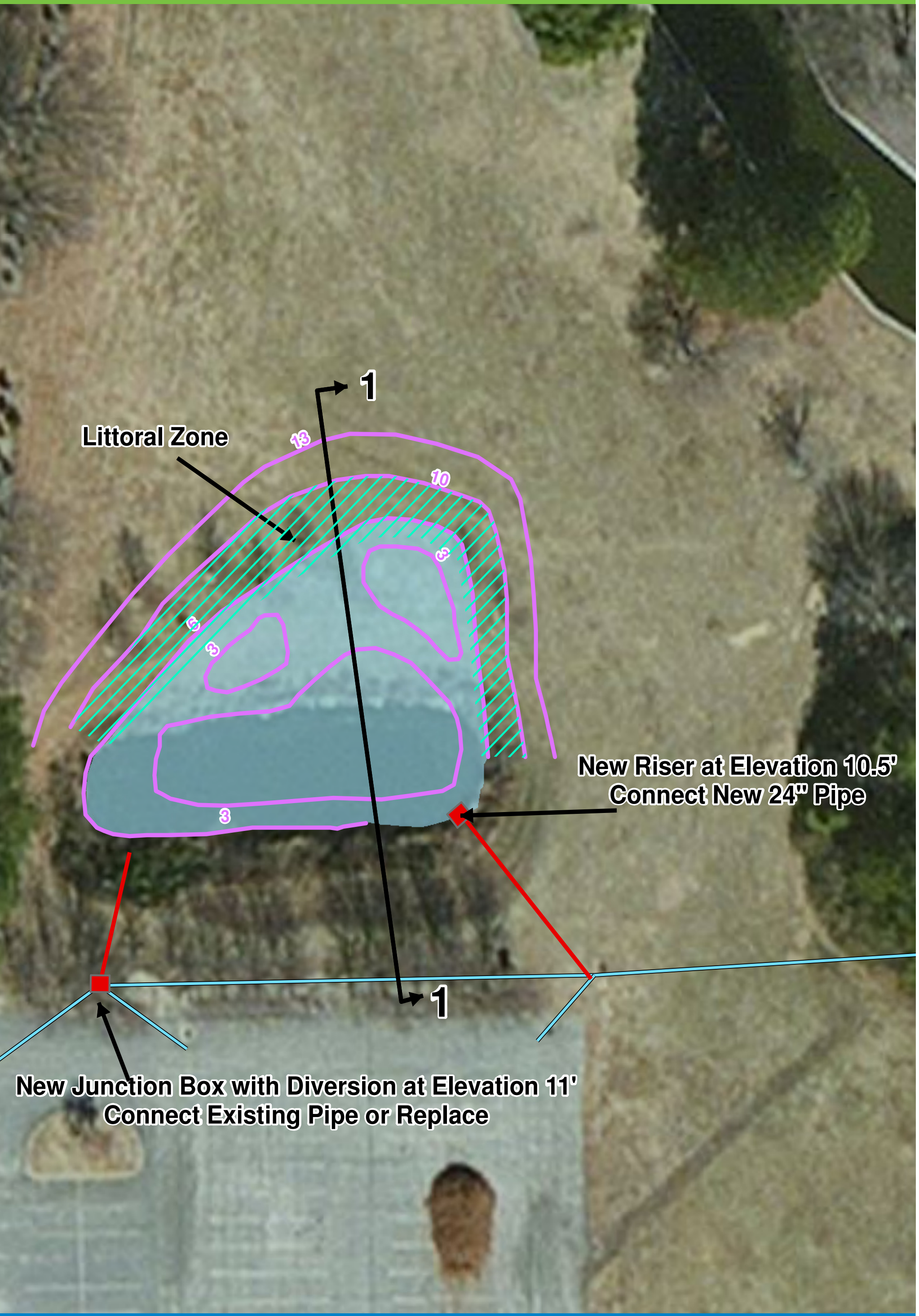
City of Norfolk

DRAFT REPORT

Stormwater BMP Retrofit Evaluation

MAY 2013



CDM Smith

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Section 1

Background and Purpose

1.1 Background and Purpose

In December 2010, the U.S. Environmental Protection Agency (EPA) established the Chesapeake Bay Total Maximum Daily Load (TMDL). EPA has characterized the Chesapeake Bay TMDL as a historic and comprehensive "pollution diet" to restore clean water in the Chesapeake Bay and the region's streams, creeks and rivers. Specific requirements are defined to limit annual discharges of nitrogen, phosphorus and sediment. As a result, implementation of best management practices (BMPs) at the local level is needed to reduce nutrients and sediment. The potential implications facing each locality include costs impacts to modify existing stormwater infrastructure, revisions to comprehensive plans and local ordinances for additional land use and BMP requirements, and the documentation and tracking of progress toward compliance with the TMDL.

Virginia's effort to comply with the Chesapeake Bay TMDL is documented in the Phase II Watershed Implementation Plan (WIP). As a first step, one opportunity for progress towards required nutrient and sediment reductions is to retrofit, or modify, existing stormwater BMPs to enhance nutrient and sediment load reductions. These retrofits provide opportunities to cost-effectively implement improvements to provide needed water quality benefit for TMDL compliance.

The TMDL allocation is still being evaluated by US EPA, but it is expected that some allocation for TN, TP, and TSS reduction will be required by the City; therefore, this evaluation was performed to determine cost-effective options for load reduction and identify ranges for costs for future load reduction planning.

1.2 Project Scope

CDM Smith performed an evaluation of 27 existing stormwater BMPs for the purpose of identifying and evaluating candidate retrofit opportunities to improve the water quality benefits of the BMPs. The candidate BMPs presented in **Table 1-1** were selected by City staff based on prior knowledge of general characteristics, existing conditions and expected potential for improvement. Examples of existing BMPs that were excluded from the list of candidate sites include existing BMPs that serve small areas, BMPs constructed to meet current standards, and BMPs where modifications would not likely be implementable. The candidate BMP retrofits were evaluated, prioritized and screened based on a variety of factors ranging from nutrient reduction potential to relative cost and constructability. The top five BMP retrofit opportunities were selected for further evaluation and conceptual design of improvements. Table 1-1 summarizes the 27 candidate BMPs, as provided by the City. An overall map showing the locations of the candidate BMPs is presented as **Figure 1-1.**

The remainder of this report presents the evaluations and analyses that were conducted, and the conceptual designs of the top five BMP retrofit opportunities. The organization of the report includes the following sections:

- Section 2 – BMP Evaluation and Prioritization
- Section 3 – BMP Existing Conditions Analysis

- Section 4 – BMP Conceptual Design Conditions Analysis
- Section 5 – Water Quality Analysis
- Section 6 – Analysis of Probable Costs
- Section 7 – Conclusions and Recommendations

Table 1-1 – Summary of BMPs Evaluated

Project ID	Site ID	Site Title	SWMF Type[1]
1	05-0087	Sherwood Forest Elementary School	Detention Basin
2	T107	Norfolk Public Schools Transportation Operations	Detention Basin
3	T51	Norfolk Juvenile Detention Center	Detention Basin
4	00-4462	Titustown Recreation Center	Extended Detention Basin
5	09-0030	2nd Patrol Division	Extended Detention Basin
6	92067.082	Norview Middle School	Extended Detention Basin
7	92067.082	Norview Middle School	Extended Detention Basin
8	01-0053	Roberts Pond	Retention Basin
9	01-0095	Lamberts Point Pond	Retention Basin
10	02-0010	Norview High School	Retention Basin
11	02-2367	ODU University Village	Retention Basin
12	06-0059	Coleman Place Elementary School	Retention Basin
13	91067.029	Lake Liberty, NRHA	Retention Basin
14	99-3931	Central Business Park	Retention Basin
15	S1	Anne Outten Pond	Retention Basin
16	S14	Silver Lake/Duck Pond	Retention Basin
17	S15	Meadow Lake	Retention Basin
18	S2	Ballentine Elementary School Lake	Retention Basin
19	S6	Lake Modoc	Retention Basin
20	S8	Lake Scott	Retention Basin
21	T103	Norfolk Botanical Gardens - Visitors Reception	Retention Basin
22	T276	NPD 2nd Precinct Training Center	Retention Basin
23	T559	Central Brambleton	Retention Basin
24	T66/S	Cedar Grove Parking Lot	Retention Basin
25	n/a	Light Rail Station	Retention Basin
26	n/a	Norfolk Commerce Park Pond 3	Detention Basin
27	n/a	Wells Fargo Pond	Retention Basin

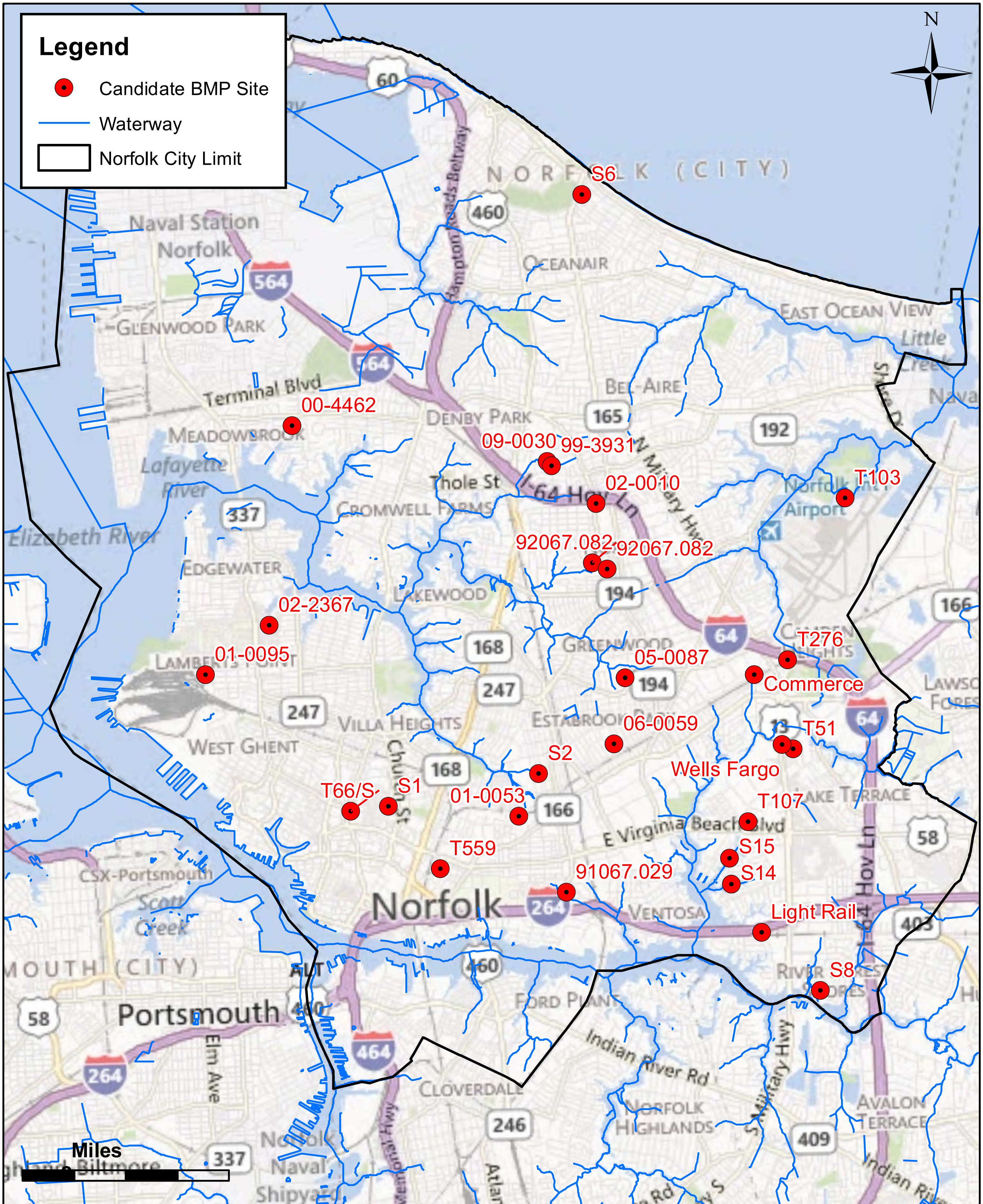
Notes:

1.) *The SWMF Type was provided by the City. The terminology used by the City differs from that used by the Chesapeake Bay Program. The calculations performed for this evaluation are based on the design volumes and site considerations, not the SWMF Type.*

The findings of the report specifically provide the following for each of the five retrofit BMP designs:

- Recommended components of the five conceptual designs

- Opinions of probable cost for construction of each of the five conceptual designs
- Anticipated water quality benefits to reduce discharge of nitrogen, phosphorus and sediment.



Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Candidate BMP Locations
Figure 1-1

Section 2

BMP Evaluation and Prioritization

This section focuses on the data collection and evaluation methodology used to evaluate and prioritize the candidate BMP sites. The section is divided into discussions of the data collected and reviewed, the field visits, the BMP evaluation and matrix development, the BMP prioritization, and the selected BMP sites.

2.1 Data Collection and Project List Modifications

The City provided CDM Smith with an initial list of 27 candidate BMP sites and several sources of information for the sites including GIS data, design and record drawings, reports, and maintenance logs. The complete list of data and sources (including the initial list of BMP sites) can be found in **Appendix A**. CDM Smith performed a preliminary review of the information provided for the initial list of candidate BMP sites and met with City staff to kickoff the project on January 14, 2013. During the meeting, it was determined that the initial list of 27 candidate BMP sites should be modified as summarized below:

- The two Central Business Park BMPs (City Site ID 99-3931, initially listed as Project IDs 16 and 17), represent a single BMP, not two separate BMPs. Therefore, one was eliminated from further consideration.
- The BMP initially named Marshall Manor Senior Living Apartments (City Site ID 01-0053, initially listed as Project ID 10) was changed to Roberts Pond.
- The two Broad Creek Villas BMPs (City Site ID 08-0042, initially listed as Project IDs 5 and 6), were removed from consideration.

Based on the above modifications, three of the 27 BMPs originally scoped were removed from consideration. The City identified three new BMPs sites for inclusion in the project including:

- Norfolk Commerce Park Pond 3 (no City Side ID available)
- Light Rail Station Pond (no City Side ID available)
- Wells Fargo Pond (no City Side ID available)

The final list of 27 candidate BMPs to be included in this study is presented in Table 1-1 in Section 1. The following summary of work performed reflects the final BMP list.

2.2 Field Investigation and Preliminary Retrofit Identification

City and CDM Smith staff conducted field visits to each of the 27 candidate BMP sites over a three-day period, January 28th to 30th 2012, for the purpose of identifying potential retrofit opportunities as well as collecting relevant information anticipated to be used during the evaluation, prioritization and conceptual design tasks. The types of data that were collected on the field visits include:

- Constructability concerns, such as available space and land ownership, environmental impacts, utility impacts, and development impacts.

- Potential high cost factors, such as large diameter utility relocation, private property impacts, and structural concerns for the existing BMP.
- New development or utilities not included in the GIS data, such as new residential/commercial structures, roads, and public amenities.
- Existing BMP dimensions, configurations, and sizes, such as spillway length, width, diameter, and material; dam length, width, and height; and depth to normal pool from the dam crest.

In preparation of the field visits, CDM Smith developed a book of GIS maps for each of the sites, which included the relevant GIS information collected prior to the field visits. The maps are included as an attachment under a separate cover. Data collection forms were also used during the field visits to document the information collected, which are included in Appendix A. Pictures of each of the candidate sites were collected and are included on CD in Appendix A.

The information collected during the field investigations were documented in a technical memorandum (TM), dated March 8, 2013, and included in **Appendix B**. The TM includes a detailed description of the information collected in the field, a site picture, and the retrofit opportunities identified during the field investigation for each of the candidate BMP sites. This information was used as the basis for performing the preliminary BMP evaluation and developing the prioritization matrix.

2.3 BMP Evaluation and Prioritization

The City recognizes that they have limited funding for implementing the retrofit opportunities identified for each of the 27 BMPs evaluated. Therefore, it was necessary to evaluate and prioritize the existing BMPs to allow the City to realize the greatest benefit for the limited funding available. The benefit is focused primarily on water quality, but can also include water quantity and public benefits as well.

CDM Smith and City staff worked together to develop a list of factors that could be used to evaluate and compare the retrofit recommendations for each of the 27 candidate BMPs. In order to prioritize the retrofit recommendations for each of the 27 candidate BMPs, CDM Smith developed a matrix to estimate a score for each of the factors, which was then be used to calculate a total score to rank the sites. The scores for each factor were based on a scale of 1 to 5, with 1 being the least beneficial and 5 being the most beneficial. The scores are relative only to the 27 candidate BMPs included in this study. A list of the factors selected along with a brief description of how each was scored is provided below:

- Permitability - The anticipated level of effort required to obtain the necessary permits. A score of one (1) indicates a significant amount of permitting would be required to implement the recommended retrofit(s). A score of five (5) indicates little to no permitting would be required.
- Public Acceptance - The anticipated level of public acceptance of the recommended retrofit(s). A score of one (1) indicates anticipation that the public would be opposed to implementation of the recommended retrofit(s). A score of three (3) indicates a neutral public acceptance of implementation. A score of five (5) indicates the public would support implementation.
- Nutrient and Sediment Reduction - The anticipated nutrient and sediment reduction benefit gained through implementation of the candidate retrofit(s). A score of one (1) indicates there would be little to no nutrient and/or sediment reduction credit provided through implementation of the recommended retrofit(s). A score of five (5) indicates there would be substantial nutrient and/or sediment reduction credit provided.

- Relative Cost - The anticipated construction cost of the recommended retrofit(s). A score of one (1) indicates there would be significant cost to implement the recommended retrofit(s). A score of five (5) indicates there would be minimal cost.
- Impact to Flood Control - The anticipated impact to the existing flood control benefit caused by the candidate retrofit(s). A score of one (1) indicates implementation of the recommended retrofit(s) would be expected to increase flooding. A score of three (3) indicates implementation would not be expected to increase or reduce flooding. A score of five (5) indicates implementation would be expected to decrease flooding.
- Constructability - The anticipated level of difficulty to construct the retrofit project. A score of one (1) indicates the project would be very difficult to construct. A score of five (5) indicates the project would be very easy to construct.
- Maintenance Access - The anticipated ease or difficulty of accessing the BMP for maintenance activities. A score of one (1) indicates the retrofitted BMP would be very difficult to access and/or maintain. A score of five (5) indicates the retrofitted BMP would be relatively easy to access and/or maintain.

Once the individual factor scores were developed, a total score for each retrofitted BMP was calculated. The total score was based on a 'weighted' score. Each factor was assigned a relative weighting factor of 10 percent, except for nutrient and sediment removal, which was assigned a 'weight' of 40 percent. Although all seven factors are considered important, water quality is the primary driver for this project, thus nutrient and sediment removal was chosen as the factor that drives the overall rating. The overall rating per BMP site is the mathematical sum of 'weight' and score of all seven factors.

CDM Smith performed an initial first cut at assigning scores for the Permitability, Nutrient Reduction, Relative Cost, Constructability, and Maintenance Access factors based on information collected during the site investigations, GIS analyses, preliminary water quality volume calculations, and experience with BMP evaluations, design, and construction. The scores for the Public Acceptance and Impact to Flood Control factors were assigned by City staff based on their local knowledge of residents and flooding issues in proximity to the BMPs. CDM Smith facilitated a workshop with City staff on March 11, 2013 to present the preliminary scores and associated ranking. CDM Smith and City staff evaluated the scores in detail for the top 15 sites, making some minor adjustments to the factor scores. **Table 2-1** presents the final matrix, with the 27 candidate BMPs ranked from highest (most preferred) to lowest (least preferred) total score. A brief justification of each score is provided for each factor for each individual BMP.

2.4 Priority BMP Sites

As indicated earlier, a goal of the evaluation and prioritization is to identify the five highest priority BMPs for inclusion in a more detailed analysis and development of conceptual designs. Based on the matrix and prioritization ranking shown in Table 2-1, the five highest priority BMPs include:

1. Norfolk Botanical Gardens (City Site ID T103)
2. Ballentine Elementary School (S2)
3. Central Brambleton (T559)
4. Norfolk Juvenile Detention Center (T51)
5. Second Patrol Division (09-0030)

Table 2-1 – Final BMP Matrix

Priority	Project ID[1]	BMP Site ID	BMP Site Title	Prioritization Factors[2]														*Total Score[10]*
				Permitability[3]		Public Acceptance[4]		Nutrient and Sediment Reduction[5]		Relative Cost[6]		Impact to Flood Control[7]		Constructability[8]		Maintenance Access[9]		
Weighting Factor				10%		10%		40%		10%		10%		10%		10%		
1	21	T103	Norfolk Botanical Gardens - Visitors Reception	4	Will require land disturbance permit.	5		5	Increased system volume will provide added removal credit	3	Cost includes grading, plantings, storm sewer modifications, and new/modified outlet	3		4	Good access and staging area. Moderate pedestrian traffic. Possible utility conflict.	5	Excellent access for routine maintenance	**4.4**
2	18	S2	Ballentine Elementary School Lake	2	Will require environmental and land disturbance permits. May also require coastal permits	4		5	Increased system volume will provide added removal credit	2	Cost includes dewatering, flow bypass, sediment removal, grading and plantings	3		4	Good access and staging area. Moderate difficulty to bypass flow.	5	Excellent access for routine maintenance	**4.0**
3	23	T559	Central Brambleton	4	Will require land disturbance permit.	4	High public acceptance due to reduced flooding.	4	New facility provides volume. Credit also from converting from a piped system to a BMP	2	Cost includes plantings	5		4	Good access and staging area.	5	Excellent access for routine maintenance	**4.0**
4	3	T51	Norfolk Juvenile Detention Center	4	Will require land disturbance and environmental permits.	3		4	Good added credit w/ conversion from dry pond to wet pond	3	Cost includes grading, plantings, storm sewer modifications, and new/modified outlet	4		5	Good access and staging, low difficulty to bypass flow, minimal pedestrian traffic	4	Excellent access for routine maintenance	**3.9**
5	5	09-0030	2nd Patrol Division	3	Will require land disturbance and environmental permits. Might require easement for new culvert.	4		3	Increased system volume will provide added removal credit	3	Cost includes grading, plantings, and new/modified outlet and culvert	3		3	Good access and staging. Low difficulty to bypass flow. Possible utility conflicts	5	Excellent access for routine maintenance	**3.3**
6	14	99-3931	Central Business Park	3	Will require land disturbance and environmental permits. Might require easement for new culvert.	4		3	Increased system volume will provide added removal credit	3	Cost includes grading, plantings, and new/modified outlet and culvert	3		3	Good access and staging. Low difficulty to bypass flow. Possible utility conflicts	5	Excellent access for routine maintenance	**3.3**
7	19	S6	Lake Modoc	3	Will require environmental and land disturbance permits. May also require USACE and coastal permits	5		4	Increased system volume will provide added removal credit	1	Cost includes dewatering, flow bypass, sediment removal, grading, plantings, new aerator, force main relocation, and new/modified outlet	3	There is concern that the adjacent apartment building may flood. Adjusting the spillway to lower the normal pool will help.	1	Good access. Poor staging area. High difficulty to bypass flow. Likely utility conflicts.	3	Good access to spillway, but poor access around lake for routine maintenance	**3.2**
8	15	S1	Anne Outten Pond	4	Will require land disturbance permit.	3		4	Increased system volume will provide added removal credit	1	Cost includes dewatering, flow bypass, sediment removal, grading, plantings, and floating wetlands	3		1	Good access. Poor staging area. High difficulty to bypass flow.	3	Pond is adjacent to a road, but outlet is difficult to access	**3.1**
9	10	02-0010	Norview High School	4	Will require land disturbance permit.	3		3	Increased system volume will provide added removal credit	2	Cost includes dewatering, flow bypass, sediment removal, grading and plantings	3		2	Good access. Poor staging area. Moderate difficulty to bypass flow. Moderate pedestrian and vehicle traffic	4	Good access for routine maintenance, pedestrian and traffic could hender	**3.0**

Priority	Project ID[1]	BMP Site ID	BMP Site Title	Prioritization Factors[2]														Total Score[10]
				Permitability[3]		Public Acceptance[4]		Nutrient and Sediment Reduction[5]		Relative Cost[6]		Impact to Flood Control[7]		Constructability[8]		Maintenance Access[9]		
Weighting Factor				10%		10%		40%		10%		10%		10%		10%		
10	12	06-0059	Coleman Place Elementary School	4	No permit required. Coordination with School will be required.	4		1	Minimal added removal credit due to low nutrient inflow volume from overland flow	5	Cost includes plantings	3		5	Good access and staging	5	Excellent access for routine maintenance	**3.0**
11	8	01-0053	Roberts Pond	5	No permit required.	3		1	Minimal added removal credit due to low nutrient inflow volume from overland flow	5	Cost includes plantings	3		5	Good access and staging area	5	Excellent access for routine maintenance	**3.0**
12	4	00-4462	Titustown Recreation Center	5	Should not require any permits, only notifications	2		1	Minimal added removal credit	5	Cost includes harvesting	3		5	Good access and staging area	5	Excellent access for routine maintenance	**2.9**
13	26	n/a	Norfolk Commerce Park Pond 3	4	Will require land disturbance permit.	3		2	Increased system volume, but low nutrient inflow volume provides minimal benefit	3	Cost includes grading, plantings, storm sewer modifications, and new/modified outlet	3		4	Good access. Limited staging area.	4	Good access for routine maintenance	**2.9**
14	13	91067.029	Lake Liberty, NRHA	2	Will require environmental permits. USACE could consider this an existing wetland.	2		4	Increased system volume will provide added removal credit	1	Cost includes dewatering, flow bypass, sediment removal, grading, plantings, and baffle boxes	3		1	High pedestrian and traffic flow, poor staging area, high difficulty to bypass flow	3	Good access by road, moderate staging area.	**2.8**
15	9	01-0095	Lamberts Point Pond	3	Will require land disturbance permit.	1		3	Increased system volume will provide added removal credit	2	Cost includes dewatering, flow bypass, sediment removal, grading and plantings	3	Some flooding concerns, but need to figure out if mod will help or hurt.	2	Good access. Poor staging area. Moderate difficulty to bypass flow. Possible utility conflicts	4	Good access for routine maintenance, pedestrian and vehicular traffic could hender	**2.7**
16	22	T276	NPD 2nd Precinct Training Center	5	No permit required.	3		1	No additional nutrient removal credit	4	Cost includes installing an aerator.	3		4	Access to existing power supply only concern.	4	Adjacent to a road and parking lot, but limited access around pond.	**2.7**
17	25	n/a	Light Rail Station	4	Will require land disturbance permit.	3		2	Increased system volume, but low nutrient inflow volume provides minimal benefit	3	Cost includes dewatering, flow bypass, sediment removal, grading, and plantings	3		3	Good access. Poor staging area. Low difficulty to bypass flow.	3	Moderate access for routine maintenance	**2.7**
18	27	n/a	Wells Fargo Pond	2	Will require land disturbance permit. Need to acquire property and/or easements	2		3	Increased system volume, but moderate to low nutrient inflow volume provides minimal benefit	2	Cost includes dewatering, flow bypass, sediment removal, grading, and plantings	3		2	Good access. Moderate staging area. Moderate difficulty to bypass flow. High traffic.	4	Good access for routine maintenance	**2.7**
19	11	02-2367	ODU University Village	5	No permit required.	2		1	Minimal added removal credit due to low nutrient inflow volume from overland flow	5	Cost includes plantings	3		4	High pedestrian and traffic flow	3	Difficult to access due to high traffic volume, high pedestrian traffic, and limited staging area.	**2.6**
20	16	S14	Silver Lake/Duck Pond	5	No permit required, but need to notify USACE	3		1	No additional nutrient removal credit	4	Cost includes installing an aerator.	3		4	May require some work on private property.	3	Adjacent to a road, but limited public access.	**2.6**

Priority	Project ID[1]	BMP Site ID	BMP Site Title	Prioritization Factors[2]														*Total Score[10]*
				Permitability[3]		Public Acceptance[4]		Nutrient and Sediment Reduction[5]		Relative Cost[6]		Impact to Flood Control[7]		Constructability[8]		Maintenance Access[9]		
Weighting Factor				**10%**		**10%**		**40%**		**10%**		**10%**		**10%**		**10%**		
21	7	92067.082.B	Norview Middle School	3	Will require environmental permit. Approval/coordination with school may be required.	4		2	Improved removal credit, but low nutrient inflow volume	3	Cost includes tree removal, grading, plantings, and new/modified outlet	3		1	Good access. Poor staging area. High pedestrian and vehicle traffic	4	Good access for routine maintenance, pedestrian traffic could hender	**2.6**
22	6	92067.082.A	Norview Middle School	2	Will require environmental permits. USACE could consider this an existing wetland. Approval/coordination with school may be required.	4		2	Improved removal credit, but low nutrient inflow volume	3	Cost includes tree removal, grading, plantings, and new/modified outlet	3		1	Good access. Limited staging area. High pedestrian and vehicle traffic	3	Moderate access for routine maintenance, pedestrian and vehicular traffic could hender	**2.4**
23	1	05-0087	Sherwood Forest Elementary School	3	Will require land disturbance permit. Approval/ coordination with school may be required.	2		1	Minimal added removal credit due to low nutrient inflow volume	4	Cost includes grading, plantings, and new/modified outlet	3		4	Good access and staging area. Moderate pedestrian and vehicle traffic	4	Excellent access for routine maintenance	**2.4**
24	2	T107	Norfolk Public Schools Transportation Operations	2	Will require environmental permits. USACE could consider this an existing wetland.	3		1	Minimal added removal credit due to low nutrient inflow volume	4	Cost includes grading, plantings, and new/modified outlet	3	Some flooding concerns, but need to determine if retrofit will help or hurt.	2	Good access. Limited staging and high vehicle traffic	4	Good access for routine maintenance, bus parking could hender.	**2.2**
25	20	S8	Lake Scott	1	No permit required, but easement acquisition for multiple properties required	2		1	Minimal added removal credit due to low nutrient inflow volume from overland volume	5	Cost includes plantings	3		4	Limited public access around lake.	3	Moderate access for routine maintenance	**2.2**
26	24	T66/S	Cedar Grove Parking Lot	1	Will require land disturbance permit, assuming it's not currently a wetland	3		2	Minimal added removal credit due to low nutrient inflow volume	1	Cost includes grading, plantings, and new/modified outlet	3		1	Good access and staging area. High traffic volume.	2	Access good today, but won't be in the future when parking lot is used again.	**1.9**
27	17	S15	Meadow Lake	3	Will require land disturbance permit and USACE notification/permit.	4		1	Pond is oversized, so recovering volume not expected to provide additional credit.	1	Cost includes dewatering, flow bypass, sediment removal, grading and plantings	3		1	High difficulty to bypass flow	3	Pond is adjacent to a road, but very limited access around pond.	**1.9**

Notes:

1. Refer to separate attachment to report for a map of the individual project sites.
2. The Prioritization Factors are based on a relative comparison between the candidate BMPs are scored from one (1) to five (5), with five (5) being the most favorable.
3. Permitability represents the anticipated level of effort required to obtain the necessary permits. One (1) is difficult to permit, five (5) is easy to permit.
4. Public Acceptance represents the anticipate level of public acceptance of the proposed modification(s). One (1) is low public acceptance, five (5) is high public acceptance.
5. Nutrient Reduction represents the relevant anticipated nutrient reduction benefit. One (1) is low nutrient reduction, five (5) is high nutrient reduction.
6. Relative Cost represents the relative anticipated construction cost of the proposed modification(s). One (1) is high construction cost, five (5) is low construction cost.
7. Impact to Flood Control represents the relative impacts to the existing flood control benefit resulting from the proposed modification(s). One (1) is low flood control benefit, five (5) is high flood control benefit.
8. Constructability represents the relative anticipated level of difficulty to construct the proposed modification(s). One (1) is high difficulty to construct, five (5) is low difficulty to construct.
9. Maintenance Access represents the relative anticipated difficulty to access the BMP for maintenance. One (1) is poor maintenance access, five (5) is good maintenance access.
10. Total Score represents the sum of the individual factors scores multiplied by their respective weighting factors.

During the March 11, 2013 workshop, City staff noted that they are currently evaluating implementation of a new flood control facility in the vicinity of the Central Brambleton site. That facility would provide similar water quality benefits as those anticipated to be provided as part of the retrofits recommended for the Central Brambleton BMP. As a result, the Central Brambleton BMP was removed from consideration for this study. The sixth highest priority BMP in the ranking is the Central Business Park (99-3931) BMP. The initial retrofit recommendation for that facility was to combine it with the Second Patrol Division (09-0030) BMP. Therefore, the two were combined to represent a single BMP. The seventh highest priority BMP in the ranking is Lake Modoc (S6). City and CDM Smith agreed that it should be included among the top five highest priority sites.

The final list of the top five priority BMPs to be included in a more detailed evaluation and development of conceptual designs is presented below.

1. Norfolk Botanical Gardens (City Site ID T103)
2. Ballentine Elementary School (S2)
3. Norfolk Juvenile Detention Center (T51)
4. Second Patrol Division / Central Business Park (09-0030/99-3931)
5. Lake Modoc (S6)

A brief description of the existing facilities and recommended retrofit improvements for the top five priority sites is provided below:

2.4.1 Norfolk Botanical Gardens

The Norfolk Botanical Gardens (NBG) site includes a shallow wet detention pond that receives runoff from the adjacent parking lot and visitor center buildings (**Figures 2-1 and 2-2**). There is a 42-inch diameter storm sewer pipe that runs west to east, paralleling the existing pond. A junction box at the southwest corner of the pond has a 42-inch diameter diversion pipe that also sends flows to the pond. Larger flows bypass the pond and discharge directly to Lake Whitehurst to the east. The bypass pipe, which is not included in the City's GIS data, discharges into the southwest corner of the pond. The pond outlet is a 12-inch diameter conduit pipe and exits from the southeast corner of the pond back into the adjacent 42-inch diameter storm sewer pipe.

Since the pond outfall does not have a riser structure, the pond does not retain a significant depth and can operate as either a wet or dry pond depending on antecedent rainfall and groundwater conditions. The buffer around the pond is entirely grassed, down to nearly the bottom of the pond. There is abundant open space to the north and east of the pond. The topographic relief is relatively deep, with approximately 8 to 12 feet of depth from the pond bottom to the top of bank.

Recommended retrofits include expanding the pond's size and volume by increasing its surface area to capture larger stormwater runoff volumes from the 42-inch diameter storm sewer, adding a low flow diversion weir to direct the first flush of runoff to the pond, converting the outlet conduit pipe to a riser spillway to allow the pond retain greater depth, planting a minimum 50-foot vegetated buffer around the wetland, and incorporate an educational component through signage and interactive opportunities with visitors.

Figure 2-1
Norfolk Botanical Gardens (Site ID T103) – View of wet pond looking northeast from parking lot.

Figure 2-2
Norfolk Botanical Gardens (Site ID T103) – View of wet pond and surrounding open space, image from Google.

2.4.2 Ballentine Elementary School Lake

The Ballentine Elementary School (BES) site includes a relatively shallow wet detention pond that receives runoff from two 42-inch diameter outfalls from the east and overland flow from the surrounding open space (**Figures 2-3 and 2-4**). The GIS shows a third 42-inch diameter stormwater pipe bypassing the lake to the north, but it was determined in the field that the system had been modified to direct the northern 42-inch diameter pipe into the lake. According to City staff, the lake is tidally influenced.

The lake's outfall consists of two 12-inch orifices and a long (approximately 80 feet) concrete spillway. The principal spillway was recently upgraded; however, no lake dredging was performed. The surrounding open space is not regularly used by residents. Heavy sediment accumulation was observed at the east end of the lake near the pipe inflows.

Recommended BMP retrofits include dredging and/or excavating the pond to provide additional surface area and volume, planting a minimum 50-foot vegetated buffer around the pond, and creating a littoral shelf with wetland vegetation.

Figure 2-3

Ballentine Elementary School Lake (Site ID S2) – View of wet pond with concrete spillway and orifices at lake outfall.

Figure 2-4

Ballentine Elementary School Lake (Site ID S2) – View of wet pond and adjacent school, image from Google.

2.4.3 Norfolk Juvenile Detention Center

The Norfolk Juvenile Detention (NJD) Center site consists of a dry detention basin with a concrete-lined swale through the middle (**Figure 2-5**). There is a 12-inch diameter inlet at the southeast corner, which drains the adjacent parking lot. The outlet consists of a 12-inch diameter pipe with 3-inch orifice that connects to an adjacent grated riser, which discharges through a 21-inch diameter pipe into the adjacent storm sewer system. There is open space around the site, which does not appear to be utilized. During the site visit, several small sinkholes and undermined inlets were noted along the adjacent storm sewer system. The adjacent storm sewer system ranges from 18-inches to 30-inch in diameter and also serves upstream and adjacent developed areas north and south of Lowery Road and the ditch along Security Lane. The City noted that some flooding conditions have been reported in the upstream ditch system.

Recommended retrofit opportunities include converting the dry detention basin into an expanded wet pond. Also by reconfiguring the adjacent storm sewer system to discharge directly into the pond the drainage area served by the BMP could be increased as well as the associated volume of pollutants removed.

Figure 2-5
Norfolk Juvenile Detention Center (Site ID T51) – View of existing BMP from outlet spillway, looking southwest.

2.4.4 Second Patrol Division/Central Business Park

The Second Patrol Division (SPD) site includes a relatively shallow wet detention pond that receives runoff from an industrial park to the east (**Figure 2-6**). There are two inlet pipes (30-inches and 48-inches in diameter) entering the east end of the pond and an orifice/weir pond outfall exiting from the west end of the pond. The 30-inch inlet pipe is connected to a junction box, which has a flow diversion weir that sends low flows to the ponds and higher flows to the pond and the adjacent channel north of the pond. According to review of available documentation, the pond previously had a forebay, but it has been combined with the wet pond and is no longer evident. There is another City BMP candidate project site located to the southeast, Central Business Park (Site ID 99-3931).

The Central Business Park (CBP) site includes a long, linear wet detention pond that receives runoff from a small-developed complex to the north and an open field (**Figure 2-7**). There were not any large diameter inlets to the pond, but a number of connecting roof drains from the adjacent building and swales from the parking areas were identified. It is believed that most of the runoff entering the pond is contributed via overland flow. The outlet structure is a concrete riser section with a 36-inch diameter opening on the side. There is a good buffer around a majority of the bank. The pond is shallow with heavy algae growth observed.

Recommended retrofits include modifying the Central Business Park BMP to flow into the SPD BMP, which would improve the water quality benefit of the runoff currently being treated by the CBP BMP. Recommended improvements for the SPD BMP include dredging to increase volume and remove accumulated sediment. The junction box immediately upstream of the pond could be replaced with a baffle box to provide for improved and more cost-effective maintenance access for sediment removal in the future. Alternatively, a forebay could be excavated at the eastern end of the SPD pond near the inflow pipes.

Figure 2-6
Second Patrol Division (Site ID 09-0030) – View of inlet pipes and east end of pond.

Figure 2-7
Central Business Park (Site ID 99-3931) – View of wet pond and principal spillway riser, looking east.

During further analysis (modeling), it was determined that combining the BMP sites (specifically to reconfigure the CBP BMP to outfall to the SPD BMP) could cause hydraulic impacts to the CBP pond and short-circuiting of the flow and treatment from the SPD system. Therefore, it was decided that retrofit improvements should not link these BMPs.

Further, the CBP BMP was found to already provide significant pollutant removal from its relatively small tributary area. Therefore, it was decided that the BMP retrofit should solely apply to the SPD site. No additional reference to the Central Business Park site is henceforth provided in this report.

2.4.5 Lake Modoc

Lake Modoc site includes a relatively shallow wet detention pond (**Figure 2-8**) with three inflow pipes entering the southern portion of the lake. There is a 6-foot by 3-foot overflow spillway with a 48-inch diameter outlet pipe at the northwest corner, which discharges into the storm sewer system along Chesapeake Boulevard. The GIS shows a force main piping crossing the lake, though it was not observed in the field. There was moderate vegetative growth throughout the lake, suggesting shallow depth. Heavy sediment accumulation was observed at the southern end of the lake. There is moderate algae growth within the lake. There is an apartment building located along the northwest bank, near the outfall, that appears to have its finished floor elevation approximately 12 inches above the lake normal pool elevation, which suggests a potential for structural flooding (**Figure 2-9**). There is poor to moderate riparian buffer vegetation.

Recommended retrofits include dredging and/or excavating to provide increased volume, planting a minimum 50-foot vegetated buffer around the pond, creating a littoral shelf with wetland vegetation, installing aerator(s), and modifying the spillway or providing flood protection around the apartment building to reduce risk of structural flooding.

Figure 2-8

Lake Modoc (Site ID S6) – View of wet pond looking northwest towards Chesapeake Boulevard.

Figure 2-9
Lake Modoc (Site ID S6) – View of adjacent apartment building with a finished floor elevation approximately 12-inches above the lake normal pool.

Section 3

BMP Existing Conditions Analysis

3.1 Modeling Approach

Hydrologic and hydraulic stormwater models were developed to evaluate the performance of the five selected existing BMPs. For this evaluation, CDM Smith used the USEPA SWMM version 5.0.022 to simulate the surface water hydrology and hydraulics. SWMM was chosen because it has been verified through use in multiple past studies and stormwater management plans throughout the country, and is accepted as an industry standard modeling platform for urban systems with open channels and piped networks. This section presents the approach, data sources and assumptions used to develop the models.

The three main components of stormwater models, rainfall, hydrology and hydraulics are described below.

- Rainfall – A fundamental input to hydrologic modeling is rainfall, which in turn produces a hydrologic system response (runoff). SWMM provides a hydrologic model capable of performing continuous or event simulations of rainfall and surface runoff. As discussed in Section 3.2, synthetic storm events for 1-inch/6-hour and 1-, 2-, 10-, 25-, 50-, and 100-year/24-hour events were simulated to develop runoff hydrographs.
- Hydrologic Modeling – The hydrologic model computes the rates and volumes of runoff that is generated from a drainage area (or hydrologic unit) during a specified rainfall. The BMP study areas are delineated into hydrologic units (HUs) based on surface topography and drainage features to generate runoff at locations where it enters the drainage system. Runoff hydrographs to these loading points provide input for hydraulic routing through the system and to the system outlet. A hydrologic model is defined using basin characteristics and parameters such as drainage area, imperviousness, and infiltration capacity. The use of reliable GIS and topographic data collected from multiple sources provided a foundation for developing defendable and consistent basin parameters.
- Hydraulic Model – The hydraulic model simulates the movement of stormwater runoff through the stormwater management systems. This includes flow through channels, pipes, weirs, and overland flow. The hydraulic component of the SWMM accounts for backwater caused by system geometry and hydraulic structures. The primary objective of a hydraulic model is to determine the depths and flow rates through the stormwater management systems that result from the stormwater inflows generated by the hydrologic model. Data needs for the model are the storage volumes, connectivity, and physical characteristics of the drainage system such as channel bottom elevations, channel cross-sections, storm drain sizes, and invert elevations and road elevations.

3.2 Hydrologic Parameters

3.2.1 Rainfall

Five and fifteen-minute resolution rainfall distributions were developed for the 1-inch storm/6-hour and the 1-, 2-, 10-, 25-, 50-, and 100-year/24 hour design storms respectively, using data collected by the National Oceanic and Atmospheric Administration (NOAA) at the Norfolk WSO Airport. Total 24-hour rainfall amounts for each return period storm are based on NOAA Atlas 14 – Precipitation-Frequency Atlas for the United State and are shown in **Table 3-1**. The Natural Resources Conservation Service (formerly the Soil Conservation Service or SCS) Type III rainfall distribution was applied to the 24-hour storm events modeled using the methods described in the United States Department of Agriculture (USDA) Technical Resource 55 - Urban Hydrology for Small Watersheds. A smaller more typical 1-inch, 6-hour storm event was also simulated using the SCS rainfall distribution.

Table 3-1 - Rainfall Totals

Storm Event	Duration (Hours)	Rainfall Total (Inches)
1-inch	6-hour	1.00
1-year	24-hour	2.93
2-year	24-hour	3.57
10-year	24-hour	5.51
25-year	24-hour	6.82
50-year	24-hour	7.96
100-year	24-hour	9.21

3.2.2 Hydrologic Units

Hydrologic units (or subbasins) were delineated within the tributary area for each of the five selected BMP sites (**Figure 3-1** through **3-5**). These delineations are based on surface topograpy and other drainage features within the tributary area to generate stormwater runoff at locations where it enters the stormwater global system. The HUs developed for each site under existing and proposed conditions are nearly identical with the only difference being a slightly larger basin for the Norfolk Botanical Gardens site to account for the proposed larger BMP. This is discussed further in Section 4. Selected HU parameters for the five selected BMP sites are presented in **Table 3-2**.

3.2.3 Land Use and Soils

Land use and soils data are used to develop SWMM hydrologic input parameters. Existing conditions land use (City, 2009) and GIS data for impervious land cover (City, 2011) were used to estimate hydrologic parameters including total percent imperviousness, directly connected imperviousness, initial abstractions, and runoff roughness coefficients. SCS soils were used to estimate soil infiltration and soil storage capacities. Hydrologic soil groups (HSGs) were identified from the SCS data and designated as type A, B, C, or D. HSG A soils have high infiltration and low runoff potential while HSG D soils have low infiltration and high runoff potential. Types C and D soils have infiltration and runoff parameters between HSG's A and D.

3.3 Hydraulic Parameters

3.3.1 Stormwater Management System

The City provided an inventory of all documented storm structures and pipes, which includes details such as material, size, critical elevations and condition. The stormwater management systems in the study areas typically consist of conveyance pipes larger than 12 inches, and in some locations drainage ditches. Hydraulic input data for the model was derived from the available inventory, which included a combination of the City GIS and the record drawings. In cases where differences were observed between the two sources, the record drawing data were used. The models also include representations of the storage in existing BMP ponds that provide attenuation of stormwater runoff during rainfall events

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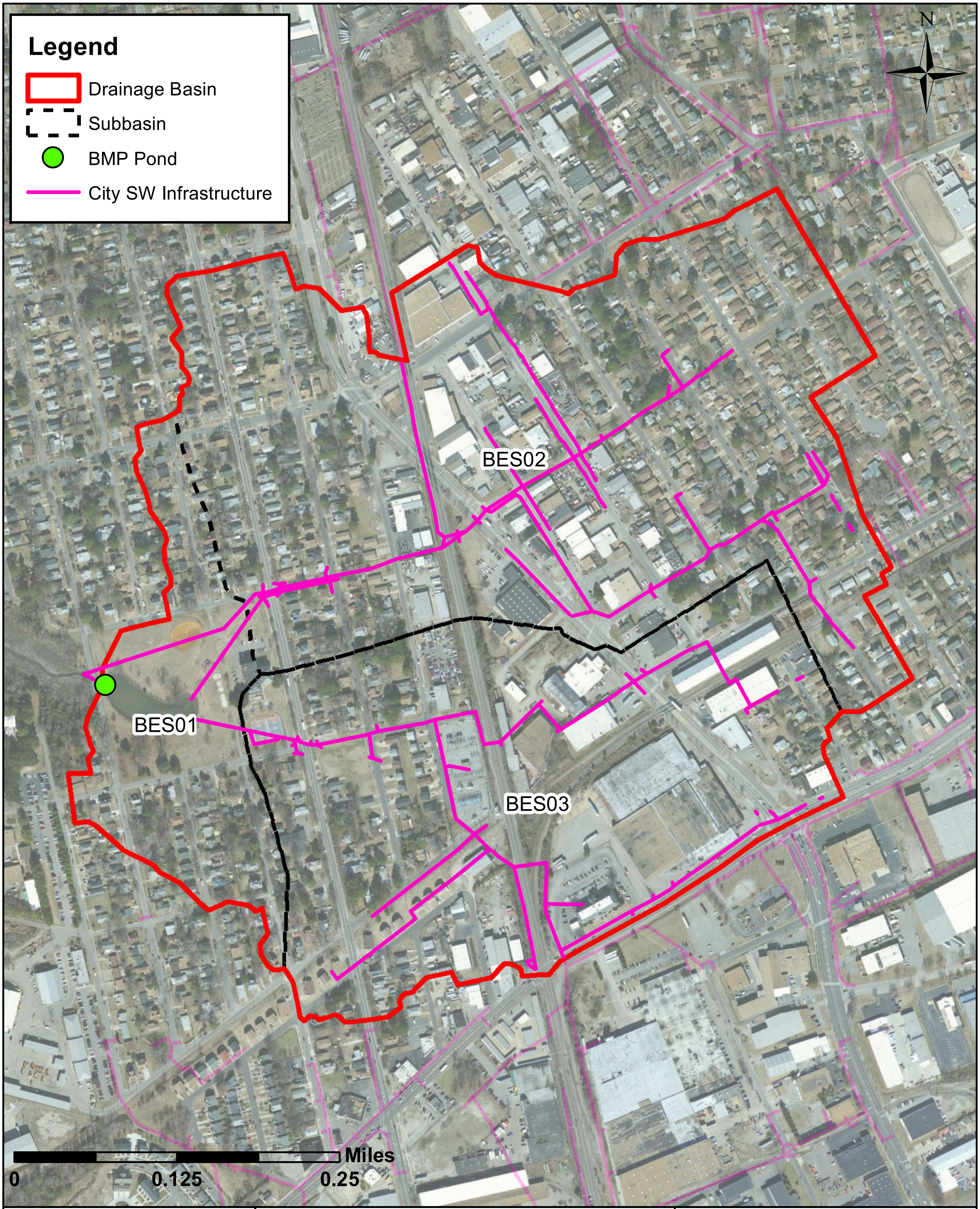
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Norfolk Botanical Gardens
BMP Drainage Basin
Figure 3-1



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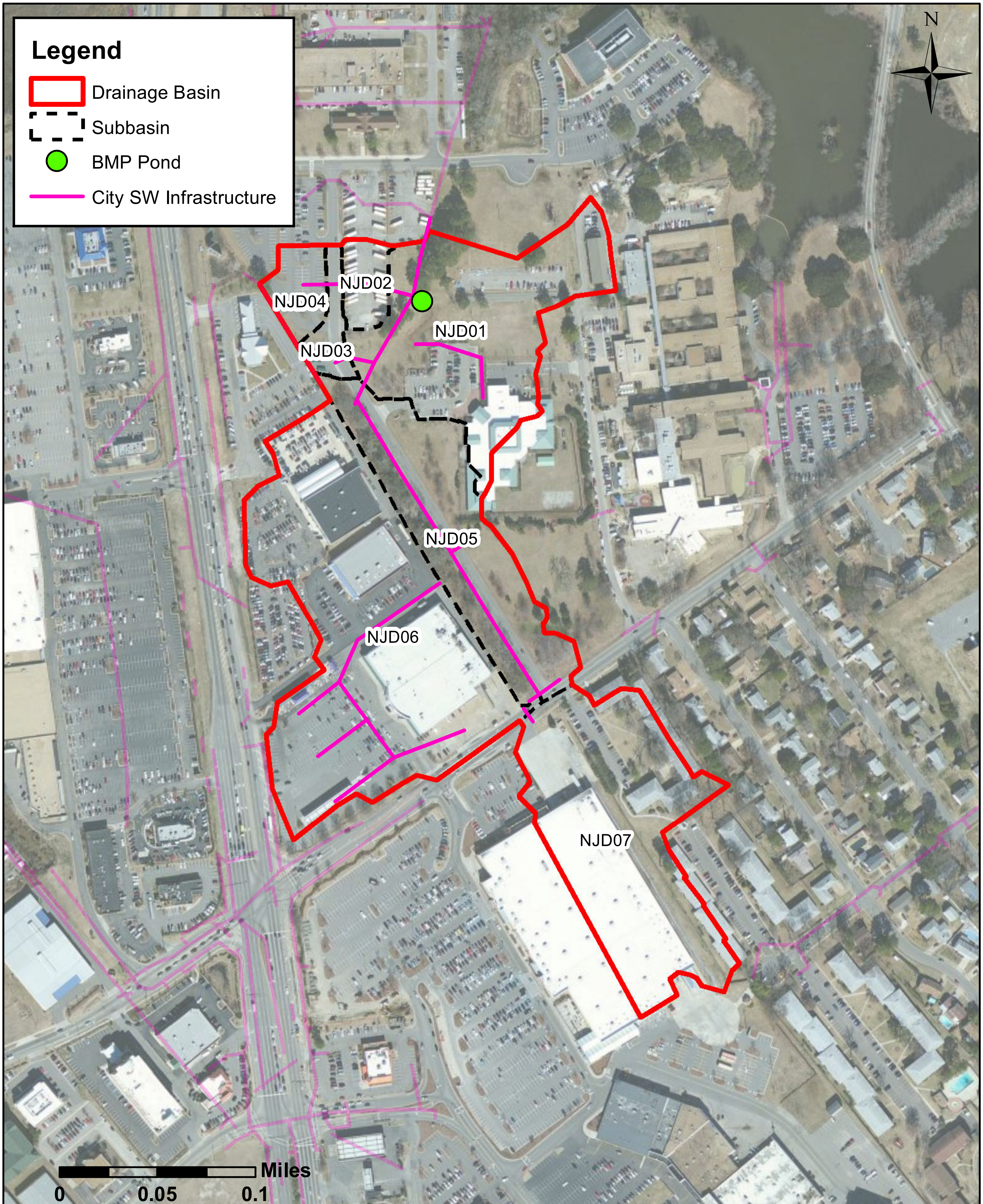
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Ballentine Elementary School
BMP Drainage Basin
Figure 3-2



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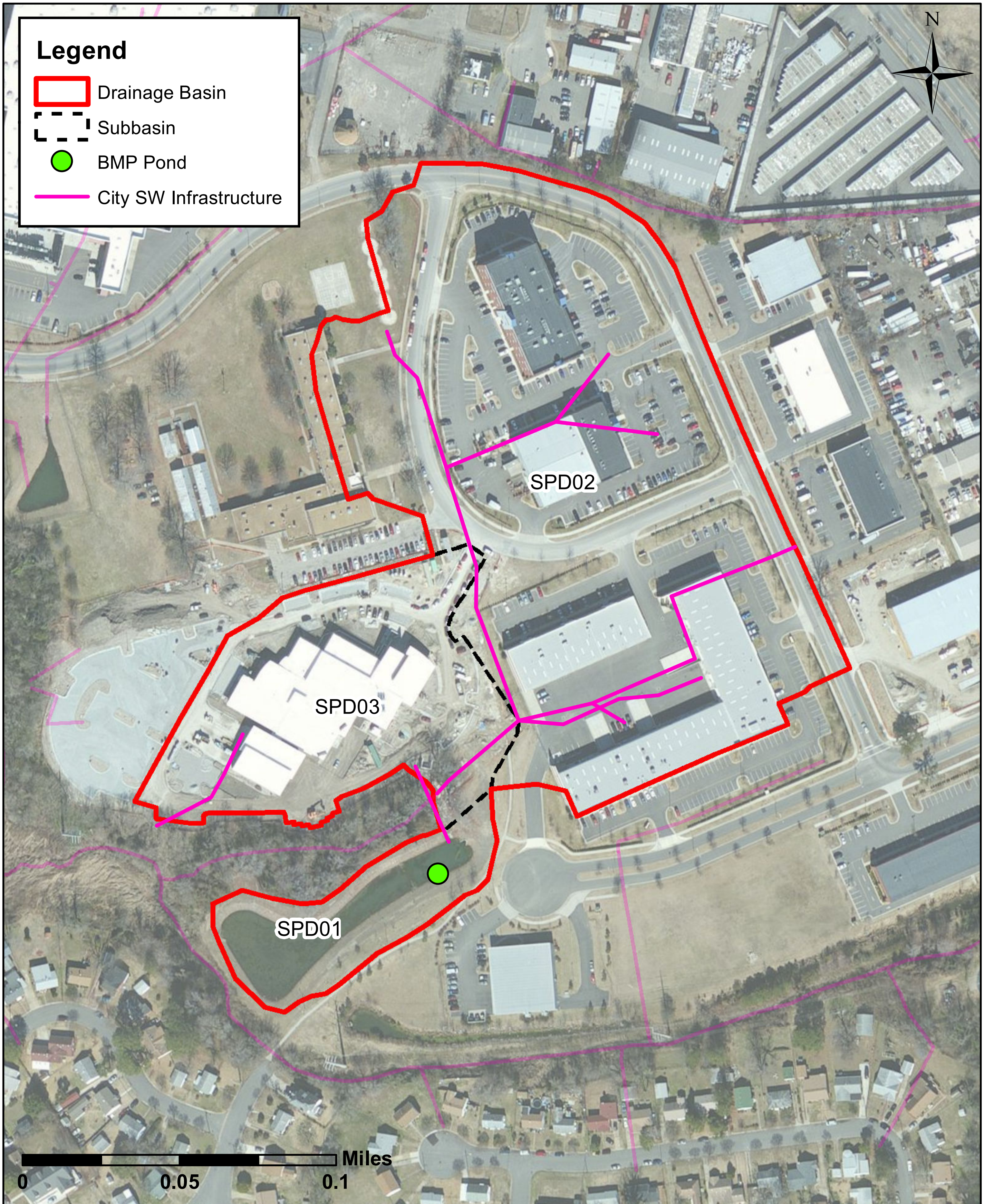
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Norfolk Juvenile Detention
BMP Drainage Basin
Figure 3-3



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Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Second Patrol Division
BMP Drainage Basin
Figure 3-4

CDM Smith

Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Lake Modoc
BMP Drainage Basin
Figure 3-5

Table 3-2 – HU Parameters

HU ID	Area (acres)	Percent Impervious	Impervious Area (acres)
Norfolk Botanical Gardens			
NBG01	0.90	77.8%	0.70
NBG02	0.53	30.2%	0.16
NBG03	7.74	64.0%	4.95
Ballentine Elementary School			
BES01	20.98	43.4%	9.11
BES02	93.18	68.8%	64.15
BES03	65.67	71.7%	47.08
Norfolk Juvenile Detention Center			
NJD01	5.99	43.7%	2.62
NJD02	0.66	95.1%	0.63
NJD03	0.58	81.5%	0.47
NJD04	0.77	81.0%	0.62
NJD05	4.56	25.0%	1.14
NJD06	10.59	97.2%	10.29
NJD07	6.81	75.0%	5.11
Second Patrol Division			
SPD01	1.66	54.8%	0.91
SPD02	13.33	77.9%	10.38
SPD03	4.34	84.5%	3.67
Lake Modoc			
HU-5	14.73	46.0%	6.78
HU-6	4.19	53.0%	2.22
HU-7	22.80	58.0%	13.22
HU-8	6.59	60.0%	3.95
HU-9	4.40	64.0%	2.82
HU-10	4.74	67.0%	3.18
HU-11	5.10	49.0%	2.50
HU-12	2.39	60.0%	1.43
HU-13	0.99	9.0%	0.09
HU-14	0.93	21.0%	0.20
HU-15	1.24	27.0%	0.33
HU-16	2.85	19.0%	0.54
HU-18	2.57	11.0%	0.28
HU-19	4.06	3.0%	0.12
HU-20	4.10	31.0%	1.27
HU-21	4.07	42.0%	1.71
HU-22	2.27	14.0%	0.32
Pond1	1.70	100.0%	1.70

Note: Model parameters consider open water as impervious while it is separated out for water quality purposes.

3.3.2 Modeled Hydraulic Features

SWMM is accepted as an industry standard modeling platform for urban systems with open channels and piped networks. The hydraulic flow routing routine of SWMM uses a link-node representation of the stormwater management system to dynamically route flows by continuously solving the complete one-dimensional Saint-Venant flow equations. The dynamic flow routing allows for representation of channel storage, branched or looped networks, backwater effects, free surface flow, pressure flow, entrance and exit losses, weirs, orifices, pumping facilities, rating curves, and other special structures or links. SWMM also provides the option to use control rules to operate structures based on timing and/or stage and flow conditions within the model. Hydraulic features for the five selected BMPs are described below:

3.3.2.1 Norfolk Botanical Gardens

The hydraulic model contains 4 nodes and 4 closed pipe segments. For the pond BMP, a stage-storage relationship was defined from the GIS contours and refined based on field visits and pipe infrastructure invert data. **Figure 3-6** shows the link-node model schematic and identifies the hydraulic model element types included in SWMM. This BMP discharges to the Lake Whitehurst Reservoir. For this analysis, a fixed water elevation of 4 ft-NAVD was applied at the outfall to Lake Whitehurst Reservoir to represent estimated elevated tailwater conditions based on review of the downstream topographic contours and field visit observations.

3.3.2.2 Ballentine Elementary School

The hydraulic model contains 9 nodes and 8 closed pipe segments, with one orifice and one weir. Appropriate overflow links were also added as needed. For the pond BMP, a stage-storage relationship was defined from the GIS contours. To represent roadway flooding above the closed conveyance system, stage-storage relationships and overland flow paths were developed. **Figure 3-7** shows the link-node model schematic and identifies the hydraulic model element types included in the SWMM model.

The downstream limit of the BES BMP discharges to the Lafayette River system. For this analysis, a fixed water elevation of 1.1 ft-NAVD was applied at the outfall to Lafayette River to represent an estimated high tide condition.

3.3.2.3 Norfolk Juvenile Detention Center

The hydraulic model contains 14 nodes and 13 closed pipes, with one orifice and one weir. Appropriate overflow links were also added as needed. For the pond BMP, a stage-storage relationship was defined from the record drawings. SWMM represents the stormwater management system in a maintained condition. **Figure 3-8** shows the link-node model schematic and identifies the hydraulic model element types included in the SWMM model.

The NJD Center BMP discharges to the adjacent downstream pipe system. For this analysis, a fixed water elevation of 5.1 ft-NAVD was applied at the downstream pipe system to represent optimum near full flow conditions in the downstream pipe.

3.3.2.4 Second Patrol Division

The hydraulic model contains 7 nodes and 4 closed pipe segments, with two orifices and three weirs. For the BMP pond, a stage-storage relationship was defined from the GIS contours and refined based on field visits and review of as-built drawings. **Figure 3-9** shows the link-node model schematic and identifies the hydraulic model element types included in the SWMM model developed for the study area.

The BMP pond outfalls to a stormwater channel that discharges to Lafayette River. For this analysis, a fixed water elevation of 4 ft-NAVD was applied at the boundary outfall to represent estimated elevated tailwater conditions based on review of the downstream topographic contours and field visit observations.

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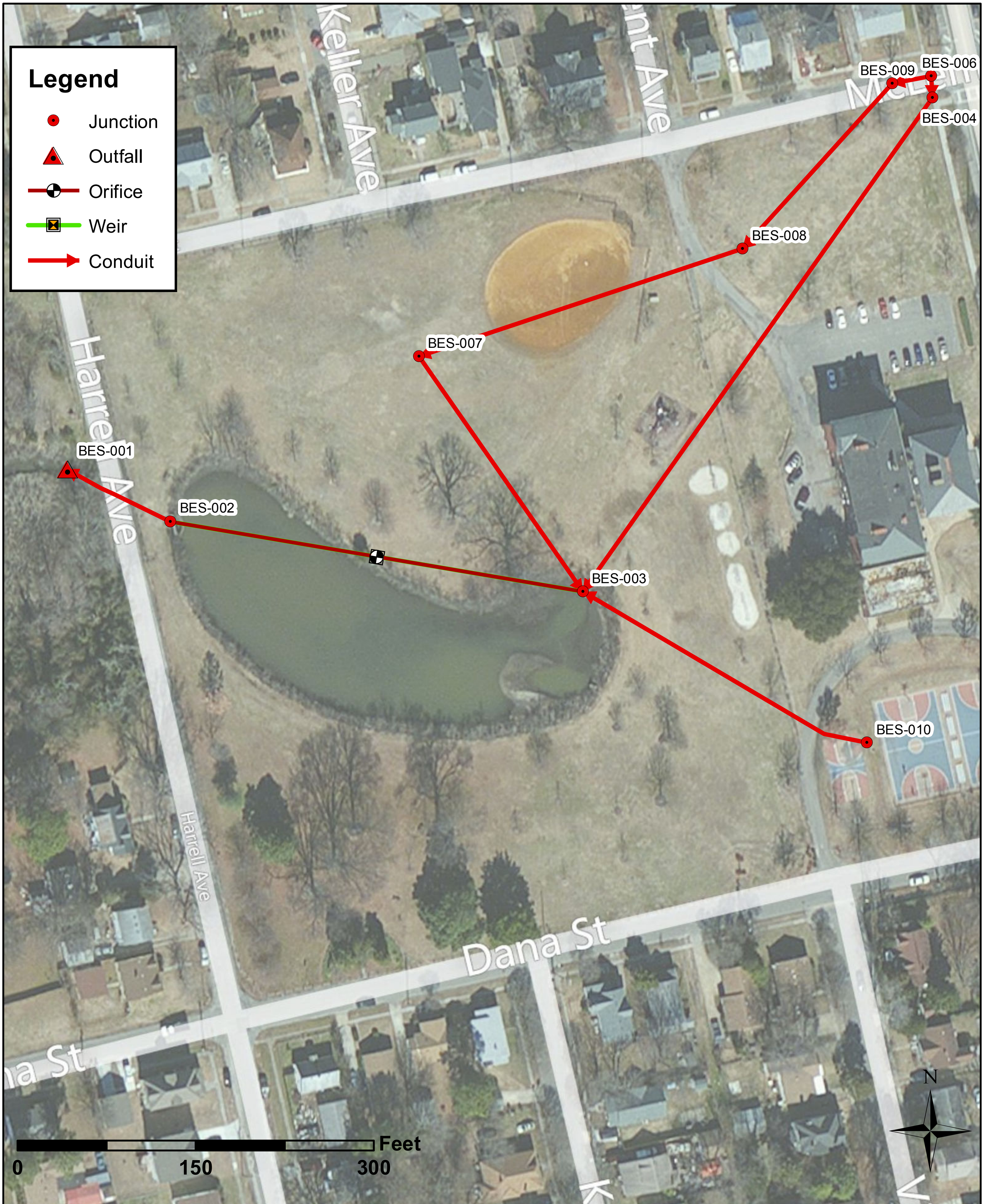
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Norfolk Botanical Gardens
Model Schematic
Existing Conditions
Figure 3-6



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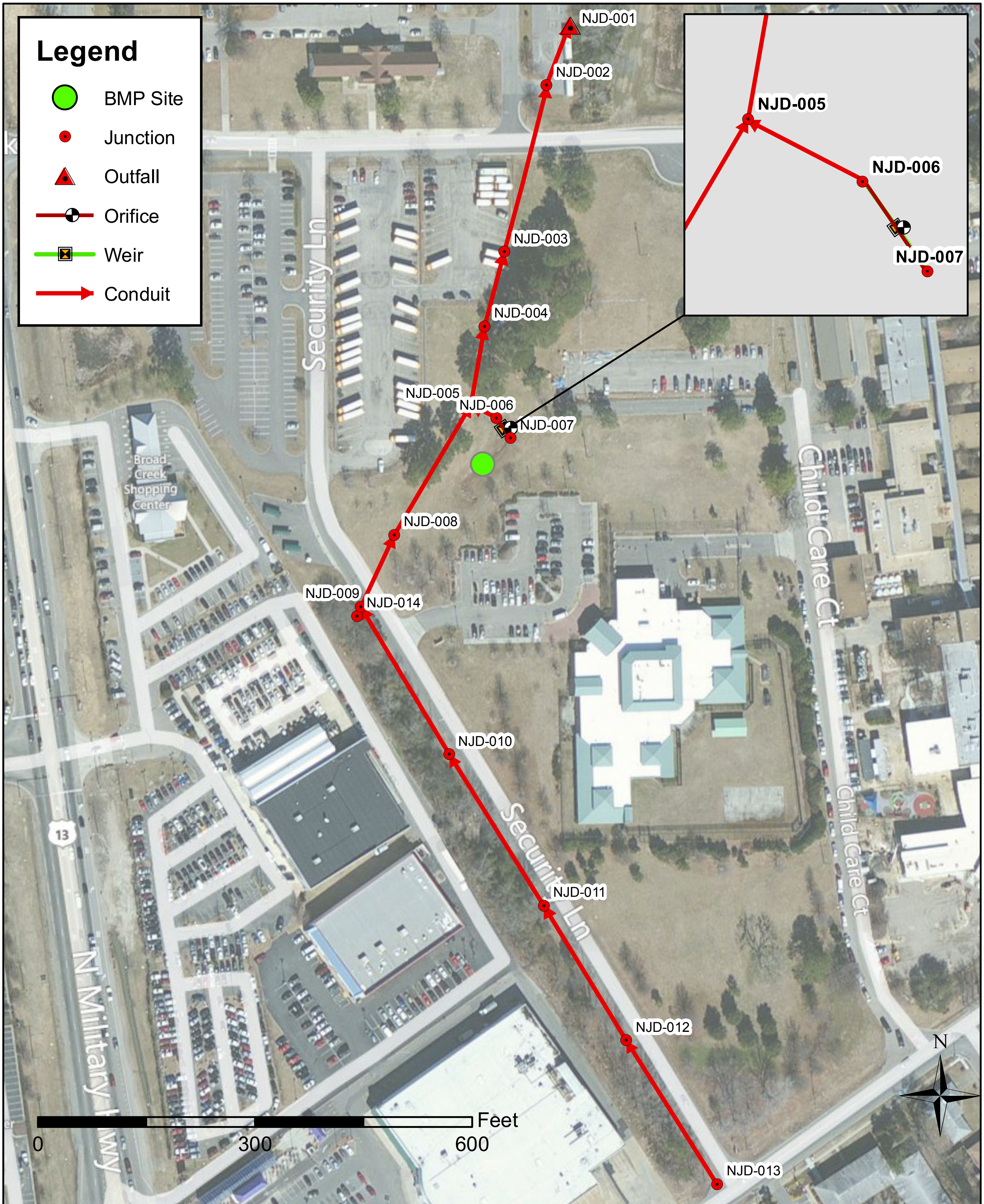
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Ballentine Elementary School
Model Schematic
Existing Conditions
Figure 3-7



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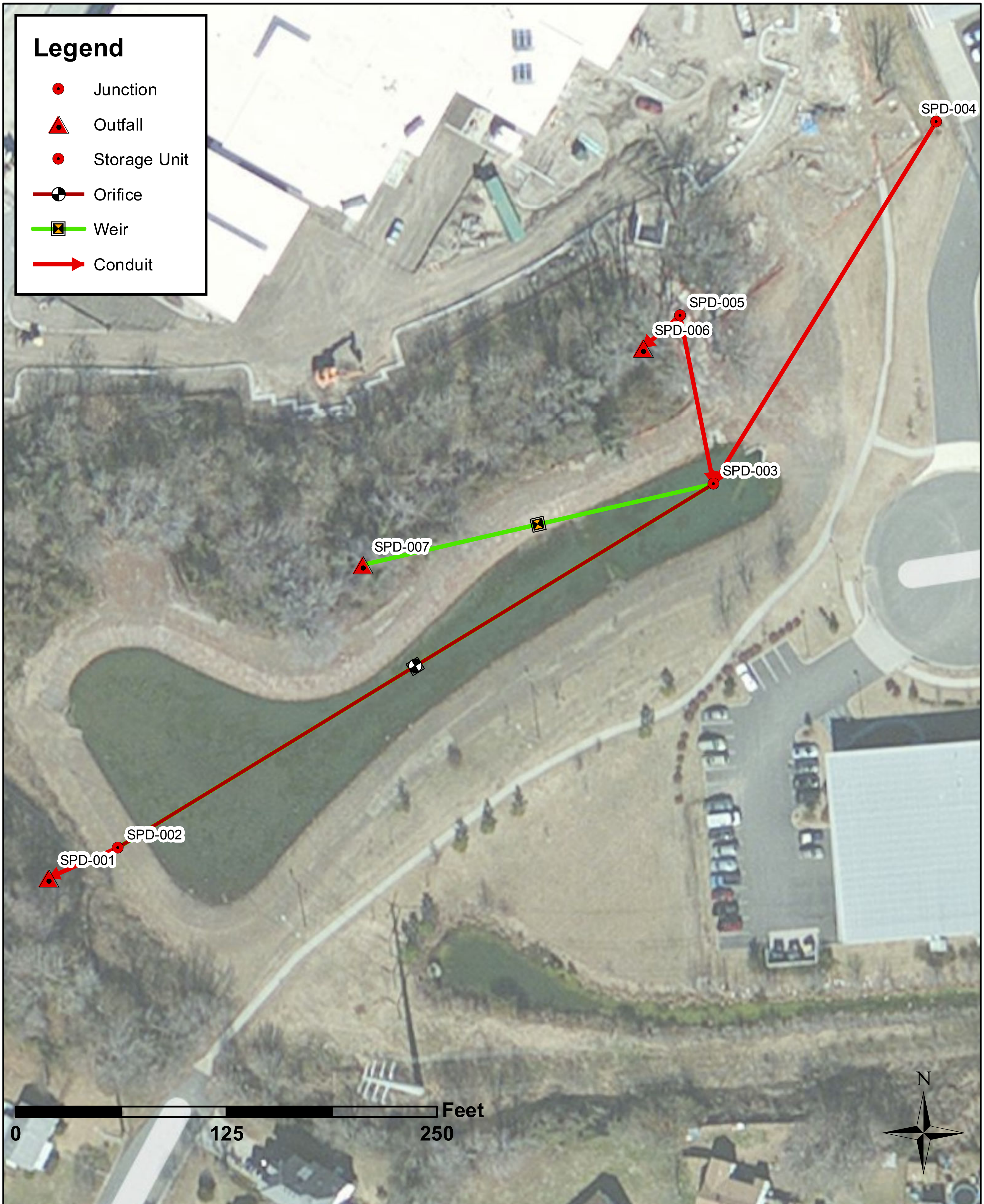
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Norfolk Juvenile Detention
Model Schematic
Existing Conditions
Figure 3-8



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Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Second Patrol Division
Model Schematic
Existing Conditions
Figure 3-9

3.3.2.5 Lake Modoc

The Lake Modoc drainage system was previously studied by CDM Smith as part of the Lenox Avenue Drainage Analysis completed for the City in July 2011. As part of this study, Lake Modoc and its drainage system were modeled using SWMM. Because this is a published and accepted drainage study for the City, the model was used as-is for this study. Additional information for this drainage system is available in the 2011 Drainage Analysis Report.

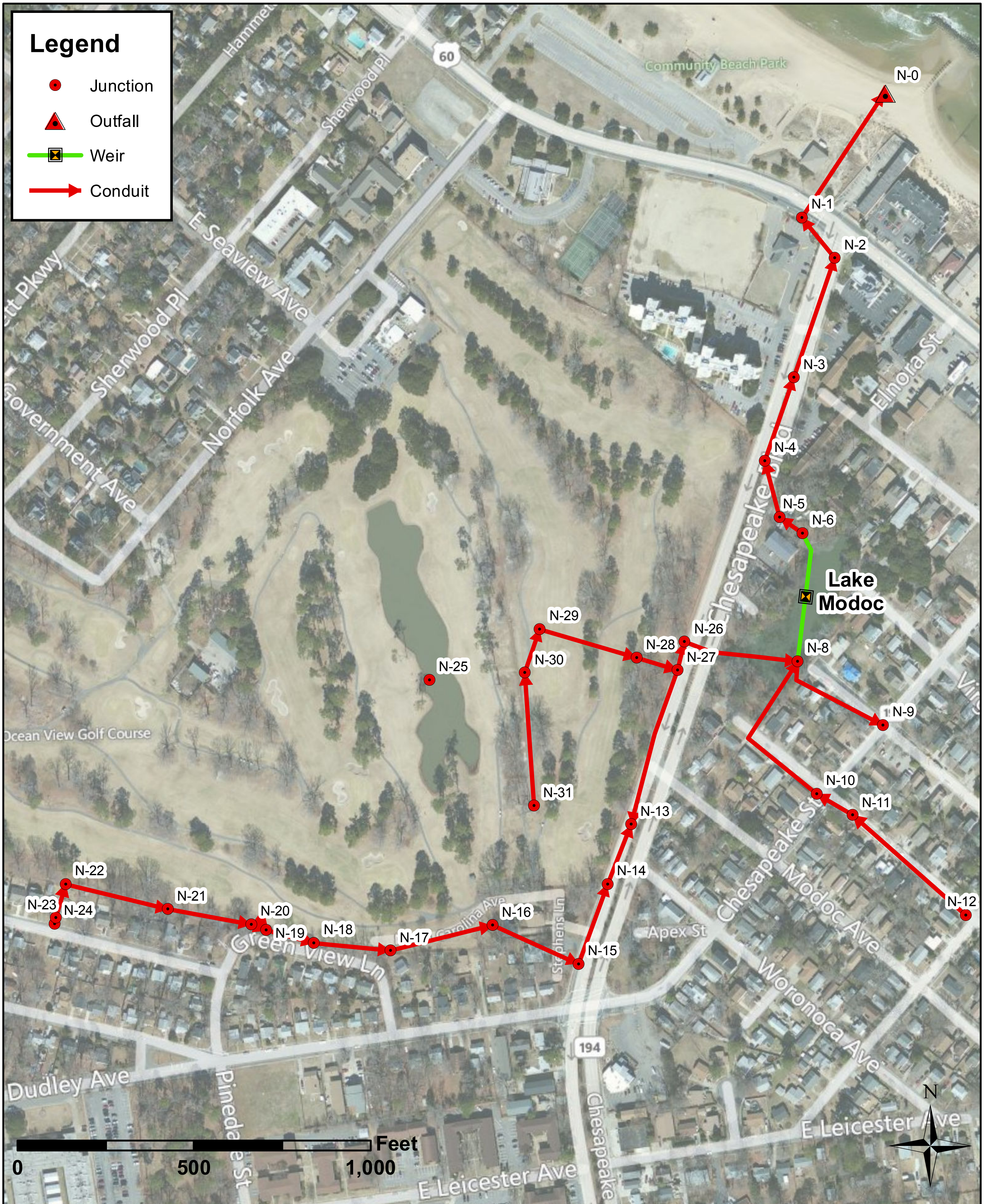
The hydraulic model for Lake Modoc contains various nodes and conduits, including open channel sections, one weir, and various closed pipe segments (**Figure 3-10**). The study area also includes a self-contained golf course pond (Node N-25). For the two ponds, stage-storage relationships were previously defined from the digital elevation model derived from LiDAR. For the golf course pond, the topography indicates this is a closed basin and therefore no linkages from the pond to downstream conveyance systems are made.

To represent roadway flooding above the closed conveyance system, stage-storage relationships and overflow channels were derived as needed. These model elements above were defined by extracting cross sections across the roadway using the digital elevation model derived from LiDAR. The reported roadway flooding is based solely on the system conveyance capacity and does not account for any flooding which may actually occur due to limitations of inlet capacity, either by design, maintenance condition, or clogging. The SWMM model represents the stormwater management system in a maintained condition. Figure 3-10 shows the link-node model schematic and identifies the hydraulic model element types included in the SWMM model developed for the study area.

Lake Modoc and its downstream outfall system discharges to the Chesapeake Bay. For this analysis, a fixed water elevation of 1.1 ft-NAVD was applied at the outfall to Chesapeake Bay to represent an annual high tide condition. The elevation of 1.1 ft-NAVD was derived from the Mean Higher High Water (MHHW) elevation documented for the NOAA tide gauge at Sewells Point. Because of the frontal dune northeast of Ocean View Avenue at approximate elevation 12-15 ft-NAVD and the invert elevation of the storm sewer on Ocean View Avenue at elevation 3.3 ft-NAVD, the area near the outfall does not appear vulnerable to flooding or a capacity constraint due to the tidal influence of a MHHW condition.

3.3 Model Results

Existing conditions model results for selected nodes for the five BMP sites for the simulated storm events are presented in **Table 3-3**.



Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Lake Modoc
Model Schematic
Existing Conditions
Figure 3-10

Table 3-3 – Existing Conditions Model Results

Model Node	Description	Ground EL (ft NAVD)	Existing Conditions Peak Stages (ft NAVD)						
			Storm Event						
			1-inch	1-year	2-year	10-year	25-year	50-year	100-year
Norfolk Botantical Gardens									
NBG-002	d/s pipe inlet	17	4.2	4.6	4.7	4.9	5.1	5.2	5.5
NBG-003	Pond BMP	14	6.7	7.0	7.1	7.6	7.7	7.9	8.0
NBG-004	u/s pipe inlet	17	7.0	7.3	7.4	7.6	7.8	7.9	8.0
Ballentine Elementary School									
BES-003	Pond BMP	4.2	2.4	3.1	3.4	4.5	4.9	5.2	5.4
BES-006	u/s road inlet	8	4.1	7.0	7.7	8.3	8.4	8.4	8.5
BES-010	u/s road inlet	5.4	3.8	5.8	5.9	6.0	6.1	6.2	6.2
Norfolk Juvenile Detention Center									
NJD-004	d/s pipe inlet	9	5.9	6.3	6.4	8.2	9.5	9.8	10.1
NJD-005	d/s pipe inlet	9	6.4	6.9	7.0	8.8	9.6	9.9	10.1
NJD-007	Pond BMP	9	6.6	8.4	8.7	9.3	9.7	9.9	10.1
NJD-008	u/s pipe inlet	9.5	7.5	7.7	7.8	9.4	9.9	10.0	10.2
NJD-009	u/s pipe inlet	10.5	8.8	9.8	10.0	10.8	11.0	11.0	11.0
NJD-014	u/s ditch	10.5	9.1	10.3	10.7	11.2	11.4	11.5	11.6
Second Patrol Division									
SPD-003	Pond BMP	10	6.2	7.3	7.6	8.6	9.2	9.5	9.7
SPD-003A	u/s pipe inlet	10	6.2	7.3	7.6	8.6	9.2	9.5	9.7
SPD-004	u/s pipe inlet	13	6.2	7.3	7.7	8.9	9.7	10.2	10.7
Lake Modoc									
N-6	d/s pipe inlet	11	5.6	6.1	6.2	7.2	8.4	9.3	10.3
N-8	Lake Modoc	11	7.8	8.1	8.2	8.8	9.4	10.0	10.7

Section 4

BMP Conceptual Design Conditions Analysis

4.1 Conceptual BMP Retrofit Design

Extensive review of many potential existing BMP sites for potential retrofit (see Sections 1 and 2) resulted in the selection of five sites for retrofit design. The retrofit design configuration considered for each BMP site varied based on existing site conditions, site constraints, and the existing upstream and downstream stormwater drainage systems. Factors influencing the retrofit designs include the existing BMP configuration, contributing drainage area, available site acreage, groundwater table, tailwater conditions, and dimensions and elevations of the existing stormwater inflow and outflow systems. Descriptions of the five conceptual BMP retrofit designs are provided below.

4.1.1 Norfolk Botanical Gardens

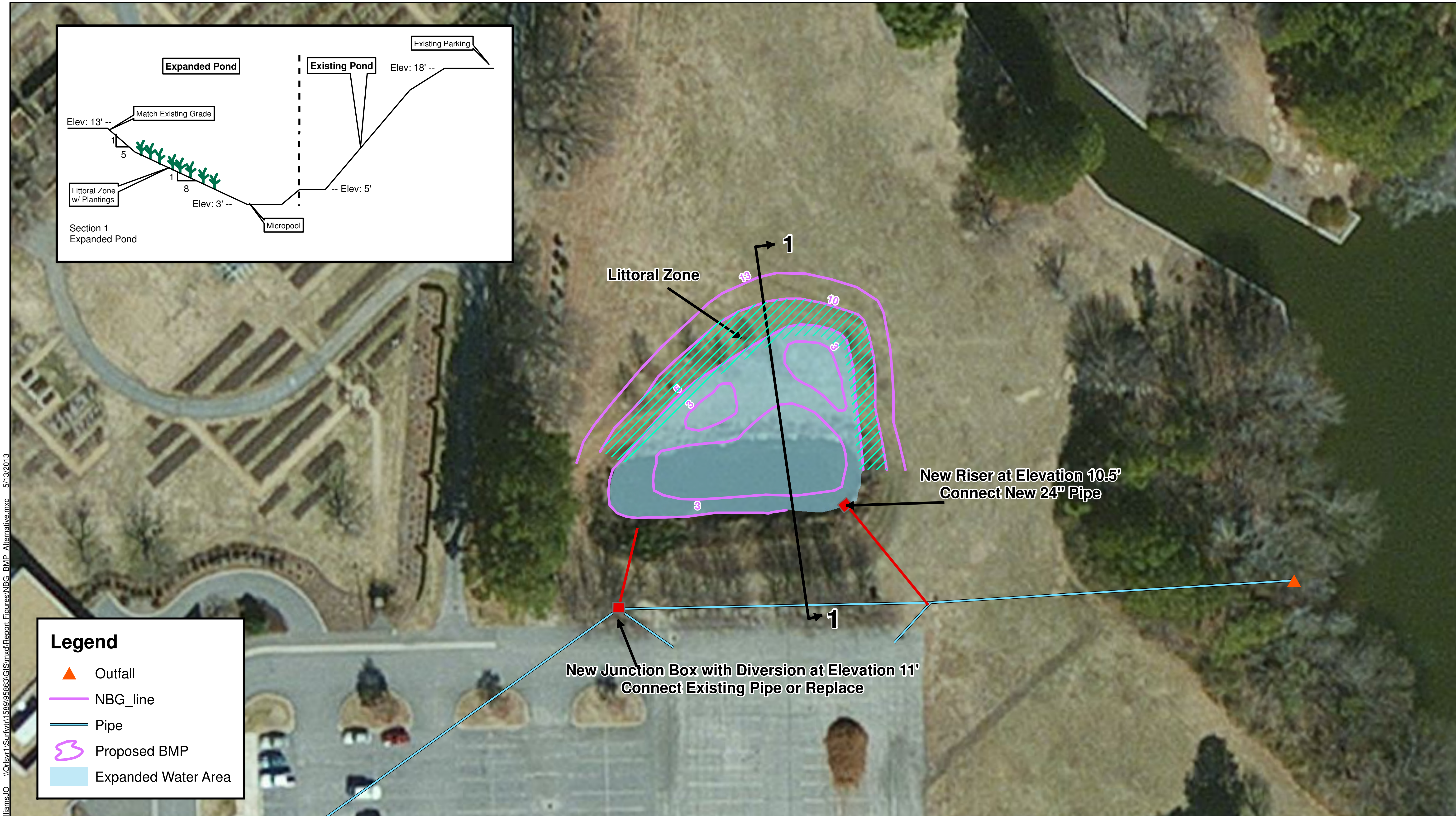
The existing NBG BMP is an offline, seasonally wet, shallow pond. The existing small pond receives inflow from an adjacent pipe system that serves roadway, parking, and building areas of the Botanical Gardens. The pond discharges via a small pipe back to the adjacent pipe system that outfalls to the Lake Whitehurst Reservoir. The existing pond BMP captures and treats runoff from the adjacent developed 7.7-acre area primarily south and west of the BMP. The existing pond BMP is approximately 0.3 acres in size (at top of bank) and has approximately 0.3 acre-feet of stormwater treatment storage. Because the existing pond is offline and the adjacent pipe system can flow freely, the pond receives inflow only when the pond depth is relatively low; otherwise, when the pond partially fills the pipe discharge is routed directly downstream to the Lake Whitehurst Reservoir outfall. The existing pond does not have a riser structure and therefore does not retain an appreciable storage depth.

The conceptual BMP retrofit design expands and deepens the pond and reconfigures the inflow and outflow infrastructure (**Figure 4-1**). A littoral zone proposed along the pond's northern bank. The adjacent pipe junction will be retrofit with a diversion weir to allow the inflow pipe to convey a greater volume of flow into the pond. Higher flows will be allowed to bypass the pond via the diversion weir. In addition, the pond outfall structure will be retrofit with a control structure and orifice to allow the runoff captured by the pond to be detained and drawn down over a longer period of time. The retrofit design expands the pond area and effective stormwater treatment volume to approximately 0.5 acres and 2.0 acre-feet, respectively.

4.1.2 Ballentine Elementary School

The existing BES BMP is a shallow wet pond that discharges via an orifice and weir structure to the existing Lafayette River system. The existing pond BMP captures and treats runoff from the adjacent developed 179.8-acre area primarily east of the BMP. The existing pond BMP is approximately 1.1 acres in size and has approximately 3.6 acre-feet of stormwater treatment storage.

The conceptual BMP retrofit design expands and deepens the pond (**Figure 4-2**). A forebay to capture and store sediment is proposed at the eastern end of the pond near the inflow pipes. No modification of the existing inflow or outflow pipes or weir infrastructure is needed to accomplish the proposed retrofit. The retrofit design expands the pond area and stormwater treatment volume to approximately 1.6 acres and 8.4 acre-feet, respectively.



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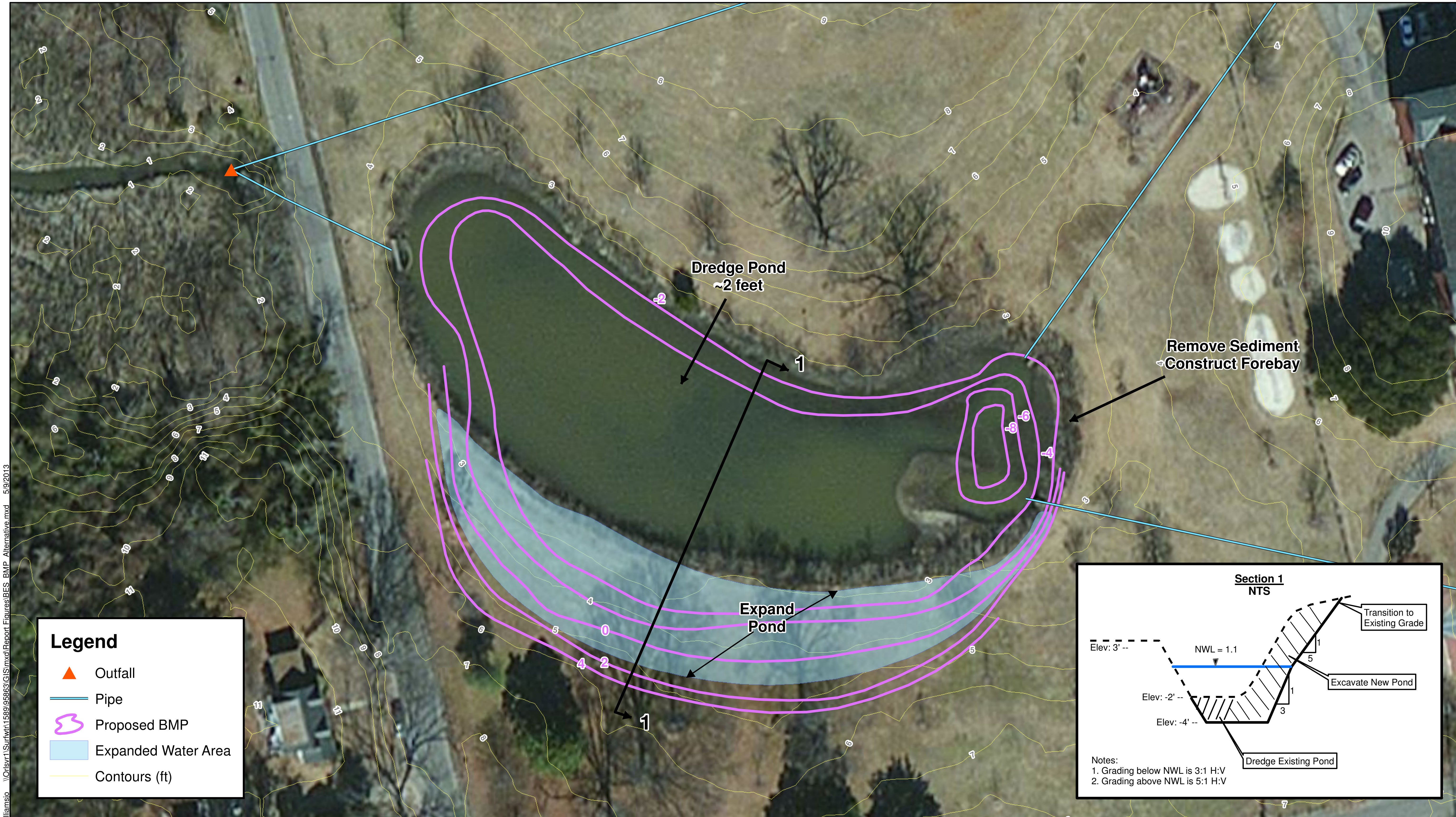
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Norfolk Botanical Gardens
Conceptual Retrofit BMP Design
Figure 4-1



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Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Ballentine Elementary School
Conceptual Retrofit BMP Design
Figure 4-2

4.1.3 Norfolk Juvenile Detention Center

The existing NJD BMP is a shallow dry pond with a concrete-lined ditch that discharges via an orifice and weir structure to an existing adjacent stormwater pipe system. The existing outfall pipe system also serves developed areas south of Lowery Road and west of Security Lane, and the existing ditch along Security Lane (see Figure 3-3). The existing pond BMP captures and treats runoff from the adjacent developed 6.0-acre area south and east of the BMP. The existing pond BMP is approximately 0.8 acres in size and has approximately 0.9 acre-feet of stormwater treatment storage.

The conceptual BMP retrofit design converts the dry pond to a wet pond and expands the pond footprint (**Figure 4-3**). A littoral zone is proposed along the pond's eastern bank. As part of the retrofit, portions of the existing pipe systems, south and west of the BMP will be removed to allow the pipes to outfall directly into the expanded pond BMP. By tying these pipe systems directly into the pond, the tributary area that can be captured and treated by the retrofit BMP expands to approximately 30 acres. The retrofit pond discharges to the existing outfall pipe system via a control structure and orifice (Figure 4-3). The retrofit design expands the pond area and effective stormwater treatment volume to approximately 0.8 acres and 4.8 acre-feet, respectively.

4.1.4 Second Patrol Division

The existing SPD BMP is a wet shallow pond that receives inflow from two adjacent pipe systems that serve roadway, parking, and building areas. One existing inflow pipe from the north has a diversion weir that conveys lower flows to the pond and allows higher flows to bypass the pond and flow to the Lafayette River system. The pond discharges via an orifice and weir structure and pipe to the downstream Lafayette River system. The existing pond BMP captures and treats runoff from the adjacent developed 19.3-acre area primarily north of the BMP. The existing pond BMP is approximately 0.8 acres in size and has approximately 1.7 acre-feet of stormwater treatment storage.

The conceptual BMP retrofit design is limited to deepening the pond to create a forebay (near the pipe inflows) and increase its overall storage volume (**Figure 4-4**). No modifications to the pond inflow or outflow infrastructure are proposed. The retrofit design maintains the pond area at 0.8 acres and expands the stormwater treatment volume to approximately 3.6 acre-feet.

4.1.5 Lake Modoc

The existing BMP is a wet shallow pond that receives inflow from three pipe systems that serve roadway and residential areas. The pond discharges via a weir structure to a downstream pipe system that outfalls to the Chesapeake Bay. The existing pond BMP captures and treats runoff from the adjacent developed 89.7-acre area south and west of the BMP. The existing pond BMP is approximately 1.7 acres in size and has approximately 5.0 acre-feet of stormwater treatment storage.

The conceptual BMP retrofit design is limited to deepening the pond to increase its overall storage volume (**Figure 4-5**). No modifications to the pond inflow or outflow infrastructure are proposed. The retrofit design maintains the pond area at 1.7 acres and expands the stormwater treatment volume to approximately 7.7 acre-feet.

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Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Norfolk Juvenile Detention Center
Conceptual Retrofit BMP Design
Figure 4-3

CDM Smith

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Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Second Patrol Division
Conceptual Retrofit BMP Design
Figure 4-4

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Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Lake Modoc
Conceptual Retrofit BMP Design
Figure 4-5

4.2 Proposed Conditions Analysis

Hydrologic and hydraulic stormwater models were developed to evaluate the performance of the retrofit design modifications of the five selected BMP sites. For this evaluation, CDM Smith revised the SWMM models previously developed for the existing BMPs (Section 3) to represent the proposed applicable modifications to the pond areas and volumes and the stormwater conveyance infrastructure. The hydrologic input parameters for the study area and the hydraulics for areas upstream and downstream of the project remained essentially unchanged from existing conditions. The NBG pond HU (NBG02) was expanded by 0.2 acres due to the proposed pond expansion. Also the NJD connecting stormwater infrastructure was reconfigured as described further below.

The concept BMP designs were evaluated using the same storm events simulated for existing conditions (the 1-inch/6-hour storm and the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year/24 hour design storms) to support design and to allow comparison of existing and proposed conditions (Section 4.3). Multiple iterations of proposed design parameters for the retrofit BMPs were simulated to establish designs that improve BMP performance without causing hydraulic impacts to offsite areas. The design parameters for the BMPs are described further below.

4.2.1 Norfolk Botanical Gardens

The hydraulic model for this retrofit BMP is similar to the existing BMP. As indicated in **Figure 4-6**, the existing conditions model was revised to include the proposed diversion weir and pond riser weir and orifice. The expanded BMP pond stage-storage relationship was developed from the GIS (Figure 4-1). Figure 4-6 shows the link-node model schematic and identifies the hydraulic model element types included in the SWMM model developed for the NBG BMP retrofit. This BMP discharges to the Lake Whitehurst Reservoir. As with the existing conditions analysis, a fixed water elevation of 4 ft.-NAVD was applied at the outfall to Lake Whitehurst Reservoir to represent estimated elevated tailwater conditions based on review of the downstream topographic contours.

4.2.2 Ballentine Elementary School

The hydraulic model for the BES BMP retrofit is nearly identical to that developed for existing conditions. The only difference being the retrofit pond BMP stage-storage relationship was revised to reflect the expanded pond storage volume. **Figure 4-7** shows the link-node model schematic and identifies the hydraulic model element types included in the SWMM model developed for the Ballentine Elementary School BMP.

The downstream limit of the Ballentine Elementary School BMP discharges to the Lafayette River system. For this analysis, a fixed water elevation of 1.1 ft.-NAVD was applied at the outfall to Lafayette River to represent an estimated annual high tide condition.

4.2.3 Norfolk Juvenile Detention Center

The hydraulic model for the NJD retrofit BMP was revised to reflect the proposed expanded pond and reconfigured stormwater management system. For the pond BMP, a stage-storage relationship was defined from the GIS (Figure 4-3). **Figure 4-8** shows the link-node model schematic and identifies the hydraulic model element types included in the SWMM model developed for the NJD retrofit BMP.

The Norfolk Juvenile Detention Center BMP discharges to the adjacent downstream pipe system. For this analysis, a fixed water elevation of 5.1 ft.-NAVD was applied at the downstream pipe system to represent optimum near full flow conditions.

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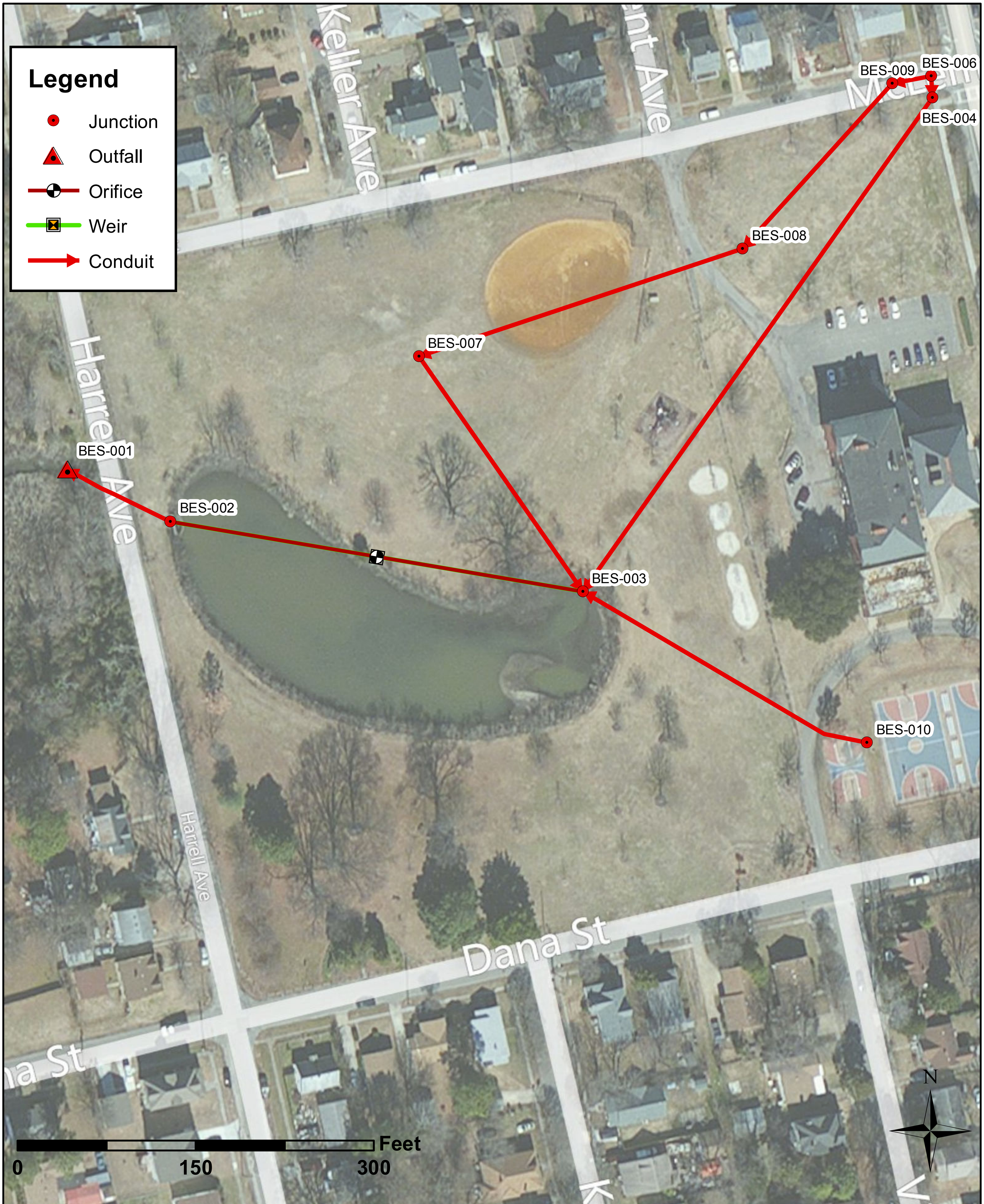
Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

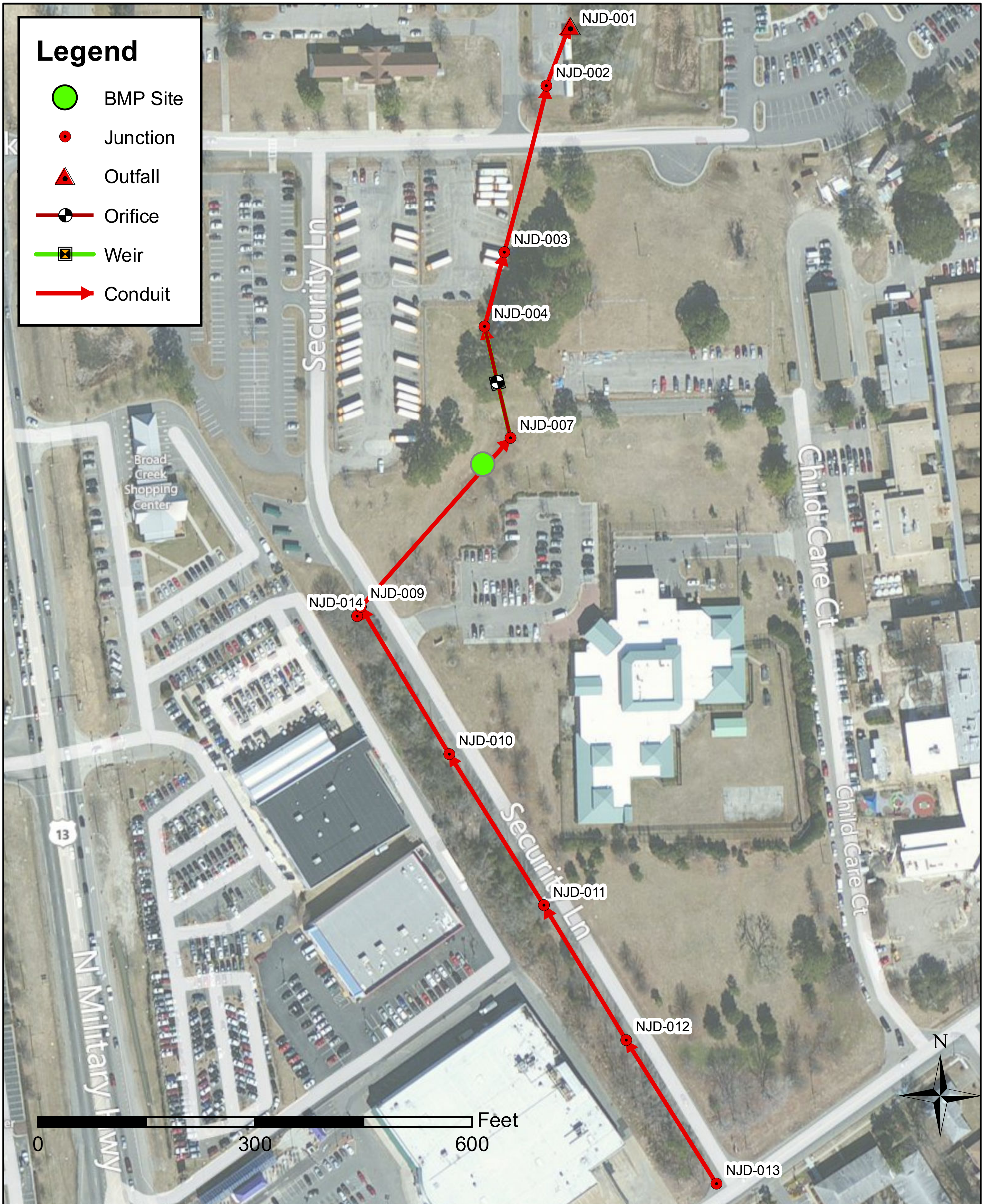
Norfolk Botanical Gardens
Model Schematic
Proposed Conditions
Figure 4-6



CDM Smith

Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Ballentine Elementary School
Model Schematic
Proposed Conditions
Figure 4-7



Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Norfolk Juvenile Detention
Model Schematic
Proposed Conditions
Figure 4-8

4.2.4 Second Patrol Division

There are no differences in the SWMM model results between existing and proposed conditions because the proposed retrofit modifications do not affect conveyance capacity or available attenuation storage for the Second Patrol Division drainage system. While the additional storage volume created by deepening the shallow pond (below normal water level) does not increase attention volume, it does increase overall pond volume and water quality treatment as discussed in Section 5. The model schematic for the proposed SPD retrofit BMP is presented in **Figure 4-9**.

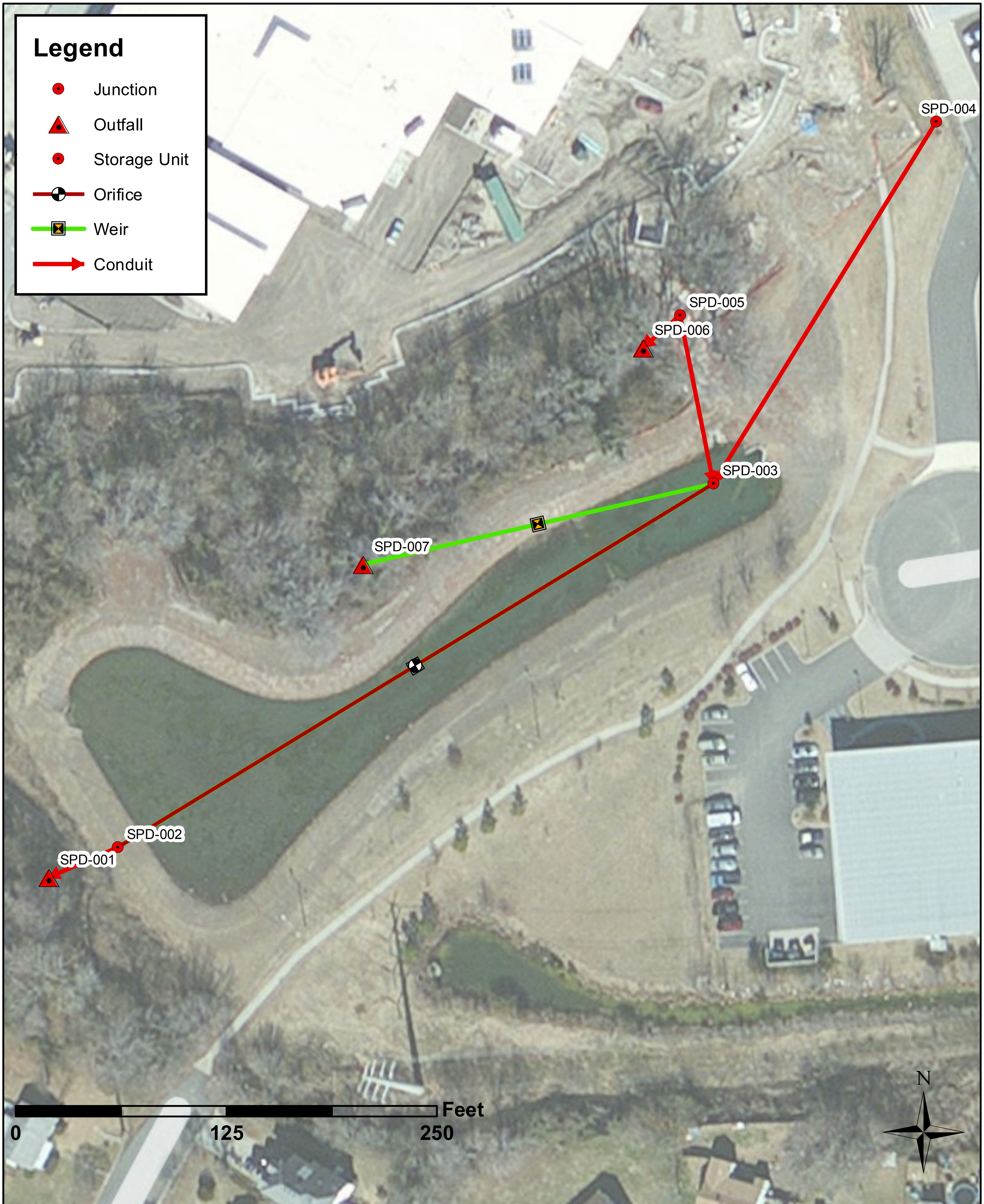
4.2.5 Lake Modoc

There are no differences in the SWMM model results between existing and proposed conditions because the proposed retrofit modifications do not affect conveyance capacity or available attenuation storage for the Lake Modoc drainage system. While the additional storage volume created by deepening the shallow pond (below normal water level) does not increase attention volume, it does increase overall pond volume and water quality treatment as discussed in Section 5. The model schematic for the proposed Lake Modoc retrofit is presented in **Figure 4-10**.

4.3 Model Results

4.3.1 Modeled BMP Retrofits

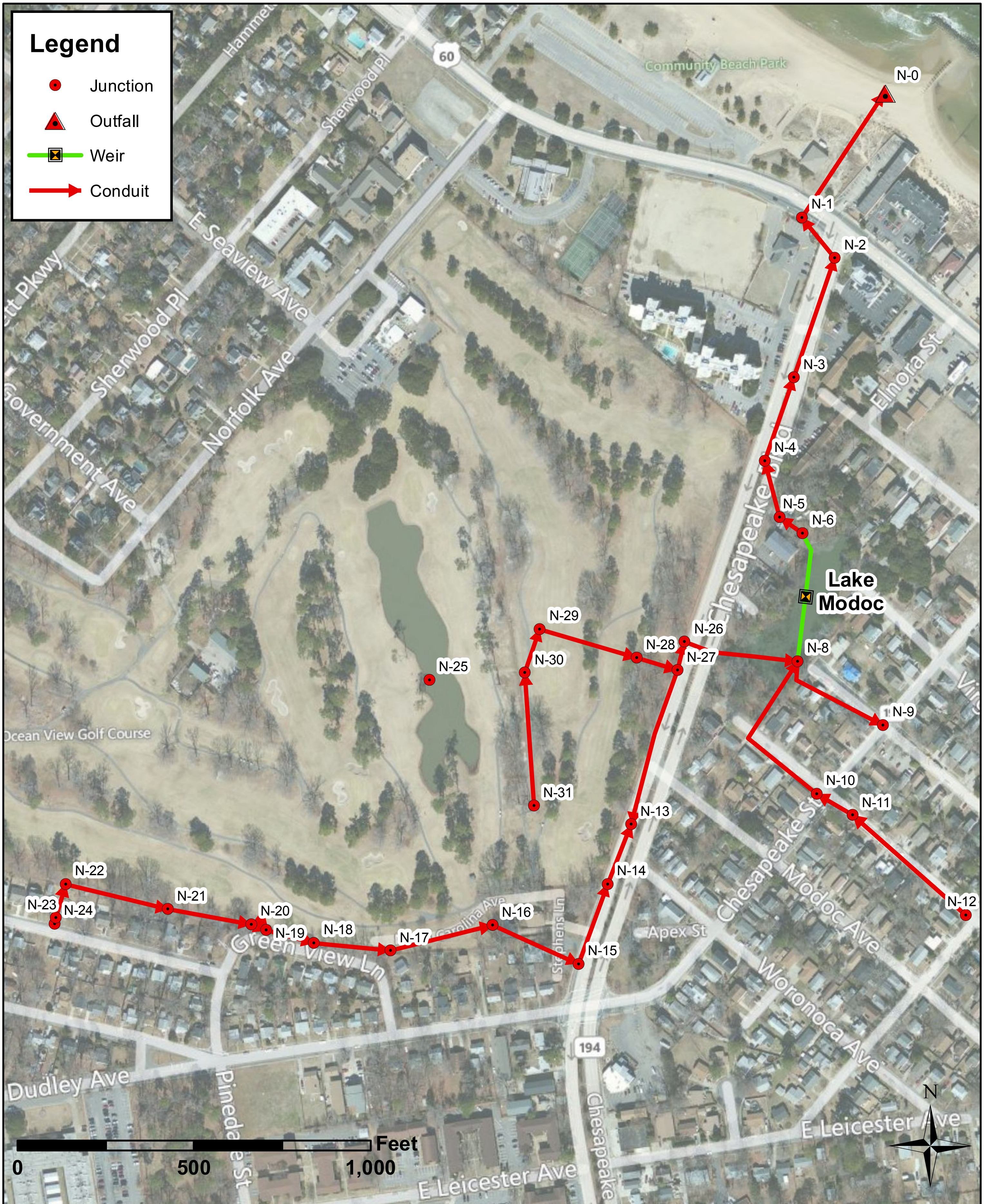
As described above, the existing conditions SWMM models were used to develop proposed conditions SWMM models of the five retrofit BMPs. Comparison of the model results for the BMPs for existing and proposed conditions is important to estimate performance and confirm that the design does not adversely affect any offsite areas upstream or downstream. Model results for the BMPs are presented in **Table 4-1**. It can be seen from the table that in some cases the model-predicted peak stage increases from the existing condition. However, the increase is contained with the retrofitted BMP and is not expected to result in increased flooding of the contributing drainage system.



CDM Smith

Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Second Patrol Division
Model Schematic
Proposed Conditions
Figure 4-9



CDM Smith

Stormwater BMP Retrofit Evaluation
City of Norfolk, Virginia

Lake Modoc
Model Schematic
Proposed Conditions
Figure 4-10

Table 4-1 – Existing and Proposed Conditions Peak Stages

Model Node	Description	Ground EL (ft NAVD)	Existing Conditions Peak Stages (ft NAVD)							Proposed Conditions Peak Stages (ft NAVD)						
			Storm Event							Storm Event						
			1-inch	1-year	2-year	10-year	25-year	50-year	100-year	1-inch	1-year	2-year	10-year	25-year	50-year	100-year
Ballentine Elementary School																
BES-003	Pond BMP	4.2	2.4	3.1	3.4	4.5	4.9	5.2	5.4	2.4	3.1	3.3	4.4	4.9	5.2	5.4
BES-006	u/s road inlet	8	4.1	7.0	7.7	8.3	8.4	8.4	8.5	4.1	7.0	7.7	8.3	8.4	8.4	8.5
BES-010	u/s road inlet	5.4	3.8	5.8	5.9	6.0	6.1	6.2	6.2	3.8	5.8	5.9	6.0	6.1	6.2	6.2
Norfolk Botanical Gardens																
NBG-002	d/s pipe inlet	17	4.2	4.6	4.7	4.9	5.1	5.2	5.5	4.1	4.1	4.2	4.8	5.1	5.2	5.5
NBG-003	Pond BMP	14	6.7	7.0	7.1	7.6	7.7	7.9	8.0	7.4	9.5	10.2	11.1	11.3	11.4	11.4
NBG-004	u/s pipe inlet	17	7.0	7.3	7.4	7.6	7.8	7.9	8.0	7.4	9.5	10.2	11.2	11.4	11.5	11.7
Norfolk Juvenile Detention Center																
NJD-004	d/s pipe inlet	9	5.9	6.3	6.4	8.2	9.5	9.8	10.1	5.4	6.2	6.4	8.2	9.2	9.6	9.9
NJD-005	d/s pipe inlet	9	6.4	6.9	7.0	8.8	9.6	9.9	10.1	--	--	--	--	--	--	--
NJD-007	Pond BMP	9	6.6	8.4	8.7	9.3	9.7	9.9	10.1	6.2	7.5	7.6	8.4	9.4	9.7	10.0
NJD-008	u/s pipe inlet	9.5	7.5	7.7	7.8	9.4	9.9	10.0	10.2	--	--	--	--	--	--	--
NJD-009	u/s pipe inlet	10.5	8.8	9.8	10.0	10.8	11.0	11.0	11.0	8.7	9.6	9.8	10.4	10.8	10.9	11.0
NJD-014	u/s ditch	10.5	9.1	10.3	10.7	11.2	11.4	11.5	11.6	9.0	10.2	10.6	11.2	11.4	11.5	11.6
Second Patrol Division																
SPD-003	Pond BMP	10	6.2	7.3	7.6	8.6	9.2	9.5	9.7	6.2	7.3	7.6	8.6	9.2	9.5	9.7
SPD-003A	u/s pipe inlet	10	6.2	7.3	7.6	8.6	9.2	9.5	9.7	6.2	7.3	7.6	8.6	9.2	9.5	9.7
SPD-004	u/s pipe inlet	13	6.2	7.3	7.7	8.9	9.7	10.2	10.7	6.2	7.3	7.7	8.9	9.7	10.2	10.7
Lake Modoc																
N-6	d/s pipe inlet	11	5.6	6.1	6.2	7.2	8.4	9.3	10.3	5.6	6.1	6.2	7.2	8.4	9.3	10.3
N-8	Lake Modoc	11	7.8	8.1	8.2	8.8	9.4	10.0	10.7	7.8	8.1	8.2	8.8	9.4	10.0	10.7

Notes: Nodes
Model-predicted peak stage increases are not expected to result in increased flooding of the existing drainage system.
NJD-005 and NJD-008 do not exist in proposed conditions as they are replaced by the expanded pond, node NJD-007.

Section 5

Water Quality Analysis

5.1 Introduction

Since EPA established the Chesapeake Bay TMDL in December 2010, two phases of planning have been completed by each of the states in the Chesapeake Bay watershed to comply the requirements of the TMDL. Virginia's most recent planning effort to comply with the Chesapeake Bay TMDL is documented in the Phase II Watershed Implementation Plan (WIP). The formulation of the implementation plan has been a complex process that includes a wide range of technical and policy issues. Technical issues relevant to understanding the benefit and effectiveness of stormwater BMP retrofits include:

- Types of BMPs recognized as providing a reduction in the pollutants of concern: nitrogen, phosphorus and sediment;
- Calculation of removal rates for individual types of retrofit BMP improvements; and
- Accountability procedures to obtain credit towards pollutant load reduction requirements.

The most recent progress on these issues recognized by the Chesapeake Bay Program was technical guidance prepared by the Urban Stormwater Group entitled *Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects* (CSN, 2012). This documentation is included in Appendix D. The guidance provided by the Panel provides important advances to address the three issues listed above. This study focuses on opportunities to retrofit existing stormwater BMPs to improve performance and reduce the discharge of nutrients and sediment. Retrofits defined by the Panel include the following:

- **BMP Conversions** – modifying an existing BMP to provide a more effective treatment mechanism than was provided previously
- **BMP Enhancements** – preserve the treatment mechanism of the existing BMP, but increase the reduction of nutrients and sediment by providing additional treatment volume, increasing the contributing drainage area and associated pollutant loading volume, or increasing hydraulic residence time
- **BMP Restoration** – maintenance to re-establish the function of a BMP that has failed or lost its original treatment capacity

The protocol developed by the Panel defines retrofit removal adjustor curves to quantify the pollutant removal benefit for each retrofitted BMP, based on the incremental pollutant reduction between the existing BMP and the retrofitted BMP. This approach provides the ability to account for area treated and pollutant reductions in terms of percentages. However, it does not provide for estimating the load reduction in terms of the annual pounds discharged or calculation of the cost per pound reduced, which are beneficial for equitably comparing multiple pollutant reduction options. These calculations require the estimates of the source pollutant load.

5.2 Pollutant Loading Methodology

The definition of pollutant load allocations and pollutant reduction targets have been points of debate during development of the TMDL and the subsequent formulation of the Phase II WIP. For the purpose of this study, pollutant loading values are based the Virginia Assessment Scenario Tool (VAST) that Virginia localities used during development of the Phase II WIP. The loading values from VAST presented in **Table 5-1** represent the best available information for current planning, and the estimated load reduction and cost per pound values can be refined in the future as updated information becomes available.

Table 5-1
Baseline Pollutant Loads by Land Use

Land Use Category	Annual Average Load[1]		
	Nitrogen (lbs / acre)	Phosphorus (lbs / acre)	Total Suspended Solids (lbs / acre)
Regulated Impervious Developed	8.63	1.63	491
Regulated Pervious Developed	8.62	0.59	72.8
Water	7.79	0.66	0.00

[1] VAST 2010 No BMP Scenario – Urban land use edge of stream loads

5.3 Pollutant Loading for Existing and Proposed Conditions

Pollutant loadings for the five selected BMP sites based on the baseline pollutant loads defined in Table 5-1 were calculated under existing land use conditions. The contributing areas (by subbasins as described in Section 3) for the five BMP sites under existing and proposed conditions are broken out by impervious, pervious, and water areas in **Tables 5-2** and **5-3** below. The areas served by the existing and proposed retrofit BMPs are identical except for the NBG and the NJD sites. For the NBG, basin NBG02 is slightly larger (0.2 acres) under proposed conditions due to the proposed increase in BMP size. For the NJD basin, the overall area served by the BMP was increased significantly (from 5.99 acres to 29.97 acres) under proposed conditions due to the reconfiguration of the site stormwater management system (see Section 4).

As indicated in Table 5-2, the drainage areas served by the five existing BMP sites range from about 6 acres (NJD) to 180 acres (BES). Three of the five BMP tributary areas are comprised of greater than 50% imperviousness, while the areas served by NJD and Lake Modoc are slightly less than 50% impervious. Based on these land use distributions, overall pollutant loadings for nitrogen, phosphorus, and total suspended solids (TSS) were determined for the existing and proposed BMP sites as presented in **Tables 5-4** and **5-5**. As expected the largest and most impervious tributary areas and basins generate the highest loads. The pollutant loadings between existing and proposed conditions are similar; however, there are some important differences. The largest difference is in the NJD basin where the loading to the proposed BMP increased significantly due to the larger drainage area served. Other smaller differences are in the NBG basin due to a larger contributing basin (larger proposed BMP) and in the BES basin due to change in land use from pervious to water area (larger proposed BMP).

Table 5-2
Existing BMP Site Land Use Acreages by Contributing Subbasin

HU ID	Total Area (ac)	Impervious Area (ac)	Pervious Area (ac)	Water (ac)
Norfolk Botanical Gardens				
NBG02	0.53	0.00	0.37	0.16
NBG03	7.74	4.95	2.79	0.00
Totals	**8.27**	**4.95**	**3.16**	**0.16**
Ballentine Elementary School				
BES01	20.98	8.01	11.87	1.10
BES02	93.18	64.15	29.03	0.00
BES03	65.67	47.08	18.59	0.00
Totals	**179.83**	**119.24**	**59.49**	**1.10**
Norfolk Juvenile Detention				
NJD01	5.99	2.62	3.38	0.00
Totals	**5.99**	**2.62**	**3.38**	**0.00**
Second Patrol Division				
SPD01	1.66	0.01	0.75	0.90
SPD02	13.33	10.38	2.95	0.00
SPD03	4.34	3.67	0.67	0.00
Totals	**19.34**	**14.07**	**4.37**	**0.90**
Lake Modoc				
HU-5	14.73	6.78	7.95	0.00
HU-6	4.19	2.22	1.97	0.00
HU-7	22.8	13.22	9.58	0.00
HU-8	6.59	3.95	2.64	0.00
HU-9	4.4	2.82	1.58	0.00
HU-10	4.74	3.18	1.56	0.00
HU-11	5.1	2.50	2.60	0.00
HU-12	2.39	1.43	0.96	0.00
HU-13	0.99	0.09	0.90	0.00
HU-14	0.93	0.20	0.73	0.00
HU-15	1.24	0.33	0.91	0.00
HU-16	2.85	0.54	2.31	0.00
HU-18	2.57	0.28	2.29	0.00
HU-19	4.06	0.12	3.94	0.00
HU-20	4.1	1.27	2.83	0.00
HU-21	4.07	1.71	2.36	0.00
HU-22	2.27	0.32	1.95	0.00
Pond1	1.7	0.00	0.00	1.70
Totals	**89.72**	**40.96**	**47.06**	**1.70**

Notes: HU NBG01 does not drain to the NBG BMP thus is not included.
Impervious areas reported above do not include open water areas

Table 5-3
Proposed Retrofit BMP Site Land Use Acreages by Contributing Subbasin

HU ID	Total Area (ac)	Impervious Area (ac)	Pervious Area (ac)	Water (ac)
Norfolk Botanical Gardens				
NBG02	0.70	0.00	0.42	0.28
NBG03	7.74	4.95	2.79	0.00
Totals	**8.44**	**4.95**	**3.21**	**0.28**
Ballentine Elementary School				
BES01	20.98	8.01	11.38	1.59
BES02	93.18	64.15	29.03	0.00
BES03	65.67	47.08	18.59	0.00
Totals	**179.83**	**119.24**	**59.00**	**1.59**
Norfolk Juvenile Detention				
NJD01	5.99	2.62	2.71	0.67
NJD02	0.66	0.63	0.03	0.00
NJD03	0.58	0.47	0.11	0.00
NJD04	0.77	0.62	0.15	0.00
NJD05	4.56	1.14	3.42	0.00
NJD06	10.59	10.29	0.30	0.00
NJD07	6.81	5.11	1.70	0.00
Totals	**29.97**	**20.88**	**8.42**	**0.67**
Second Patrol Division				
SPD01	1.66	0.01	0.75	0.90
SPD02	13.33	10.38	2.95	0.00
SPD03	4.34	3.67	0.67	0.00
Totals	**19.34**	**14.07**	**4.37**	**0.90**
Lake Modoc				
HU-5	14.73	6.78	7.95	0.00
HU-6	4.19	2.22	1.97	0.00
HU-7	22.8	13.22	9.58	0.00
HU-8	6.59	3.95	2.64	0.00
HU-9	4.4	2.82	1.58	0.00
HU-10	4.74	3.18	1.56	0.00
HU-11	5.1	2.50	2.60	0.00
HU-12	2.39	1.43	0.96	0.00
HU-13	0.99	0.09	0.90	0.00
HU-14	0.93	0.20	0.73	0.00
HU-15	1.24	0.33	0.91	0.00
HU-16	2.85	0.54	2.31	0.00
HU-18	2.57	0.28	2.29	0.00
HU-19	4.06	0.12	3.94	0.00
HU-20	4.1	1.27	2.83	0.00
HU-21	4.07	1.71	2.36	0.00
HU-22	2.27	0.32	1.95	0.00
Pond1	1.7	0.00	0.00	1.70
Totals	**89.72**	**40.96**	**47.06**	**1.70**

Notes: HU NBG01 does not drain to the NBG BMP thus is not included.
Impervious areas reported above do not include open water areas

Table 5-4
Existing BMP Site Pollutant Loadings by Subbasin

HU ID	Total Area (ac)	Nitrogen (lbs)	Phosphorus (lbs)	TSS (lbs)
Norfolk Botanical Gardens				
NBG02	0.53	4	0.3	27
NBG03	7.74	67	10	2,637
Totals	**8.27**	**71**	**10**	**2,663**
Ballentine Elementary School				
BES01	20.98	180	21	4,800
BES02	93.18	804	122	33,634
BES03	65.67	567	88	24,486
Totals	**179.83**	**1,551**	**230**	**62,919**
Norfolk Juvenile Detention				
NJD01	5.99	52	6	1,532
Totals	**5.99**	**52**	**6**	**1,532**
Second Patrol Division				
SPD01	1.66	14	1	60
SPD02	13.33	115	19	5,317
SPD03	4.34	38	6	1,853
Totals	**19.34**	**166**	**26**	**7,230**
Lake Modoc				
HU-5	14.73	127	16	3,908
HU-6	4.19	36	5	1,235
HU-7	22.8	197	27	7,195
HU-8	6.59	57	8	2,135
HU-9	4.4	38	6	1,499
HU-10	4.74	41	6	1,674
HU-11	5.1	44	6	1,417
HU-12	2.39	21	3	774
HU-13	0.99	9	1	109
HU-14	0.93	8	1	149
HU-15	1.24	11	1	230
HU-16	2.85	25	2	434
HU-18	2.57	22	2	305
HU-19	4.06	35	3	346
HU-20	4.1	35	4	830
HU-21	4.07	35	4	1,012
HU-22	2.27	20	2	298
Pond1	1.7	13	1	0
Totals	**89.72**	**772**	**96**	**23,552**

Notes: HU NBG01 does not drain to the NBG BMP thus is not included.
Impervious areas reported above do not include open water areas

Table 5-5
Proposed Retrofit BMP Site Pollutant Loadings by Subbasin

HU ID	Total Area (ac)	Nitrogen (lbs)	Phosphorus (lbs)	TSS (lbs)
Norfolk Botanical Gardens				
NBG02	0.70	6	0.4	31
NBG03	7.74	67	10	2,637
Totals	**8.44**	**73**	**10**	**2,667**
Ballentine Elementary School				
BES01	20.98	180	21	4,764
BES02	93.18	804	122	33,634
BES03	65.67	567	88	24,486
Totals	**179.83**	**1,550**	**230**	**62,884**
Norfolk Juvenile Detention				
NJD01	5.99	51	6	1,483
NJD02	0.66	6	1	312
NJD03	0.58	5	1	241
NJD04	0.77	7	1	317
NJD05	4.56	39	4	810
NJD06	10.59	91	17	5,077
NJD07	6.81	59	9	2,634
Totals	**29.97**	**258**	**39**	**10,874**
Second Patrol Division				
SPD01	1.66	14	1	60
SPD02	13.33	115	19	5,317
SPD03	4.34	38	6	1,853
Totals	**19.34**	**166**	**26**	**7,230**
Lake Modoc				
HU-5	14.73	127	16	3,908
HU-6	4.19	36	5	1,235
HU-7	22.8	197	27	7,195
HU-8	6.59	57	8	2,135
HU-9	4.4	38	6	1,499
HU-10	4.74	41	6	1,674
HU-11	5.1	44	6	1,417
HU-12	2.39	21	3	774
HU-13	0.99	9	1	109
HU-14	0.93	8	1	149
HU-15	1.24	11	1	230
HU-16	2.85	25	2	434
HU-18	2.57	22	2	305
HU-19	4.06	35	3	346
HU-20	4.1	35	4	830
HU-21	4.07	35	4	1,012
HU-22	2.27	20	2	298
Pond1	1.7	13	1	0
Totals	**89.72**	**772**	**96**	**23,552**

Notes: HU NBG01 does not drain to the NBG BMP thus is not included.
Impervious areas reported above do not include open water areas

5.4 Removal Efficiencies for Existing and Proposed BMPs

The existing and proposed retrofit BMPs provide treatment of the pollutants they capture from contributing stormwater runoff. The BMP efficiencies (or percent removal) are based on the removal adjustor curves developed by the expert panel (Appendix D). From these curves, percent removal of TN, TP, and TSS is estimated using the runoff depth (RD) captured as calculated below.

$$\text{Runoff Depth (inches)} = \frac{(RS)(12)}{IA}$$

Where

RS = Runoff Storage Volume of the BMP (acre-feet)

IA = Impervious Area in the contributing drainage area (acres)

The existing and proposed retrofit BMP parameters and associated pollutant removal percentages are presented in **Table 5-6**. As indicated in Table 5-6, the BMP efficiencies (removal percentages) of the proposed retrofit BMPs exceed those of the existing BMPs except for the NJD site. However, as indicated in the table, the drainage area and the impervious area for the NJD site was significantly increased by the proposed BMP reconfiguration, therefore providing a comparable BMP efficiency to serve a much larger area results in greater overall pollutant removal.

Table 5-6
Existing and Proposed BMP Pollutant Removal Efficiencies

BMP Site	Area (ac)	RS (ac-ft)	IA (ac)	RD (inches)	TN Removal	TP Removal	TSS Removal
Norfolk Botanical Gardens							
Existing	8.27	0.29	4.95	0.71	30%	46%	59%
Proposed	8.44	2.05	4.95	4.96	43%	67%	85%
Ballentine Elementary School							
Existing	179.83	3.56	119.24	0.36	23%	36%	45%
Proposed	179.83	8.40	119.24	0.85	32%	49%	63%
Norfolk Juvenile Detention							
Existing	5.99	0.86	2.62	3.95	43%	67%	85%
Proposed	29.97	4.76	20.88	2.74	43%	67%	85%
Second Patrol Division							
Existing	19.34	1.75	14.07	1.49	37%	58%	74%
Proposed	19.34	3.58	14.07	3.05	43%	67%	85%
Lake Modoc							
Existing	89.72	5.04	40.96	1.48	37%	58%	74%
Proposed	89.72	7.74	40.96	2.27	42%	65%	85%

Note: The maximum RD value in the adjustor curves is 2.5 inches. For RD values greater than 2.5, the % removal at 2.5 inches is used.

The removal efficiencies reported in Table 5-6, were applied to the pollutant loadings for the BMP sites (as reported in Tables 5-4 and 5-5) to determine the quantities of pollutants removed by the BMPs under existing and proposed conditions. The pollutant removal for the existing and proposed BMPs are reported in **Table 5-7**.

Table 5-7
Existing and Proposed BMP Pollutant Removal Quantities

BMP Site	TN load (lbs)	TP load (lbs)	TSS load (lbs)	TN Removal	TP Removal	TSS Removal	TN Removed (lbs)	TP Removed (lbs)	TSS Removed (lbs)
Norfolk Botanical Gardens BMP									
Existing	71	10	2,663	30%	46%	59%	21	5	1,571
Proposed	73	10	2,667	43%	67%	85%	31	7	2,267
Delta	**2**	**0**	**4**	**13%**	**21%**	**26%**	**10**	**2**	**696**
Ballentine Elementary School BMP									
Existing	1,551	230	62,919	23%	36%	45%	349	83	28,314
Proposed	1,550	230	62,884	32%	49%	63%	488	113	39,617
Delta	**-1**	**0**	**-35**	**9%**	**13%**	**18%**	**139**	**30**	**11,303**
Norfolk Juvenile Detention BMP									
Existing	52	6	1,532	43%	67%	85%	22	4	1,302
Proposed	258	39	10,874	43%	67%	85%	110	26	9,243
Delta	**206**	**33**	**9,342**	**0%**	**0%**	**0%**	**88**	**22**	**7,941**
Second Patrol Division BMP									
Existing	166	26	7,230	37%	58%	74%	61	15	5,350
Proposed	166	26	7,230	43%	67%	85%	71	17	6,145
Delta	**0**	**0**	**0**	**6%**	**9%**	**11%**	**10**	**2**	**795**
Lake Modoc BMP									
Existing	772	96	23,552	37%	58%	74%	286	56	17,428
Proposed	772	96	23,552	42%	65%	85%	321	62	20,019
Delta	**0**	**0**	**0**	**5%**	**7%**	**9%**	**35**	**6**	**2,591**

Note: The pollutant load for the Ballentine Elementary School site decreased for the proposed condition because the footprint of the BMP was increased, which resulted in a decrease in the area that generates pollutant loads, based on the methodology used to develop pollutant loads for this project.

The planning period for this project is assumed to be 20 years. The incremental pollutant volume removed over the 20 year planning period is presented in **Table 5-8** for each of the BMPs.

Table 5-8
Incremental Pollutant Volume Removed Over 20-Year Planning Period

BMP Retrofit Project	Incremental Pollutant Removed Over 20-Year Planning Period (lbs)		
	TN	TP	TSS
Norfolk Botanical Gardens	200	40	13,920
Ballentine Elementary School	2,780	600	226,060
Norfolk Juvenile Detention	1,760	440	158,820
Second Patrol Division	200	40	15,900
Lake Modoc	700	120	51,820

Section 6

Analysis of Probable Costs

6.1 Methodology

In support of the implementation of the retrofit BMPs proposed in this study, CDM Smith has developed conceptual opinions of probable costs for each of the five selected BMP retrofit projects. The conceptual opinions of probable costs are comprised of capital costs and operation and maintenance (O&M) costs. The capital costs represent the upfront investment required to design and construct the improvements. The O&M costs represent the long term investment to operate and maintain the facility to keep it functioning as intended.

Capital costs are estimated by first determining the quantities associated with the retrofit design components, such as volume of excavation, dredging, sections of stormwater pipe, drop inlet structures, and mitered end sections. Appropriate unit costs are then determined and applied to the proposed design quantities. Unit costs used in the capital cost estimates are based on our engineering and construction cost estimating experience in the region and review of other local resources such as the Virginia Department of Transportation (VDOT) construction cost index. Other construction cost components are also accounted for such as mobilization, traffic control, sodding, and erosion and turbidity control measures. Since the retrofit designs are currently at the conceptual phase, a 30% contingency is also included. Surveying, engineering, and permitting are assumed to be 20% of the subtotal capital cost plus contingency, or $50,000, whichever is greater.

An annual O&M cost was calculated as 5% of the retrofit construction cost (which includes a 30% contingency). The present value of the O&M costs were then calculated over a 20-year planning period using the following uniform series present worth equation:

$$P = A \times \frac{((1+i)^n - 1)}{i(1+i)^n} \qquad \text{Eqn. 4.1.}$$

Where (P) is the present value over (n = 20) years, (A) is the annual cost, and (i = 4 percent) is the rate of inflation over the (n = 20) year period.

6.2 Conceptual Opinions of Probable Costs

Detailed capital cost line items for the projects are presented in **Tables 6-1** through **6-5**. The estimated BMP retrofit project costs range from $145,000 for Norfolk Botanical Gardens to $236,000 for Ballentine Elementary School. As noted in the detailed cost tables, these estimates do not include costs associated with potential land or easement acquisition, utility relocation, or wetland mitigation. Also, the total project costs presented do not include additional planting, buffers, and amenities not referenced in the cost items. These and other additional improvements may be considered as funding becomes available. As additional site-specific data is collected and more detailed design is developed, these cost estimates should be further refined.

Table 6-1
Opinion of Conceptual Capital Cost for Norfolk Botanical Gardens BMP Retrofit

Item No.	Item Description	Unit	Qty	Unit Cost	Capital Cost
1	Mobilization (approx. 5 percent)	LS	1	$3,400	$3,400
2	Traffic Control (approx. 2 percent)	LS	1	$1,360	$1,360
3	24-in RCP, Class III	LF	145	$75	$10,875
4	VDOT Type DI-1 24" Drop Inlet <10' w/ Collar	EA	1	$6,000	$6,000
5	Manhole, Type J-bottom, <10'	EA	1	$8,000	$8,000
6	Dredging/Excavation	CY	290	$17	$4,930
7	Excavation	CY	2,819	$8	$22,552
8	Embankment	CY	66	$5	$330
9	Floating Turbidity Barrier	LF	100	$10	$1,000
10	24" Mitered End Section	EA	1	$1,200	$1,200
11	Rubble Riprap	TN	1	$130	$130
12	Littoral Zone Planting	SF	5250	$2	$10,500
13	Sodding	SY	914	$2	$1,828
14	Staked Silt Fence	LF	545	$1	$545
			Subtotal		**73,000**
			Contingency:	30%	$21,900
			Survey, Engineering, and Permitting:	20%	$50,000
			Total Preliminary Engineer's Estimate of Probable Cost		**$145,000**
			(Rounded to the nearest $1,000)		

These Opinions of Conceptual Capital Cost:

1. Are in 2013 dollars.
2. Include contractor's overhead, profit, mobilization, and bonding.
3. Do not include potential replacement or rehabilitation of non-stormwater infrastructure (e.g., water, sewer, reuse, cable, telephone, gas, fiber optic, etc.)
4. Do not include potential land acquisition (unless noted).
5. Do not include any potential hazardous material or groundwater remediation.
6. Do not include any potential wetlands mitigation.
7. Have a 30% contingency.
8. Survey, Engineering, and Permitting is the greater of 20% of the Subtotal plus Contingency or $50,000, whichever is greater
9. Are rounded to the next highest $1,000.
10. Excavation and Embankment estimates are preliminary and are based on digitized contours and proposed grading.

Table 6-2
Opinion of Conceptual Capital Cost for Ballentine Elementary School BMP Retrofit

Item No.	Item Description	Unit	Qty	Unit Cost	Capital Cost
1	Mobilization (approx. 5 percent)	LS	1	$6,700	$6,700
2	Traffic Control (approx. 2 percent)	LS	1	$2,680	$2,680
3	Dredging/Excavation	CY	5,632	$17	$95,744
4	Excavation	CY	2,838	$8	$22,704
5	Embankment	CY	115	$5	$575
6	Floating Turbidity Barrier	LF	220	$10	$2,200
7	36" Mitered End Section	EA	1	$2,400	$2,400
8	Rubble Riprap	TN	2	$130	$260
9	Sodding	SY	3,966	$$2	$7,932
10	Staked Silt Fence	LF	1,400	$1	$1,400
			Subtotal		**$143,000**
			Contingency:	30%	$42,900
			Survey, Engineering, and Permitting:	20%	$50,000
			Total Preliminary Engineer's Estimate of Probable Cost		**$236,000**
			(Rounded to the nearest $1,000)		

These Opinions of Conceptual Capital Cost:

1. Are in 2013 dollars.
2. Include contractor's overhead, profit, mobilization, and bonding.
3. Do not include potential replacement or rehabilitation of non-stormwater infrastructure (e.g., water, sewer, reuse, cable, telephone, gas, fiber optic, etc.)
4. Do not include potential land acquisition (unless noted).
5. Do not include any potential hazardous material or groundwater remediation.
6. Do not include any potential wetlands mitigation.
7. Have a 30% contingency.
8. Survey, Engineering, and Permitting is the greater of 20% of the Subtotal plus Contingency or $50,000, whichever is greater
9. Are rounded to the next highest $1,000.
10. Excavation and Embankment estimates are preliminary and are based on digitized contours and proposed grading.

Table 6-3
Opinion of Conceptual Capital Cost for Norfolk Juvenile Detention Center BMP Retrofit

Item No.	Item Description	Unit	Qty	Unit Cost	Capital Cost
1	Mobilization (approx. 5 percent)	LS	1	$4,400	$4,400
2	Traffic Control (approx. 2 percent)	LS	1	$1,760	$1,760
3	Demolition, 12-in RCP, Class III	LF	40	$5	$200
4	Demolition, 15-in RCP, Class III	LF	42	$6	$252
5	Demolition, 18-in RCP, Class III	LF	30	$7	$210
6	Demolition, 24-in RCP, Class III	LF	262	$11	$2,882
7	Demolition, 30-in RCP, Class III	LF	130	$15	$1,950
8	Miscellaneous Pipe/Concrete Removal	LF	200	$12	$2,400
9	VDOT Type DI-2D 30" Drop Inlet <9' w/ Collar	EA	1	$6,000	$6,000
10	Excavation	CY	7,562	$8	$60,496
11	Embankment	CY	136	$5	$680
12	24" Mitered End Section	EA	3	$1,200	$3,600
13	Rubble Riprap	TN	3	$130	$390
14	Littoral Zone Planting	SF	2300	$2	$4,600
15	Sodding	SY	1,517	$2	$3,034
16	Staked Silt Fence	LF	1,080	$1	$1,080
			Subtotal		**94,000**
			Contingency:	30%	$28,200
			Survey, Engineering, and Permitting:	20%	$50,000
			Total Preliminary Engineer's Estimate of Probable Cost		**$172,000**
			(Rounded to the nearest $1,000)		

These Opinions of Conceptual Capital Cost:

1. Are in 2013 dollars.
2. Include contractor's overhead, profit, mobilization, and bonding.
3. Do not include potential replacement or rehabilitation of non-stormwater infrastructure (e.g., water, sewer, reuse, cable, telephone, gas, fiber optic, etc.)
4. Do not include potential land acquisition (unless noted).
5. Do not include any potential hazardous material or groundwater remediation.
6. Do not include any potential wetlands mitigation.
7. Have a 30% contingency.
8. Survey, Engineering, and Permitting is the greater of 20% of the Subtotal plus Contingency or $50,000, whichever is greater
9. Are rounded to the next highest $1,000.
10. Excavation and Embankment estimates are preliminary and are based on digitized contours and proposed grading.

Table 6-4
Opinion of Conceptual Capital Cost for Second Patrol Division BMP Retrofit

Item No.	Item Description	Unit	Qty	Unit Cost	Capital Cost
1	Mobilization (approx. 5 percent)	LS	1	$4,050	$4,050
2	Traffic Control (approx. 2 percent)	LS	1	$1,620	$1,620
3	Dredging/Excavation	CY	4,205	$17	$71,485
4	Embankment	CY	1,284	$5	$6,420
5	Floating Turbidity Barrier	LF	150	$10	$1,500
6	Staked Silt Fence	LF	1,250	$1	$1,250
			Subtotal		**87,000**
			Contingency:	30%	$26,100
			Survey, Engineering, and Permitting:	20%	$50,000
			Total Preliminary Engineer's Estimate of Probable Cost		**$163,000**
			(Rounded to the nearest $1,000)		

These Opinions of Conceptual Capital Cost:

1. Are in 2013 dollars.
2. Include contractor's overhead, profit, mobilization, and bonding.
3. Do not include potential replacement or rehabilitation of non-stormwater infrastructure (e.g., water, sewer, reuse, cable, telephone, gas, fiber optic, etc.)
4. Do not include potential land acquisition (unless noted).
5. Do not include any potential hazardous material or groundwater remediation.
6. Do not include any potential wetlands mitigation.
7. Have a 30% contingency.
8. Survey, Engineering, and Permitting is the greater of 20% of the Subtotal plus Contingency or $50,000, whichever is greater
9. Are rounded to the next highest $1,000.
10. Excavation and Embankment estimates are preliminary and are based on digitized contours and proposed grading.

Table 6-5
Opinion of Conceptual Capital Cost for Lake Modoc BMP Retrofit

Item No.	Item Description	Unit	Qty	Unit Cost	Capital Cost
1	Mobilization (approx. 5 percent)	LS	1	$4,000	$4,000
2	Traffic Control (approx. 2 percent)	LS	1	$1,580	$1,580
3	Dredging/Excavation	CY	4,400	$17	$74,800
4	Floating Turbidity Barrier	LF	190	$10	$1,900
5	Staked Silt Fence	LF	1,500	$1	$1,500
			Subtotal		**$84,000**
			Contingency:	30%	$25,200
			Survey, Engineering, and Permitting:	20%	$50,000
			Total Preliminary Engineer's Estimate of Probable Cost		**$159,000**
			(Rounded to the nearest $1,000)		

These Opinions of Conceptual Capital Cost:

1. Are in 2013 dollars.
2. Include contractor's overhead, profit, mobilization, and bonding.
3. Do not include potential replacement or rehabilitation of non-stormwater infrastructure (e.g., water, sewer, reuse, cable, telephone, gas, fiber optic, etc.)
4. Do not include potential land acquisition (unless noted).
5. Do not include any potential hazardous material or groundwater remediation.
6. Do not include any potential wetlands mitigation.
7. Have a 30% contingency.
8. Survey, Engineering, and Permitting is the greater of 20% of the Subtotal plus Contingency or $50,000, whichever is greater
9. Are rounded to the next highest $1,000.
10. Excavation and Embankment estimates are preliminary and are based on digitized contours and proposed grading.

The O&M cost was developed for each of the five selected retrofit BMPs using the construction costs presented in Tables 6-1 through 6-5, the 5% annual O&M cost, and the 20-year present worth cost, which are presented in **Table 6-6**.

Table 6-6
O&M Costs for Selected Retrofit BMP Projects

BMP Retrofit Project	Construction Cost	Annual O&M Cost	20-Year Present Worth O&M Cost
Norfolk Botanical Gardens	$95,000	$5,000	$64,000
Ballentine Elementary School	$186,000	$9,000	$126,000
Norfolk Juvenile Detention Center	$122,000	$6,000	$83,000
Second Patrol Division	$113,000	$6,000	$77,000
Lake Modoc	$109,000	$5,000	$74,000

The conceptual opinions of probable costs for the five selected retrofit BMPs are summarized in **Table 6-7**, which include the capital cost to construct and 20-year present worth O&M cost.

Table 6-7
Conceptual Opinion of Probable Costs for Selected Retrofit BMP Projects

BMP Retrofit Project	Opinion of Probable Cost (20-year Planning Period)		
	Total Capital Cost	Total O&M Cost	Total Project Cost
Norfolk Botanical Gardens	$145,000	$64,000	$209,000
Ballentine Elementary School	$236,000	$126,000	$362,000
Norfolk Juvenile Detention Center	$172,000	$83,000	$255,000
Second Patrol Division	$163,000	$77,000	$240,000
Lake Modoc	$159,000	$74,000	$233,000

6.3 Costs Relative to Pollutants Removed

In order to better compare relative costs of the five selected retrofit BMP projects, it is necessary to also consider the quantities of pollutants projected to be removed by each retrofit BMP. Based on the estimated pollutant removal rates determined in Section 5, the costs per pound of pollutant removal over a 20-year planning period is determined and presented in **Table 6-8**. It is important to note that values of pollutant removed used to determine the costs per pound in Table 6-8 reflect the estimated *additional* pollutant removed (above that already removed by the existing BMP) by the retrofit BMP design.

Table 6-8
Estimated Costs per Pound of Pollutant Removed Over 20-Year Planning Period

BMP Retrofit Project	Estimated Cost	Cost per lb TN Removed	Cost per lb TP Removed	Cost per lb TSS Removed
Norfolk Botanical Gardens	$209,000	$1,045	$5,225	$15
Ballentine Elementary School	$362,000	$130	$603	$2
Norfolk Juvenile Detention	$255,000	$145	$580	$2
Second Patrol Division	$240,000	$1,200	$6,000	$15
Lake Modoc	$233,000	$333	$1,942	$4

Note: Pollutants removed quantities reported reflect the additional removal above those already removed by the existing BMPs.

As indicated by Table 6-8, the BES and NJD retrofit projects are the two most cost-effective retrofit BMP projects when pollutant removal performance is factored in. The unit cost per pound of TN removed for BES is slightly lower than that of NJD ($130 versus $145), the TP unit cost for NJD is slightly lower than that of BES ($603 versus $5800) and the TSS unit cost is the same for both BES and NJD ($2).

Other unit cost factors often considered for retrofit BMP projects is the capital cost per total area treated and capital cost per impervious area treated. These unit costs are reported for the five selected BMPs in **Table 6-9**. As indicated, the cost per total and impervious acre treated has a relatively wide range from $1,300 and $2,000 at BES to $17,200 and $29,300 at NBG.

The unit cost per pollutant removed (Table 6-8) may provide a more effective basis of comparison of BMP performance than the unit cost per area treated because it considers the performance of the existing BMP and is more closely tied to actual pollutant removal and potential TMDL pollutant load reduction goals.

Table 6-9
Estimated Costs per Impervious Acre Treated

BMP Retrofit Project	Capital Cost	Total Area (ac)	Impervious Area (ac)	Cost per Total Area ($/ac)	Cost per Impervious Area ($/ac)
Norfolk Botanical Gardens	$145,000	8.44	4.95	$17,200	$29,300
Ballentine Elementary School	$236,000	179.83	119.24	$1,300	$2,000
Norfolk Juvenile Detention	$172,000	29.97	20.88	$5,700	$8,200
Second Patrol Division	$163,000	19.34	14.07	$8,400	$11,600
Lake Modoc	$159,000	80.72	40.96	$2,000	$3,900

Section 7

Conclusions and Recommendations

7.1 Conclusions

This study provides a means for screening many potential candidate existing BMP sites for retrofit conversion or enhancement. From the intial list of 27 candidate sites, five existing BMPs were selected for further evaluation based on consideration of several factors including site conditions, potential pollutant load removal, permitting, and public acceptance (Section 2). Once selected, further evaluation of the five selected BMP sites included modeling, conceptual design, water quality analysis, and cost estimating. The findings and results of this study, confirm the efforts by the City to effectively screen and identify cost-effective BMP retrofit opportunities to address the Chesapeake Bay TMDL and WIP goals.

The projected benefits and costs associated with the retrofit of the five existing BMPs were discussed in Sections 5 and 6. These costs and performance results are summarized in **Table 7-1** below along with a ranking of the five selected retrofit projects. As indicated in this table, the five BMP retrofits provide a range of pollutant removal benefits and implementation costs. The range in both cost and pollutant removal benefits is typical of retrofit projects due to multiple underlying factors. From the perspective of performance, the ability to improve nutrient and sediment removal benefit depends in part on the amount of treatment provided by the existing BMP. Similarly, the cost to construct retrofit improvements depends on site specific factors at each existing BMP. When reviewed for cost-effectiveness, the Norfolk Juvenile Detention and the Ballentine Elementary School retrofit projects provide the most cost-effective performance and were ranked the highest.

Features that contribute to the BES BMP retrofit being cost-effective include a relatively large tributary area served (179.8 acres) which includes a corresponding large impervious area (119.2 acres). Features that contribute to the NJD BMP retrofit being cost effective include a reconfiguration design that redirects additonal runoff to the BMP signficantly increasing its overall area served from 6.0 acres to 30.0 acres.

Table 7-1
Projected BMP Costs and Performance by Pollutant Removal over 20-Year Planning Period

Rank	BMP Retrofit Project	Total Project Cost	TN Removed (lbs)	TN Cost ($/lb)	TP Removed (lbs)	TP Cost ($/lb)	TSS Removed (lbs)	TSS Cost ($/lb)
1	Ballentine Elementary School	$362,000	2,780	$130	600	$603	226,060	$2
2	Norfolk Juvenile Detention	$255,000	1,760	$145	440	$580	158,820	$2
3	Lake Modoc	$233,000	700	$333	120	$1,942	51,820	$4
4	Norfolk Botanical Gardens	$209,000	200	$1,045	40	$5,225	13,920	$15
5	Second Patrol Division	$240,000	200	$1,200	40	$6,000	15,900	$15

Note: Pollutants removed quantities reported reflect the additional removal above those already removed by the existing BMPs
Total project cost includes capital cost and O&M cost over 20-year planning period.

In addition to expressing the performance of BMP retrofits in terms of cost per pound of pollutant removed, an alternative metric is to express performance in terms of cost per acre treated or cost per impervious acre treated. **Table 7-2** summarizes the cost per acre values associated with the retrofit of the five existing BMPs. As shown, the costs range from $1,300 to $17,200 per total acreage treated and from $2,000 to $29,300 per impervious acreage treated. Because retrofits are highly dependent on site specific conditions, the cost to construct BMP retrofits is highly variable. The costs per acre for the retrofits shown in Table 7-2 are within expected ranges for BMP conversions and enhancements. As Table 7-2 indicates, the BMPs serving the largest areas (and largest impervious areas) have the lowest per acreage retrofit costs. However, unit cost comparison based on acreage alone does not consider the performance of the existing BMP, the incremental pollutant load reduction provided by the BMP retrofit, or the cost-effectiveness of the BMP retrofit opportunity.

Table 7-2
Projected BMP Costs and Performance by Acreage

BMP Retrofit Project	Total Capital Cost	Total Area (ac)	Impervious Area (ac)	Cost per Total Area ($/ac)	Cost per Impervious Area ($/ac)
Ballentine Elementary School	$236,000	179.83	119.24	$1,300	$2,000
Lake Modoc	$159,000	80.72	40.96	$2,000	$3,900
Norfolk Juvenile Detention	$172,000	29.97	20.88	$5,700	$8,200
Second Patrol Division	$163,000	19.34	14.07	$8,400	$11,600
Norfolk Botanical Gardens	$145,000	8.44	4.95	$17,200	$29,300

Note: Capital cost includes construction cost and engineering, surveying, and permitting costs.

7.2 Recommendations

It can be seen from Tables 7-1 and 7-2 that three of the five selected retrofit BMP projects stand out in their cost per pound of pollutant removed and cost per acre, which include:

- Ballentine Elementary School
- Norfolk Juvenile Detention Center
- Lake Modoc

CDM Smith recommends that the City move forward by considering implementation of the top three BMP retrofit opportunities within the context of other actions being evaluated to reduce pollutant loads to downstream receiving waters and meet the requirements of the Chesapeake Bay TMDL. The next steps to implement these retrofits include final design and permitting. As part of the final design effort, survey and geotechnical data should be collected to support design specifications and confirm other site constraints. During the final design process, construction cost estimates can also be refined.

In addition to implementation of the top three BMP retrofit opportunities, the City should continue to seek out opportunities to evaluate and implement improvements for reducing nutrient and sediment loads, such as:

- Conduct a more detailed evaluation of the 22 sites identified by the City, but not included in the detailed analyses performed for the top 5 BMP retrofit opportunities.

- Consider evaluating existing privately-owned BMPs that can be purchased by the City and retrofitted.
- Seek out opportunities to implement new BMPs in existing developed areas.
- Coordinate with transportation (City, County, and VDOT), water, sewer, and park projects for future opportunities and cost-savings (5 and 20 year programs)

Appendix A

References

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Memorandum

To: *City of Norfolk*

From: *CDM Smith*

Date: *March 8, 2013*

Subject: *Stormwater BMP Retrofit Evaluation*
Existing BMP Site Descriptions and Preliminary Retrofit Recommendations

The purpose of this memorandum is to present the conditions observed in the field and preliminary retrofit recommendations for each of the candidate existing best management practice (BMP) sites included in the Stormwater BMP Retrofit Evaluation project.

Table 1 summarizes the BMPs included in this evaluation. It should be noted that the existing extended detention basins at Broad Creek Villas (Site ID 08-0042) were removed from the original scope of work and replaced with Projects 25, 26, and 27, as presented in Table 1 below. Projects 16 and 17, which is the existing retention basin at Central Business Park (Site ID 99-3931), is a single BMP, not two separate BMP. Therefore, Project 17 was removed from Table 1 below.

Table 1 – Summary of BMPs

Project ID	Site ID	Site Title	SWMF Type
1	05-0087	Sherwood Forest Elementary School	Detention Basin
2	T107	Norfolk Public Schools Transportation Operations	Detention Basin
3	T51	Norfolk Juvenile Detention Center	Detention Basin
4	00-4462	Titustown Recreation Center	Extended Detention Basin
5	09-0030	2nd Patrol Division	Extended Detention Basin
6	92067.082	Norview Middle School	Extended Detention Basin
7	92067.082	Norview Middle School	Extended Detention Basin
8	01-0053	Roberts Pond	Retention Basin
9	01-0095	Lamberts Point Pond	Retention Basin
10	02-0010	Norview High School	Retention Basin
11	02-2367	ODU University Village	Retention Basin
12	06-0059	Coleman Place Elementary School	Retention Basin
13	91067.029	Lake Liberty, NRHA	Retention Basin
14	99-3931	Central Business Park	Retention Basin
15	S1	Anne Outten Pond	Retention Basin
16	S14	Silver Lake/Duck Pond	Retention Basin
17	S15	Meadow Lake	Retention Basin
18	S2	Ballentine Elementary School Lake	Retention Basin
19	S6	Lake Modoc	Retention Basin
20	S8	Lake Scott	Retention Basin
21	T103	Norfolk Botanical Gardens - Visitors Reception	Retention Basin
22	T276	NPD 2nd Precinct Training Center	Retention Basin
23	T559	Central Brambleton	Retention Basin
24	T66/S	Cedar Grove Parking Lot	Retention Basin
25	n/a	Light Rail Station	Retention Basin
26	n/a	Norfolk Commerce Park Pond 3	Detention Basin
27	n/a	Wells Fargo Pond	Retention Basin

Existing Conditions and Retrofit Opportunities

CDM Smith and City of Norfolk (City) staff performed site investigations for each of the candidate BMPs from January 28th through the 30th for the purpose of evaluating each of the BMPs and identifying potential retrofit opportunities. Those retrofits opportunities were further evaluated by CDM Smith using available GIS data and the BMP volume evaluations performed prior to and following the site investigations. The following is a brief description of the existing conditions observed in the field followed by the recommended retrofit opportunities for each BMP site included in Table 1.

- 1.) Sherwood Forest Elementary School (Site ID 05-0087) – This site includes a small dry pond intended to capture stormwater runoff from the bus turn-out (seen at the far end in the photo inset). There is a single 12-inch diameter inlet, which was observed to be buried and no longer active. The outlet consists of a grated riser (dimensions not known) with a notch in the front for controlled drawdown.

  There are no recommended retrofit opportunities for this site. However, it is recommended that the buried inlet be uncovered and put back into service.

Sherwood Forest Elementary School (Site ID 05-0087) – View of BMP looking south from Little John Drive

- 2.) Norfolk Public Schools Transportation Operations (Site ID T107) – This site consists of a long, linear grass swale, which generally serves as a dry detention basin, though there was some standing water observed near the outlet. The swale ranges in width from a few feet at the northeast corner to approximately 15-feet wide at the outlet, near the southeast corner. The site drains runoff from the paved transportation operations facility as well as some runoff from Raby Road. There is a single 12-inch diameter inlet under the main entrance, at the southwest corner of the complex, which receives runoff from a drainage swale separating the west side of the complex from Raby Road. The outlet consists of a grated riser (dimensions not known), which discharges into the adjacent wetland to the east. There is also a breach in the berm that is discharging runoff into the adjacent wetland.

Recommended retrofit opportunities include converting the dry detention basin into an extended dry detention basin, installing wetland plantings, and consideration of harvesting practices.

Norfolk Public Schools Transportation Operation (Site ID T107) – View of Existing BMP, near outlet spillway, looking northeast.

- 3.) Norfolk Juvenile Detention Center (Site ID T51) – This site consists of a dry detention basin with a concrete-lined swale through the middle. There is a 12-inch diameter inlet at the southeast corner, which drains the adjacent parking lot. The outlet consists of a 12-inch diameter flared-end section which flows into an adjacent grated riser, which discharges through a pipe (dimensions not known) into the adjacent storm sewer system. There is open space around the site which doesn't appear to be utilized. There were several sinkholes and damaged inlets along the adjacent storm sewer system.

  Recommended retrofit opportunities include converting the dry detention basin into a wet pond and have the adjacent storm sewer system discharge into the pond, which will increase the drainage area and associated volume of pollutants removed.

Norfolk Juvenile Detention Center (Site ID T51) – View of existing BMP from outlet spillway, looking southeast.

- <u>4.) Titustown Recreation Center (Site ID 00-4462)</u> – This site includes a small dry pond that has become overwhelmed with cattails. There are two inlet pipes, which appear to convey runoff from the recreation parking lot and building rooftop.. The outlet consists of a grated riser (dimensions not known) with a 6-inch diameter PVC inlet pipe for controlled drawdown.

  Recommended retrofits include removing the cattails and replacing with wetland plantings and harvesting those routinely.

Titustown Recreation Center (Site ID 00-4462) – View of existing BMP outlet structure.

- 5.) 2nd Patrol Division (Site ID 09-0030) – This site includes a wet detention pond that receives runoff from an industrial park to the east. There are two inlet pipes (diameters not known) entering the east end of the pond and a single outlet pipe (diameter not known) exiting from the west end of the pond. The inlet pipes are connected to a junction box, which has a flow diversion weir that sends low flows to the ponds and higher flows to the ponds and the adjacent channel to the north. The pond previously had a forebay, but it has been combined with the wet pond and is no longer evident. There is another BMP project site located to the southeast, Central Business Park (Site ID 99-3931).

  Recommended retrofits include modifying the Central Business Park BMP to flow into the 2nd Patrol Division BMP, which would improve the water quality benefit of the runoff currently being treated by the Central Business Park BMP. The pond was constructed in 2011, so sediment accumulation is not expected to currently be a problem, but replacing the junction box with a a baffle box will provide for improved and more cost-effective maintenance access for sediment removal in the future.

2nd Patrol Division (Site ID 09-0030) – View of inlet pipes and east end of pond.

- 6.) Norview Middle School (Site ID 92067.082-A) – This site includes a dry detention pond that receives runoff from the surrounding paved access road and parking area. There are three 12-inch diameter inlet pipes entering from the east, southeast, and west. The outlet structure is a concrete riser with rectangular weirs across the top on all four sides and a v-notch weir for controlled drawdown. The corrugated metal trash guard on the front is not attached to the riser and requires repair. Though it is believed the pond was intended to be dry, there is standing water throughout, ranging from 1 to 3 inches in depth. Based on field observation, there are organic materials and soils within the BMP, many small diameter trees, and little vegetative growth (though there may be seasonal growth not apparent during the field visit). The considerable tree growth deposits heavy leaf litter into the BMP, which likely results in elevated nutrient levels.

Recommended retrofits include removing the trees and converting the pond to a wetland.

Norview Middle School (Site ID 92067.082-A) – View of pond and spillway.

- 7.) Norview Middle School (Site ID 92067.082-B) – This site includes a dry detention pond that receives runoff from surrounding basketball courts, tennis courts, and parking area. There are two 12-inch diameter inlet pipes draining the parking lot and basketball courts. There is a 4-inch diameter pipe draining the tennis courts. The outlet structure is a concrete riser with rectangular weirs across the top on all four sides and a v-notch weir for controlled drawdown, with a corrugated metal trash guard on the front. Based on field observation, there are organic materials and soils within the BMP, many small diameter trees, and little vegetative growth (though there may be seasonal growth not apparent during the field visit). The considerable tree growth deposits heavy leaf litter into the BMP, which likely results in elevated nutrient levels. There is also heavy urban trash within the BMP.

  Recommended retrofits include removing the trees and converting the pond to a wetland.

Norview Middle School (Site ID 92067.082-B) – View of dry detention pond and spillway.

- 8.) Roberts Pond (Site ID 01-0053) – This site includes a wet detention pond that receives runoff from an industrial and residential development. There is a 60-inch diameter inlet pipe at the southern corner of the pond and dual 48-inch diameter outlet pipes at the east corner. There is minimal buffer along a majority of the bank.

  Recommended retrofit includes planting a minimum 50-foot vegetated buffer around the pond.

Roberts Pond (Site ID 01-0053) – View of pond looking west.

- 9.) Lamberts Point Pond (Site ID 01-0095) – This site includes a wet detention pond that receives runoff from an overflow pipe from the adjacent WTP. No other inlet pipes could be identified during the site visit or from the GIS, though there may be submerged inlets that could not be seen. The outlet structure is a 15-inch diameter pipe that discharges into the adjacent storm sewer system. There is minimal buffer along a majority of the bank. Vegetation was observed near the center of the pond, which could indicate heavy sediment accumulation. The pond was constructed in January 2002.

  Recommended retrofits include planting a minimum 50-foot vegetated buffer around the pond, dredging and/or excavating the pond to provide increased volume and depth, and providing additional aeration devices.

Lamberts Point Pond (Site ID 01-0095) – View of wet pond and WTP overflow pipe.

- 10.) Norview High School (Site ID 02-0010) – This site includes a wet detention pond that receives runoff from Norview High School, through a 42-inch diameter inlet pipe. The outlet structure is an 18-inch diameter pipe that discharges into the adjacent storm sewer system running along Sewell's Point Road. There is some tree growth and bushes within the buffer, but it is generally grassed. Very heavy algae growth was observed within the pond. The depth appeared to be shallow, possibly due to heavy sediment accumulation or insufficient constructed volume.

  Recommended retrofits include planting a minimum 50-foot vegetated buffer around the pond, dredging and/or excavating the pond to provide increased volume and depth, and installing one or more aeration devices.

Norview High School (Site ID 02-0010) – View of wet pond with heavy algae growth, looking north.

- 11.) ODU University Village (Site ID 02-2367) – This site includes two wet detention ponds. No inlet pipes could be observed in the field or GIS and there is minimal overland flow contributing to the ponds. The source of water into the ponds is not known. The buffer for both ponds are primarily grassed with little brush or trees. The outlet for the east pond consists of a riser structure with a large concrete cover, which is believed to discharge into the storm sewer system between the two ponds. The outlet for the west pond could not be identified in the field or GIS.

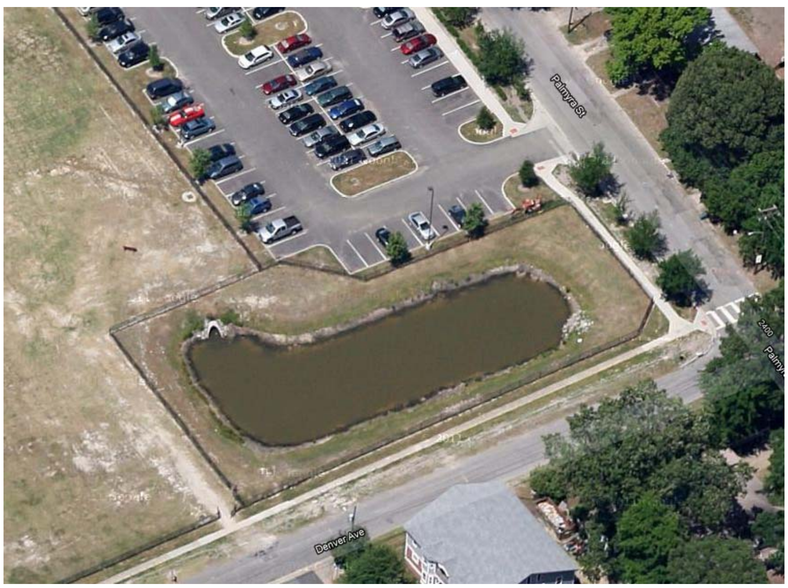
  Recommended retrofit includes planting a minimum 50-foot vegetated buffer around the pond. It is also recommended that the inlets be identified such that the pond drainage area can be evaluated to determine if there is a potential to increase volume for improved nutrient removal benefit. Also, the outlet for the west pond should be identified such that it can be properly maintained in the future.

ODU University Village, East Pond (Site ID 02-2367-A) – View of wet pond and outlet structure, looking east.

ODU University Village, West Pond (Site ID 02-2367-B) – View of wet pond and submerged large diameter pipe, looking west.

- <u>12.) Coleman Place Elementary School (Site ID 06-0059)</u> – This site includes a wet detention pond that receives runoff from the adjacent school and possibly from Denver Avenue. There is a 24-inch diameter inlet entering from the northwest corner, which drains runoff from the school parking lot. There is a 15-inch diameter inlet at the southwest corner. It could not be determined in the field if this pipe serves as an inlet, outlet, or both. There is a 38-inch diameter (dimension from GIS) outlet pipe at the southeast corner that discharges into the storm sewer running along Denver Avenue. The pond appears to have been constructed with a shallow depth, not believed to be from sediment accumulation. Nearby residents have complained of odor and mosquito problems during the summer. The pond was constructed in December 2008.

Recommended retrofits include planting a minimum 50-foot vegetated buffer around the pond, determining if the pond has adequate volume or if it should be increased, and providing aeration devices to address algae growth and mosquito problems.



Coleman Place Elementary School (Site ID 06-0059) – View of wet pond and adjacent school parking lot, image from Google.

- 13.) Lake Liberty, NRHA (Site ID 91067.029) – This site includes a wet detention pond that receives runoff from a residential development to the east. There are three inlet pipes. There is a 54-inch diameter pipe entering the northwest corner of the pond, which conveys runoff from Ballentine Boulevard and the adjacent neighborhood. There is also a 48-inch diameter inlet approximately 100 feet east of the 54-inch, which drains Ballentine Boulevard. There is also a curb inlet on Ballentine Boulevard, near the northern corner of the pond, which has two outlet pipes, one 48-inch diameter continuing to run parallel to Ballentine Boulevard and the other a small diameter pipe (dimension not known) which flows in the direction of Lake Liberty. The outlet of the pipe could not be found, but could be submerged. The pipe is not included in the GIS data. The lake outlets to the southeast under Lakebridge Drive. There is minimal buffer along a majority of the bank. The vegetated island includes heavy tree growth and encompasses approximately a third of the pond's surface area. Heavy sediment accumulation was observed at the northeast corner of the lake. North Lakebridge Drive has storm sewer drainage, though it is not shown in GIS, which flows into the Lake and should therefore be included in its contributing drainage area. There are two to three aerators in the lake.

Recommended retrofits include planting a minimum 50-foot vegetated buffer around the pond, determining if there is heavy sediment accumulation and dredging if needed, and installing baffle boxes on the 48-inch and 54-inch inlet pipes to capture sediment and urban trash before entering the lake.

Lake Liberty, NRHA (Site ID 92067.029) – View of wet pond and vegetated island.

- 14.) Central Business Park (Site ID 99-3931) – This site includes a long, linear wet detention pond that receives runoff from a small developed complex to the north and an open space field. There were not any large diameter inlets, but a number of roof drains from the adjacent building were identified. It is believed that most of the runoff entering the pond is contributed via overland flow. The outlet structure is a concrete riser section with a 36-inch diameter opening on the side. There is a good buffer around a majority of the bank. The pond is shallow with heavy algae growth observed. There is another BMP located to the northwest, 2nd Patrol Division (Site ID 09-0030).

  Recommended retrofits include modifying the Central Business Park BMP to flow into the 2nd Patrol Division BMP, which would improve the water quality benefit of the runoff currently being treated by the Central Business Park BMP. The pond should be dredged and/or excavated to provide additional volume. The 18-inch diameter storm sewer pipe to the east should be modified to discharge into the pond.

Central Business Park (Site ID 99-3931) – View of wet pond and principal spillway riser, looking east.

- 15.) Anne Outten Pond (Site ID S1) – This site includes a wet detention pond that receives runoff from the residential development to the east. There are five inlet pipes entering from the north, east, and south, and an elliptical pipe outlet (dimension not known) on the west side of the pond. The pond is significantly undersized given the drainage area. Heavy sediment accumulation was observed at the north end of the pond. The pond was constructed in 1985, with no records of dredging performed since construction. Some algae growth was observed, but there are two aerators already in service.

  Recommended retrofits include dredging the lake, creating a littoral shelf with wetland vegetation, and implementing floating wetlands.

Anne Outten Pond (Site ID S1) – View of wet pond, looking west.

- 16.) Silver Lake / Duck Pond (Site ID S14) – This site includes the portion of the pond east of Duck Pond Road. The site is a wet detention pond that receives runoff from the surrounding residential development. There is a single 30-inch diameter inlet (dimension from GIS) from the east. The pond outlets through an HDPE pipe (dimension not known) under Duck Pond Road and is hydraulically-connected to the downstream lake. Residents have complained about minor algae growth.

  Recommended retrofits include adding aeration device(s) to address algae growth.

Silver Lake / Duck Pond (Site ID S14) – View of wet pond, looking east.

- 17.) Meadow Lake (Site ID S15) – This site includes a wet detention pond that receives runoff from the surrounding residential development. There inlet pipes all along the bank, as shown in GIS, with a concrete overflow spillway outlet system, which discharges under River Edge Road into the downstream pond. City staff noted that the lake was dredged in the late 1990s to early 2000s. The City is in the process of rehabilitating the spillway. Heavy sediment accumulate and erosion was observed along the banks.

  Recommended retrofits include dredging the lake, preferably while the spillway is being rehabilitated.

Meadow Lake (Site ID S15) – View of southwest portion of the upstream dam slope, which shows the reduction in normal pool level & sediment accumulation.

- <u>18.) Ballentine Elementary School Lake (Site ID S2)</u> – This site includes a wet detention pond that receives runoff from two 36-inch diameter outfalls to the east and overland flow from the surrounding open space. The GIS shows a 42-inch diameter stormwater pipe bypassing the lake to the north, but it was determined in the field that the system had been modified such that the 42-inch diameter pipe now discharges into the lake. The lake is tidally influenced. The principal spillway was recently upgraded, however no dredging was performed. The surrounding open space is not regularly used by residents. Heavy sediment accumulation was observed at the east end of the lake.

  Recommended retrofits include dredging and/or excavating the pond to provide additional volume based on actual drainage area, planting a minimum 50-foot vegetated buffer around the pond, and creating a littoral shelf with wetland vegetation.

Ballentine Elementary School Lake (Site ID S2) – View of wet pond with concrete weir and orifices around principal spillway.

Ballentine Elementary School Lake (Site ID S2) – View of wet pond and adjacent school, image from Google.

- <u>19.) Lake Modoc (Site ID S15)</u> – This site includes a wet detention pond with three inflow pipes entering the southern portion of the lake. There is a grated 6-foot by 3-foot overflow spillway with a 48-inch diameter outlet pipe at the northwest corner, which discharges into the storm sewer system along Chesapeake Boulevard. The GIS shows a force main piping crossing the lake, though it was not observed in the field. There was moderate vegetative growth within the lake, which would indicate a shallow depth. There is heavy sediment accumulation observed at the southern end of the lake. There is moderate algae growth within the lake. There is an apartment building located along the northwest bank, near the outfall, that appears to have its finished floor elevation approximately 12 inches above the normal pool elevation, which would suggest potential structural flooding. There is poor to moderate riparian buffer vegetation.

Recommended retrofits include dredging and/or excavating to provide increased volume, planting a minimum 50-foot vegetated buffer around the pond, creating a littoral shelf with wetland vegetation, installing aerator(s), and modifying the spillway or provide flood protection around the apartment building to reduce risk of structural flooding.

Lake Modoc (Site ID S6) – View of wet pond, looking northwest towards Chesapeake Boulevard.

Lake Modoc (Site ID S6) – View of adjacent apartment building with a finished floor elevation approximately 12-inches above the normal pool.

- 20.) Lake Scott (Site ID S8) – This site includes a wet detention pond that receives runoff from primarily residential development. There are two inlet, a 24-inch and 15-inch diameter, entering at the headwaters of the lake, as shown in the GIS. The primarily outlet consists of two 18-inch diameter conduit pipes, which are hydraulically-connected to the Elizabeth River immediately downstream. The shoreline is heavily protected with riprap. The water appears to be relatively clear with no obvious signs of substantial sediment accumulation. The buffer is relatively poor, with grass generally present up to the water level.

  Recommended retrofits include planting a minimum 50-foot vegetated buffer around the pond.

Lake Scott (Site ID S8) – View of wet pond looking northeast from McGinnis Circle.

- <u>21.) Norfolk Botanical Gardens (Site ID T103)</u> – This site includes a wet detention pond that receives runoff from the adjacent parking lot and visitor center buildings. There is a 42-inch diameter storm sewer pipe that runs west to east, paralleling the existing pond. A junction box at the southwest corner of the pond has a diversion weir that sends low flows to the pond, with higher flows bypassing the pond and discharging into Lake Whitehurst to the east. The bypass pipe, which is not included in the City's GIS data, is 42-inches in diameter and discharges into the southwest corner of the pond. The outlet is a 12-inch diameter conduit pipe and exits from the southeast corner of the pond into the adjacent 42-inch diameter storm sewer pipe. The buffer is entirely grassed, down to the normal pool elevation. There is abundant open space to the north and east of the pond. The pond is deep, with approximately 8- to 12-feet from the normal pool to the pond crest.

  Recommended retrofits include expanding the pond's volume by increasing its surface area to capture larger rainfall volumes from the 42-inch diameter storm sewer, converting the wet pond into a wetland, converting the outlet conduit pipe to a riser spillway, planting a minimum 50-foot vegetated buffer around the wetland, and incorporate an educational component through signage and interactive opportunities with visitors.

Norfolk Botanical Gardens (Site ID T103) – View of wet pond looking northeast from parking lot.

Norfolk Botanical Gardens (Site ID T103) – View of wet pond and surrounding open space, image from Google.

- 22.) NPD 2nd Precinct Training Center (Site ID T276) – This site includes a wet detention pond that receives runoff from the adjacent parking lot to the west through two 12-inch diameter inlet pipes, one at the northwest corner and the other at the southwest corner. The outlet consists of a 12-inch diameter conduit pipe at the southwest corner of the pond, which discharges to the adjacent swale paralleling the railroad tracks. The buffer was moderate to good.

  Recommended retrofits include adding an aerator for improved aesthetics and dissolved oxygen levels.

NPD 2ND Precinct Training Center (Site ID T276) – View of wet pond looking northeast from TWA Drive.

- 23.) Central Brambleton (Site ID T559) – This site includes a wet detention pond that receives runoff from an 18-inch diameter outfall off Hanson Avenue as well as overland flows from the surrounding park. The outfall consists of a 24-inch by 45-inch diameter elliptical conduit pipe, which is connected to the storm sewer system along Cecelia Street. It is believed that the outlet pipe may backflow into the pond during periods of high flow. The buffer is entirely grassed, down to the normal pool elevation. The GIS shows a 2- and 4-inch diameter waterline crossing through the middle of the pond, though it was not observed in the field. There is reported flooding upstream of the pond. The City is considering constructing another pond on the west side of Cecelia Street for increased flood protection.

  Recommended retrofits include planting a minimum 50-foot vegetated buffer around the pond. Due to site restrictions and anticipated issues with public acceptance, it is not believed to be feasible to increase the volume of the pond for increased flood protection. Therefore, it is recommended that the City pursue alternatives methods to decrease upstream flooding, such as the additional pond being considered.

Central Brambleton (Site ID T559) – View of wet pond looking east from Cecelia Street.

- 24.) Cedar Grove Parking Lot (Site ID T66/S) – This site includes a dry detention pond that receives runoff from the adjacent parking lot. The outfall consists of a concrete riser, which discharges to the storm sewer system along Monticello Avenue and East Princess Anne Road. Based on field observation, there are organic materials and soils within the BMP, many small diameter trees, and little vegetative growth (though there may be seasonal growth not apparent during the field visit). The considerable tree growth deposits heavy leaf litter into the BMP, which likely results in elevated nutrient levels. The dry pond is also undersized given the drainage area and associated high imperviousness. Though the parking lot doesn't appear to be currently in use, when in use it is expected that high oil and grease concentrations are contributed to the dry pond, which provides minimal removal benefit. City staff noted that there is significant flooding downstream of the site along Monticello Avenue.

Recommended retrofits include converting the dry pond to a wet pond or wetland and expanding the footprint into the parking lot. If the BMP volume can be increased significantly, there may be an opportunity to direct flow from the storm sewer system along Monticello Avenue and East Princess Anne Road for water quality and flood control benefits. Also, due to its location, this BMP may be an opportunity for this to be a high profile project, educating the public on water quality.

Cedar Grove Parking Lot (Site ID T66-S) – View of dry pond and parking lot contributing stormwater runoff, image from Google.

- <u>25.) Light Rail Station (Site ID n/a)</u> – This site includes a wet detention pond that receives runoff from the adjacent parking lot to the east through a 12-inch diameter outfall. The outlet consists of an 8-inch diameter Department of Transportation (DOT) Parallel Pipe End Section culvert, which discharges into the swale running parallel to Curlew Drive. There is minimal to no overland flow, so existing buffer is adequate. Pond appears to be moderately shallow, with a potential for sediment re-suspension during large storm events.

  Recommended retrofit includes dredging and/or excavating to provide for increased volume and pond depth.

Light Rail Station (Site ID n/a) – View of wet pond looking east.

- 26.) Norfolk Commerce Park Pond 3 (Site ID n/a) – This site includes a dry detention pond / swale system that receives runoff from a small portion of the office park to the north. There are two inlets connected to curb inlets within the parking lot, both assumed to be 12-inch diameter. The outlet consists of a 48-inch diameter corrugated metal conduit, which is connected to the storm sewer system along Almeda Avenue. The bottom of the outlet pipe was severely deteriorated, with seepage likely causing, or already caused, undermining of the pipe. The invert of the outlet pipe is at the bottom of the dry pond/swale, which results in little to no detention of stormwater flows within the pond itself. The upstream portion of the BMP is dry, with the swale holding a minor amount of water on the downstream end.

  Recommended retrofits include converting the dry pond/swale into an extended dry detention pond and modifying the storm sewer system on Cape Henry Avenue to discharge into the BMP. If the dry pond cannot be converted into a wet pond or wetland, then the outlet of the dry pond should be modified to provide detention and controlled drawdown. Also, the deteriorated outlet pipe should be investigated and repaired.

Norfolk Commerce Park Pond 3 (Site ID n/a) – View of dry pond looking north-east, from outlet.

Norfolk Commerce Park Pond 3 (Site ID n/a) – View of dry pond, office complex to the north, and Cape Henry Avenue to the south, image from Google.

- <u>27.) Wells Fargo Pond (Site ID n/a)</u> – This site includes a wet detention pond that receives runoff from the parking areas and commercial businesses to the south. There are three 24-inch diameter inflow pipes entering the south end of the pond. The outfall consists of a 24-inch diameter riser, which discharges into the road swale along North Military Highway. There is also a riprap emergency spillway parallel to the principal spillway. The pond has an average depth ranging from 6- to 12-inches, likely resulting from heavy sediment accumulation. City staff noted that there are preliminary plans for VDOT to widen North Military Highway, which could impact the pond or provide for a partnering opportunity.

Recommended retrofits include dredging and/or excavating the pond to provide additional volume and depth and planting a minimum 50-foot vegetated buffer around the pond. If the pond is undersized, there may be an opportunity to expand to the east by removing some of the parking spaces in the adjacent lot. The City should consider discussing an opportunity to retrofit the pond with VDOT, since it is expected that there could be modifications required as part of the road widening project. The City should take ownership of the pond, or obtain an easement to ensure it is not removed in the future.

Wells Fargo Pond (Site ID n/a) – View of wet pond looking south.

Appendix C

Model Input and Output

Electronic copies of the model input and output files are located on the report CD.

Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects

Ray Bahr, Ted Brown, LJ Hansen, Joe Kelly, Jason Papacosma, Virginia Snead, Bill Stack, Rebecca Stack and Steve Stewart

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Final Approval by WQGIT: **October 9 2012**

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List of common acronyms used throughout the text:

BMP	Best Management Practices
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
CBWM	Chesapeake Bay Watershed Model
GIS	Geographic Information Systems
GPS	Global Positioning System
ICPRB	Interstate Commission on the Potomac River Basin
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
RR	Runoff Reduction
RT VM	Reporting, Tracking, Verification and Monitoring
ST	Stormwater Treatment
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WIP	Watershed Implementation Plan
WQGIT	Water Quality Group Implementation Team
WTM	Watershed Treatment Model

Note: text in blue denotes additional language added by Watershed Technical Work Group or Water Quality Goal Implementation Team

Summary of Panel Recommendations

Over the last two decades, the Chesapeake Bay states have pioneered new techniques for finding, designing and delivering retrofits to remove pollutants, improve stream health and maintain natural hydrology in developed watersheds. Several important regulatory drivers are likely to increase the amount of future stormwater retrofit implementation across the Chesapeake Bay watershed. Some communities need to install retrofits to meet pollutant reduction targets under recently issued municipal stormwater permits or meet local TMDLs. In addition, each of the seven Bay states are considering greater use of urban stormwater retrofits as part of an overall strategy to meet nutrient and sediment load reduction targets for existing urban development under the Chesapeake Bay TMDL.

Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. The Panel classified retrofits into two broad project categories -- new retrofit facilities and retrofits of existing BMPs. These two categories encompass a broad range of potential local retrofit options and applications including new constructed wetlands, green streets or rain gardens, as well as conversion, enhancements or restoration of older BMPs to boost their performance.

Given the diversity of possible retrofit applications, the Panel decided that assigning a single universal removal rate was not practical or scientifically defensible. Every retrofit is unique, depending on the drainage area it treats, the treatment mechanism employed, its volume or size and the antecedent degree of stormwater treatment, if any.

Instead, the Panel elected to develop a protocol whereby the removal rate for each individual retrofit project is determined based on the amount of runoff it treats and the degree of runoff reduction it provides. The Panel conducted an extensive review of recent BMP performance research and developed a series of retrofit removal adjustor curves to define sediment, nitrogen and phosphorus removal rates. The Panel then developed specific calculation methods tailored for different retrofit categories. To assist users, the Panel has included numerous design examples to illustrate how retrofit removal rates are calculated.

The Panel recommended simple retrofit reporting criteria to reduce the administrative burden on local and state agencies. The Panel also stressed that verification of retrofit installation and subsequent performance is critical to ensure that pollutant reductions are actually achieved and maintained across the watershed. To this end, the Panel recommends that the retrofit removal rate be limited to 10 years, although it can be renewed based on a field inspection that verifies the retrofit still exists, is adequately maintained and operating as designed. To prevent double counting, removal rates cannot be granted if the retrofit project is built to offset, compensate or otherwise mitigate for a lack of compliance with new development stormwater performance standards elsewhere in the jurisdiction.

Section 1
The Expert Panel and its Charge

EXPERT BMP REVIEW PANEL Stormwater Retrofits	
Panelist	Affiliation
Ray Bahr	Maryland Department of the Environment
Steve Stewart	Baltimore County
Ted Brown	Biohabitats, Inc.
LJ Hansen	City of Suffolk, VA
Jason Papacosma	Arlington, VA
Bill Stack	Center for Watershed Protection
Rebecca Stack	District Department of the Environment
Joe Kelly	Pennsylvania Department of Environmental Protection
Virginia Snead	Virginia Department of Conservation and Recreation
Jeff Sweeney	U.S. Environmental Protection Agency, Chesapeake Bay Program Office
Tom Schueler	Chesapeake Stormwater Network (facilitator)
The Panel would like to acknowledge the following additional people for their contribution: Norm Goulet, Chair Urban Stormwater Workgroup Lucinda Power, U.S. Environmental Protection Agency, Chesapeake Bay Program Office Chris Brosch formerly of University of Maryland and the Chesapeake Bay Program Office modeling team	

The charge of the Panel was to review all of the available science on the pollutant removal performance and runoff reduction capability of BMPs that can be used to derive methods or protocols to derive nutrient and sediment removal rates for individual retrofits.

Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. Removal rates will need to be inferred from other known BMP pollutant removal and runoff reduction data. Every retrofit is unique, depending on the drainage area treated, BMP treatment mechanisms, volume or sizing and the antecedent degree of stormwater treatment, if any.

Stormwater retrofits can be classified into two broad project categories, as shown below:

a. New retrofit facilities
b. BMP conversions, enhancements, or restoration

The Panel was specifically requested to:

- Provide a specific definition for each class of retrofits and the qualifying conditions under which a locality can receive a nutrient/sediment removal rate.

- Assess whether the retrofit class can be addressed by using existing CBP-approved BMP removal rates, or whether new methods or protocols need to be developed to define improved rates.

- Evaluate which load estimation methods are best suited to characterize the baseline pre-retrofit for the drainage area to each class of retrofit.

- Define the proper units that local governments will report retrofit implementation to the state to incorporate into the Watershed Model.

Beyond this specific charge, the Panel was asked to:

- Determine whether to recommend if an interim BMP rate should be established for one or more classes of retrofits prior to the conclusion of the Panel for WIP planning purposes.

- Recommend procedures for reporting, tracking and verifying the recommended retrofit removal rates. The Panel also will look at the potential to develop regional monitoring consortium to devise strategies for future collaborative monitoring to better define the performance of various retrofit projects.

- Critically analyze any unintended consequence associated with the removal rates and any potential for double or over-counting of the load reduction achieved.

While conducting its review, the Panel followed the procedures and process outlined in the WQGIT BMP review protocol (WQGIT, 2010). The process begins with BMP expert panels that evaluate existing research and make initial recommendations on removal rates. These, in turn, are reviewed by the Urban Stormwater Workgroup, and other Chesapeake Bay Program (CBP) management committees, to ensure they are accurate and consistent with the Chesapeake Bay Watershed Model (CBWM) framework.

Appendix C documents the process by which the expert panel reached consensus, in the form of a series of five meeting minutes that summarize their deliberations. Appendix D documents how the Panel satisfied the requirements of the BMP review panel protocol.

Section 2
Background on Retrofitting in the Bay

Over the last two decades, communities across the Chesapeake Bay have pioneered new techniques for finding, designing and delivering retrofits to remove pollutants, improve stream health and maintain natural hydrology in developed watersheds (Schueler, 2007). Several important regulatory drivers are likely to increase the amount of future stormwater retrofit implementation across the Chesapeake Bay watershed.

For example, some communities need to install retrofits to meet pollutant reduction targets under recently issued municipal stormwater permits. Other communities are employing retrofits to control pollutants to meet local TMDLs. Each of the seven Bay states are considering greater use of urban stormwater retrofits as part of an overall strategy to remove nutrients and sediment loads, to meet reduction targets for existing urban development under the Chesapeake Bay TMDL. This section provides highlights about these retrofit strategies, which differ from state to state. More detail on individual state retrofitting strategies can be found in the stormwater sector section of their Phase 1 and Phase 2 Watershed Implementation Plans, the links to which can be found in Table 1.

PA DEP indicated that most of the retrofit activity in the Pennsylvania portion of the watershed to this point has involved various demonstration projects, many of which were funded under the Growing Greener program. The scope of retrofit activity will expand in the coming years as communities implement their new PAG-13 MS4 permits which require localities to develop strategies in the form of a local Chesapeake Bay Pollutant Reduction Plan by 2013.

VA DCR indicated that most of the retrofit activity in the Commonwealth included demonstration projects under state grants and revolving funds, although some suburban counties have also supported strong retrofit programs employing their own capital budgets. VA DCR intends to issue new Phase 1 MS4 permits during 2012 that will require as much as 40% pollutant reduction for existing development over a 15 year period. The pollutant reductions from existing development may be achieved by a variety of urban restoration practices, including stormwater retrofits. During the first permit cycle, communities are encouraged to conduct local watershed assessments to identify the most cost effective combinations of retrofits and other restoration practices.

MDE noted that Maryland has had a long retrofitting history. For more than a decade, Phase 1 MS4 communities have needed to treat 10% of their impervious cover in each five year permit cycle. Most communities have elected to meet that target through stormwater retrofits. Over the years, MDE has offered several grant programs to defray local retrofit project costs, but most communities have relied on their local capital budgets to finance the majority of their retrofits. MDE intends to issue new Phase 1 permits during 2012 that will expand the retrofit requirement to as much as 20% of untreated impervious cover during each permit cycle, and may also institute numerical retrofitting requirements for Phase 2 MS4 permits.

The District of Columbia has also had a long history of retrofitting, particularly in the Anacostia watershed. The focus of retrofitting in DC has evolved over the years to reflect the challenges and opportunities within their highly urban watersheds. DDOE currently relies on several residential and business incentive programs to build on-site LID retrofits, such as bioretention, rain barrels, green roofs or permeable pavers. The District is also implementing an extensive green street retrofit program on municipal streets. DDOE tracks these retrofits over time using a GIS tracking tool to record the aggregate acreage treated, and generally assumes a five year removal rate duration for on-site retrofits, which can be renewed based on inspection.

While Delaware has been involved in numerous retrofits over the years, they are not relying heavily on them in the small portion of their state that actually drains to the Chesapeake Bay. This part of the watershed area is primarily rural, and most of their urban restoration activity will involve septic system upgrades rather than retrofitting.

Similarly, the other upstream states (West Virginia and New York) are not expecting a great deal of stormwater retrofit activity in the coming years, and are focusing on other pollutant source sectors (e.g., agricultural, wastewater, abandoned mines) to achieve the bulk of their pollutant reductions. Both states, however, are expanding stormwater treatment requirements on new and redevelopment projects to prevent increased urban loading.

Stormwater retrofits have been uncommon at federal facilities until quite recently. The President's Executive Order on the Chesapeake Bay directed federal agencies to lead by example and demonstrate more pollution prevention and stormwater retrofits at the many federal properties in the watershed. Numerous federal agencies are now conducting retrofit and site benchmarking investigations at their facilities and it is likely that much more federal retrofit implementation will occur in the coming years.

Table 1 Key Web links for State and Federal Bay TMDL and WIP Guidance[1]

EPA	http://www.epa.gov/chesapeakebaytmdl/
DC	http://ddoe.dc.gov/service/total-maximum-daily-load-tmdl-chesapeake-bay
DE	http://www.dnrec.delaware.gov/wr/Information/Pages/Chesapeake_WIP.aspx
MD	http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/PhaseIIBayWIPDev.aspx
NY	http://www.dec.ny.gov/lands/33279.html
PA	http://www.depweb.state.pa.us/portal/server.pt/community/chesapeake_bay_program/10513
VA	http://www.dcr.virginia.gov/vabaytmdl/index.shtml
WV	http://www.dep.wv.gov/WWE/watershed/wqmonitoring/Pages/ChesapeakeBay.aspx

1 links current as of 3.16.2012

Section 3
Retrofit Definitions and Qualifying Conditions

Definition: Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. Stormwater retrofits can be classified into two broad project categories, as shown below:

1. New retrofit facilities
2. Existing BMP retrofits

1. New retrofit facilities: This category includes new retrofit projects that create storage to reduce nutrients from existing developed land that is not currently receiving any stormwater treatment. Common examples of new retrofit facilities include creating new storage:

(a) Near existing stormwater outfalls
(b) Within the existing stormwater conveyance system
(c) Adjacent to large parking lots
(d) Green street retrofits
(e) On-site LID retrofits

With the exception of (e), many new retrofit facilities are typically located on public land, and utilize a range of stormwater treatment and runoff reduction mechanisms. Due to site constraints, new retrofits may not always meet past or future performance standards for BMP sizing that applies to new development.

2. Existing BMP retrofits: are a fairly common approach where an existing BMP is either:

(a) Converted into a different BMP that employs more effective treatment mechanism(s).
(b) Enhanced by increasing its treatment volume and/or increasing its hydraulic retention time.
(c) Restored to renew its performance through major sediment cleanouts, vegetative harvesting, filter media upgrades, or full-scale replacement.

Most ***BMP conversions*** involve retrofits of older existing stormwater ponds, such as converting a dry pond into a constructed wetland or wet pond, although many other types of BMP conversions are also possible. BMP conversions can be located within existing BMPs located on public land, or at privately-owned BMPs. BMP conversions can utilize a wide range of stormwater treatment mechanisms.

BMP enhancements utilize the original stormwater treatment mechanism, but improve removal by increasing storage volume or hydraulic residence time. An example of a BMP enhancement is an upgrade to an older stormwater pond built under less stringent sizing and design standards. These upgrades may increase treatment volume, prevent short circuiting, extend flow path or hydraulic residence time, or add internal design features to enhance overall nutrient and/or sediment reduction. BMP enhancements typically occur within existing BMPs located on public land, or at privately-owned BMPs.

BMP restoration applies to major maintenance upgrades to existing BMPs that have either failed or lost their original stormwater treatment capacity. The method to calculate the removal rate increase depends on whether or not the BMP has previously been reported to EPA.

If the BMP has been previously reported, a lower removal rate is calculated using the curves that reflects the existing level of treatment, and this value must be reported for at least one progress reporting cycle. After the qualifying BMP restoration is completed, the curves are used to derive a higher rate for the increased treatment volume in subsequent years. If the BMP was not previously reported to EPA, it is considered a new retrofit, and the curves are used to define the removal rate based on the total treatment volume provided.

Only four types of BMP restoration are allowed:

(a) *Major Sediment Cleanouts* – Removal of sediment, muck and debris that is equal to or greater than 1/10 the volume of the facility. For wet ponds, the volume of the facility would be where the normal water elevation or invert of the outfall pipe is. For dry ponds or enhanced extended detention facilities, the volume would include the volume of any fore bays, to their overflows, and ½ the height of the dewatering structure.

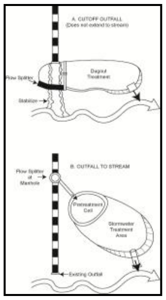
(b) *Vegetative Harvesting* – Removal of excessive, non-planned vegetative growth with off-site sequestration or composting. Appropriate plant species shall be re-planted and re-established when the vegetative harvesting causes an erosive or denuded condition.

(c) *Filter Media Enhancements* – Removal and sequestration of contaminated material and replacement with a media that is superior to those originally proposed in the design specification (i.e., replacing sand with a sand/organic or sand/zeolite mixture).

(d) *Complete BMP Rehabilitation* – Complete rehabilitation of a failed BMP to restore its performance (e.g., converting a failed infiltration basin into a constructed wetland). This restoration option only applies to older BMPs that were not previously reported to EPA.

Figure 1. Examples of New Retrofit Facilities and their Potential Applications

New retrofit facilities provide stormwater treatment in places that treatment did not previously occur. There are many opportunities for new retrofit facilities in the urban landscape. Some common examples are listed below.



Near Existing Stormwater Outfalls

Within the Existing Stormwater Conveyance System

Adjacent to Large Parking Lots

Green Street Retrofits

On-Site LID Retrofits

Figure 2. Examples of Existing BMP Retrofit Facilities and their Potential Applications


BMP Conversion: from a Dry Pond (left) to a Constructed Wetland (right) to allow for more effective treatment of stormwater.


BMP Enhancement: by adding a berm you can increase the flow path thereby extending the hydraulic retention time within the practice leading to better treatment.


BMP Restoration: increasing performance of a BMP by conducting major repairs or upgrades. In this example, an underperforming pond is dredged for sediment thereby restoring it to its full performance capacity.

Important Notes:

- No pollutant removal rates are given for routine maintenance of existing stormwater practices.

- Routine maintenance is essential to ensure the pollutant removal performance of any stormwater practice.

- The WTWG added a further qualifying condition that the proposed BMP restoration activities must be significant enough to achieve the intent of the original water quality design criteria in the era in which it was built (e.g., sediment cleanouts would, at a minimum, need to recover the original water quality storage capacity under the prevailing design standards at the time the BMP was constructed).

- Individual state stormwater agencies are encouraged to develop more detailed guidance on the qualifying conditions for acceptable BMP restoration.

- Applying more stringent stormwater requirements at redevelopment sites that had not previously treated stormwater runoff is functionally equivalent to a new retrofit facility. However, the Performance Standards Expert Panel recommended a protocol to compute load reductions at redevelopment projects.

Section 4
Protocol for Determining Retrofit Removal Rates

Basic Approach

Given the diversity of possible retrofit applications, the Panel decided that assigning a single universal removal rate was not practical or scientifically defensible. Instead, the Panel opted to develop a protocol whereby the removal rate for each individual retrofit project is determined based on the amount of runoff it treats and the degree of runoff reduction it provides. This approach is generally supported by a review of the recent pollutant removal and runoff reduction research, which is summarized in Appendix A.

The Panel initially developed a retrofit removal rate adjustor table that provides increasing sediment and nutrient removal rates for retrofits that treat more runoff and/or employ runoff reduction practices. For ease of use, the adjustor table was converted into a series of three curves, which are portrayed in Figures 3 to 5. Readers that wish to see the technical derivation for the adjustor curves should consult Appendix B.

In order to determine the runoff volume treated by a retrofit practice, the designer must first estimate the Runoff Storage volume (RS) in acre-feet. This, along with the Impervious Area (IA) in acres, is used in the standard retrofit equation to determine the amount of runoff volume in inches treated at the site:

$$= \frac{(RS\,)(12)}{IA}$$

Where:

RS = Runoff Storage Volume (acre-feet)
IA = Impervious Area (acres)

Once the amount of runoff captured by the practice is determined, the retrofit removal adjustor curves make it easy to determine pollutant removal rates for individual stormwater retrofits. The designer first defines the runoff depth treated by the project (on the x-axis), and then determines whether the project is classified as having runoff reduction (RR) or stormwater treatment (ST) capability (from Table 2). The designer then goes upward to intersect with the appropriate curve, and moves to the left to find the corresponding removal rate on the y-axis (see example in Figure 3).

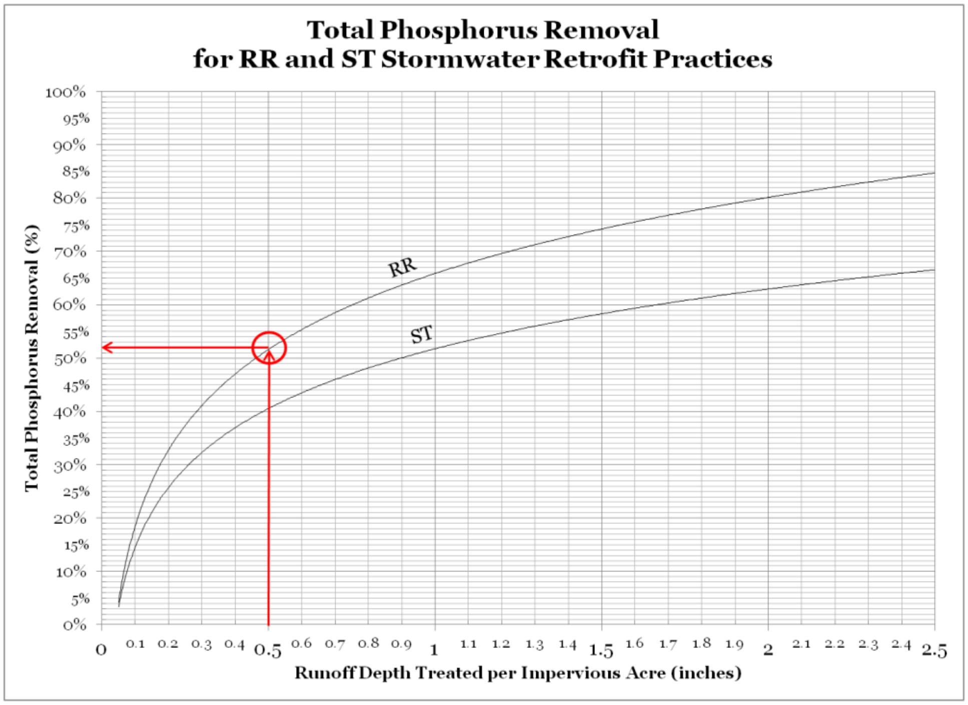


Figure 3. Retrofit Removal Adjustor Curve for Total Phosphorus

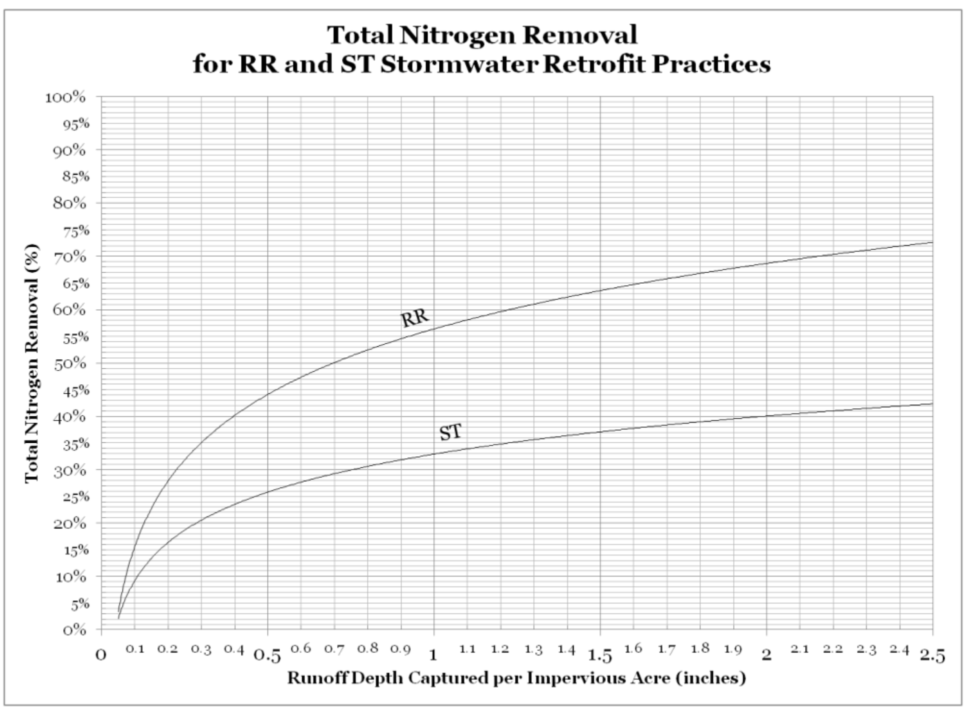


Figure 4. Retrofit Removal Adjustor Curve for Total Nitrogen

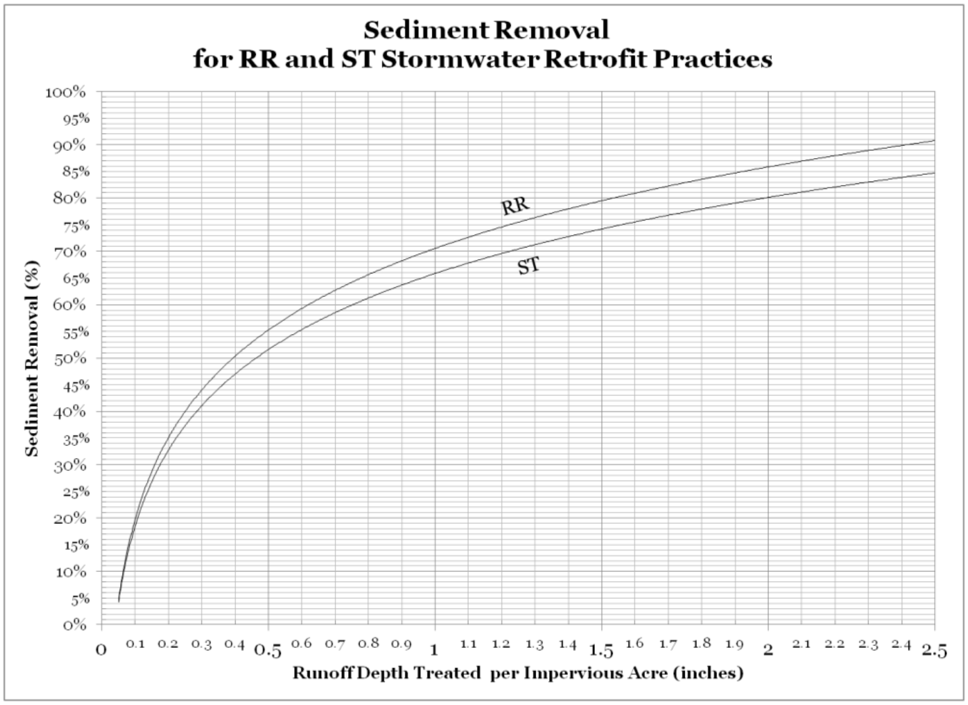


Figure 5. Retrofit Removal Adjustor Curve for Sediment

Runoff reduction is defined as the total post development runoff volume that is reduced through canopy interception, soil amendments, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapo-transpiration. Retrofit projects that achieve at least a 25% reduction of the annual runoff volume are classified as providing Runoff Reduction (RR), and therefore earn a higher net removal rate. Retrofit projects that employ a permanent pool, constructed wetlands or sand filters have less runoff reduction capability, and their removal rate is determined using the Stormwater Treatment (ST) curve.

Table 2 assigns all of the stormwater practices referenced in Bay State stormwater manuals into either the ST or RR category, so that designers can quickly determine which curve they should use based on the primary treatment practice employed by the retrofit. In situations where a mix of ST and RR practices are used within the same retrofit project, the designer should use the curve based on either the largest single practice used in the project or the ones that provide the majority of the retrofit treatment volume.

The removal rates determined from the retrofit removal rate adjustor curves are applied to the entire drainage area to the retrofit, and not just its impervious acres. Also, the retrofit reporting unit is the entire treated area, regardless of whether it is pervious or impervious.

Table 2 Classification of BMPs based on Runoff reduction capability[1]

Runoff Reduction Practices (RR)	*Stormwater Treatment Practices (ST)* [2]
Site Design/Non-Structural Practices	
Landscape Restoration/Reforestation	
Riparian Buffer Restoration	Constructed Wetlands
Rooftop Disconnection (aka Simple Disconnection to Amended Soils, to a Conservation Area, to a Pervious Area, Non-Rooftop Disconnection)	Filtering Practices (aka Constructed Filters, Sand Filters, Stormwater Filtering Systems)
Sheetflow to Filter/Open Space* (aka Sheetflow to Conservation Area, Vegetated Filter Strip)	Proprietary Practices (aka Manufactured BMPs)
All Non-structural BMPS – Chapter 5 of the 2006 Pennsylvania Stormwater BMP Manual	Wet Ponds (aka Retention Basin)
Practices	Wet Swale
All ESD practices in MD 2007	
Bioretention or Rain Garden (Standard or Enhanced)	
Dry Swale	
Expanded Tree Pits	
Grass Channels (w/ Soil Amendments, aka Bioswale, Vegetated Swale)	
Green Roof (aka Vegetated Roof)	
Green Streets	
Infiltration (aka Infiltration Basin, Infiltration Bed, Infiltration Trench, Dry Well/Seepage Pit, Landscape Infiltration)	
Permeable Pavement (aka Porous Pavement)	
Rainwater Harvesting (aka Capture and Re-use)	

*May include a berm or a level spreader

[1]Refer to DC, MD, PA, VA or WV State Stormwater Manuals for more information

[2] Dry ED ponds have limited removal capability , their efficiency is calculated using rates in Table A-4, Appendix A

Protocol for New Retrofit Facilities

To determine the sediment and nutrient removal rate for an individual new retrofit project, the designer should go the appropriate curve and find the unique rate for the combination of runoff depth captured and runoff reduction/stormwater treatment that is achieved. The designer should also estimate the total contributing drainage area to the retrofit. Several examples are provided in the next section to illustrate how the protocol is applied.

Protocol for Existing BMP Retrofit Facilities

The method used to define removal rates differs slightly for each of the three classes in this category, as follows:

BMP Conversion: The specific method for defining the removal rate depends on the type and age of the BMP being converted:

- *If the BMP being converted is a dry detention pond or flood control structure that currently is providing no effective water quality treatment*, then the existing BMP will have a zero removal rate. A higher CBP-approved BMP rate that reflects the improved stormwater treatment mechanism associated with the conversion can be taken directly from Table A-5 of Appendix A (i.e., dry ED, wet pond, constructed wetland or bioretention)

- *If the BMP being converted involves a significant increase in runoff capture volume and/or an increase in runoff reduction, than an incremental rate is used*. The removal rate for the existing BMP should be determined from the adjustor curve. A higher removal for the converted BMP will reflect the higher degree of runoff treatment and/or runoff reduction associated with the retrofit, as determined from the retrofit removal adjustor curves (Figure 3 to 5). This method will generally be the most applicable to the majority of conversion retrofits.

In all cases, the designer should also estimate the total contributing drainage area to the retrofit. Examples are provided in the next section, that illustrate how both of these methods are applied to conversion retrofits.

BMP Enhancement: The sediment and nutrient removal rates for individual BMP enhancement retrofits are also expressed as an incremental removal rate (enhanced BMP - existing BMP).

- The rate for the existing BMP is defined based on its combination of runoff treatment and runoff reduction using the retrofit removal adjustor curves. Designers may reduce the actual amount of runoff treatment in the existing BMP that is not effective (e.g., treatment volume that is ineffective because of short-circuiting or other design problems that reduce the hydraulic retention time).

- The enhanced BMP will have either a greater runoff treatment volume and/or achieve a better runoff reduction rate. Designers can determine the higher rate for the enhanced BMP using the retrofit removal adjustor curves.

- The removal rate for the BMP enhancement is then defined as the difference between the enhanced rate and the existing rate. An example of how to apply this protocol for BMP enhancements is provided in the next section.

BMP Restoration: The removal rate for BMP restoration depends on whether the existing BMP has been previously reported to EPA.

- If the BMP has not been previously reported, it is considered to be a new retrofit facility and the removal rate is determined by the retrofit removal adjustor curves for the drainage area contributing to the BMP.

- If the BMP was previously reported to EPA, then the removal rate for a restored BMP is expressed as an incremental removal rate (restored BMP - existing BMP). The existing BMP removal rate is defined using the curves based on the original BMP sizing and design criteria. The restored BMP rate is defined using the retrofit removal rate adjustor curve for the runoff treatment volume "restored" (i.e., by sediment cleanouts, vegetative harvesting or practice rehabilitation) and/or shifting to RR runoff reduction (i.e., media replacement).

  To prevent double counting, the removal rate credit is reported to EPA by the jurisdiction in a two step process. First, it must be reported at the degraded condition (lower removal rate) for at least one annual progress run. Second, the incremental rate improvement associated with the BMP restoration is then reported the next progress year.

Other Key Issues:

What Data to Report

To be eligible for the removal rates in the model, localities need to check with their state stormwater agency on the specific data to report individual retrofit projects, and must meet the BMP reporting and tracking procedures established by their state. The Panel recommended that the following information be reported:

a. Retrofit class (i.e., new retrofit facility or existing BMP retrofit)
b. GPS coordinates
c. Year of installation (and expected rate duration)
d. 12 digit watershed in which it is located
e. Total drainage area and impervious cover area treated
f. Runoff volume treated and identify “type” of BMP
g. Projected sediment, nitrogen and phosphorus removal rates

Jurisdictions will also be responsible for other tracking and verification procedures as outlined in Section 6 of this memo.

The Baseline Load Issue

The protocol developed by the Panel does not require jurisdictions to define a pre-retrofit baseline load. The Panel acknowledges, however, that many jurisdictions may want to estimate pre-retrofit baseline loads when it comes to finding the most cost-effective combination of retrofit projects to pursue in their subwatershed retrofit investigations.

Analyzing Retrofit Options in the Context of CAST/MAST/VAST

The Panel acknowledges that its retrofit assessment protocol does not fit easily within the context of assessment and scenario builder tools that have been recently developed to assist states and localities to evaluate BMP options to develop watershed implementation plans (i.e., each retrofit has a unique rate and consequent load reduction, while the CAST tools apply a universal rate for all retrofits).

The CBPO modeling team has expressed a willingness to incorporate the adjustor curves into the CAST modeling framework in the next year or so. Until these refinements are made, the Panel felt that it was reasonable, for planning purposes, for each state to assign a single removal rate to characterize the performance of a generic type of retrofit to evaluate alternate BMP scenarios.

As an example, a state might assume a generic stormwater retrofit that is a 50/50 blend of RR and ST practices and treat 1 inch of runoff from impervious area. This generic retrofit rate could be used in the context of CAST to compare load reductions for different levels of local drainage area treated by retrofits. As noted, each state would elect to develop its own scenarios to be consistent with their unique scenario assessment tools.

Section 5
Retrofit Examples

The following examples have been created in order to demonstrate the proper application of the retrofit removal adjustor curves for the purpose of determining the nutrient and sediment removal rates of retrofits.

New Retrofit Facilities

Constructed Wetland. A Bay County has discovered an un-utilized parcel of parkland where it is feasible to build a constructed wetland. The engineer has estimated that the retrofit storage in the constructed wetland is 1.67 acre-feet. The proposed retrofit will treat the runoff from a 50 acre residential neighborhood with 40% impervious cover. The engineer determines the number of inches that the retrofit will treat using the standard retrofit equation:

$$\frac{(RS\ )(12)}{IA} = x\ inches \qquad \frac{(1.67\ )(12)}{20} = 1.0\ inch$$

The constructed wetland retrofit will capture and treat 1.0 inch of rainfall. Table 2 informs that constructed wetlands are considered to be a ST practice.

By referring to Figures 3-5, we can see that this proposed retrofit will have the following pollutant removal rates:

TP	TN	TSS
52%	33%	66%

Green Street. A Bay City is considering a plan to construct green streets as part of a revitalization project for the downtown commercial area. Their engineering consultant plans to employ permeable pavement, expanded tree pits and street bioretention to treat runoff and she estimates the runoff storage volume for the combined practices to be 0.27 acre-feet. Since the 4.3 acres of 100% impervious urban land that drain to the existing street have not provided stormwater management in the past, the new green street project is classified as a new retrofit. The engineer determines the number of inches that the retrofit will treat using standard retrofit equation:

$$\frac{(0.27)(12)}{4.3} = 0.75\ inches$$

Collectively, the new LID practices will treat 0.75 inches of runoff and fall under the RR practice category. Based on this information, the City uses the retrofit removal adjustor curves (Figures 3 to 5) to determine the following removal rates for the green street retrofit project:

TP	TN	TSS
60%	51%	64%

On-Site LID Retrofits. A Bay Township creates an incentive program for residential homeowners to install rain gardens on their property and would like to determine the pollutant removal rates associated with such a program. Each homeowner has an average roof size of 500 ft^2 and if 100 homeowners participate in the program, treatment can occur for a combined drainage area of 1.15 acres, at 100% impervious. The runoff storage volume associated with the combined retrofits is estimated to be 0.05 acre-feet. The amount of runoff volume treated by the rain gardens is calculated using standard retrofit equation:

$$\frac{(0.05)(12)}{1.15} = 0.5\ inches$$

Each rain garden is assumed to treat 0.5 inches of rainfall and is classified as a RR practice. The township engineer uses the curves to estimate the projected removal rates associated with the rain garden incentive program:

TP	TN	TSS
52%	44%	55%

In all three of the above examples, the information that needs to be reported is the retrofit removal rates and the total contributing drainage area to the practices.

Existing BMP Retrofits

BMP Conversion. A dry pond was built in 1985 in Maryland which was designed to provide flood control only. The designer is able to create new water quality storage using a combination of a forebay with a permanent pool, a submerged gravel wetland cell and a final bioretention polishing cell. As a result, the facility now provides a runoff storage volume of 1.3 acre-feet for its 65 acre urban drainage area that is 40% impervious. The amount of runoff volume treated by the converted BMP is calculated using the standard retrofit equation:

$$\frac{(1.3)(12)}{26} = 0.6 \ inches$$

Because the project is a dry pond conversion, the designer evaluated both methods to assess pollutant removal rates. The designer rejected the use of existing CBP-approved rates because the conversion involved three different stormwater treatment mechanisms. Instead the designer opted to use the retrofit removal adjustor curves, since the retrofit conversion produced a large increase in runoff treatment volume and a modest increase in runoff reduction. The comparative removal rate projections are shown below:

	TP	TN	TSS
CBP approved rates	N/A	N/A	N/A
Adjustor removal rates	55%	47%	59%

BMP Enhancement. A dry extended detention pond was built in a Bay County in 1995 that served a 10 acre commercial property. The facility was originally designed to under older standards that only required that the “first flush” of stormwater runoff be treated. Analysis of drainage area characteristics indicated that the dry ED pond was sized to capture only 0.3 inches of runoff per impervious acre. In addition, field investigations showed that the pond had a major short-circuiting problem, such that half of its storage volume was hydraulically ineffective.

The Bay County engineer realized that this site was a good candidate for a BMP enhancement retrofit, and modified the configuration of the pond to increase its hydraulic retention time, provide missing pretreatment and excavate several shallow wetland cells in the bottom of the pond to improve treatment.

Collectively, these design enhancements created an additional 0.3 inches of new runoff treatment volume per impervious acre, for a total runoff of 0.6 inches. For BMP enhancement retrofits, the removal rate is defined as the incremental difference between the new removal rate and the original removal rate. The engineer analyzed the retrofit removal adjustor curves, and computed the net effect of the BMP design enhancements, as follows:

	TP	TN	TSS
Enhanced Rate	44%	28%	55%
Original Rate	22%	14%	28%
Incremental Removal Rate	22%	14%	27%

*BMP Restoration***.** A wet pond was installed in Bay City in 1980, which captured 0.5 inches of runoff from the impervious cover of its contributing watershed. Bay City had previously reported the pond to Bay State. Over time, however, the storage capacity of the wet pond was seriously diminished due to sedimentation and growth of invasive plants. The maintenance crew noted that 60% of the pond's storage capacity had been lost, resulting in an actual capacity of a mere 0.2 inches of runoff treatment.

Bay City DPW conducted a major dredging effort to clean out the sediments and replanted the pond with native species. As a result of the pond restoration, 0.3 inches of storage were recovered, increasing the total storage in the pond to its original design volume of 0.5 inches of runoff depth captured. Bay County employed the retrofit removal adjustor curves for ST practices to determine the incremental pollutant removal rates associated with the pond restoration, as follows:

	TP	TN	TSS
Restored Rate (0.5)	40%	25%	48%
Existing Rate (0.2)	26%	16%	33%
Incremental Removal Rate	14%	9%	15%

Consequently, Bay City would report the existing rate to the state in the first year, and then submit the additional incremental rate for the restoration in subsequent years after the BMP is restored.

BMP Restoration (Non-Reported BMP). A sand filter was built in Bay City in 1998 and was sized to capture 0.5 inches of runoff from a municipal parking garage. Due to poor design, the sand filter had clogged over time and is no longer functioning as a BMP. Because the sand filter had never been reported to the state, it was eligible to get the full BMP pollutant reduction rate.

Bay City DPW upgraded the original sand filter to improve its retention time and replace the old media with a more effective bioretention mix. The removal rates are calculated from the retrofit removal adjustor curves:

TP	TN	TSS
52%	44%	55%

Non Eligible Restoration Example. Bay County inspectors concluded that it was time to clean out sediments trapped within the pre-treatment cell of a large bioretention facility. The facility was originally sized to capture 1.0 inch of runoff volume and achieves a 66% TP removal rate. This routine maintenance operation recovered 0.05 inches of runoff volume capacity in the bioretention area. Because this cleanout did not meet the 10% recovery threshold, it does not qualify for BMP restoration and no additional removal rate credit is given.

Section 6
Accountability Procedures

The Panel concurs with the conclusion of the National Research Council (NRC, 2011) that verification of BMP installation and subsequent performance is a critical element to ensure that pollutant reductions are actually achieved and sustained across the watershed. The Panel also concurred with the broad principles for urban BMP reporting, tracking and verification contained in the draft memo to the Urban Stormwater Workgroup. The Panel recommends that CBP adopt the following reporting, tracking and verification protocols for stormwater retrofit projects:

1. *Duration of Retrofit Removal Rate.* The maximum duration for the removal rate will be 10 years, although it can be renewed based on a field performance inspection that verifies the retrofit still exists, is adequately maintained and operating as designed. The duration of the removal rate will be 5 years for on-site retrofits installed on private property, and can only be renewed based on visual inspection that the on-site retrofit still exists.

2. *No Double Counting*. A removal rate cannot be granted if the retrofit project is built to offset, compensate or otherwise mitigate for a lack of compliance with new development stormwater performance standards elsewhere in the jurisdiction. Instead, the removal rate can only be applied as an offset (i.e., the acres of new development that will now fully meet the state stormwater performance standard). The Panel also recommends more frequent inspection and verification process for any retrofit built for the purpose of stormwater mitigation, offsets, trading or banking, in order to assure the project(s) is meeting its nutrient or sediment reduction design objectives.

3. *Initial Verification of Performance*. Jurisdictions will need to provide a post-construction certification that the urban retrofit was installed properly, meets or exceeds the design standards under its retrofit classification and is achieving its hydrologic function prior to submitting the retrofit removal rate to the state tracking database. This initial verification is provided either by the retrofit designer or a local inspector as a condition of retrofit acceptance, as part of the normal municipal retrofit design and review process. From a reporting standpoint, the MS4 community would simply indicate in its annual report whether or not it has retrofit review and inspection procedures in place and adequate staff to implement them.

4. *Retrofit Reporting Units*. Localities will submit documentation to the state stormwater or TMDL agency to document the nutrient/sediment reduction claimed for each individual urban retrofit project that is actually installed. Localities should check with their state stormwater agency on the specific data to report for individual retrofit projects. The Panel recommends that the following reporting data be submitted:

a. Retrofit class
b. GPS coordinates
c. Year of installation (and expected duration)
d. 12 digit watershed in which it is located
e. Total drainage area and impervious cover area treated
f. Runoff volume treated and identify "type" of BMP
g. Projected sediment, nitrogen and phosphorus removal rates

5. *Retrofit Recordkeeping*. The agency that installs the retrofit should maintain a more extensive project file for each urban retrofit project installed (i.e., construction drawings, as-built survey, digital photos, inspection records, and maintenance agreement, etc). The file should be maintained for the lifetime for which the retrofit removal rate will be claimed.

6. *Ongoing Field Verification of BMP Performance*. Inspectors need to look at visual and other indicators every 10 years to ensure that individual retrofit projects are still capable of removing nutrients/sediments. If the field inspection indicates that a retrofit is not performing to its original design, the jurisdiction has up to one year to take corrective maintenance or rehabilitation actions to bring it back into compliance. If the facility is not fixed after one year, the pollutant reduction rate for the retrofit would be eliminated, and the jurisdiction would report this in its annual MS4 report. The retrofit removal rate can be renewed, however, if evidence is provided that corrective maintenance actions have restored retrofit performance.

Collaborative Monitoring of Retrofit Performance

The Panel agreed on the continuing need to monitor the effectiveness of retrofits at both the project and watershed scale to provide greater certainty in the removal rate estimates. The Panel also noted the importance of monitoring both innovative and traditional retrofit techniques in varied applications, terrain and climatic conditions.

The Panel indicated the best route to acquire such monitoring data was through retrofit monitoring programs undertaken as part of municipal MS4 stormwater permit programs.

The Panel recommended that localities pool their scarce local MS4 monitoring resources together to create a monitoring consortium that could fund selected retrofit monitoring projects to be performed by monitoring experts (i.e., universities and qualified consulting firms).

In the interim, the Panel recommended that any local retrofit monitoring be conducted under a standard quality assurance project plan (QAPP) developed under the auspices of the USWG to ensure the performance data is reliable and accurate. Since several communities may be interested retrofit monitoring, USWG might not have the capacity to review all of the designs. The Panel therefore recommended that the CBP retain a consultant with expertise in "applied" monitoring to develop basic QAPP guidelines and make suggestions to monitoring plans. A possible model might be the 3-tiered QA certification process that increases in rigor with the increased need for data accuracy employed by the city of Suffolk and other Virginia communities (Details can be found at http://www.deq.virginia.gov/cmonitor/guidance.html).

The consultant would also be charged with identifying synergies among research to avoid duplication of effort and also prioritize monitoring needs. The initial guidelines would be fairly generic cutting across retrofit types and would be flexible to account for local site conditions. Ultimately, the Panel recommended that a standard methodology be established for each type of retrofit practice as long as it allows for local site variability.

The Panel also discussed the timeframe by which new retrofit monitoring data would be considered in adjusting future retrofit efficiencies, and recommended the Panel be reconvened at every two year WIP milestone, which fits in nicely with the "adaptive management" approach that is advocated by NRC (2011). One of the chief considerations should be whether the efficiency changes would be adjusted locally or applied globally across the Bay watershed.

Appendix A Evolution of Stormwater BMP Removal Rates

The Panel agreed that the performance of stormwater retrofits could only be inferred by analyzing previous studies that have looked at pollutant removal and runoff reduction data for groups of stormwater BMPs.

Over the past three decades, considerable research has been undertaken to understand the nutrient removal dynamics of urban stormwater practices and translate these into generic removal rates that can be used by watershed managers. This appendix begins with a brief review of how our understanding about BMP performance has evolved in response to new monitoring data and shifts in stormwater technology. This background is needed to interpret the many different (and sometimes conflicting) removal rates that have been assigned to BMPs over time, and to support the retrofit analysis approach.

Evolution of the Science of Stormwater BMPs

Stormwater managers have been grappling to define nutrient removal rates for stormwater practices, with at least ten different sets of rates published in the last 25 years (Schueler, 1987, Schueler, 1992, Brown and Schueler, 1997, Winer, 2000, Baldwin et al, 2003, CWP, 2007, CWP and CSN, 2008, Simpson and Weammert, 2009, ISBD, 2010, and CSN, 2011). It is no small wonder that managers are confused given that the nutrient removal rates change so frequently.

Each new installment of published BMP removal rates reflects more research studies, newer treatment technologies, more stringent practice design criteria and more sophisticated meta-analysis procedures.

For example, the first review involved only 25 research studies and was exclusively confined to stormwater ponds and wetlands, most of which were under-sized by today's design standards. The monitoring design for this era of BMP assessment evaluated the change in nutrient concentration as storms passed through individual practices. Analysis of individual performance studies showed considerable variability in nutrient removal efficiency from storm to storm (negative to 100%), and among different practices in the same BMP category.

The variability in removal rates was damped by computing a median removal rate for each individual practice and then computing a group mean for all the practices within the same group. This enabled managers to develop a unique "percent removal rate" for each group of BMPs.

By the turn of the century, about 80 research studies were available to define BMP performance, which expanded to include new practices such as grass swales, sand filters and a few infiltration practices. The number of BMP research studies available for analysis had climbed to nearly 175 by 2007. Table A-1 portrays the percent removal rates for nutrients for different groups of stormwater practices. The percent removal approach provides general insights into the comparative nutrient capability of different BMP groups, both in terms of total and soluble nutrient removal. For example, wet ponds and filtering systems are clearly superior to dry ponds when it comes to TN and TP removal, but wet ponds do a much better job than filtering systems in removing soluble N and P.

Table A-1
Typical Percent Removal Rates for Total and Dissolved Fractions of Phosphorus and Nitrogen (N=175)

Practice Group	TP (%)	Sol P (%)	TN (%)	Nitrate-N(%)
Dry Ponds	20	- 3	24	9
Wet Ponds	52	64	31	45
Wetlands	48	24	24	67
Infiltration	70	85	42	0
Filtering Systems	59	3	32	-14
Water Quality Swales	24	-38	56	39

Source: CWP, 2007

At about the same time, researchers began to recognize the limits of the percent removal approach. First, percent removal is a black box approach that provides general performance data, but little or no insight into the practice design features that enhance or detract from nutrient removal rates (Jones et al, 2008). Second, new data analysis showed that there were clear limits on how much any BMP could change nutrient concentrations as they passed through a practice. Extensive analysis of the nutrient levels in BMP effluent indicated that there appeared to be a treatment threshold below which nutrient concentrations could not be lowered.

This threshold has been termed the "irreducible concentration". The nutrient concentration limits for each group of practices is shown in Table A-2, and are caused by pass-thru of fine particles, internal re-packaging of nutrients, biological activity and nutrient leaching and/or release from sediments.

The third critique of the percent removal approach was that the population of monitoring studies upon which it is based is biased towards newly installed and generally well-designed practices. Very few monitoring studies have been performed on older practices or practices that have been poorly installed or maintained. The clear implication is that the ideal percent removal rate may need to be discounted to reflect these real world concerns, and several BMP reviews (Baldwin et al, 2003 and Simpson and Weammert, 2009) have derived more conservative rates in order to account for them.

Table A-2 **"Irreducible" Nutrient Concentrations Discharged from Stormwater Practices**				
Stormwater Practice Group	Total Phosphorus	Soluble Phosphorus	Total Nitrogen	Nitrate Nitrogen
	mg/l			
Dry Ponds	0.19	0.13	ND	ND
Wet Ponds	0.13	0.06	1.3	0.26
Wetlands	0.17	0.09	1.7	0.36
Filtering Practices	0.16	0.06	1.1	0.55
Water Quality Swales	0.21	0.09	1.1	0.35
Untreated Runoff	0.30	0.16	2.0	0.6
Source: Winer (2000)				

The most serious critique, however, of the percent removal approach is that it focuses exclusively on nutrient concentrations and not flow reductions. This was not much of an issue with the first generation of BMPs (ponds, wetlands, and sand filters) since they had little or no capability to reduce runoff as it passed through a practice (ISBD, 2010). With the emergence of new research on LID practices, however, the importance of runoff reduction in increasing the mass nutrient removal rate became readily apparent.

Nearly 50 new performance studies on the pollutant and runoff reduction capability of LID practices have been published in the last five years. Collectively, this new research has had a profound impact on how nutrient reduction rates are calculated, and in particular, isolating the critical practice design and site variables that can enhance rates. CWP and CSN (2008) synthesized the runoff reduction research and calculated new (and higher) mass nutrient removal rates for both traditional and LID stormwater practices.

A key element of the new runoff reduction approach is that it prescribes two design levels for each practice that have a different nutrient removal rate. An example of the two level design approach for bioretention is shown in Table A-3. The table reflects recent research that indicates which design features, soil conditions and performance standards can boost TN and TP removal. Some of these include:

- Increased depth of filter media
- No more than 3-5% carbon source in media
- Create an anoxic bottom layer to promote denitrification
- Increased hydraulic residence time through media (1-2 in/hr)
- Test media to ensure soils have a low phosphorus leaching risk

Designers that meet or exceed the Level 2 design requirements are rewarded with a higher nutrient mass reduction rate.

Table A-3 Example of Two Level Design Approach for Bioretention	
LEVEL 1 DESIGN	**LEVEL 2 DESIGN**
RR = 40% TP = 55% TN = 64%	RR= 80% TP= 90% TN = 90%
Treats the 90% storm	Treats the 95% storm
HSG C and D soils and/or under drain	HSG A and B soils OR has 12 inch stone sump below under drain invert
Filter media at least 24" deep	Filter media at least 36" deep
One cell design	Two cell design
Both: Maximum organic material in media of 5% and hydraulic residence time of 1 inch per hour through media	

The basics of the runoff reduction method and/or design level approach are now being incorporated into stormwater design manuals and compliance tools in Virginia, West Virginia, District of Columbia, Delaware and the Maryland Critical Area. Table A-4 summarizes the mass nutrient removal rates developed to implement the new Virginia stormwater regulations.

The runoff reduction method enables designers to achieve high removal rates when a mix of site design and LID practices and conventional stormwater practices are combined together to meet a specific phosphorus performance standard. In many cases, the aggregate nutrient reduction achieved by a mix of LID practices at a site exceeds the existing CBP approved rate for the individual practices (which reflects the higher treatment volume, better soil conditions and more stringent design criteria). In summary, urban BMP nutrient removal rates have constantly evolved over time in response to new performance research, changing stormwater practices and paradigms, and more stringent design criteria and regulations.

Approved Removal Rates for Urban BMPs in the Chesapeake Bay

Given the proliferation of removal rates described in the preceding section, the Chesapeake Bay Program has established a peer-review process to derive standard and consistent removal rates for a wide range of urban BMPs. These rates are used for the purpose of defining the aggregate nutrient and sediment reduction associated with BMP implementation in the context of the Chesapeake Bay Watershed Model. Since 2003, about 20 urban BMP rates have been established, with the supporting documentation provided in Baldwin et al (2003) and Simpson and Weammert (2009). The most current CBP-approved efficiency rates that relate to retrofitting are provided in Table A-5.

Table A-4 Mass Nutrient Removal Rates for Stormwater Practices			
Practice	**Design Level[1]**	**TN Load Removal[4]**	**TP Load Removal[4]**
Rooftop Disconnect [5]	*1*	*25 to 50*	*25 to 50*
	2 [6]	*50*	*50*
Filter Strips [5]	*1*	*25 to 50*	*25 to 50*
	2 [6]	*50 to 75*	*50 to 75*
Green Roof	*1*	*45*	*45*
	2	*60*	*60*
Rain Tanks & Cisterns [7]	*1*	*15 to 60*	*15 to 60*
	2	*45 to 90*	*45 to 90*
Permeable Pavers	*1*	*59*	*59*
	2	*81*	*81*
Infiltration Practices	*1*	*57*	*63*
	2	*92*	*93*
Bioretention Practices	*1*	*64*	*55*
	2	*90*	*90*
Dry Swales	*1*	*55*	*52*
	2	*74*	*76*
Wet Swales	*1*	*25*	*20*
	2	*35*	*40*
Filtering Practices	*1*	*30*	*60*
	2	*45*	*65*
Constructed Wetlands	*1*	*25*	*50*
	2	*55*	*75*
Wet Ponds [8]	*1*	*30 (20)*	*50 (45)*
	2	*40 (30)*	*75 (65)*
ED Ponds	*1*	*10*	*15*
	2	*24*	*31*

Notes

[1] See specific level 1 and 2 design requirements within each practice specification
[2] Annual runoff reduction rate (%) as defined in CWP and CSN (2008)
[3] Change in nutrient event mean concentration in and out of practice, as defined in CWP and CSN (2008)
[4] Load removed is the product of annual runoff reduction rate and change in nutrient EMC
[5] Lower rate is for HSG soils C and D, Higher rate is for HSG soils A and B
[6] Level 2 design involves soil compost amendments, may be higher if combined with secondary runoff reduction practices
[7] Range in RR depends on whether harvested rainwater is used for indoor, outdoor or discharged to secondary runoff reduction practice. Actual results will be based on spreadsheet
[8] lower nutrient removal parentheses apply to ponds in coastal plain terrain

Table A-5 Approved CBP BMP Efficiency Rates for Retrofit Analysis [1, 2, 3]				
URBAN BMP		**Total Nitrogen**	**Total Phosphorus**	**TSS**
		MASS LOAD REDUCTION (%)		
Wet Ponds and Constructed Wetlands		20	45	60
Dry Detention Ponds		5	10	10
Dry Extended Detention Ponds		20	20	60
Infiltration		80 (85) [4]	85	95
Filtering Practices (Sand Filters)		40	60	80
Bioretention	C & D w/UD	25	45	55
	A & B w/ UD	70	75	80
	A & B w/o UD	80	85	90
Permeable Pavement	C & D w/UD	10 (20)	20	55
	A & B w/ UD	45 (50)	50	70
	A & B w/o UD	75 (80)	80	85
Grass Channels	C & D w/o UD	10	10	50
	A & B w/o UD	45	45	70
Bioswale	aka dry swale	70	75	80

[1] In many cases, removal rates have been discounted from published rates to account for poor design, maintenance and age, and apply to generally practices built prior to 2008
[2] Current Practices are designed to more stringent design and volumetric criteria, and may achieve higher rates –see Table A-4
[3] Some practices, such as forest conservation, impervious cover reduction, tree planting are modeled as a land use change. Urban stream restoration is modeled based on a reduction per linear foot of qualifying stream restoration project
[4] Numbers in parentheses reflect design variation with a stone sump to improve long term infiltration rates

A quick glance at Table A-5 reveals that the rates for ponds and wetlands tend to be fairly conservative, which reflects the concern that ideal or initial removal rates should be discounted due to real world implementation issues such as poor design, installation and maintenance, or simply the age of the practice. The removal rates for newer LID practices, by contrast, is not discounted.

Appendix B Documentation of How the Retrofit Removal Adjustor Table/Curve Was Derived

The Panel started by noting the strong relationship between the runoff volume treated and the degree to which runoff reduction is achieved at individual BMPs. The primary source was a comprehensive analysis of runoff reduction and pollutant event mean concentration reduction data for a wide range of BMPs that are typically applied in retrofitting (CWP and CSN, 2008).

CSN (2011) developed a general table to determine nutrient removal rates for all classes of retrofits, and this approach was used as a starting point. The basic technical approach defines an “anchor” rate for composite stormwater treatment (ST) and runoff reduction (RR) practices for one inch of runoff treatment (see Table B-1). The RR practices included six different LID practices including bioretention, dry swales, infiltration, permeable pavement and green roofs/rain tanks.

The composite for ST practices included wet ponds, constructed wetlands, sand filters, and wet swales. Dry ponds and Dry ED pond were omitted from the ST category since they have such low removal rates that they are typically not targets of retrofitting. The annual mass nutrient removal rates associated with each practice presented in Table A-4 was averaged for the composite practices, as shown in Table B-1 below.

Table B-1 Composite Approach to Derive Nutrient Mass Load Reductions for RR ad ST Practices [1, 2]

PRACTICE	TP Mass Reduction (%)	TN Mass Reduction (%)
Bioretention	73	77
Dry Swale	66	63
Infiltration	75	78
Permeable Pavers	70	70
Green Roof/Rain Tank	55	55
Average RR	**70**	**70**[2]
Wet Ponds	63	35
Constructed Wetlands	63	40
Filtering Practice	63	38
Wet Swale	30	30
Average ST	**55**	**35**

[1] Source: Table A-4, nutrient rates computed using the average mass reduction for both Design Level 1 and Level 2.
[2] This value was subsequently discounted by 18% to reflect the impact of nitrate migration from runoff reduction practices described later in this appendix.

The next step involved using a rainfall frequency spreadsheet analysis from Washington, DC to estimate how the anchor removal rate would change based on different levels of runoff capture by the composite practice. The percent of the annual rainfall that would be captured by a retrofit designed for a specific control depth was estimated by summing the precipitation for all of the storms less than the control depth, plus the product of the number of storm events greater than the control depth multiplied by the control depth. This sum was then divided by the sum of the total precipitation. A visual representation of this may be helpful and can be seen as follows:

$$\%\ Annual\ Rainfall = \frac{(SUM\ P_{<CD} +\ CD(in) * (\#\ of\ Storms\ P_{>CD}))}{Sum\ of\ Total\ Precipitation\ (inches)}$$

Where:

$P_{<CD}$ = Precipitation of Storms less than Control Depth (inches)
$P_{>CD}$ = Precipitation of Storms greater than Control Depth (inches)
CD = Control Depth (inches): the depth of rainfall controlled by the practice

Once the percent annual rainfall has been determined for a specific control depth, we can use this along with the anchor pollutant removal rates to determine the pollutant removal values associated with a specific control depth. For example:

$$Pollutant\ Removal\ _{CD} = \frac{(Pollutant\ Removal\ Value_{AR} * \%\ Annual\ Rainfall_{CD})}{\%\ Annual\ Rainfall_{AR}}$$

Where:

Pollutant Removal Value $_{AR}$ = The anchor rates for N, P or TSS and ST or RR practices per 1.0" of Control Depth (~88% Annual Rainfall)

Phosphorus		Nitrogen		Sediment	
ST	RR	ST	RR	ST	RR
55%	70%	35%	60%	70%	75%

% Annual Rainfall $_{CD}$ = The % Annual Rainfall for a specific Control Depth as determined by the previous equation

% Annual Rainfall $_{AR}$ = This will always be 88%

The same basic approach was used to define maximum mass nutrient reduction rates for storms above the anchor rate, up to the 2.5 inch storm event. In general, no BMP performance monitoring data is available in the literature to evaluate removal for runoff treatment depths beyond 1.5 inches, so this conservative approach was used for the extrapolation. The Panel had limited confidence in removal rates in the 1.5 to 2.5 inch range, although it was not overly concerned with this limitation, since few of any retrofits are sized to capture that much runoff. A spreadsheet that defines how the anchor rates and bypass adjustments were derived can be obtained from CSN.

The tabular data was converted into a series of curves to make it easier for users to define a rate for the unique combination of runoff capture volume and degree of runoff reduction. This was done by fitting a log-normal curve to the tabular data points, which came within a few percentage points of the tabular values for a wide range of runoff capture depths and removal rates.

A 0.05 inch runoff capture volume was established as the cut-off point for getting any retrofit removal rate, since this roughly corresponds to the depth of initial abstraction that occurs on impervious surface. It should be noted that retrofits in this small size range will require very frequent maintenance to maintain their performance over time.

The Panel concluded that the generalized retrofit removal adjustor curves were a suitable tool for estimating the aggregate pollutant load reductions associated with hundreds or even thousands of future retrofit projects at the scale of the Bay watershed and the context of the Chesapeake Bay Watershed Model.

Notes on the Standard Retrofit Equation

The specific retrofit storage volume achieved at an individual site is usually "discovered" and is measured or estimated by an engineer based on site constraints. The retrofit storage volume (usually reported in acre-feet) needs to be converted into the appropriate unit on the X-axis of the curves (i.e., depth of runoff captured by retrofit per impervious acre).

The basic rationale is that the Rainfall Frequency Analysis method used to derive the adjustor curve (above and below the anchor points) is based on the assumption that the runoff delivered to a practice is generated from a unit impervious acre. By contrast, the retrofit storage volume available at each retrofit is unique, based on the upstream land cover, soils and the drainage area. Consequently, the retrofit storage volume must be adjusted to get a standard depth of runoff treatment per unit impervious cover to get the correct depth to use on the x-axis of the retrofit adjustor curves.

This is done by using standard retrofit equation which multiplies the retrofit storage volume by 12 to get acre-inches, and then is divided by the impervious acres to get the desired unit for the retrofit adjustor curves. Numerically, the standard retrofit equation is:

$$= \frac{(RS\ )(12)}{IA}$$

The removal rates determined from the retrofit removal adjustor curves are applied to the <u>entire</u> drainage area of the retrofit, and not just its impervious acres. Also, the retrofit reporting unit is the <u>entire</u> treated area, regardless of whether it is pervious or impervious.

Notes on the Derivation of Sediment Removal Rates

The original retrofit removal rate adjustor table (CSN, 2011) did not include estimates for sediment removal. They were derived in January of 2012 after a detailed analysis of BMP sediment removal rates drawn from the following sources --Brown and Schueler, (1997), Winer (2000), Baldwin et al, (2003), CWP (2007), Simpson and Weammert, (2009), and ISBD (2011a). Collectively, these BMP performance research reviews analyzed more than 200 individual urban BMP performance studies conducted both within and outside of the Chesapeake Bay watershed. The following general conclusions were drawn from the analysis.

Sediment removal by both traditional BMPs and LID practices was consistently higher and less variable than nutrient removal. This is attributed to the particulate nature of sediment which makes it easier to achieve reductions through settling, trapping, filtering and other physical mechanisms.

The analysis began with an examination of existing CBP-approved rates (see Table A-5). Two important trends were noted. First, TSS removal always exceeded TP and TN rates for every category of urban BMP. Second, nearly all the rates were within a fairly narrow range of 60 to 90%.

The same composite BMP method was employed using the CBP-approved rates to define sediment removal rates for RR and ST practices. The ST practice category included wet ponds, constructed wetlands and sand filters, which collectively had a TSS removal rate of 70%. The RR category included all design variations of bioretention, permeable pavement, infiltration and bio-swales in Table A-5, and had a slightly higher composite TSS removal rate of 75%.

Other BMP performance reviews have also noted that TSS removal rates exceed TP or TN removal rates for all individual studies of traditional urban BMPs (up to 1.0 inch of runoff treated, Winer, 2000 and CWP, 2007).

The sediment removal rate for traditional BMPs is ultimately limited by particle size considerations. Studies have shown that there is an irreducible concentration associated with the outflow from traditional BMPs (Winer, 2000 and NRC, 2008) around 15 to 20 mg/l which reflects the limits of settling for the most fine-grained particles. In practical terms, this sets an upper limit on maximum sediment removal around 70 to 80% for the range of monitored BMPs (i.e., sized to capture 0.5 to 1.5 inches of runoff).

Additional analysis was done to examine whether sediment removal rates for LID practices (i.e., runoff reduction practices) would achieve high rates of runoff reduction. Recent sediment mass removal rates were reviewed for bioretention, permeable pavers, green roofs, rain tanks, rooftop disconnection and bioswales (Simpson and Weammert, 2009, ISBD, 2011a, and a re-analysis of individual studies contained in CWP and CSN, 2008). The following general conclusions about LID sediment removal rates were drawn from the analysis:

- Most LID practices had lower TSS loadings than traditional BMPs, primarily because there was no major up-gradient sediment source area (e.g., green roofs, rain tanks, permeable pavers, rooftop disconnection) or a small contributing drainage area (bioretention, bio-swales).

- In general, LID practices had a slightly lower outflow sediment concentration than their traditional BMP counterparts (around 10 mg/l-- ISBD, 2011a).

- The ability of LID practices to change the event mean concentration of sediment as it passed through a practice differed among the major classes of LID practices. For example, nearly a dozen studies showed that bioretention and bioswales could achieve significant reduction in sediment concentrations. On the other hand, permeable pavers and green roofs generally produced low or negative changes in sediment concentrations through the practice. This finding was not deemed to be that important given how low the sediment inflow concentrations were.

Based on these conclusions, the Panel took a conservative approach and did not assign higher sediment removal rates for LID practices that achieved a high rate of runoff reduction, at least for facilities designed to capture less than an inch or more of runoff.

Beyond that point, the Panel did assign a modest increase in sediment removal rate for LID practices under the assumption that the combination of high runoff capture and reduction would work to reduce or prevent accelerated downstream channel erosion. The Panel notes that the extra sediment removal rate for this range of LID practices is an untested hypothesis that merits further research.

Notes on Revising TN Adjustor Curve to Reflect Nitrate Migration from BMPs to Groundwater

The adjustor curves are used to define a removal rate that applies to both the pervious and impervious areas in the contributing drainage areas for the stormwater treatment practices. The removal rates properly apply to surface runoff and some portion of the interflow delivered to the stream, but may not properly apply to groundwater export of nitrate-nitrogen from the urban landscape. The "missing" nitrate may be nitrate that exits a runoff reduction practice via infiltration into soil, or slowly released through an under drain (e.g., bioretention).

Once stormwater runoff is diverted to groundwater, the overall load is reduced by using the ground as a filtering medium, but not eliminated. Therefore, the WTWG concluded that the original TN adjustor curves developed by the expert panel may over-estimate TN removal rates, and should be discounted to reflect the movement of untreated nitrate from runoff reduction BMPs. This discounting is not needed for TKN, TP or TSS as these pollutants are not mobile in urban groundwater.

The USWG concurred with this approach and developed the following procedure to derive a new TN adjustor curve to account for groundwater nitrate migration from runoff reduction practices.

This discount factor is fairly straight forward to calculate and is simply based on the ratio of nitrate in relation to total nitrogen found in urban stormwater runoff. Stormwater runoff event mean concentration data from the National Stormwater Quality Database (Pitt et al, 2006) was analyzed for more than 3000 storm events, and the nitrate:TN fraction was consistently around 0.3. This sets an upper boundary on the fraction of the inflow nitrate concentration to the BMP which could be lost to groundwater or under drains at about 30%.

The next step is to account for any nitrate loss within the BMP due the combination of either plant uptake and storage and/or any de-nitrification within the BMP. Most runoff reduction practices employ vegetation to promote ET and nutrient uptake, whereas the de-nitrification process is variable in both space and time.

Over 70 performance studies have measured nitrate removal within runoff reduction BMPs. A summary of the national research is shown in Table B-2. Clearly, there is a great deal of variability in nitrate reductions ranging from nearly 100% to negative 100% (the negative removal occurs when organic forms of nitrogen are mineralized/nitrified into nitrate within the BMP).

Some well studied runoff reduction practices, such as bioretention and bioswales, have a median nitrate removal ranging from 25 to 45%, presumably due to plant uptake. Initial results for green roofs indicate moderate nitrate reduction as well. Non-vegetative practices, such as permeable pavers and a few infiltration practices, show zero or even negative nitrate removal capability (Table B-2). Submerged gravel wetlands that create an aerobic/anaerobic boundary that promotes denitrification appear capable of almost complete nitrate reduction.

Therefore, it is recommended that maximum nitrate removal within runoff BMPs be assumed to be no more than 40%. Although this value may seem generous, it should be noted that some additional nitrate reduction occurs as the nitrate moves down-gradient through soils on the way to the stream. Under this conservative approach, no additional nitrate reduction is assumed after it exits the BMP and migrates into groundwater.

Given the nitrate inflow concentrations, the potential groundwater/under drain nitrate loss would be (0.3)(0.60) = 0.18, or a discount factor of 0.82

The discount factor is then applied to the anchor rates used to derive a new N adjustor curve. The anchor rate for RR practices would be adjusted downward from the current 70% to 57%, and the existing runoff frequency spectrum equation would be used to develop a new, lower curve for TN removal. An example of the how this discount influences the existing N adjustor curve is shown in Figure B-1.

Table B-2 Nitrate Removal by Runoff Reduction Practices [1]				
Practice	Median Removal Rate	No. of Sites	Range	Source
Bioretention [2]	43%	9	0 to 75	CWP, 2007
Bioretention [2]	44%	1	NA	UNH, 2009
Bioretention [2]	24%	10	NA	ISBD, 2010
Bioswales	39%	14	-25 to 98	CWP, 2007
Bioswales	7%	18	NA	ISBD, 2010
Infiltration [3]	0	5	-100 to 100	CWP,2007
Permeable Pavers	-50% [4]	6	NA	IBSD, 2010
Permeable Pavers	0	4		Collins, 2007
Green Roof [5]	Positive	4	NA	Long et al 2006
Gravel Wetland	98%	1	NA	UNH, 2009

Notes:
[1] As measured by change of event mean concentration (EMC) entering device and final exfiltrated EMC, and involves either or plant uptake or denitrification
[2] For "conventional" runoff reduction practices only, i.e., no specific design features or media enhancements to boost nitrate removal
[3] Category includes several permeable paver sites
[4] A negative removal rate occurs when organic forms of nitrogen are nitrified to produce additional nitrate which is
[5] Test column study

It is also noted that no nitrate loss parameter needs to be defined for stormwater treatment (ST) practices, since inlet and outlet monitoring of these larger facilities already takes this into account (and is a major reason why the ST curve is so much lower than the RR curve).

The de-nitrification process can be enhanced through certain design features (inverted under drain elbows, IWS, enhanced media). Several good research reviews indicate that these design features show promise in enhancing nitrate removal (Kim et al, 2003, NCSU, 2009, Weiss et al, 2010), these features are not currently required in Bay state stormwater manuals. Should future research confirm that these features can reliably increase nitrate removal through denitrification and/or plant uptake, it is recommended that a future expert panel revisit the existing nitrogen adjustor curve.

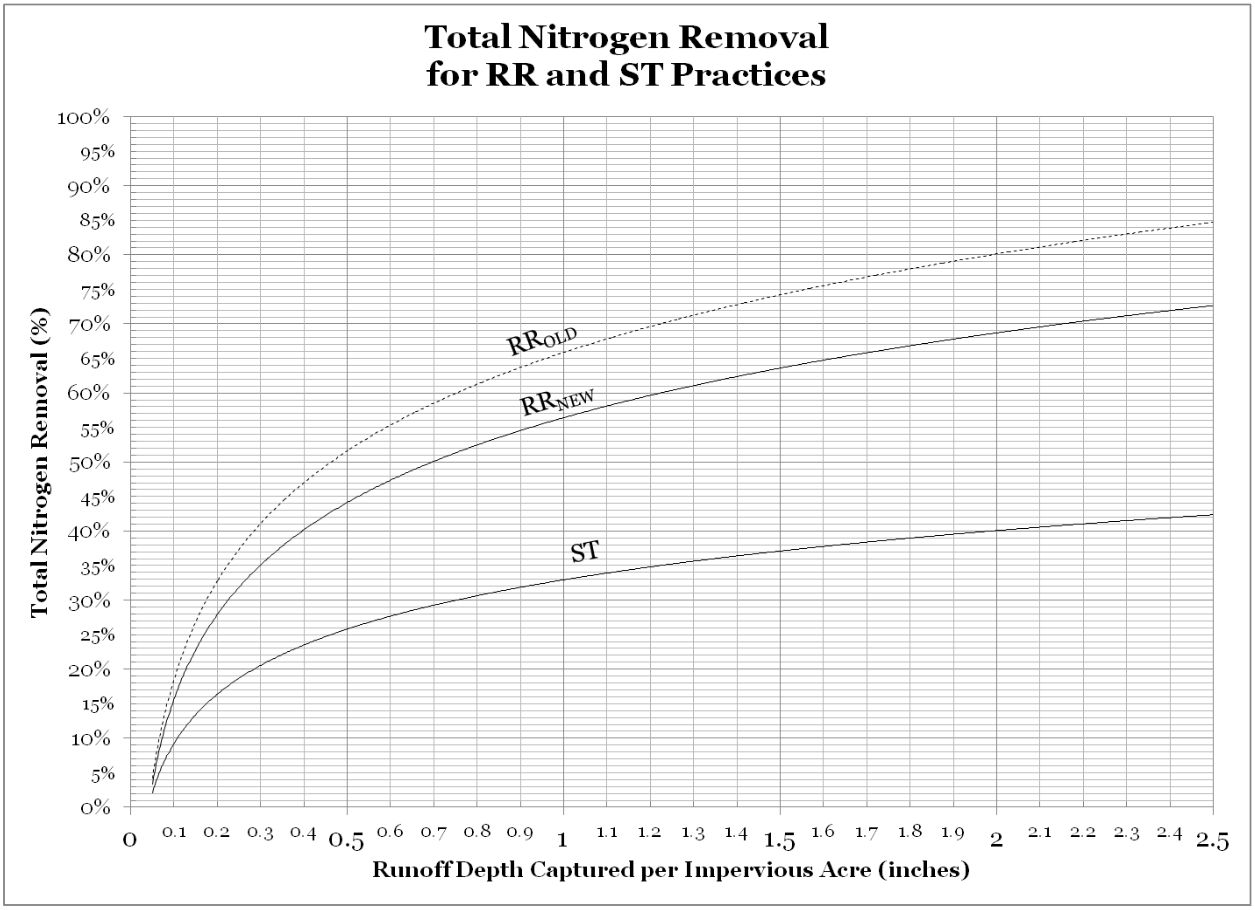


Figure B-1. Revised TN Adjustor Curve

Appendix C Panel Meeting Minutes

First Meeting Minutes
Stormwater Retrofit Review Panel
Thursday October 28, 2011

Members Present

Panelist	**Affiliation**	**Present ?**
Ray Bahr (Cappucitti)	MDE	Yes
Steve Stewart	Baltimore County	Yes
Ted Brown	Biohabitats	Briefed
LJ Hansen	City of Suffolk, VA	Yes
Jason Papacosma	Arlington, VA	Yes
Bill Stack	CWP	Yes
Rebecca Stack	DDOE	briefed
Joe Kelly	PA DEP	Yes
Jeff Sweeney	EPA, CBP	Yes
Facilitator: Tom Schueler	CSN	Yes
Non-panelists		
Norm Goulet, chair USWG; Lucinda Power, EPA CBP		

Attachments distributed in advance of call: (1) Performance standard excerpts from Technical Bulletin #9; (2) MDE document; and (3) CBP BMP Protocol Process.

Proposed next call date: It was agreed that the next teleconference would be a 2-hour call on November 21st from 10 AM to Noon, pending verification from the two panelists who could not make today's meeting

Action: the Panel amended the charge to add discussion of future retrofit monitoring protocols in the reporting, tracking and verification area. The Panel endorsed the amended charge, but it was agreed that the Panel would have an additional week to provide comments or revisions to the charge. Any comments received will be distributed to the Panel and discussed at the next teleconference.

Action: Panelists are requested to provide any additional research studies, performance data or reports to Tom Schueler by November 10, who will send them to the entire Panel. If no further data is provided by then, the Section 5 summary will be considered the core research on retrofits.

Action: The Panel was asked to provide a thorough review of the retrofit excerpts from Technical Bulletin #9 and the MDE document to Tom Schueler by the second week of November. All comments received will be distributed to the Panel.

Action: Jeff Sweeney (EPA) will provide a summary of CBP annual urban runoff loads per acre following the general format shown in Table 1 of MDE (2011) for CBWM version 5.3.2.

Action: Several panelists indicated the need to get better information on each state's unique retrofit, maintenance and inspection issues. Tom and the states will provide a brief profile of these issues at the next meeting.

Action: *Norm and Tom will confer on getting an official VA DCR rep to serve on the panel, and Tom will work with Lucinda and Jeff Sweeney on whether other states (NY, DE, and WV) should be invited as well.*

Call to Order and Panelist Introductions

Each of the panelists introduced themselves and explained their background in retrofit analysis and implementation in their jurisdiction. Tom briefly outlined the WQGIT BMP review panel protocol by which the Panel would conduct its business, and asked the Panel whether they understood their role and had any questions about the protocol

Tom then outlined his role was to facilitate the Panel, organize the research and methods, and document its progress, but not be involved in the decision-making process.

Review of the Charge for the Panel, the BMP Panel Review Process and Panel Member Responsibilities

Tom proposed a draft charge for the Panel to ensure that it has reviewed all of the available science on the pollutant removal performance of different retrofit classes.

The initial charge of the Panel is to review all of the available science on the pollutant removal performance and runoff reduction capability of BMPs that can be used to derive methods or protocols to derive nutrient and sediment removal rates for individual retrofits:

Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. Removal rates will need to be inferred from other known BMP pollutant removal and runoff reduction data. Every retrofit is unique, depending on the drainage area treated, BMP treatment mechanisms, volume or sizing and the antecedent degree of stormwater treatment, if any.

Stormwater retrofits can be classified into six broad project categories, as shown below:

a. New retrofit facilities
b. BMP conversions (e.g., a dry ED pond to a constructed wetland)

c. Enhanced design or volume of existing BMPs
d. Green street retrofits
e. On-site LID retrofits
f. Maintenance upgrades

The Panel is specifically requested to:

- Provide a specific definition for each class of retrofits and the qualifying conditions under which a locality can receive a nutrient/sediment reduction rate
- Assess whether the retrofit class can be addressed by using existing CBP-approved BMP removal rates, or whether new methods or protocols need to be developed to define improved rates
- Evaluate which load estimation methods are best suited to characterize the baseline pre-retrofit for the drainage area to each class of retrofit
- Define the proper units that local governments will report retrofit implementation to the state to incorporate into the Watershed Model

Beyond this specific charge, the Panel is asked to:

- Determine whether to recommend whether an interim BMP rate be established for one or more classes of retrofits prior to the conclusion of the panel for WIP planning purposes
- Recommend procedures for reporting, tracking and verifying the removal rates achieved by retrofit projects
- Critically analyze any unintended consequence associated with the removal rate and any potential for double or over-counting of the load reductions achieved

While conducting its review, the Panel shall follow the procedures and process outlined in the WQGIT BMP review protocol.

The Panel indicated that the charge should be amended to specifically recommend potential future retrofit monitoring protocols and regional monitoring consortia that could improve/refine our understanding of retrofit removal performance.

Second Meeting Minutes
Stormwater Retrofit Review Panel
Monday, November 21, 2011

Members Present

Panelist	**Affiliation**	**Present?**
Ray Bahr	MDE	X
Steve Stewart	Baltimore County	X
Ted Brown	Biohabitats	X
LJ Hansen	City of Suffolk, VA	X
Jason Papacosma	Arlington, VA	X
Bill Stack	CWP	X
Rebecca Stack	DDOE	
Joe Kelly	PA DEP	X
Jeff Sweeney	EPA, CBP	
Ginny Snead	VA DCR	X
Tom Schueler	CSN Facilitator:	X
Non-panelists		
Norm Goulet, chair USWG; Lucinda Power, EPA CBP		

Action items

- **Rebecca Stack** will provide an overview of DDOE retrofit activities at next meeting.

- **Tom** to revise the draft retrofit definitions in time for next panel call.

- **LJ and Tom** to work on more detailed draft of qualifying conditions of BMP maintenance upgrades for next panel call.

- **Bill Stack and Tom** to evaluate sediment removal rates for Table 23 for panel consideration at next meeting. Tom will also coordinate on the issue with the Performance Standards Panel.

- **Tom and Ray Bahr** to meet off-line to ensure that retrofit methods are integrated with existing MDE guidance.

- Tom requested the **Panel** provide any additional comments on the RT VM protocol in the next two weeks, and then he would revise the protocol in advance of the next meeting.

- **Bill Stack, Jason P and LJ Hansen** will coordinate on procedures for retrofit monitoring and present some recommendations at next meeting.

- The Panel agreed to reconvene for a third teleconference from **2 to 4 PM on Wednesday January 11th, 2012**.

Call to Order, Review of the Charge for the Retrofit Panel and Review of Meeting Minutes

Meeting called to order @ 10.04 AM. The meeting minutes and charge for the panel were approved. The Panel also confirmed that the summary of BMP performance research provided in the first meeting was adequate for their purposes.

State Perspectives on their Retrofitting Programs.

The state stormwater representatives discussed their ongoing retrofit activity.

Joe Kelly (PA DEP) indicated that most retrofit activity to this point was of the demonstration variety, although will change in the coming years as their new PAG-13 MS-4 permits are implemented, and localities developed their local Chesapeake Bay pollutant reduction plan.

Doug Fritz of VA DCR indicated that most of their retrofitting activity so far included demonstration projects under state grants and revolving funds. Their new Phase 1 permits may avoid the term retrofit and use the term existing pollutant reductions. Although the new permits are still being developed, Doug indicated that they may include numerical requirements for reducing existing pollutant loads, which would initially be low, but expanded in future permit cycles. The next permits would also likely include "retrofit" planning and assessment requirements.

Ray Bahr (MDE) noted that Maryland had a longer retrofitting history, and is writing new Phase 1 permits that will require retrofitting of up to 20% of untreated impervious cover in each permit cycle, and may institute retrofitting requirements for Phase 2 MS4 permittees. MDE has had several grant programs to defray local retrofit project costs, but these have not been fully funded in recent years.

Tom attempted to describe DDOE retrofit activities, which originally focused on Anacostia River restoration. The current effort relies heavily on green street and green roof retrofits, as well as on-site LID projects through residential and commercial stewardship incentive programs. Tom will contact **Rebecca Stack** about presenting more detail on DC retrofit situation at next teleconference

Review and Discussion of Retrofit Definitions

Consensus: The Panel had an extensive discussion on retrofit definitions and came to the following consensus.

The "lumpers" defeated the "splitters", such that the six retrofit classes were collapsed into two broad retrofit categories:

On-site LID retrofits and green streets should be classified as a new retrofit facility, and not as a separate category.

BMP conversions, enhancements and upgrades should all be classified within a single existing BMP category

The Panel felt that more information was needed on the qualifying conditions for BMP maintenance upgrades, and JL and Tom will work on a draft for our next meeting.

The Panel asked Tom to revise the draft definitions for their consideration at the next call

Discussion of Methods to Define Pre-Retrofit Baseline Loads

The Panel briefly discussed the issue of how to define pre-retrofit loads (simple method and/or CBWM unit loads). While there was some interest in recommending the Simple method, the discussion was deferred until the next meeting when **Jeff Sweeney** will hopefully provide unit area loading for all states using CBWM

The Panel had a much longer discussion of the issue of edge of stream, edge of field and delivered loads, and how the Panel should interpret these. **Steve Stewart** noted that the methods are best used to determine edge of stream loads for individual retrofits, but that localities should use tools like MAST/CAST/VAST to identify those areas in their jurisdiction that had the highest delivered loads (e.g., shortest distance/travel time to Bay and lack of impoundments) when conducting retrofit assessments at the watershed level. The **Panel** though this was a good idea, but wanted Tom to check in with Bay modelers to make sure this is the correct interpretation

Review of Methods for Defining Retrofit Removal Rates

Tom provided an overview of the various methods for defining retrofit removal rates, and the Panel provided the following feedback.

MDE design by era method is already established in Maryland as a default method, although localities can opt for a different method.

Method(s) should be consistent and not unduly complicated. The fewer the methods proposed the better to avoid multiple sets of differing numbers.

There was support for the retrofit adjustor table (Table 23), since it provided scale-able removal rates, based on rainfall capture and degree of runoff reduction. Several refinements were needed to make it a useful tool. 1) add sediment removal rates, 2) drop the reductions above 1.5 inch since few retrofits can achieve this degree of treatment, there is much less research to support these projections and the high removal rates for the 2.0 to 2.5 inch range provide counter intuitive results that nutrient loads from urban land could be lower than forest land

There was strong support to avoid use of past CBP approved BMP removal rates for the purpose of defining retrofit performance.

Bill Stack and Tom to evaluate sediment removal rates for Table 23 for Panel consideration at next meeting. Tom will also coordinate on the issue with the Performance Standards Panel

Tom and Ray Bahr to meet off-line to ensure that retrofit methods are integrated with existing MDE guidance

Protocols for Reporting, Tracking, Verifying and Monitoring Retrofits

The Panel discussed the proposed protocol for retrofit reporting, tracking, verification and monitoring. (Attachment D). The Panel indicated that the general framework was useful, but could be improved in several areas:

No need to require signed local certification for state reporting, but these records should be maintained in project file (e.g., as-built)

Ray Bahr wanted to see if CBPO could accept GIS files rather than spreadsheets, as this would make detection of double BMP accounting easier to do.

Support for limiting the duration of the removal rate for approx 5 to 10 years, with renewal based on local inspection. The shorter duration might apply to retrofits where there is only a limited maintenance pledge (e.g., homeowner BMPs) and the longer duration applies when there is a more formal maintenance agreement in place with a responsible authority.

Tom requested the Panel provide any additional comments on the protocol in the next two weeks, and then he would revise the protocol in advance of the next meeting

Set Next Meeting Date. The **Panel** agreed to reconvene for a third teleconference from 2 to 4 PM on Wednesday January 11th, 2012.

The call adjourned at 11:50 AM

Urban Stormwater Retrofit BMP Review Panel
Third Teleconference
Wednesday, January 11, 2012

Members Present

Panelist	**Affiliation**	**Present?**
Ray Bahr	MDE	X
Steve Stewart	Baltimore County	X
Ted Brown	Biohabitats	X
LJ Hansen	City of Suffolk, VA	X
Jason Papacosma	Arlington, VA	X
Bill Stack	CWP	X
Rebecca Stack	DDOE	X
Joe Kelly	PADEP	X
Jeff Sweeney	EPA, CBP	
Ginny Snead	VA DCR	X
Tom Schueler	CSN Facilitator:	X
Non-panelists		
Norm Goulet, chair USWG; Lucinda Power, EPA CBP		

Call to Order, Review of November Meeting Minutes and Action Items

Tom called the meeting to order @ 2.04 PM. Tom commended the Panel for all their hard work in completing all the assigned action items since the last teleconference. The Panel reviewed and approved the November meeting minutes.

DC Perspectives on Retrofitting. (10 mins)

Rebecca Stack *(DDOE) gave a short presentation from DC about their current and future level of retrofit activity in their highly urban watersheds. She noted that they rely heavily on residential and business incentive programs to get on-site LID retrofits implemented (e.g., bioretention, rain barrels, green roofs, permeable pavers etc). In addition, DC is implementing an extensive green street retrofit program on municipal streets.* ***Jason Papacosma*** *asked how these retrofits were tracked and maintained over time.* ***Rebecca*** *noted that they use a GIS tracking tool to record the aggregate acreage treated, and generally assume a five year removal rate for on-site retrofits.*

The state perspectives on retrofitting from this and the last meeting will be incorporated into the final technical memo.

Consensus: Review and Adoption of Retrofit Definitions

***Tom** reviewed the revised retrofit definitions provided in Attachment B**. LJ Hansen** described the proposed new definition for BMP restoration which replaces the previous category of maintenance upgrades. After discussion, the Panel concurred with the revised definitions for three classes of stormwater retrofits, with several edits and revisions, mostly to delete references to baseline loads. The Panel asked to have a last chance to provide review and comment on the final memo, prior to final acceptance.*

Consensus: Methods to Define Pre-Retrofit Baseline Loads

The Panel continued its discussions on the proper method(s) to define pre-retrofit baseline loads, including the Simple Method and generic CBWM urban unit loading rates (Attachment C). After considerable discussion, the Panel elected not to recommend a method for defining baseline loads to retrofit projects, when it comes to reporting individual retrofits to state TMDL agencies. Instead, localities would simply report the removal rates computed from the retrofit adjustor table and the contributing drainage area for each project. The Panel also indicated that states could decide whether to use the Simple Method, CBWM unit loads or other suitable methods when conducting local watershed analyses for retrofit investigation or MS4 permit reporting. They also indicated that both methods should be included as an appendix in the technical memo.

Consensus: Method to Define Retrofit Removal Rates

Tom presented a revised version of the retrofit removal adjustor table that includes new sediment removal rates, and incorporates other changes recommended, defines rates based on runoff reduction and runoff volume treated. The Panel asked to see more written documentation on the sediment removal rates. The Panel generally concurred with the revised retrofit adjustor table, but wanted to see examples for each of the retrofit classes in the final technical memo so that local users would be able to understand how it would be computed. They also indicated they wanted to see a table that defined which BMPs would be classified as RR or ST runoff reduction, and also be clear that the computed removal rate applies to the entire drainage area of the retrofit project, and not just the impervious acres.

Consensus: Protocol for Reporting, Tracking and Verifying Retrofits

The Panel discussed the revised general framework for RTV and adopted it subject to the following modifications:

Provide more specific guidance as to what constitutes "installed properly, meets or exceeds state design standards and is functioning hydrologically as defined" so that it can be physically defined in the field.

Change certification to verification

Simplify the local retrofit reporting requirements, and especially drop the baseline load calculation

Recap Consensus Achieved and Structure for Panel Report

The Panel indicated that they had achieved consensus on many items and approved the proposed outline for the documentation memo to be submitted to the Urban Stormwater Workgroup. The Panel directs Tom to prepare a draft of their memo for their final review by mid-February.

Combined Meeting Minutes
Urban Retrofit Expert Panel
Final Review Teleconferences

March 12, 2012
and
April 2, 2012

Panelist	Affiliation	Present 3/12 ?	Present 4/2?
Ray Bahr	MDE	X	X
Steve Stewart	Baltimore County	X	X
Ted Brown	Biohabitats	X	X
LJ Hansen	City of Suffolk, VA	X	X
Jason Papacosma	Arlington, VA	X	X
Bill Stack	CWP	X	C
Rebecca Stack	DDOE	X	
Joe Kelly	PADEP	X	X
Jeff Sweeney	EPA, CBP		
Ginny Snead/Fritz	VA DCR	X	X
Tom Schueler	CSN Facilitator:	X	X
Non-panelists			
Norm Goulet, chair USWG; Lucinda Power, EPA CBP			

The Panel held two calls and provided extensive written and verbal comments on the Feb 19 and March 12 drafts of the final panel memo. These minutes summarizes the key technical changes made to the method by CSN during this review period, as well as a providing a record for how the Panel resolved its more substantive comments. Based on this, the Panel voted 9-0 to tentatively adopt the final memo, subject to a two week period for errata and state-specific comments, and report out on its final recommendations at the April 30 USWG meeting.

1. **Key Technical Changes to the Method**

Changes after First draft

1. *Dropped reference to the Original Retrofit Adjustor Table and replaced with curves.* The tabular data was converted into a series of curves to make it easier for users to define a rate for the unique combination of runoff capture volume and degree of runoff reduction. This was done by fitting a log-normal curve to the tabular data points, which came within a few percentage points of the tabular values for a wide range of runoff capture depths and removal rates.

2. *The technical basis for defining the anchor rates was provided in a new table in Appendix C.*

3. *More accurate estimates of runoff capture were derived using an explicit rainfall frequency spectrum equation, and this supplemental documentation was incorporated into Appendix C.* The new more accurate method has the result of flattening the removal curves for higher depths of runoff capture.

4. *The cut-off threshold for minimum retrofit capture volume was reduced.* A 0.05 inch runoff capture volume was established as the cut-off point for getting any retrofit removal rate, since this roughly corresponds to the depth of initial abstraction that occurs on impervious surface. It should be noted that retrofits in this small size range will require very frequent maintenance to maintain their performance over time.

5. *Suitability of method.* The Panel concluded that the generalized retrofit removal adjustor curves were a suitable tool for estimating the aggregate pollutant load reductions associated with hundreds or even thousands of future retrofit projects at the scale of the Bay watershed and the context of the Chesapeake Bay Watershed Model.

Changes after 2nd Draft

1. *Modify HI/LO Designation.* Change the HI runoff reduction designation to RR (runoff reduction) and the LO designation to ST (stormwater treatment). DE recommended this clarification as it is more consistent with how these practices are treated in state stormwater manuals. This would be reflected in the text and on the curve labels in the memo, however, there would be no change in how the current list of stormwater practices are categorized (i.e., Table 2).

2. *Make the following clarifications in the methods section*:

   - Clearly define the x-axis as being "depth of runoff captured by practice per impervious acre."

   - Clearly state that the retrofit storage volume for each site must be adjusted using a "unitization" equation that converts the storage volume into a unit depth per impervious acre at each site.

- Note that the corresponding removal rate determined from the appropriate curve applies to the entire drainage area of the retrofit.

3. *Change the retrofit storage equation to divide by impervious area rather than site area.* To ensure consistency in how the adjustor curves are used to define removal rates for retrofits, the standard retrofit storage equation needs to be modified. The current equation is:

$$= \frac{(RS\ )(12)}{SA}$$

The specific retrofit storage volume achieved at an individual site is usually measured or estimated, and is a given (usually acre-feet). The user will need to interpret how this volume will be adjusted to use on the x-axis of the curves. This is done by using standard retrofit equation which multiplies the retrofit storage volume by 12 to get acre-inches, and then divides by the impervious acres to get the unit "depth of runoff captured by practice per impervious acre." This value is used with the curves to define the retrofit removal rates. The new version of the standard retrofit equation will be:

$$= \frac{(RS\ )(12)}{IA}$$

4. *Provide documentation on why the unitization equation is needed for retrofits in Appendix C.* Add a section in Appendix C that documents why the unitization for impervious area is needed to provide a common basis of comparison among states and drainage areas. The basic reason is that the Rainfall Frequency Analysis used to derive the curve above and below the anchor points is based on the assumption that the runoff delivered to a practice is generated from a unit impervious acre. The runoff storage volumes achieved for individual retrofits, however, are unique, based on the land cover, soils and hydrologic assumptions used in each state. Therefore, these volumes must be adjusted by a unitization equation to get the correct depth to use on the x-axis of the curves.

2. **Resolving Key Comments From the Panel**

General Comments: In general, the Bay states wanted to ensure that the memo would protect state prerogatives with respect to their existing and/or future BMP reporting and tracking systems.

Retrofit Definitions Section

Comment: PA DEP noted that applying more stringent stormwater requirements at redevelopment sites was functionally equivalent to a new retrofit facility.

Resolution: the Panel agreed, but noted that a specific BMP crediting system for redevelopment projects was being developed by the Performance Standards Expert Panel. The Panel indicated that the redevelopment should be cross-referenced in the text, so readers would be aware of that option.

Comment: PA DEP, MDE noted that the photo illustrating "Storage behind Roadway Crossings" appeared to show a retrofit in waters of the US and would not be allowed under state or federal wetland permits.

Resolution: The Panel agreed that the photo and the retrofit sub-category should be dropped.

Comments about BMP Restoration category:

- Concern that some localities may interpret this as a chance to claim additional nutrient reduction credit for routine BMP maintenance which is needed to sustain the performance of existing BMPs (for which they are already getting credit).

- For BMP restoration the protocol depends on whether or not the State has included the BMP in its pre 2006 input deck. Based on previous conversations with DCR, this does not seem possible in Virginia.

Resolution: The Panel noted that the definition of BMP restoration only applies to major BMP upgrades that produce a substantive recovery or expansion of stormwater treatment volume, as measured by at least a 10% increase. The Panel also recommended that the following text be added to drive home the point: "Important Note: No pollutant removal credit is given for routine maintenance of existing stormwater practices. Routine maintenance is essential to ensure the pollutant removal performance of any stormwater practice." The Panel noted that individual states may want to develop their own more detailed guidance on qualifying conditions for acceptable BMP restoration.

Methods Section

Comment: MDE requested the removal of the BMP by ERA option from the retrofit memo, for the sake of simplicity, and because the curve method tends to produce a higher removal rate for more retrofit categories.

Resolution: The Panel agreed that it should be dropped from the text and the appendices.

Comment: MDE and others noted that some runoff reduction practices take surface stormwater and shift it to groundwater, so that it is possible that some fraction of the nitrogen entering a runoff reduction practice may ultimately end up in a stream, and that the nitrogen removal rates shown on the curve may not be as high in the real world.

Resolution: The Panel acknowledged the potential for this, but did not have any data to confirm or refute that it exists. The Panel agreed that this issue should be a top retrofit research priority, and indicated that the following statement be added to the existing section on research collaboration: "The Panel expressed a particular interest in defining the fate of nitrogen in retrofits that rely heavily on infiltration or extended filtration to provide runoff reduction".

Accountability Section

Comment: Various states indicated that their BMP reporting systems are unique, and they did not want a "one-size fits all" approach to retrofit reporting.

Resolution: The Panel agreed that states will need to aggregate data on individual retrofit location, year installed, and removal rate for reporting them to EPA, and also have the capacity to remove retrofits that are no longer functioning. However, the Panel agreed the following language should be added to the memo:

"Localities must submit basic documentation to the state stormwater or TMDL agency to document the nutrient/sediment reduction claimed for each individual urban retrofit project that is actually installed. Localities should check with their state stormwater agency on the specific data to report for individual retrofit projects. Some *typical* information that may be reported includes…".

Comment: Several states and localities on the panel indicated concerns over the language on initial verification/certification of individual retrofit performance. The concerns ranged from effect on local resources, and that localities should be able to use the existing annual MS4 annual reports as an alternative.

Resolution: The Panel agreed and re-drafted the section as follows: This initial verification is provided either by the retrofit designer or a local inspector as a condition of retrofit acceptance, as part of the normal municipal retrofit design and review process. From a reporting standpoint, the MS4 community would simply indicate in its annual report whether or not it has retrofit review and inspection procedures in place and adequate staff to implement them.

Comment: Several panelists questioned the process for down-grading individual BMPs, noting that as long as a local jurisdiction has a regular inspection and maintenance program/procedures in place to correct under or non-performance of retrofits, then removal and replacement of credits should be rare. This requirement could be excessively burdensome and the subject of error and confusion not only at the local level, but also at the level of the Bay Program modelers.

Resolution: The Panel agreed that downgrading based on field inspection was an important component of retrofit verification. The Panel drafted language on a reasonable time frame for corrective action and that downgrades only need to be reported through MS4 permit annual reports, as follows: If the field inspection indicates that a retrofit is not performing to its original design, the locality would have up to one year to take corrective maintenance or rehabilitation actions to bring it back into compliance. If the facility is not fixed after one year, the pollutant reduction rate for the retrofit would be eliminated, and the locality would report this to the state in its annual MS4 report.

Comment: The Panel noted that the field inspection and verification procedures should be more rigorous when retrofits are built for stormwater offsets or load reduction credits are being banked or traded. The prescribed inspection cycle for this special case of retrofits should be shorter.

Resolution: The Panel agreed with this, and suggested that the issue be addressed with the trading and offsets workgroup, and recommended the following language be added to the text: The Panel also recommends more frequent inspection and verification process for any retrofit built for the purpose of stormwater mitigation, offsets, trading or banking, in order to assure the project(s) is meeting its nutrient or sediment reduction design objectives.

Comment: If these protocols are accepted by the CBP, then the CAST, MAST, VAST will need to be modified as well. There will be no utility to these programs if they don't effectively predict CBP model results. Coordination with CAST needs to be a priority that should happen in concert with the update of urban BMP removal rates and not as an afterthought.

Resolution: The Panel agreed with this, and instructed CSN to share the final memo with the CB Modeling Team to ensure procedures were in place to prior to USWG meeting to address these concerns, They also added the following language to the text: "The Panel acknowledges that its retrofit assessment protocol does not fit easily within the context of assessment and scenario builder tools that have been recently developed to assist states and localities to evaluate BMP options to develop watershed implementation plans (i.e., each retrofit has a unique rate and consequent load reduction, while the CAST tools apply a universal rate for all retrofits).

The Panel recommends that localities use the CAST tools to evaluate non-retrofit urban BMPs to determine how much nutrient and sediment load remains after these cost-effective practices are applied. The retrofit removal rate protocol developed by the Panel can then be used to assess the most cost-effective combination of individual retrofit practices to close the remaining gap. CSN will work with ICPRB and Bay Partners to make improvements to future versions of CAST to improve its ability to handle stormwater retrofits."

Appendix C

Comment: It was noted that a Table in Appendix C had incorrect units for sediment loading rate from CBWM.

Resolution: Table Corrected.

Comment: A locality noted that when it comes to defining baseline loads from which the removal rates are applied, the two methods in Appendix C can give different loads for the same scenario (e.g., Simple Method cs. CBWM unit loads). The main issues is that Simple Method computes load solely based on IC, where the CBWM unit load method has employs both IC and pervious cover to compute baseline loads. Depending on the method, this could result in an over-estimate of load removed.

Resolution: The Panel noted that the baseline loads are only done for the purpose of enabling localities identify the most cost-effective retrofits and track their load reductions over time in MS4 permits. The actual retrofit load reductions are calculated for each project based on the NEIN location on the CBWM. The Panel noted that each Bay state should provide guidance to their MS4 localities on which of the two methods they prefer, to assure consistency in their MS4 permit reports.

Appendix D
Conformity of Report with BMP Review Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT, 2010) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where panel addressed the requested protocol criteria.

1. Identity and expertise of panel members*:* Table in Section 1, p. 4

2. Practice name or title: Section 3, p. 8

3. Detailed definition of the practice*:* Section 3: p. 8-12

4. Recommended N, P and TSS loading or effectiveness estimates

Protocol provided in Section 4 p. 13-18

5. Justification of selected effectiveness estimates*:* Appendix A and B, p. 26-41

6. List of references used*:* p. 60-64

7. Detailed discussion on how each reference was considered*:*
Appendix A andB, p. 26-41

8. Land uses to which BMP is applied: All qualifying acres of urban land(pervious or impervious)

9. Load sources that the BMP will address and potential interactions with other practices: Stormwater loads from urban land.

10. Description of pre-BMP and post-BMP circumstances and individual practice baseline: The Protocol is used to provide a specific removal rate for each retrofit project, based on the drainage area treated and the degree of runoff reduction or stormwater treatment provided. The pre-BMP baseline is defined as no BMP treatment for new retrofit facilities, and an incremental rate for certain categories of existing BMP retrofits (see Section 4, p. 16 to 18). The design examples (Section 5) also illustrate how removal rates are determined pre and post project

11. Conditions under which the BMP works/not works

Qualifying conditions to be eligible for the credit depend on the retrofit category, and are described in Section 3, p.8 to 14.

12. Temporal performance of BMP including lag times between establishment and full functioning

Retrofits are assumed to be fully functioning once they have met the requirements for initial performance verification: Section 6, page 23.

The new state stormwater performance standards go into effect at different times, see Section 5, p. 19

13. Unit of measure: Project specific removal rate for the acres of urban pervious and impervious land treated by the qualifying retrofit (Section 3, p. 13 and Section 6, p.23-24).

14. Locations in CB watershed where the practice applies: Retrofits are applicable throughout the Bay watershed, subject to the normal feasibility limitations for retrofits.

15. Useful life of the BMP: 10 years, and renewable based on visual inspection of practice performance (Section 6, p.23-25)

16. Cumulative or annual practice: See # 15 above

17. Description of how BMP will be tracked and reported: Section 6, p, 23-25

18. Ancillary benefits, unintended consequences, double counting

See No double counting, Section 6, p. 23

19. Timeline for a re-evaluation of the panel recommendations

Panel feels the estimates should be reevaluated when warranted by future retrofit performance monitoring data

20. Outstanding Issues

See Section 3: Analyzing retrofit options in the context of CAST, SB and CBWM (p. 18-19) and Section 6: Collaborative monitoring of retrofit performance (p. 24 -25)

21. Pollutant relocation

See Appendix B, Notes on Revising TN adjustor curve to reflect nitrate migration from BMP to groundwater, p. 36-39.

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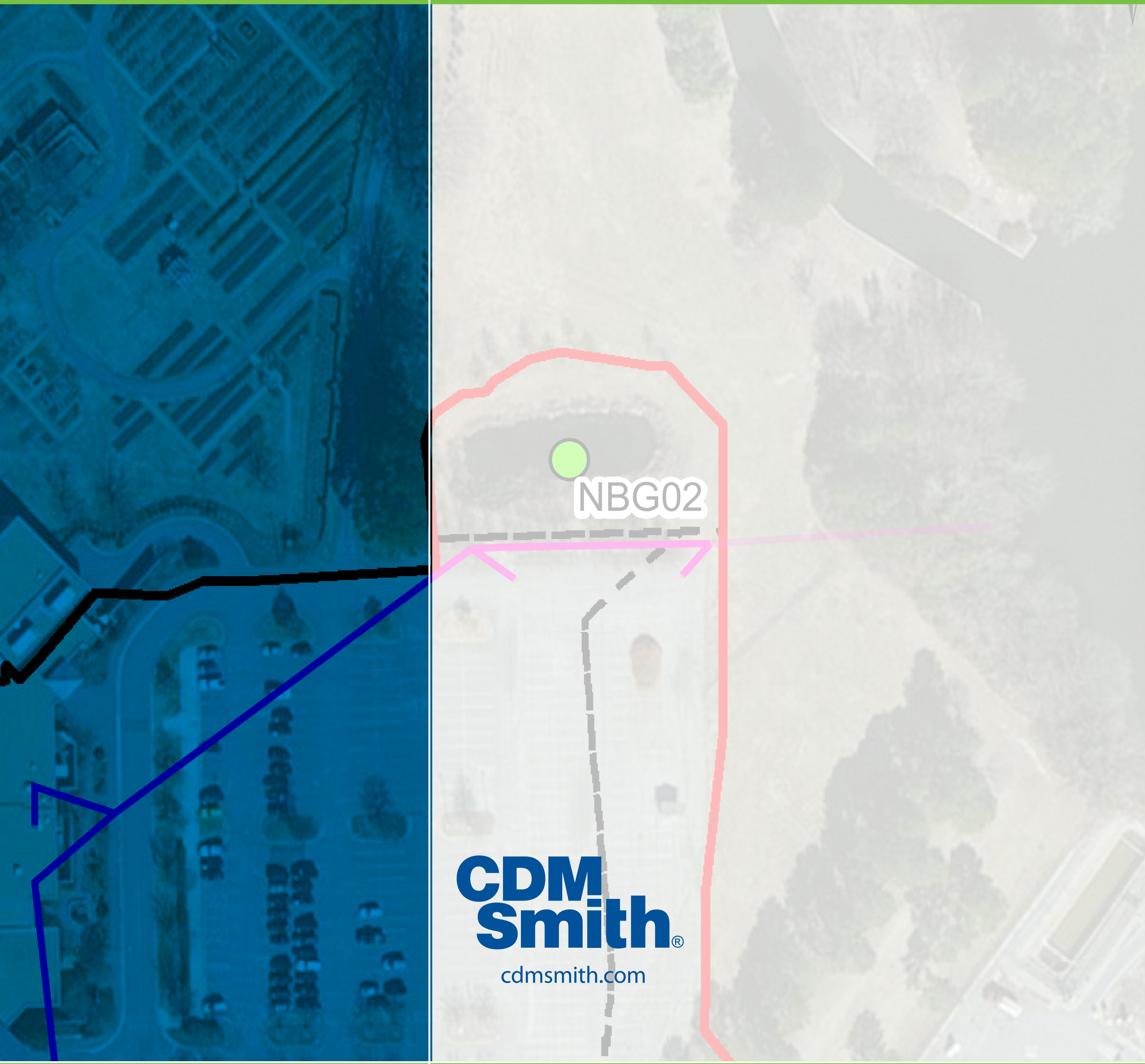

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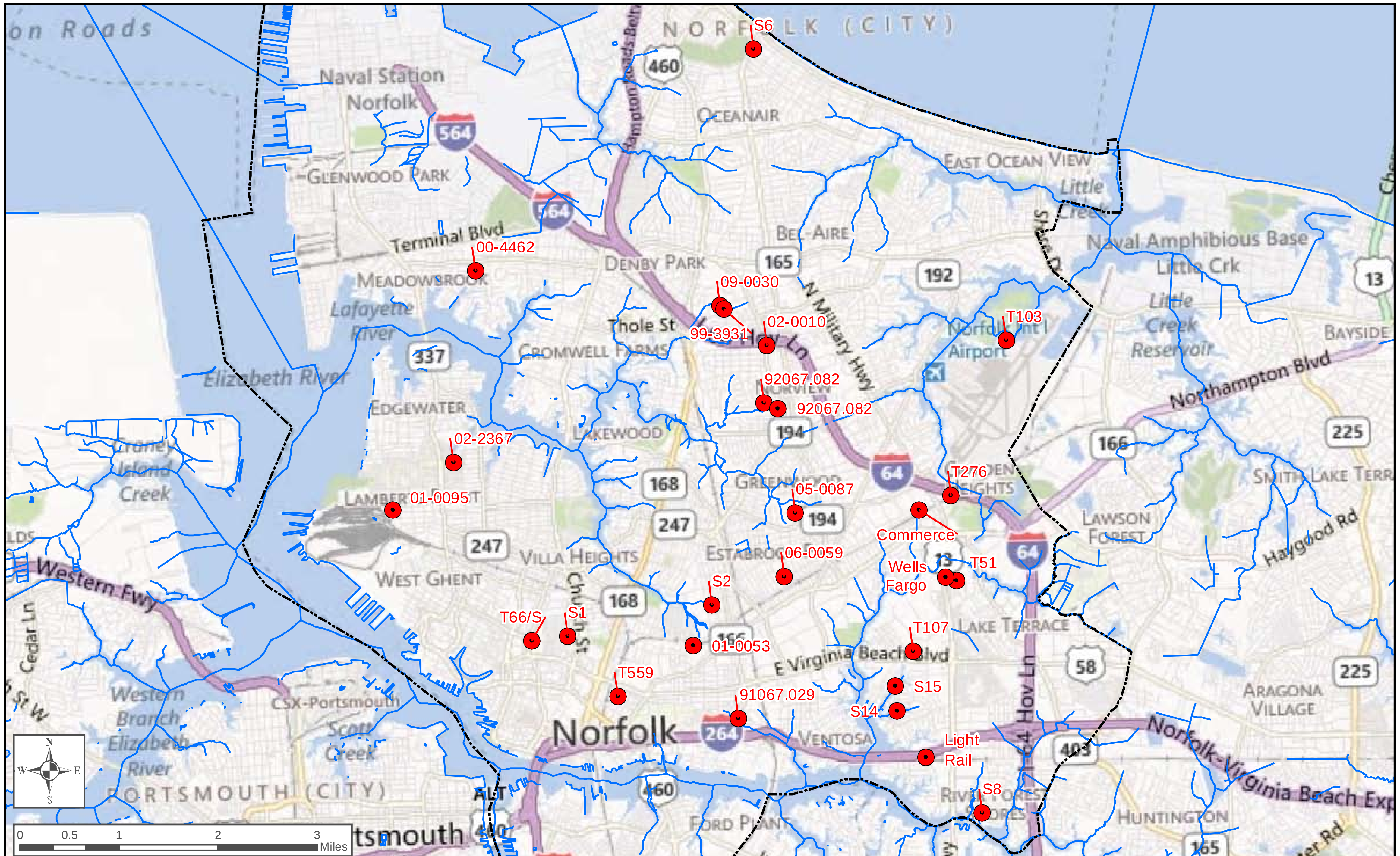
City of Norfolk, Virginia

Stormwater BMP Retrofit Evaluation

Candidate BMP Location Maps

May 2013



Symbol Legend

- Candidate BMP Site
- Waterway
- Norfolk City Limit

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Figure - 1

Site ID: 05-0087

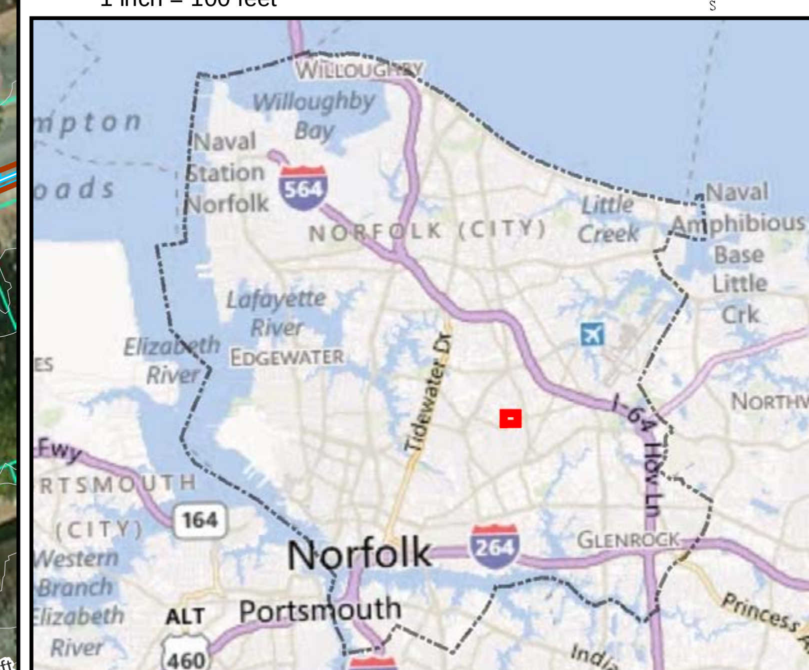
Site Title: Sherwood Forest Elementary School

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet



City of Norfolk
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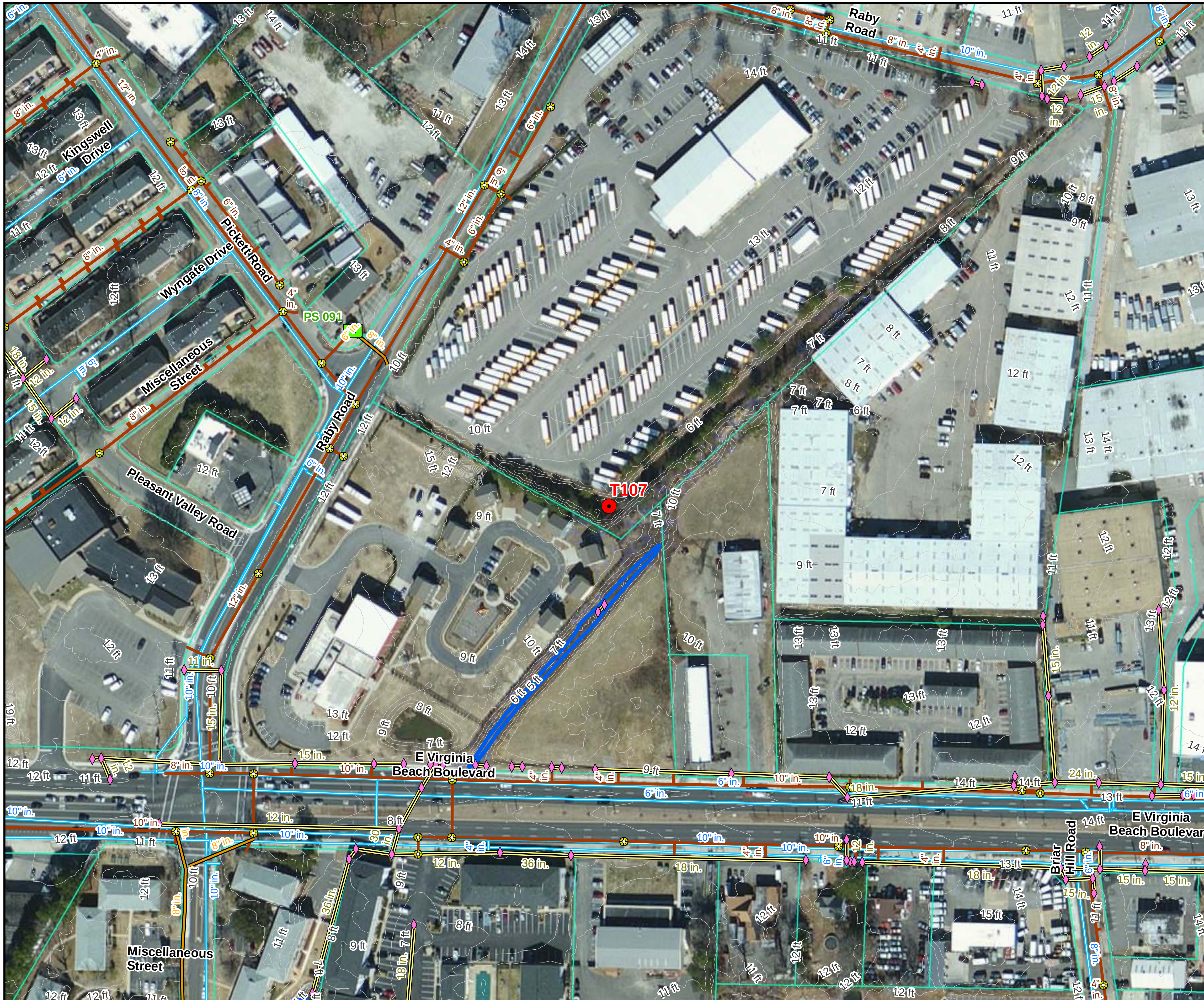
Figure - 2
Site ID: T107
Site Title: Norfolk Public Schools Transportation Operations



Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 75 150 300 Feet
1 inch = 150 feet

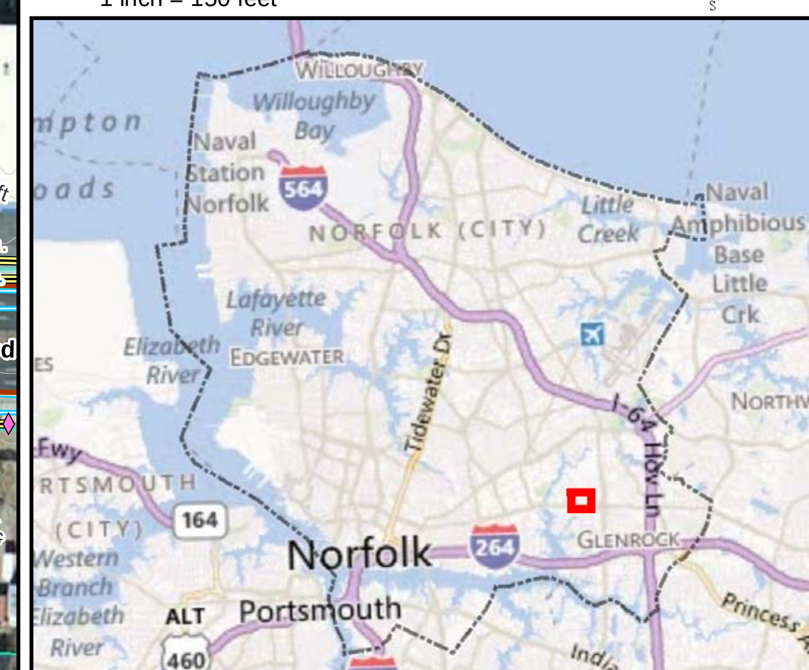


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Figure - 3
Site ID: T51
Site Title: Norfolk Juvenile Detention Center

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet

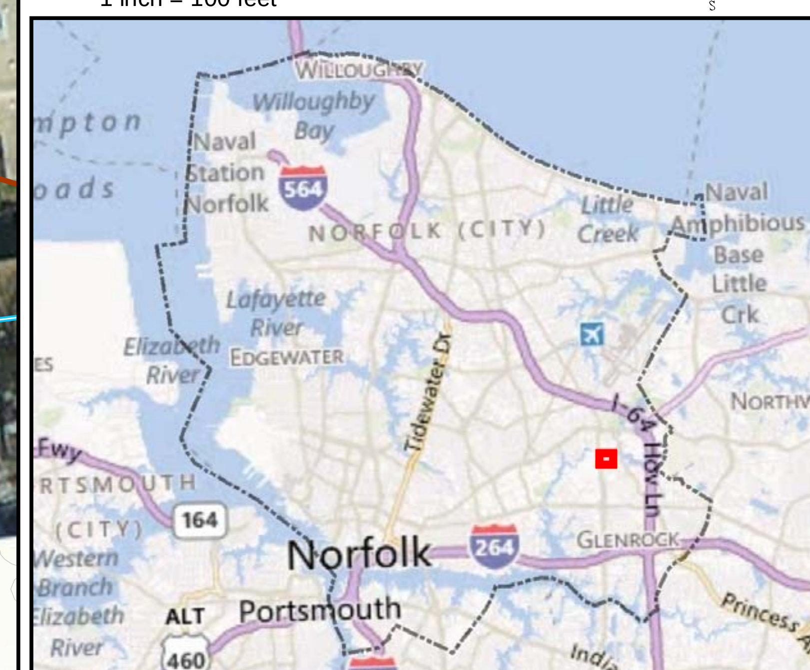

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Figure - 4
Site ID: 00-4462
Site Title: Titustown Recreation Center

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 25 50 100 Feet
1 inch = 50 feet

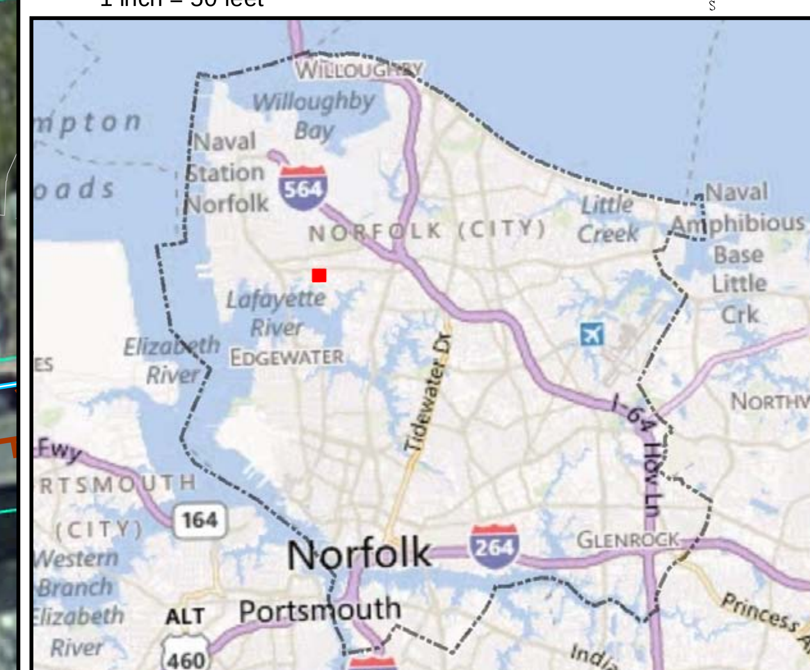

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Figure - 5

Site ID: 09-0030

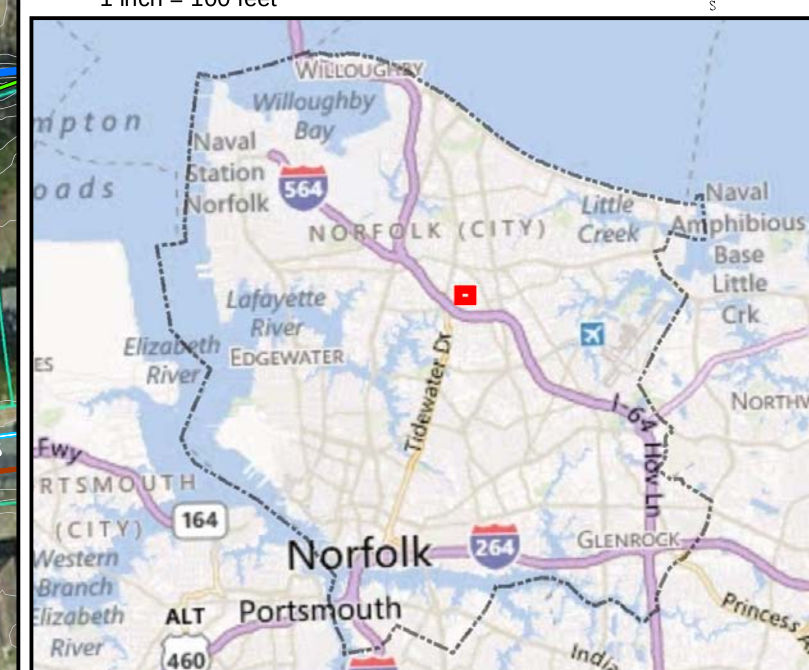
Site Title: 2nd Patrol Division

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet



City of Norfolk

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Figure - 6

Site ID: 92067.082

Site Title: Norview Middle School

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 25 50 100 Feet

1 inch = 50 feet

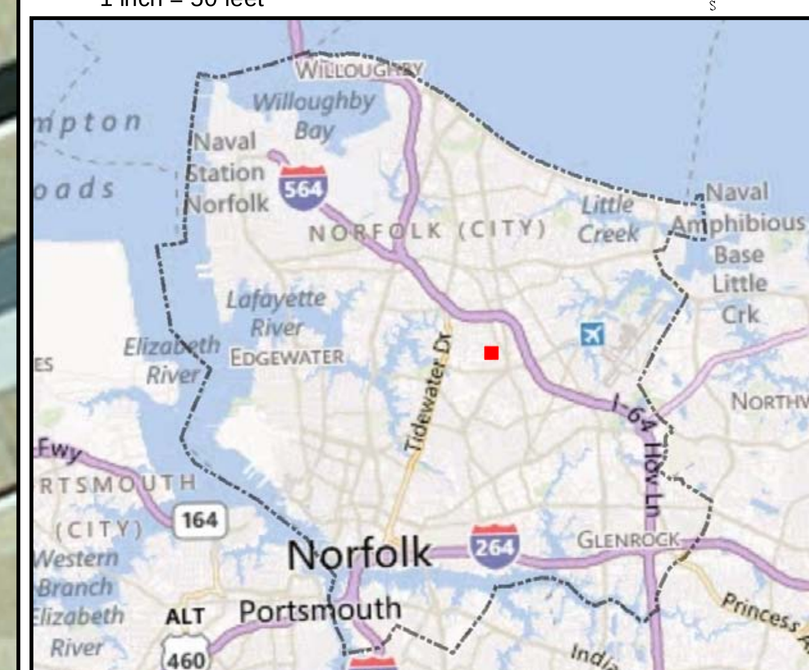

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Figure - 7
Site ID: 92067.082
Site Title: Norview Middle School

Symbol Legend

Other Candidate BMP Site	Railroad
Candidate BMP Site	Manhole
Sewer Lift Station	SW Structure
Stormwater Lift Station	Force Main
Parcel Boundary	Sewer Line
Topography (2' interval)	Water Main
Wetland Community	SW Pipe
Marsh/Wetland	SW Ditch
Parks and Rec Area	Waterway
Norfolk City Limit	

0 25 50 100 Feet
1 inch = 50 feet

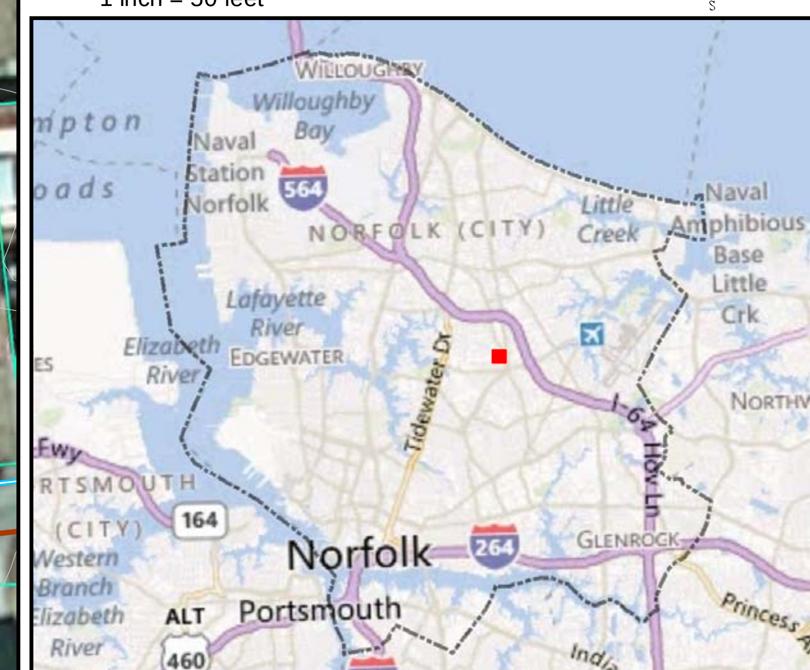

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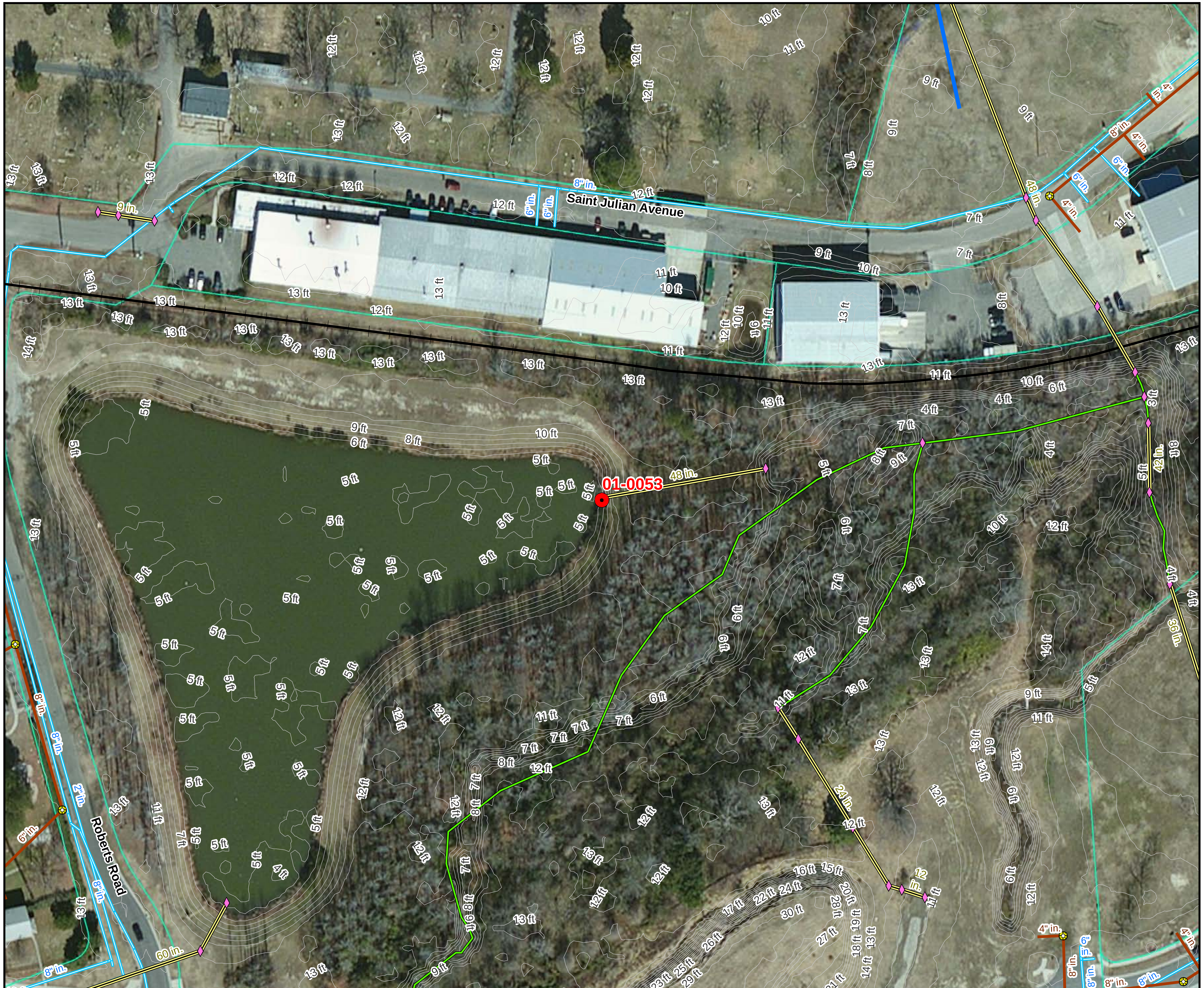
Figure - 8

Site ID: 01-0053

Site Title: Roberts Rd Pond

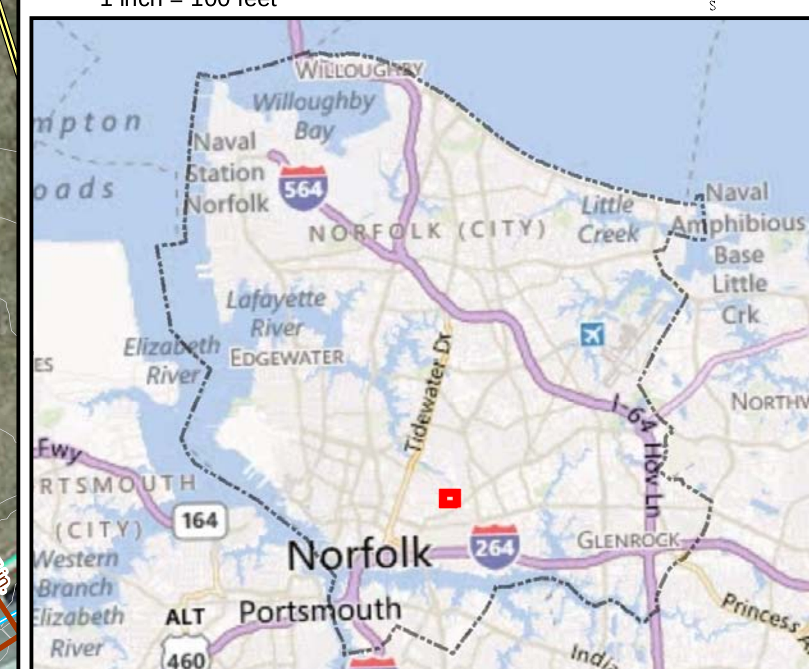


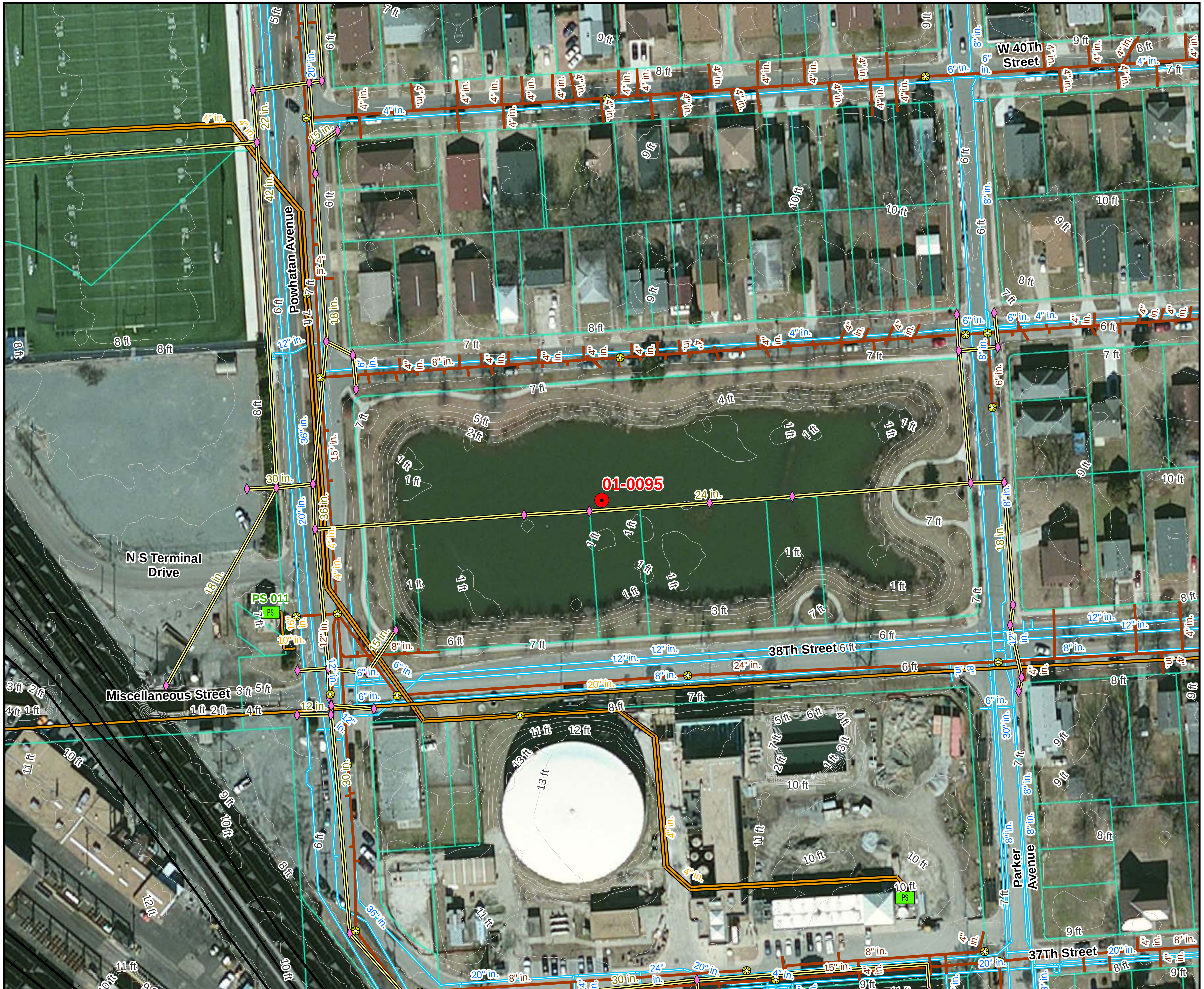
Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet





City of Norfolk | CDM Smith

Figure - 9

Site ID: 01-0095

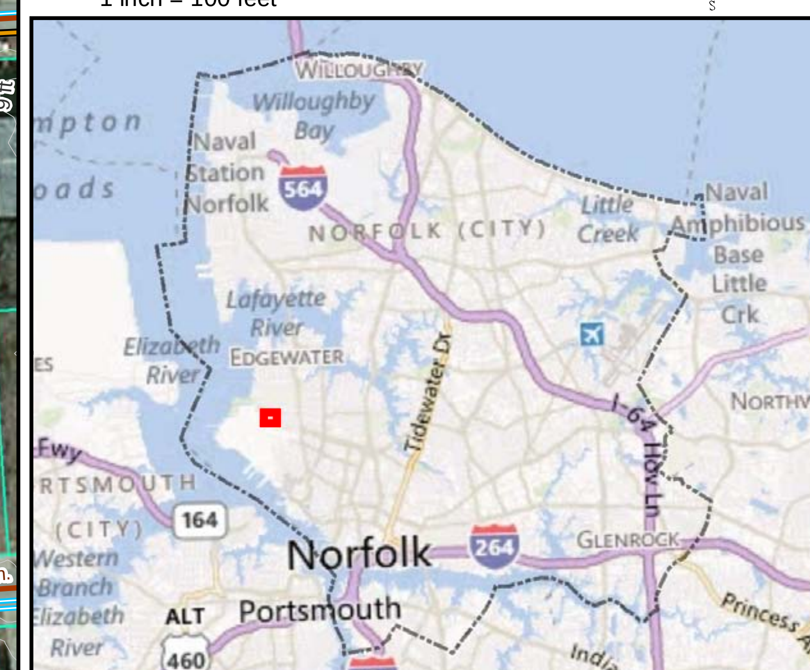
Site Title: Lamberts Point Pond

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet



City of Norfolk | CDM Smith

Figure - 10

Site ID: 02-0010

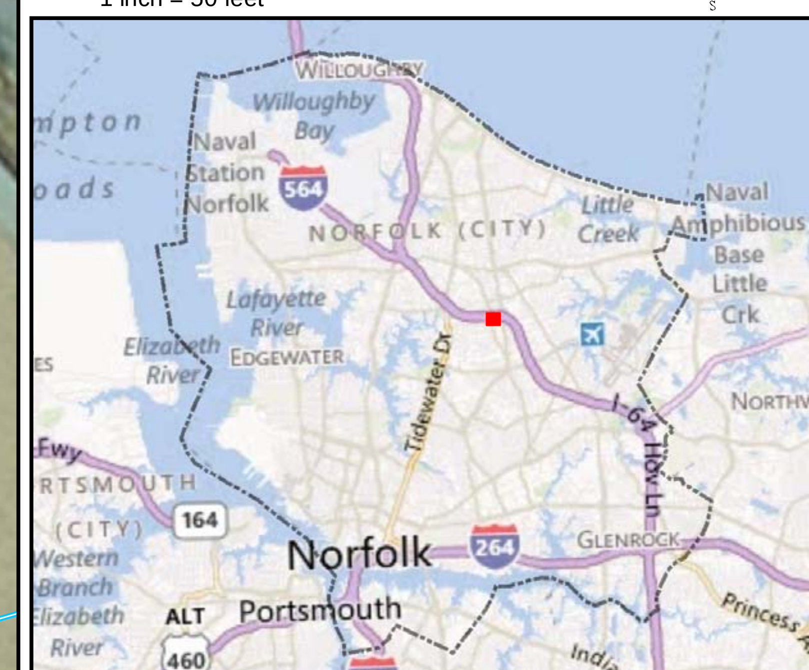
Site Title: Norview High School

Symbol Legend

Other Candidate BMP Site		Railroad	
Candidate BMP Site		Manhole	
Sewer Lift Station		SW Structure	
Stormwater Lift Station		Force Main	
Parcel Boundary		Sewer Line	
Topography (2' interval)		Water Main	
Wetland Community		SW Pipe	
Marsh/Wetland		SW Ditch	
Parks and Rec Area		Waterway	
Norfolk City Limit			

0 25 50 100 Feet

1 inch = 50 feet



City of Norfolk | CDM Smith

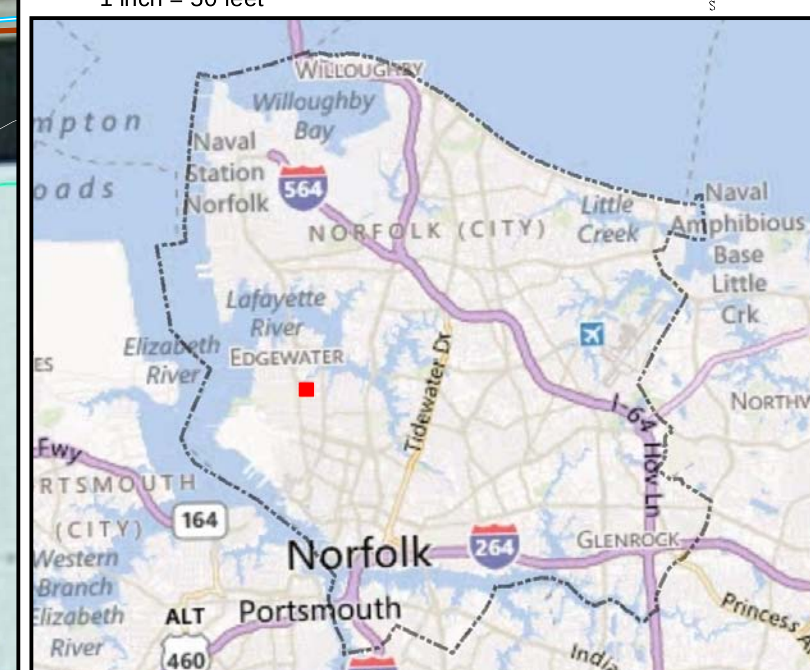
Figure - 11
Site ID: 02-2367
Site Title: ODU University Village

Symbol Legend

Other Candidate BMP Site	Railroad
Candidate BMP Site	Manhole
Sewer Lift Station	SW Structure
Stormwater Lift Station	Force Main
Parcel Boundary	Sewer Line
Topography (2' interval)	Water Main
Wetland Community	SW Pipe
Marsh/Wetland	SW Ditch
Parks and Rec Area	Waterway
Norfolk City Limit	

0 25 50 100 Feet

1 inch = 50 feet



City of Norfolk | CDM Smith

Figure - 12

Site ID: 06-0059

Site Title: Coleman Place Elementary School

Symbol Legend

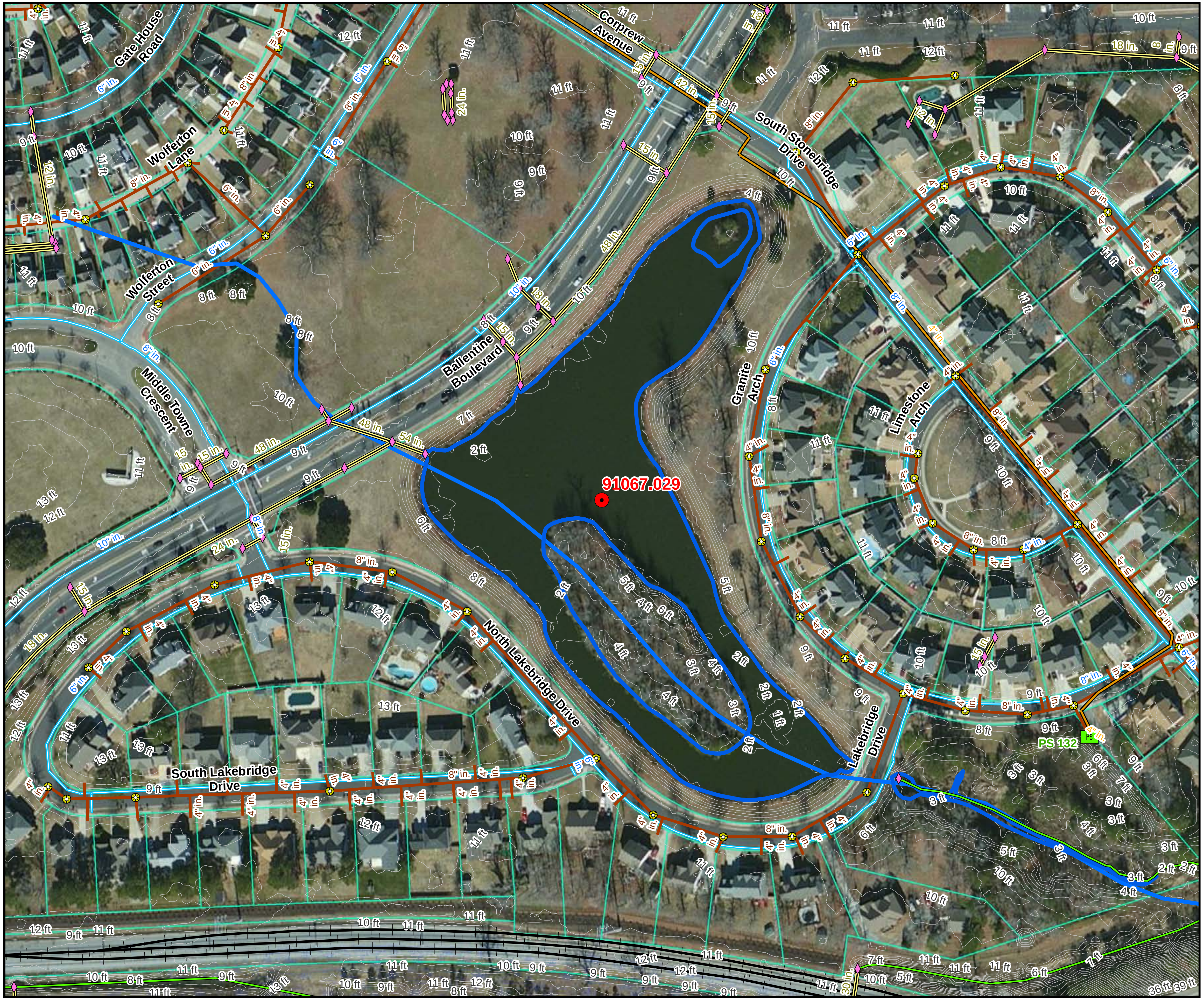
- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet

City of Norfolk | CDM Smith

Figure - 13
Site ID: 91067.029
Site Title: Lake Liberty, NRHA



Symbol Legend

Other Candidate BMP Site	Railroad
Candidate BMP Site	Manhole
Sewer Lift Station	SW Structure
Stormwater Lift Station	Force Main
Parcel Boundary	Sewer Line
Topography (2' interval)	Water Main
Wetland Community	SW Pipe
Marsh/Wetland	SW Ditch
Parks and Rec Area	Waterway
Norfolk City Limit	

0 75 150 300 Feet

1 inch = 150 feet

Figure - 14
Site ID: 99-3931
Site Title: Central Business Park Small

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet

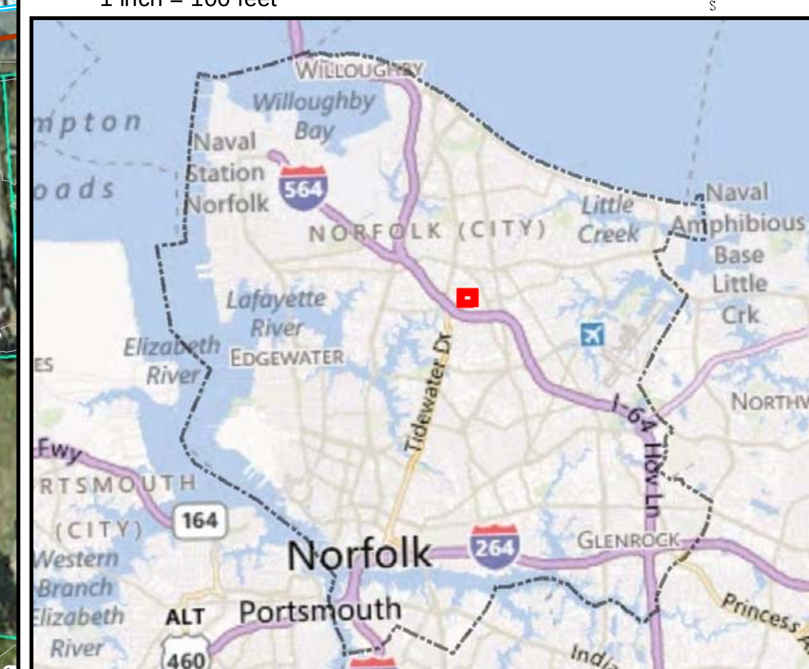


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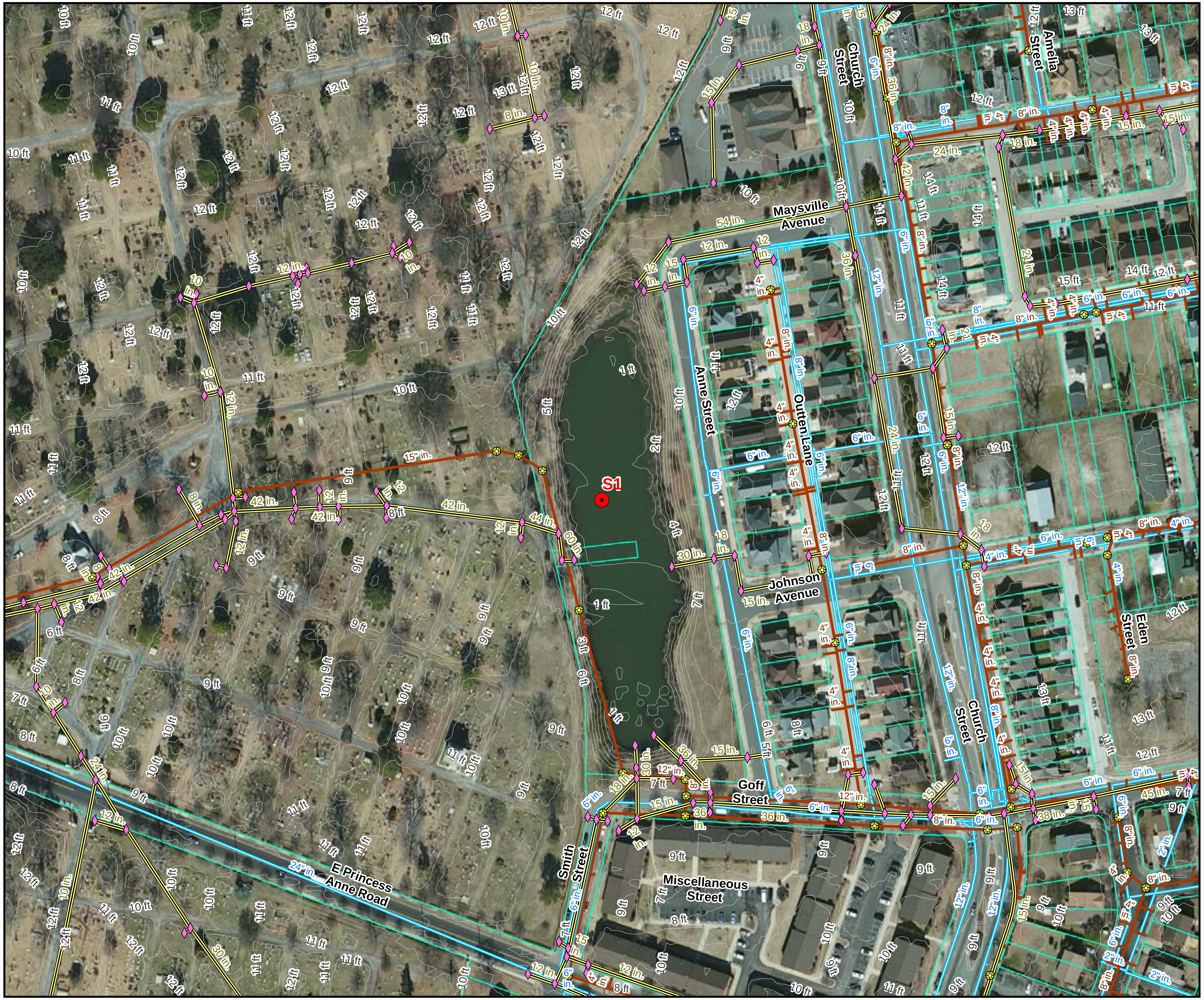
Figure - 15

Site ID: S1

Site Title: Anne Outten Pond



Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 75 150 300 Feet

1 inch = 150 feet

City of Norfolk | CDM Smith

Figure - 16
Site ID: S14
Site Title: Silver Lake/Duck Pond

Symbol Legend

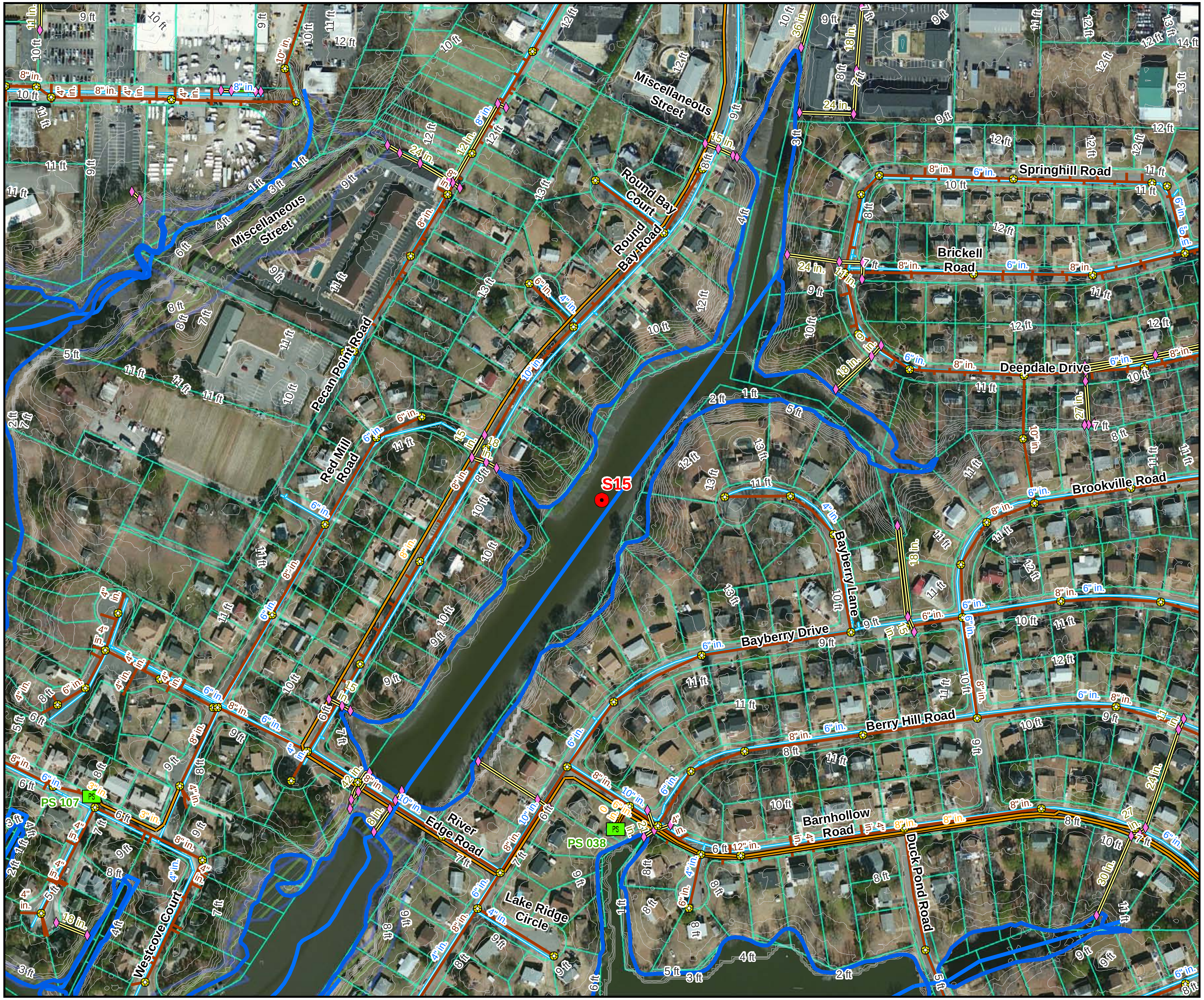
- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 100 200 400 Feet

1 inch = 200 feet

City of Norfolk CDM Smith

Figure - 17
Site ID: S15
Site Title: Meadow Lake



Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 125 250 500 Feet

1 inch = 250 feet

City of Norfolk | CDM Smith

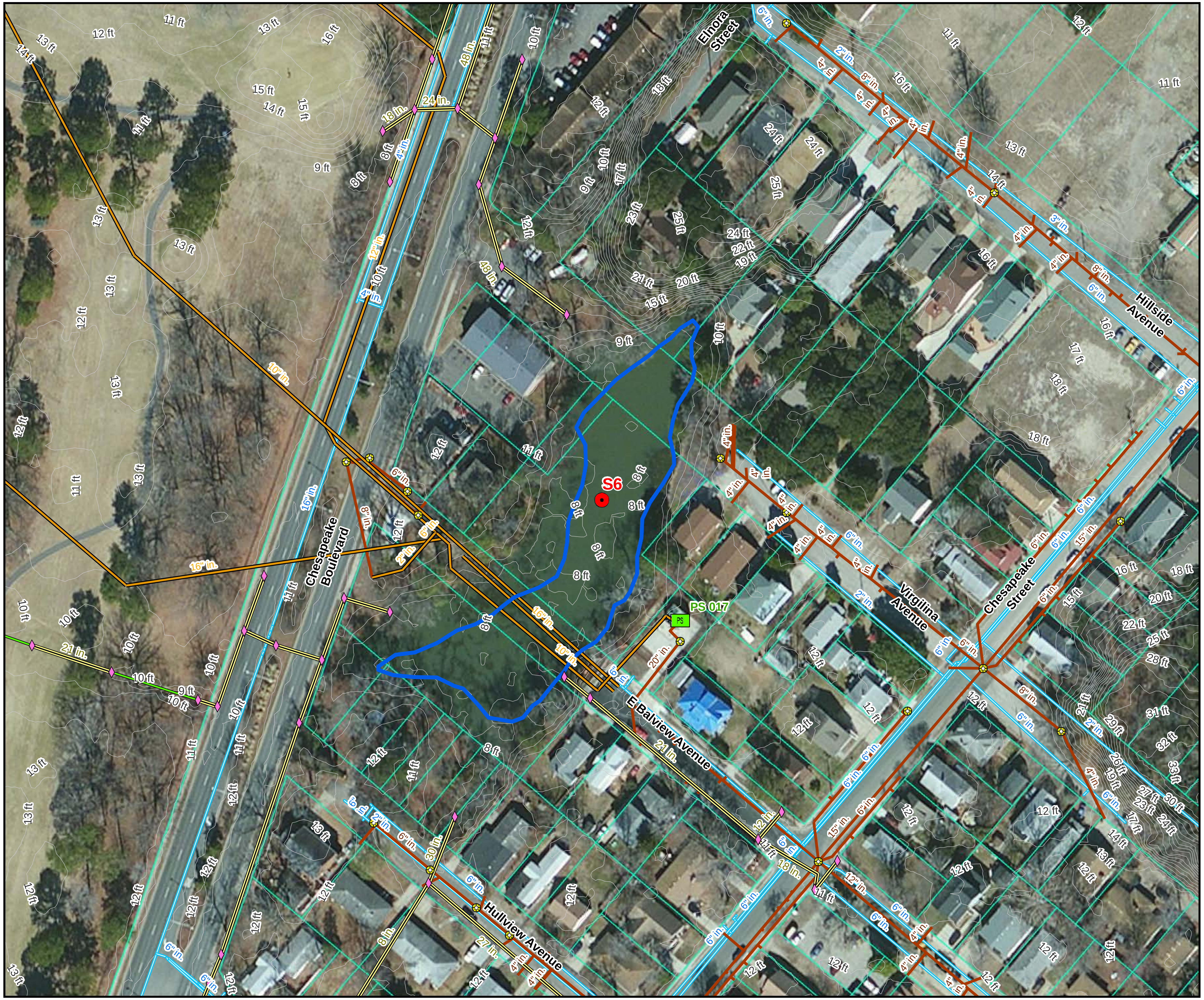
Figure - 18
Site ID: S2
Site Title: Ballentine Elementary School Lake

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet



City of Norfolk

CDM Smith

Figure - 19
Site ID: S6
Site Title: Lake Modoc

Symbol Legend

Other Candidate BMP Site	Railroad
Candidate BMP Site	Manhole
Sewer Lift Station	SW Structure
Stormwater Lift Station	Force Main
Parcel Boundary	Sewer Line
Topography (2' interval)	Water Main
Wetland Community	SW Pipe
Marsh/Wetland	SW Ditch
Parks and Rec Area	Waterway
Norfolk City Limit	

0 50 100 200 Feet

1 inch = 100 feet

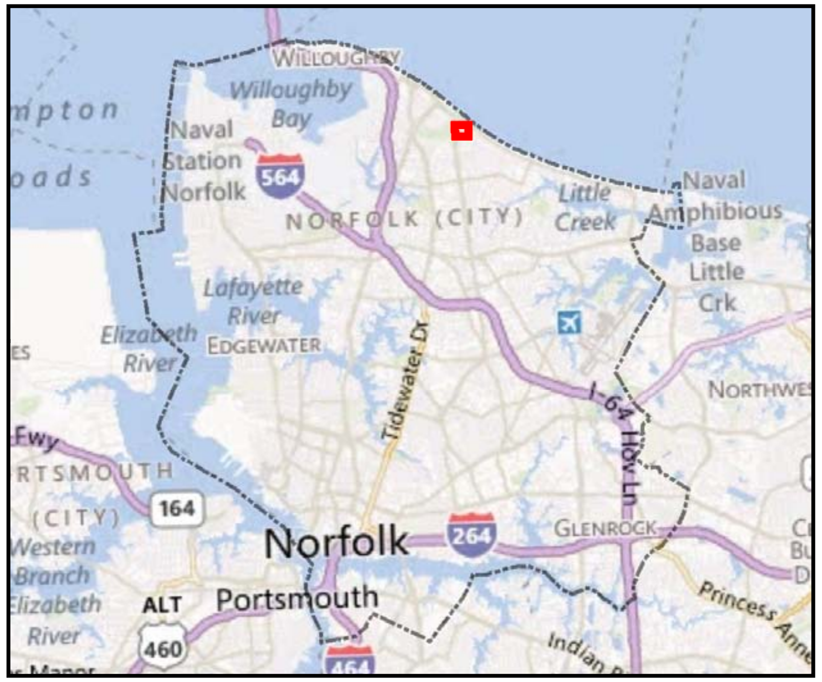


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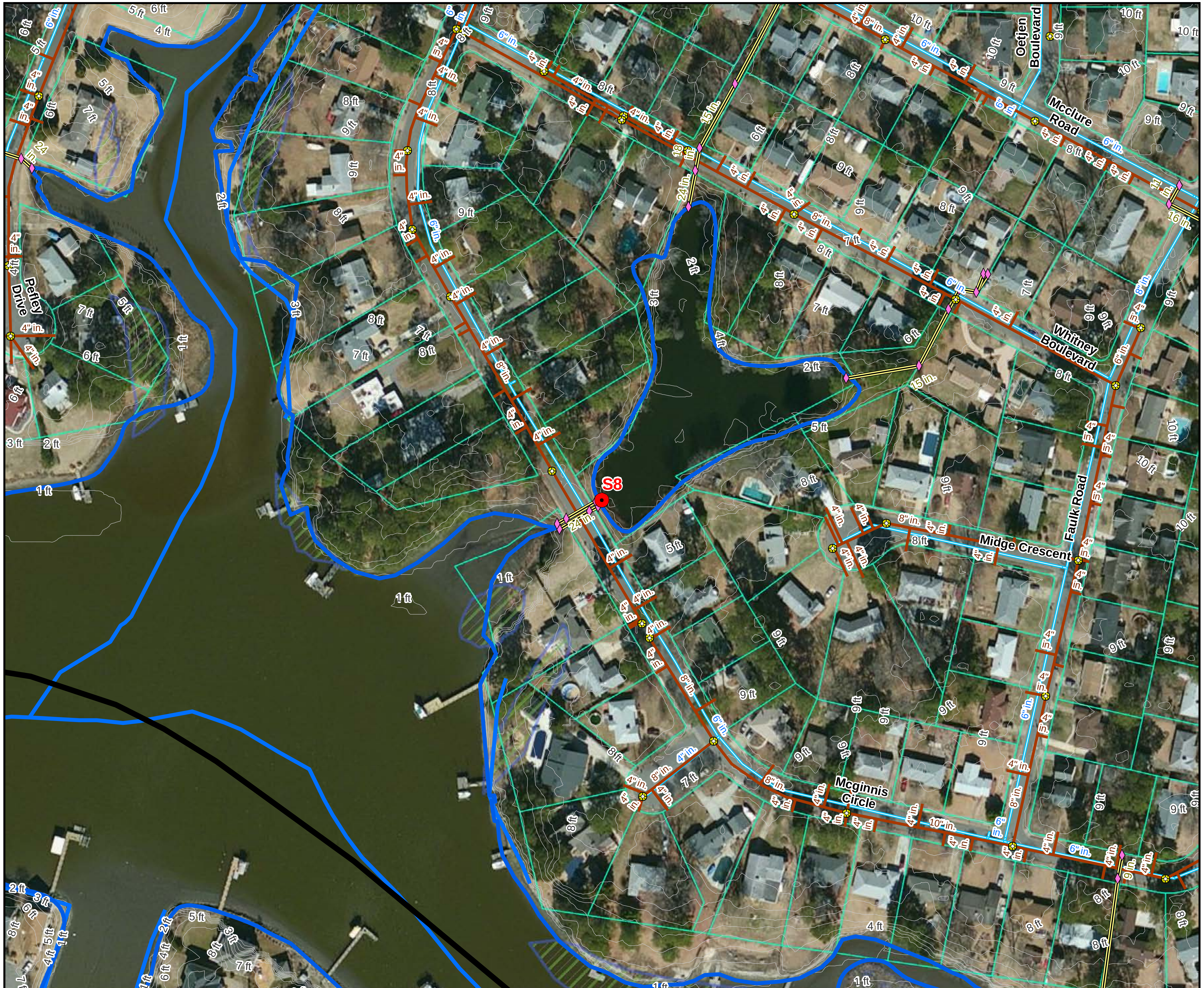
Figure - 20
Site ID: S8
Site Title: Lake Scott

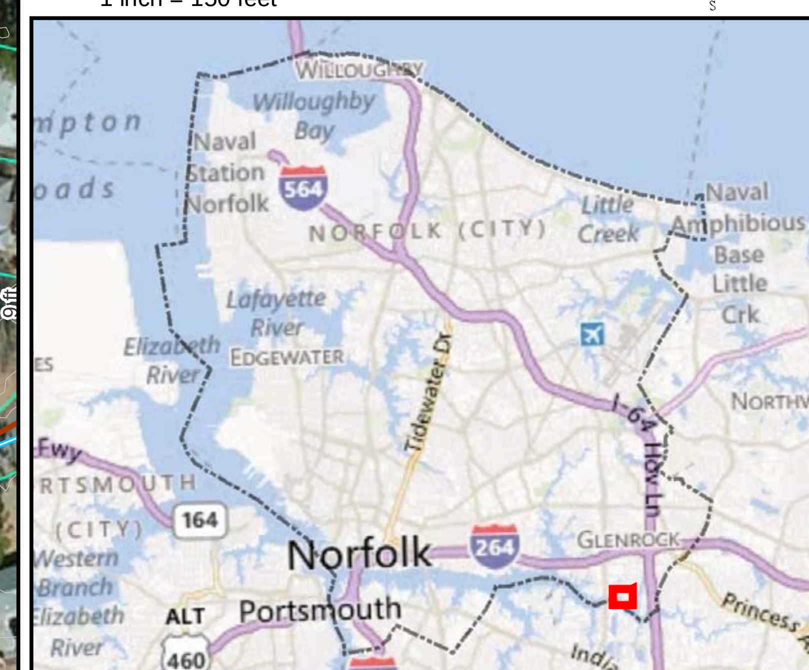


Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 75 150 300 Feet

1 inch = 150 feet



City of Norfolk

CDM Smith

Figure - 21

Site ID: T103

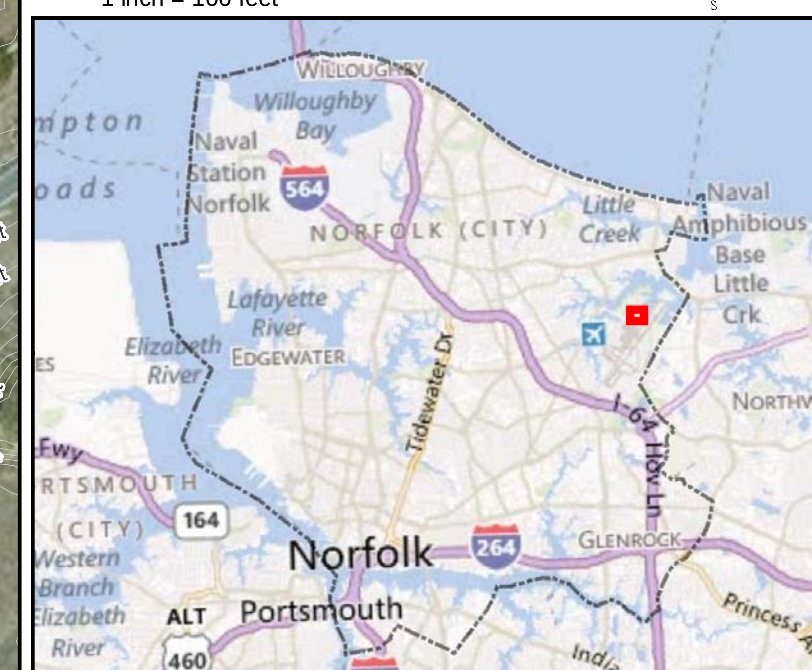
Site Title: Norfolk Botanical Gardens - Visitors Reception

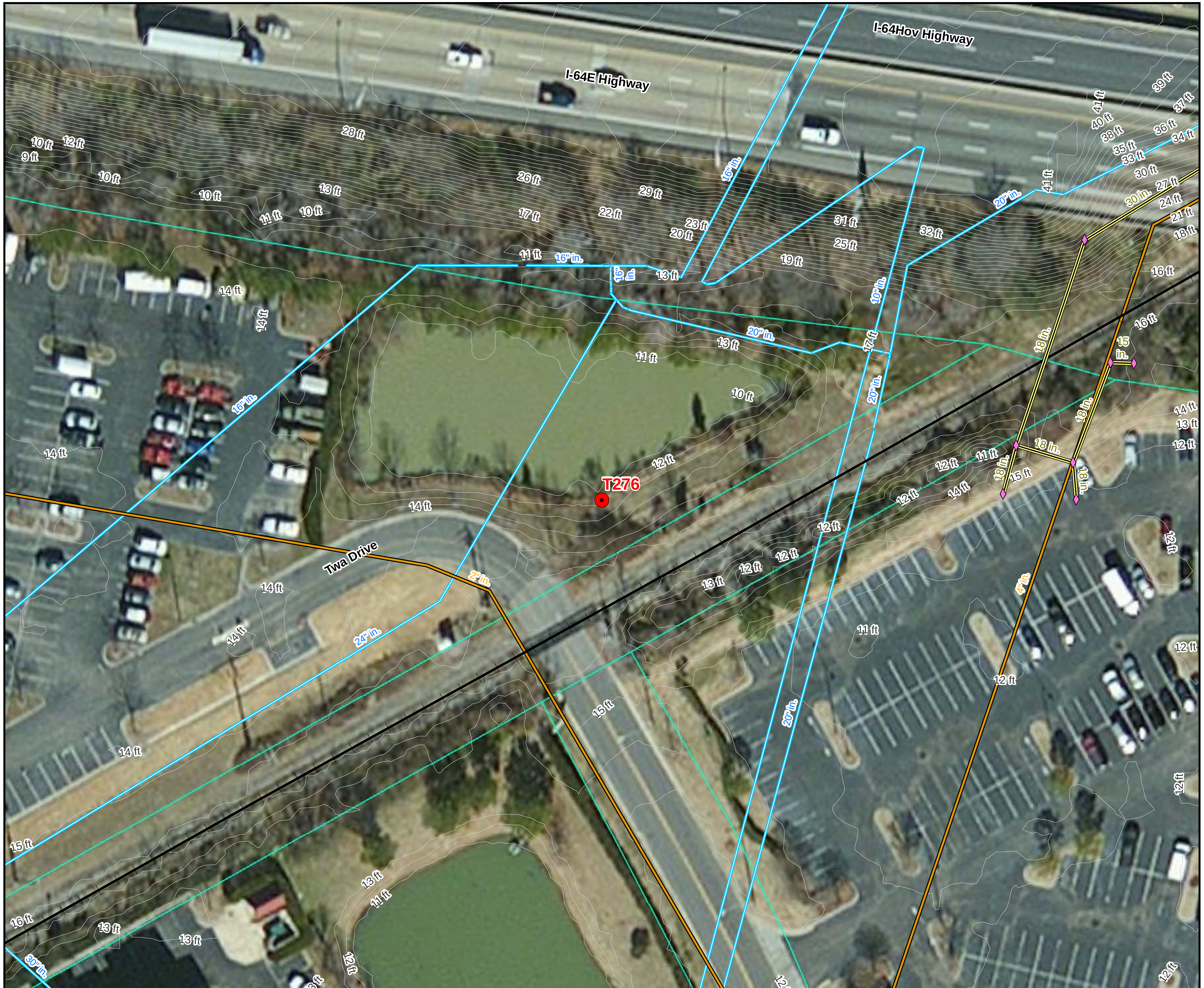
Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet





City of Norfolk CDM Smith

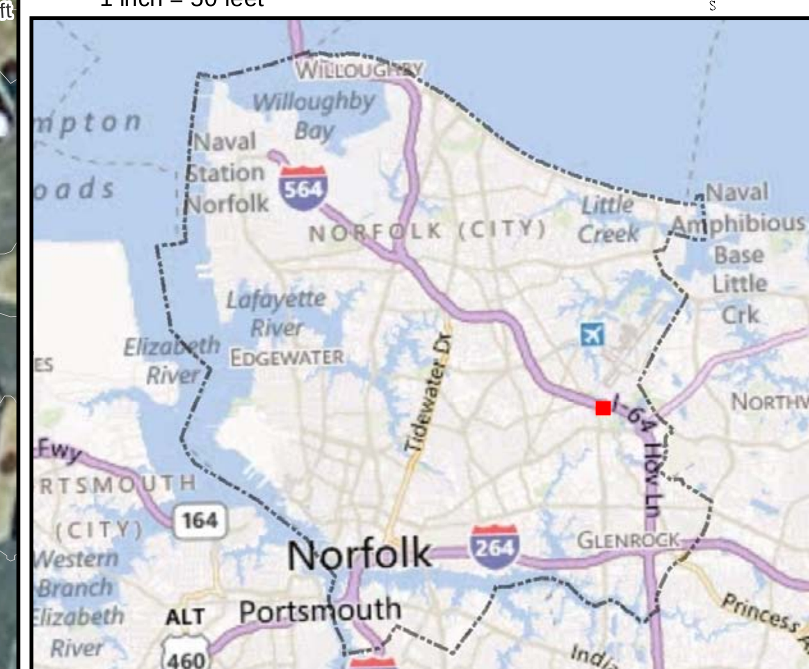
Figure - 22
Site ID: T276
Site Title: NPD 2nd Prencinct Training Center

Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 25 50 100 Feet

1 inch = 50 feet



City of Norfolk | CDM Smith

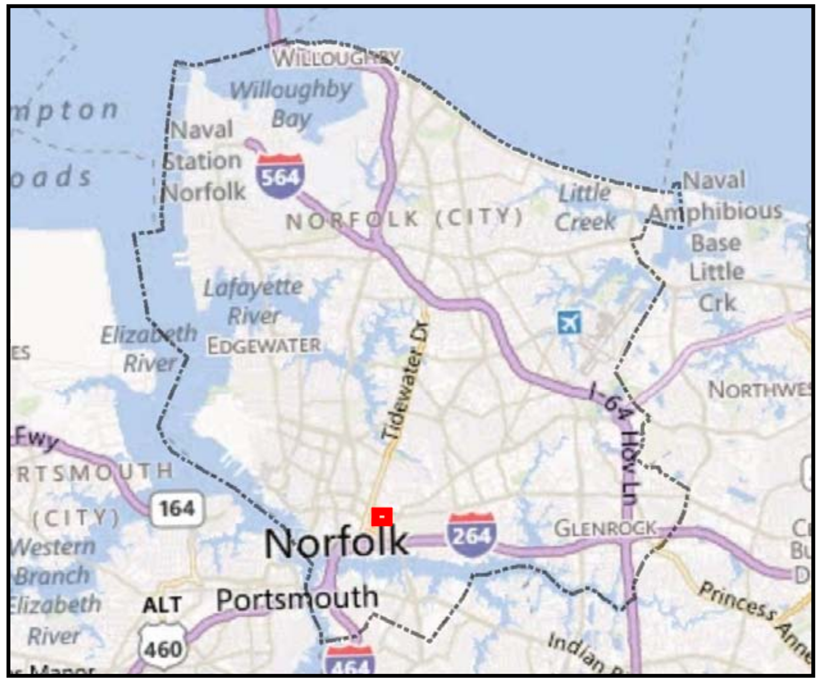
Figure - 23
Site ID: T559
Site Title: Central Brambleton Pond

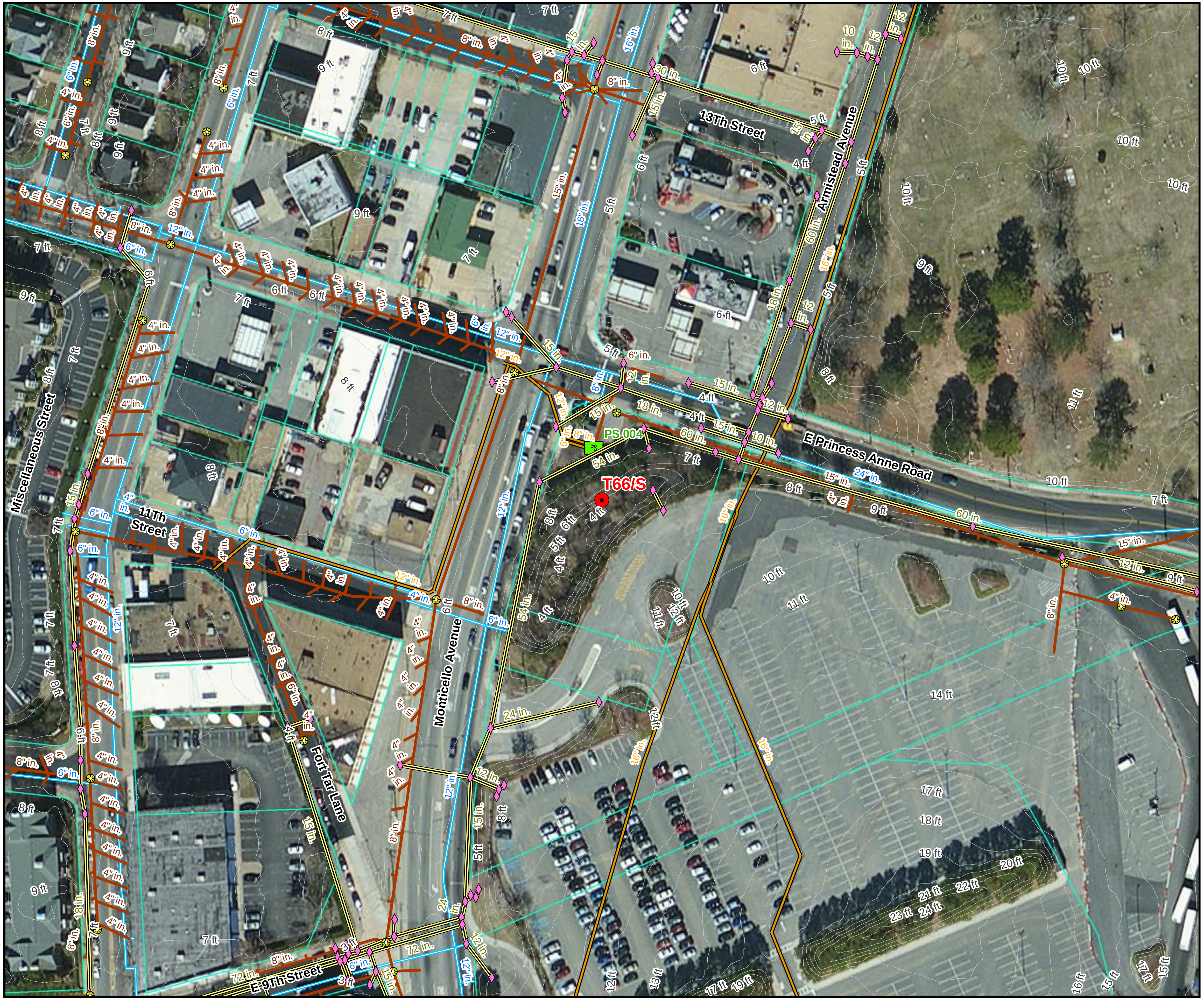
Symbol Legend

	Other Candidate BMP Site		Railroad
	Candidate BMP Site		Manhole
	Sewer Lift Station		SW Structure
	Stormwater Lift Station		Force Main
	Parcel Boundary		Sewer Line
	Topography (2' interval)		Water Main
	Wetland Community		SW Pipe
	Marsh/Wetland		SW Ditch
	Parks and Rec Area		Waterway
	Norfolk City Limit		

0 50 100 200 Feet

1 inch = 100 feet





City of Norfolk
CDM Smith

Figure - 24
Site ID: T66/S
Site Title: Cedar Grove Parking Lot

Symbol Legend

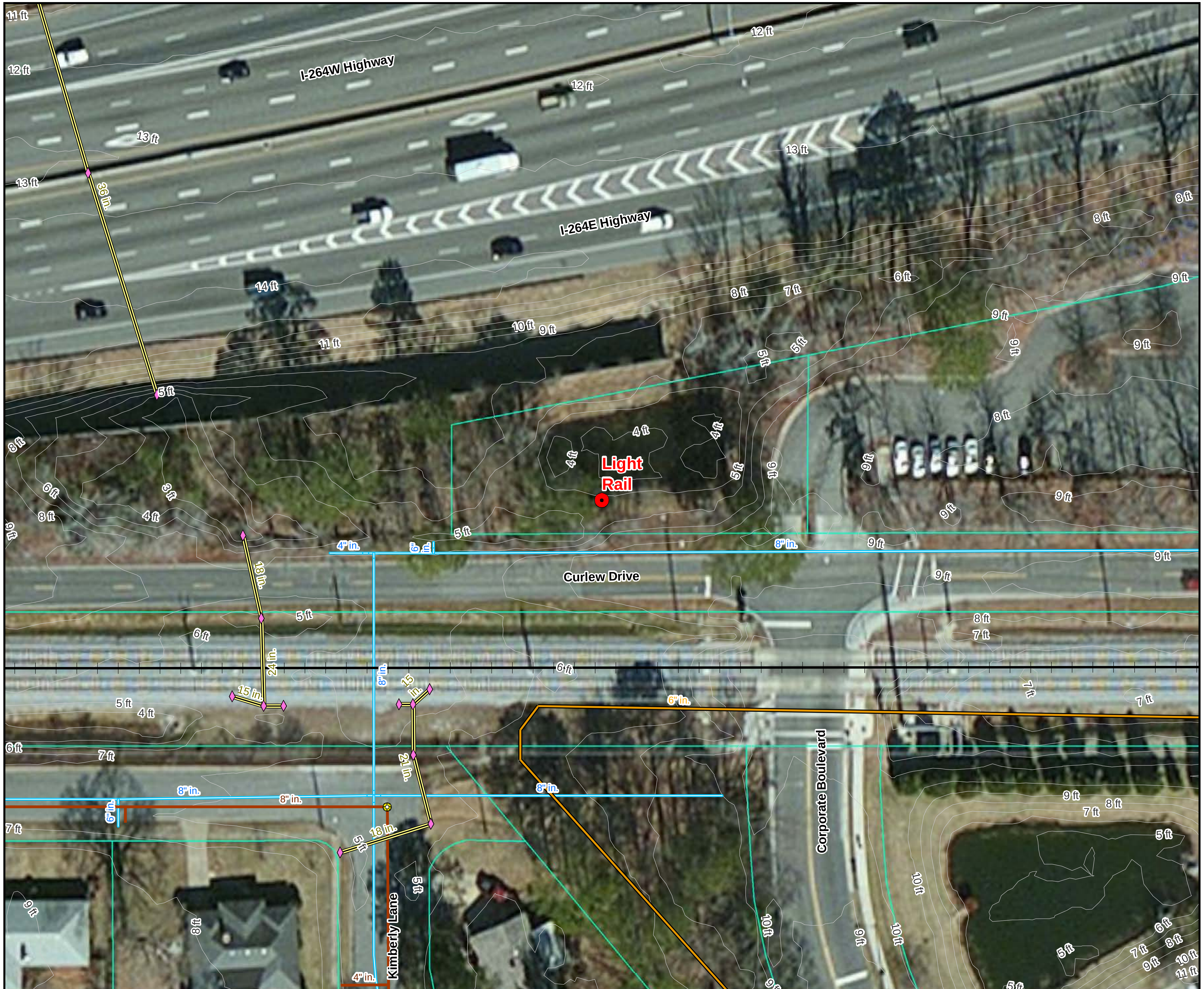
- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 50 100 200 Feet

1 inch = 100 feet

City of Norfolk
CDM Smith

Figure - 25
Site ID: Light Rail
Site Title: Light Rail Station



Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 25 50 100 Feet

1 inch = 50 feet

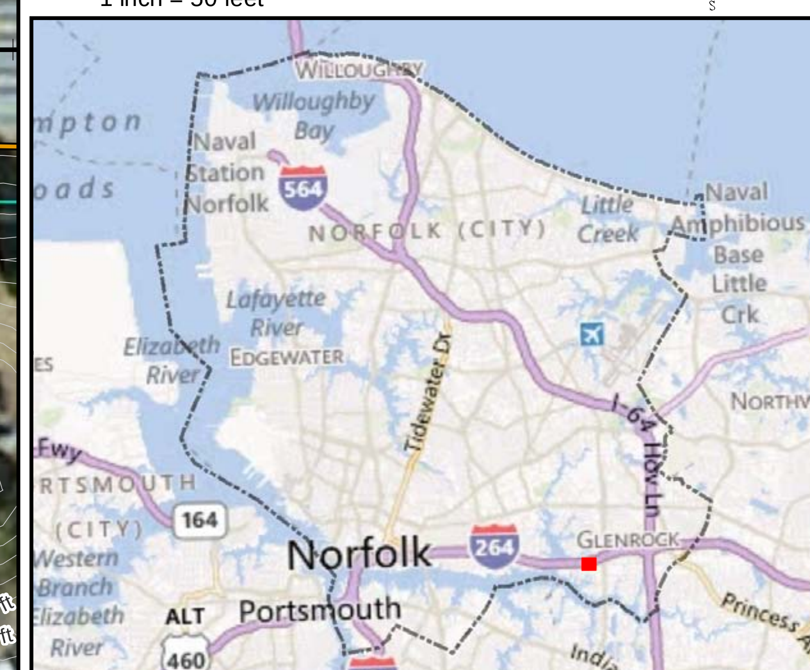


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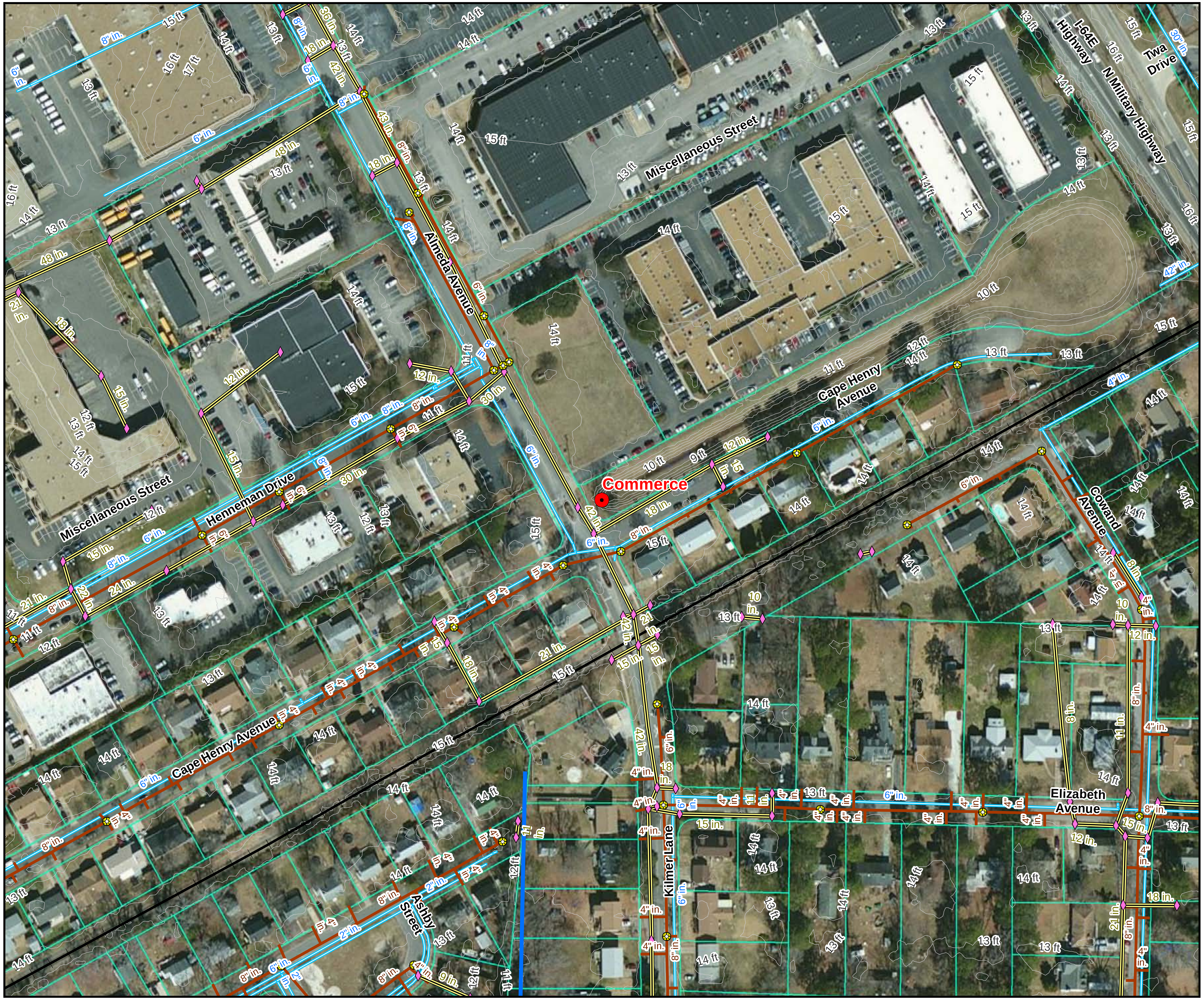
Figure - 26
Site ID: Commerce
Site Title: Norfolk Commerce Park Pond 3



Symbol Legend

- Other Candidate BMP Site
- Candidate BMP Site
- Sewer Lift Station
- Stormwater Lift Station
- Parcel Boundary
- Topography (2' interval)
- Wetland Community
- Marsh/Wetland
- Parks and Rec Area
- Norfolk City Limit
- Railroad
- Manhole
- SW Structure
- Force Main
- Sewer Line
- Water Main
- SW Pipe
- SW Ditch
- Waterway

0 75 150 300 Feet

1 inch = 150 feet

City of Norfolk

CDM Smith

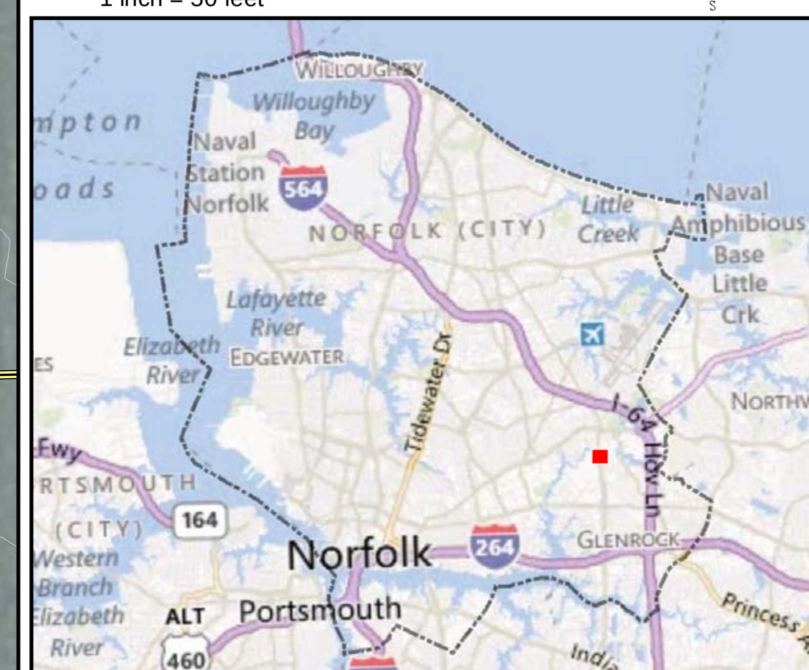
Figure - 27
Site ID: Wells Fargo
Site Title: Wells Fargo Pond

Symbol Legend

Other Candidate BMP Site	Railroad
Candidate BMP Site	Manhole
Sewer Lift Station	SW Structure
Stormwater Lift Station	Force Main
Parcel Boundary	Sewer Line
Topography (2' interval)	Water Main
Wetland Community	SW Pipe
Marsh/Wetland	SW Ditch
Parks and Rec Area	Waterway
Norfolk City Limit	

0 25 50 100 Feet

1 inch = 50 feet



City of Norfolk, Virginia

Stormwater BMP Retrofit Evaluation

Candidate BMP Location Maps

May 2013