though the interpretation of MEP will need to be defined, as discussed later in this section.

Chapter 6 provides **Tables 6-1**, **6-2** and **6-3** for Alternatives A, B and C, respectively. These demonstrate that stormwater quantity and quality requirements can be met for Alternative A, and nearly met for Alternative B. However, Alternative C has proven more complex. Stormwater management was not met in all alternatives because the urban areas of Bethesda, Rockville Town Center, and Gaithersburg do not have adequate open space to install stormwater BMPs in their respective sub-watersheds. This deficit would be accommodated within other parts of the larger watershed. Alternatives B and C used ESD to the MEP to manage stormwater quality and proposed additional controls in open space and underground facilities to manage stormwater quantity. Discounting that some sub-watershed requirements were not fully met, if the total water quality and quantity requirements are summed for each Alternative, Alternatives A and B exceeded the stormwater requirements, while Alternative C was under by less than two percent for water quality volume and by almost 14 percent for impervious area treated.

As part of this Phase 2 study, the installation of stormwater practices to the MEP was applied in available open space, and within the proposed MD 355 BRT study area on adjacent properties where right-of-way impacts would require the purchase of the entire parcel.

If Alternative B, C, or a hybrid alternative is selected as the Recommended Alternative, more detailed analysis would be conducted to address stormwater management issues as the design advances. This would include refining the LOD associated with the proposed roadway improvements and updating the associated stormwater management requirements. The level of encroachment onto private property may need to be further explored if adequate area within and immediately adjacent to the MD 355 BRT right-of-way is not available to implement all stormwater management BMPs necessary to meet the stormwater management requirements.