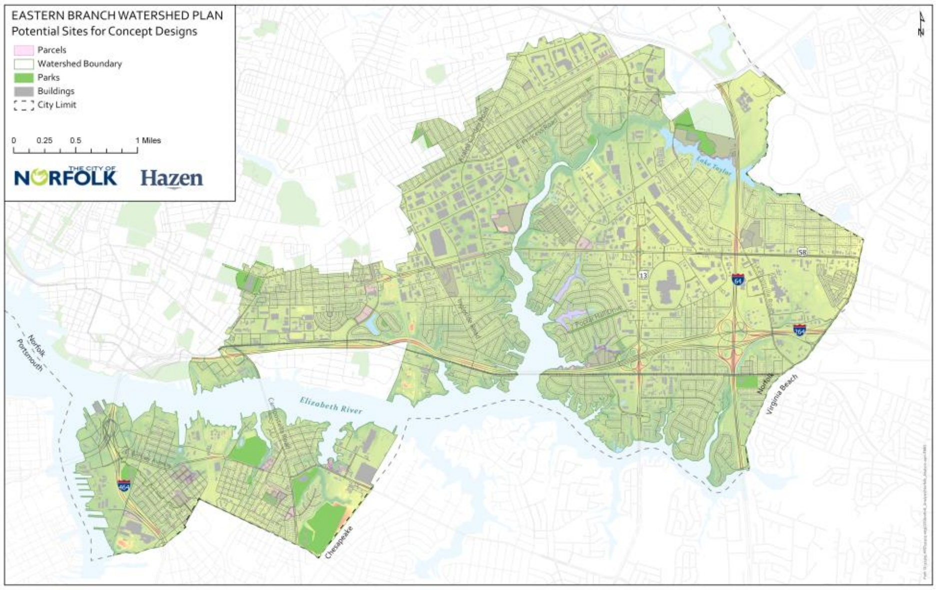
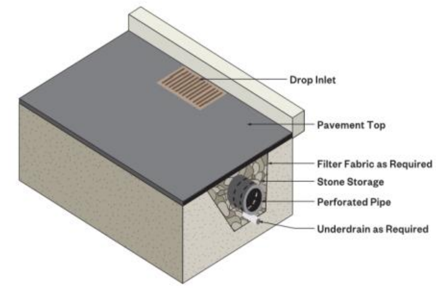
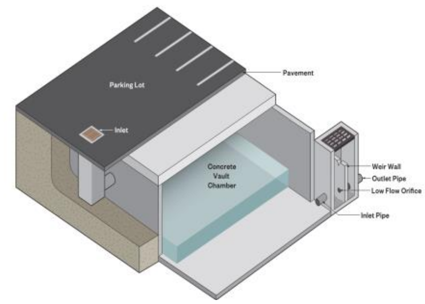
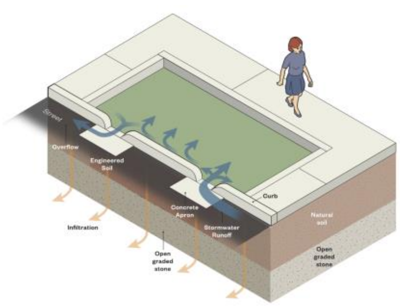
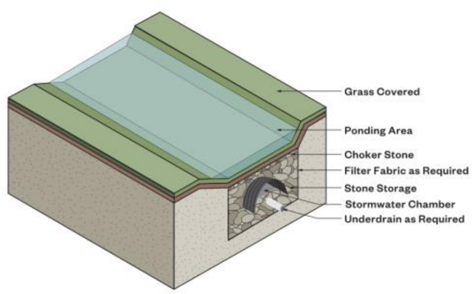
Hazen and Sawyer
4500 Main Street, Suite 500
Virginia Beach, VA 23462

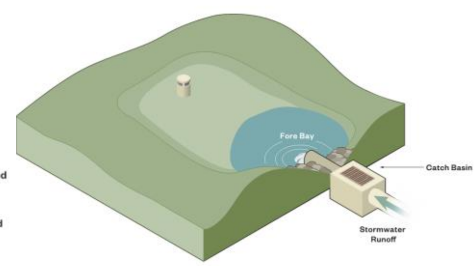












City of Norfolk

Eastern Branch Watershed Master Plan

Final Report
June 13, 2019

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Executive Summary

The Eastern Branch Watershed Master Plan was developed to characterize the watershed and identify structural best management practice (BMP) opportunities with the potential to decrease flooding, improve water quality, and address resident complaints associated with stormwater.

To identify appropriate opportunities within the watershed, a structured GIS approach was taken that focused on publicly owned parcels and the right-of-way. Beginning with 966 public parcels, a total of 38 sites were identified for field visits. The field verification looked at suitability factors including proximity to existing infrastructure, favorable topography, distance to outfalls, proximity to known flooding areas, and existing litter and debris problems. From this list, a total of 20 sites were chosen for the development of concept designs.

The 20 concepts provide constructible opportunities at each site and are also meant to serve as a template for future opportunities within the watershed and the City of Norfolk. To manage stormwater at the sites, a total of 30 BMPs were chosen. These facility types include traditional practices such as dry swales, grassed channels, hydrodynamic separators, and infiltration trenches. Other more innovative practices, such as iceberg bioretention and subsurface gravel wetlands, are included which minimize maintenance without sacrificing performance.

Through meetings with City staff, a prioritization calculator was developed to identify the priority opportunities for design and construction. This spreadsheet is based on quantifiable characteristics associated with a concept and the in-depth knowledge about a site provided by City staff.

The top five scoring concept designs in the Eastern Branch Watershed based on this prioritization are provided in Table E-1.

Table E-1 Top Five Ranked Concept Designs

Rank	Concept Design	BMPs Included in Concept
1	Town and Country Day School	Pipe Detention
2	Meadow Lake	Riser Structure Retrofit; Actuated Controls
3	Seay Ave.	Infiltration Basin
4	E. Princess Anne Rd.	Stormwater Chamber
5	Fairlawn Recreational Center	Porous Concrete; Subsurface Detention; Soil Amendment

1. Introduction

The Eastern Branch Watershed Master Plan has been developed to provide a characterization of the watershed and identify opportunities for stormwater management. Through a structured desktop analysis in geographic information systems (GIS), publicly owned parcels and right-of-ways (ROWs) were investigated for their suitability for stormwater best management practices (BMPs). After field verification of site constraints, a total of twenty sites were chosen within the watershed for the development of concept level designs. These concept plans provide a template for BMPs that can be applied throughout the Eastern Branch Watershed as well as the greater City of Norfolk.

1.1 Background

The 11.6 square mile watershed evaluated as part of this project includes the majority of the Eastern Branch Watershed and a small section of the Southern Branch Watershed. The area around Chesterfield Heights, which is part of an on-going redevelopment program, is not be included in this plan.

The City of Norfolk is increasingly at risk from flooding related to coastal storms. With its relatively flat topography, low elevation (nearly entire City below elevation of 15 ft) and tidal connections to the Elizabeth River and Chesapeake Bay, the majority of the City is at risk of flooding, both from precipitation events as well as from tidal/coastal conditions. Sea level rise and changing storm conditions further exacerbate the flooding conditions throughout the City. As such, the City has taken a proactive approach in evaluating opportunities to mitigate flooding impacts. This project was established to identify opportunities to address localized flooding problems within the Eastern Branch Watershed.

The Eastern Branch Watershed includes residential, commercial and industrial land uses with a significant portion of the area draining directly to Broad Creek before discharging into the Eastern Branch. The waterways within the watershed are subject to both a bacteria (enterococcus) TMDL as well as the Chesapeake Bay TMDL for total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS). Both TMDLs, assign waste load allocations that limit discharge of specific pollutants to the impaired waters.

The Elizabeth River provides direct economic benefits to the City of Norfolk through waterway access, marine fisheries, tourism, and enhanced quality of life for residents. Over the past few decades, the City of Norfolk has demonstrated a commitment to addressing both the water quantity and quality problems associated with stormwater runoff, in keeping with state and federal regulations. This plan provides the City with a prioritized list of alternative improvements which will provide both water quality and flood mitigation, in keeping with the City’s commitment to environmental quality and flood risk reduction.

1.2 Objectives

This Master Plan evaluates alternative BMP concept designs in the Eastern Branch Watershed. Plan objectives are two-fold:

1. Provide feasible concept designs that address water quantity, water quality, and other stormwater issues as identified by City residents.

2. Establish an approach to characterization, design, and prioritization that can serve as a template for evaluation of projects within the watershed and the greater City of Norfolk.

2. Watershed Characterization

2.1 Watershed Description

The Eastern Branch Watershed of the Elizabeth River is 11.6 square miles and is composed of residential, commercial, and industrial land uses. Most of the drainage area flows to Broad Creek before discharging into the Eastern Branch of the Elizabeth River. Broad Creek and the Elizabeth River are both subject to TMDLs for enterococcus, nitrogen, phosphorus, and sediment impairments. Much of the coastal portion of the Eastern Branch Watershed is low-lying and prone to tidal flooding as well as precipitation driven floods.

2.2 GIS Analysis

The focus of the initial GIS analysis was on City-owned parcels with available open space to facilitate the coordination and installation of a variety of concept practices. Additional considerations included the slope, soils, land cover, floodplain, and citizen complaints. The analysis was conducted in a structured manner with a model developed in ArcGIS Pro which served as the basis of the selection process. A diagram of the model is included in Appendix A.

2.2.1 Available Data/Information

Multiple spatial datasets were used in the analysis, including:

- Civic Leagues (Norfolk)
- Flood Insurance Rate Map (Norfolk)
- Flooded Street Complaints (Norfolk)
- Landcover, 2014 base with 2107 updates (Norfolk)
- Lidar DEM, 2013 (Norfolk)
- Parcel Boundaries (Norfolk)
- Parcel Ownership (Norfolk)
- Parks (Norfolk)
- Soils – Hydrologic Soil Group and Drainage (Natural Resources Conservation Service, US Department of Agriculture)

2.2.2 Municipal Property

The City owns 966 properties, distributed throughout and covering more than 10% of the watershed. Of those parcels, 62% are vacant or have schools, recreation centers, or parks, all of which could be amenable to concept practices and retrofit projects. Vacant parcels owned by the Norfolk Redevelopment and Housing Authority (NRHA) were also included in this analysis.

2.2.3 Landscape

Slope – A determining factor in the initial site selection was the slope. The City's 2013 Lidar DEM was used to create a slope layer and an average slope per aggregated parcel polygon was calculated.

Soils - Of the rated soils within the watershed, there is roughly a 60/40 ratio between poorly and well-draining soils. Depending on the soil type, a variety of practices can be implemented.

Land Cover – The watershed is largely urban and developed. Aggregated parcel land cover is seen in Table 2-1.

Table 2-1 Land Cover Summary

Land Cover	Overall Watershed	Aggregated Parcel Average
Tree canopy	19%	38%
Tree canopy over impervious	3%	1%
Pervious	23%	27%
Water	1%	23%
Impervious	49%	5%
Bare earth	1%	1%
Wetlands	4%	7%

Floodplain - With 71% of the watershed in or within 1,000 feet of the 100-year floodplain, the watershed is largely flat and prone to flooding. A variety of practices can be implemented both within or outside of the floodplain.

Drainage Issues – There have been 146 reported street flooding complaints within the watershed, 18 of which are within 100 feet of aggregated parcel polygons.

2.3 Site Selection

Site selection began with all parcels in the Eastern Branch Watershed and was filtered by City ownership down to 966. The City owned parcels were then filtered to vacant lots, schools, parks, and recreation centers narrowing the parcel number to 670. Any parcels adjacent to each other were aggregated so they could be evaluated as one opportunity narrowing the count to 580. Next, parcel polygons of greater than 1,000 square feet, less than a 5-degree average slope, and less than 100% tree canopy were selected for consideration[1]. This selection produced a set of 195 aggregated parcel polygons. Of these, 36 sites were in the Campostella neighborhood. The final list of sites for field investigation were selected based on a manual review of imagery and Google/Bing Street View, favorable flow patterns, nearby infrastructure, and distribution across the watershed. Specific, City-suggested opportunities outside of the structured process, such as with the Salvation Army and sites with known flooding issues in the ROW, were also

[1] No filters were applied for floodplain proximity or soil type due to a high percentage of the watershed being within the floodplain or buffer and the variety of practices that can be implemented to accommodate different soil types.

selected for field analysis and review. The following map shows the selected sites. A complete list of field sites is provided in Appendix B and seen spatially in Figure 2-1.

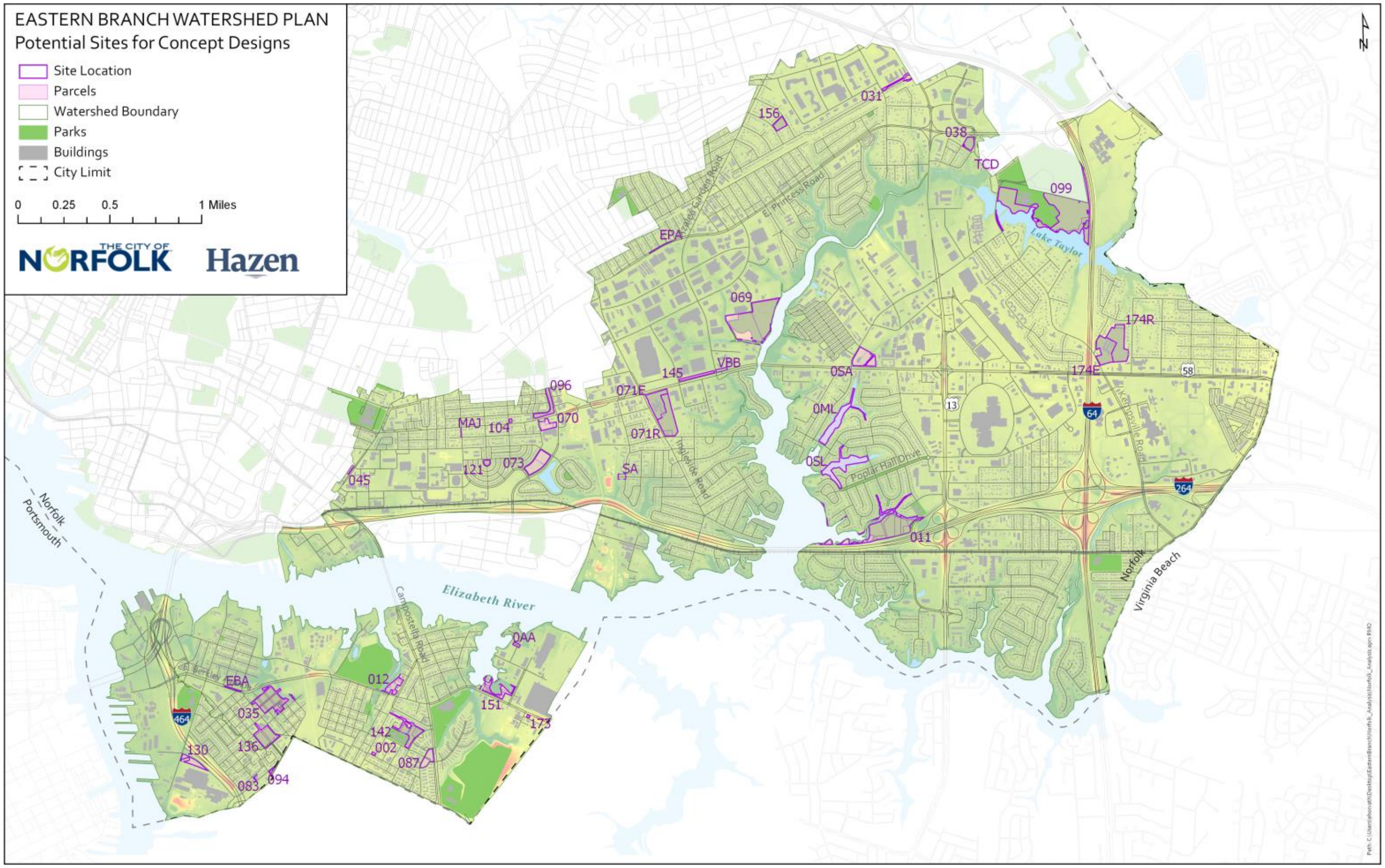


Figure 2-1: Sites Selected for Field Investigation

3. Watershed Improvement Planning

3.1 Field Investigation

After completion of the desktop analysis, 38 sites were scheduled for field investigation. The sites were chosen based on characteristics including open space opportunity, ROW opportunity, proximity to existing infrastructure, favorable topography, potential retrofit opportunities, proximity to outfalls, proximity to known flooding issues, and existing litter and debris problems. Field crews photographed the sites, documented overall feasibility for varying features and potential alternatives, identified existing infrastructure, and discussed potential community benefits. Appendix B provides the detailed list of field notes for each site visited.

3.2 Summary of Improvement Opportunities

After field investigation and preliminary siting evaluations were completed, the final group of 20 sites were selected for concept plan development. The refined list of sites, their addresses, and proposed features are included in Table 3-1. These sites were selected to be a representative sample of green infrastructure projects that could be piloted throughout the Eastern Branch Watershed. A total of 30 different BMPs were sited (Figure 3-1). The BMPs range in size from smaller stormwater controls that manage immediate adjacent impervious areas to larger stormwater controls on undeveloped land that have the capability to manage multiple connected drainage areas. Planning level costs, load reductions, footprint sizing, and water quality storage volume for each proposed practice were quantified during the concept design phase for prioritization. Concept plans detailing the existing site, proposed practices, site photographs, plan view maps, standard details, and calculations for the 20 final sites are provided in Appendix C.

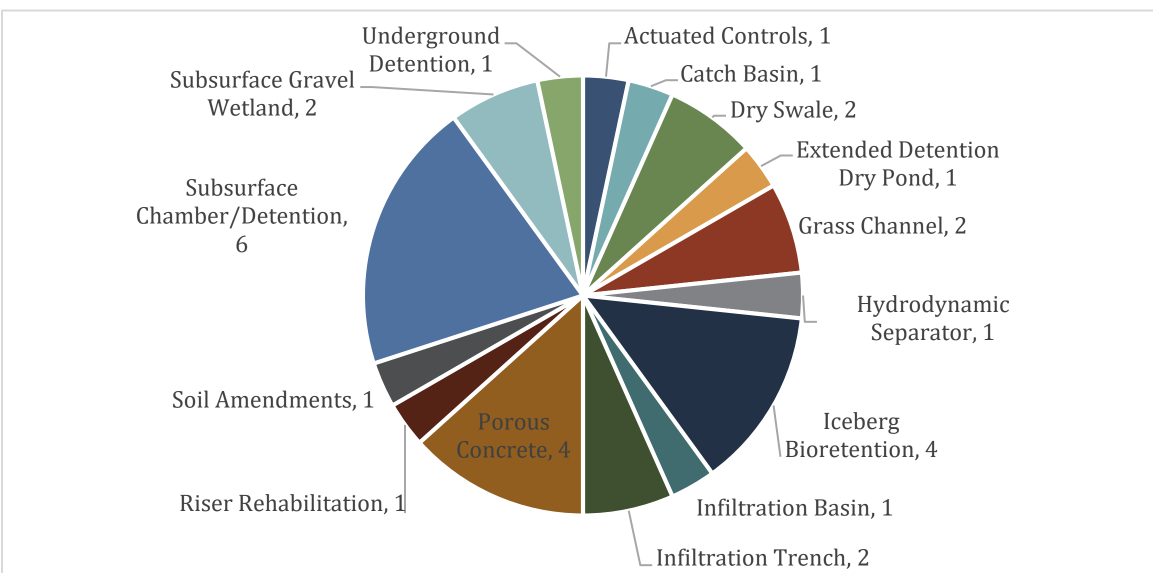


Figure 3-1: BMP Types included in Concept Designs

Table 2-1: Site Details

Site	Address	Features
Arlington Ave. Right-of-Way	2128 Arlington Ave.	• Dry Swale
Meadow Lake	5398 River Edge Rd.	• Riser Rehabilitation • Actuated Controls
Poplar Hall Park	101 N. Military Hwy.	• Infiltration Trench
Princess Anne Park	1450 Kempsville Rd.	• Right-of-Way Iceberg Bioretention
Park Ave.	815 Park Ave.	• Right-of-Way Iceberg Bioretention
Azalea Little League	1147 Pineridge Rd.	• Extended Detention Dry Pond • Dry Swale
Open Space, Ballentine and Virginia Beach Blvd.	985 Ballentine Blvd.	• Subsurface Gravel Wetland
Ballentine at NSU Entrance	801 Ballentine Blvd.	• Grass Channel • Iceberg Bioretention
Campostella Park	1501 Campostella Rd.	• Subsurface Gravel Wetland
Lake Taylor Middle and High School	1380 Kempsville Rd.	• Porous Concrete • Underground Detention
Corner Lot off Virginia Beach Blvd.	2900 E. Virginia Beach Blvd.	• Iceberg Bioretention
Berkley Park	706 Walker Ave.	• Porous Concrete • Subsurface Detention
Diggs Towne Recreation Center	1401 Melon St.	• Porous Concrete • Subsurface Chamber • Grass Channel
Fairlawn Recreation Center	1014 Kempsville Rd.	• Porous Concrete • Subsurface Detention • Soil Amendments
E. Berkley Ave. Median	307 E. Berkley Ave.	• Median Pipe Detention
E. Princess Anne Rd. Median	3801 E. Princess Anne Rd.	• Median Stormwater Chamber
Majestic Ave. Right-of-Way	2630 Myrtle Ave.	• Infiltration Trench
Seay Ave. Right-of-Way	3494 Seay Ave.	• Infiltration Basin

Site	Address	Features
Town and Country Day School Right-of-Way	1421 Kempsville Rd.	• Right-of-Way Pipe Detention
Virginia Beach Blvd. Right-of-Way	3777 E. Virginia Beach Blvd.	• Catch Basin • Hydrodynamic Separator

4. Prioritization

4.1 Prioritization Process

A prioritization calculator was developed to rank concept designs and assist the City of Norfolk with future project selection. A proposed list of factors was presented to the City and refined during a prioritization workshop to ensure alignment with municipal goals and objectives. Following completion of the 20 final concept plans, a meeting was held with the City to review the prioritization and consider appropriate weighting of the different factors.

4.1.1 Prioritization Factors

The factors that were considered for the prioritization are reflective of the City of Norfolk's values and goals for their stormwater program and also align with the City's Stormwater Management Plan and TMDL Action Plans. Each factor in the following list was quantified with planning level estimates by Hazen or through knowledge of the watershed by the City. The criteria for each factor's scoring can be found in Appendix D.

Potential Flood Control – This factor includes proximity to flooding studies and trunk line analysis, proximity to known flooding complaints, and practice water quality storage volume. Quantities were assigned to these from the City's knowledge, visual review in ArcGIS, and planning level design calculations. For sites with multiple features, the sum of the water quality storage volume was used.

Water Quality Benefits – This factor accounts for the TN, TP, and TSS load reductions calculated for each concept design. Load reductions were based on Virginia and Chesapeake Bay TMDL guidance. For sites with multiple features, the sum of the load reductions was used.

Maintenance – The maintenance frequency for different features was referenced from DEQ recommended maintenance. For sites with multiple features, the practice with the highest maintenance demand was used.

Cost – Planning level costs were tabulated for each concept plan with a 30% contingency. Total cost for all practices at a site were used in the prioritization.

Public Perception – This factor was used to gauge the level of public interest for each different concept plan based on the neighborhood proposed sites were in. This was quantified through various identified levels of positive public engagement within different parts of the City.

Known Infrastructure Improvement – This is a bonus factor which accounts for the potential of known infrastructure condition problems.

4.1.2 Prioritization Weights

After a final set of factors was established, weights that properly addressed each factor were developed through collaboration with City staff. The final weights for the prioritization calculator are provided in Table 4-1.

Table 4-1 Prioritization Factor Weights

Factor	Description	Category Weights	Global Weights	Units	Populated By
Potential Flood Controls	Proximity to Flooding Studies/Trunk Line Analysis	5%	36%	0, 1, or 2	City
	Number of Complaints Nearby	16%		0, 1, or 2	Hazen
	Practice WQ Storage Volume	15%		CF	Hazen
Water Quality Benefits	TN Removed	3%	9%	Lbs/yr	Hazen
	TP Removed	3%		Lbs/yr	Hazen
	TSS Removed	3%		Lbs/yr	Hazen
Maintenance	Maintenance and Maintainability	25%	25%	1 through 5	Hazen
Cost	Concept Level Construction Cost	15%	15%	$	Hazen
Public Interest	Qualitative Evaluation of Known Public Interests	5%	5%	1, 3, or 5	City
Known Infrastructure Condition	Does Nearby Infrastructure Need Improvement	10%	10%	0, 1, or 2	City

4.2 Prioritization Results

After finalization of raw scores and factor weights, weighted scores were generated for all 20 concept plans. The final ranking of concept plans is provided in Table 4.2, with the top prioritized project represented by the rank of 1. The full prioritization calculator is included in Appendix D.

Table 4-2 Final Concept Plan Ranking

Rank	Concept Plan
1	Town and Country Day School
2	Meadow Lake
3	Seay Ave.
4	E. Princess Anne Rd.
5	Fairlawn Recreational Center
6	E. Berkley Ave.
7	Campostella Park
8	Berkley Park
9	Virginia Beach Blvd.
10	Ballentine Blvd. near Virginia Beach Blvd.
11	Lake Taylor Schools
12	Poplar Hall Park
13	Princess Anne Park
14	Arlington Ave.
15	Majestic Ave.
16	Corner Lot at E. Virginia Beach Blvd.
17	Diggs Town Recreation Center
18	Industrial Park Azalea Little League
19	Ballentine Blvd. at NSU Entrance
20	Park Ave.

5. Conclusions and Recommendations

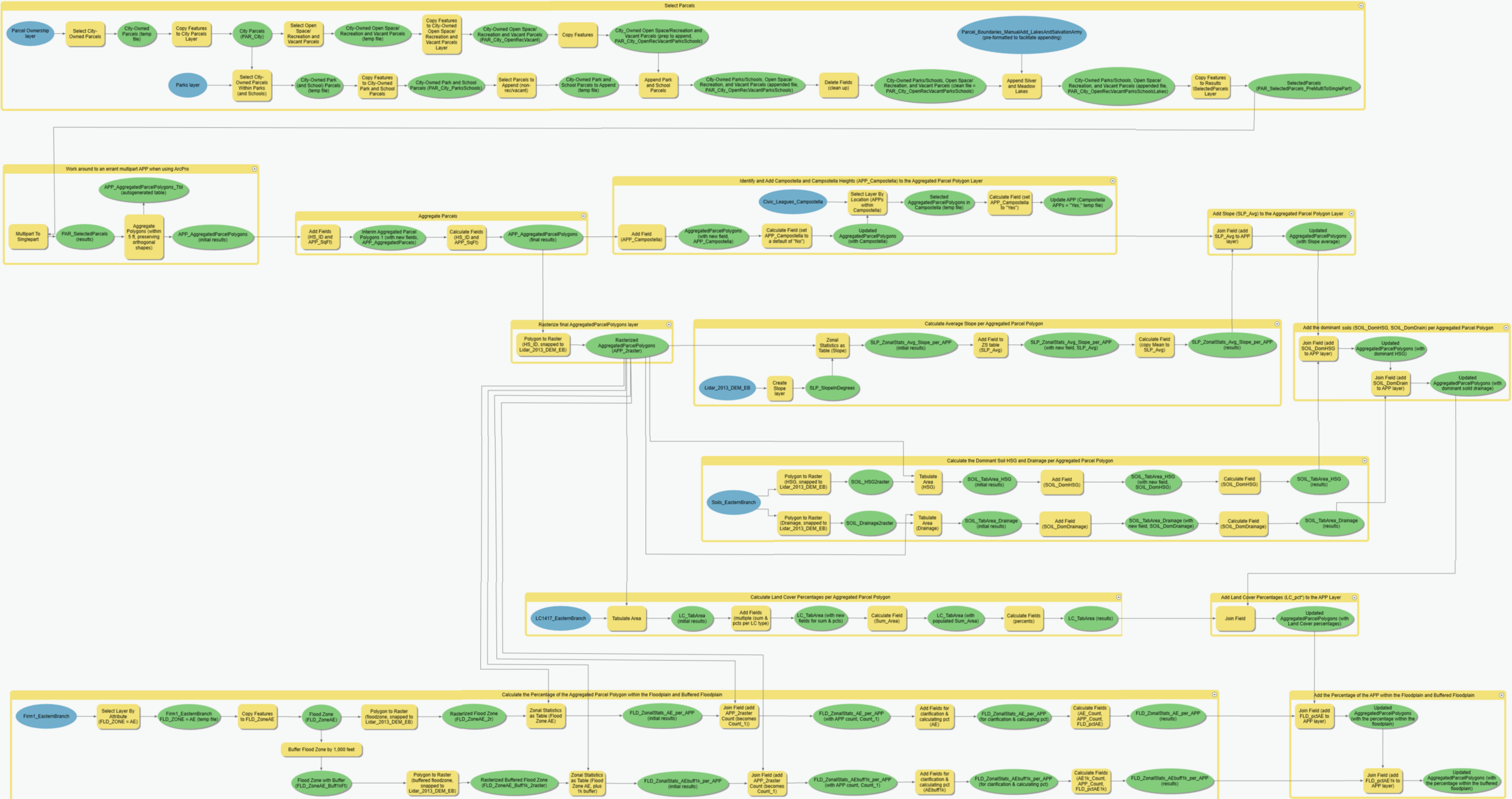
The 20 concepts plans provide a toolbox of potential BMPs that can be applied in the Eastern Branch Watershed and the greater City of Norfolk. The practices have been selected to help reduce flooding and improve water quality. Some BMPs, such as the subsurface gravel wetland and iceberg bioretention, also offer storage benefits with a smaller footprint and reduced maintenance needs.

The prioritization calculator provides an ordered list of projects based on the City's current objectives and values. This prioritization can be re-run if City priorities change causing a re-shuffle in the highest scoring project. The calculator is an adaptable tool which can be used to validate a decision process for implementation.

As general practice, projects, which are identified as having immediate public safety concerns, should receive top priority. The Meadow Lake project site is a good example. This site poses an immediate risk to public safety as the riser structure at the dam is currently uncovered, clogged and non-functional. Hazen recommends that the City conduct maintenance to remove debris and consider design and construction of a replacement structure to improve control of storage volume in the lake.

The BMP opportunities included in this project were selected to include innovative design options. As projects from this list are designed and constructed, Hazen recommends that the City consider post construction monitoring. Through low cost monitoring options, it is possible to evaluate the benefits to flood reduction and water quality improvement. These findings can also be used to enable the City to adapt standard designs for improved function under future conditions related to Sea Level Rise and changing storm conditions.

Appendix A. GIS Parcel Selection Model



Select Parcels
Parcel Ownership layer
Select City-Owned Parcels
City-Owned Parcels (temp file)
Copy Features to City Parcels Layer
City Parcels (PAR_City)
Select Open Space/ Recreation and Vacant Parcels
City-Owned Open Space/ Recreation and Vacant Parcels (temp file)
Copy Features to City-Owned Open Space/ Recreation and Vacant Parcels Layer
City-Owned Open Space/ Recreation and Vacant Parcels (PAR_City_OpenRecVacant)
Copy Features
City_Owned Open Space/Recreation and Vacant Parcels (prep to append, PAR_City_OpenRecVacantParksSchools)
Parcel_Boundaries_ManualAdd_LakesAndSalvationArmy (pre-formatted to facilitate appending)
Parks layer
Select City-Owned Parcels Within Parks (and Schools)
City-Owned Park (and School) Parcels (temp file)
Copy Features to City-Owned Park and School Parcels
City-Owned Park and School Parcels (PAR_City_ParksSchools)
Select Parcels to Append (non-rec/vacant)
City-Owned Park and School Parcels to Append (temp file)
Append Park and School Parcels
City-Owned Parks/Schools, Open Space/ Recreation, and Vacant Parcels (appended file, PAR_City_OpenRecVacantParksSchools)
Delete Fields (clean up)
City-Owned Parks/Schools, Open Space/ Recreation, and Vacant Parcels (clean file = PAR_City_OpenRecVacantParksSchools)
Append Silver and Meadow Lakes
City-Owned Parks/Schools, Open Space/ Recreation, and Vacant Parcels (appended file, PAR_City_OpenRecVacantParksSchoolsLakes)
Copy Features to Results \SelectedParcels Layer
SelectedParcels (PAR_SelectedParcels_PreMultiToSinglePart)
Work around to an errant multipart APP when using ArcPro
APP_AggregatedParcelPolygons_Tbl (autogenerated table)
Multipart To Singlepart
PAR_SelectedParcels (results)
Aggregate Polygons (within 5 ft, preserving orthogonal shapes)
APP_AggregatedParcelPolygons (initial results)
Aggregate Parcels
Add Fields (HS_ID and APP_SqFt)
Interim Aggregated Parcel Polygons 1 (with new fields, APP_AggregatedParcels)
Calculate Fields (HS_ID and APP_SqFt)
APP_AggregatedParcelPolygons (final results)
Identify and Add Campostella and Campostella Heights (APP_Campostella) to the Aggregated Parcel Polygon Layer
Civic_Leagues_Campostella
Select Layer By Location (APPs within Campostella)
Selected AggregatedParcelPolygons in Campostella (temp file)
Calculate Field (set APP_Campostella to "Yes")
Update APP (Campostella APPs = "Yes," temp file)
Add Field (APP_Campostella)
AggregatedParcelPolygons (with new field, APP_Campostella)
Calculate Field (set APP_Campostella to a default of "No")
Updated AggregatedParcelPolygons (with Campostella)
Add Slope (SLP_Avg) to the Aggregated Parcel Polygon Layer
Join Field (add SLP_Avg to APP layer)
Updated AggregatedParcelPolygons (with Slope average)
Rasterize final AggregatedParcelPolygons layer
Polygon to Raster (HS_ID, snapped to Lidar_2013_DEM_EB)
Rasterized AggregatedParcelPolygons (APP_2raster)
Calculate Average Slope per Aggregated Parcel Polygon
Zonal Statistics as Table (Slope)
SLP_ZonalStats_Avg_Slope_per_APP (initial results)
Add Field to ZS table (SLP_Avg)
SLP_ZonalStats_Avg_Slope_per_APP (with new field, SLP_Avg)
Calculate Field (copy Mean to SLP_Avg)
SLP_ZonalStats_Avg_Slope_per_APP (results)
Lidar_2013_DEM_EB
Create Slope layer
SLP_SlopeInDegrees
Add the dominant soils (SOIL_DomHSG, SOIL_DomDrain) per Aggregated Parcel Polygon
Join Field (add SOIL_DomHSG to APP layer)
Updated AggregatedParcelPolygons (with dominant HSG)
Join Field (add SOIL_DomDrain to APP layer)
Updated AggregatedParcelPolygons (with dominant soild drainage)
Calculate the Dominant Soil HSG and Drainage per Aggregated Parcel Polygon
Soils_EasternBranch
Polygon to Raster (HSG, snapped to Lidar_2013_DEM_EB)
SOIL_HSG2raster
Tabulate Area (HSG)
SOIL_TabArea_HSG (initial results)
Add Field (SOIL_DomHSG)
SOIL_TabArea_HSG (with new field, SOIL_DomHSG)
Calculate Field (SOIL_DomHSG)
SOIL_TabArea_HSG (results)
Polygon to Raster (Drainage, snapped to Lidar_2013_DEM_EB)
SOIL_Drainage2raster
Tabulate Area (Drainage)
SOIL_TabArea_Drainage (initial results)
Add Field (SOIL_DomDrainage)
SOIL_TabArea_Drainage (with new field, SOIL_DomDrainage)
Calculate Field (SOIL_DomDrainage)
SOIL_TabArea_Drainage (results)
Calculate Land Cover Percentages per Aggregated Parcel Polygon
LC1417_EasternBranch
Tabulate Area
LC_TabArea (initial results)
Add Fields (multiple (sum & pcts per LC type)
LC_TabArea (with new fields for sum & pcts)
Calculate Field (Sum_Area)
LC_TabArea (with populated Sum_Area)
Calculate Fields (percents)
LC_TabArea (results)
Add Land Cover Percentages (LC_pct*) to the APP Layer
Join Field
Updated AggregatedParcelPolygons (with Land Cover percentages)
Calculate the Percentage of the Aggregated Parcel Polygon within the Floodplain and Buffered Floodplain
Firm1_EasternBranch
Select Layer By Attribute (FLD_ZONE = AE)
Firm1_EasternBranch FLD_ZONE = AE (temp file)
Copy Features to FLD_ZoneAE
Flood Zone (FLD_ZoneAE)
Polygon to Raster (floodzone, snapped to Lidar_2013_DEM_EB)
Rasterized Flood Zone (FLD_ZoneAE_2r)
Zonal Statistics as Table (Flood Zone AE)
FLD_ZonalStats_AE_per_APP (initial results)
Join Field (add APP_2raster Count (becomes Count_1))
FLD_ZonalStats_AE_per_APP (with APP count, Count_1)
Add Fields for clarification & calculating pct (AE)
FLD_ZonalStats_AE_per_APP (for clarification & calculating pct)
Calculate Fields (AE_Count, APP_Count, FLD_pctAE)
FLD_ZonalStats_AE_per_APP (results)
Buffer Flood Zone by 1,000 feet
Flood Zone with Buffer (FLD_ZoneAE_Buff1kFt)
Polygon to Raster (buffered floodzone, snapped to Lidar_2013_DEM_EB)
Rasterized Buffered Flood Zone (FLD_ZoneAE_Buff1k_2raster)
Zonal Statistics as Table (Flood Zone AE, plus 1k buffer)
FLD_ZonalStats_AEbuff1k_per_APP (initial results)
Join Field (add APP_2raster Count (becomes Count_1)
FLD_ZonalStats_AEbuff1k_per_APP (with APP count, Count_1)
Add Fields for clarification & calculating pct (AEbuff1k)
FLD_ZonalStats_AEbuff1k_per_APP (for clarification & calculating pct)
Calculate Fields (AE1k_Count, APP_Count, FLD_pctAE1k)
FLD_ZonalStats_AEbuff1k_per_APP (results)
Add the Percentage of the APP within the Floodplain and Buffered Floodplain
Join Field (add FLD_pctAE to APP layer)
Updated AggregatedParcelPolygons (with the percentage within the floodplain)
Join Field (add FLD_pctAE1k to APP layer)
Updated AggregatedParcelPolygons (with the percentage within the buffered floodplain)

Appendix B. Field Investigation Sites and Addresses

Parcel ID	Parcel Name	Campostella Area	Address Used	NorfolkAir Parcel GPIN(s)	NorfolkAir Ownership	Parcel Notes	Concept Notes	Concept Plan
0ML	Meadow Lake		5398 River Edge Rd	1447975310	City of Norfolk	looks like some waterfront properties do extend into part of the water body but not significantly	Extended pond storage into ditch on Salvation Army's property. Newly designed control structure for its connection to Elizabeth River.	yes
0SL	Silver Lake		5500 Sandpiper Ln	1457060514	City of Norfolk	one parcel	Meadow Lake was chosen over this site due to the immediate need for a new structure (for safety). Silver Lake has a culvert connection under the roadway that appears to be sloped in the wrong direction. Roadway is currently known for flooding out during intense wet weather events and roadway improvements and a control structure would need to be added.	no
002	Corner Lot Conoga St	Y	1629 Conoga St	1436684164	GPMC Properties, LLC	complete site was within one parcel	Not ideal for improvements. No existing infrastructure to tie into, very small grass strips not large enough to add feature to.	no
011	Poplar Hall Park		101 N Military Hwy	1457147587, 1457147717, 1457145730, 1457143609, 1457140356, 1457048661	City of Norfolk	Park is made up of several parcels	Retrofit existing ditch running along side of playground with grass infiltration trench. Potential for a constructed wetland in median in parking lot if water table is favorable.	yes
012	Open Lot Wilson @ E Ind River	Y	1041 Wilson Rd	1436790867	City of Norfolk	complete site was within one parcel	Curb cuts along roadway and tie in of existing stormwater infrastucture (catch basins on roadway) into meandering swales with weirs along downward slope of site towards outfall.	no
031	Culinary Institute		2410 Almeda Ave	1458178650	City of Norfolk	complete site was within one parcel	Has new BMP on site. Not ideal for improvements.	no
035	Campostella Craig St Playground	Y	431,429,427,425 Craig St; 498, 496, 494, 492, 490, Culpepper St; 711 Fairfield Ave	1436397481, 1436398403, 1436398424, 1436398446, 1436397512, 1436397446, 1436397584, 1436398506, 1436398528, 1436398549	City of Norfolk	503 Craig St is neighboring empty parcel (GPIN 1436397315) owned by NRHA.	Curb cuts into trench drains and infiltration feature of porous pavers with subsurface storage.	no
038	Princess Anne Park		1450 Kempsville Rd	1458355689	City of Norfolk	City owns the single parcel that the park sits on	Potential for ROW iceberg bioretention with subsurface storage or infiltration feature such as infiltration trench in swale. Could add precast modular porous pavers around perimeter of basketball court and tie into drop inlets to mitigate play area ponding. Site is near outfall of SW system so could have high water table and be a good site for a piloted constructed wetland.	yes
045	Corner Lot - Park Ace - Across from NSU		815, 819, 823, 827, 829 Park Ave; 1513 Bond St	1437566281, 1437567215, 1437567351, 1437567374, 1437567397, 1437568450, 1437568403	NRHA	while NRHA owns all of the parcels lining this roadway, do not think it will be an issue due to our plan for this area to be a ROW feature	Great opportunity for showcasing a "green street" in Norfolk right by a college campus. Large grass strips in the ROW beside sidewalk could be used. Curb cuts from road into an icebert bioretnention with subsurface storage/infiltration practice since there is no existing infrastructure to tie into. Very replicable throughout the City.	yes
069	Industrial Park Azaela Little League		1147 and 1176 Pineridge Rd	1448700665, 1448716351	City of Norfolk	the park sits on two different parcels both owned by the City, is DIRECTLY adjacent to Broad Creek	In parking lot could do precast modular porous pavement and tie into catch basins downstream. Opportunity for ROW feature in grass strip beside sidewalk with microbioretnention depending on the water table/iceberg bioretention. Library downspouts could be directed to feature in greenspace to right of building. Open space median infront of library has large enough footprint for a larger highlighted feature.	yes
070	Open Space Corner of Ballentine and VB Blvd (gas station)		985 Ballentine Blvd, 986 Bellmore Ave	1447176670, 1447174526	City of Norfolk	Lot is already subdivided, 985 Ballentine is much smaller and could be ideal to do GI improvements on and leave lot 986 Bellmore open for potential development	Standing water area could be great location for a gravel wetland. This could incorportate flow from sidewalks,downspouts from neighboring building, and tie into existing infrastructure. Could double as an amenity for the bus stop.	yes

Parcel ID	Parcel Name	Campostella Area	Address Used	NorfolkAir Parcel GPIN(s)	NorfolkAir Ownership	Parcel Notes	Concept Notes	Concept Plan
071E	Ingleside Elementary School		960 Ingleside Rd	1447477945	City of Norfolk	Elementary school sits on same parcel as rec center	Grades at this site are not favorable for any features in the available open space or retrofitting existing bioretention. Could be opportunity for handling parking lot ponding issues with porous pavement in parking spots and subsurface storage that ties into existing infrastructure.	no
071R	Ingleside Rec Center		960 Ingleside Rd	1447477945	City of Norfolk	Elementary school sits on same parcel as rec center	Site already has a rain garden and a rain barrel catching the downspouts from the building. Could do porous pavement with subsurface storage but would not have large impact on the site.	no
073	Ballentine at NSU Entrance		801 Ballentine Blvd, 825 Ballentine Blvd	1447160389, 1447163626	NRHA	801 Ballentine was the parcel of focus for our conceptual plan ideas	There is a lot of drainage that could be captured at this site offering large benefits from a feature. Large enough space for ROW feature with an underdrain under sidewalk tying into meandering swale. Cobenefits with the bus stop, NSU entrance, and it is in public eye on major Norfolk roadway - great promo of green infrastructure.	yes
083	Water tower	Y	921 Halifax St	1436370443	City of Norfolk	small sliver of land right beside fenced in water tower property	Smaller lot that has catch basins on both sides. Would have to look further into drainage patterns to see if this site is worth a feature or not. Would not be a good site for showcasing since it is out of public eye	no
087	Campostella Park	Y	1501 Campostella Rd, 1550 Vernon Dr	1436880079, 1436779838	NRHA	NRHA owns ALL of the land, the only thing that the City of Norfolk owns is the WW PS building on the 1501 Campostella parcel	Potential for several curb cuts into meandering swales that all come together as one major feature/daylight (gravel swale or iceberg bioretention) and tie back into the existing DI at the low point of the site.	yes
094	Median - Halifax @ E Liberty St	y	Halifax St at E Liberty St	1436375605, 1436375529, 1436375782	NRHA	This lot is subdivided into 3 smaller lots by NRHA. No definite street number address - had to pan to correct location on map	Is used as makeshift parking lot and would be difficult to discourage nearby residents from using this as parking. Smaller median site that could be a good median duplication project that could be done throughout the city. Has existing infrastructure but would need to check the drainage pattern to see what could be captured by a feature on this site.	no
096	Open Space near Kroc Center		3000 E Virginia Beach Blvd	1447183751	City of Norfolk	neighbors the Kroc Center which is owned by Salvation Army	The Kroc Center's large detention pond is neighboring this site but appeared in GIS to be out of the boundary of the watershed. Need to check drainage pattern and where the SW system conveys water. Site could be difficult for addition of features due to the trees that run along the ROW.	no
099	Lake Taylor Middle & High School		1380 Kempsville Rd	1458548391	City of Norfolk	Middle and high school are all considered to be on one large City parcel	Large space in medians for possible detention opportunity. Large parking lot has clear ponding issues that could be handled with precast modular porous pavement and subsurface storage that ties into existing CBs. Could also do curb cuts into grass strips in parking lot leading into a smaller infiltration feature.	yes
104	Corner Lot off VB Blvd		2900 E Virginia Beach Blvd	1447074701	City of Norfolk	corner lot that has not been subdivided, right next to an apartment building	Potential for rerouting roadway drainage to this site and trench the catch basins captured flow under the sidewalk into some sort of retention feature. Bus stop is at this siteand could put up shelter and have retention as an amenity or make this retention and signage incorporated into part of a small city pop up park.	yes
121	Park Crescent - neighborhood near NSU		2724 Park Crescent	1437967510	NRHA	large park like space for the residential area - GI feature could be a nice amenity	Currently has no existing SW infrastructure to tie into, not much space to work with that would not interfere with play space. Could change brick to permeable brick pavers with subsurface storage if water table is appropriate. Also potential for ROW grass strip infiltration feature.	no

Parcel ID	Parcel Name	Campostella Area	Address Used	NorfolkAir Parcel GPIN(s)	NorfolkAir Ownership	Parcel Notes	Concept Notes	Concept Plan
130	US Gypsum Company	Y	1350 South Main St	1436161888	United States Gypsum Co	it appears that full site evaluated in field is on private property	Visited site and appears to be owned by Gypsum Co.	no
136	Berkley Park	Y	706 Walker Ave	1436382593, 1436384772	City of Norfolk	full park is on two parcels	Could add in feature with curb cuts/depressions leading to infiltration practice or gravel wetland with subsurface storage on perimeter of volleyball/tennis play area to allow flow from court to mitigate ponding	yes
142	Diggs Town Rec Center	Y	1401 Melon St, 1530 Cypress St	1436787715, 1436782689	NRHA, City of Norfolk	Our conceptual plan formulated in the field composed pieces of both NRHA and Norfolk's parcels (baseket ball court is on Norfolk's property, but swale would be on NRHA's)	Precast modular porous pavement around perimeter of basketball court with traditional pavement in center. Site already has favorable grading for a swale, just needs more definition. Would add in a geotex grid material mat with grass as an access path for maintenance vac trucks to get to court.	yes
145	Azaela Open Space		3760 E Virginia Beach Blvd	1447587958	not listed	showed up very strange in NorfolkAir	Appears to be a high point so not much flow would be able to be captured by a feature here. Gas line also marked down length of site. Not an ideal site.	no
151		Y	2218, 2210, 2206, 2200, 2216 E Indian River Rd	1446091747, 1446090851, 1446090823, 1436999875, 1446091900	City of Norfolk	Random subdivided parcel 2214 E Indian River Rd (GPIN 1446090880) is privately owned by Reuben Carder	Site didn't have opportunity to capture and treat much flow before the outfall. There were spots of greenspace but they were all directly downstream of existing catch basins and would only catch extremely small drainage areas from street sheet flow.	no
156	North Fox Hall Playground		2651 Bartin St	1448861254	City of Norfolk	Playground sits on one large parcel that is owned by City	ROW grass strip area feature with curb cuts into an infiltration feature lining the sidewalk. Other side of site has CBs that could potentially be tied into. Playground is good area for educational signage and public engagement.	no
173	Open Lot at Poppleton by bridge and RR	Y	Poppleton St at E Indian River Rd	1446098233, 1446098280, 1446099129	Commonwealth of VA, City of Norfolk	parcel owned by Mt Zion Interdemoninational Com Church to the right (GPIN 1446190172)	Opportunity for a gravel swale or wetland OR iceberg bioretention - all depends on water table. Could be repeatable for parcels near bottoms of bridges. This site is out of the public eye so not ideal for GI promo.	no
174E	Fairlawn Elementary School		1014 Kempsville Rd	1457792862	City of Norfolk	another tax account under Verizon Virginia, Inc is also on this parcel - may need to look into this to see if they partially own. Elementary school and rec center are all on same parcel	Several downspots on front of building where runoff could be captured by an infiltration feature that is incorporated in with flowerbeds landscaping infront of school building. Parking lot is in poor condition and shows history of ponding issues, could do porous pavers here with subsurface storage tying into existing infrastructure.	no
174R	Fairlawn Rec Center		1014 Kempsville Rd	1457792862	City of Norfolk	another tax account under Verizon Virginia, Inc is also on this parcel - may need to look into this to see if they partially own. Elementary school and rec center are all on same parcel	Precast modular porous pavement around perimeter of basketball court with traditional pavement in center. Potential grass areas near courts that could be utilized for detention/swales. Ponding in parking lot could be handled with porous pavers and subsruf's storage. At time of assessment they had large amount of standing water in grass areas that appeared to be from downspouts runoff, could do a subsurface gravel wetland or constructed wetland that captures downspout flow and incorporate it into buildings landscaping.	yes
SA	Salvation Army Site		5525 Raby Rd	1457095580	The Salvation Army	from client "they have shown interest in teaming up to do something at this site and will contribute to the funding of a GI project here"	Site has potential for extending storage of Meadow Lake into this area. Salvation Army has expressed interest. Already had heavy restoration work being done on the channel.	no

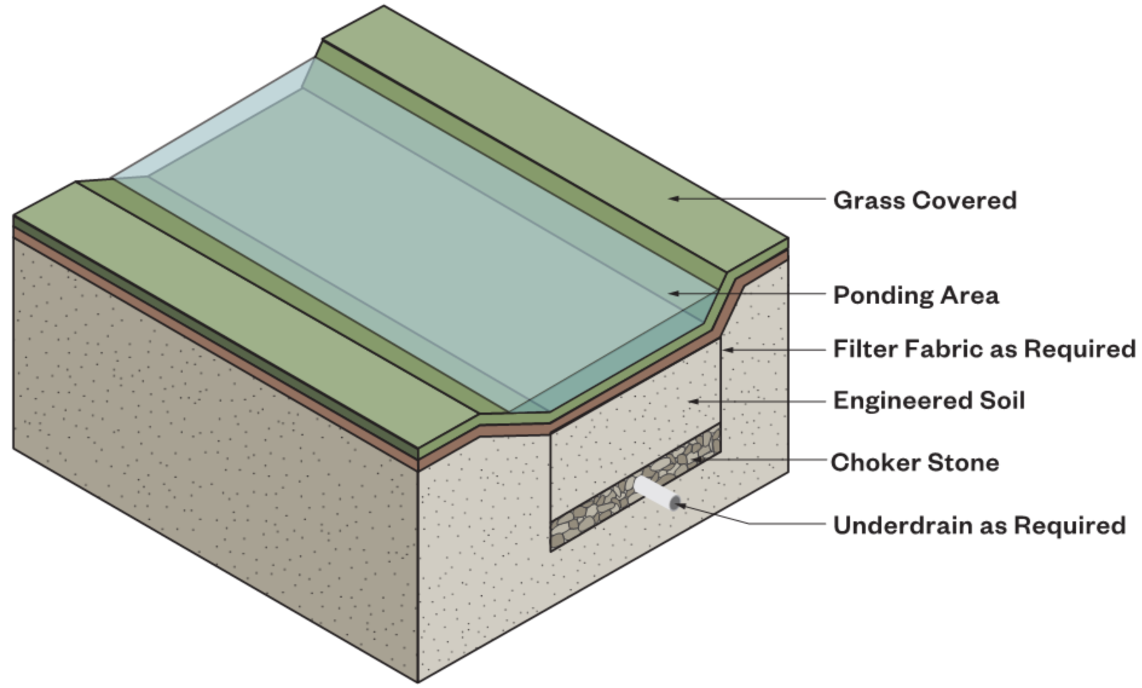
Parcel ID	Parcel Name	Campostella Area	Address Used	NorfolkAir Parcel GPIN(s)	NorfolkAir Ownership	Parcel Notes	Concept Notes	Concept Plan
0AA	City Recommended - Arlington Avenue		2128 Arlington Ave	ROW	ROW	ROW	Good opportunity for a right of way feature. Appears to have repeated in shallowly depressed area parallel to road. Good space for linear right of way feature with subsurface storage or surface conveyance. Infiltration trench or a swale would be a good fit.	yes
SA	City Recommended - Seay Avenue		3494 Seay Ave	ROW	ROW	ROW	Site has grassy ROW space along the side of the N side of the roadway and valley gutter along S side. The west end of the road had ponding and an open grassy space that could be utilized to capture the ponding water. Infiltration basin on end of street could be good feature. Might also have potential of other ROW features along N and S of road to tie into the infiltration basin	yes
TCD	City Recommended - Town and Country Day School		1421 Kempsville Rd	ROW	ROW	ROW	Area in front of this school is large, depending on where the ponding is there could be potential to have a feature in the R/W with subsurface detention that could tie into existing SW piping. Can't take away impervious area in parking lot due to dimensions and needed turn around space.	yes
VBB	R/W Space on VB Blvd		3777 E VB Blvd	ROW	ROW	ROW	Ponding slopes towards the NE corner of the intersection. Could be easily solved with installation of additional catch basin on corner. Trash and sediment could be addressed with addition of a hydrodynamic separator.	yes
EBA	R/W Space on Berkley Ave @ Frederick St		616 Fauquier St	ROW	ROW	ROW	Opportunity to capture roadway sheetflow into a feature that has large subsurface detention in the median. This could relieve the existing persistant ponding issue. Might need added capacity of stormwater chambers or pipe detention. Has a curb around median so feature would need curb cuts to allow sheet flow into feature.	yes
EPA	R/W Space on E Princess Ann		3801 E Princess Anne Rd	ROW	ROW	ROW	Opportunity to capture roadway sheetflow into a feature that has large subsurface detention in the median. This could relieve the existing persistant ponding issue. Might need added capacity of stormwater chambers or pipe detention. Median is flush with roadway and center is depressed, would not need curb cuts for this type of design at this site.	yes
MAJ	R/W Space at Majestic Ave and E VB Blvd		2630 Myrtle Ave	ROW	ROW	ROW	Currently does not connect to any infrastructure--drainage has nowhere to go. Litter is a big issue. Catch basins located on VB Blvd that a feature overflow could tie into. Consider infiltration trench--stone or grass covered. Residential fences are within the R/W. There are also 2 driveways.	yes

Appendix C. Concept Plans

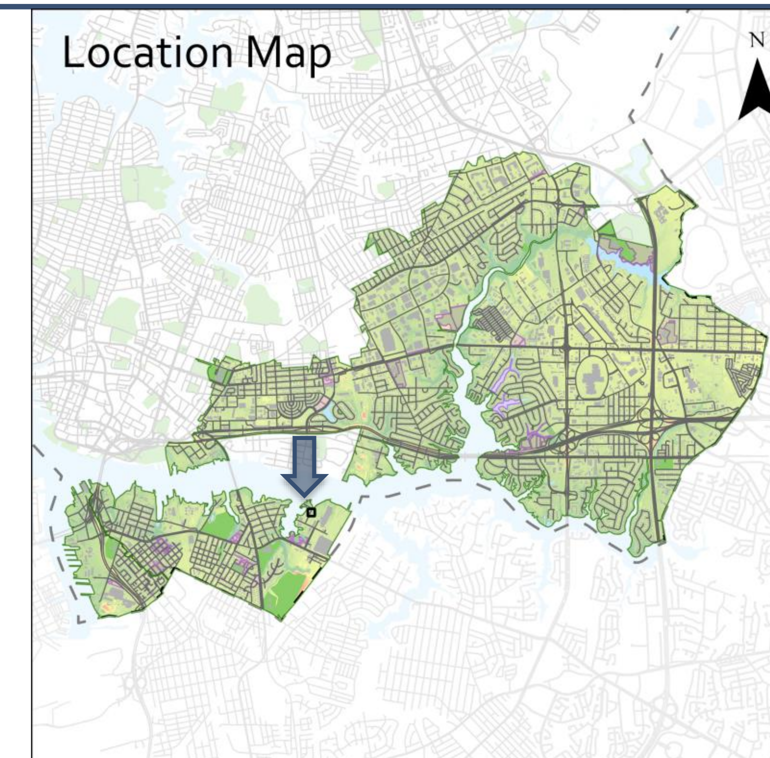
Arlington Avenue
Concept Overview


Proposed Site


Proposed Site



Dry Swale



Drainage Area Map

0AA – Arlington Ave.
Dry Swale

Existing Conditions

The east end of Arlington Ave. at the intersection of Decker St. has repeated reports of flooding issues after wet weather events. During the field visit there was visible ponding off the roadside with drainage depressions in the grass areas indicating persistent ponding at the site. The existing grading of the roadside has no definition for capturing wet weather flow for conveyance to the stormwater network. Existing stormwater piping runs under Decker St. with structures near the area of ponding. The site captures drainage from 0.13 acres of 18% impervious that includes sheet flow directed towards the right-of-way space. The next page provides additional site photographs.

Proposed Improvement

The proposed dry swale will run along the right-of-way on Decker St., starting at the intersection of Arlington Ave. The feature will consist of a grass top dry swale with a subsurface layer of bioretention soils, as well as a stone storage layer with an underdrain tying into an existing stormwater structure. The downstream end of the swale will have an outlet structure and discharge to the existing stormwater structure at its downstream end. The entire practice will have the potential to manage at least 1” of runoff from up to 0.13 acres of drainage in the area, providing stormwater conveyance to relieve the localized ponding issues on this site. Stormwater runoff routing may require subsurface utility relocation or coordination within the practice footprint location.

Type: Dry Swale
Address: 2128 Arlington Ave
Area Managed: 0.13 acres

Conceptual Level Estimates:

Construction Cost: $23,000
TN Load Reduction: 0.5 lb/yr
TP Load Reduction: 0.1 lb/yr
TSS Load Reduction: 20 lb/yr

WQ Treatment Volume: 140 ft^3
Cost/Storage Volume: $166/$ft^3$
TN Reduction Cost: $46,000/lb/yr
TP Reduction Cost: $233,000/lb/yr
TSS Reduction Cost: $1,200/lb/yr

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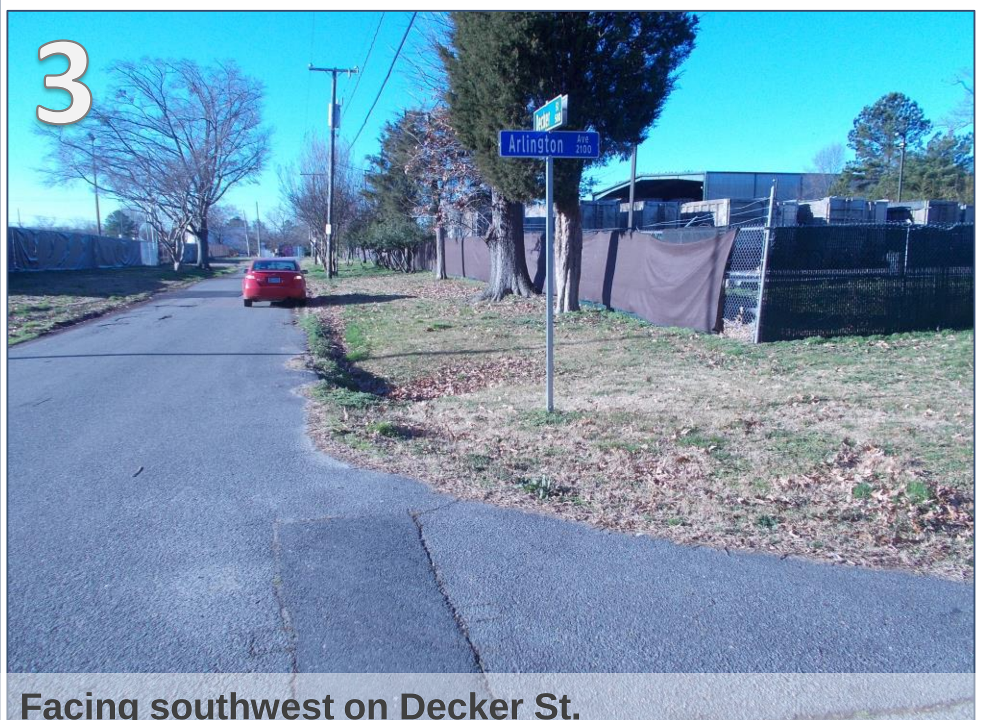
Arlington Avenue
Concept Overview

Facing northwest at east end of Arlington Ave.

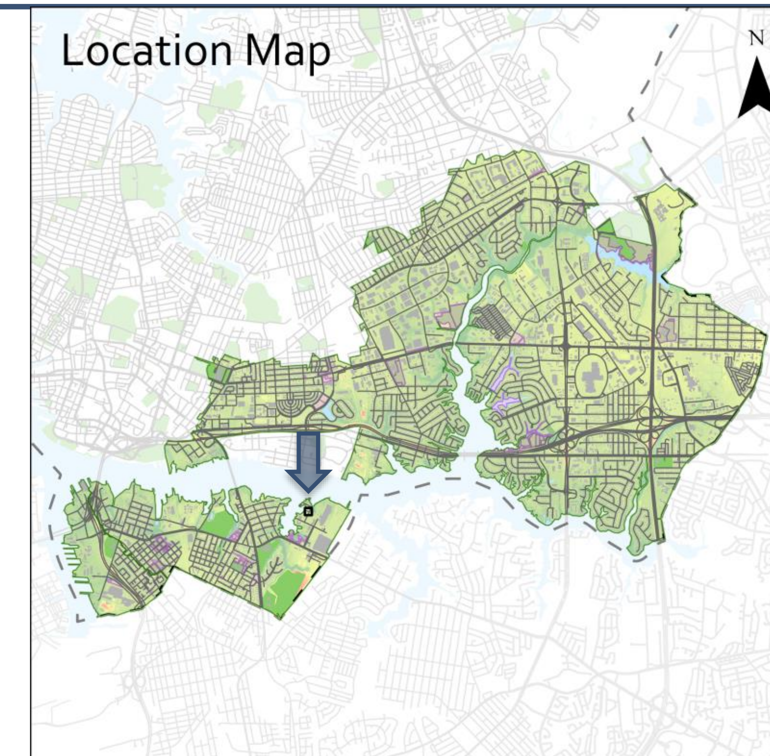
Facing northeast on Decker St.

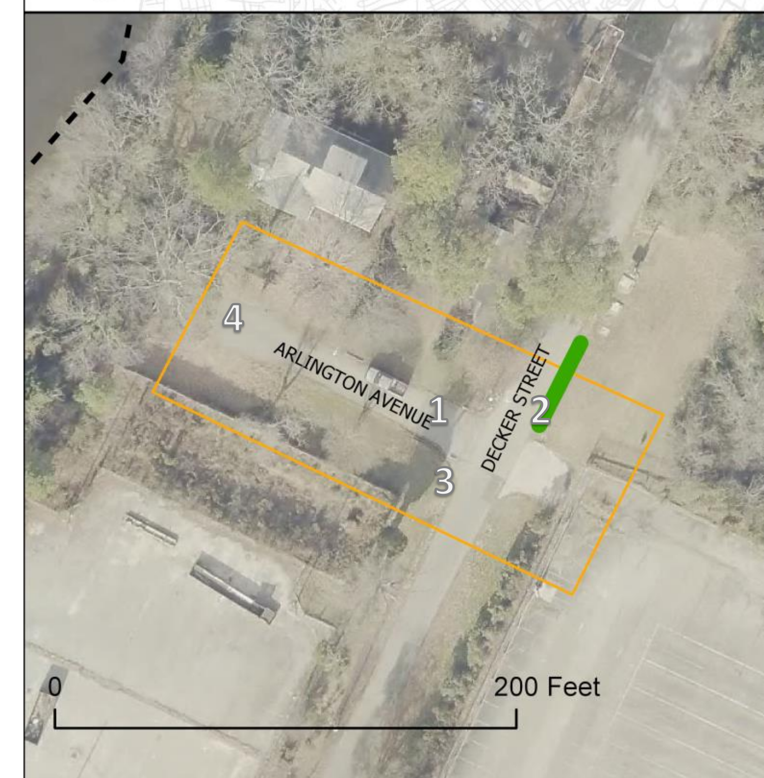


Facing southwest on Decker St.

Facing northwest at west end of Arlington Ave.

See inset map on the right for photograph locations





0AA – Arlington Ave.
Dry Swale

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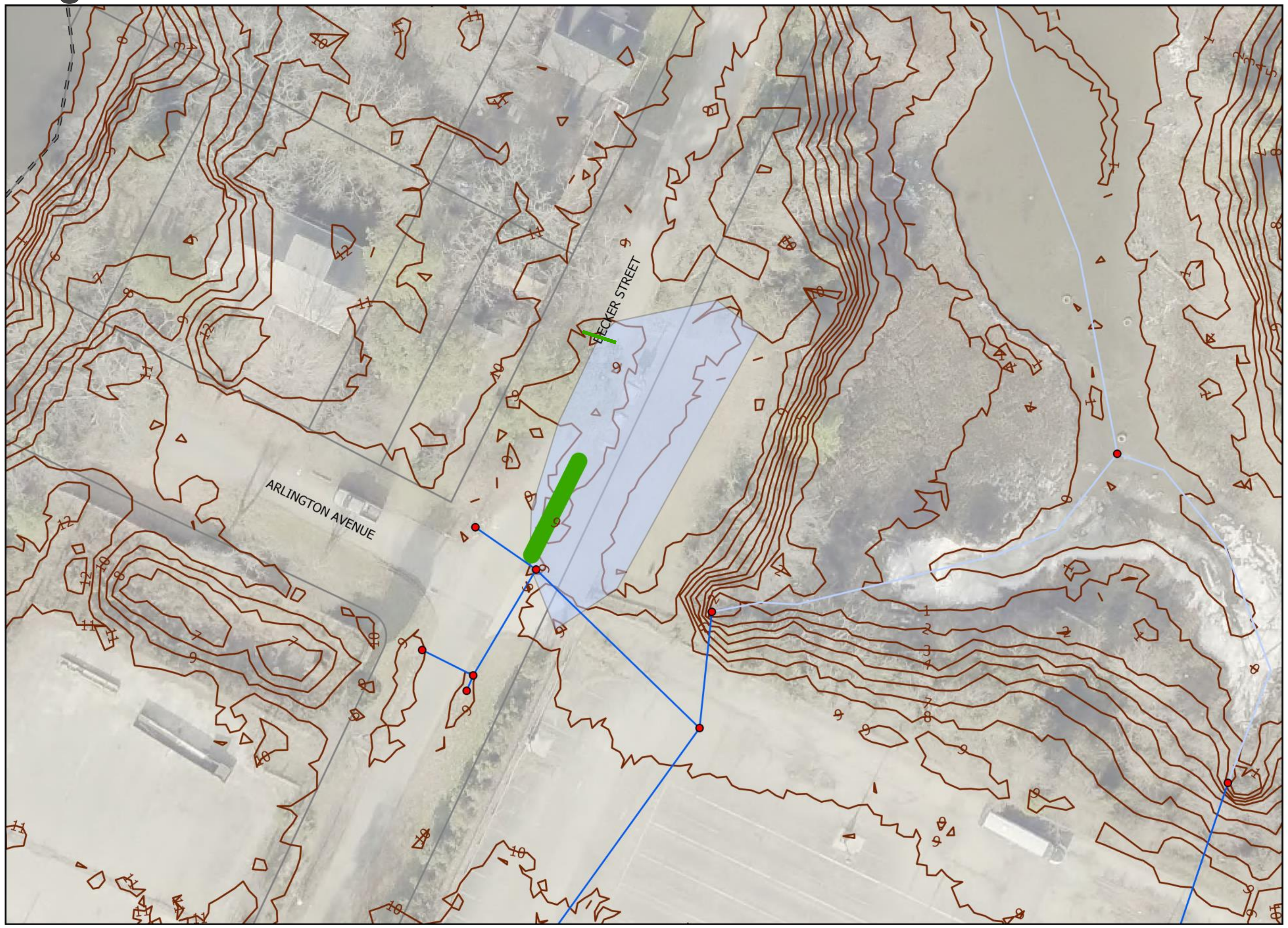
Arlington Avenue

Drainage Area Plan View



LEGEND

- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

Alternative Design Options:

- Right-of-way infiltration trench in same location as the proposed swale
- Infiltration trench would allow for a higher subsurface storage volume
- Underdrain from infiltration trench would tie into an outlet structure and discharge back into the existing system

0AA – Arlington Ave.
Dry Swale

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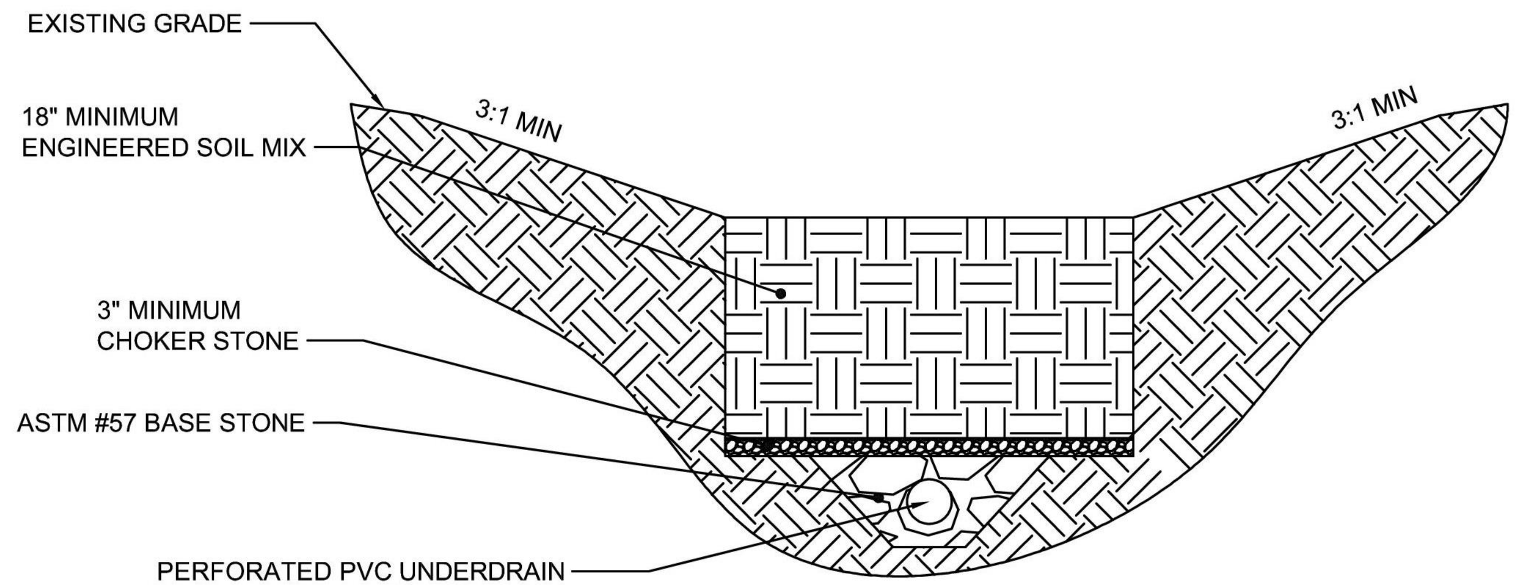
Conceptual Design – Not for Construction

Arlington Avenue
Dry Swale Standard Detail



DRY SWALE
(NOT TO SCALE)

0AA – Arlington Ave. Dry Swale	
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Arlington Avenue

Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 18\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.21 in$
  - $A = 5{,}633\ ft^2$
- $WQ_V = 100\ ft^3$

Calculate full storage volume provided

- $Vol_{treatment} = (Area_{ponding} + Area_{subsurface})\frac{1}{2} \times D_{ponding} + Area_{subsurface}(D_{soil} \times Porosity_{soil} + D_{stone} \times Porosity_{stone})$
  - $Area_{ponding} = 270 ft^2$
  - $Area_{subsurface} = 80 ft^2$
  - $D_{ponding} = 9\ in$
  - $D_{soil} = 1.5\ ft$
  - $Porosity_{soil} = 0.25$
  - $D_{stone} = 0.25\ ft$
  - $Porosity_{stone} = 0.4$
- $Vol_{treatment} = 140 ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = 0.13\ ac$
  - $\%_{impervious} = 18\%$
  - $\%_{pervious} = 82\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**0.1 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**1.0 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**26 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	52%[2]	**0.1 lb/yr**
TN	55%[2]	**0.5 lb/yr**
TSS	74%[3]	**20 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Dry Swale Specification No. 10, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

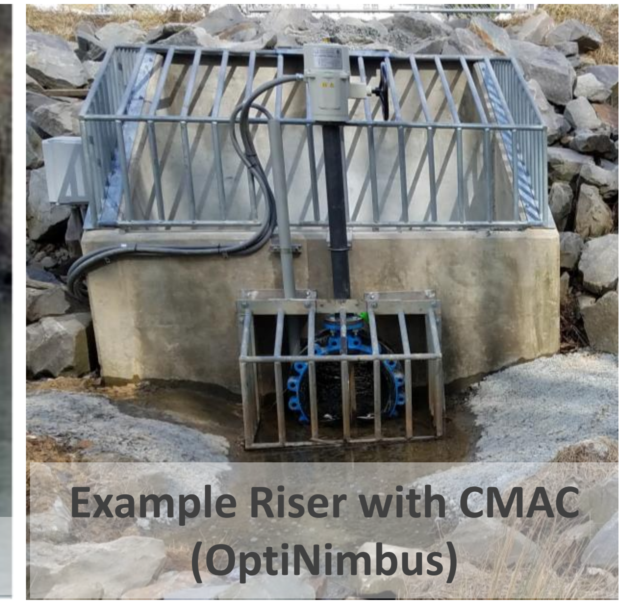
Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 76%, TN: 74%, TSS: 74%).

Meadow Lake

Concept Overview


Proposed Site


Riser with Pyramid Trash Rack


Example Riser with CMAC (OptiNimbus)

Existing Conditions

Meadow Lake, roughly 8 acres in size, captures stormwater runoff from a drainage area of approximately 180 acres. The outlet structure is directly adjacent to the Lake dam. The riser opening has no trash rack or exclusion fencing. This creates a safety hazard and allows debris to build up and reduce effective hydraulic capacity of the structure. Currently, properties adjacent to the lake are known to experience flooding.

Proposed Improvement

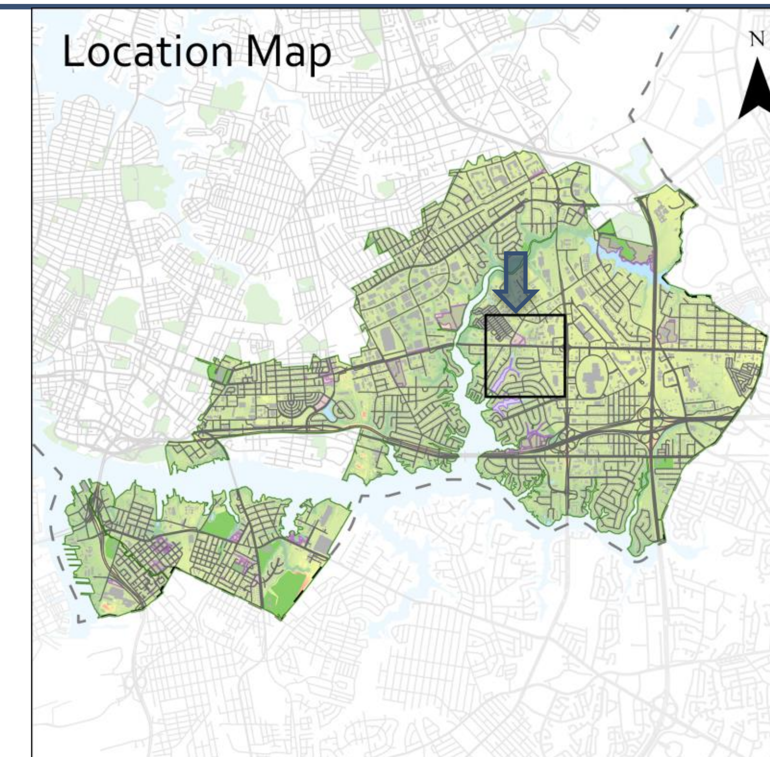
The proposed improvements include installing a trash rack/debris cage for safety and a continuous monitoring and adaptive control (CMAC) solution that enables water levels of Meadow Lake to be drawn down before forecasted storms. The reduced water surface elevation will allow for additional storage volume associated with storm runoff. The basic components consist of a new drawdown structure (or modified existing structure), valve, and weather receiver connected to the National Weather Service. An instrumentation and controls (I&C) system would be developed to allow for automatic opening of the valve prior to the beginning of a predicted storm event. The I&C system will also control pumps, if required.

At the concept level, several assumptions were made regarding the existing broad-crested weir and tailwater conditions:

- Surface area of elevations below water surface assumed to equal the water surface.
- Flap valve to prevent backflow.
- Existing weir elevation at elevation 1.00 ft based on LiDAR topography of the water surface.
- Existing 42” outlet pipe per Norfolk GIS; Inv -4.00’ per field observation (no visible pipe).
- Tailwater conditions are dictated by tidal Elizabeth River.

The design of the system is highly dependent on these assumptions. During detailed design, components will need to be confirmed to size the drawdown structure and orifice/weir to maximize the available storage volume during a storm event. The design will support optimization of the timing for valve opening relative to the start of a storm event. It is anticipated that a pump will be required due to the tailwater conditions in the Elizabeth River during rising and high tide.

Location Map



Drainage Area Map

0ML – Meadow Lake
Riser Rehabilitation and Actuated Controls

Type: Riser Rehab and Actuated Controls

Address: 5398 River Edge Rd.

Area Managed: Lake Surface Area of 7.9 ac

Conceptual Level Estimates:

Construction Cost: $150,000 for retrofit of existing riser

Storage Volume: 490,000 ft^3

Cost/Storage Volume: $3.27/$ft^3$

Load Reduction: 0 lb/yr

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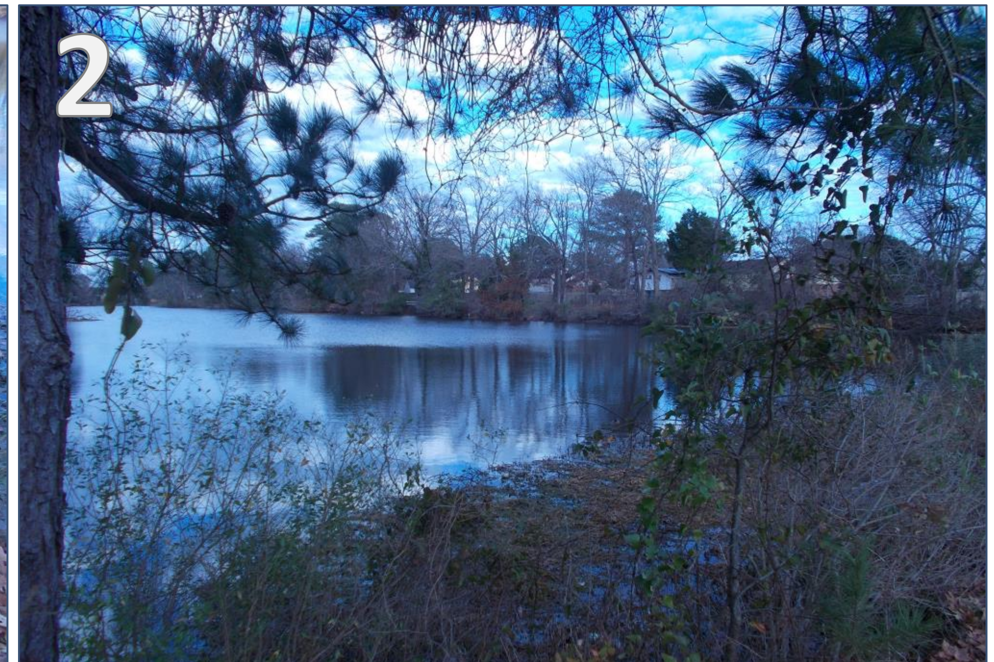
Conceptual Design – Not for Construction

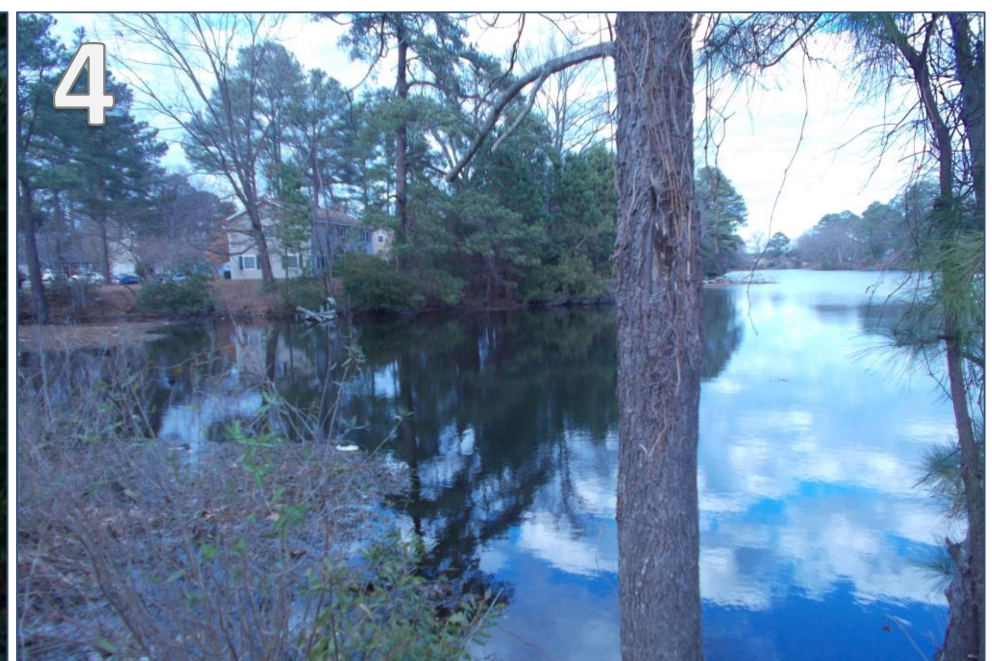
Meadow Lake
Concept Overview

Existing debris filled outlet structure at Meadow Lake



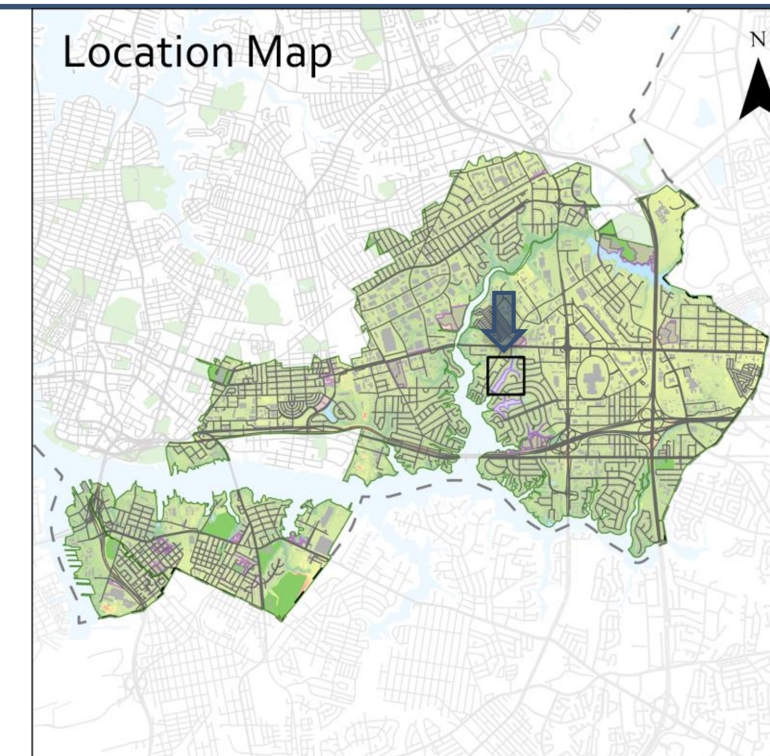
Facing east towards Meadow Lake

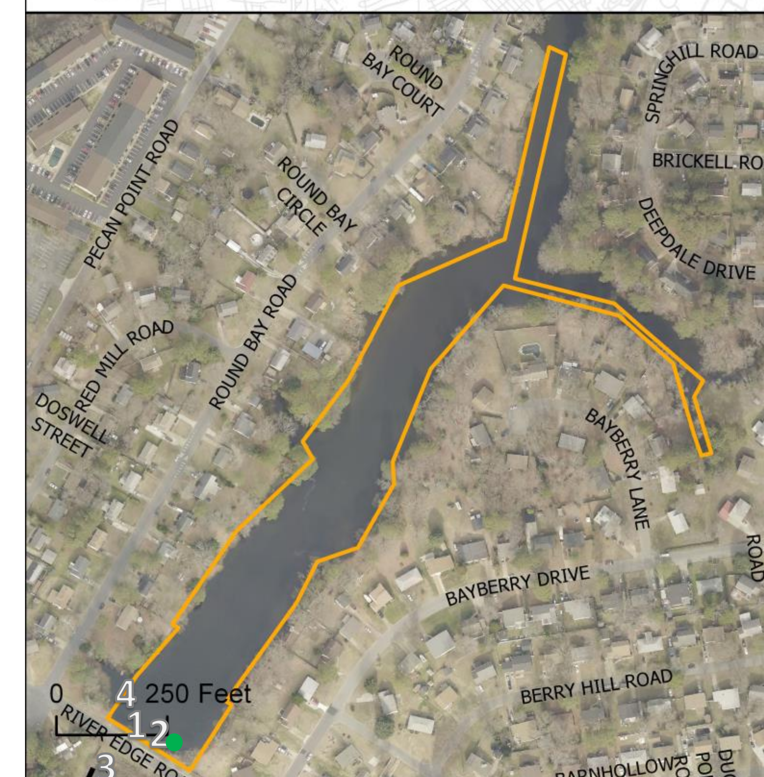
Facing SW towards discharge point in Elizabeth River



Facing north towards Meadow Lake

See inset map on the right for photograph locations





0ML – Meadow Lake
Riser Rehabilitation and Actuated Controls

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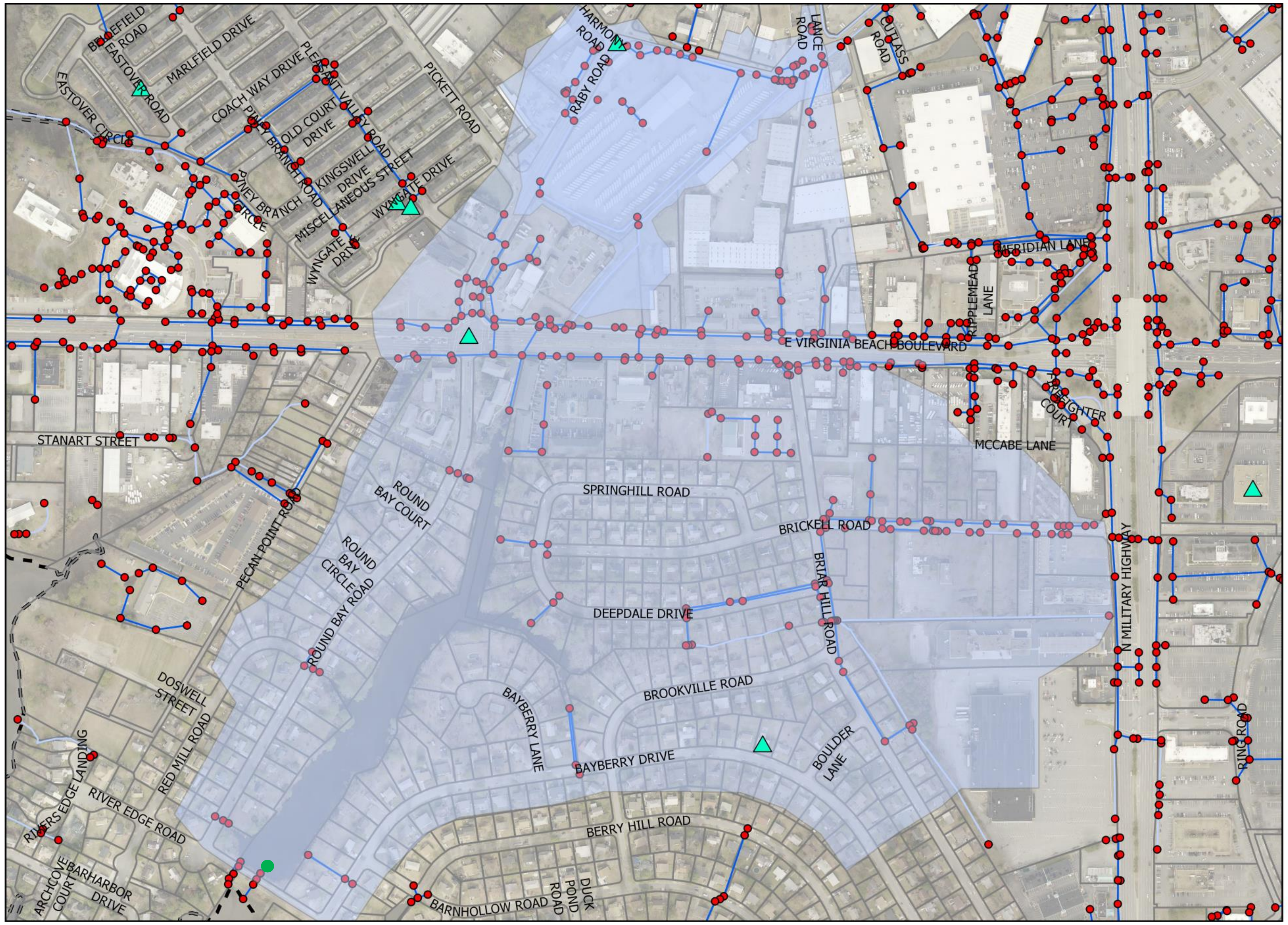
Conceptual Design – Not for Construction

Meadow Lake

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 125250 500 750 1,000 1,250 Feet

Design Notes:
- Multiple manufactures provide continuous monitoring and adaptive control (CMAC) solutions. When options are evaluated, the ability of a system to interact with existing City SCADA will be an important factor to consider.
- Possible systems for evaluation include, but are not limited to, ACF smartPOND, ALERT Stormwater Control, and OptiRTC.

0ML – Meadow Lake
Riser Rehabilitation and Actuated Controls

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Conceptual Design – Not for Construction

Meadow Lake
Design Calculations

Composite Curve Number Calculation

Land Use [a]	Area (ac) [b]	HSG [c]	CN [d]
Open Water (Lake)	7.9	-	98
Residential (1/4-acre lots)	80.3	C	83
Residential (town houses)	8.0	D	92
Urban: Industrial	75.6	D	93
Impervious: Highway	9.0	D	98
Total	180.8		89.0

[a] Source: Estimation from Google Earth 2019 Imagery
[b] Area delineated with AutoCAD Civil 3D 2018 Software
[c] Source: USDA Web Soil Survey
[d] Source: NRCS TR-55, Table 2-2a

Hydrologic and drainage data were modeled in HydroCAD software to determine the effect of drawdown on the lake storage volume. Peak flows were determined using the NRCS TR-20 method with SCS Type II 24-hour Storm Events. A time of concentration of 27 minutes was calculated using the NRCS Part 630 Velocity Method. The calculated curve number and time of concentration are consistent with a highly developed watershed such as this, however, a more precise analysis of both is warranted as part of a more detailed feasibility study or full design project.

Lake Stage-Storage

Elev	Surface Area (ac) [a]	Inc. Vol (cf)	Cumul. Vol (cf)	Notes
-1.0	4.9 [b]	0	0	
0.0	4.9	213,880	213,880	
1.0	7.9	279,655	493,535	Assumed existing weir / water surface elevation
2.0	9.7	383,546	877,081	
3.0	10.5	439,520	1,316,601	
4.0	11.4	476,111	1,792,712	
5.0	12.2	512,701	2,305,413	
6.0	13.3	555,172	2,860,585	Approximate road elevation

[a] Area obtained from LiDAR
[b] Surface area below the water surface assumed to equal the water surface

Peak Flow Data[a]

	10-yr	25-yr	50-yr	100-yr
Flow Into Pond	690	890	1,070	1,240
Lake Outflow (Existing) [b]	140	150	220	410
Lake Outflow (Proposed) [c]	130	140	150	280
Peak Reduction from Drawdown	7%	5%	54%	47%

[a] Assume Tailwater: -2.0 ft
[b] Assume existing weir elevation: 1.0 ft
[c] Proposed 24” orifice inv: -1.0 ft

Water Surface Elevations (WSE) were obtained from the HydroCAD. Scenarios were computed for WSE based on three tailwater conditions: minimum, maximum, and average. Tidal data were obtained from the nearest USGS Gauge with at least 1 year of tidal data, USGS Gauge 0204288721 Elizabeth River at Route 165 at Virginia Beach, VA. The water surface elevation, as modeled, will draw down by approximately 2.0 feet in 24 hours when modeled by gravity. However, because of the variable tidal levels reported at the USGS Gauge (-2.0 MSL to +4.0 MSL), a pump may be required to draw down the lake level during rising and high tides.

Meadow Lake
Design Calculations

Estimated Water Surface Elevation (WSE) Reductions

	Tailwater Condition [a]		
	Min [-2.0 ft]	Avg [1.0 ft]	Max [4.0 ft]
Lake Storage Gained (Gravity) (cf)	493,535	0	0
Lake Storage Gained (Pump) (cf)	N/A	493,535	493,535
Results - 10-Year Storm			
Existing Lake Peak WSE [b]	3.8	4.1	5.0
Proposed Lake Peak WSE [c]	3.1	3.6	4.4
Results - 25-Year Storm			
Existing Lake Peak WSE [b]	4.7	5.0	5.5
Proposed Lake Peak WSE [c]	4.0	4.6	5.1
Results - 50-Year Storm			
Existing Lake Peak WSE [b]	5.3	5.4	5.8
Proposed Lake Peak WSE [c]	4.8	5.3	5.5
Results - 100-Year Storm			
Existing Lake Peak WSE [b]	5.6	5.7	>6
Proposed Lake Peak WSE [c]	5.4	5.6	5.8

[a] Tailwater from a range of Tidal data at Elizabeth River – minimum, average, and maximum reported values from Mar 2018 – Mar 2019
[b] Assume existing weir elevation = 1.00 ft
[c] Proposed 24" orifice at inv = -1.00 ft

Estimated Annual Pollutant Load Reduction

- The primary focus of this retrofit is safety and flood reduction.
- There may be limited water quality benefits, but Chesapeake Bay TMDL credits are not clearly established when CMAC systems are added to a non-traditional BMPs such as Meadow Lake.

Cost Estimation Notes

- The estimated costs for this project are based on a retrofit of the existing riser structure.
- If a new riser is required, the construction cost may increase.
- The need and size of pump will also significantly impact cost estimates for this project.

0ML – Meadow Lake Riser Rehabilitation and Actuated Controls	
The City of Norfolk	Hazen
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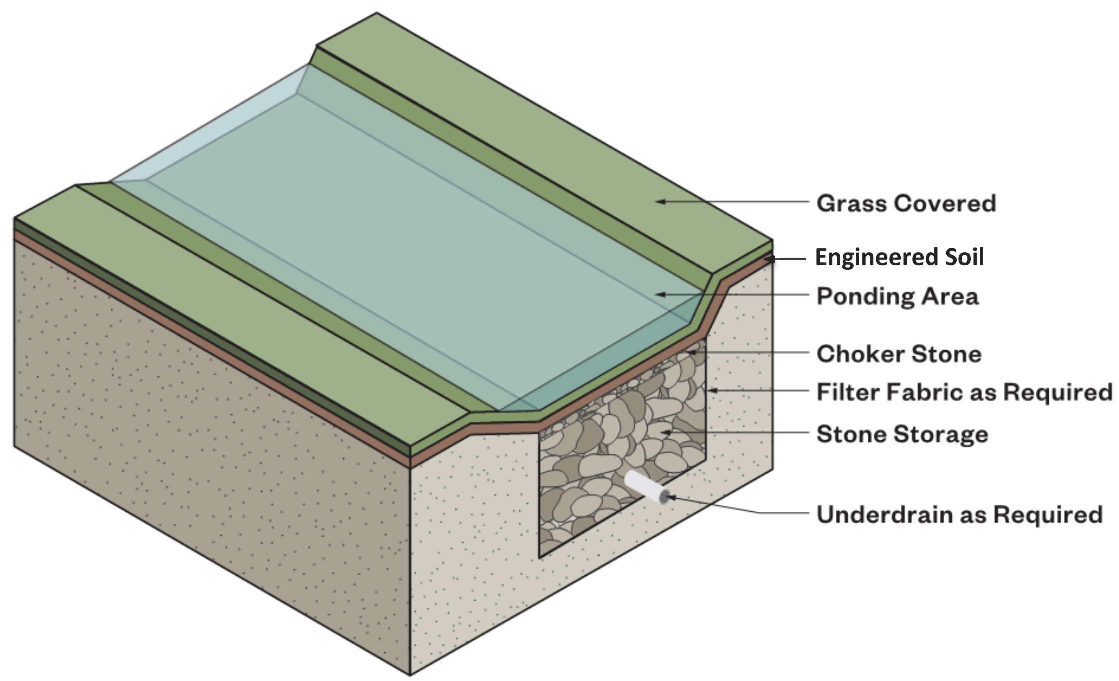
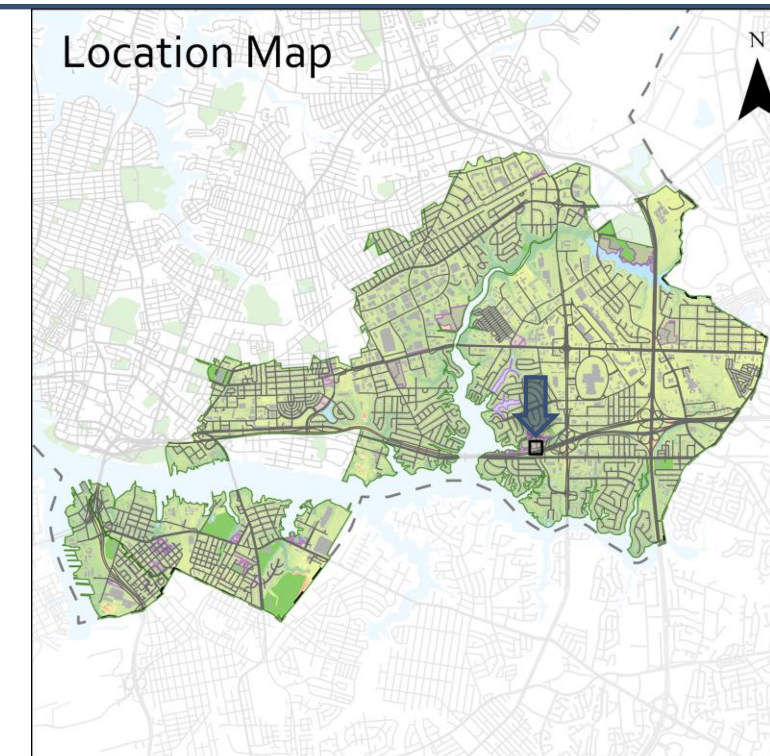
Poplar Hall Park
Concept Overview



Infiltration Trench



011 – Poplar Hall Park
Infiltration Trench

Existing Conditions

The west end of Seay Avenue has had repeated reports of flooding after intense wet weather events. The roadway currently has no existing infrastructure for drainage relief. At the west end of the street there is open space in the right-of-way with signs of standing water. The sheet flow directed towards the right-of-way space at the west end of the street has a drainage area of 0.94 acres with 60% impervious. The next page provides additional site photographs.

Proposed Improvement

The proposed infiltration trench will be on the north side of the roadway and south of the parking lot at Poplar Hall Park. The feature will have a grass-covered surface ponding area with 3:1 side slopes and below grade stone storage with an underdrain. During detailed design, an overflow structure that connects to the existing stormwater network will be designed to maximize treatment and storage volumes of the feature. The practice will have the potential to manage at least 1" of runoff from 0.94 acres of drainage in the area, providing stormwater storage capacity to relieve persistent flooding issues that occur on this end of Seay Avenue. Subsurface utility relocation or coordination may be required within the practice footprint location.

Type: Infiltration Trench

Address: 101 N. Military Highway

Area Managed: 0.94 acres

Conceptual Level Estimates:

Construction Cost: $151,000
TN Load Reduction: 4.5 lb/yr
TP Load Reduction: 0.7 lb/yr
TSS Load Reduction: 310 lb/yr

WQ Treatment Volume: 2,600 ft^3
Cost/Storage Volume: $59/$ft^3$
TN Reduction Cost: $33,000/lb/yr
TP Reduction Cost: $202,000/lb/yr
TSS Reduction Cost: $490/lb/yr

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03/22/19

Conceptual Design – Not for Construction

Poplar Hall Park
Concept Overview

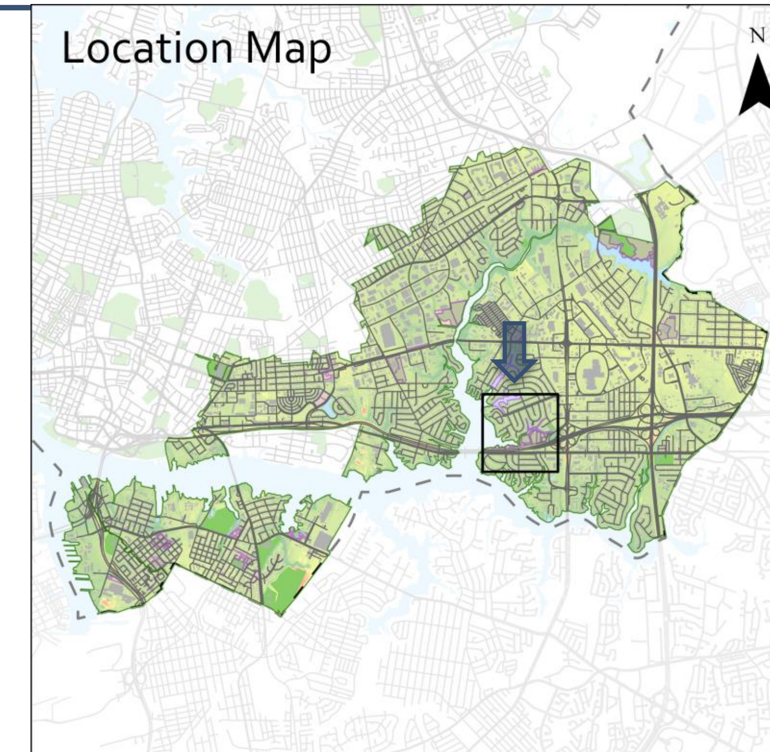
Facing east toward parking lot median ponding

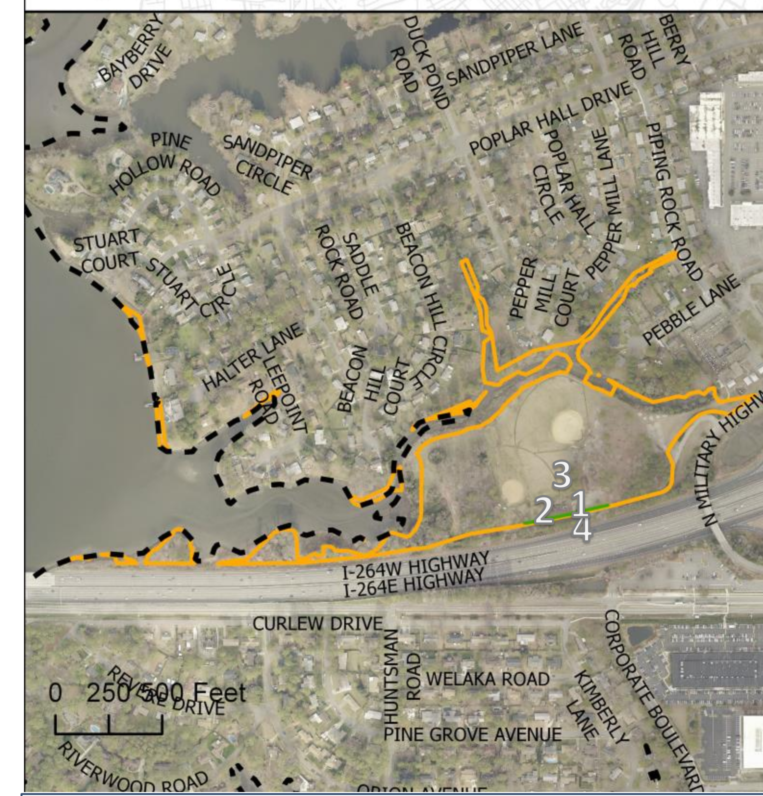
Facing west toward park path ponding

Facing southwest toward park path ponding

Facing north toward parking lot median ponding

See inset map on the right for photograph locations





011 – Poplar Hall Park
Infiltration Trench

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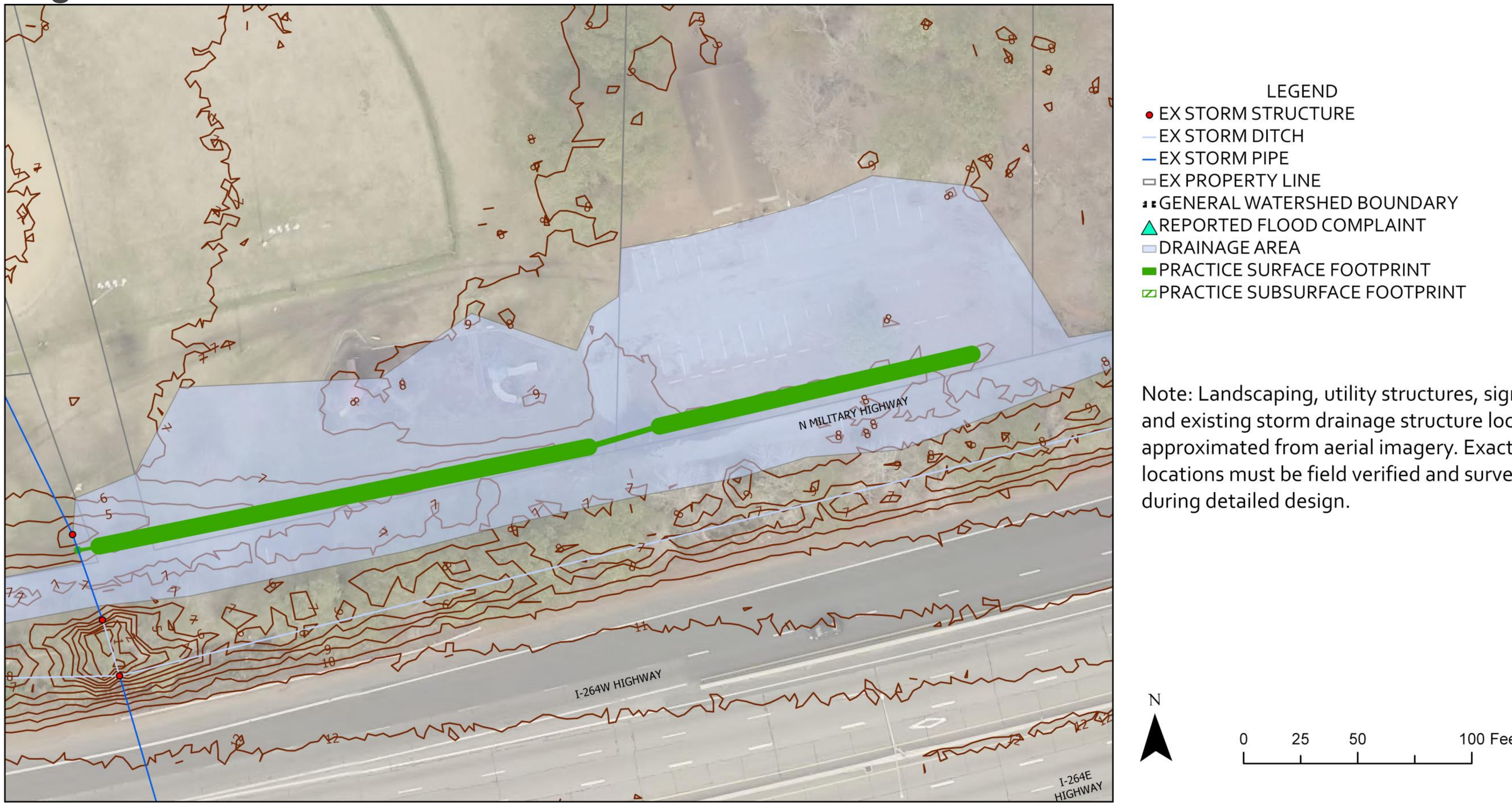
Conceptual Design – Not for Construction

Poplar Hall Park

Drainage Area Plan View



Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

<u>Alternative Design Options:</u>

- Infiltration trench on parking lot median with culvert connection to a dry swale
- Dry swale would have an outlet structure that would tie back into the existing stormwater network

011 – Poplar Hall Park Infiltration Trench	
THE CITY OF NORFOLK	Hazen
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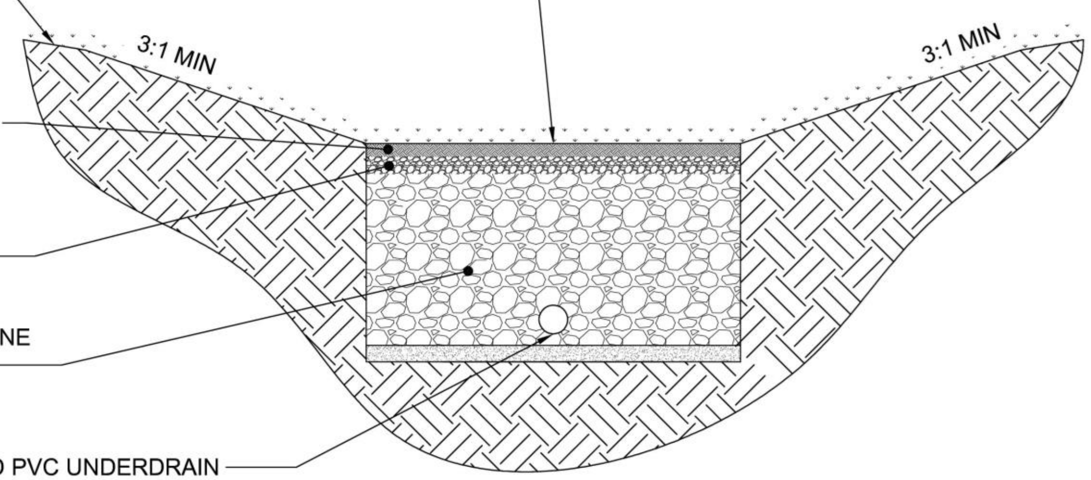
Conceptual Design – Not for Construction

Poplar Hall Park

Infiltration Basin Standard Detail



INFILTRATION TRENCH
(NOT TO SCALE)

011 – Poplar Hall Park Infiltration Trench	
Sheet 4 of 5	03/22/19

Conceptual Design – Not for Construction

Poplar Hall Park

Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 60\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.59 in$
  - $A = 40{,}971\ ft^2$
- $WQ_V = 2{,}014\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = (Area_{ponding} + Area_{subsurface}) \frac{1}{2} \times D_{ponding} + Area_{subsurface}(D_{soil} \times Porosity_{soil} + D_{stone} \times Porosity_{stone}) + Vol_{Pretreatment}$
  - $Area_{ponding} = 2{,}520 ft^2$
  - $Area_{subsurface} = 1{,}080 ft^2$
  - $D_{ponding} = 9\ in$
  - $D_{soil} = 2\ in$
  - $Porosity_{soil} = 0.25$
  - $D_{stone} = 3\ ft$
  - $Porosity_{stone} = 0.4$
  - $Vol_{pretreatment} = .15 \times WQ_V = 300 ft^3$
- $Vol_{treatment} = 2{,}600\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = .94\ ac$
  - $\%_{impervious} = 60\%$
  - $\%_{pervious} = 40\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**1.2 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**7.9 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**419 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

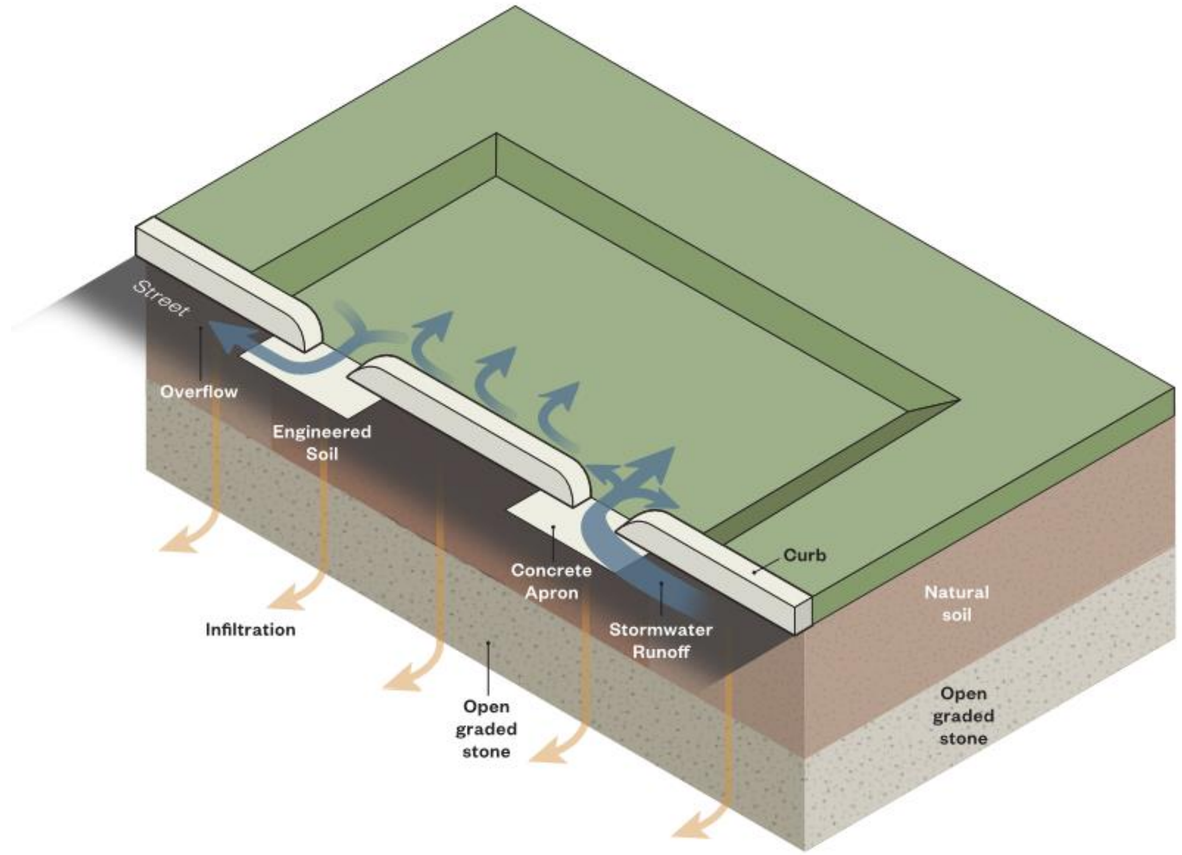
- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	63%[2]	**0.3 lb/yr**
TN	57%[2]	**1.2 lb/yr**
TSS	74%[3]	**310 lb/yr**

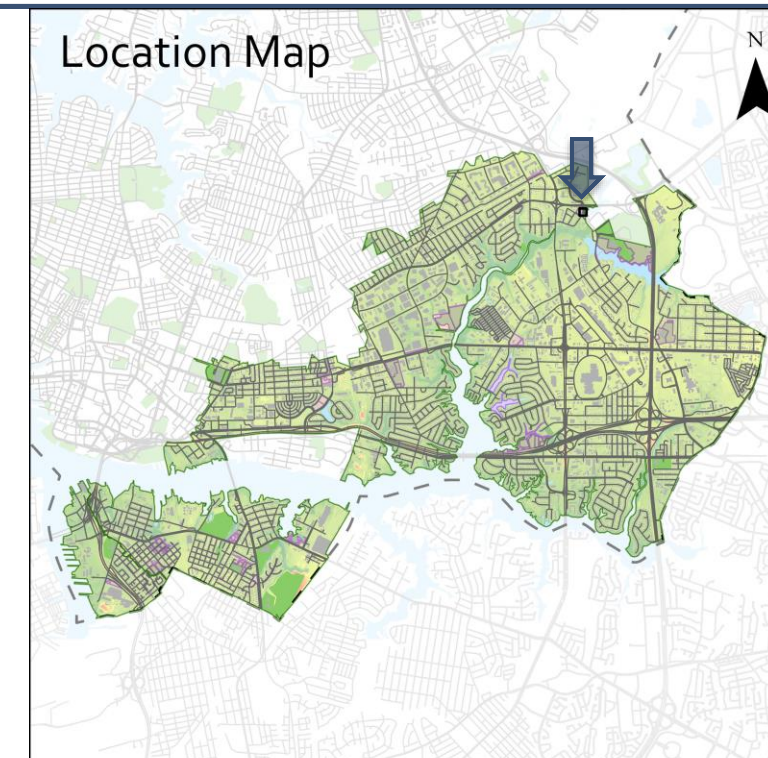
[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Infiltration Feature Specification No. 8, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 93%, TN: 92%, TSS: 74%).

Princess Anne Park
Concept Overview



Right-of-Way Iceberg Bioretention



038 – Princess Anne Park
ROW Iceberg Bioretention

Existing Conditions

The site consists of a public park owned by the City of Norfolk, located across from and adjacent to residential lots. Existing stormwater infrastructure is located on the north and south sides of the site and also runs through the middle of the site. The site captures drainage from a total of 0.23 acres of 100% impervious sheet flow from the roadway. The right-of-way along the east side of the site consists of trees and power poles, bordered by a fence. The next page provides additional site photographs.

Proposed Improvement

The proposed right-of-way iceberg bioretention will be located on the east side of the site parallel to USAA Dr. The feature will consist of a grass top with a subsurface layer of bioretention soils as well as a stone storage layer with an underdrain reconnecting to the existing stormwater system via a new drop inlet at the corner of USAA Dr. and Kempsville Rd. Additionally, 6 curb cuts and associated gravel flow spreaders will be included for pretreatment. The practice will have the potential to manage at least 1" of runoff from up to 0.23 acres of drainage area, providing stormwater storage, conveyance, and treatment for the sheet flow along USAA Dr. Stormwater runoff routing may require subsurface utility relocation or coordination within the practice footprint location.

Type: ROW Iceberg Bioretention
Address: 1450 Kempsville Rd
Area Managed: 0.23 acres

Conceptual Level Estimates:

Construction Cost: $155,000
TN Load Reduction: 1.5 lb/yr
TP Load Reduction: 0.2 lb/yr
TSS Load Reduction: 117 lb/yr

WQ Treatment Volume: 850 ft^3
Cost/Storage Volume: $180/$ft^3$
TN Reduction Cost: $105,000/lb/yr
TP Reduction Cost: $652,000/lb/yr
TSS Reduction Cost: $1,300/lb/yr

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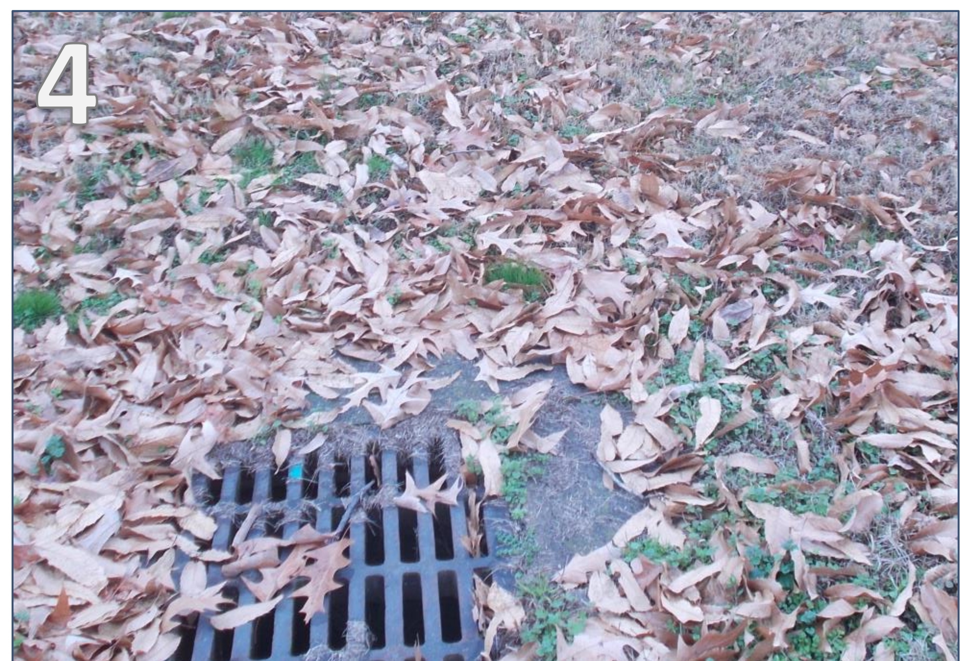
Conceptual Design – Not for Construction

Princess Anne Park
Concept Overview

Facing northwest at southern corner of site

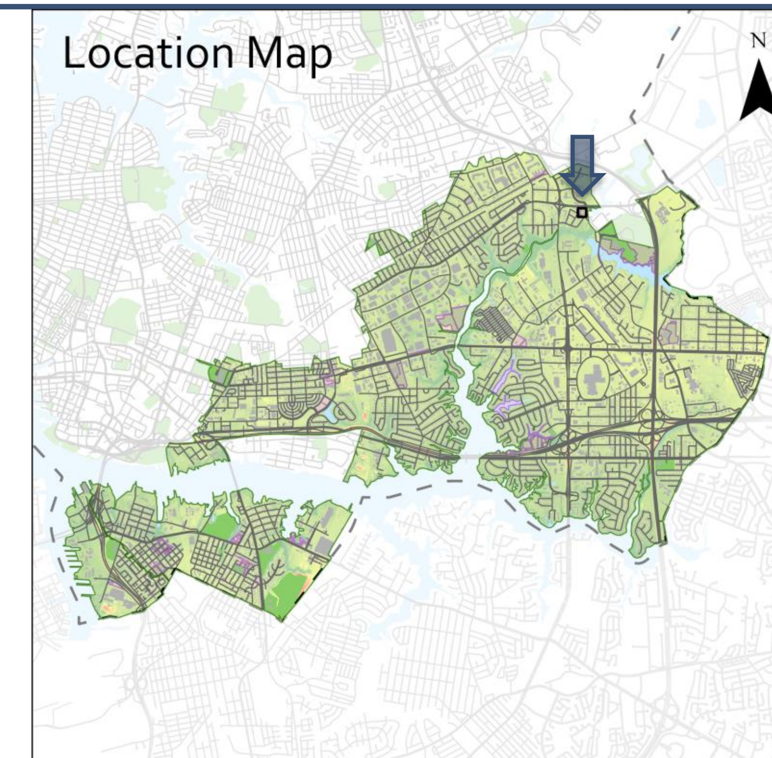
Facing north on east side of parcel

Facing north on east side of parcel



Drop inlet structure in right-of-way

See inset map on the right for photograph locations



038 – Princess Anne Park
ROW Iceberg Bioretention

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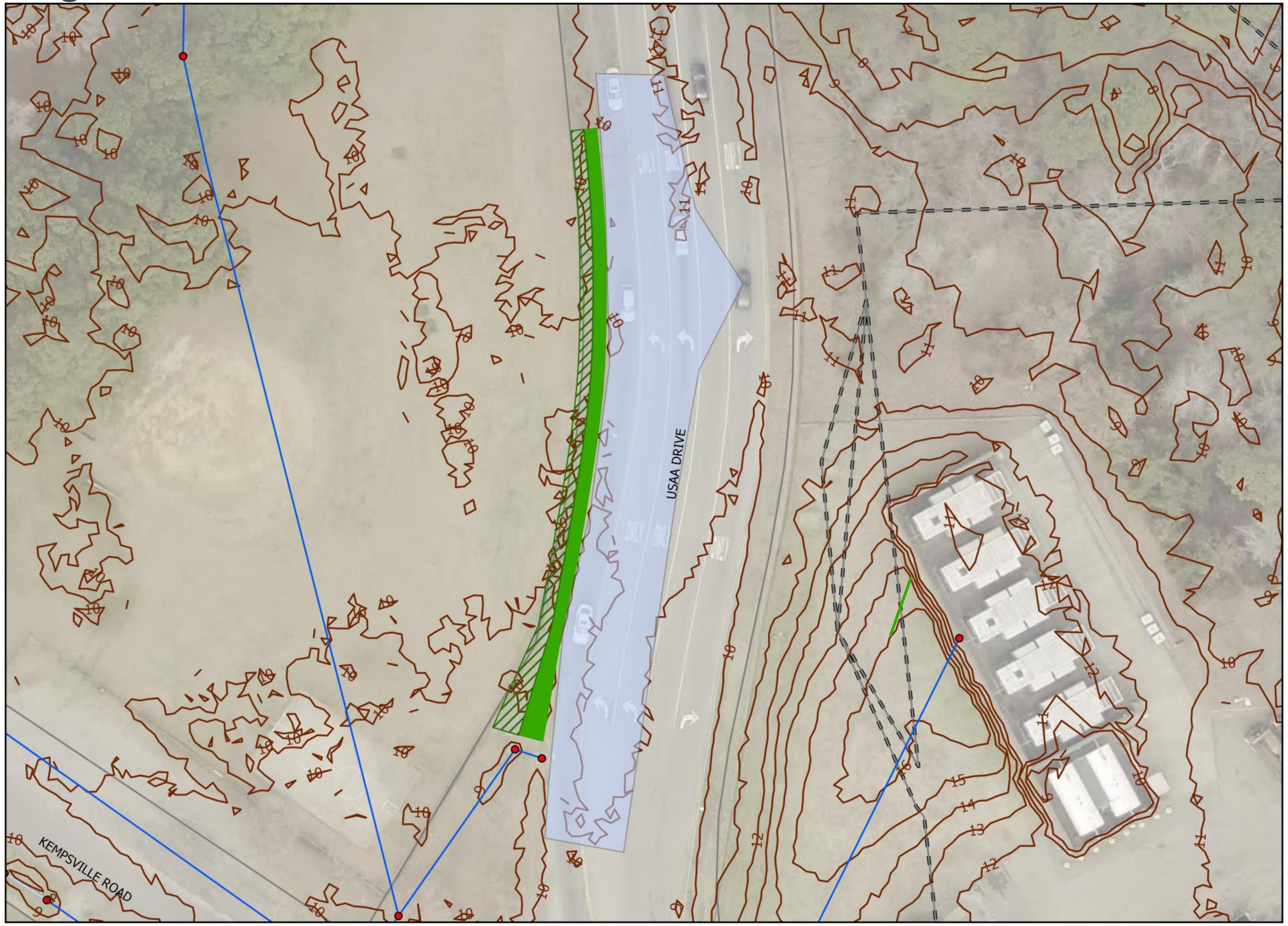
Conceptual Design – Not for Construction

Princess Anne Park
Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

038 – Princess Anne Park
ROW Iceberg Bioretention

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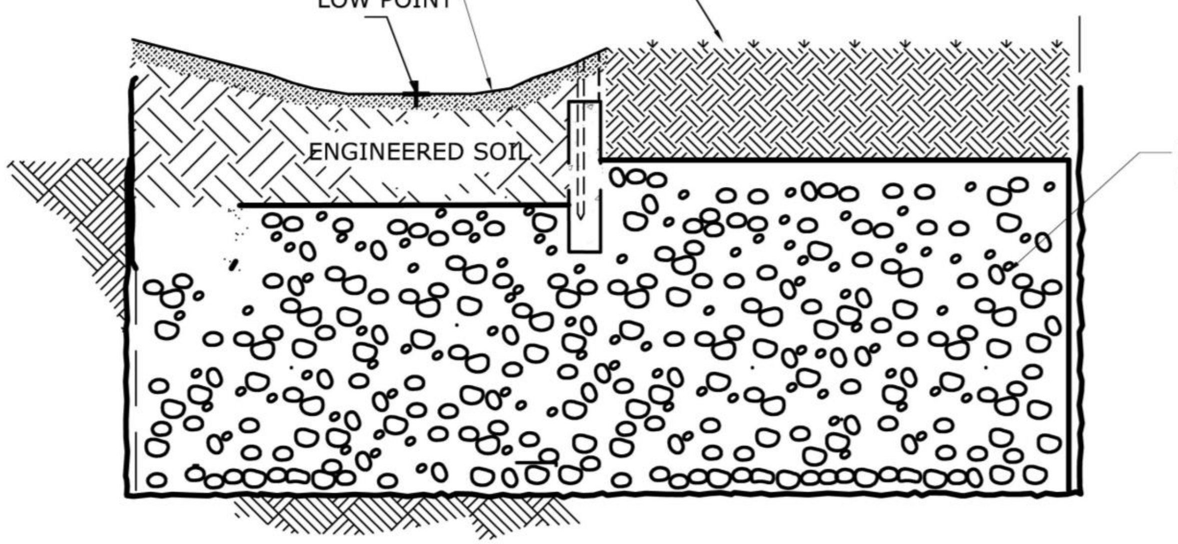
Sheet 3 of 5

03/22/19

Conceptual Design – Not for Construction

Princess Anne Park
Iceberg Bioretention Section



ICEBERG BIORETENTION
(NOT TO SCALE)

038 – Princess Anne Park ROW Iceberg Bioretention	
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Princess Anne Park

Design Calculations – Iceberg Bioretention

Calculate water quality volume

- $WQ_V = \frac{WQ_{depth}}{12} \times A$
  - $WQ_{depth} = 1.00\ in \times (0.05 + \%_{impervious} \times 0.9) = 0.64\ in$
  - $A = 10{,}171\ ft^2$
- $WQ_V = 805\ ft^3$

Calculate water quality treatment volume

- $Vol_{treatment} = \frac{A_{floor} \times A_{ponding}}{2} \times D_{ponding} + D_{soil} \times A_{floor} \times Porosity_{soil} + (D_{stone} - 1) \times Porosity_{stone} \times A_{subsurface} + Vol_{pretreatment}$
  - $A_{floor} = 101\ ft^2$
  - $A_{ponding} = 1{,}031\ ft^2$
  - $D_{ponding} = 6\ in$
  - $D_{soil} = 1.5\ ft$
  - $Porosity_{soil} = 0.25$
  - $D_{stone} = .75\ ft$
  - $Porosity_{stone} = 0.4$
  - $A_{subsurface} = 2{,}062\ ft^2$
  - $Vol_{pretreatment} = 132\ ft^3$
- $Vol_{treatment} = 850\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = 0.23\ ac$
  - $\%_{impervious} = 100\%$
  - $\%_{pervious} = 0\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**0.4 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**2.2 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**158 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

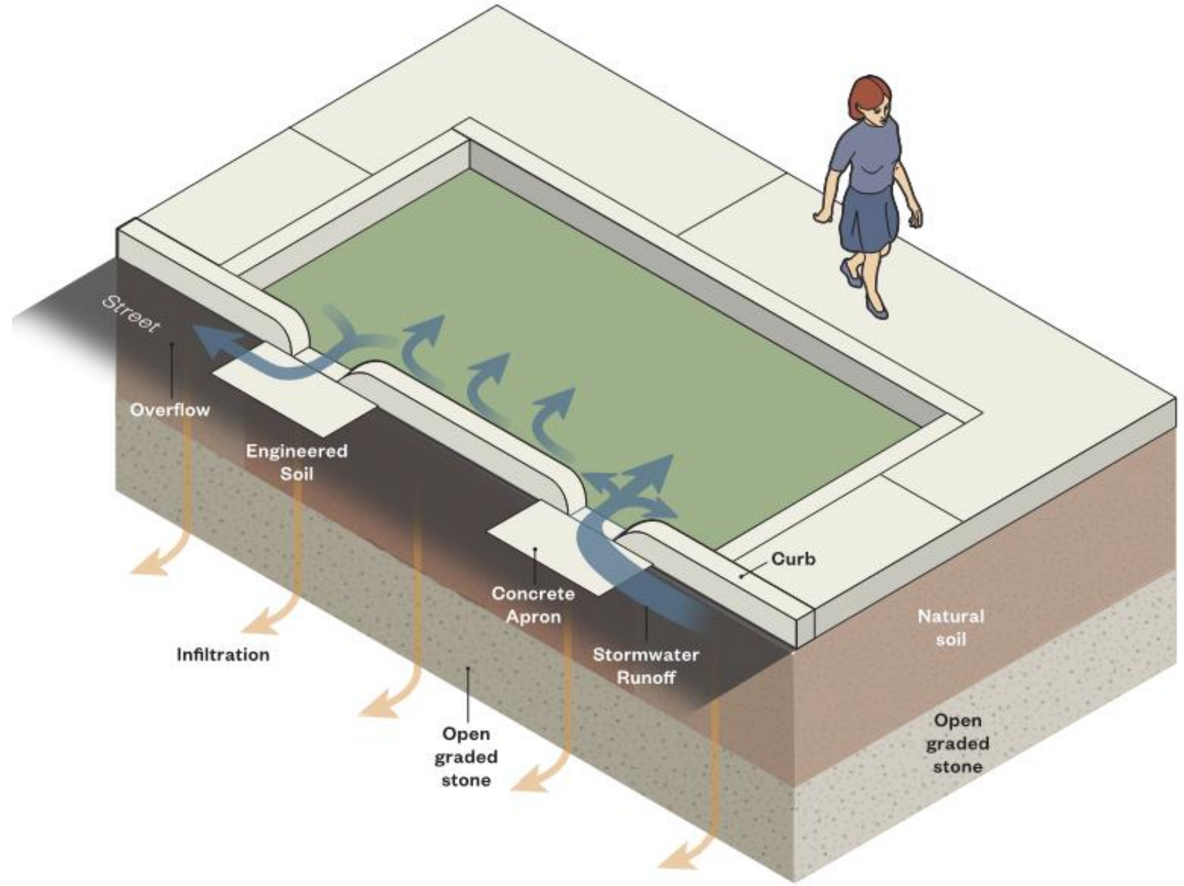
- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	55%[2]	**0.2 lb/yr**
TN	64%[2]	**1.5 lb/yr**
TSS	74%[3]	**117 lb/yr**

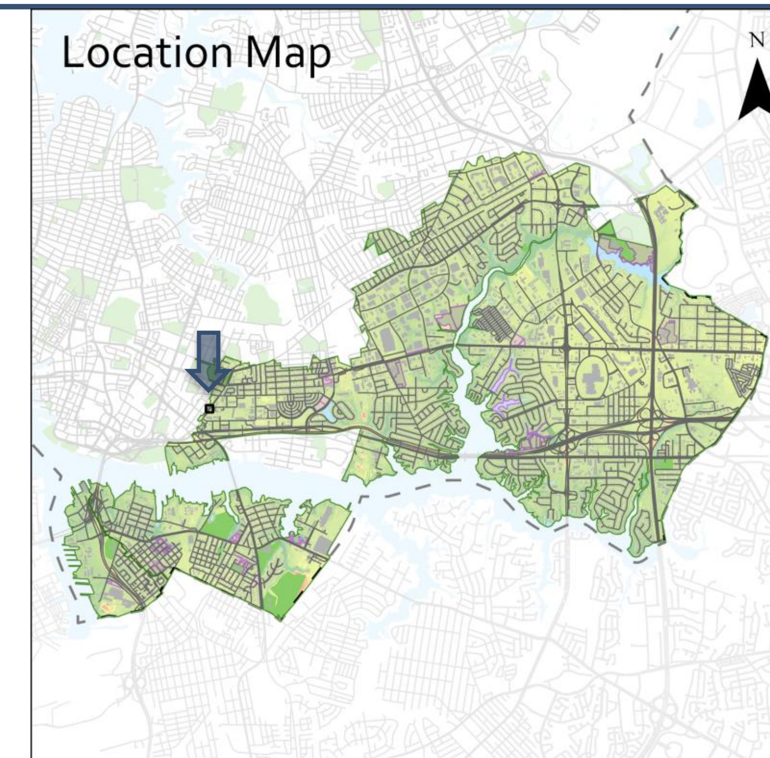
[2] Load Removal from Virginia DCR Stormwater Design Specification No. 9 Bioretention, Version 2.0, January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 90%, TN: 90%, TSS: 74%).

Park Avenue Corner Lot
Concept Overview



Right-of-Way Iceberg Bioretention



Existing Conditions

The site consists of a large vacant corner parcel owned by the Norfolk Development and Housing Authority, located across from Norfolk State University, and adjacent to residential lots. Existing stormwater infrastructure is located on the southeast side of the site—a manhole for bioretention connectivity. This site captures drainage from 1.28 acres of 94% impervious sheet flow from the roadway and median space. The right-of-ways along the northeastern and southeastern sides of the site consist of sidewalks, 4 driveway aprons, and 1 power pole. The next page provides additional site photographs.

Proposed Improvement

The proposed right-of-way iceberg bioretention will be located on the southeast side of the site, parallel to Park Ave. The feature will consist of a grass top with a subsurface layer of bioretention soils, as well as a stone storage layer with an underdrain reconnecting to the existing stormwater system on Park Ave. Additionally, 4 curb cuts and associated gravel flow spreaders will be included for pretreatment. The surface footprint of the feature has breaks to avoid interference with the existing above ground utilities and entrances to the parcel. There will be an outlet structure towards the middle of the right-of-way iceberg bioretention, which will discharge to the existing stormwater system on Park Ave. The entire practice will have the potential to manage at least 1” of runoff from up to 1.28 acres of drainage area, providing stormwater storage and conveyance to relieve any localized ponding issues on this site. Stormwater runoff routing will require subsurface utility relocation or coordination within the practice footprint location.

045 – Park Avenue Corner Lot
ROW Iceberg Bioretention

Type: ROW Iceberg Bioretention
Address: 829 Park Ave
Area Managed: 1.28 acres

Conceptual Level Estimates:

Construction Cost: $294,000
TN Load Reduction: 2.0 lb/yr
TP Load Reduction: 0.3 lb/yr
TSS Load Reduction: 164 lb/yr

WQ Treatment Volume: 1,600 ft^3
Cost/Storage Volume: $190/$ft^3$
TN Reduction Cost: $145,000/lb/yr
TP Reduction Cost: $918,000/lb/yr
TSS Reduction Cost: $1,800/lb/yr

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Conceptual Design – Not for Construction

Park Avenue Corner Lot
Concept Overview

Facing northeast towards Bond St.

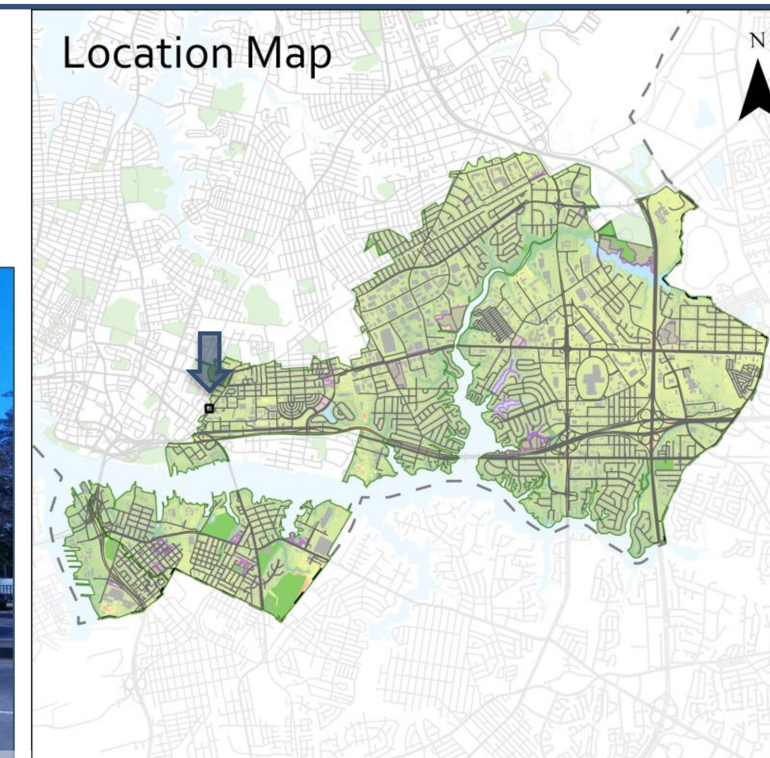
Facing southeast towards Park Ave.

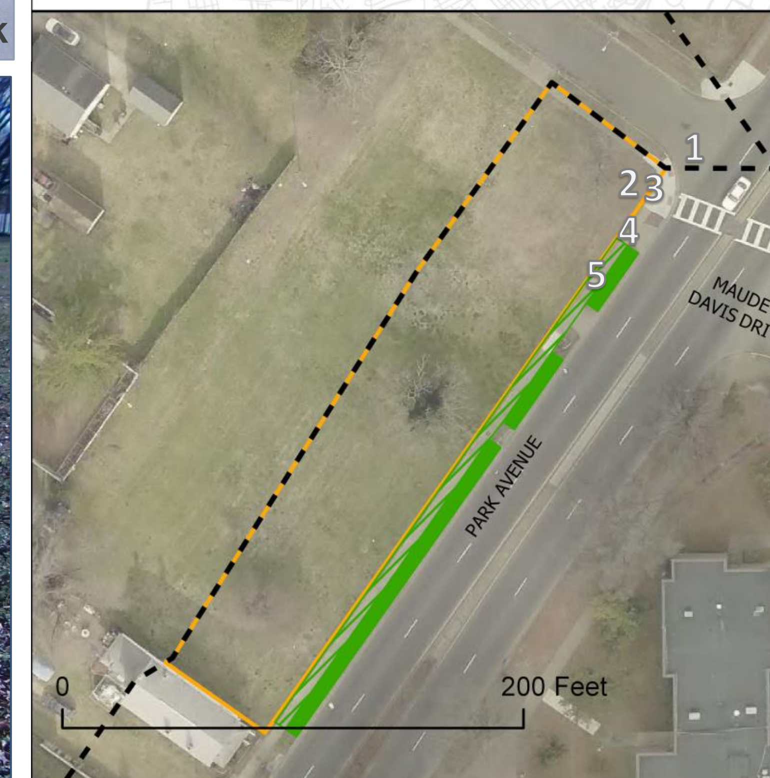
Facing northeast at Park Ave. crosswalk

Facing southwest down ROW on west side of Park Ave.

Facing southwest down ROW on west side of Park Ave.

See inset map on the right for photograph locations





045 – Park Avenue Corner Lot
ROW Iceberg Bioretention

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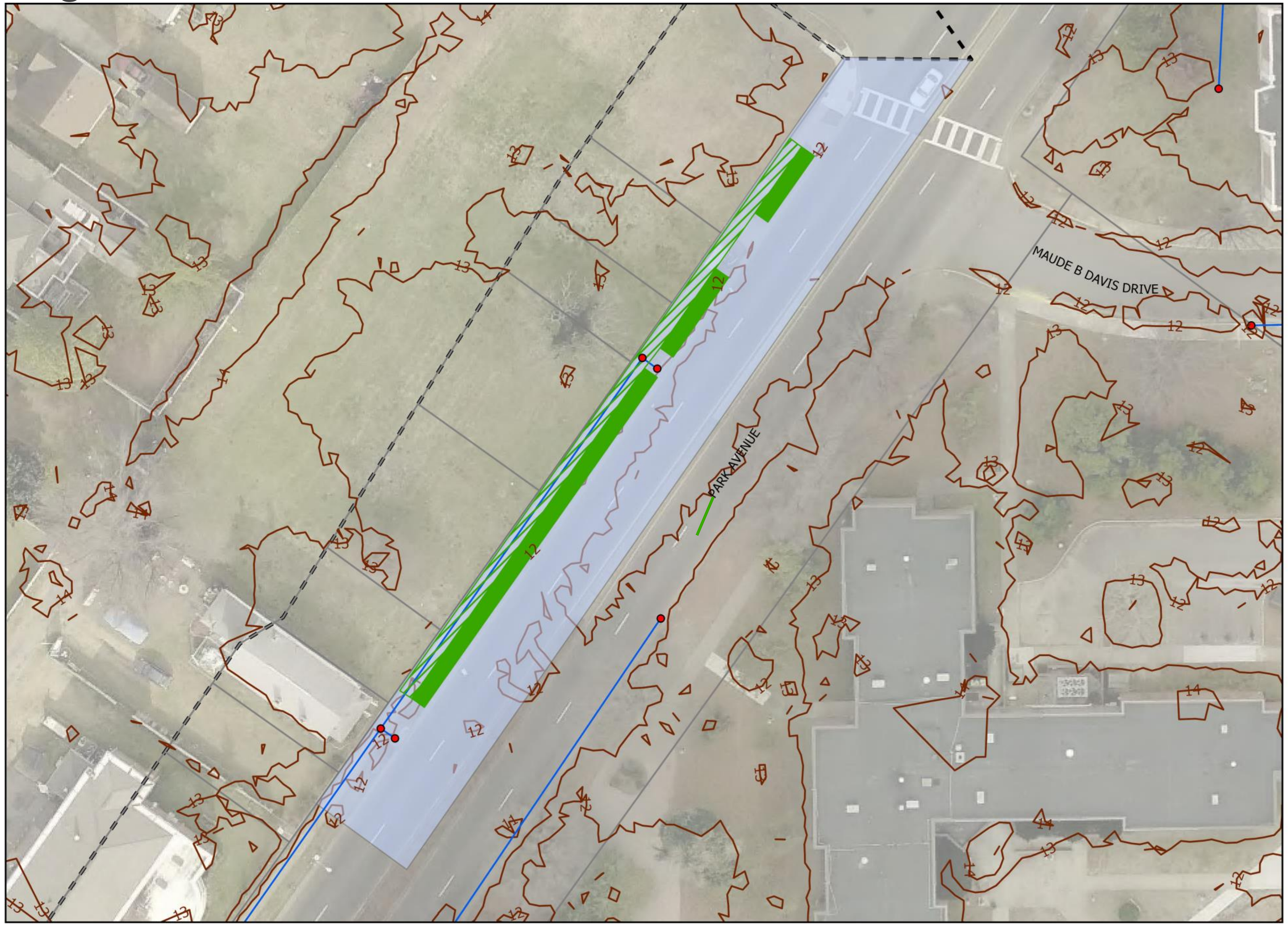
Conceptual Design – Not for Construction

Park Avenue Corner Lot
Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

045 – Park Avenue Corner Lot
ROW Iceberg Bioretention

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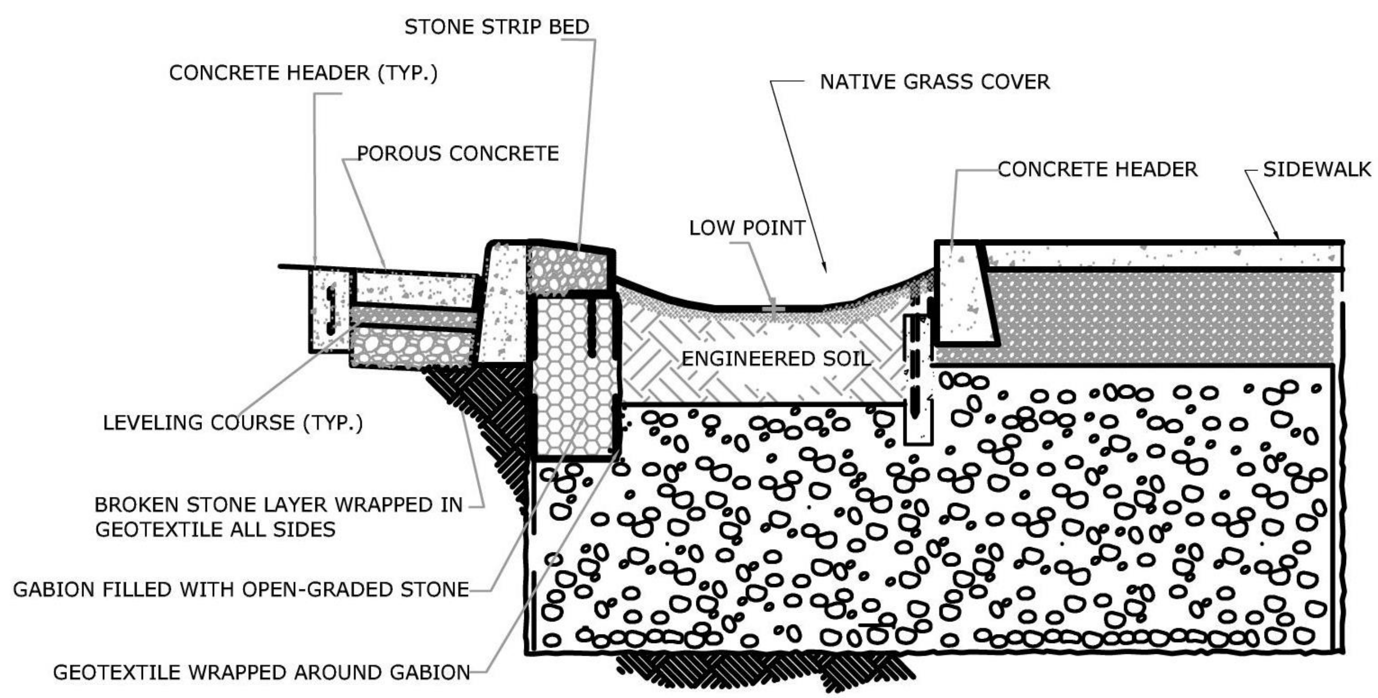
Conceptual Design – Not for Construction

Park Avenue Corner Lot
Right-of-Way Iceberg Bioretention Section



RIGHT-OF-WAY BIORETENTION
(NOT TO SCALE)

045 – Park Avenue Corner Lot ROW Iceberg Bioretention	
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Park Avenue Corner Lot

Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 96\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.91 in$
  - $A = 14{,}852\ ft^2$
- $WQ_V = 1{,}127\ ft^3$

Calculate full storage volume provided

- $Vol_{treatment} = \frac{A_{floor} \times A_{ponding}}{2} \times D_{ponding} + D_{soil} \times A_{floor} \times Porosity_{soil} + (D_{stone} - 1) \times Porosity_{stone} \times A_{subsurface} + Vol_{pretreatment}$
  - $A_{floor} = 538\ ft^2$
  - $A_{ponding} = 1{,}640\ ft^2$
  - $D_{stone} = 0.5\ ft$
  - $Porosity_{stone} = 0.4$
  - $A_{subsurface} = 3{,}300\ ft^2$
  - $Vol_{pretreatment} = 88\ ft^3$
- $Vol_{treatment} = 1{,}566\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = \left(A \times \%_{impervious} \times Loading\ Rate_{imp}\right) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = 1.28\ ac$
  - $\%_{impervious} = 94\%$
  - $\%_{pervious} = 6\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**0.6 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**3.2 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**222 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	*Load Reduction*
TP	55%[2]	**0.3 lb/yr**
TN	64%[2]	**2.0 lb/yr**
TSS	74%[3]	**164 lb/yr**

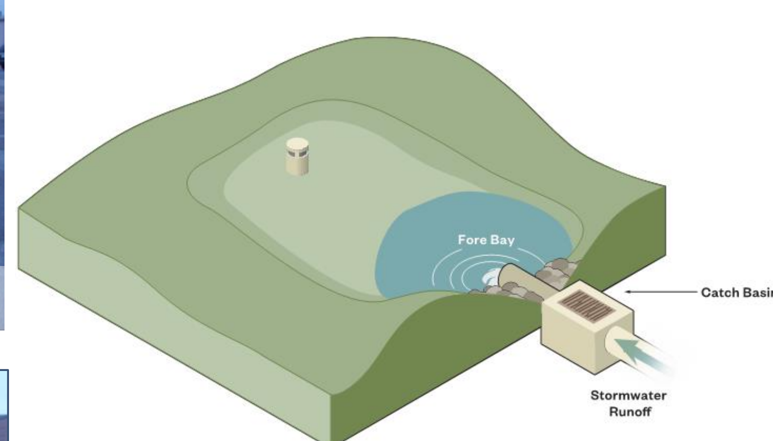
[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Bioretention Specification No. 9, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 90%, TN: 90%, TSS: 74%).

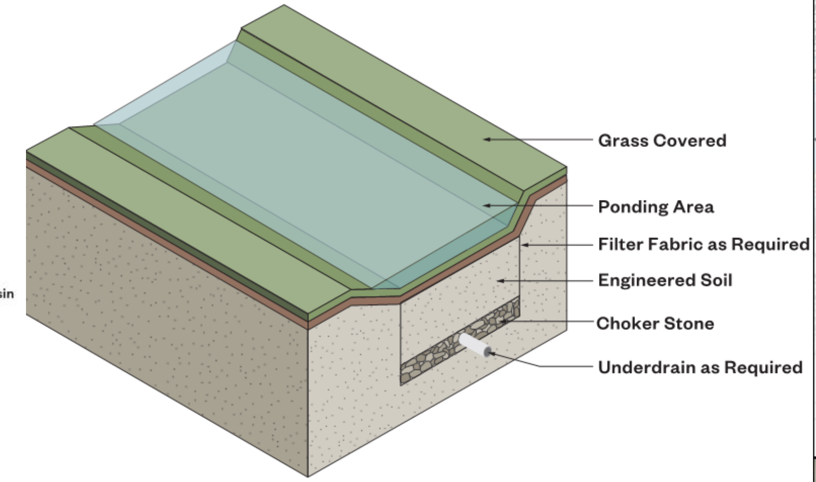
Industrial Park Azalea Little League
Concept Overview

Proposed Site

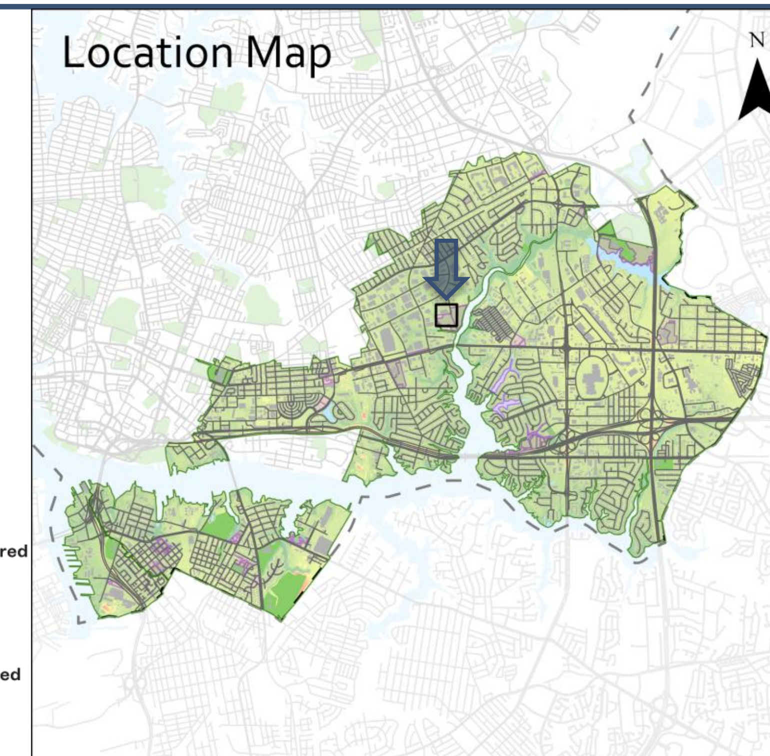
Proposed Site



Extended Detention Dry Pond



Dry Swale



Drainage Area Map

069 – Industrial Park Azalea Little League
Extended Detention Dry Pond & Dry Swale

Existing Conditions

The existing site consists of two large, developed parcels owned by the City of Norfolk, dedicated to open space and recreation. Existing stormwater infrastructure runs along Pineridge Road and discharges into a tributary of the Elizabeth River. The site is occupied by recreational baseball fields and the Norfolk Public Library. The next page provides additional site photographs.

Proposed Improvements

The recommended practices on this parcel for stormwater management are an extended detention dry pond and a dry swale. The extended detention dry pond is located to the west of the existing parking lot, located just south of the library, and the dry swale is located between the library and the existing parking lot. The existing parking lot will be repaved to ensure positive drainage towards the dry pond, with drainage swales installed to channelize the flow from the parking lot and into the dry pond's sediment forebay. A new manhole will be installed where the dry pond discharges into the existing stormwater infrastructure that is running parallel to the library. The dry swale's outfall pipe will connect to the existing catch basin adjacent to the facility. These practices will have the potential to manage up to 3.29 acres of drainage in the area, providing stormwater storage capacity to relieve flooding along the fringes of the Elizabeth River just downstream of this site. Below grade utilities are unknown at this location.

Type: Extended Detention Dry Pond / Dry Swale
Address: 1147 Pineridge Road
Area Managed: 3.29 acres

Conceptual Level Estimates:
Construction Cost: $163,000
TN Load Reduction: 4.9 lb/yr
TP Load Reduction: 1.1 lb/yr
TSS Load Reduction: 1,274 lb/yr

WQ Treatment Volume: 9,200 ft^3
Cost/Storage Volume: $18/ ft^3
TN Reduction Cost: $34,000/lb/yr
TP Reduction Cost: $151,000/lb/yr
TSS Reduction Cost: $130/lb/yr

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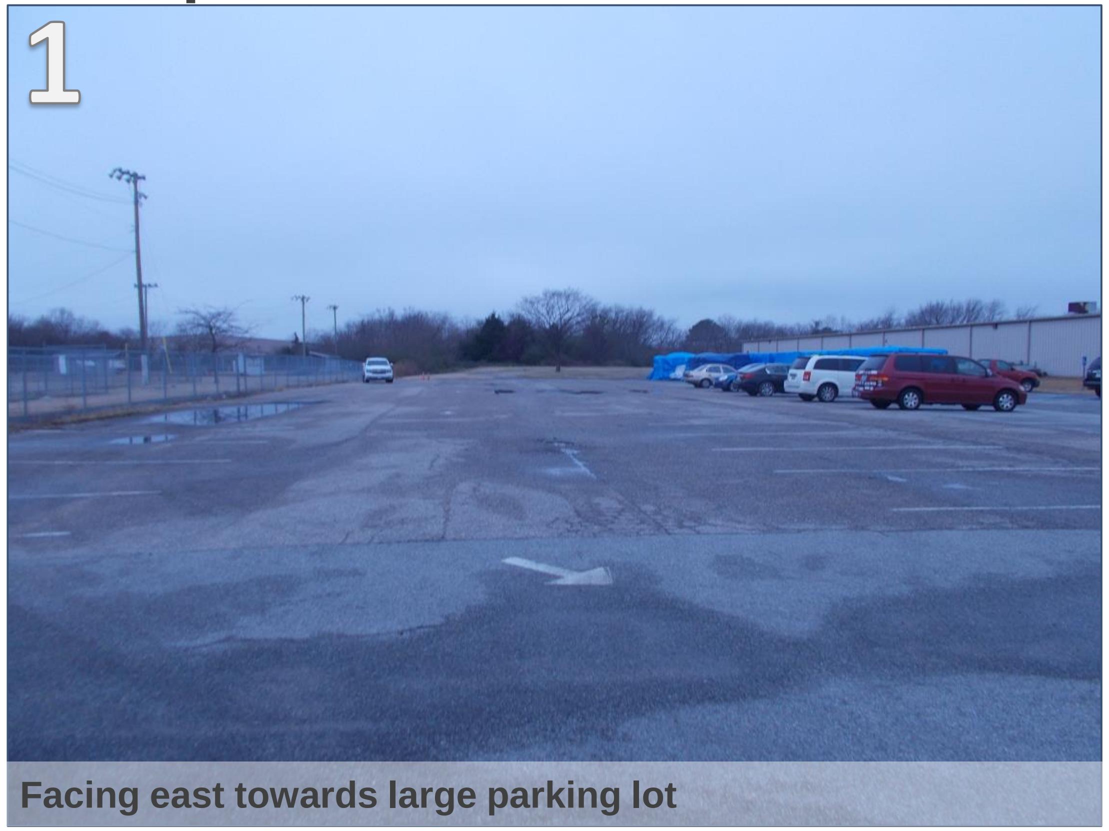
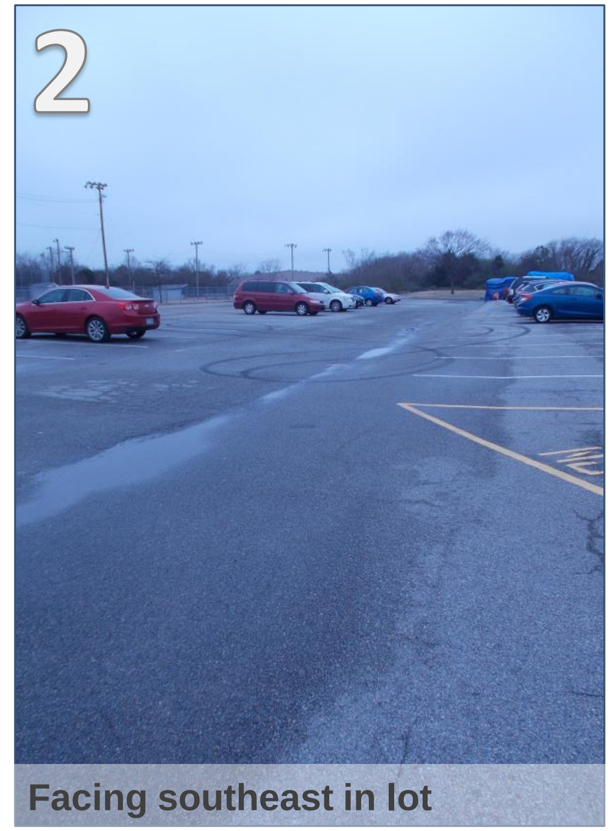
Industrial Park Azalea Little League
Concept Overview

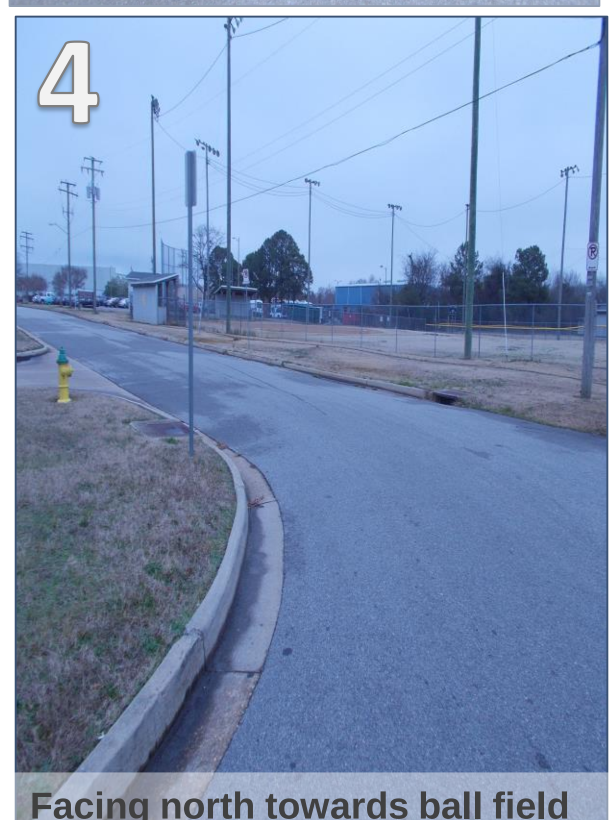


Facing east towards large parking lot



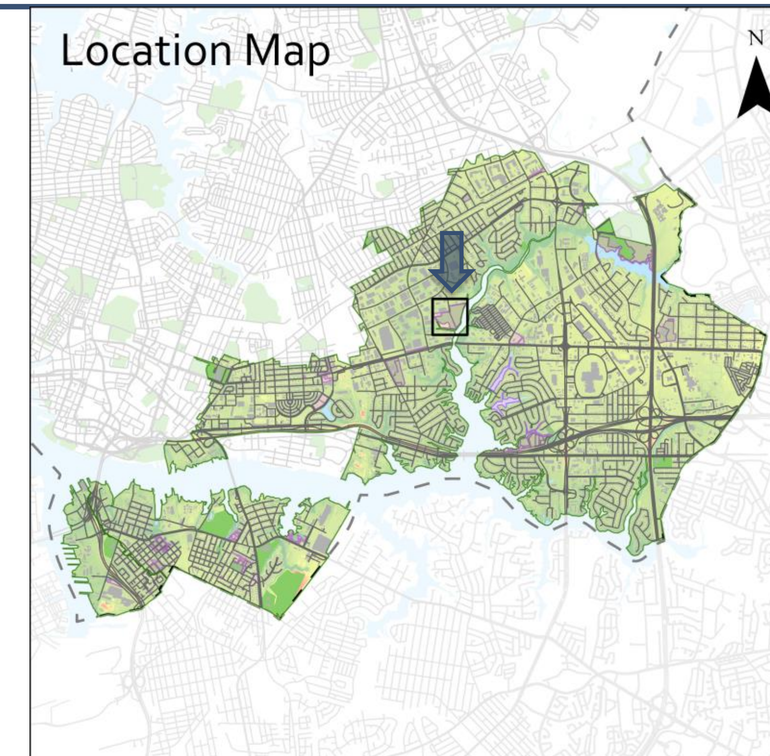
Facing southeast in lot

Facing east along the Azalea Library



Facing north towards ball field

See inset map on the right for photograph locations



069 – Industrial Park Azalea Little League
Extended Detention Dry Pond & Dry Swale

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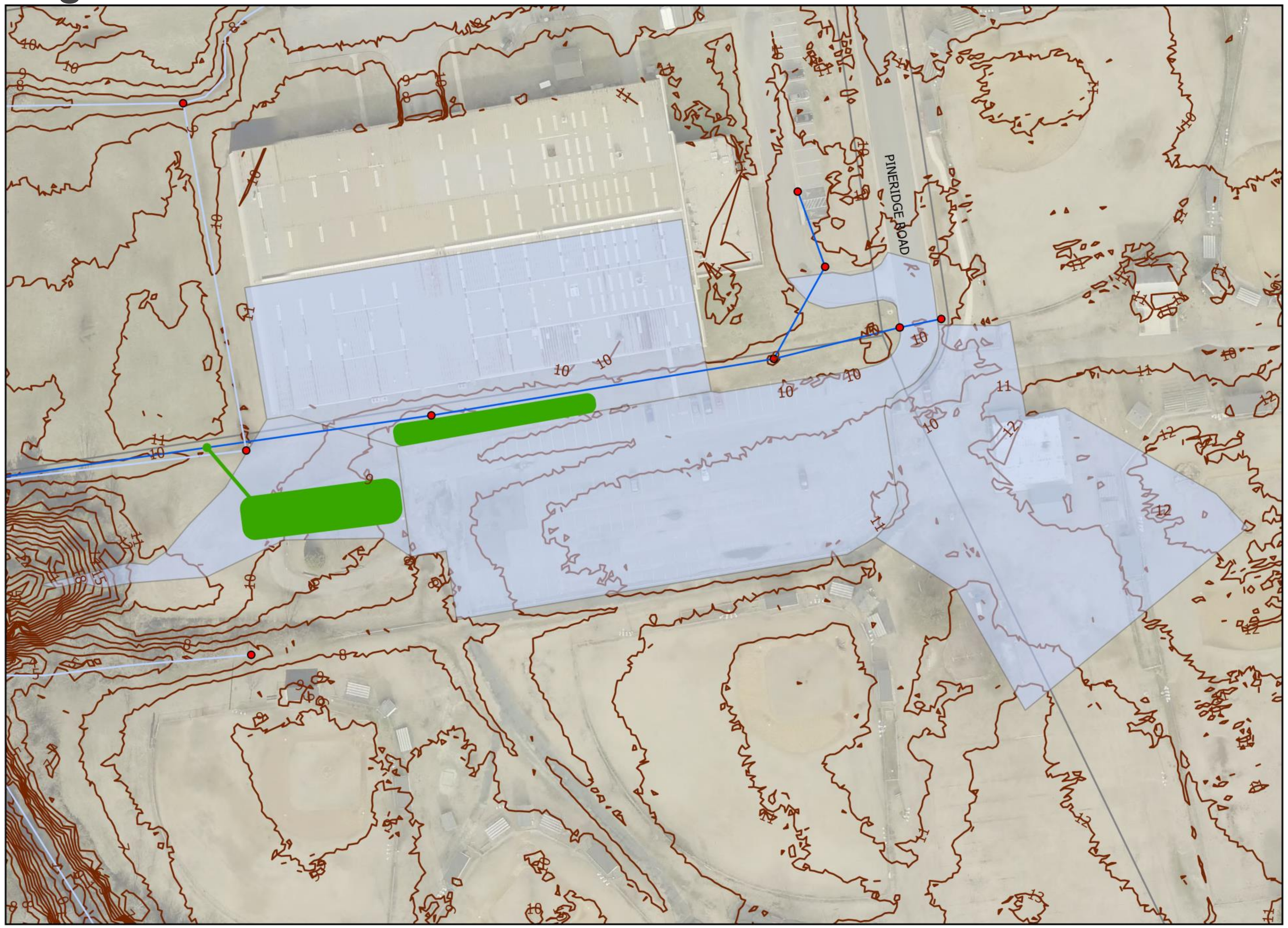
Conceptual Design – Not for Construction

Industrial Park Azalea Little League

Drainage Area Plan View



LEGEND

- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 150 200 250 Feet

069 – Industrial Park Azalea Little League
Extended Detention Dry Pond & Dry Swale

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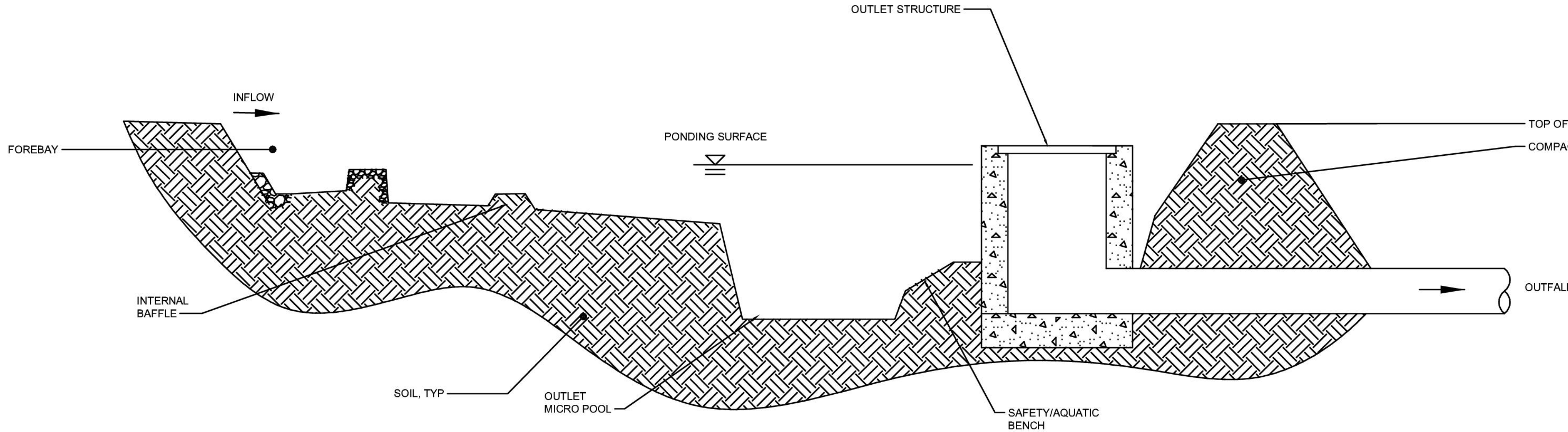
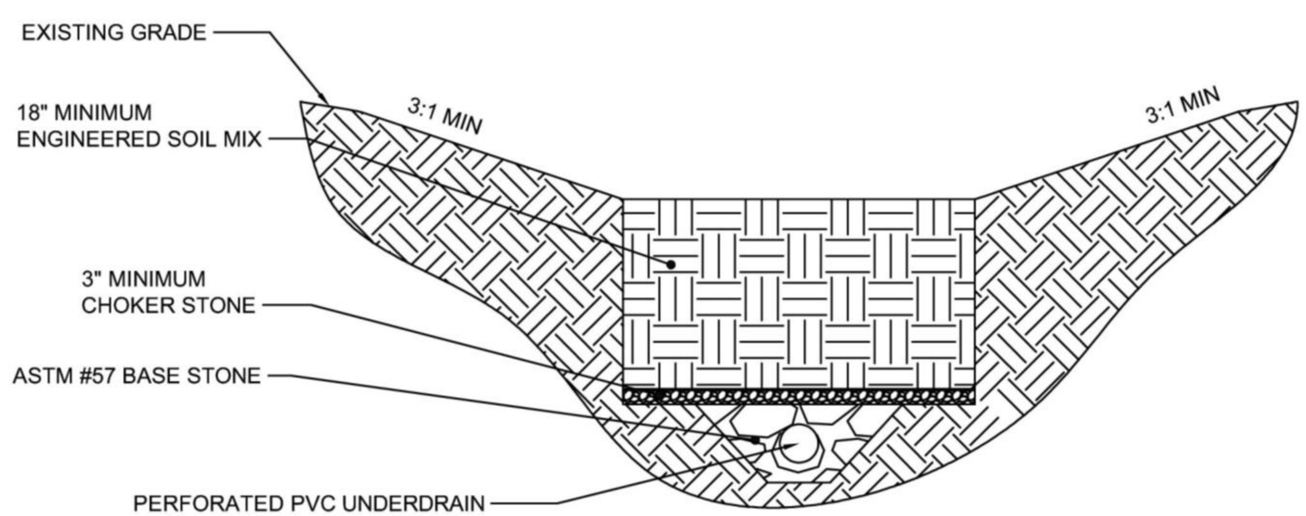
Conceptual Design – Not for Construction

Industrial Park Azalea Little League

Extended Detention Dry Pond and Dry Swale Details



DRY POND
(NOT TO SCALE)



DRY SWALE
(NOT TO SCALE)

069 – Industrial Park Azalea Little League Extended Detention Dry Pond & Dry Swale	
THE CITY OF NORFOLK	Hazen
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Conceptual Design – Not for Construction

Industrial Park Azalea Little League

Design Calculations – Dry Pond

Estimate dry pond footprint

- 100% of treatment volume (6,191 ft³) = 3,912 ft²

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times Area_{impervious}$
  - $WQ_{Depth} = 1.00\ in$
  - $Area_{impervious} = 76{,}665\ ft^2$
- $WQ_V = 6{,}191\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = Area \times D_{ponding}$
  - $D_{ponding} = 2''$
- $Vol_{treatment} = 6{,}191\ ft^3$

Design Calculations – Dry Swale

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times Area_{impervious}$
  - $WQ_{Depth} = 1.1\ in$
  - $Area_{impervious} = 33{,}976\ ft^2$
- $WQ_V = 2{,}975\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = Area \times D_{ponding}$
  - $D_{ponding} = 12''$
- $Vol_{treatment} = 2{,}975\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - Dry Pond
    - $A = 2.43\ ac$
    - $\%_{impervious} = 72\%$
    - $\%_{pervious} = 28\%$
  - Dry Swale
    - $A = 0.86\ ac$
    - $\%_{impervious} = 91\%$
    - $\%_{pervious} = 9\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$	
			Dry Pond	Dry Swale
TP	1.76 lb/ac/yr[1]	0.50 lb/ac/yr[1]	**3.4 lb/yr**	**1.4 lb/yr**
TN	9.39 lb/ac/yr[1]	6.99 lb/ac/yr[1]	**21.2 lb/yr**	**7.9 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**1,256 lb/yr**	**535 lb/yr**

[1] 2009 EOS Loading Rate (lb/ac/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ removal}$		**Load Reduction**	
	Dry Pond	Dry Swale	Dry Pond	Dry Swale
TP	15%[2]	52%[3]	**0.5 lb/yr**	**0.6 lb/yr**
TN	10%[2]	55%[3]	**2.1 lb/yr**	**2.8 lb/yr**
TSS	70%[4]	74%[4]	**879 lb/yr**	**396 lb/yr**

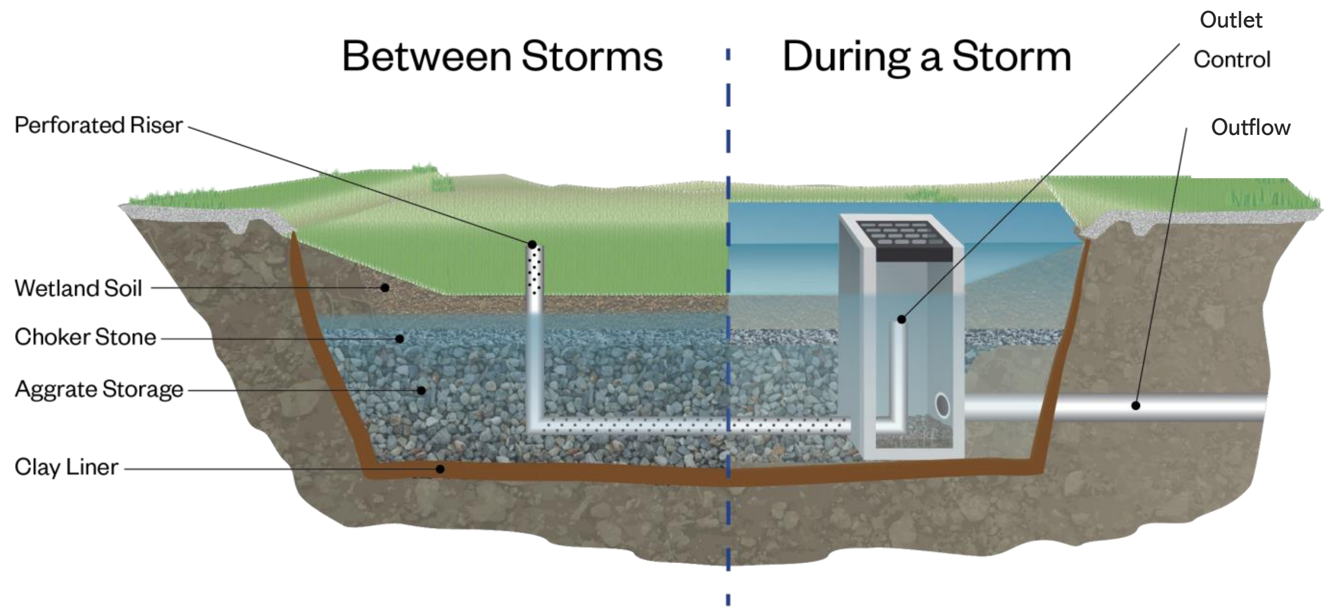
[2] Load Removal from Virginia DCR Stormwater Design Specification No. 15 Extended Detention, Version 2.0, January 1, 2013
[3] Load Removal from Virginia DCR Stormwater Design Specification No. 10 Dry Swale, Version 2.0, January 1, 2013
[4] Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints.
Dry Pond – Extended Detention – Level 2 Reductions (TP: 31%, TN: 24%, TSS: 70%)
Dry Swale – Level 2 Reductions (TP: 76%, TN: 74%, TSS: 74%)

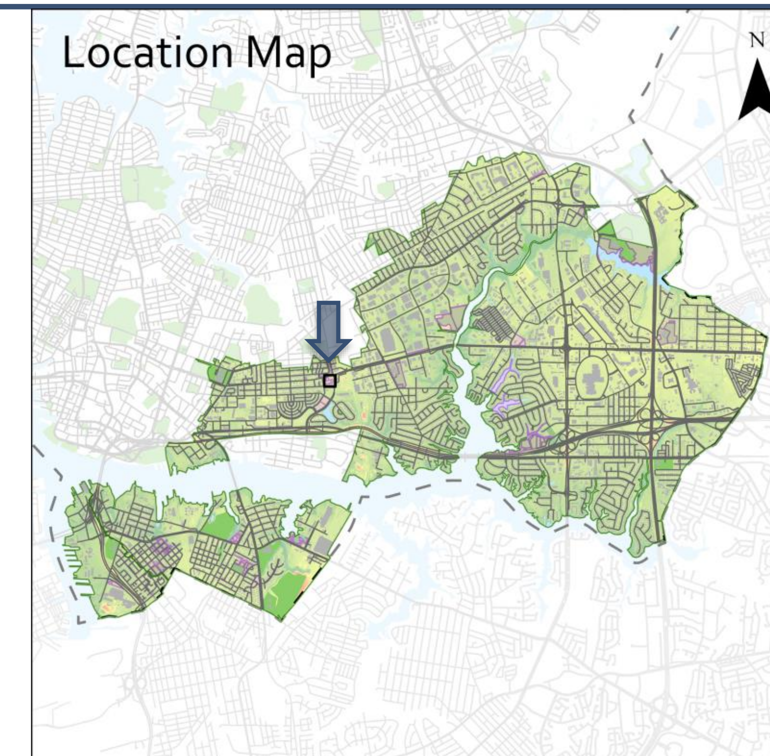
Ballentine at Virginia Beach Blvd.
Concept Overview

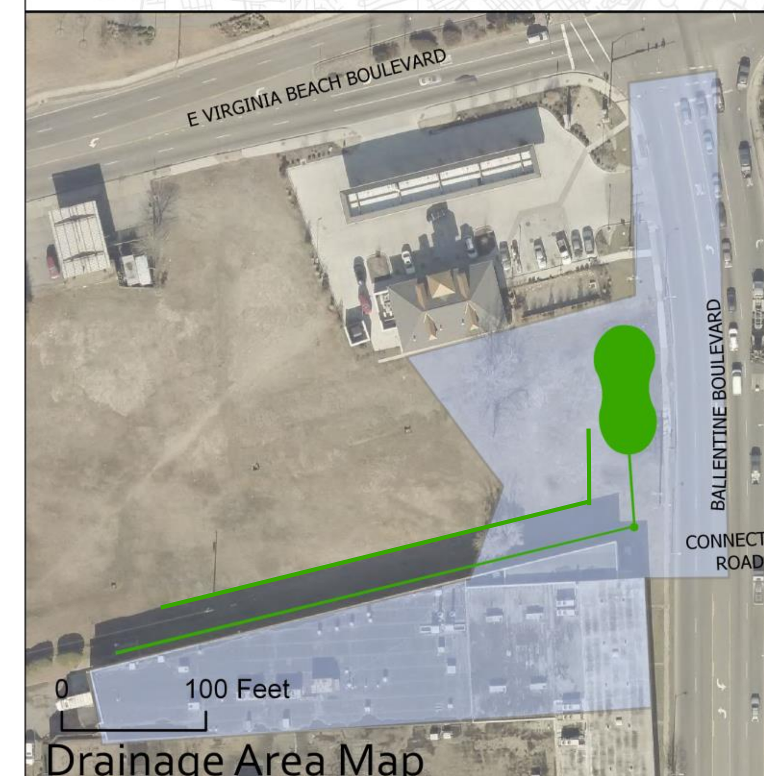
Proposed Site

Proposed Site



Subsurface Gravel Wetland





070 – Ballentine at Virginia Beach Blvd.
Subsurface Gravel Wetland

Existing Conditions

The site consists of a large vacant parcel owned by the Norfolk Redevelopment and Housing Authority. Existing stormwater infrastructure runs along the perimeter of the site for roadway drainage. The site regularly experiences ponding on the east side near a local bus stop. The site captures drainage from 1.70 acres that includes rooftop downspout drainage as well as roadway sheet flow, making the drainage area 84% impervious. The next page provides additional site photographs.

Proposed Improvement

The proposed subsurface gravel wetland practice will treat water from redirected building downspouts, as well as sheet flow from Ballentine Blvd. During detailed design the inlet will be configured to maximize treatment and storage. Downspouts will be tied into a pipe that runs parallel to the building south of the site with a connection to a manhole that will divert the flow to the gravel wetland. The feature will consist of aggregate storage, a series of risers connected to an underdrain, and an outlet structure to reconnect to the existing stormwater system. The entire practice will have the potential to manage at least 1" of runoff from up to 1.70 acres of drainage area, providing stormwater storage capacity to relieve the localized ponding issues on this site. Stormwater runoff routing may require subsurface utility relocation or coordination within the practice footprint location. Along with the subsurface gravel wetland practice, the parcel could be further retrofitted with green infrastructure practices near the bus stop to provide a public amenity while keeping with the City of Norfolk's resilience strategy to manage precipitation flooding in the City.

Type: Subsurface Gravel Wetland
Address: 985 Ballentine Blvd.
Area Managed: 1.70 acres

Conceptual Level Estimates:

Construction Cost: $231,000
TN Load Reduction: 3.8 lb/yr
TP Load Reduction: 1.3 lb/yr
TSS Load Reduction: 694 lb/yr

WQ Treatment Volume: 5,000 ft^3
Cost/Storage Volume: $47/ft^3
TN Reduction Cost: $61,000/lb/yr
TP Reduction Cost: $175,000/lb/yr
TSS Reduction Cost: $330/lb/yr

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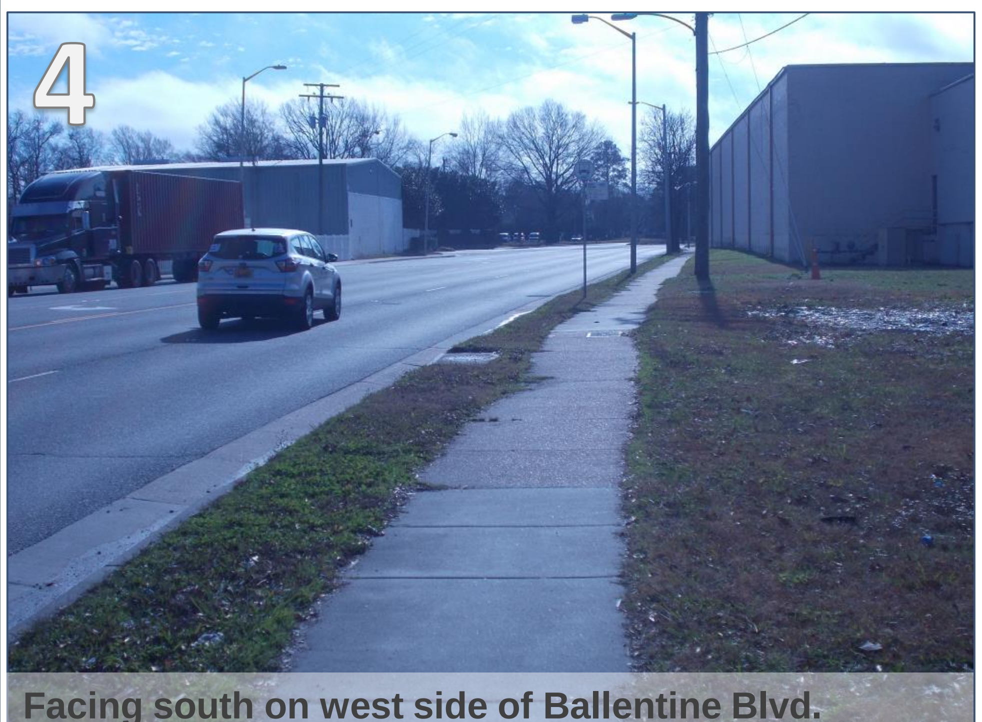
Conceptual Design – Not for Construction

Ballentine at Virginia Beach Blvd.
Concept Overview

Facing northeast towards gas station

Unidentified structure

Facing east parallel to building

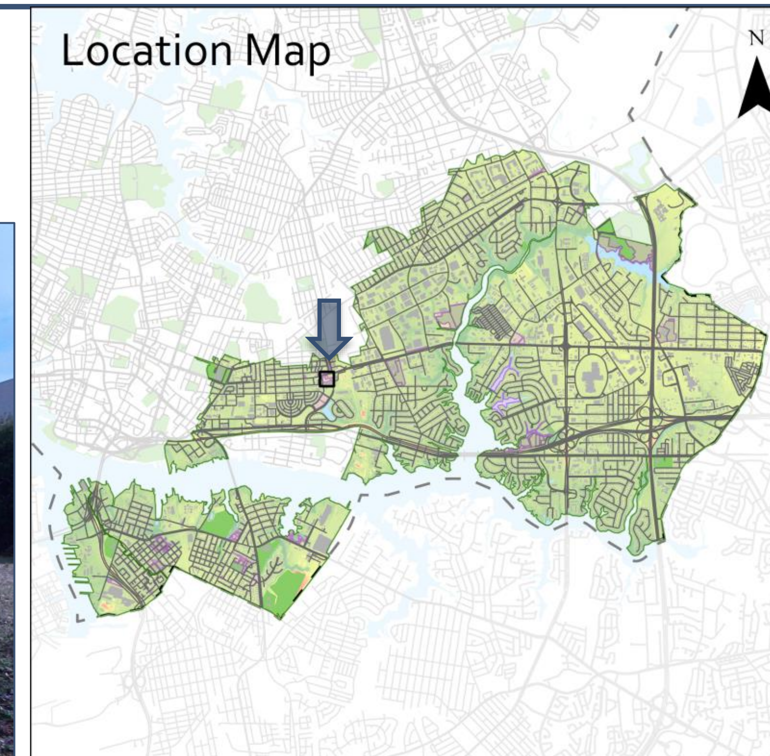


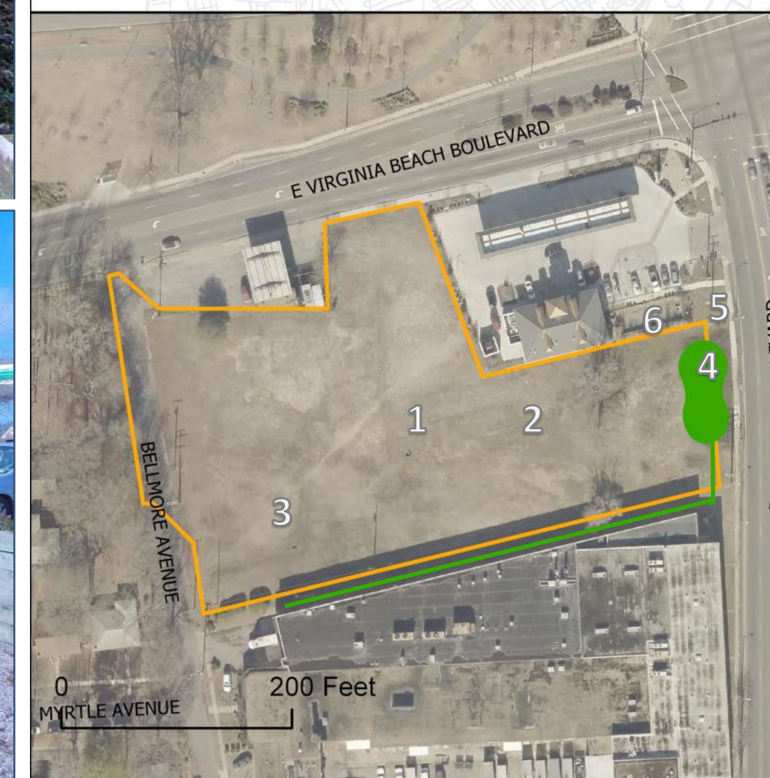
Facing south on west side of Ballentine Blvd.

Drop inlet on north of feature

Gas station detention

See inset map on the right for photograph locations





070 – Ballentine at Virginia Beach Blvd.
Subsurface Gravel Wetland

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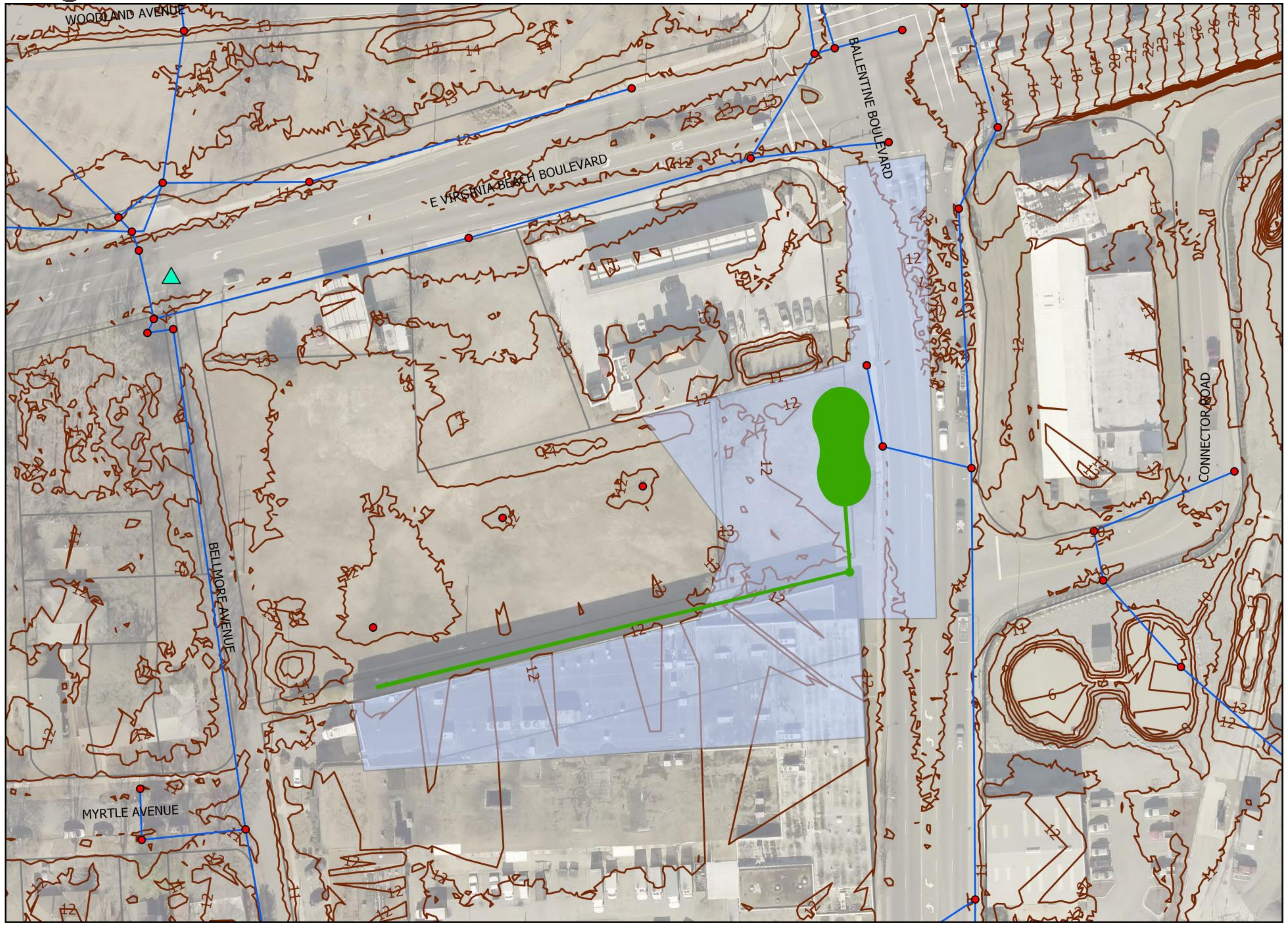
Conceptual Design – Not for Construction

Ballentine at Virginia Beach Blvd.

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 50 100 200 Feet

070 – Ballentine at Virginia Beach Blvd.
Subsurface Gravel Wetland

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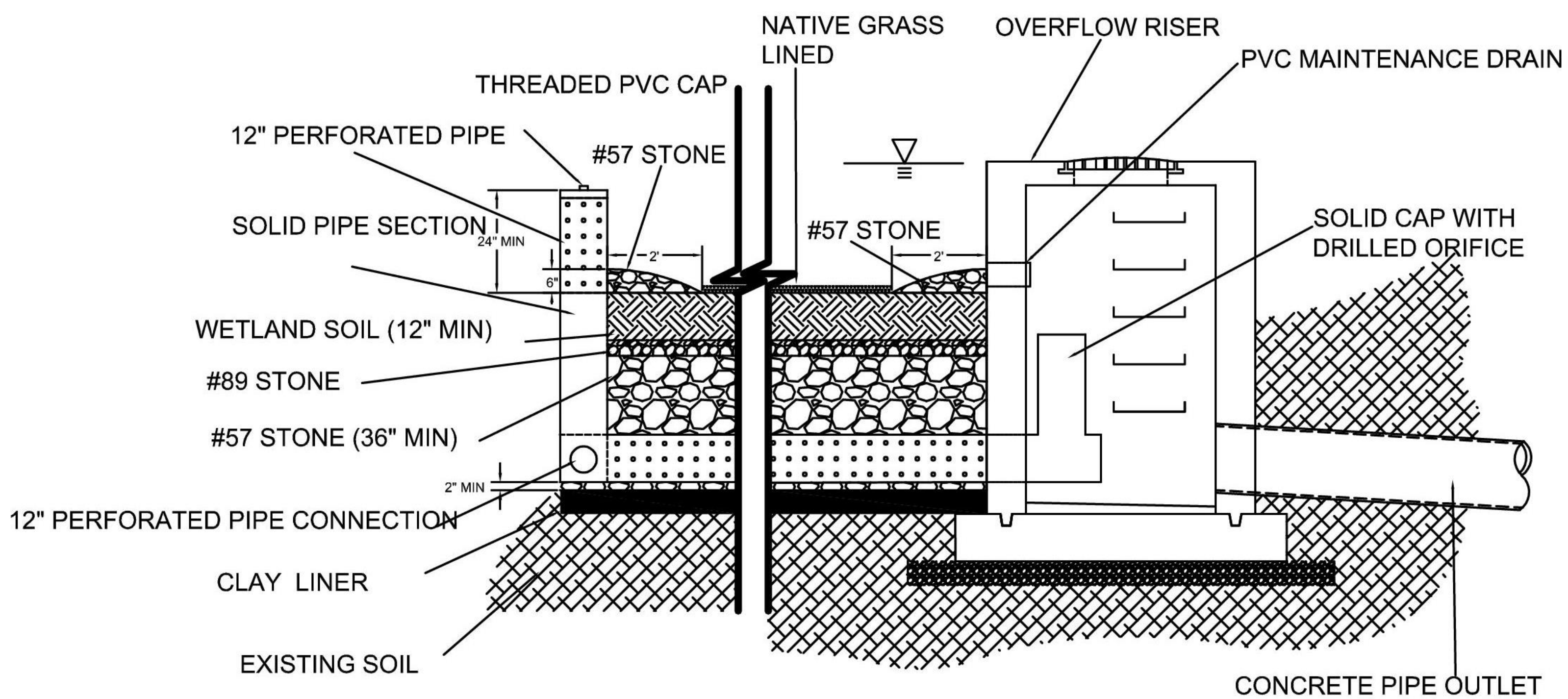
Conceptual Design – Not for Construction

Ballentine at Virginia Beach Blvd.
Subsurface Gravel Wetland Section



EXAMPLE GRAVEL WETLAND SECTION
(NOT TO SCALE)

070 – Ballentine at Virginia Beach Blvd.
Subsurface Gravel Wetland

THE CITY OF NORFOLK Hazen

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Conceptual Design – Not for Construction

Ballentine at Virginia Beach Blvd.

Design Calculations

Estimate subsurface gravel wetland footprint

- 3% of tributary area (535,000 ft^2) = 16,000 ft^2

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times Area_{impervious}$
  - $WQ_{Depth} = 1.00\ in$
  - $Area_{impervious} = 1.70\ ac$
- $WQ_V = 4{,}975\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = Area \times (D_{ponding} + D_{soil} \times Porosity_{soil} + D_{stone} \times Porosity_{stone})$
  - $D_{ponding} = 1\ ft$
  - $D_{soil} = 1\ ft$
  - $Porosity_{soil} = 0.25$
  - $D_{stone} = 3\ ft$
  - $Porosity_{stone} = 0.4$
- $Vol_{treatment} = 5{,}000\ ft^3$

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 75%, TN: 55%, TSS: 70%).

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = 1.70\ ac$
  - $\%_{impervious} = 84\%$
  - $\%_{pervious} = 16\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**2.7 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**15.3 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**991 lb/yr**

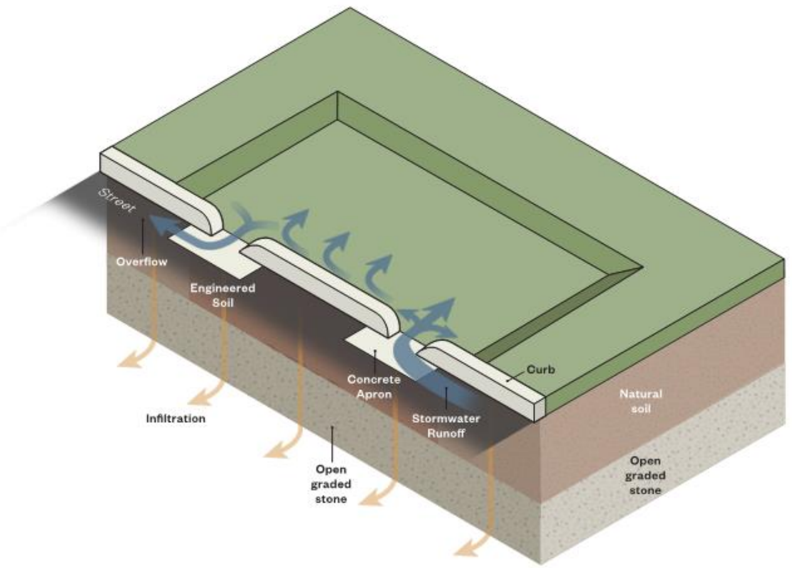
[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

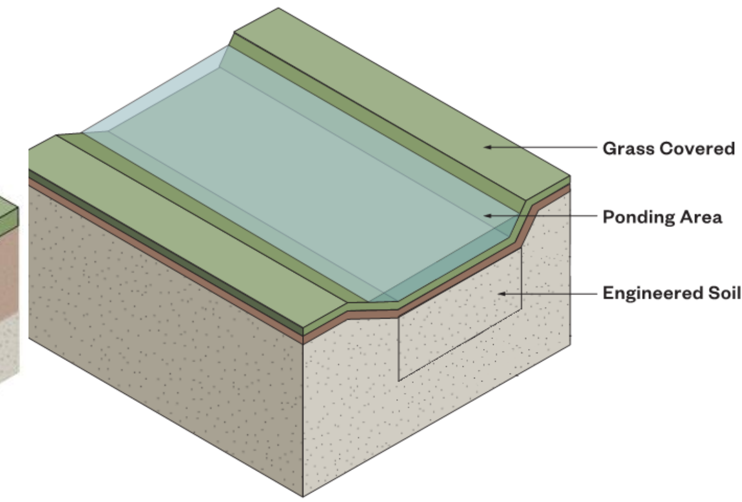
Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	50%[2]	**1.3 lb/yr**
TN	25%[2]	**3.8 lb/yr**
TSS	70%[3]	**694 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Design Specification No. 13 Constructed Wetlands, Version 2.0 January 1, 2013
[3] Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

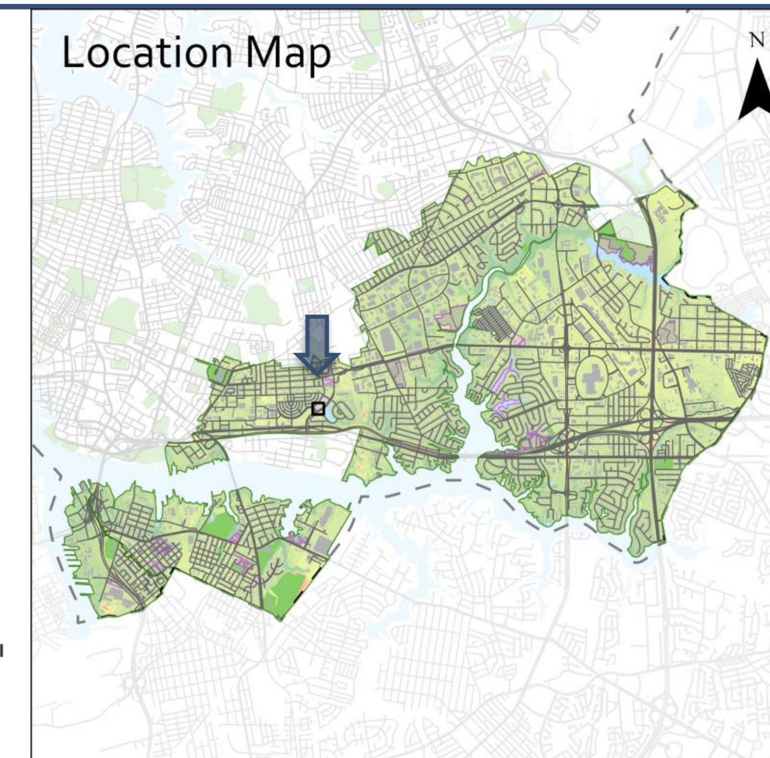
Ballentine Blvd. at NSU Entrance
Concept Overview



Iceberg Bioretention



Grass Channel



Existing Conditions

The site consists of a large vacant corner parcel owned by the Norfolk Development and Housing Authority, located across from a Norfolk State University entrance and residential lots. Existing stormwater infrastructure is located on the southeast and southwest sides of the site. The right-of-way along the southeast and southwest sites of the site consist of sidewalks, trees, traffic signal, light poles, fire hydrants, street signage, and a bus stop. The next page provides additional site photographs.

Proposed Improvements

The recommended practices on this site include a grassed channel to convey water from the center of the parcel in the low lying area with a pipe connection to the existing catch basin to treat additional impervious runoff. The grassed channel will tie into an iceberg bioretention. The iceberg bioretention will be located on the southwest corner of this site and will capture roadway runoff from Middle Town Crescent while treating flow from the grassed channel. The ponding area will have native grasses for a low maintenance vegetation and extended subsurface storage into the parcel for additional storage. The features will discharge back into the existing stormwater system with connection to a catch basin on Middle Towne Crescent. Stormwater runoff routing may require subsurface utility relocation or coordination within the practice footprint location.

073 – Ballentine Blvd. at NSU Entrance
Iceberg Bioretention & Grass Channel

Type: Grassed Channel & Iceberg Bioretention
Address: 801 Ballentine Blvd
Area Managed: 0.94 acres

Conceptual Level Estimates:

Construction Cost: $216,000
TN Load Reduction: 5.6 lb/yr
TP Load Reduction: 0.7 lb/yr
TSS Load Reduction: 325 lb/yr

Water Volume Storage: 2,600 ft^3
Cost/Storage Volume: $83/$ft^3$
TN Reduction Cost: $39,000/lb/yr
TP Reduction Cost: $309,000/lb/yr
TSS Reduction Cost: $670/lb/yr

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Conceptual Design – Not for Construction

Ballentine Blvd. at NSU Entrance
Concept Overview

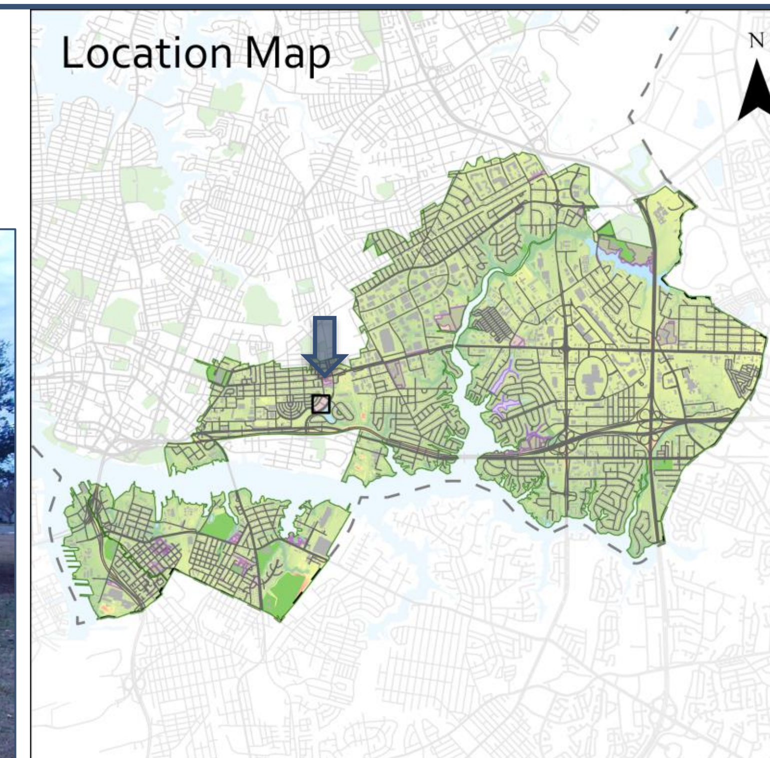
Facing west towards Middle Town Crescent

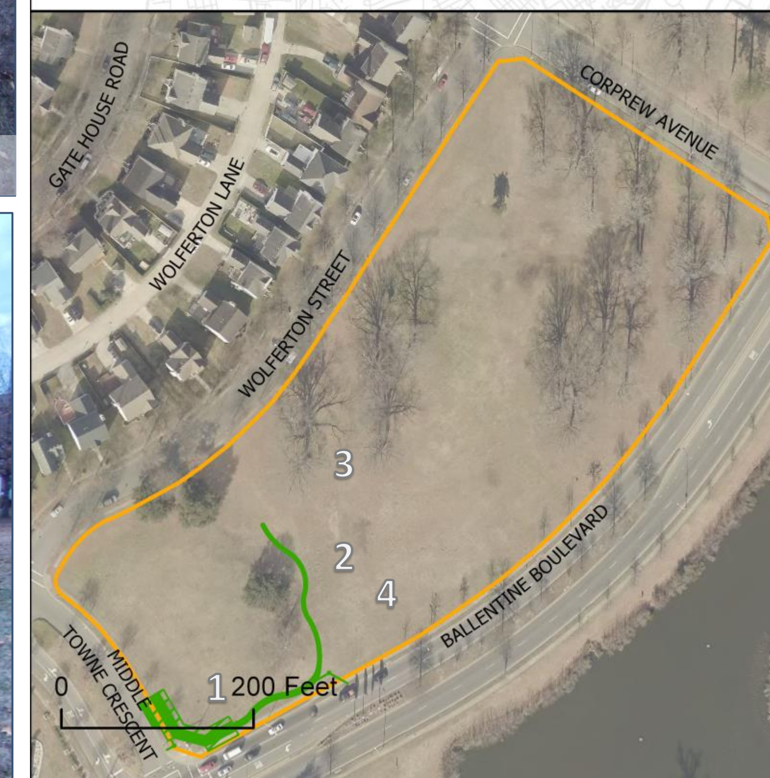
Facing SW towards trees and ponding area

Facing NW towards Wolferton Street

Facing NW towards trees and ponding area

See inset map on the right for photograph locations





073 – Ballentine Blvd. at NSU Entrance
Iceberg Bioretention & Grass Channel

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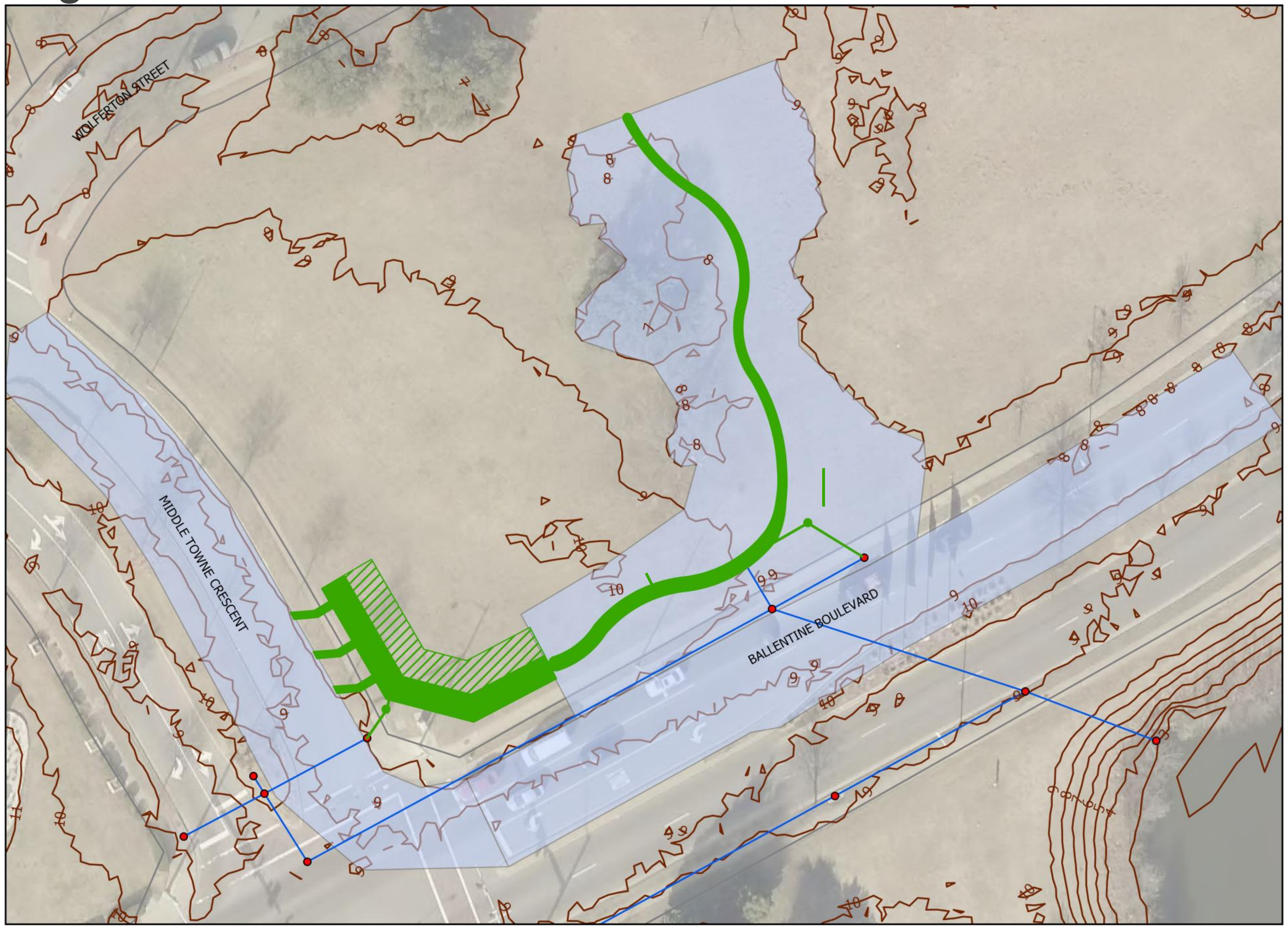
Conceptual Design – Not for Construction

Ballentine Blvd. at NSU Entrance

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

073 – Ballentine Blvd. at NSU Entrance
Iceberg Bioretention & Grass Channel

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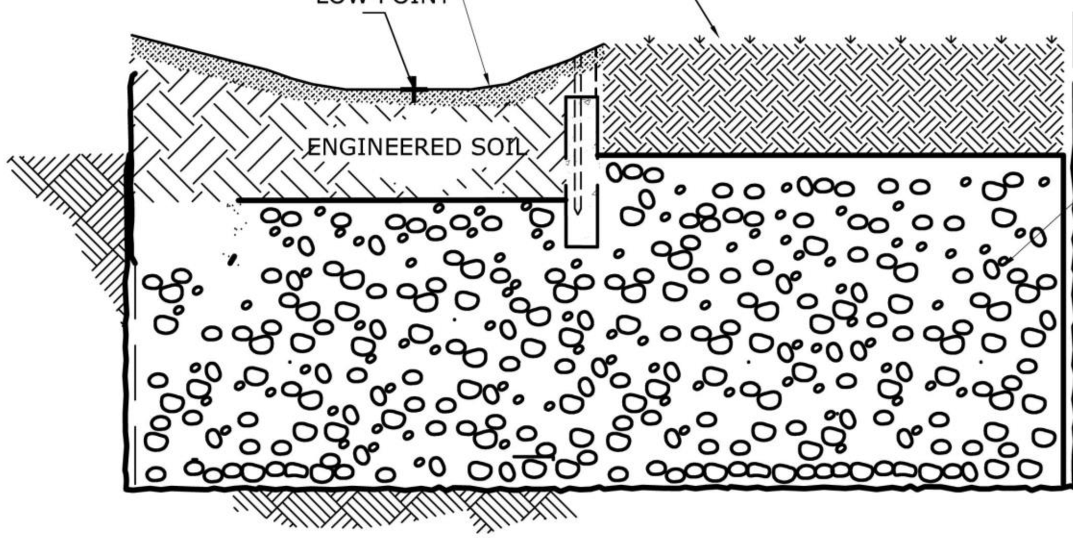
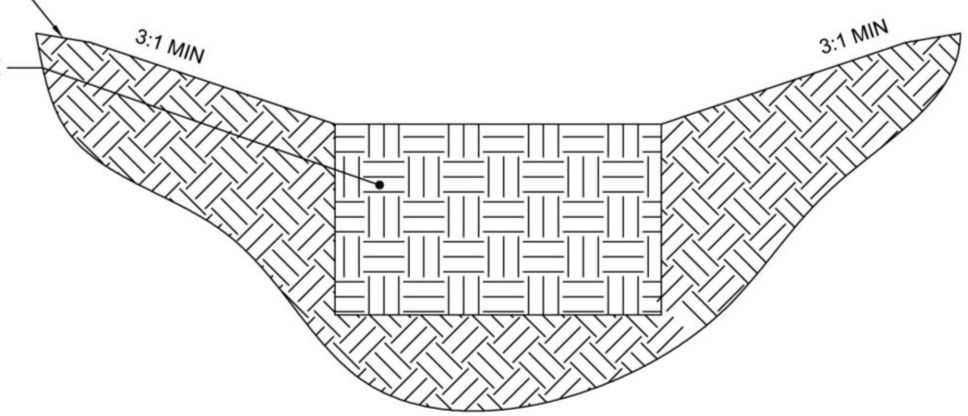
Ballentine Blvd. at NSU Entrance

Iceberg Bioretention & Grass Channel Sections



ICEBERG BIORETENTION
(NOT TO SCALE)



GRASSED CHANNEL
(NOT TO SCALE)

073 – Ballentine Blvd. at NSU Entrance
Iceberg Bioretention & Grass Channel

THE CITY OF NORFOLK | Hazen

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Conceptual Design – Not for Construction

Ballentine Blvd. at NSU Entrance

Design Calculations – Grass Channel

- **Calculate water quality volume**
  - $WQ_V = \frac{WQ_{depth}}{12} \times A$
    - $WQ_{depth} = 1.00\ in \times (0.05 + \%_{impervious} \times 0.9) = 0.62\ in$
    - $A = 30{,}932\ ft^2$
  - $WQ_V = 1{,}590\ ft^3$

- **Calculate channel sizing**

Grass Channel Sizing - 1 in storm		
Rational Parameters	Drainage Area (Ac)	0.71
	Percent Imp	38%
	"C"	0.39
	Watershed Length (ft)	100
	Delta H (ft)	2
	Kirpich Tc	1.22
	Intensity (in/hr)	1
	Flow (cfs)	0.28
Valley Gutter Characteristics	Top Width (ft)	5.5
	Bottom Width (ft)	1
	Depth (ft)	0.75
	Side Slope (ft/ft)	3
	Long Slope (ft/ft)	0.01
Mannings Analysis	Mannings N	0.035
	Flow in Ditch	0.28
	Normal Depth	0.17
Check Ditch Capacity		OK

Grass Channel Sizing - 2yr		
Rational Parameters	Drainage Area (Ac)	0.71
	Percent Imp	38%
	"C"	0.39
	Watershed Length (ft)	100
	Delta H (ft)	2
	Kirpich Tc	1.22
	Intensity (in/hr)	3.58
	Flow (cfs)	0.99
Valley Gutter Characteristics	Top Width (ft)	5.5
	Bottom Width (ft)	1
	Depth (ft)	0.75
	Side Slope (ft/ft)	3
	Long Slope (ft/ft)	0.01
Mannings Analysis	Mannings N	0.035
	Flow in Ditch	0.99
	Normal Depth	0.23
Check Ditch Capacity		OK

Grass Channel Sizing - 10yr		
Rational Parameters	Drainage Area (Ac)	0.71
	Percent Imp	38%
	"C"	0.39
	Watershed Length (ft)	100
	Delta H (ft)	2
	Kirpich Tc	1.22
	Intensity (in/hr)	5.52
	Flow (cfs)	1.54
Valley Gutter Characteristics	Top Width (ft)	5.5
	Bottom Width (ft)	1
	Depth (ft)	0.75
	Side Slope (ft/ft)	3
	Long Slope (ft/ft)	0.01
Mannings Analysis	Mannings N	0.035
	Flow in Ditch	1.54
	Normal Depth	0.28
Check Ditch Capacity		OK

Design Calculations – Iceberg Bioretention

- **Calculate water quality volume**
  - $WQ_V = \frac{WQ_{depth}}{12} \times A$
    - $WQ_{depth} = 1.00\ in \times (0.05 + \%_{impervious} \times 0.9) = 0.53\ in$
    - $A = 40{,}840\ ft^2$
  - $WQ_V = 1{,}794\ ft^3$

- **Calculate full water quality treatment volume**
  - $Vol_{treatment} = \frac{A_{floor} \times A_{ponding}}{2} \times D_{ponding} + D_{soil} \times A_{floor} \times Porosity_{soil} + (D_{stone} - 1) \times Porosity_{stone} \times A_{subsurface} + Vol_{pretreatment}$
    - $A_{floor} = 615\ ft^2$
    - $A_{ponding} = 1{,}100\ ft^2$
    - $D_{ponding} = 6\ in$
    - $D_{soil} = 1.5\ ft$
    - $Porosity_{soil} = 0.25$
    - $D_{stone} = 1.17\ ft$
    - $Porosity_{stone} = 0.4$
    - $A_{subsurface} = 2{,}250\ ft^2$
    - $Vol_{pretreatment} = 270\ ft^3$
  - $Vol_{treatment} = 1{,}900\ ft^3$

- **Estimate annual pollutant load reduction**
  - $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
    - Grass Channel
      - $A = 0.71\ ac$
      - $\%_{impervious} = 38\%$
      - $\%_{pervious} = 62\%$
    - Iceberg Bioretention
      - $A = 0.94\ ac$
      - $\%_{impervious} = 53\%$
      - $\%_{pervious} = 47\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$	
			Grass Channel	Iceberg Bioretention
TP	1.76 lb/ac/yr[1]	0.5 lb/ac/yr[1]	**0.7 lb/yr**	**0.9 lb/yr**
TN	9.39 lb/ac/yr[1]	6.99 lb/ac/yr[1]	**5.6 lb/yr**	**5.7 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**226 lb/yr**	**213 lb/yr**

[1] 2009 EOS Loading Rate (lb/ac/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ removal}$		$Load\ Reduction\ (in\ series)$	
	Grass Channel	Iceberg Bioretention	Grass Channel	Iceberg Bioretention
TP	32%[2]	55%[3]	**0.2 lb/yr**	**0.5 lb/yr**
TN	36%[2]	64%[3]	**2.0 lb/yr**	**3.6 lb/yr**
TSS	74%[4]	74%[4]	**167 lb/yr**	**158 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Design Specification No. 3 Grass Channels, Version 2.0, January 1, 2013
[3] Load Removal from Virginia DCR Stormwater Design Specification No. 9 Bioretention , Version 2.0 January 1, 2013
[4] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions Iceberg Bioretention (TP: 90%, TN: 90%, TSS: 74%).

073 – Ballentine Blvd. at NSU Entrance
Iceberg Bioretention & Grass Channel

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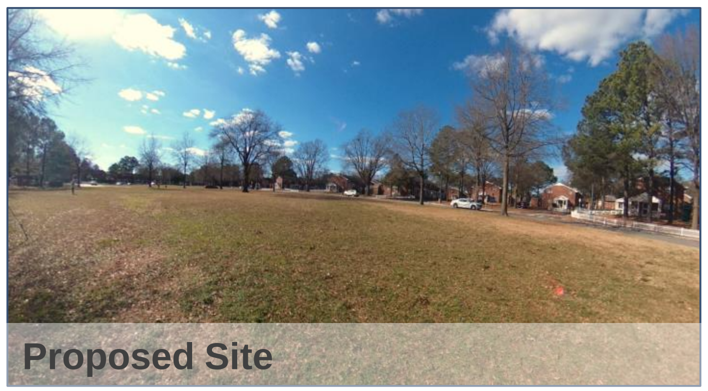
 03/22/19

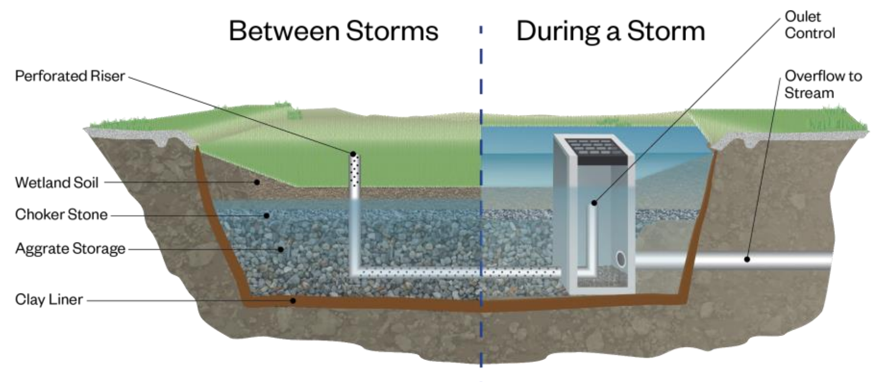
Conceptual Design – Not for Construction

Campostella Park
Concept Overview

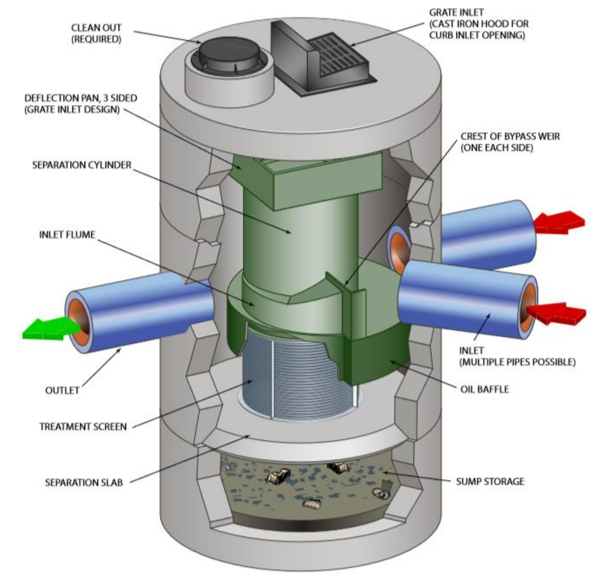
Proposed Site



Proposed Site

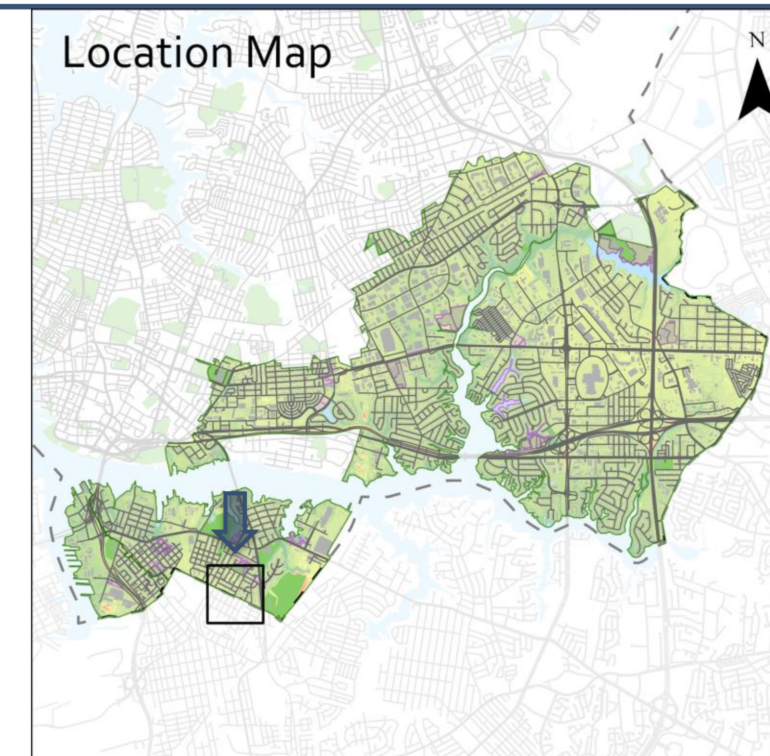


Gravel Wetland



Hydrodynamic Separator

*graphic from Contech Engineered Solutions LLC



087 – Campostella Park
Subsurface Gravel Wetland

Existing Conditions

The site consists of a large grassed vacant parcel owned by the Norfolk Redevelopment and Housing Authority. Existing stormwater infrastructure runs through the center of the parcel and a drop inlet is located on the eastern edge. A City of Norfolk Wastewater Pump Station and Dominion Energy joint building is located on the parcel. The existing stormwater infrastructure running through this site captures drainage from 43 acres of 50% impervious. The next page provides additional site photographs.

Proposed Improvement

The proposed subsurface gravel wetland practice will be hydraulically connected to the existing stormwater infrastructure. The inlet connection to the existing stormwater infrastructure should divert flow with a weir from the existing pipe network into a hydrodynamic separator to provide pretreatment and trash removal. During detailed design, the inlet and hydrodynamic separator will be configured to maximize treatment and storage. The feature will consist of a gravel subsurface, a series of risers connected to an underdrain, and an outlet structure. The entire practice will have the potential to manage at least 1" of runoff from up to 12.25 acres of drainage in the area, providing stormwater storage capacity to relieve upstream areas in the system with persistent flooding issues. Inlet stormwater runoff routing into the practices may have conflicts with below grade utilities and may require utility relocation. Along with the subsurface gravel wetland practice, the parcel could incorporate this green infrastructure as a park amenity for the public in keeping with the City of Norfolk's resilience strategy to design a coastal community with innovative water management to manage precipitation flooding in the City.

Type: Subsurface Gravel Wetland
Address: 1550 Vernon Dr.
Area Managed: 12.25 acres

Conceptual Level Estimates:

Construction Cost: $760,000
TN Load Reduction: 25.0 lb/yr
TP Load Reduction: 8.3 lb/yr
TSS Load Reduction: 4,325 lb/yr

WQ Treatment Volume: 47,000 ft^3
Cost/Storage Volume: $16/$ft^3$
TN Reduction Cost: $30,000/lb/yr
TP Reduction Cost: $91,000/lb/yr
TSS Reduction Cost: $175/lb/yr

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Conceptual Design – Not for Construction

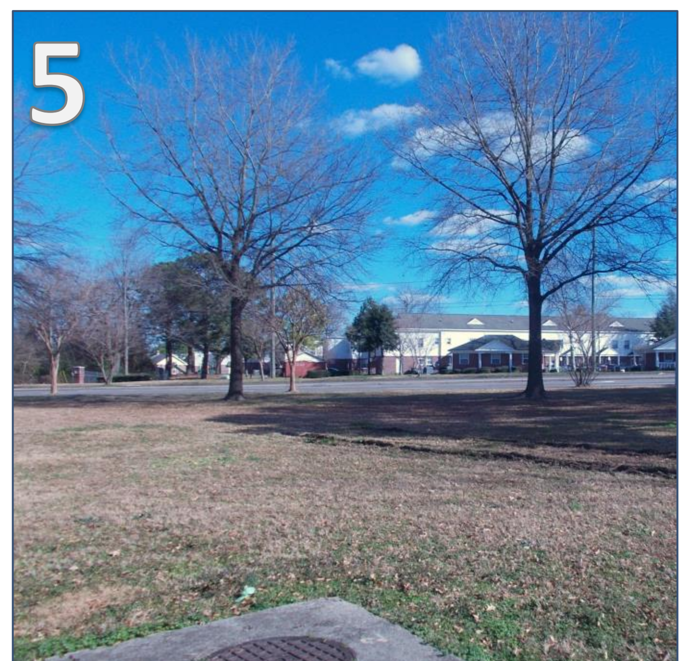
Campostella Park
Concept Overview

Facing east towards Campostella Rd.

Drop inlet at northeast corner

Campostella Rd. catch basin

Facing southwest towards Green Leaf Dr.

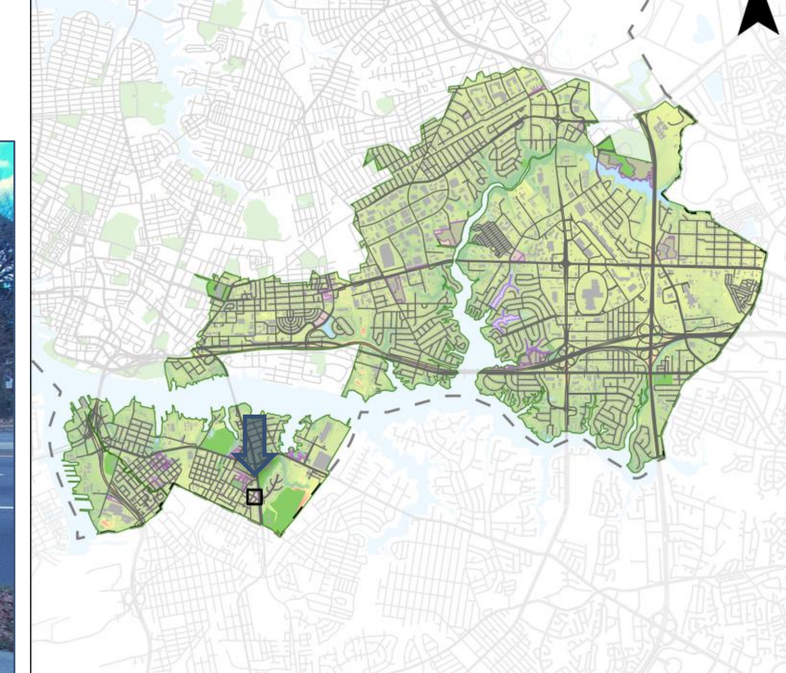


Structure in open space

Catch basins on Green Leaf Dr.

See inset map on the right for photograph locations

Location Map



087 – Campostella Park
Subsurface Gravel Wetland

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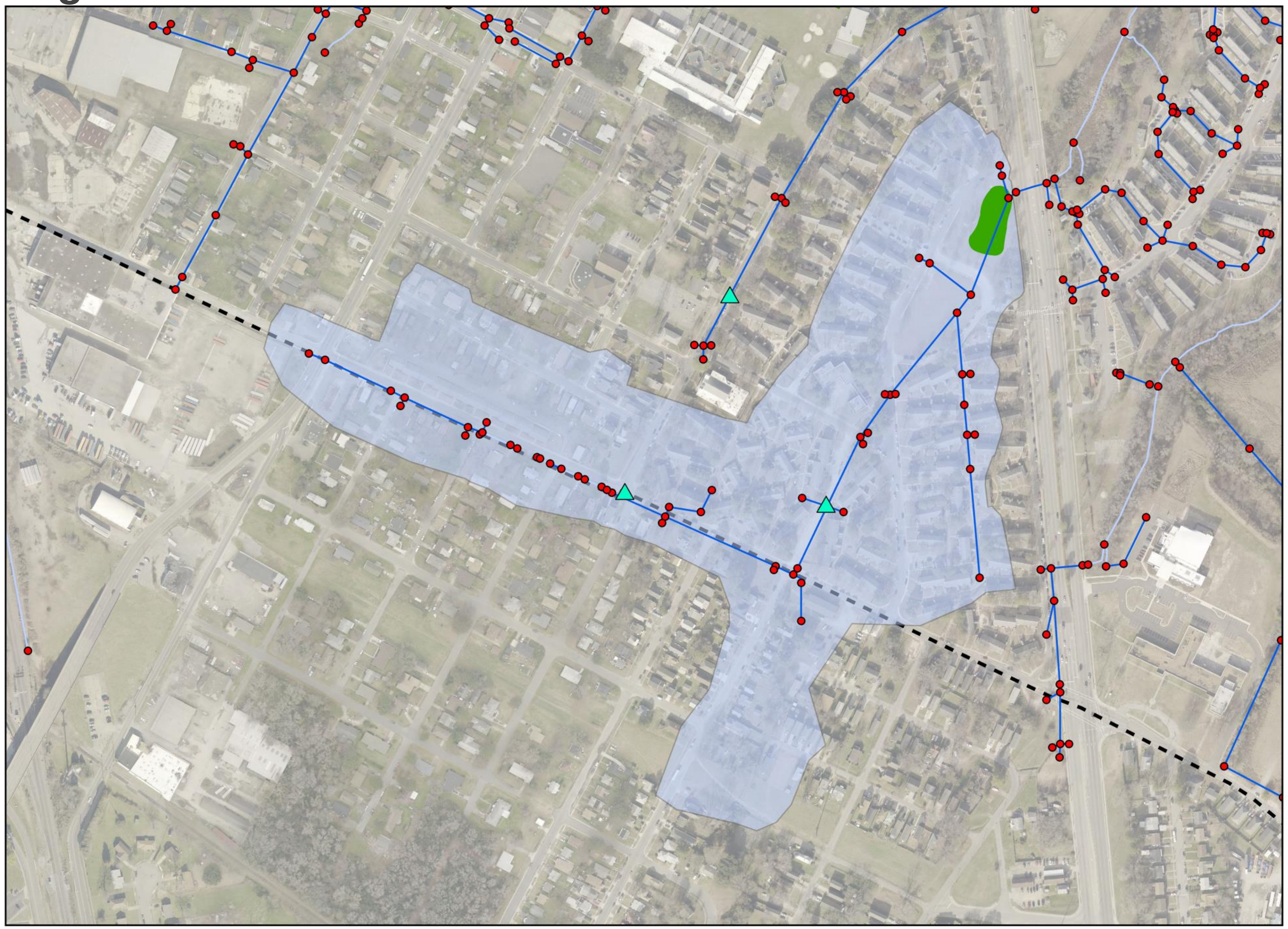
Sheet 2 of 5	03/22/19

Conceptual Design – Not for Construction

Campostella Park
Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 250 500 1,000 Feet

087 – Campostella Park
Subsurface Gravel Wetland

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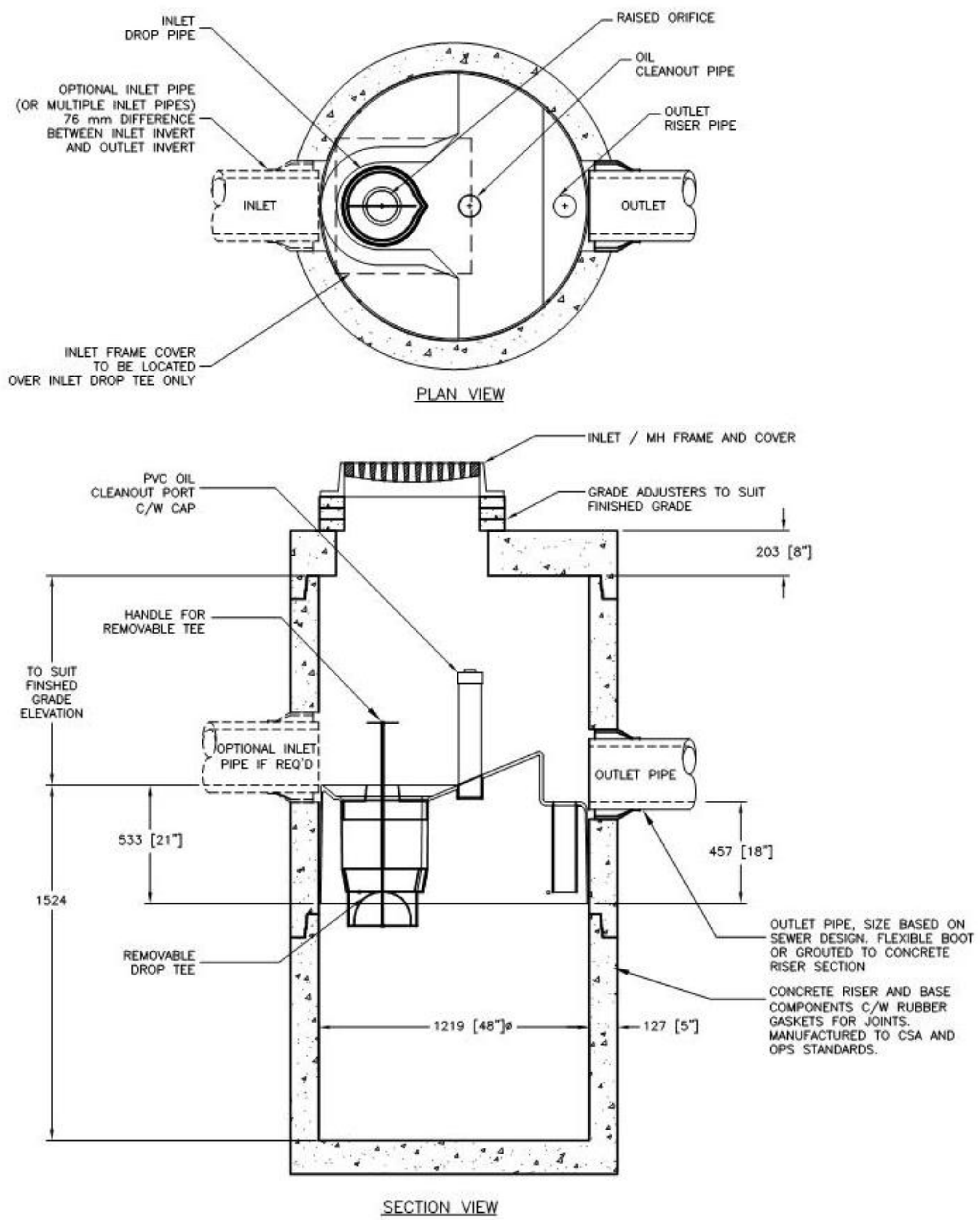
Sheet 3 of 5	03/22/19

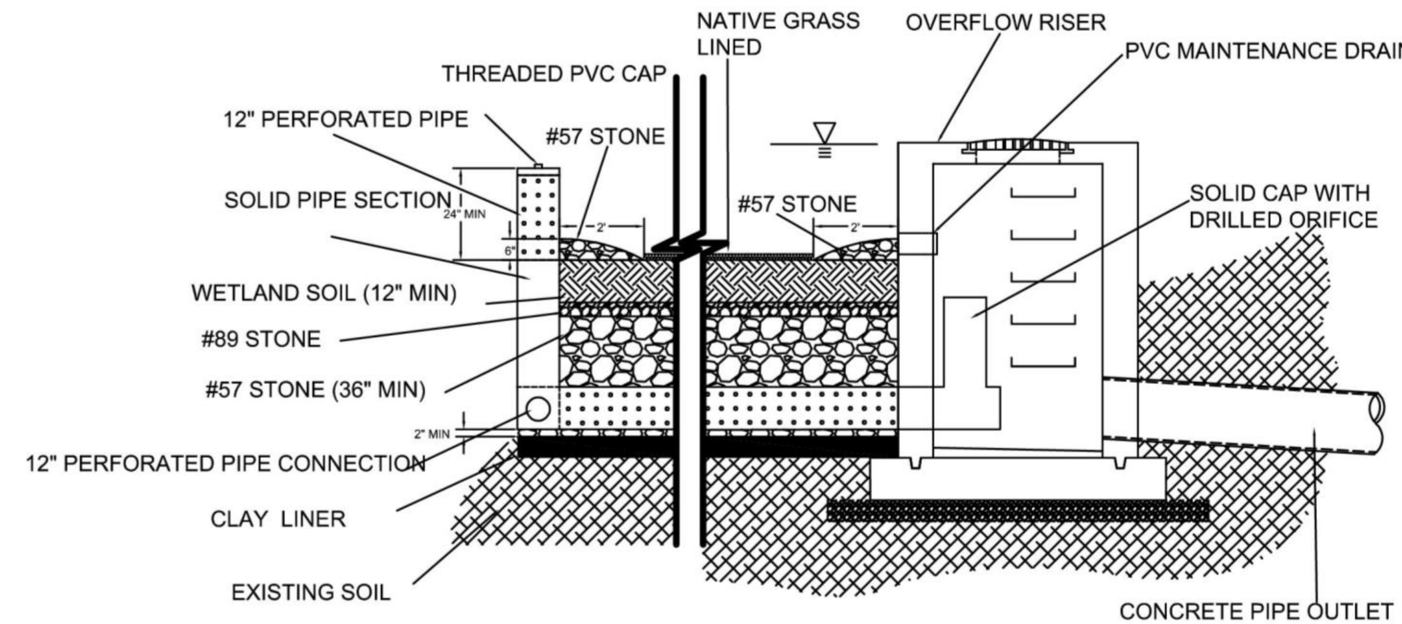
Conceptual Design – Not for Construction

Campostella Park

Hydrodynamic Separator & Subsurface Gravel Wetland Standard Detail



HYDRODYNAMIC SEPARATOR
(NOT TO SCALE)



EXAMPLE GRAVEL WETLAND SECTION
(NOT TO SCALE)

087 – Campostella Park Subsurface Gravel Wetland	
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Campostella Park
Design Calculations

Estimate subsurface gravel wetland footprint

- 3% of tributary area (535,000 ft^2) = 16,000 ft^2

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times Area_{impervious}$
  - $WQ_{Depth} = 1.00\ in$
  - $Area_{impervious} = 223{,}240\ ft^2$
- $WQ_V = 16{,}755\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = Area \times (D_{ponding} + D_{soil} \times Porosity_{soil} + D_{stone} \times Porosity_{stone})$
  - $D_{ponding} = 1\ ft$
  - $D_{soil} = 1\ ft$
  - $Porosity_{soil} = 0.25$
  - $D_{stone} = 4\ ft$
  - $Porosity_{stone} = 0.4$
- $Vol_{treatment} = 47{,}000\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = 12.25\ ac$
  - $\%_{impervious} = 50\%$
  - $\%_{pervious} = 50\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**13.8 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**100.1 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**4,753 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

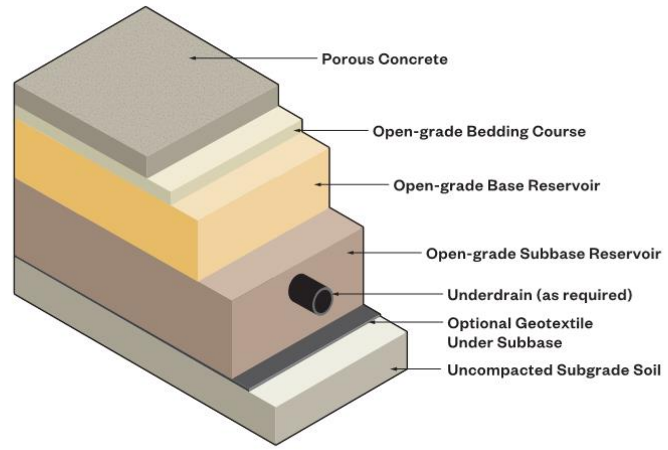
- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	50%[2] & 20%[3] (in series removal)	**8.3 lb/yr**
TN	25%[2]	**25.0 lb/yr**
TSS	70%[4] & 70%[4] (in series removal)	**4,325 lb/yr**

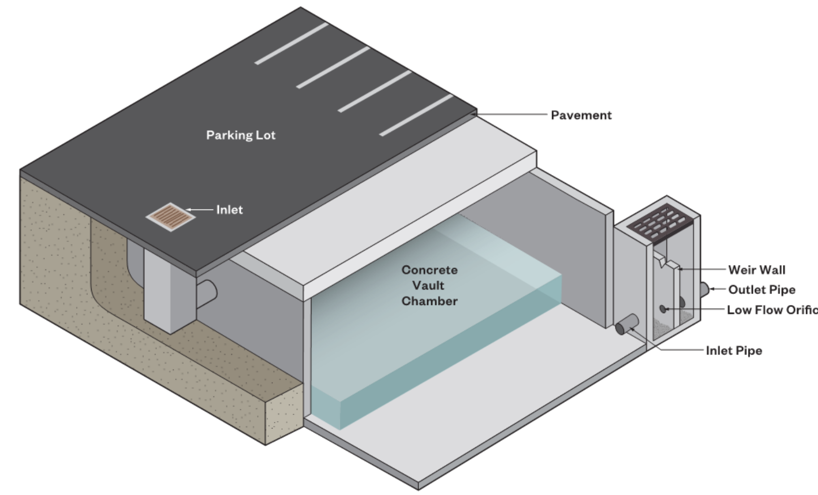
[2] Load Removal from Virginia DCR Stormwater Design Specification No. 13 Constructed Wetlands, Version 2.0 January 1, 2013
[3] Load Removal from Virginia DCR Stormwater Clearinghouse, Hydrodynamic Separator, Design Specification No. 16, Version 2.0 January 1, 2013
[4] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Gravel Wetland – Level 2 Reductions (TP: 75%, TN: 55%, TSS: 70%).

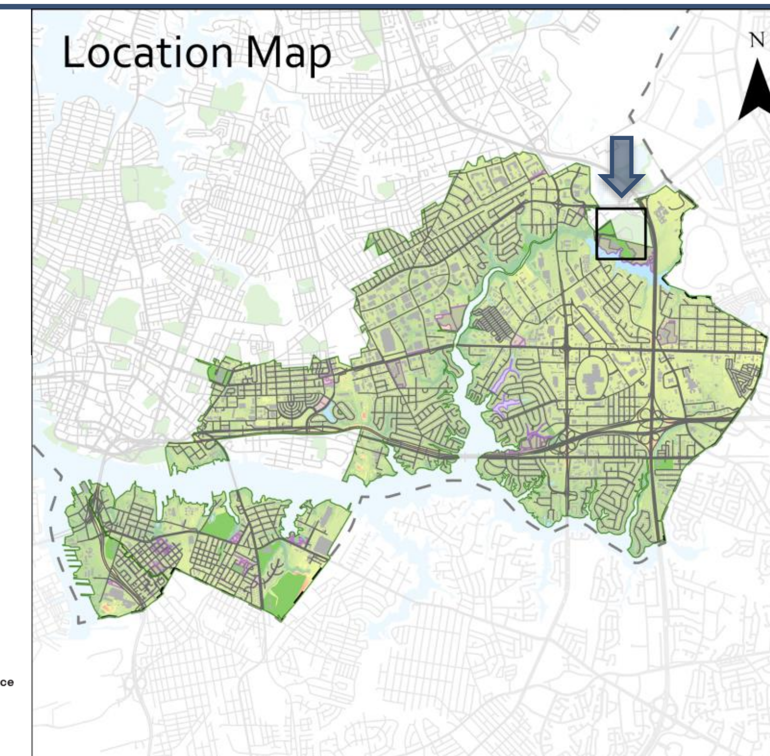
Lake Taylor Middle and High School
Concept Overview

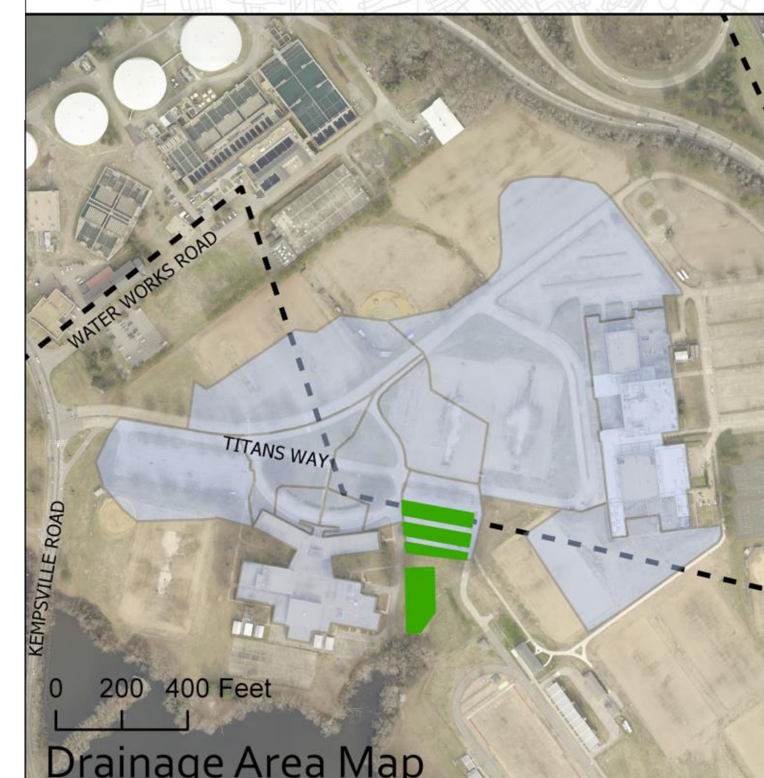


Porous Concrete



Underground Detention





099 – Lake Taylor Middle and High School
Underground Detention & Porous Concrete

Existing Conditions

The existing site consists of a large, developed parcel owned by the City of Norfolk with mixed land use types. Existing stormwater infrastructure runs throughout the parcel and discharges into Lake Taylor. The site is occupied by Lake Taylor Middle School and High School. The stormwater infrastructure that runs through this site captures drainage from 32 acres of 46% impervious area. The next page provides additional site photographs.

Proposed Improvements

The two practices recommended on this parcel for stormwater management are porous concrete and an underground detention vault. The porous concrete will be installed in the parking lot east of Lake Taylor Middle School. The entire parking lot will be replaced for grading and maintenance, but porous concrete is only recommended on the south side of the lot. The parking lot will be regraded to slope at 1% to the south, and curb cuts will be installed at various locations to act as emergency overflows to the south. The existing yard inlet at the edge of the parking lot will be left in place and will not impact the proposed drainage area to the facility. The porous concrete sections are connected through a solid underdrain that will run from north to south before discharging into the underground detention vault. The underground detention vault is sited south of the proposed porous pavement and will capture and detain the flow from the existing stormwater network from the Middle School and High School. A diversion structure will be installed on each of the discharge pipes to allow flow to bypass the facility during larger storm events. The two practices together will have the potential to manage at least 1” of runoff from up to 23.9 acres of drainage in the area, providing stormwater storage capacity to relieve flooding associated with Lake Taylor. Subsurface utilities are not anticipated to be an issue.

Type: Porous Concrete & Underground Detention
Address: 1380 Kempsville Rd
Area Managed: 23.9 acres

Conceptual Level Estimates:

Construction Cost: $2,043,000
TN Load Reduction: 31.3 lb/yr
TP Load Reduction: 6.1 lb/yr
TSS Load Reduction: 8,255 lb/yr

WQ Treatment Volume: 83,625 ft^3
Cost/Storage Volume: $24/$ft^3$
TN Reduction Cost: $65,000/lb/yr
TP Reduction Cost: $335,000/lb/yr
TSS Reduction Cost: $250/lb/yr

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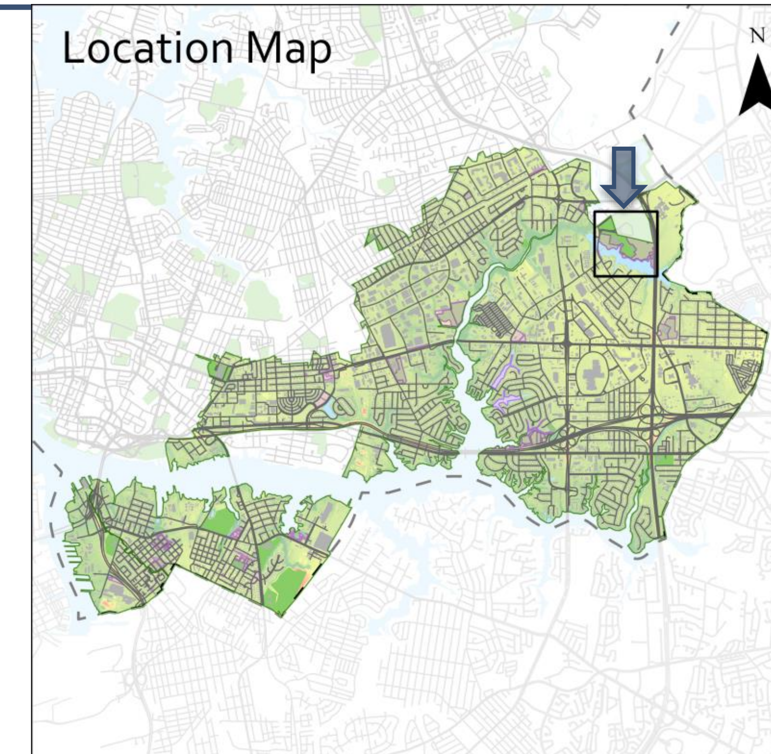
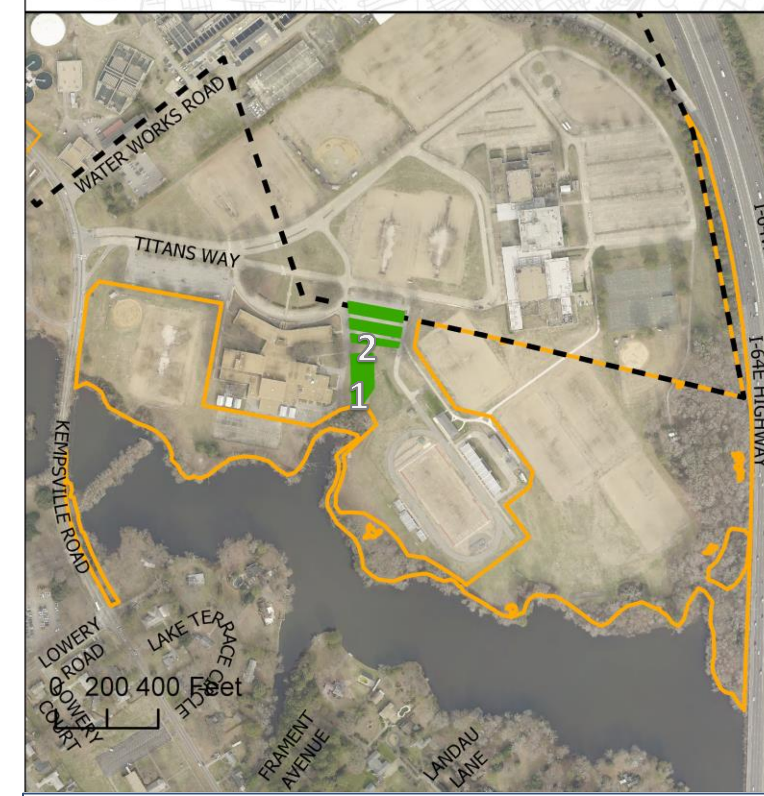
Conceptual Design – Not for Construction

Lake Taylor Middle and High School
Concept Overview

Facing south toward proposed detention downstream

Facing north towards proposed porous parking lot





099 – Lake Taylor Middle and High School
Underground Detention & Porous Concrete

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See inset map on the right for photograph locations

Conceptual Design – Not for Construction

Lake Taylor Middle and High School

Drainage Area Plan View

LEGEND

- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 100 200 400 600 Feet

099 – Lake Taylor Middle and High School Underground Detention & Porous Concrete	
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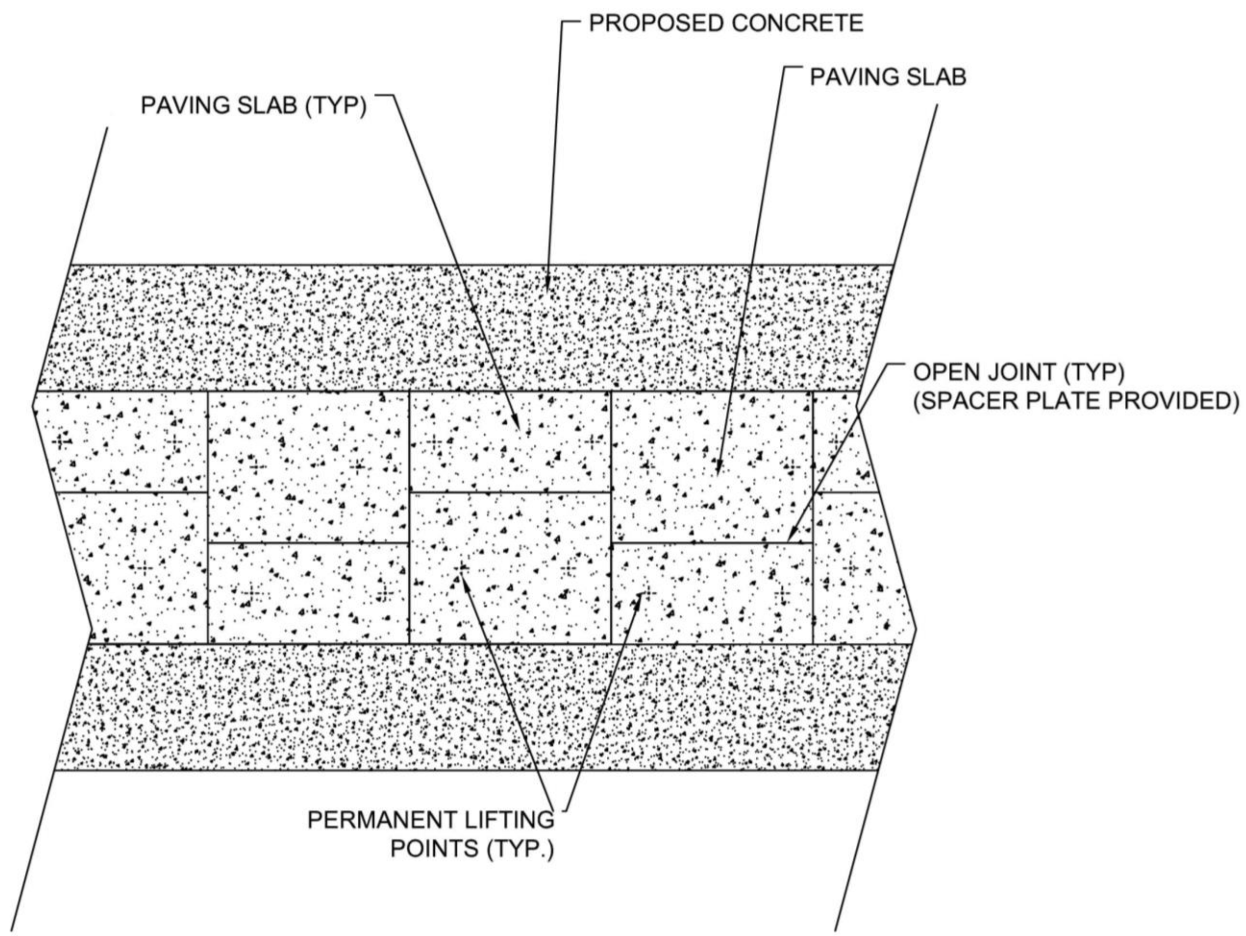
Conceptual Design – Not for Construction

Lake Taylor Middle and High School

Porous Concrete Standard Detail



MODULAR POROUS CONCRETE PAVING SLAB
PLAN VIEW
(NOT TO SCALE)

099 – Lake Taylor Middle and High School Underground Detention & Porous Concrete	
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Lake Taylor Middle and High School
Design Calculations

Design Calculations – Porous Concrete

Estimate porous concrete footprint

- Treatment volume = 4,982 ft[3]
- CDA Ratio = $\frac{Non-Porous\ Concrete\ Area}{Porous\ Concrete\ Area}$ = 2.5

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 91\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.87in$
  - $A = 54{,}885\ ft^2$
- $WQ_V = 3{,}986\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = Area \times D_{stone} \times Porosity_{stone}$
  - $D_{stone} = 7\ inches$
  - $Porosity_{stone} = 0.4$
- $Vol_{treatment} = 43{,}960\ ft^3$

Design Calculations – Underground Detention

Estimate underground detention footprint

- 72% of treatment volume (46,448 ft[3]) = 15,500 ft[2]

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A - Volume_{Upstream\ RR}$
  - $\%_{impervious} = 45\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.46in$
  - $A = 1{,}323{,}000\ ft^2$
  - $Volume_{Upstream\ RR} = 3{,}986\ ft^3$
- $WQ_V = 46{,}448\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = Area \times D_{ponding}$
  - $D_{ponding} = 2.2'$
- $Vol_{treatment} = 33{,}581\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = \left(A \times \%_{impervious} \times Loading\ Rate_{imp}\right) + \left(A \times \%_{pervious} \times Loading\ Rate_{per}\right)$
  - Porous Concrete
    - $A = 1.26\ ac$
    - $\%_{impervious} = 91\%$
    - $\%_{pervious} = 9\%$
  - Underground Detention
    - $A = 30.37\ ac$
    - $\%_{impervious} = 45\%$
    - $\%_{pervious} = 55\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$	
			Porous Concrete	Underground Detention
TP	1.76 lb/ac/yr[1]	0.50 lb/ac/yr[1]	**2.1 lb/yr**	**32.5 lb/yr**
TN	9.39 lb/ac/yr[1]	6.99 lb/ac/yr[1]	**11.5 lb/yr**	**244.9 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**787 lb/yr**	**10,960 lb/yr**

[1] 2009 EOS Loading Rate (lb/ac/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ removal}$		$Load\ Reduction$	
	Porous Concrete	Underground Detention	Porous Concrete	Underground Detention
TP	59%[2]	15%[3]	**1.2 lb/yr**	**4.9 lb/yr**
TN	59%[2]	10%[3]	**6.8 lb/yr**	**24.5 lb/yr**
TSS	74%[4]	70%[4]	**583 lb/yr**	**7,672 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Design Specification No. 7 Permeable Pavement, Version 2.0, January 1, 2013
[3] Load Removal from Virginia DCR Stormwater Design Specification No. 15 Extended Detention, Version 2.0, January 1, 2013
[4] Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints.
Porous Concrete – Level 2 Reductions (TP: 81%, TN: 81%, TSS: 74%)
Extended Detention – Level 2 Reductions (TP: 31%, TN: 24%, TSS: 70%)

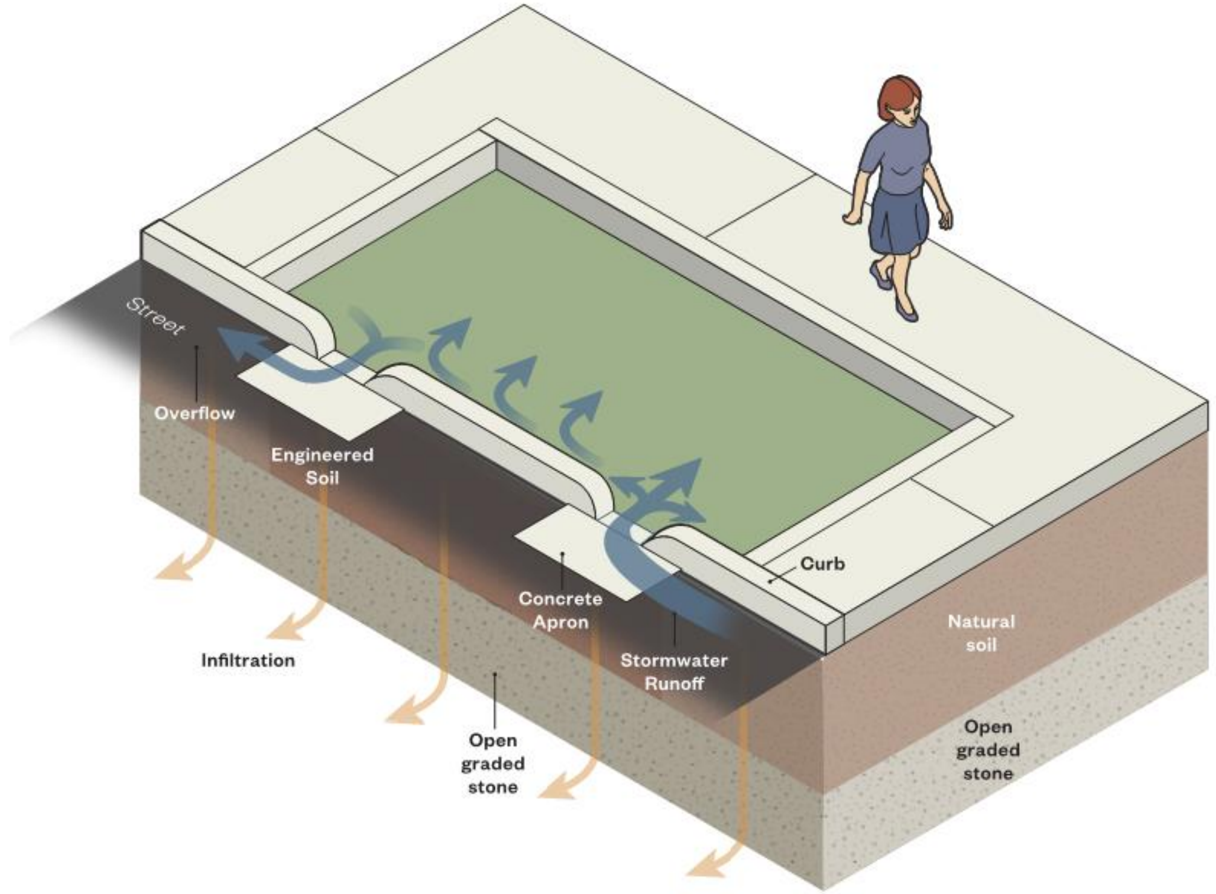
099 – Lake Taylor Middle and High School
Underground Detention & Porous Concrete

THE CITY OF NORFOLK Hazen

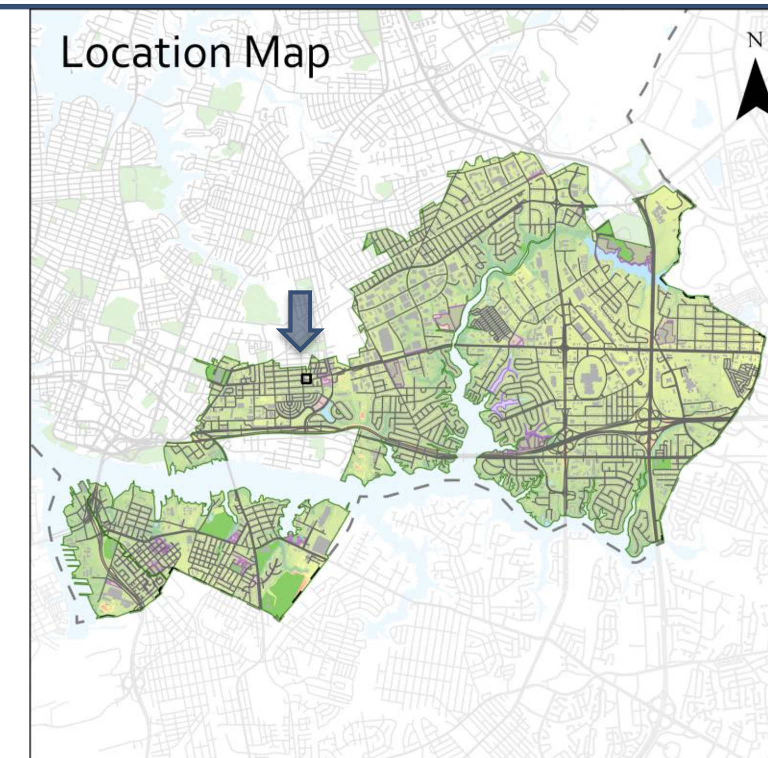
 03/22/19

Conceptual Design – Not for Construction

Corner Lot at E. Virginia Beach Blvd.
Concept Overview



Iceberg Bioretention



104 – Corner Lot at E. Virginia Beach Blvd.
Iceberg Bioretention

Existing Conditions

The site consists of a large vacant parcel owned by the City of Norfolk and is located adjacent to an apartment building. Existing stormwater infrastructure is located on the southwest corner of the site. The right-of-ways along the western and southern sides of the site have sidewalks, and the southern side has a local bus stop. The roadway area that drains towards this site is 0.24 acres of 100% impervious. Adjacent to the bus stop is a curb inlet catch basin for bioretention connectivity. The next page provides additional site photographs.

Proposed Improvement

The proposed iceberg bioretention will be located on the southwest corner of the site adjacent to E. Virginia Beach Blvd. and Merrimac Ave. The feature will consist of a grass top with a subsurface layer of bioretention soils, as well as a stone storage layer with an underdrain reconnecting to the existing stormwater system on E. Virginia Beach Blvd. The southwest corner of the iceberg bioretention will have an outlet structure and discharge to a proposed manhole which will reconnect to the existing stormwater system on E. Virginia Beach Blvd. The entire practice will have the potential to manage at least 1" of runoff from up to 0.24 acres of drainage in the area, providing stormwater storage and conveyance to relieve the localized ponding issues on this site. Stormwater runoff routing may require subsurface utility relocation or coordination within the practice footprint location.

Type: Iceberg Bioretention
Address: 2900 E. VA Beach Blvd.
Area Managed: 0.24 acres

Conceptual Level Estimates:

Construction Cost: $69,000
TN Load Reduction: 1.4 lb/yr
TP Load Reduction: 0.2 lb/yr
TSS Load Reduction: 119 lb/yr

WQ Treatment Volume: 839 ft^3
Cost/Storage Volume: $82/$ft^3$
TN Reduction Cost: $48,000/lb/yr
TP Reduction Cost: $298,000/lb/yr
TSS Reduction Cost: $578/lb/yr

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Conceptual Design – Not for Construction

Corner Lot at E. Virginia Beach Blvd
Concept Overview

Facing east on VB Blvd.

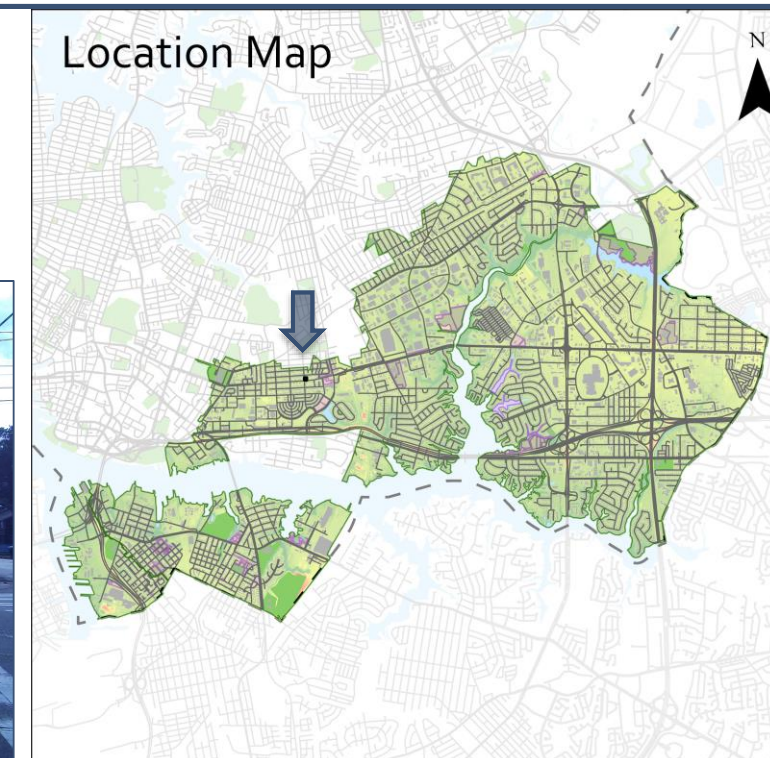
Existing catch basin on VB Blvd.

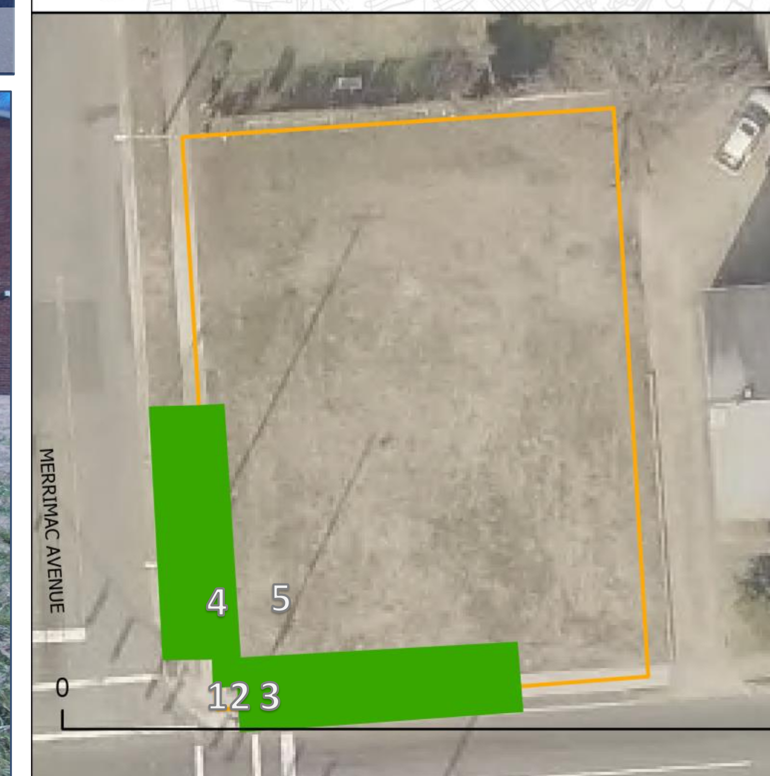
Facing south on VB Blvd.

Facing SE across open space

Facing NE to open space

See inset map on the right for photograph locations





104 – Corner Lot at E. Virginia Beach Blvd.
Iceberg Bioretention

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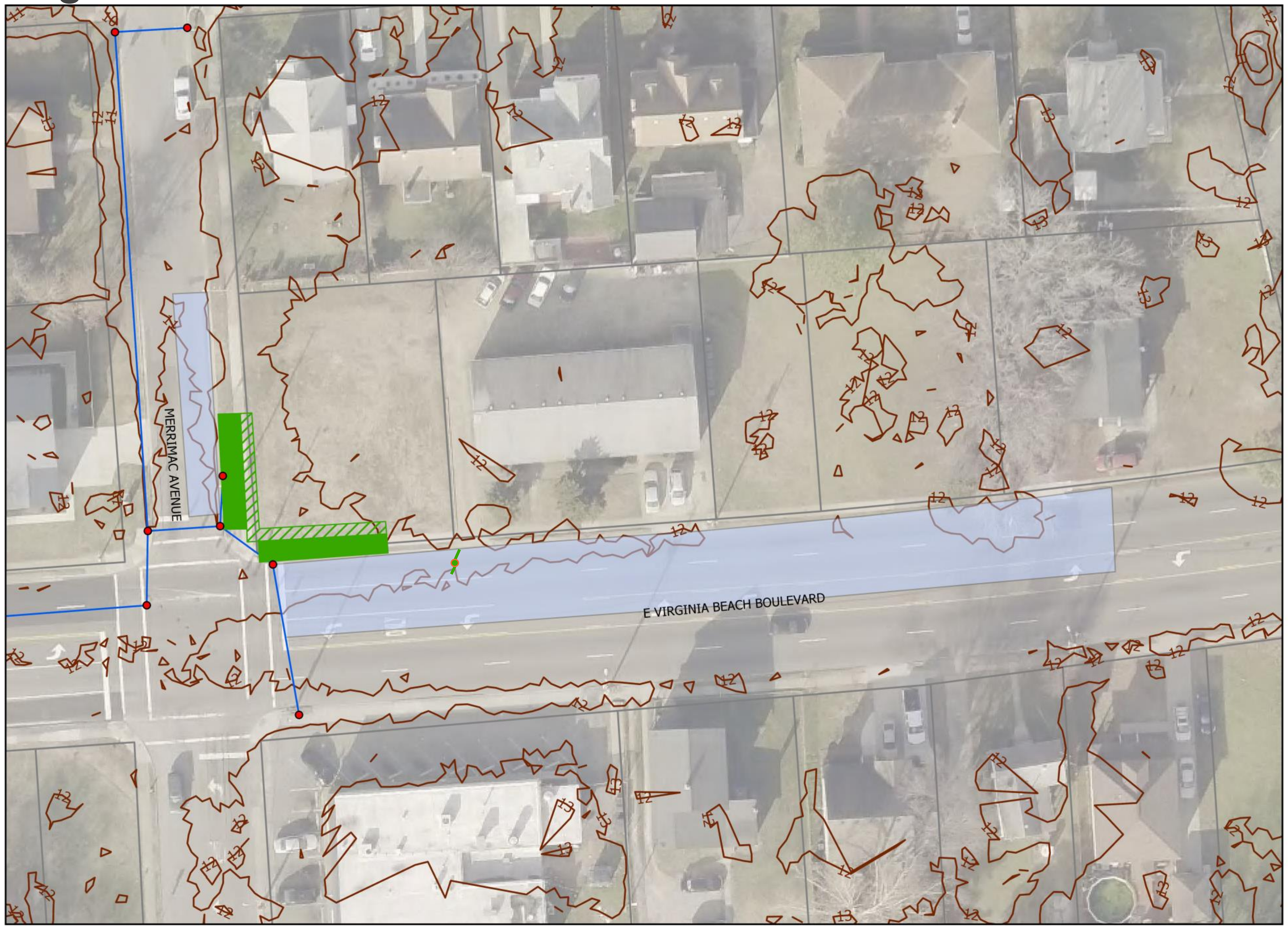
Conceptual Design – Not for Construction

Corner Lot at E. Virginia Beach Blvd
Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

104 – Corner Lot at E. Virginia Beach Blvd.
Iceberg Bioretention

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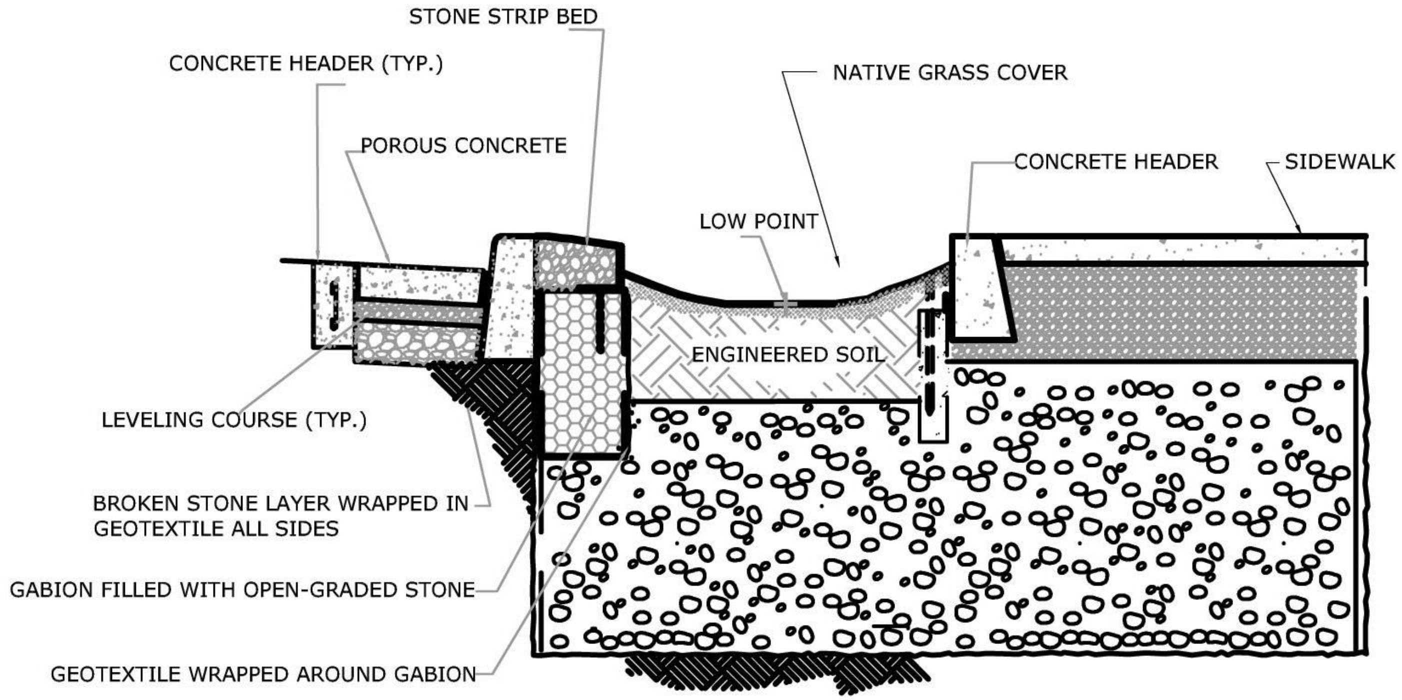
Corner Lot at E. Virginia Beach Blvd
Iceberg Bioretention Section



RIGHT-OF-WAY BIORETENTION
(NOT TO SCALE)

104 – Corner Lot at E. Virginia Beach Blvd. Iceberg Bioretention	
THE CITY OF NORFOLK	Hazen
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Corner Lot at E. Virginia Beach Blvd

Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 100\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.95 in$
  - $A = 10{,}412\ ft^2$
- $WQ_V = 824\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = \frac{A_{floor} \times A_{ponding}}{2} \times D_{ponding} + D_{soil} \times A_{floor} \times Porosity_{soil} + (D_{stone} - 1) \times Porosity_{stone} \times A_{subsurface} + Vol_{pretreatment}$
  - $A_{floor} = 400\ ft^2$
  - $A_{ponding} = 650\ ft^2$
  - $D_{stone} = 1 ft$
  - $Porosity_{stone} = 0.4$
  - $A_{subsurface} = 1{,}110\ ft^2$
  - $Vol_{pretreatment} = 124 ft^3$
- $Vol_{treatment} = 830\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = 0.24\ ac$
  - $\%_{impervious} = 100\%$
  - $\%_{pervious} = 0\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**0.4 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**2.2 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**161 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	55%[2]	**0.2 lb/yr**
TN	64%[2]	**1.4 lb/yr**
TSS	74%[3]	**119 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Bioretention Specification No. 9, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

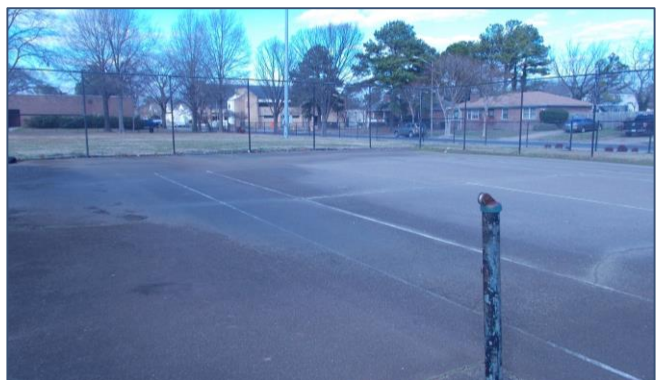
Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 90%, TN: 90%, TSS: 74%).

104 – Corner Lot at E. Virginia Beach Blvd.
Iceberg Bioretention

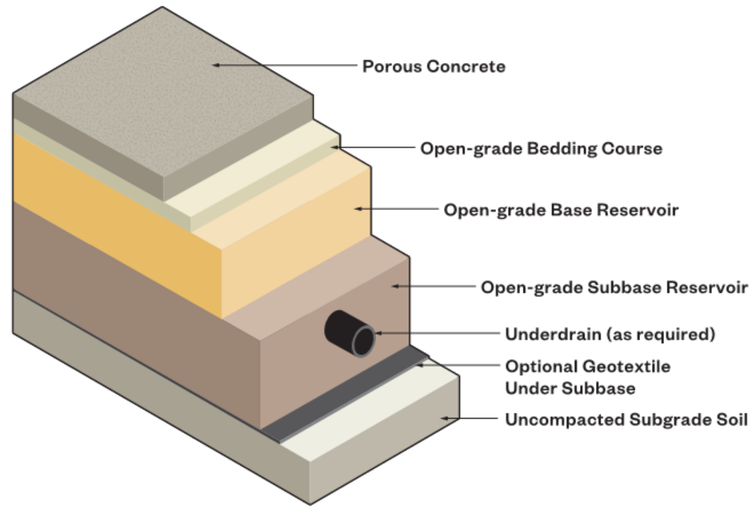
Conceptual Design – Not for Construction

Berkley Park
Concept Overview

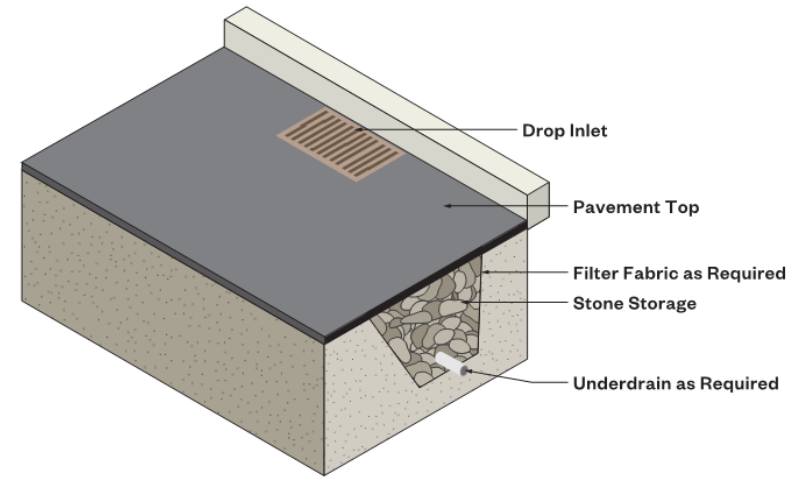
Proposed Site



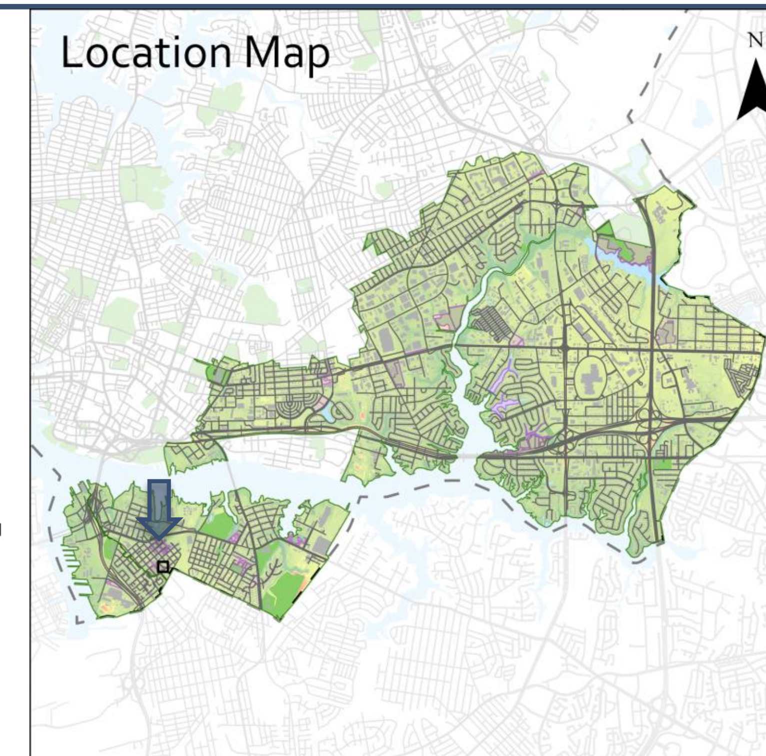
Proposed Site



Permeable Pavement



Subsurface Chamber



Existing Conditions

The site consists of a public park owned by the City of Norfolk, located across from residential lots, apartments buildings, a church, and a Boys & Girls Club. The existing volleyball/tennis court is in poor condition. Existing stormwater infrastructure is located on Berkley Ave. The playcourt area and existing infrastructure on the adjacent roadway capture drainage from 0.52 acres of 78% impervious area. The right-of-way along Berkley Ave consists of sidewalk, light poles, and trees. The next page provides additional site photographs.

Proposed Improvements

The recommended practices for this site include porous concrete around the perimeter of the volleyball/tennis court with underdrains connecting to subsurface storage underneath the volleyball/tennis court. The practice will have the potential to manage at least 1” of runoff from up to 0.17 acres of drainage area, providing stormwater storage and conveyance from the volleyball/tennis court. The subsurface detention will have the potential to manage at least 1” of runoff from up to 0.52 acres of drainage by providing storage for the porous concrete as well as runoff from Berkley Ave. Two additional catch basins would be added to the roadway to catch impervious area runoff to route to the subsurface detention. The subsurface detention would have an outlet that would tie back into the existing infrastructure on Berkley Ave. Stormwater runoff routing may require subsurface utility relocation or coordination within the practice footprint location.

136 – Berkley Park
Porous Concrete & Subsurface Detention

Type: Porous Concrete & Subsurface Chamber
Address: 706 Walker Ave.
Area Managed: 0.52 acres total

Conceptual Level Estimates:

Construction Cost: $410,000
TN Load Reduction: 1.3 lb/yr
TP Load Reduction: 0.3 lb/yr
TSS Load Reduction: 233 lb/yr

WQ Treatment Volume: 2,060 ft^3
Cost/Storage Volume: $200/$ft^3$
TN Reduction Cost: $315,000/lb/yr
TP Reduction Cost: $1,366,000/lb/yr
TSS Reduction Cost: $1,750/lb/yr

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Conceptual Design – Not for Construction

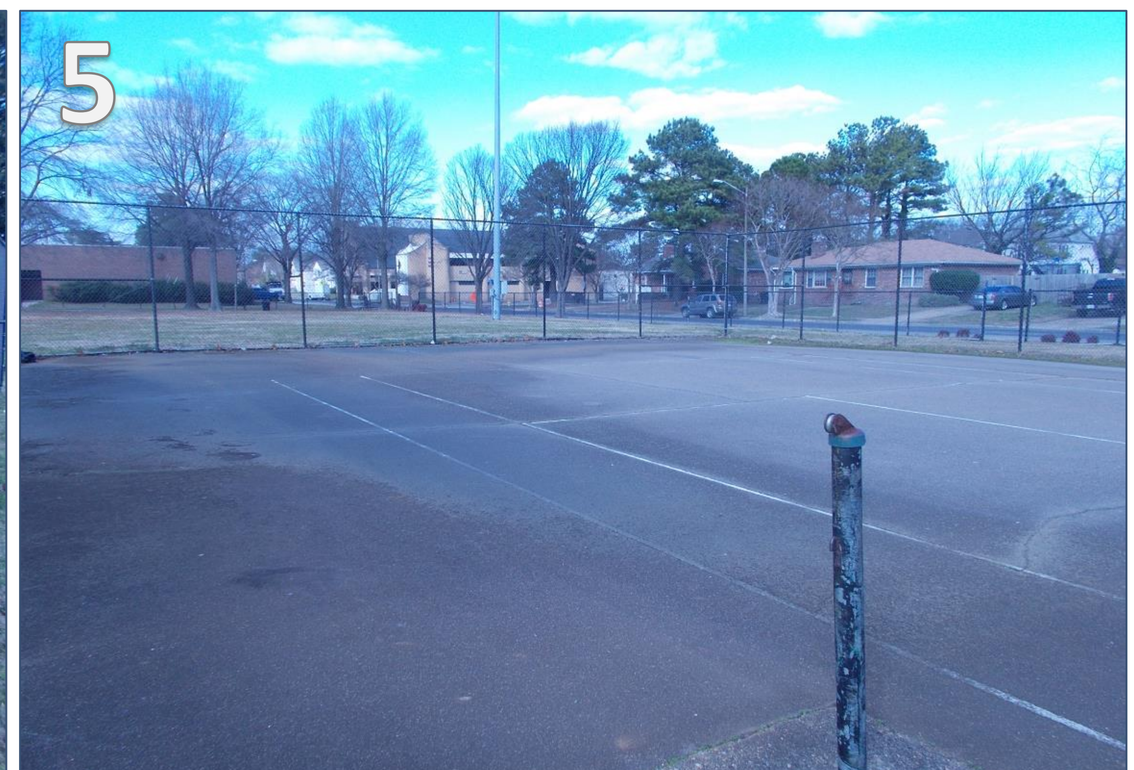
Berkley Park
Concept Overview

Entrance to Berkley Park

Facing SE to area in front of tennis/volleyball court

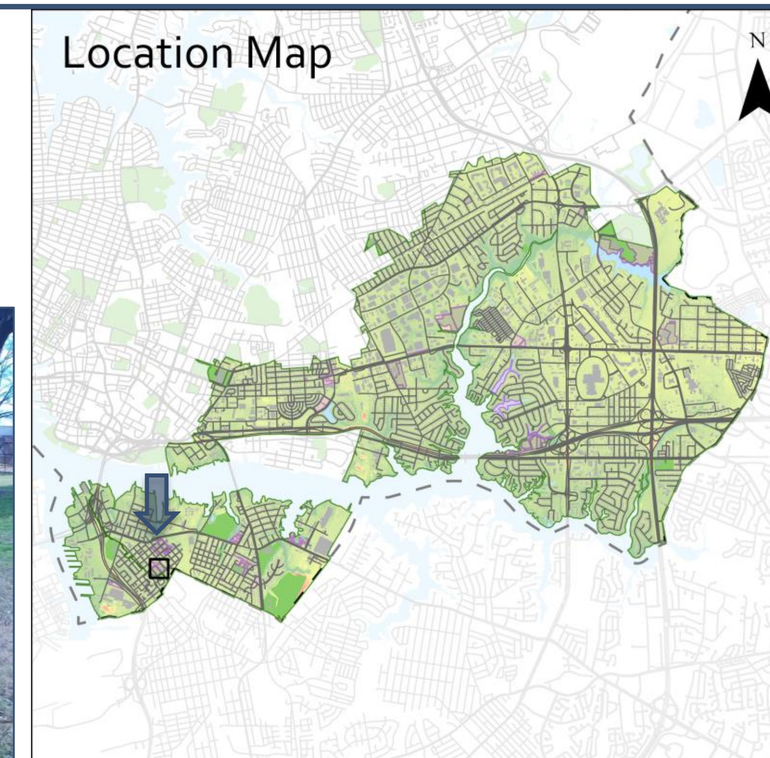
Facing SE towards ROW

Facing east towards tennis/volleyball court



Facing north towards NW end of court area

See inset map on the right for photograph locations



136 – Berkley Park
Porous Concrete & Subsurface Detention

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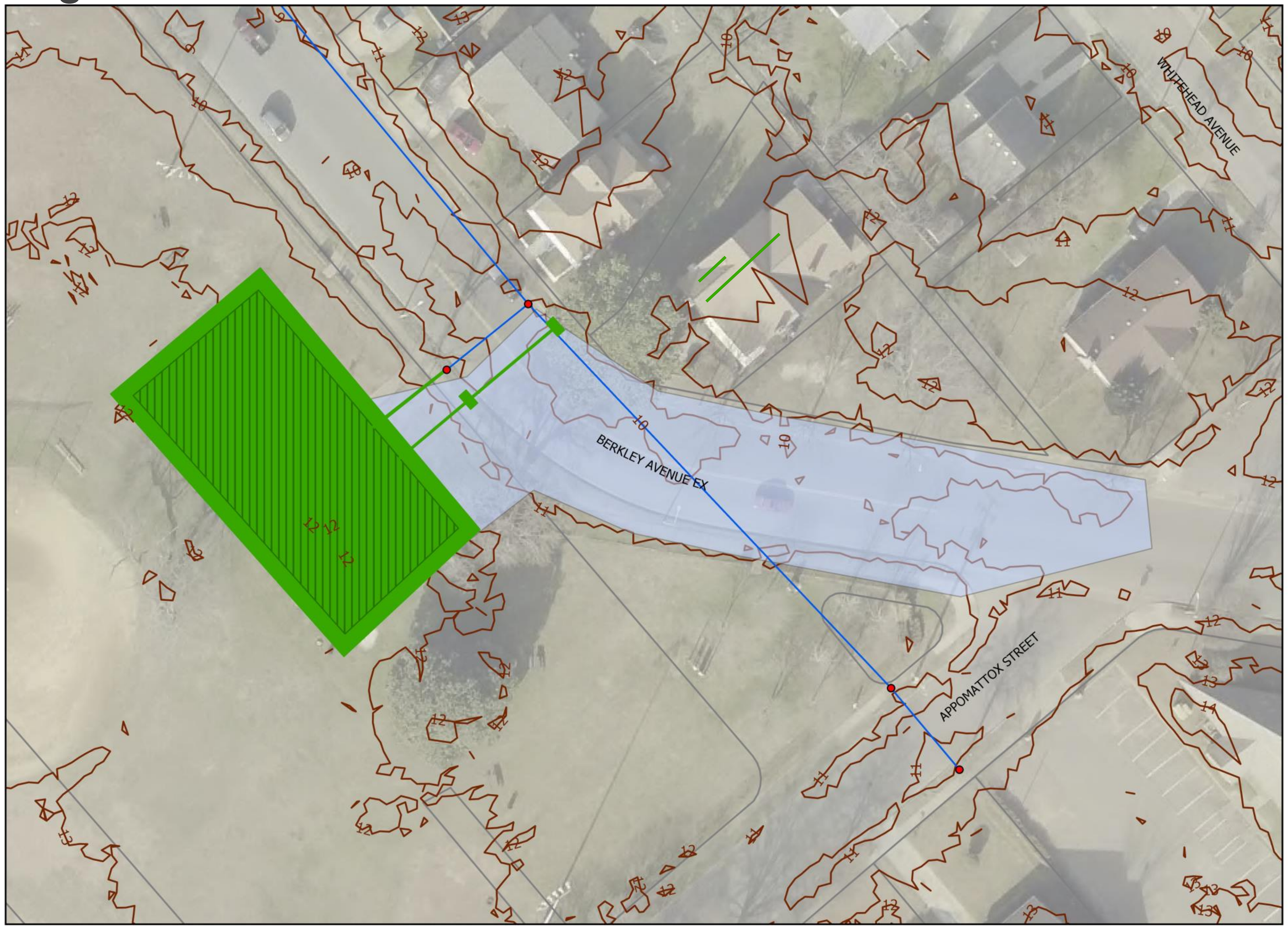
Conceptual Design – Not for Construction

Berkley Park

Drainage Area Plan View



LEGEND

- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

136 – Berkley Park
Porous Concrete & Subsurface Detention

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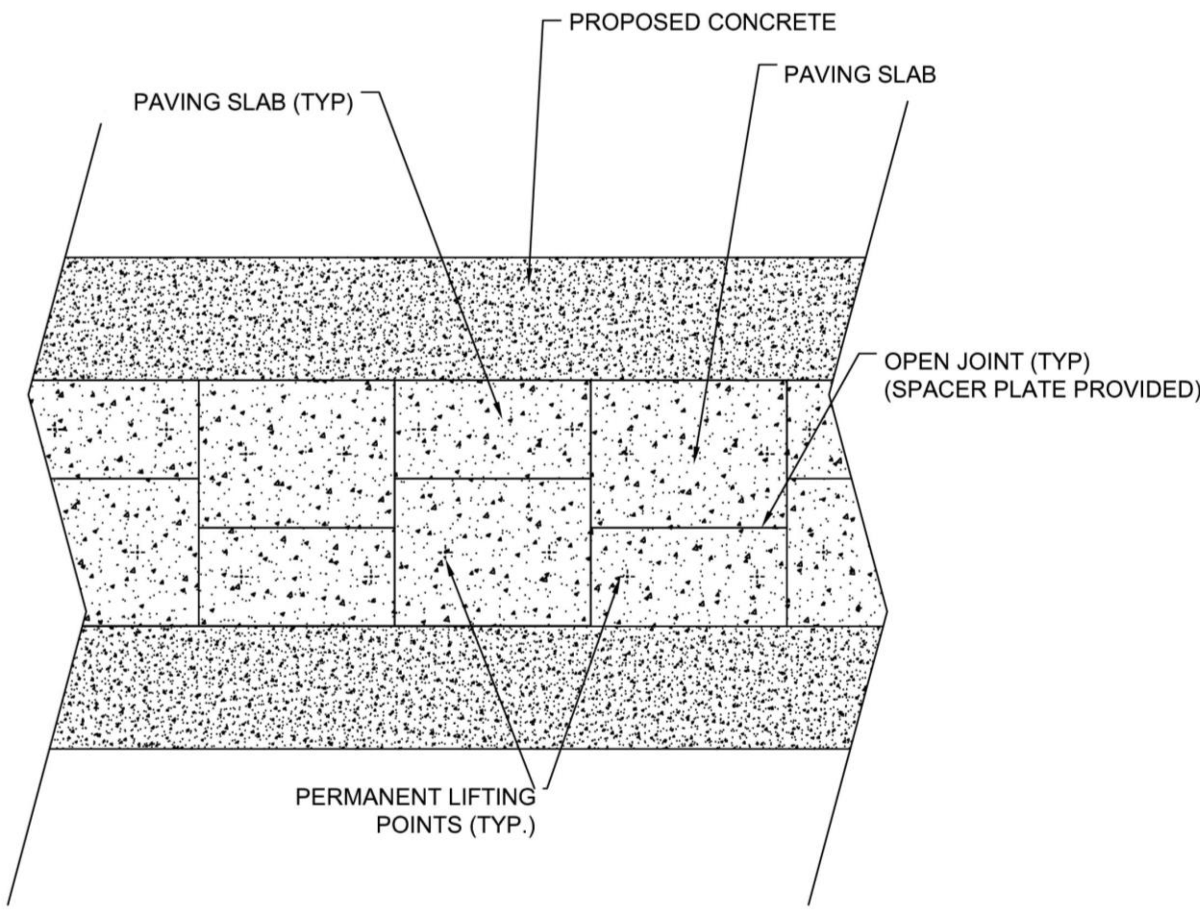
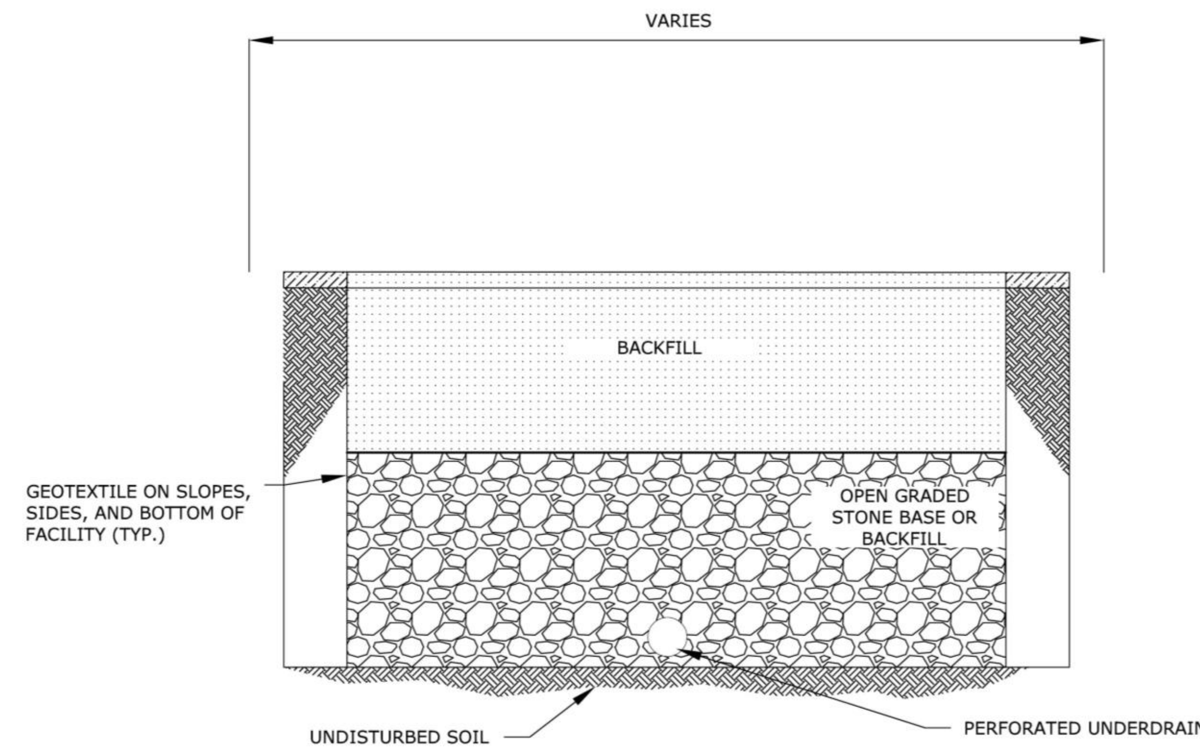
Sheet 3 of 5	03/22/19

Berkley Park

Porous Concrete & Subsurface Detention Sections



MODULAR POROUS CONCRETE PAVING SLAB
PLAN VIEW
(NOT TO SCALE)



SUBSURFACE DETENTION
(NOT TO SCALE)

136 – Berkley Park
Porous Concrete & Subsurface Detention

THE CITY OF NORFOLK | Hazen

Sheet 4 of 5	03/22/19

Conceptual Design – Not for Construction

Berkley Park

Design Calculations – Porous Concrete

Calculate water quality volume

- $WQ_V = \frac{WQ_{depth}}{12} \times A$
  - $WQ_{depth} = 1.00\ in \times (0.05 + \%_{impervious} \times 0.9) = 0.64\ in$
  - $A = 7{,}200\ ft^2$
- $WQ_V = 570\ ft^3$

Calculate full water quality volume treated

- $Vol_{treatment} = A_{porous\ concrete} \times D_{reservoir\ layer} \times Porosity_{stone} - Vol_{underdrain}$
  - $A_{permeable\ pavement} = 2{,}160\ ft^2$
  - $D_{reservoir\ layer} = 12\ in$
  - $Porosity_{stone} = 0.4$
  - $Vol_{underdrain} = 291 ft^3$
- $Vol_{treatment} = 570\ ft^3$

Design Calculations – Subsurface Detention

Calculate water quality volume

- $WQ_V = \frac{WQ_{depth}}{12} \times A$
  - $WQ_{depth} = 1.00\ in \times (0.05 + \%_{impervious} \times 0.9) = 0.75\ in$
  - $A = 22{,}860\ ft^2$
- $WQ_V = 1{,}429\ ft^3$

Calculate full water quality volume treated

- $Vol_{treatment} = A \times D_{stone} \times Porosity_{stone}$
  - $A = 2{,}400\ ft^2$
  - $D_{stone} = 18\ in$
  - $Porosity_{stone} = 0.4$
  - $Vol_{underdrain} = 291 ft^3$
- $Vol_{treatment} = 1{,}490\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - Permeable Pavement
    - $A = 0.17\ ac$
    - $\%_{impervious} = 100\%$
    - $\%_{pervious} = 0\%$
  - Subsurface Detention
    - $A = 0.52\ ac$
    - $\%_{impervious} = 78\%$
    - $\%_{pervious} = 22\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$	
			Permeable Pavement	Subsurface Detention
TP	1.76 lb/ac/yr[1]	0.50 lb/ac/yr[1]	**0.3 lb/yr**	**0.6 lb/yr**
TN	9.39 lb/ac/yr[1]	6.99 lb/ac/yr[1]	**1.6 lb/yr**	**3.8 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**112 lb/yr**	**203 lb/yr**

[1] 2009 EOS Loading Rate (lb/ac/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ removal}$		$Load\ Reduction$ (in series)	
	Permeable Pavement	Subsurface Detention	Permeable Pavement	Subsurface Detention
TP	59%[2]	15%[3]	**0.2 lb/yr**	**0.1 lb/yr**
TN	59%[2]	10%[3]	**0.9 lb/yr**	**0.4 lb/yr**
TSS	74%[4]	74%[4]	**83 lb/yr**	**150 lb/yr**

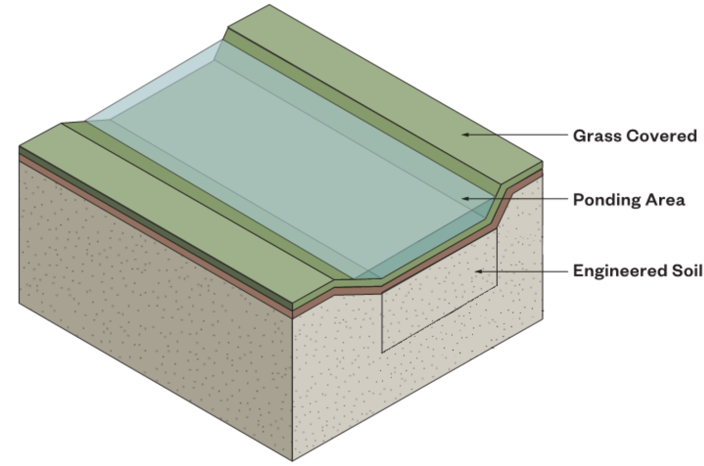
[2] Load Removal from Virginia DCR Stormwater Design Specification No. 7 Permeable Pavement, Version 2.0, January 1, 2013
[3] Load Removal from Virginia DCR Stormwater Design Specification No. 15 Extended Detention, Version 2.0, January 1, 2013
[4] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints.
Porous Concrete Level 2 Reductions (TP: 81%, TN: 81%, TSS: 74%)
Extended Detention Level 2 Reductions (TP: 31%, TN: 24%, TSS: 74%)

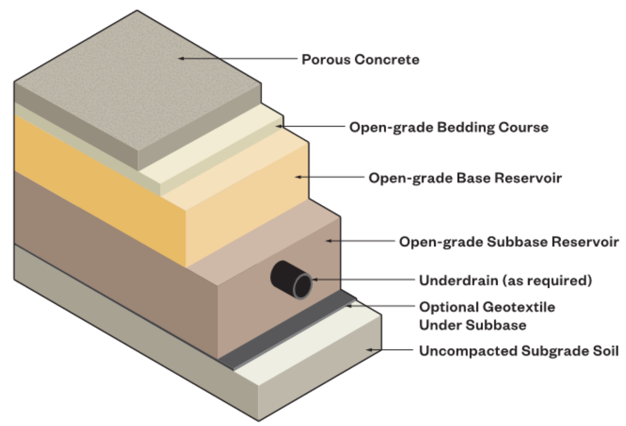
Diggs Town Recreation Center
Concept Overview


Proposed Site

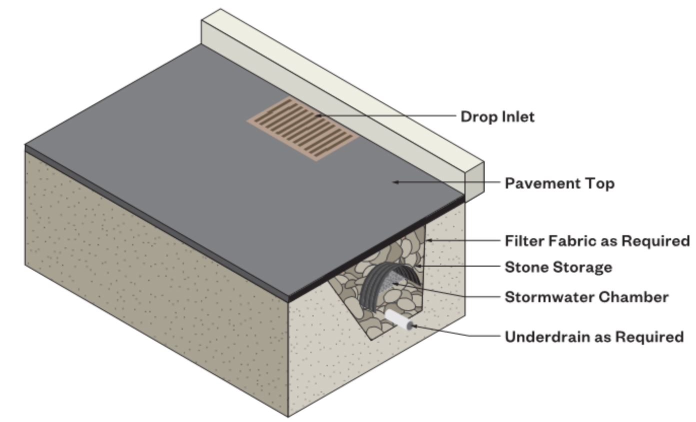

Proposed Site



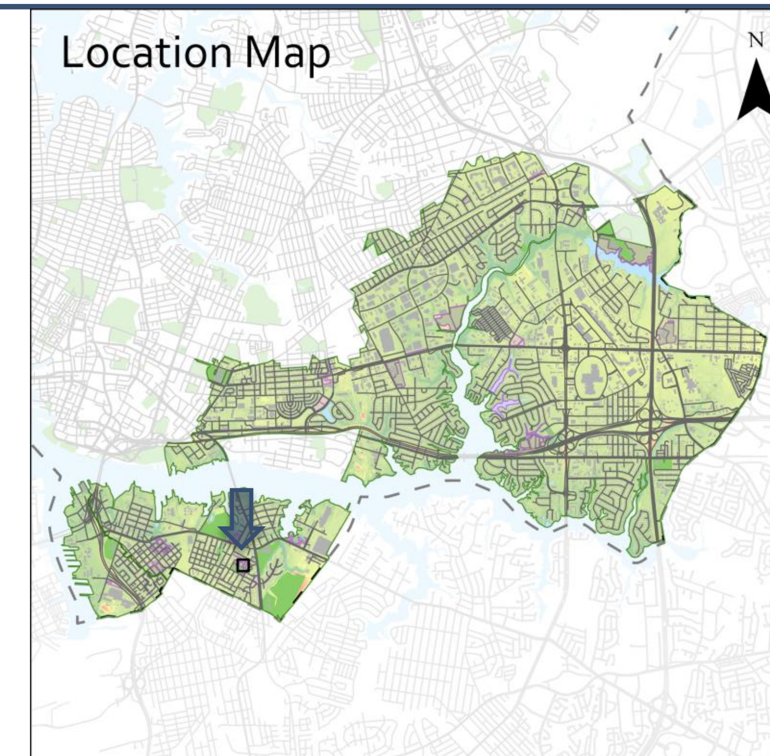
Grass Channel

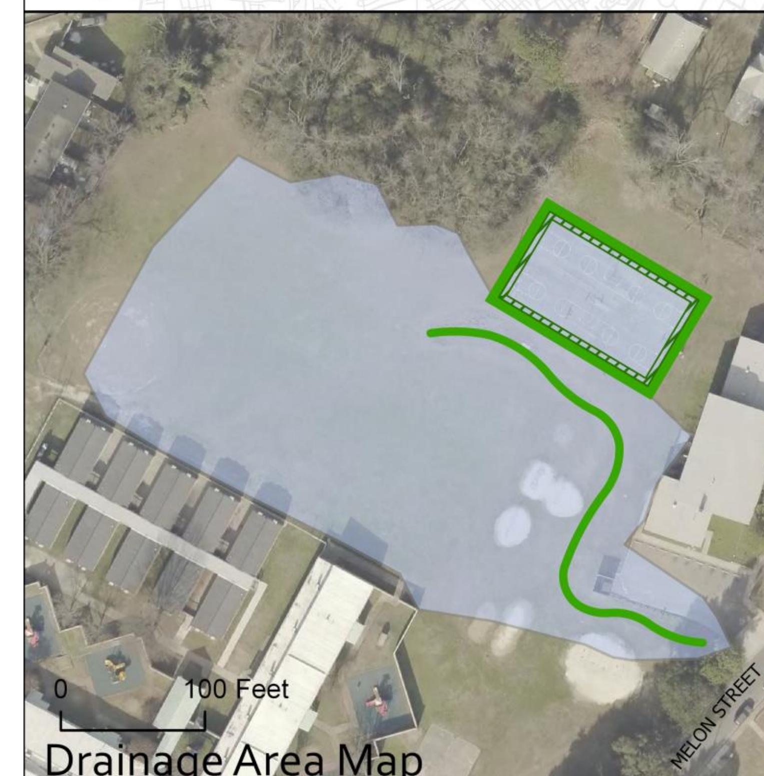


Porous Concrete



Subsurface Chamber





142 – Diggs Town Recreation Center
Porous Concrete, Chamber, & Grass Channel

Existing Conditions

The site consists of a large green space on the Diggs Town Recreation Center property. The Recreation Center, owned by Norfolk Redevelopment and Housing Authority, and Diggs Town Elementary School, owned by the City of Norfolk, share the play area for recreation space. During the site visit, there were areas that visually had signs of extended periods of standing water due to poor drainage. The site captures drainage from 2.15 acres of 11% impervious area. Existing stormwater infrastructure runs along the perimeter of the site on Melon St. with no piping or inlet structure directly connected to the school or recreation center. The next page provides additional site photographs.

Proposed Improvements

Three features are proposed for this site. Porous concrete will be located around the perimeter of the basketball court with underdrains connecting to the subsurface stormwater chamber. A subsurface stormwater chamber will be located below the basketball court around the perimeter. The permeable pavement and the subsurface stormwater chamber combined will have the potential to manage at least 1" of runoff from up to 0.22 acres of drainage to relieve any ponding issues on the basketball court. A grass channel will be located to the south of the basketball court and will convey flow down to an existing drop inlet on the site. The feature will have the potential to manage at least 1" of runoff from up to 1.93 acres of drainage to relieve ponding issues in the play area field. Subsurface utility relocation or coordination may be required within the practice footprint location.

Type: Porous Concrete, Subsurface Chamber, & Grass Channel
Address: 1401 Melon St.
Area Managed: 2.15 acres

Conceptual Level Estimates:

Construction Cost: $582,000
TN Load Reduction: 6.1 lb/yr
TP Load Reduction: 0.5 lb/yr
TSS Load Reduction: 285 lb/yr

Water Volume Storage: 2,300 ft^3
Cost/Storage Volume: $255/$ft^3$
TN Reduction Cost: $8,598,000/lb/yr
TP Reduction Cost: $60,249,000/lb/yr
TSS Reduction Cost: $2,000/lb/yr

THE CITY OF NORFOLK
Hazen

03/22/19

Conceptual Design – Not for Construction

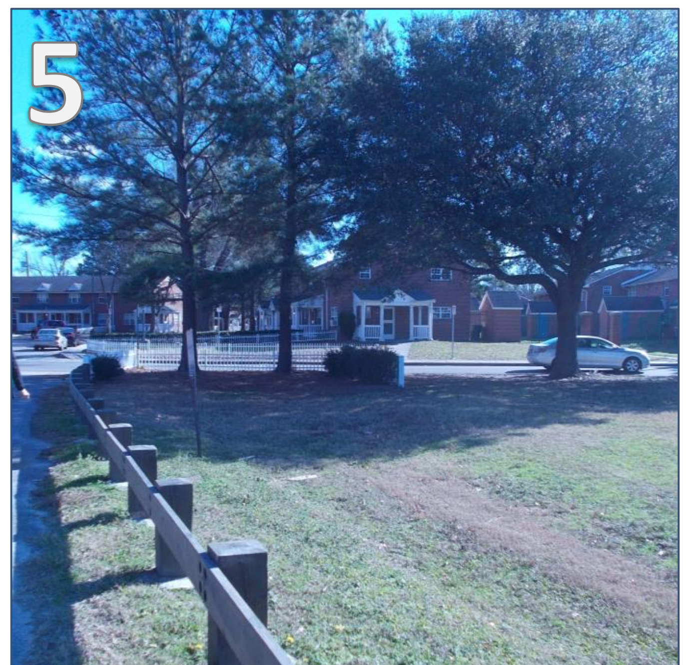
Diggs Town Recreation Center
Concept Overview

Facing north towards play court

Facing SW towards play ground

Facing north parking lot SW corner

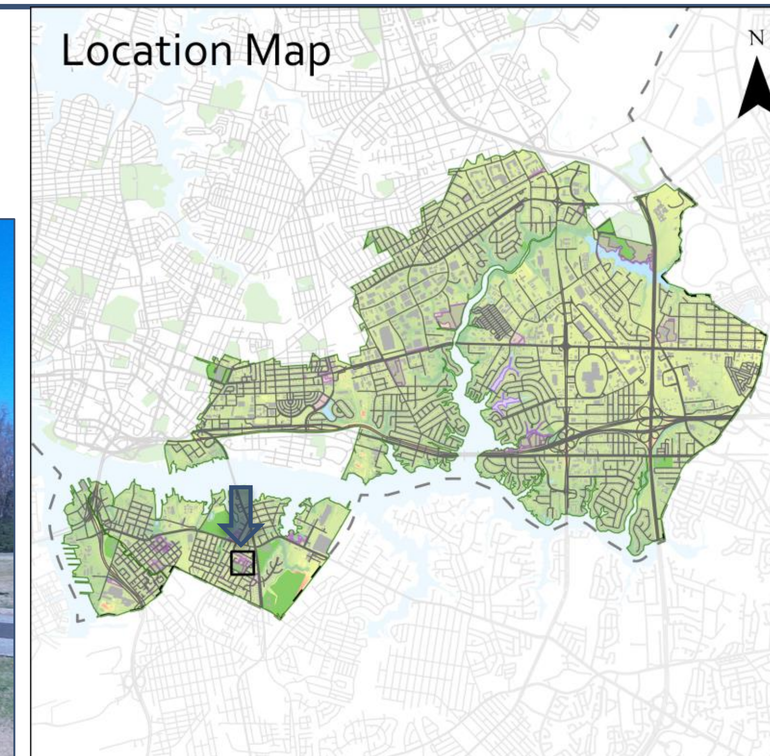
Facing NW towards ponding area south of play court

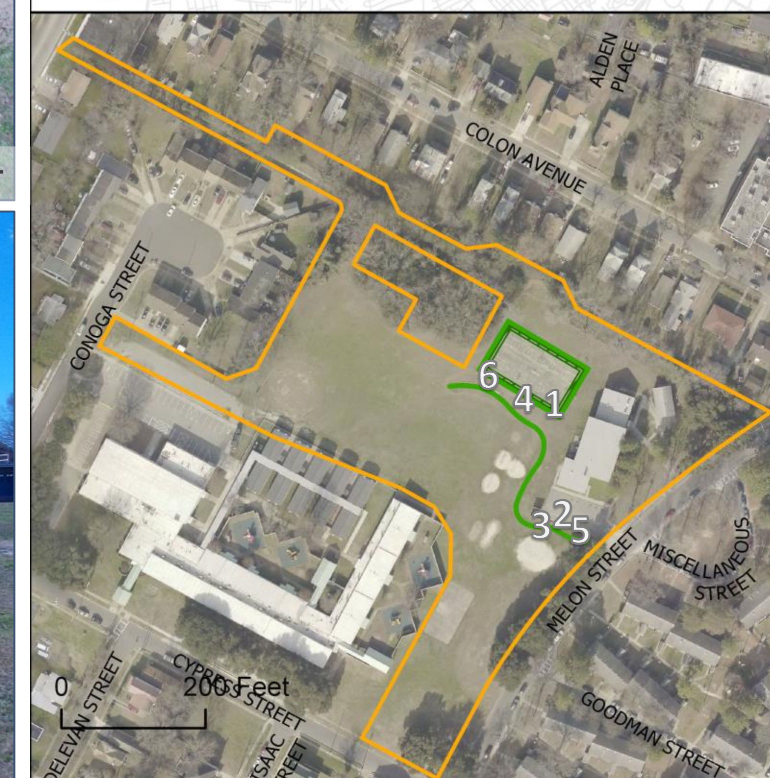


Facing west towards existing DI

Facing SW towards open space

See inset map on the right for photograph locations





142 – Diggs Town Recreation Center
Porous Concrete, Chamber, & Grass Channel

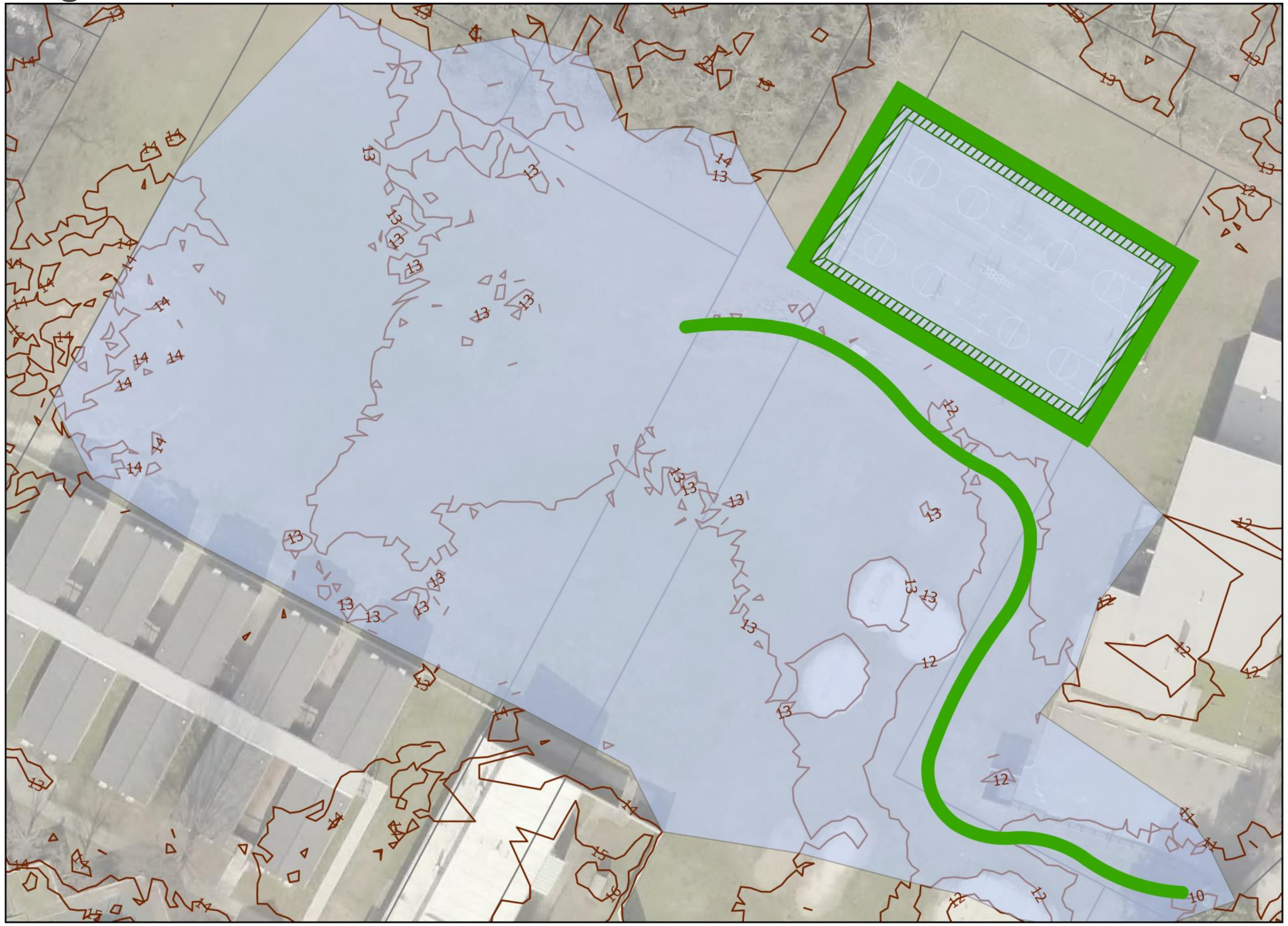
THE CITY OF NORFOLK Hazen

Sheet 2 of 5 | 03/22/19

Conceptual Design – Not for Construction

Diggs Town Recreation Center

Drainage Area Plan View



LEGEND

- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

142 – Diggs Town Recreation Center
Porous Concrete, Chamber, & Grass Channel

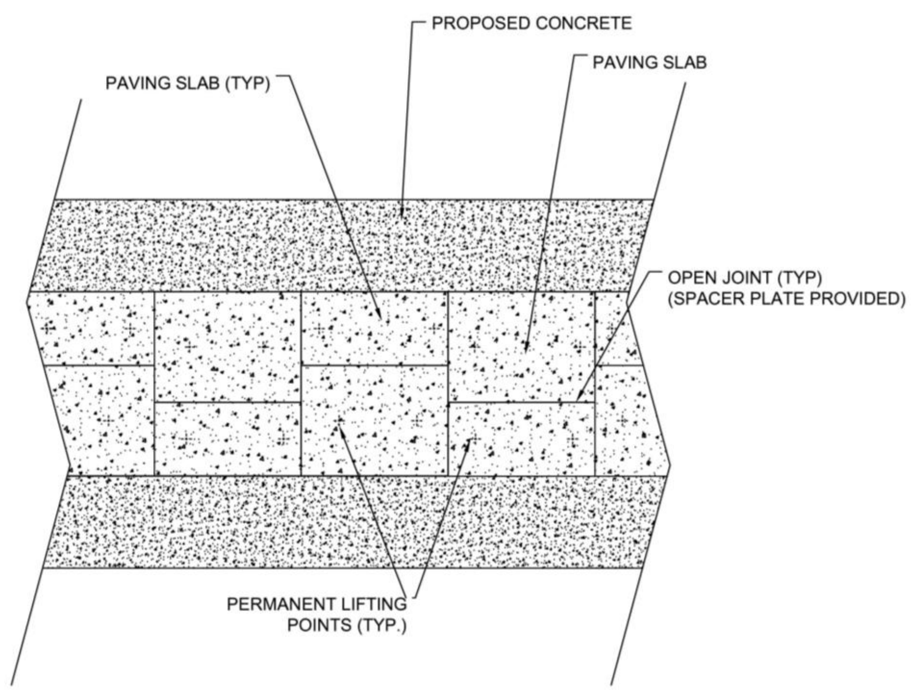
THE CITY OF NORFOLK Hazen

Sheet 3 of 5	03/22/19

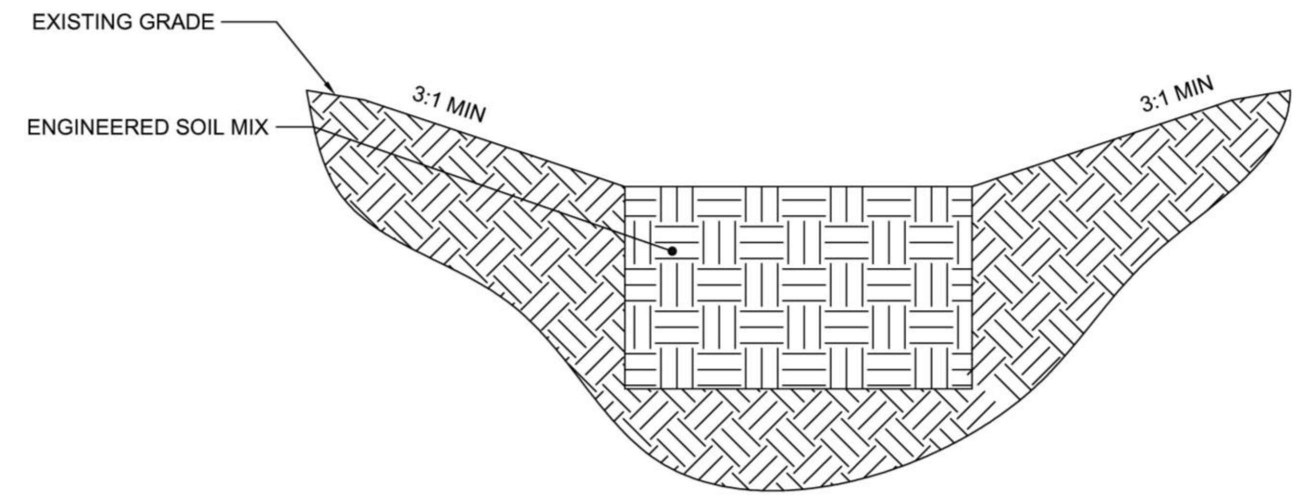
Conceptual Design – Not for Construction

Diggs Town Recreation Center

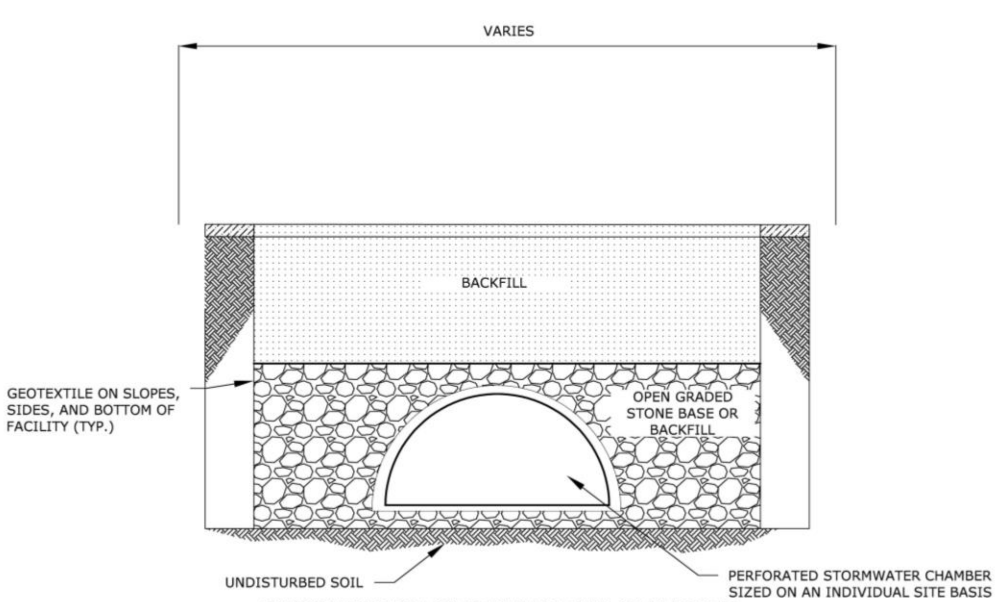
Porous Concrete, Subsurface Chamber, & Grass Channel Sections



MODULAR POROUS CONCRETE PAVING SLAB
PLAN VIEW
(NOT TO SCALE)



GRASSED CHANNEL
(NOT TO SCALE)



SUBSURFACE STORMWATER CHAMBER
(NOT TO SCALE)

142 – Diggs Town Recreation Center
Porous Concrete, Chamber, & Grass Channel

THE CITY OF NORFOLK | Hazen

Sheet 4 of 5 | 03/22/19

Conceptual Design – Not for Construction

Diggs Town Recreation Center

Design Calculations – Porous Concrete & Subsurface Detention

Calculate water quality volume

- $WQ_V = \frac{WQ_{depth}}{12} \times A$
  - $WQ_{depth} = 1.00\ in \times \left(0.05 + \%_{impervious} \times 0.9\right) = 0.78\ in$
  - $A = 9{,}500\ ft^2$
- $WQ_V = 620\ ft^3$

Calculate full water quality treatment volume

Porous Concrete

- $Vol_{treatment} = (A_{porous\ concrete} \times D_{reservoir\ layer} \times Porosity_{stone}) - Vol_{underdrain})$
  - $A_{porous\ concrete} = 2{,}600\ ft^2$
  - $D_{reservoir\ layer} = 12\ in$
  - $Porosity_{stone} = 0.4$
  - $Vol_{underdrain} = 365\ ft^3$
- $Vol_{treatment} = 675\ ft^3$

Subsurface Detention

- $Vol_{treatment} = (A \times D_{stone} - Vol_{chamber}) \times Porosity_{stone} + Vol_{chamber}$
  - $A = 2{,}600\ ft^2$
  - $D_{stone} = 12\ in$
  - $Porosity_{stone} = 0.4$
  - $Vol_{chamber} = 225\ ft^3$
- $Vol_{treatment} = 690\ ft^3$

Design Calculations – Grass Channel

Calculate water quality volume

- $WQ_V = \frac{WQ_{depth}}{12} \times A$
  - $WQ_{depth} = 1.00\ in \times \left(0.05 + \%_{impervious} \times 0.9\right) = 0.08\ in$
  - $A = 84{,}400\ ft^2$
- $WQ_V = 540\ ft^3$

Calculate channel sizing

	Grass Channel Sizing - 1 in storm	
Rational Parameters	Drainage Area (Ac)	1.94
	Percent Imp	3%
	"C"	0.08
	Watershed Length (ft)	100
	Delta H (ft)	2
	Kirpich Tc	1.22
	Intensity (in/hr)	1
	Flow (cfs)	0.15
Channel Characteristics	Top Width (ft)	5.5
	Bottom Width (ft)	1
	Depth (ft)	0.75
	Side Slope (ft/ft)	3
	Long Slope (ft/ft)	0.01
Mannings Analysis	Mannings N	0.035
	Flow in Ditch	0.15
	Normal Depth	0.12
	Check Ditch Capacity	OK

	Grass Channel Sizing - 2yr	
Rational Parameters	Drainage Area (Ac)	1.94
	Percent Imp	3%
	"C"	0.08
	Watershed Length (ft)	100
	Delta H (ft)	2
	Kirpich Tc	1.22
	Intensity (in/hr)	3.58
	Flow (cfs)	0.53
Channel Characteristics	Top Width (ft)	5.5
	Bottom Width (ft)	1
	Depth (ft)	0.75
	Side Slope (ft/ft)	3
	Long Slope (ft/ft)	0.01
Mannings Analysis	Mannings N	0.035
	Flow in Ditch	0.53
	Normal Depth	0.24
	Check Ditch Capacity	OK

	Grass Channel Sizing - 10yr	
Rational Parameters	Drainage Area (Ac)	1.94
	Percent Imp	3%
	"C"	0.08
	Watershed Length (ft)	100
	Delta H (ft)	2
	Kirpich Tc	1.22
	Intensity (in/hr)	5.52
	Flow (cfs)	0.82
Channel Characteristics	Top Width (ft)	5.5
	Bottom Width (ft)	1
	Depth (ft)	0.75
	Side Slope (ft/ft)	3
	Long Slope (ft/ft)	0.01
Mannings Analysis	Mannings N	0.035
	Flow in Ditch	0.82
	Normal Depth	0.30
	Check Ditch Capacity	OK

Estimate annual pollutant load reduction

- $Load_{annual} = \left(A \times \%_{impervious} \times Loading\ Rate_{imp}\right) + \left(A \times \%_{pervious} \times Loading\ Rate_{per}\right)$
  - Porous Pavement & Subsurface Detention
    - $A = 0.22\ ac$
    - $\%_{impervious} = 81\%$
    - $\%_{pervious} = 19\%$
  - Grass Channel
    - $A = 1.94\ ac$
    - $\%_{impervious} = 3\%$
    - $\%_{pervious} = 97\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$	
			Porous Concrete & Subsurface Detention	Grass Channel
TP	1.76 lb/ac/yr[1]	0.5 lb/ac/yr[1]	**0.3 lb/yr**	**1.0 lb/yr**
TN	9.39 lb/ac/yr[1]	6.99 lb/ac/yr[1]	**1.9 lb/yr**	**13.7 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**123 lb/yr**	**229 lb/yr**

[1] 2009 EOS Loading Rate (lb/ac/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

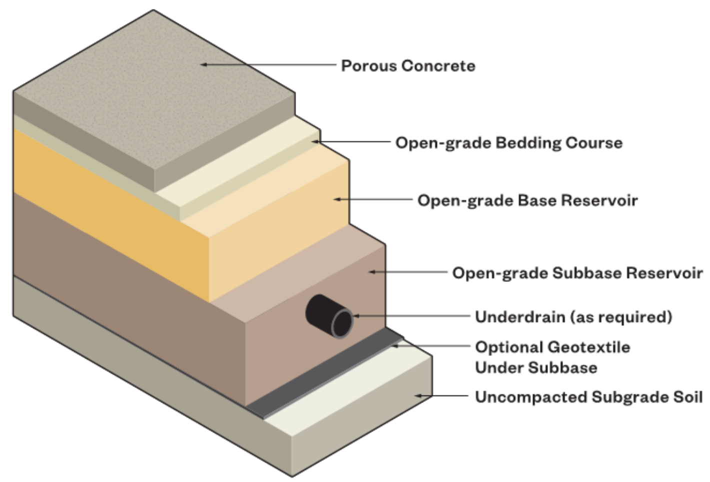
- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ removal}$		Load Reduction	
	Porous Concrete & Subsurface Detention	Grass Channel	Porous Concrete & Subsurface Detention	Grass Channel
TP	59%[2] & 15%[3] (in series)	32%[4]	**0.2 lb/yr**	**0.3 lb/yr**
TN	59%[2] & 10%[3] (in series)	36%[4]	**1.2 lb/yr**	**4.9 lb/yr**
TSS	74%[5] & 74%[5] (in series)	74%[5]	**115 lb/yr**	**170 lb/yr**

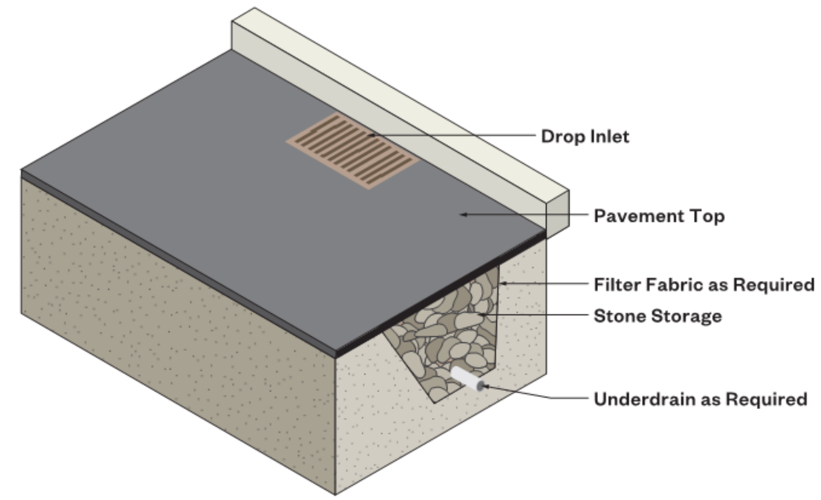
[2] Load Removal from Virginia DCR Stormwater Design Specification No. 7 Permeable Pavement, Version 2.0, January 1, 2013
[3] Load Removal from Virginia DCR Stormwater Design Specification No. 15 Extended Detention, Version 2.0, January 1, 2013
[4] Load Removal from Virginia DCR Stormwater Design Specification No. 3 Grass Channels, Version 2.0, January 1, 2013
[5] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints.
Porous Concrete Level 2 Reductions (TP: 81%, TN: 81%, TSS: 74%)
Extended Detention Level 2 Reductions (TP: 31%, TN: 24%, TSS: 74%)

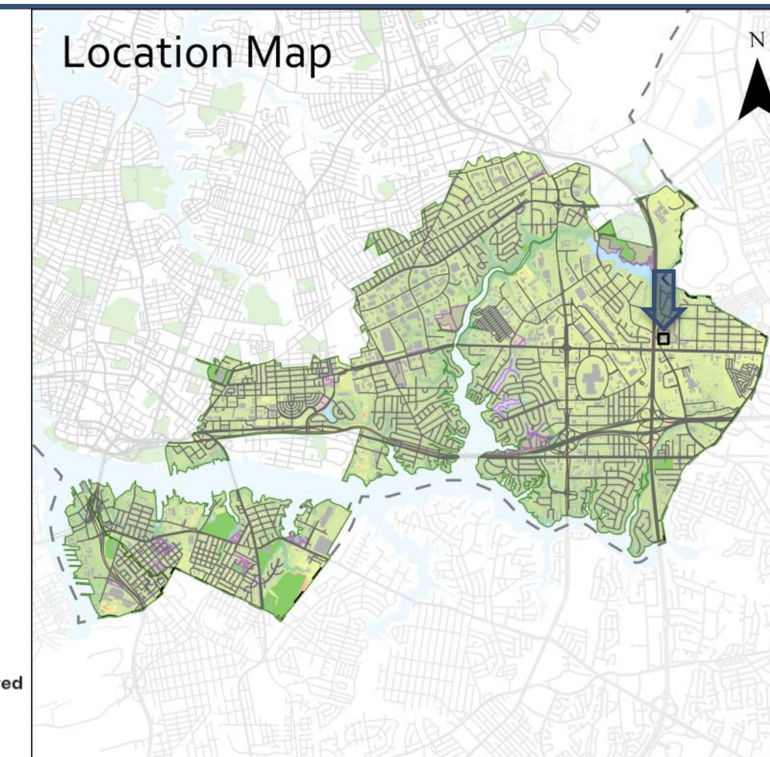
Fairlawn Recreation Center
Concept Overview

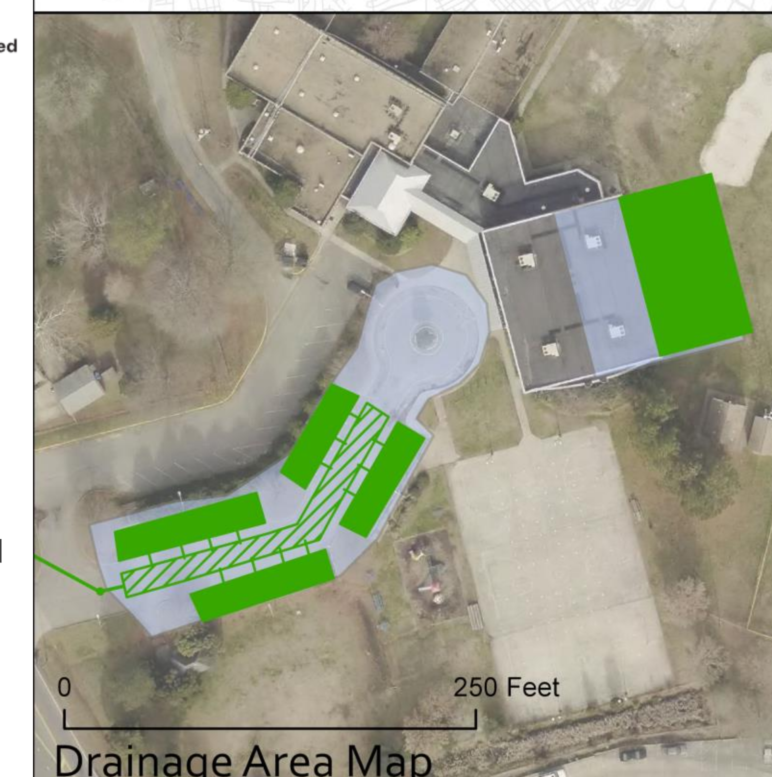


Porous Concrete



Subsurface Detention





174R – Fairlawn Recreation Center
Porous Concrete, Subsurface Detention & Soil Amendments

Existing Conditions

Fairlawn Recreation Center is adjacent to Fairlawn Elementary School, both properties are owned by the City of Norfolk. During the site visit, there was ponding water in the parking lot, on the hard top play area, and in the grassed area near the building downspouts. The sheet flow directed towards these different ponding areas on site is from 0.70 acres of 51% impervious. The next page provides additional site photographs.

Proposed Improvements

The two practices recommended for this parcel for stormwater management are porous pavement with a subsurface detention basin in the parking lot and amended soils for downspout runoff infiltration improvements. The porous concrete will be installed only in the parking spots of the lot and will have underdrain connections into a subsurface detention basin running through the center of the parking lot with an overflow structure connected to an existing stormwater structure downstream. During detailed design, drop inlets will be sized for a proper inlet connection into the basin along with the porous concrete. The amended soils feature will be installed on the east side of the recreation building to encourage infiltration of the downspout connections from the back half of the building. The two practices together will have the potential to manage at least 1" of runoff from up to 0.70 acres of drainage in the area, providing stormwater storage capacity to relieve persistent ponding issues that occur. Subsurface utility relocation or coordination may be required within the practice footprint location.

Type: Porous Concrete, Subsurface Detention, & Amended Soils
Address: 1014 Kempsville Rd.
Area Managed: 0.70 acres

Conceptual Level Estimates:

Construction Cost: $282,000
TN Load Reduction: 3.6 lb/yr
TP Load Reduction: 0.7 lb/yr
TSS Load Reduction: 41 lb/yr

WQ Treatment Volume: 3,620 ft^3
Cost/Storage Volume: $78/ft^3
TN Reduction Cost: $78,000/lb/yr
TP Reduction Cost: $402,000/lb/yr
TSS Reduction Cost: $6,870/lb/yr

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Conceptual Design – Not for Construction

Fairlawn Recreation Center
Concept Overview

Facing south towards the multipurpose play court

Facing northeast

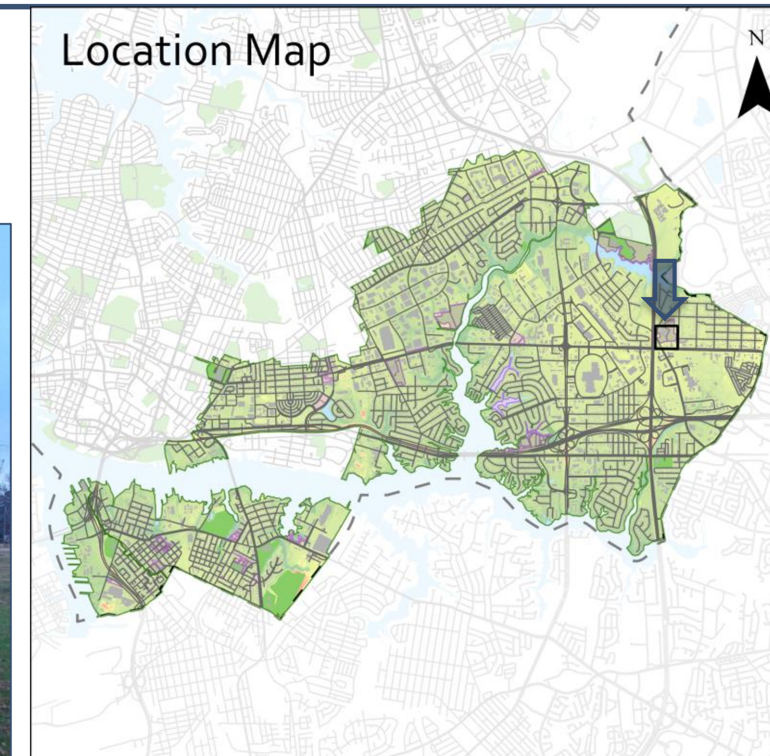
Facing north parallel to building

Facing east towards parking lot

Facing northwest towards entrance

Facing west to roof drain

See inset map on the right for photograph locations



174R – Fairlawn Recreation Center
Porous Concrete, Subsurface Detention
& Soil Amendments

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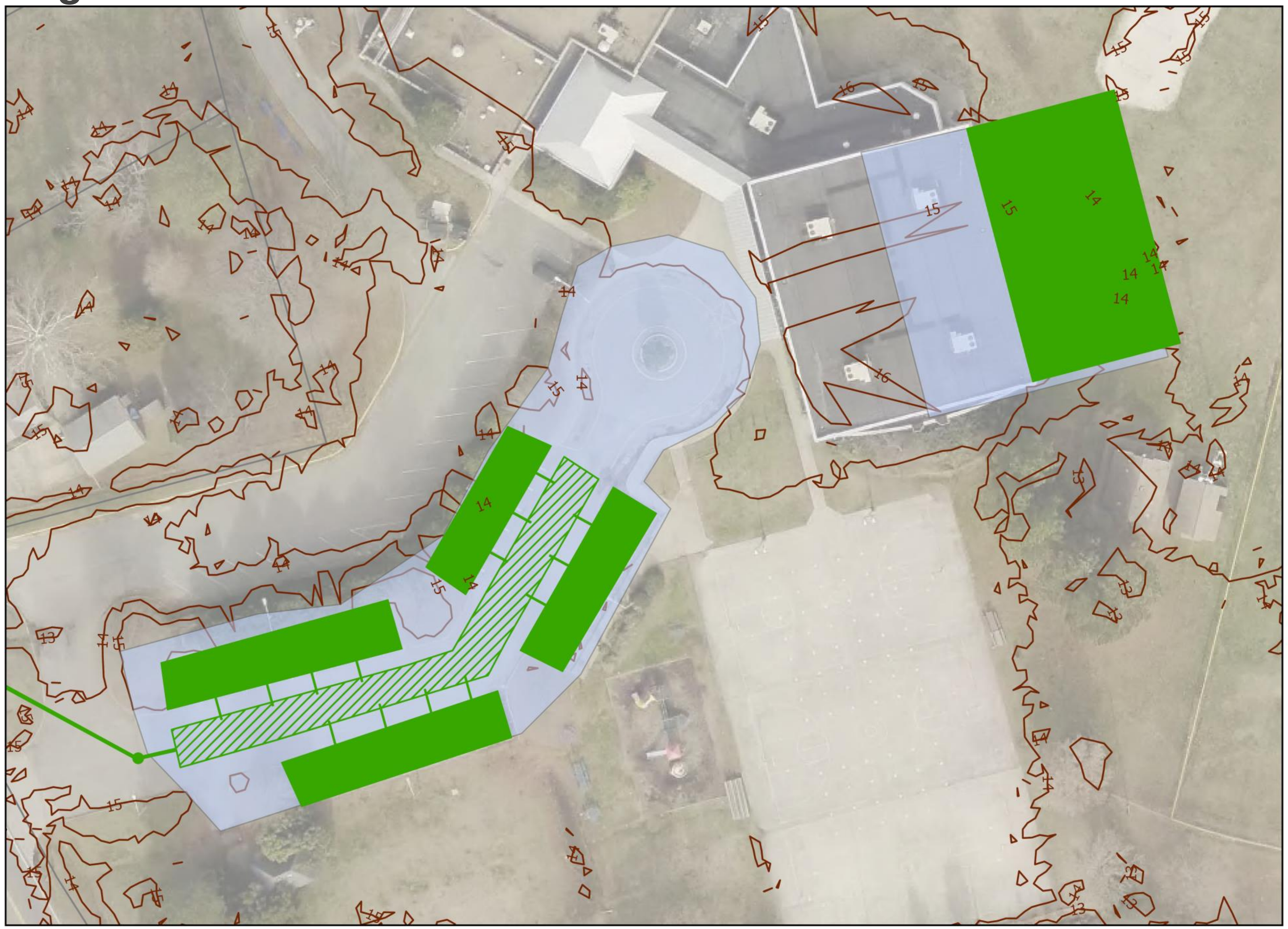
Sheet 2 of 5	03/22/19

Conceptual Design – Not for Construction

Fairlawn Recreation Center
Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 100

Alternative Design Options:
- Porous concrete around perimeter of multipurpose play court with subsurface detention
- Highlight feature to wrap around the building for roof drain connections and double as landscaping improvement opportunity

174R – Fairlawn Recreation Center
Porous Concrete, Subsurface Detention & Soil Amendments

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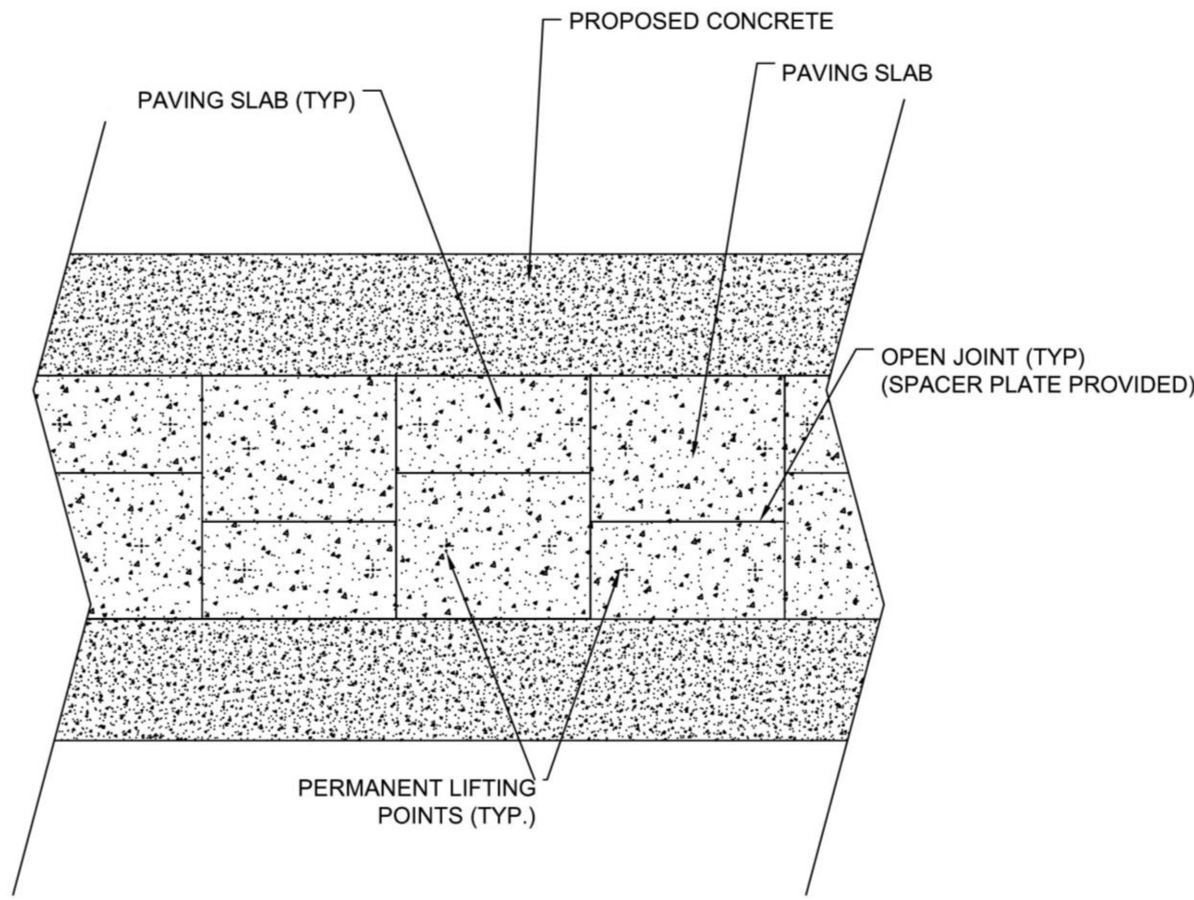
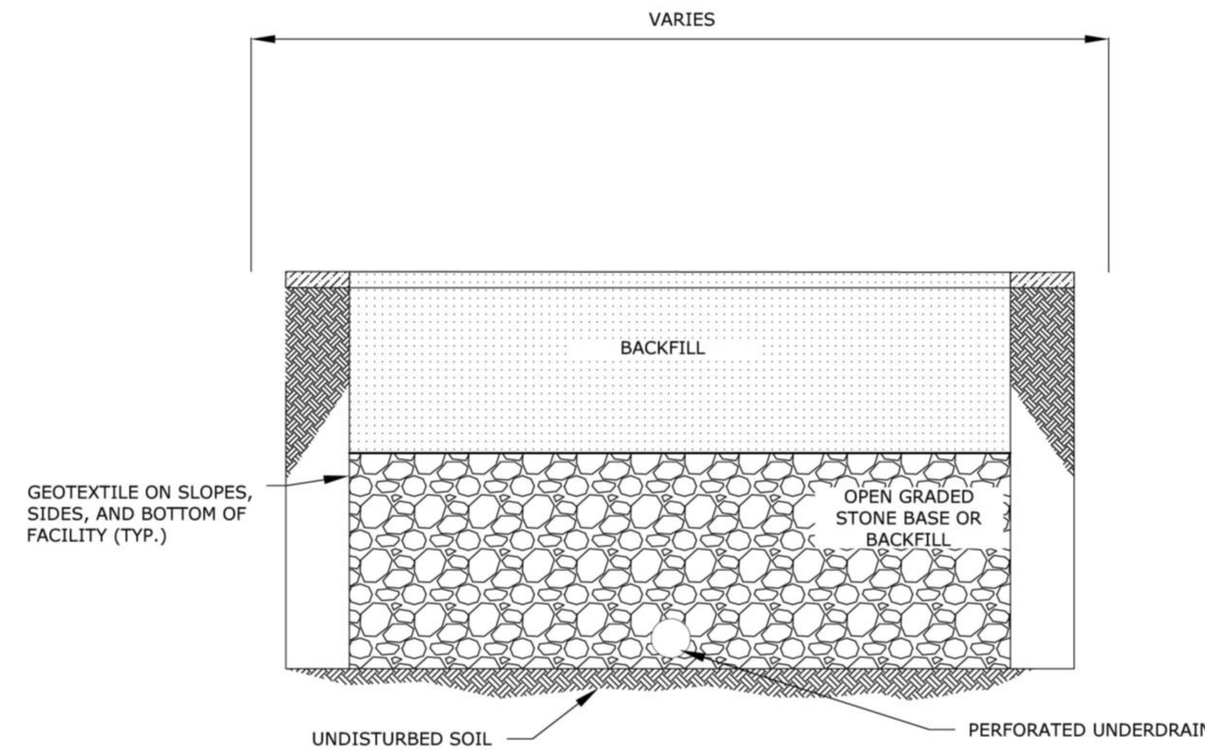
Fairlawn Recreation Center

Porous Concrete & Subsurface Detention Standard Details



MODULAR POROUS CONCRETE PAVING SLAB
PLAN VIEW
(NOT TO SCALE)



SUBSURFACE DETENTION
(NOT TO SCALE)

174R – Fairlawn Recreation Center Porous Concrete, Subsurface Detention & Soil Amendments	
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Sheet 4 of 5	03/22/19

Fairlawn Recreation Center

Design Calculations – Porous Concrete & Subsurface Detention

Calculate water quality volume

- $WQ_V = \frac{WQ_{depth}}{12} \times A$
  - $WQ_{depth} = 1.00\ in \times (0.05 + \%_{impervious} \times 0.9) = 0.80\ in$
  - $A = 21{,}075\ ft^2$
- $WQ_V = 1{,}400\ ft^3$

Calculate full water quality treatment volume

Porous Concrete

- $Vol_{treatment} = A_{porous\ concrete} \times D_{reservoir\ layer} \times Porosity_{stone}$
  - $A_{porous\ concrete} = 5{,}800\ ft^2$
  - $D_{reservoir\ layer} = 9\ in$
  - $Porosity_{stone} = 0.4$
- $Vol_{treatment} = 1{,}540\ ft^3$

Subsurface Detention

- $Vol_{treatment} = A \times D_{stone} \times Porosity_{stone}$
  - $A = 2{,}600\ ft^2$
  - $D_{stone} = 24\ in$
  - $Porosity_{stone} = 0.4$
- $Vol_{treatment} = 2{,}080\ ft^3$

Design Calculations – Amended Soils

Calculate water quality volume

- $WQ_V = \frac{WQ_{depth}}{12} \times A$
  - $WQ_{depth} = 1.00\ in \times (0.05 + \%_{impervious} \times 0.9) = 0.50\ in$
  - $A = 9{,}448\ ft^2$
- $WQ_V = 394\ ft^3$

Calculate volume of compost needed

Compost depth needed

- $\frac{IC}{SA} = A_{impervious}/A_{soil\ amendment}$
  - $A_{impervious} = 1{,}347\ ft^2$
  - $A_{soil\ amendment} = 10\ in$
- $\frac{IC}{SA} = 1.0$

Volume of compost

- $Vol_{compost} = A_{soil\ amendment} \times D_{compost} \times 0.0031$
  - $D_{compost} = 10\ in$
- $Vol_{compost} = 147\ yd^3$

- **Estimate annual pollutant load reduction**
  - $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
    - Porous Pavement & Subsurface Detention
      - $A = 0.48\ ac$
      - $\%_{impervious} = 83\%$
      - $\%_{pervious} = 17\%$
    - Soil Amendments
      - $A = 0.22\ ac$
      - $\%_{impervious} = 50\%$
      - $\%_{pervious} = 50\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$	
			Porous Concrete & Subsurface Detention	Amended Soils
TP	1.76 lb/ac/yr[1]	0.5 lb/ac/yr[1]	**0.8 lb/yr**	**0.3 lb/yr**
TN	9.39 lb/ac/yr[1]	6.99 lb/ac/yr[1]	**4.3 lb/yr**	**1.8 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**279 lb/yr**	**84 lb/yr**

[1] 2009 EOS Loading Rate (lb/ac/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ removal}$		*Load Reduction*	
	Porous Concrete & Subsurface Detention	Amended Soils	Porous Concrete & Subsurface Detention	Amended Soils
TP	59%[2] & 15%[3] (in series)	50%[4]	**0.5 lb/yr**	**0.2 lb/yr**
TN	59%[2] & 10%[3] (in series)	50%[4]	**2.7 lb/yr**	**0.9 lb/yr**
TSS	74%[5] & 74%[5] (in series)	74%[5]	**19 lb/yr**	**22 lb/yr**

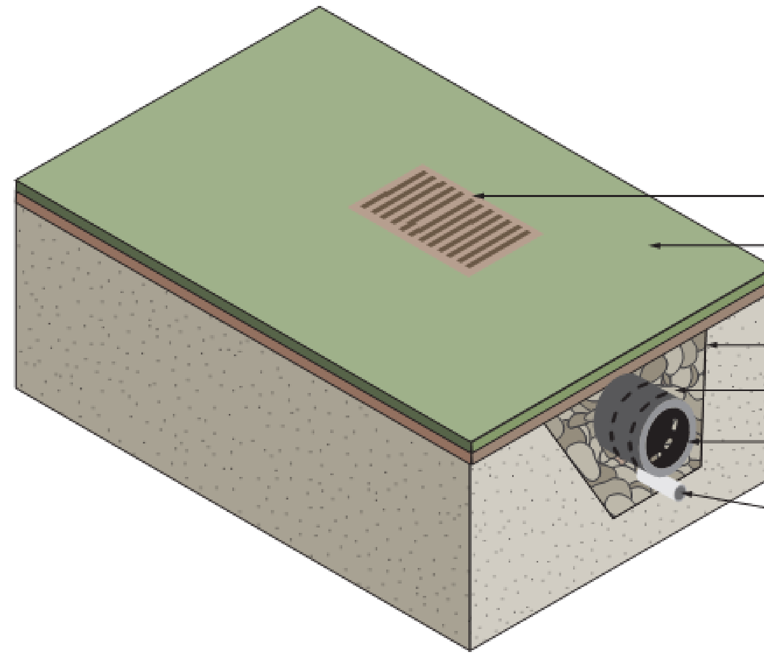
[2] Load Removal from Virginia DCR Stormwater Design Specification No. 7 Permeable Pavement, Version 2.0, January 1, 2013
[3] Load Removal from Virginia DCR Stormwater Design Specification No. 15 Extended Detention, Version 2.0, January 1, 2013
[4] Load Removal from Virginia DCR Stormwater Design Specification No. 4 Soil Amendment, Version 2.0, January 1, 2013
[5] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints.
Porous Concrete Level 2 Reductions (TP: 81%, TN: 81%, TSS: 74%)
Extended Detention Level 2 Reductions (TP: 31%, TN: 24%, TSS: 74%)
Soil Amendments Level 2 Reductions (TP: 50%, TN: 50%, TSS: 74%)

E. Berkley Avenue Median
Concept Overview

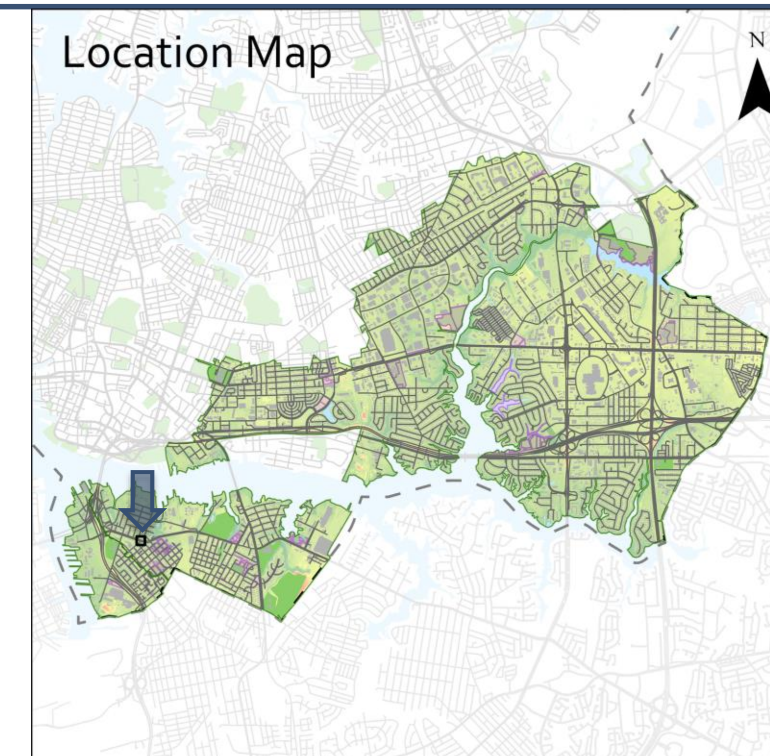
Proposed Site

Proposed Site



Median Pipe Detention

Location Map



Drainage Area Map

EBA – E. Berkley Ave.
Median Pipe Detention

Existing Conditions

A median runs down the center of E. Berkley Ave. in the right-of-way. Dead grass in the median suggests extended periods of standing water. A recurring flooding location is reported at the east side of this right-of-way space at the intersection of E. Berkley Avenue and Fauquier Street. The drainage area surrounding this median location is 0.69 acres of 80% impervious. The next page provides additional site photographs.

Proposed Improvement

The proposed median pipe detention feature will act as storage for the sheet flow that comes to this median location along E. Berkley Avenue. Curb cuts along the perimeter of the median will allow flow to enter a series of drop inlets that tie into the pipe detention. The feature will consist of stone storage, perforated pipes for increased storage volume, and outlet structures to reconnect to the existing stormwater network. The entire practice will have the potential to manage at least 1" of runoff from up to 0.69 acres of drainage in the area, providing stormwater storage capacity to relieve persistent flooding issues that occur on E. Berkley Ave. Subsurface utility relocation or coordination may be required within the practice footprint location.

Type: Median Pipe Detention
Address: 307 E Berkley Ave
Area Managed: 0.69 acres

Conceptual Level Estimates:

Construction Cost: $353,000
TN Load Reduction: 3.5 lb/yr
TP Load Reduction: 0.7 lb/yr
TSS Load Reduction: 270 lb/yr

WQ Treatment Volume: 2,200 ft^3
Cost/Storage Volume: $170/ft^3
TN Reduction Cost: $101,000/lb/yr
TP Reduction Cost: $540,000/lb/yr
TSS Reduction Cost: $1,300/lb/yr

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03/22/19

Conceptual Design – Not for Construction

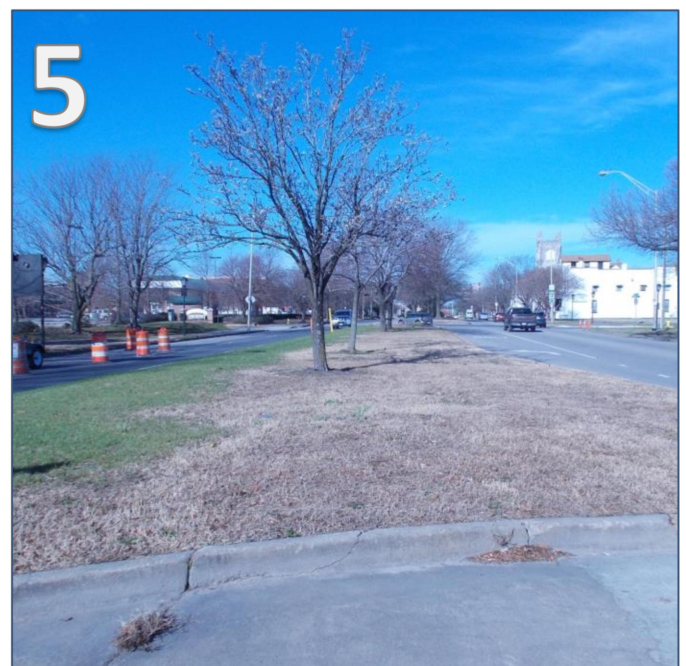
E. Berkley Ave. Median
Concept Overview

Facing east on median

Facing west at parking lot pond

Facing northeast to right-of-way

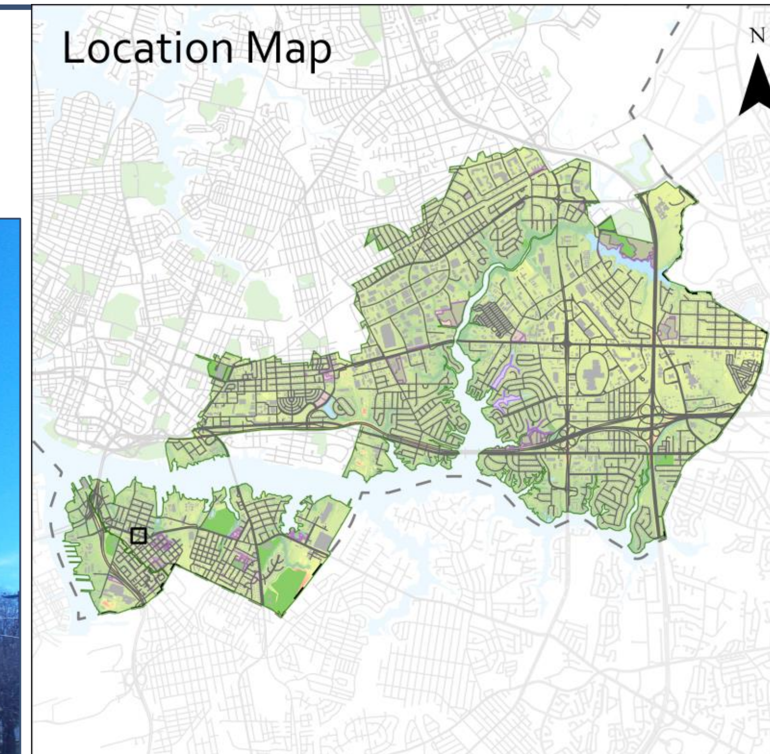
Facing west on median

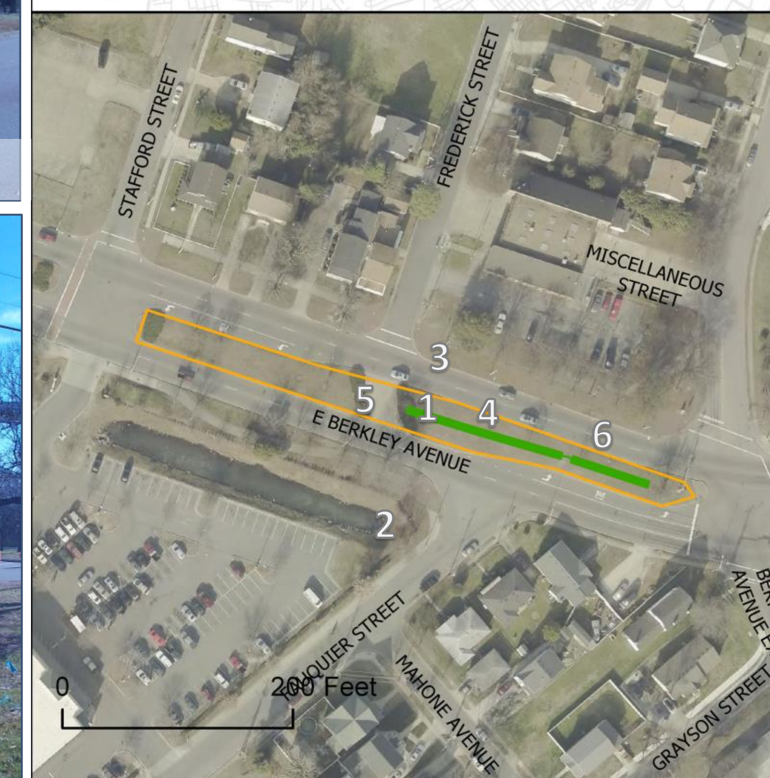


Facing west on median

Facing east towards intersection

See inset map on the right for photograph locations





EBA – E. Berkley Ave.
Median Pipe Detention

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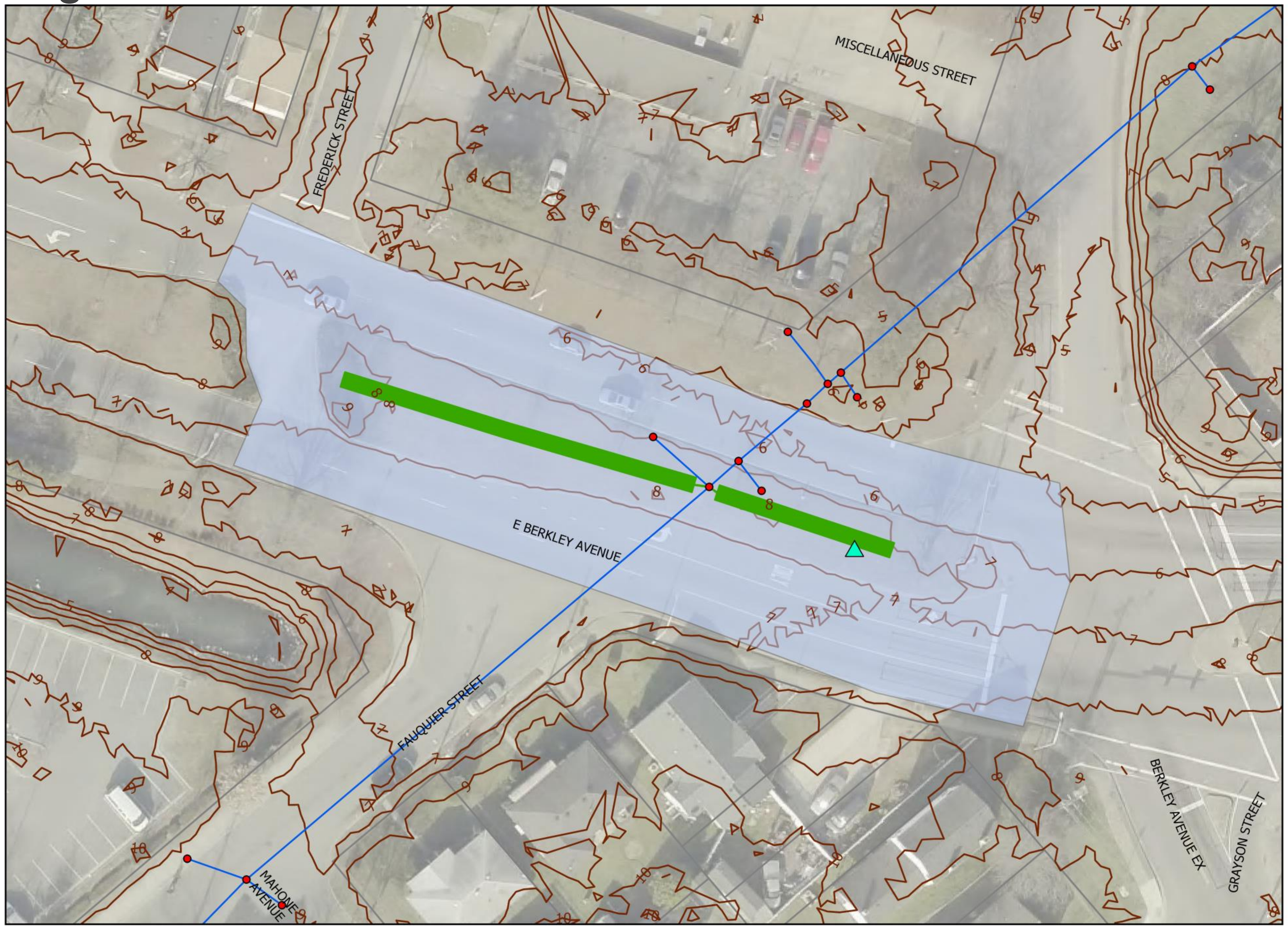
Conceptual Design – Not for Construction

E. Berkley Ave. Median

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

EBA – E. Berkley Ave.
Median Pipe Detention

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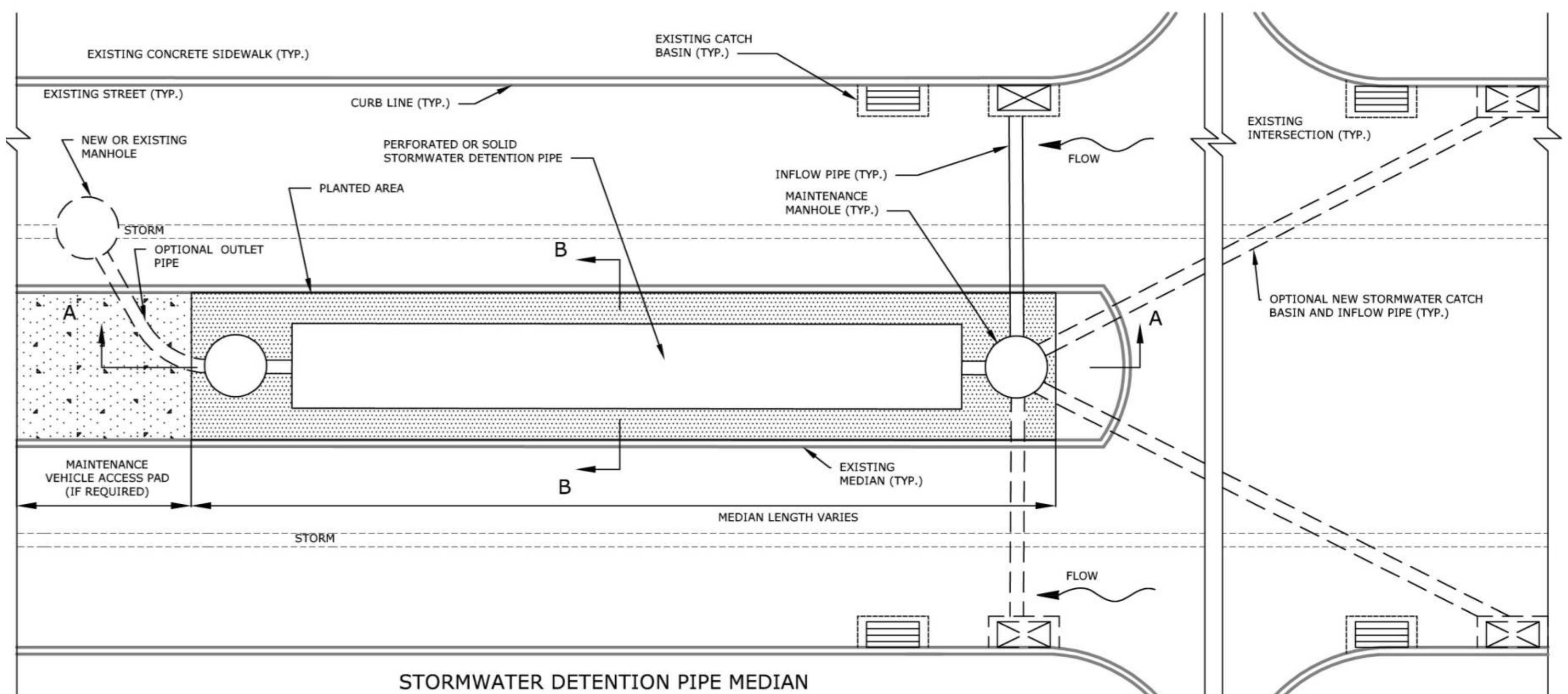
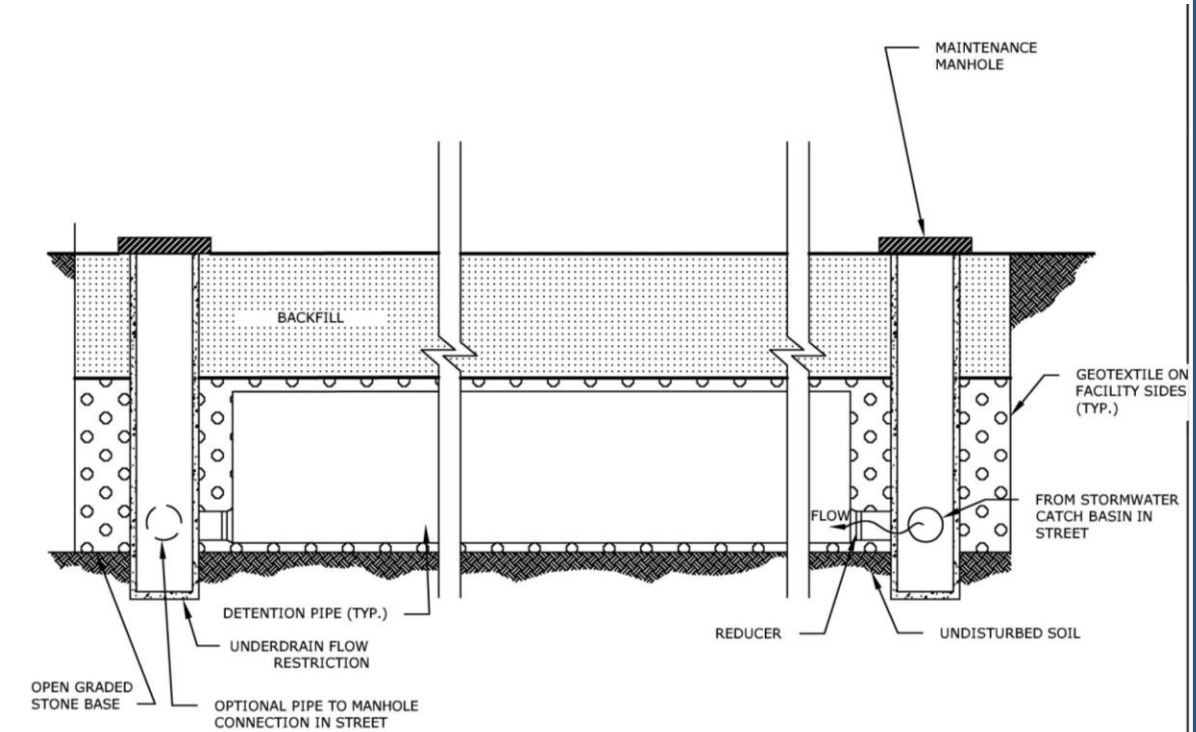
Conceptual Design – Not for Construction

E. Berkley Ave. Median

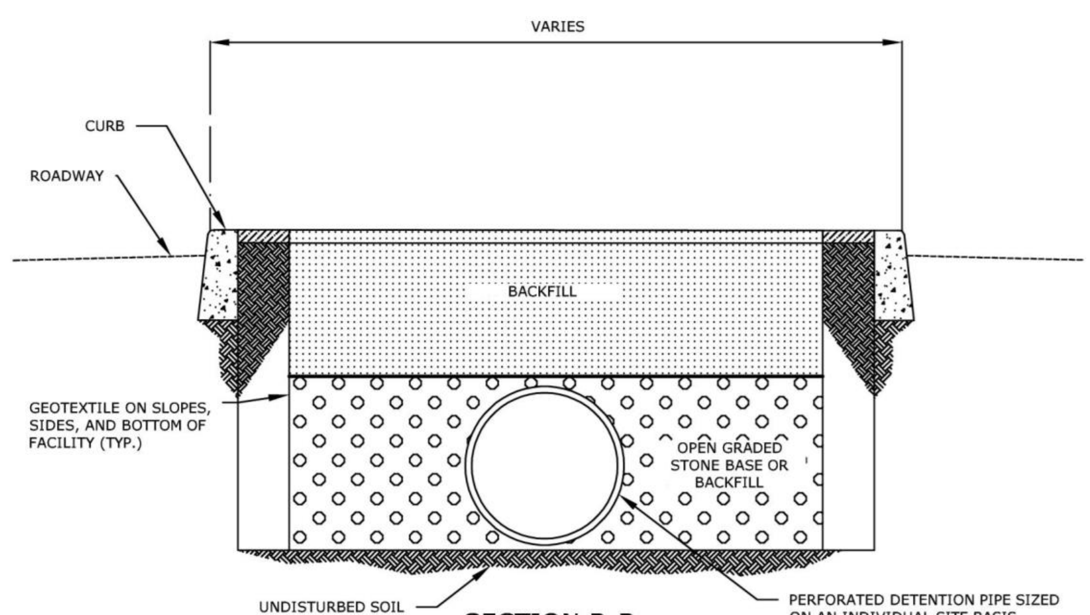
Median Pipe Detention Standard Detail



STORMWATER DETENTION PIPE MEDIAN
PLAN VIEW
(NOT TO SCALE)



SECTION A-A
STORMWATER DETENTION PIPE MEDIAN
(NOT TO SCALE)



SECTION B-B
DETENTION PIPE WITHIN MEDIAN
(NOT TO SCALE)

EBA – E. Berkley Ave.
Median Pipe Detention

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Sheet 4 of 5	03/22/19

E. Berkley Ave. Median
Design Calculations

- **Calculate water quality volume**
  - $WQ_V = \frac{WQ_{Depth}}{12} \times A$
    - $\%_{impervious} = 80\%$
    - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.77 in$
    - $A = 29{,}990\ ft^2$
  - $WQ_V = 1{,}925\ ft^3$

- **Estimate median pipe detention footprint**
  - $Footprint = 1{,}250 ft^2$

- **Calculate full water quality treatment volume**
  - $Vol_{treatment} = (Area \times D_{stone} - Vol_{chamber}) \times (Porosity_{stone}) + Vol_{chamber}$
    - $Area = 1{,}250 ft^2$
    - $D_{stone} = 4\ ft$
    - $Porosity_{stone} = 0.4$
    - $Vol_{chamber} = 328 ft^3$
  - $Vol_{treatment} = 2{,}200\ ft^3$

- **Estimate annual pollutant load reduction**
  - $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
    - $A = 0.69\ ac$
    - $\%_{impervious} = 80\%$
    - $\%_{pervious} = 20\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**1.0 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**6.1 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**386 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

  - $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

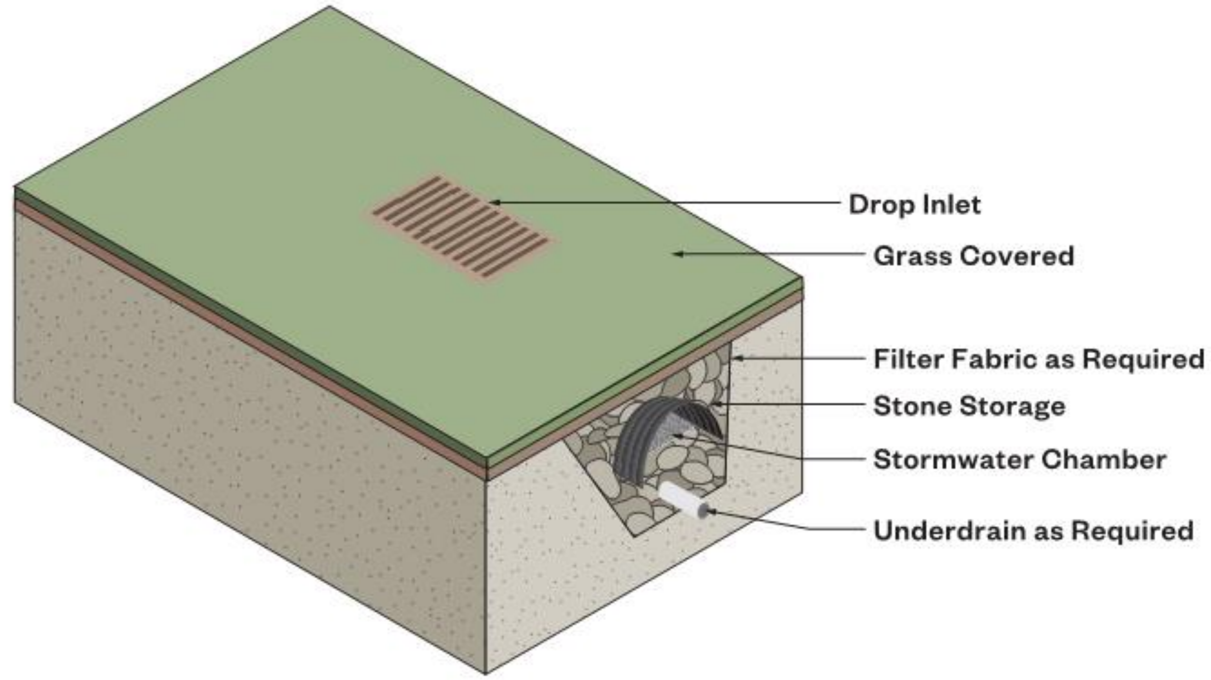
Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	63%[2]	**0.7 lb/yr**
TN	57%[2]	**3.5 lb/yr**
TSS	70%[3]	**270 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Infiltration Practices, Design Specification No. 8, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 93%, TN: 92%, TSS: 70%).

E. Princess Anne Road Median

Concept Overview



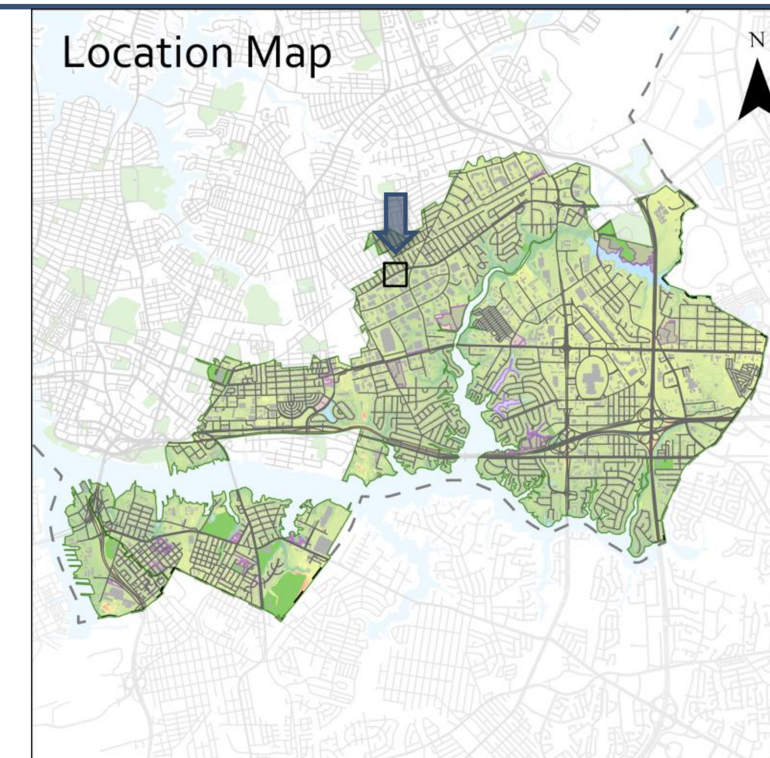
Median Stormwater Chamber

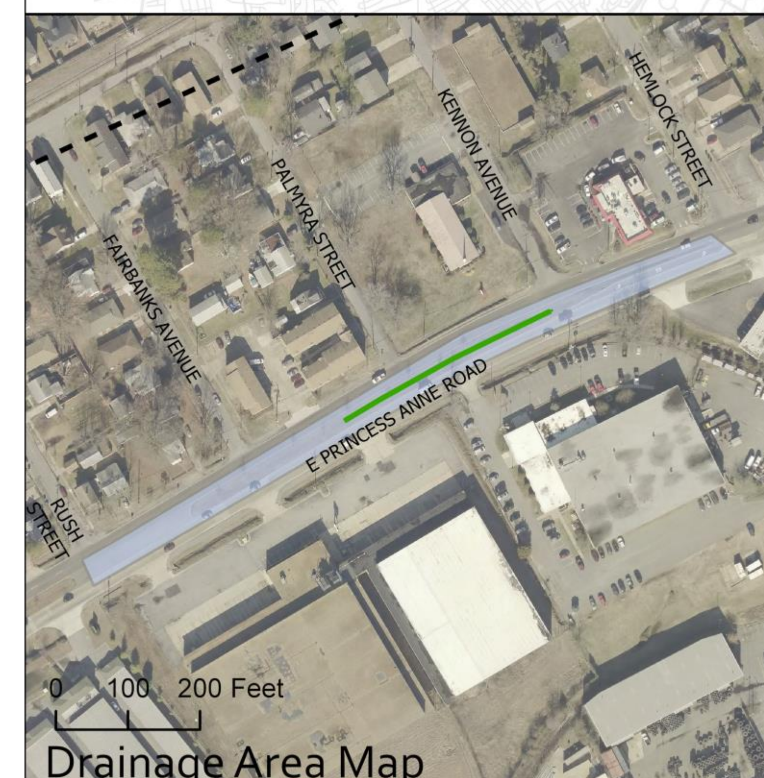
Existing Conditions

This site consists of a right-of-way median that runs down the center of E. Princess Anne Road. The existing median space has minor definition for conveyance of water to a series of existing drop inlets that tie into the City's stormwater network. A recurring flooding location is reported at this site and, during the visit, standing water was visible in the median. The right-of-way captures sheet flow from a 0.98 acre drainage area with 80% impervious area. The next page provides additional site photographs.

Proposed Green Infrastructure

The proposed median stormwater chamber will collect sheet flow from its drainage area. The feature will consist of a series of drop inlets that tie into subsurface stone storage, a stormwater chamber for increased storage volume, and an outlet structure to reconnect to the existing stormwater network. The entire practice will have the potential to manage at least 1" of runoff from up to 0.98 acres of drainage in the area, providing added stormwater storage capacity to relieve persistent flooding issues that occur on Princess Anne Rd. Subsurface utility relocation or coordination may be required within the practice footprint location.





EPA – E. Princess Anne Rd.
Median Stormwater Chamber

Type: Median Stormwater Chamber
Address: 3801 E Princess Anne Rd.
Area Managed: 0.98 acres

Conceptual Level Estimates:

Construction Cost: $214,000
TN Load Reduction: 5.0 lb/yr
TP Load Reduction: 0.9 lb/yr
TSS Load Reduction: 388 lb/yr

WQ Treatment Volume: 2,970 ft^3
Cost/Storage Volume: $72/$ft^3$
TN Reduction Cost: $43,000/lb/yr
TP Reduction Cost: $228,000/lb/yr
TSS Reduction Cost: $550/lb/yr

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03/22/19

Conceptual Design – Not for Construction

E Princess Anne Road Median – Stormwater Chamber
Concept Overview

Facing NE on median

Facing NE at existing drop inlet

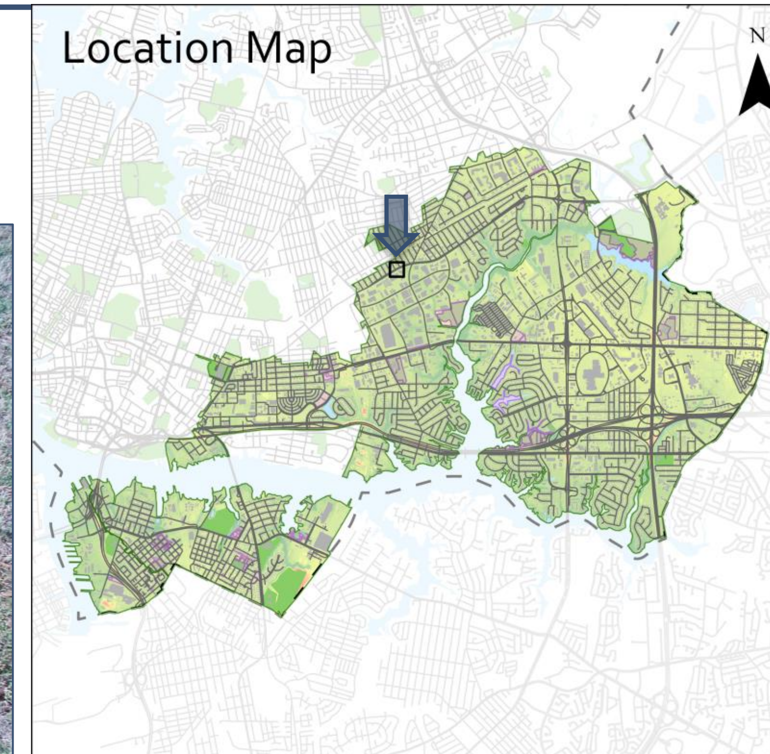
Existing drop inlet

Facing SW on median at ponding area

Marked area in median

Existing drop inlet

See inset map on the right for photograph locations



EPA – E. Princess Anne Rd.
Median Stormwater Chamber

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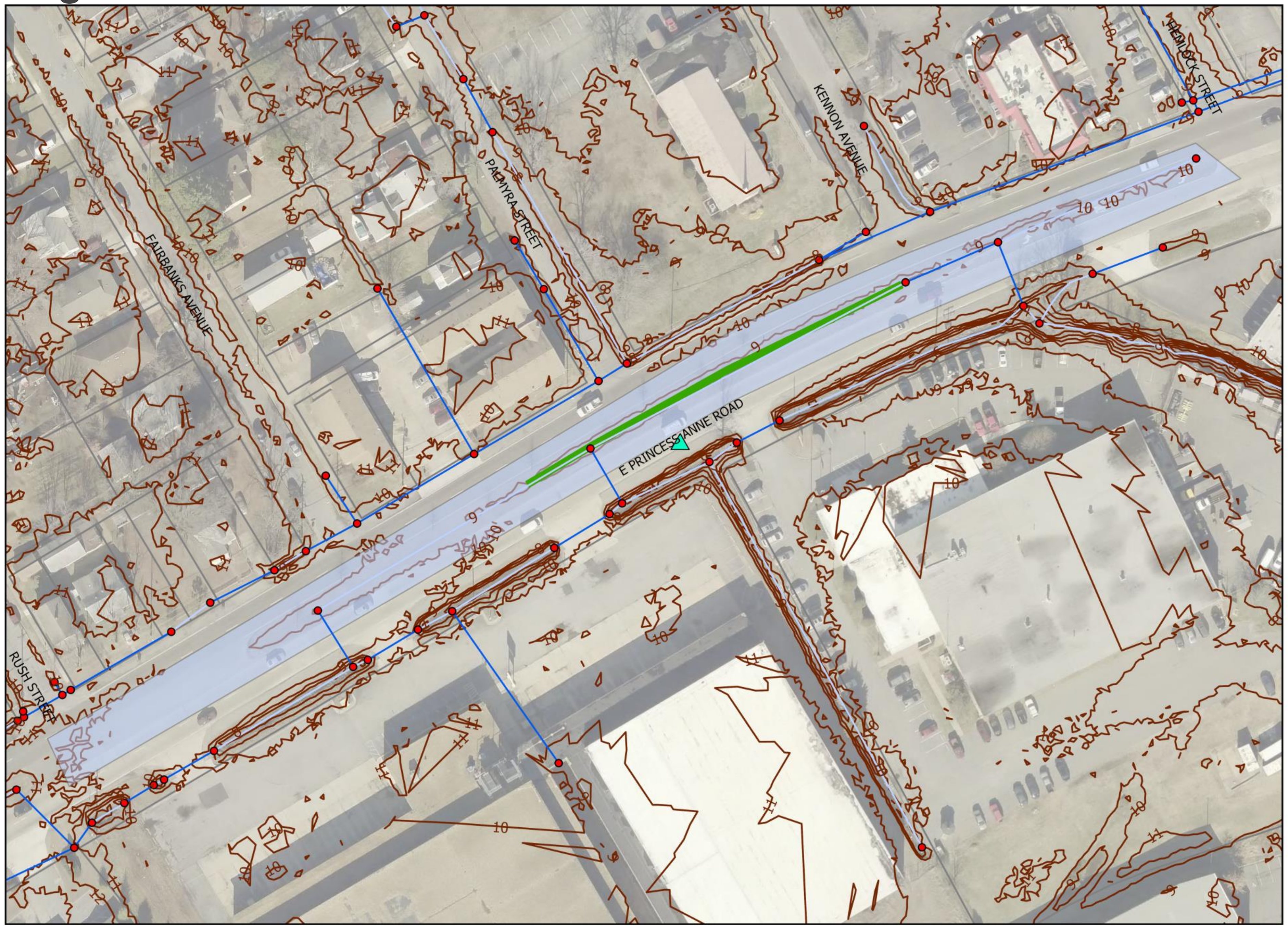
Sheet 2 of 5	03/22/19

Conceptual Design – Not for Construction

E Princess Anne Road Median – Stormwater Chamber

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 150 200 250 Feet

EPA – E. Princess Anne Rd.
Median Stormwater Chamber

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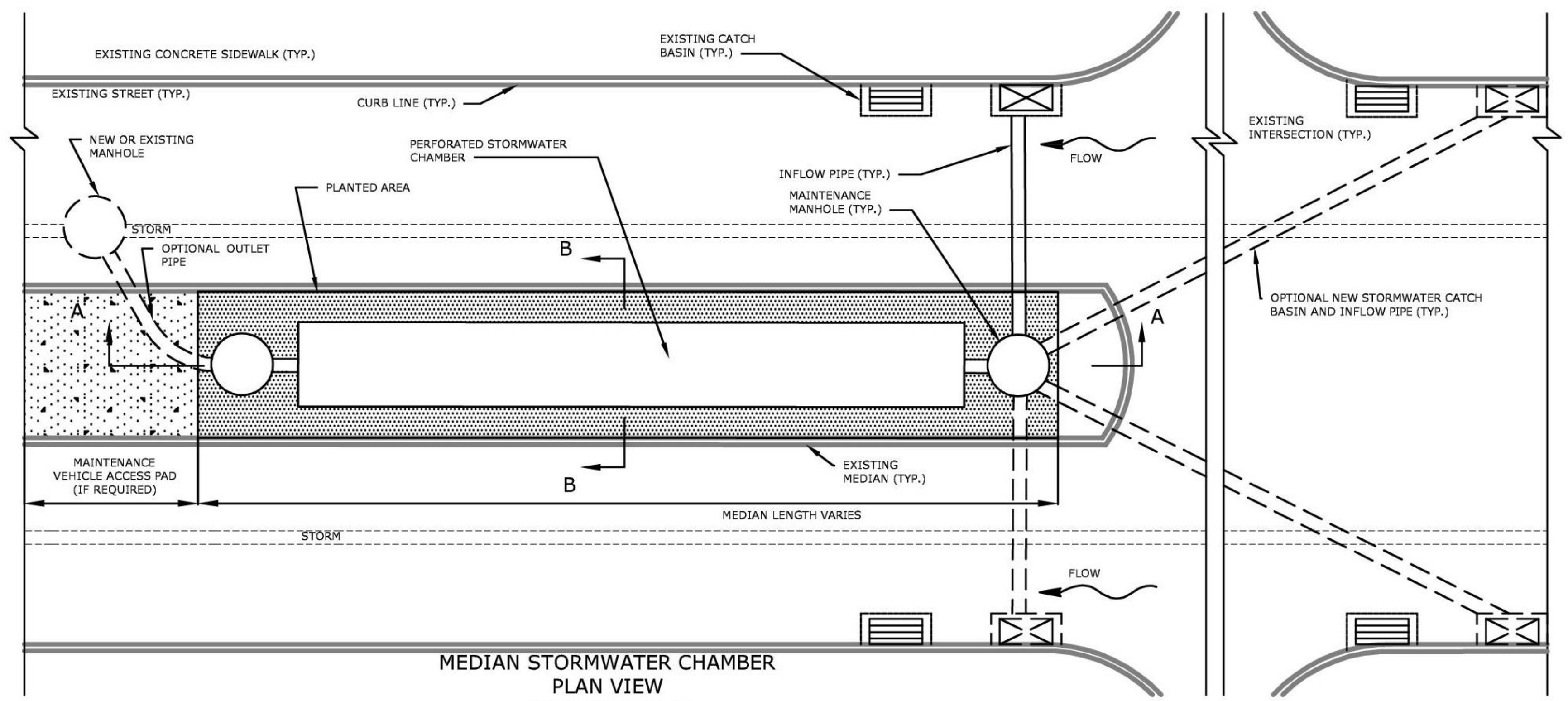
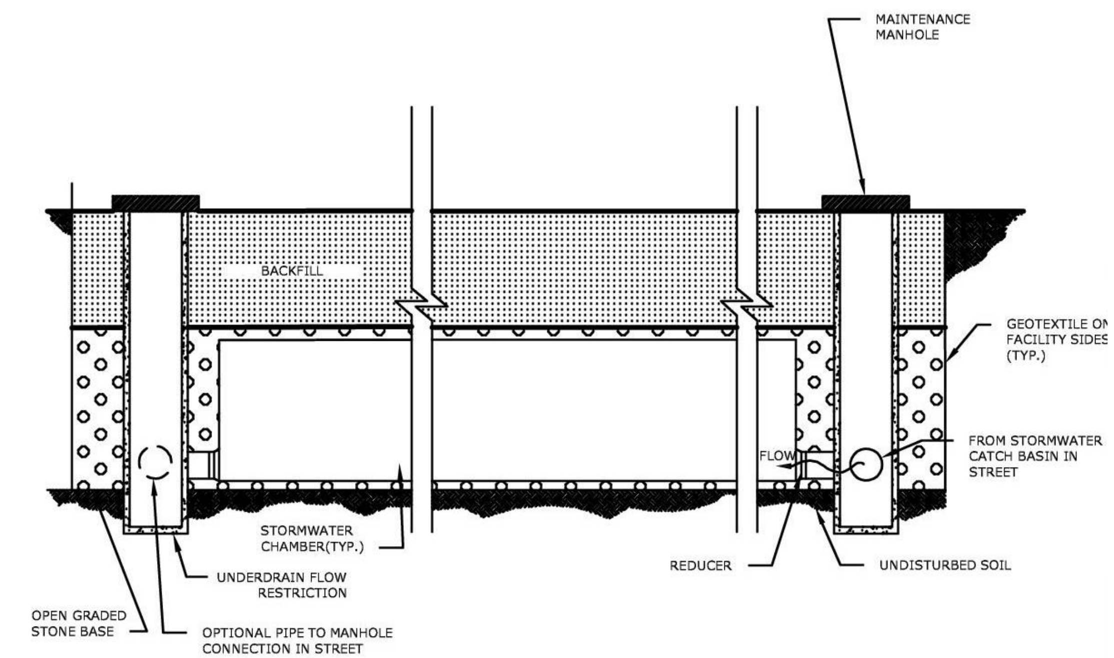
Conceptual Design – Not for Construction

E Princess Anne Road Median – Stormwater Chamber

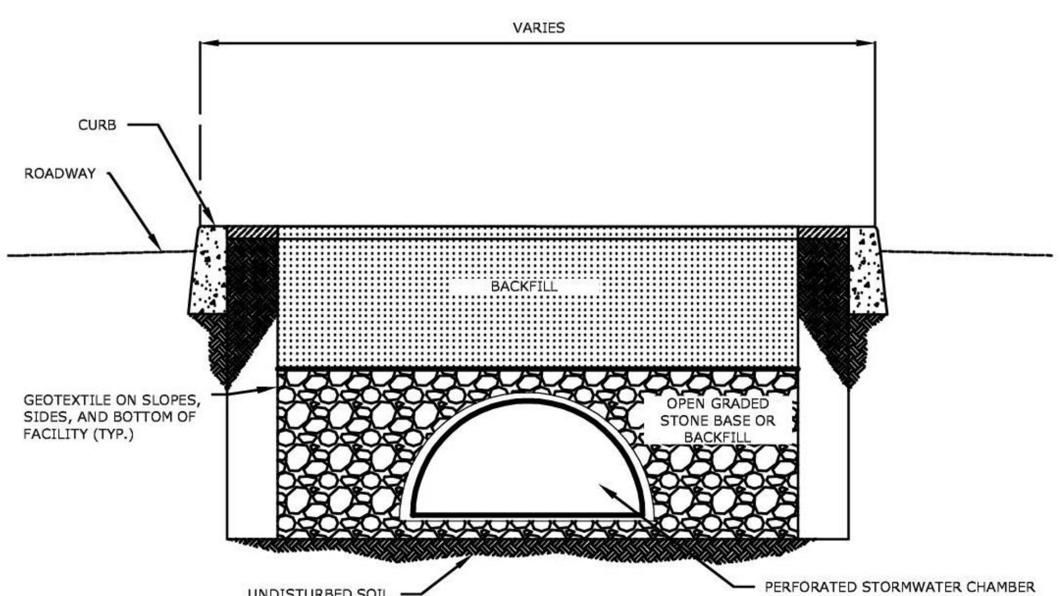
Median Stormwater Chamber Section



MEDIAN STORMWATER CHAMBER
PLAN VIEW
(NOT TO SCALE)



SECTION A-A
MEDIAN STORMWATER CHAMBER
(NOT TO SCALE)



SECTION B-B
MEDIAN STORMWATER CHAMBER
(NOT TO SCALE)

EPA – E. Princess Anne Rd.
Median Stormwater Chamber

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E Princess Anne Road Median – Stormwater Chamber

Design Calculations

- **Calculate water quality volume**
  - $WQ_V = \frac{WQ_{Depth}}{12} \times A$
    - $\%_{impervious} = 80\%$
    - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.77 in$
    - $A = 43{,}065\ ft^2$
  - $WQ_V = 2{,}763\ ft^3$

- **Estimate median stormwater chamber footprint**
  - $Footprint = 1{,}625 ft^2$

- **Calculate full water quality treatment volume**
  - $Vol_{treatment} = (Area \times D_{stone} - Vol_{chamber}) \times (Porosity_{stone}) + Vol_{chamber}$
    - $Area = 1{,}625 ft^2$
    - $D_{stone} = 4\ ft$
    - $Porosity_{stone} = 0.4$
    - $Vol_{chamber} = 608\ ft^3$
  - $Vol_{treatment} = 2{,}970\ ft^3$

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 93%, TN: 92%, TSS: 70%).

- **Estimate annual pollutant load reduction**
  - $Load_{annual} = \left(A \times \%_{impervious} \times Loading\ Rate_{imp}\right) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
    - $A = 0.98\ ac$
    - $\%_{impervious} = 80\%$
    - $\%_{pervious} = 20\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**1.5 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**8.8 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**554 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

  - $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

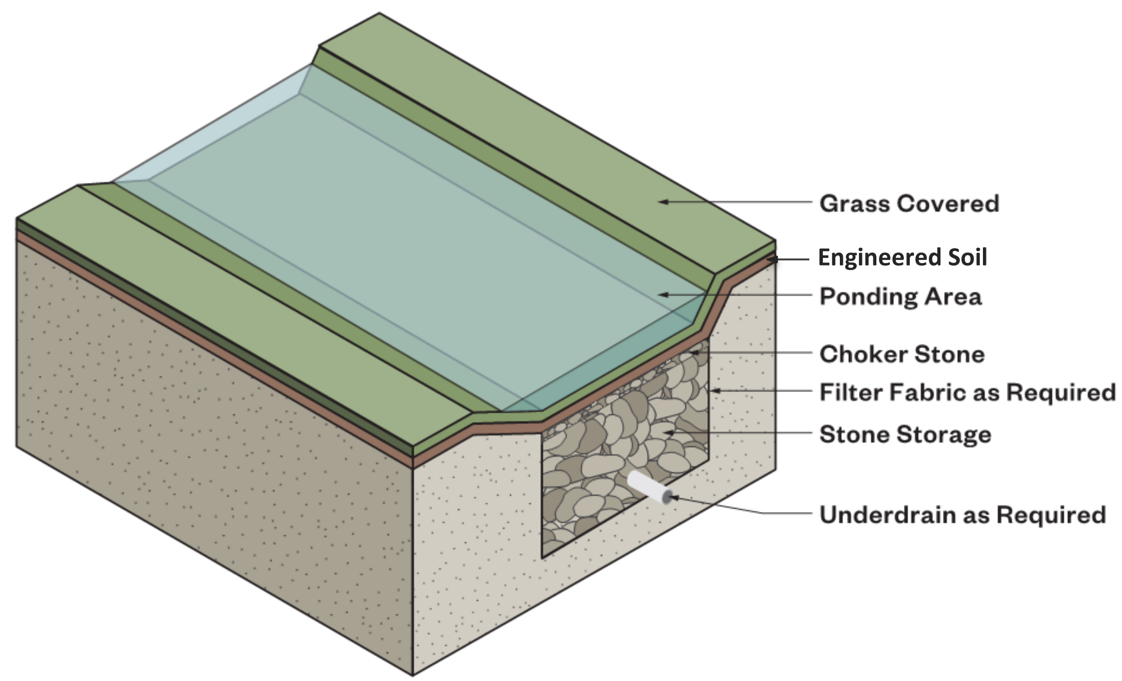
Pollutant	$\%_{load\ reduction}$	Load Reduction
TP	63%[2]	**0.9 lb/yr**
TN	57%[2]	**5.0 lb/yr**
TSS	70%[3]	**388 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Infiltration Practices, Design Specification No. 8, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

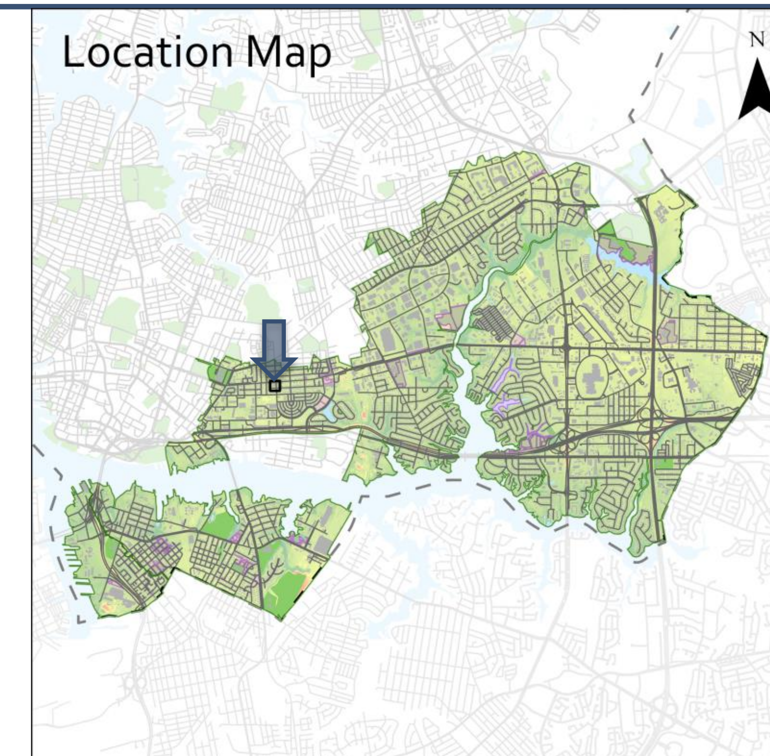
Majestic Ave. Right-of-Way
Concept Overview

Proposed Site

Proposed Site



Infiltration Trench



MAJ – Majestic Ave. Right-of-Way
Infiltration Trench

Existing Conditions

The right-of-way site runs along the block of Majestic Ave. between Virginia Beach Blvd. and Myrtle Ave. There have been flooding complaints for ponding in the roadway on both ends of the block. The right-of-way on this street has an undersized ditch that has no outlet into the stormwater network. This site captures drainage from 0.76 acres of 70% impervious that includes sheet flow from the roadway, rooftops, and residential lots. The right-of-way strip has two driveway entrances with culverts for ditch connectivity. The next page provides additional site photographs.

Proposed Improvement

The proposed right-of-way grassed infiltration trench will run along the block on Majestic Ave. from Virginia Beach Blvd. to Myrtle Ave. The feature will consist of a grass top ponding area with 3:1 side slopes and a stone storage layer with an underdrain. The downstream end of the trench will have an outlet structure and discharge to a proposed manhole and then will tie back into the existing stormwater system on Virginia Beach Blvd. The entire practice will have the potential to manage at least 1" of runoff from up to 0.76 acres of drainage in the area, providing stormwater conveyance to mitigate the localized ponding issues on this site. Stormwater runoff routing may require subsurface utility relocation or coordination within the practice footprint location.

Type: Infiltration Trench
Address: 2630 Myrtle Ave.
Area Managed: 0.76 acres

Conceptual Level Estimates:

Construction Cost: $179,000
TN Load Reduction: 3.8 lb/yr
TP Load Reduction: 0.7 lb/yr
TSS Load Reduction: 284 lb/yr

WQ Treatment Volume: 1,900 ft^3
Cost/Storage Volume: $95/$ft^3$
TN Reduction Cost: $48,000/lb/yr
TP Reduction Cost: $269,000/lb/yr
TSS Reduction Cost: $631/lb/yr

THE CITY OF NORFOLK Hazen

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Majestic Ave. Right-of-Way
Concept Overview

Facing south on west side of Majestic Ave.

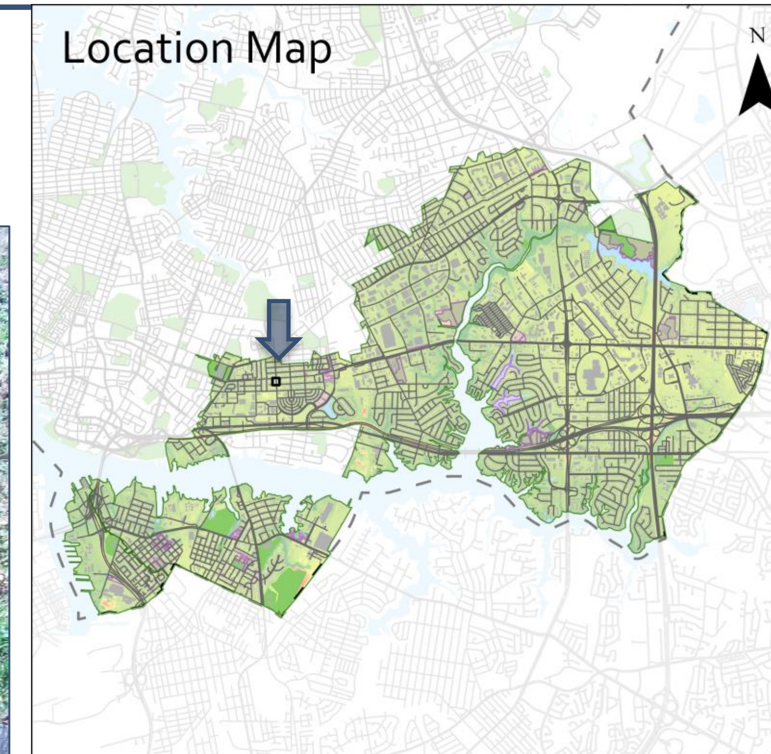
Inlet area into existing ditch

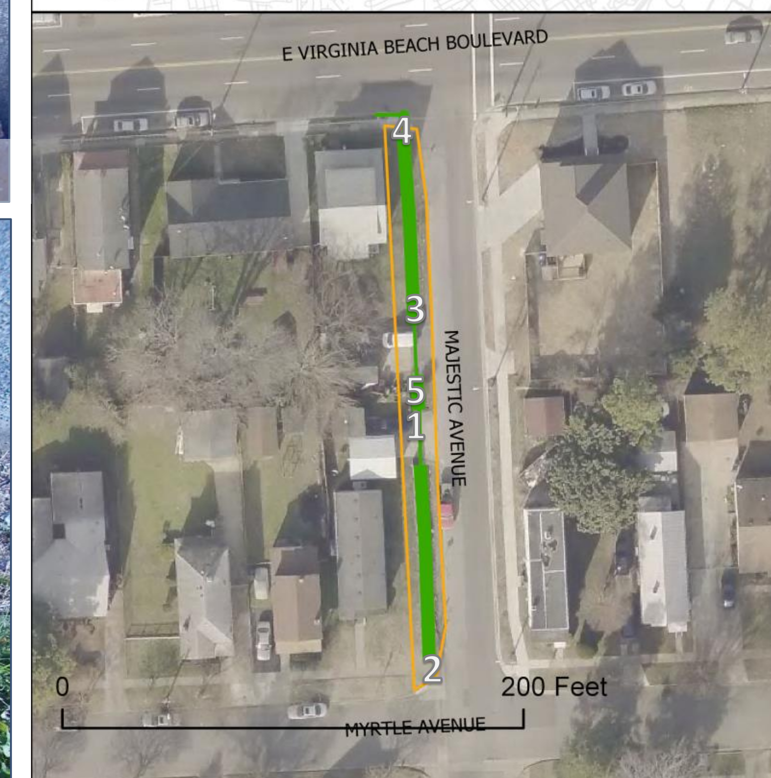
Ditch culvert connection

Outlet area of existing ditch

Trash and debris in existing ditch

See inset map on the right for photograph locations





MAJ – Majestic Ave. Right-of-Way
Infiltration Trench

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Sheet 2 of 5 | 03/22/19

Conceptual Design – Not for Construction

Majestic Ave. Right-of-Way
Drainage Area Plan View

LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

MAJ – Majestic Ave. Right-of-Way Infiltration Trench

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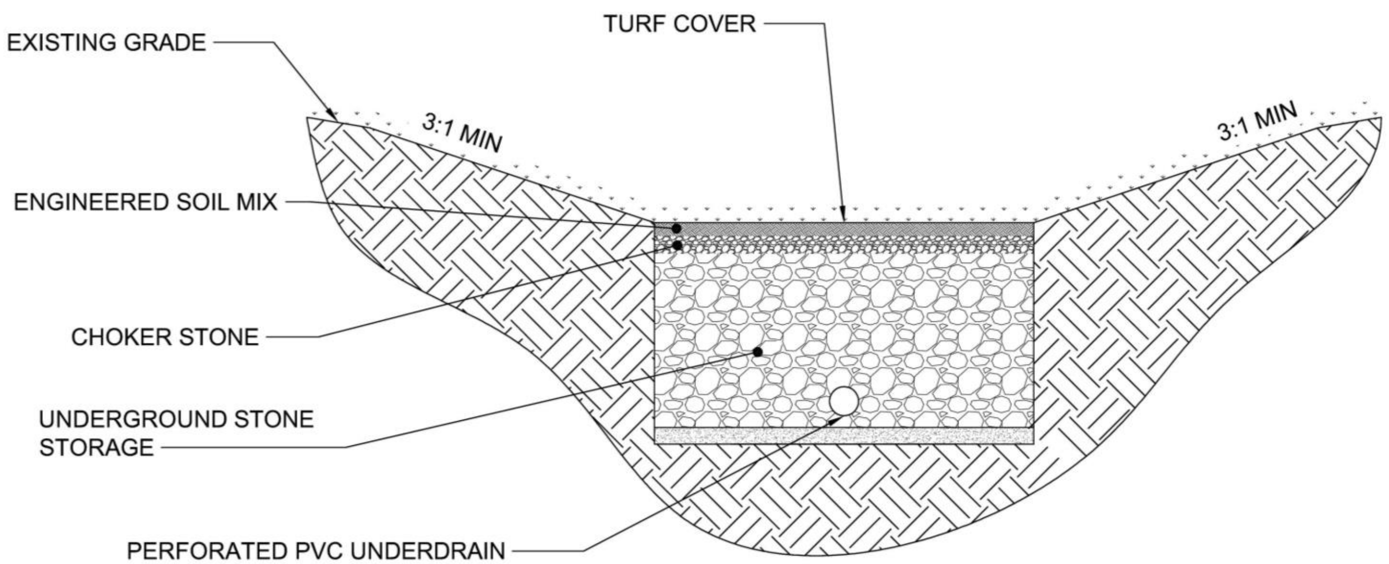
Conceptual Design – Not for Construction

Majestic Ave. Right-of-Way

Infiltration Trench Section



INFILTRATION TRENCH
(NOT TO SCALE)

MAJ – Majestic Ave. Right-of-Way Infiltration Trench	
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Conceptual Design – Not for Construction

Majestic Ave. Right-of-Way

Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 70\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.68in$
  - $A = 33{,}207\ ft^2$
- $WQ_V = 1{,}880\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = (Area_{ponding} + Area_{subsurface})\frac{1}{2} \times D_{ponding} + Area_{subsurface}(D_{soil} \times Porosity_{soil} + D_{stone} \times Porosity_{stone}) + Vol_{Pretreatment}$
  - $Area_{ponding} = 1{,}140 ft^2$
  - $Area_{subsurface} = 660 ft^2$
  - $D_{ponding} = 6\ in$
  - $D_{soil} = 2\ in$
  - $Porosity_{soil} = 0.25$
  - $D_{stone} = 4\ ft$
  - $Porosity_{stone} = 0.4$
  - $Vol_{pretreatment} = .15 \times WQ_V = 282 ft^3$
- $Vol_{treatment} = 1{,}900\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = .76\ ac$
  - $\%_{impervious} = 70\%$
  - $\%_{pervious} = 30\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**1.1 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**6.6 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**383 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

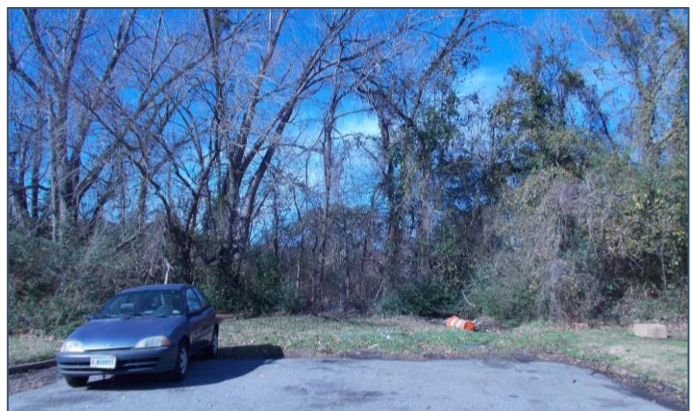
Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	63%[2]	**0.7 lb/yr**
TN	57%[2]	**3.8 lb/yr**
TSS	70%[3]	**284 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Infiltration Feature Specification No. 8, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

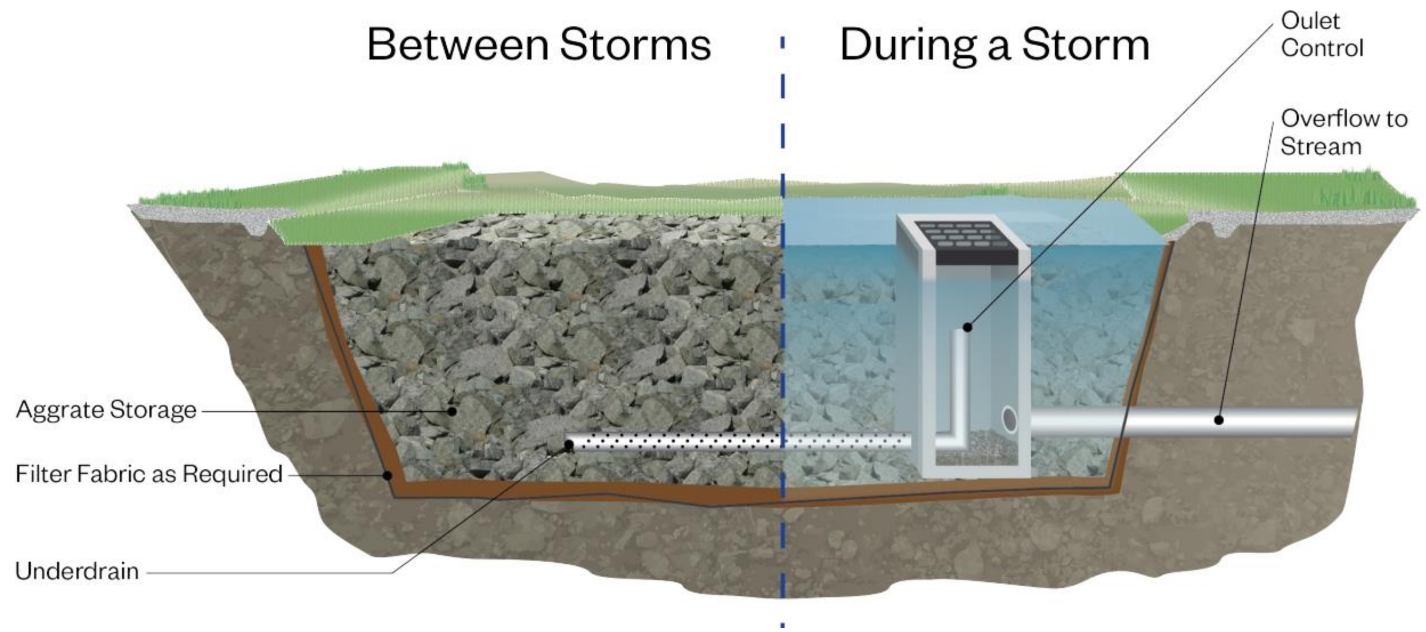
Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 93%, TN: 92%, TSS: 70%).

Seay Ave.
Concept Overview

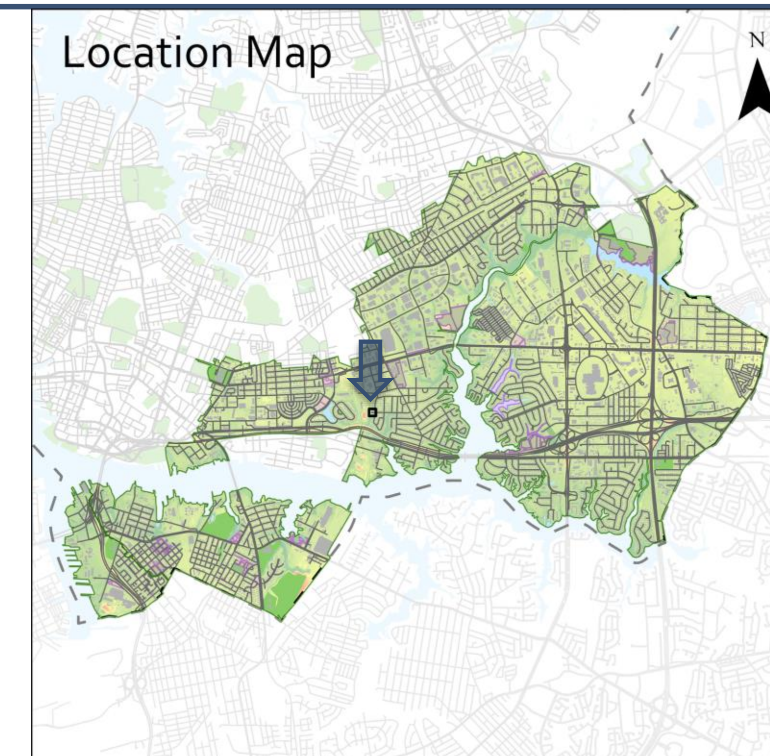
Proposed Site

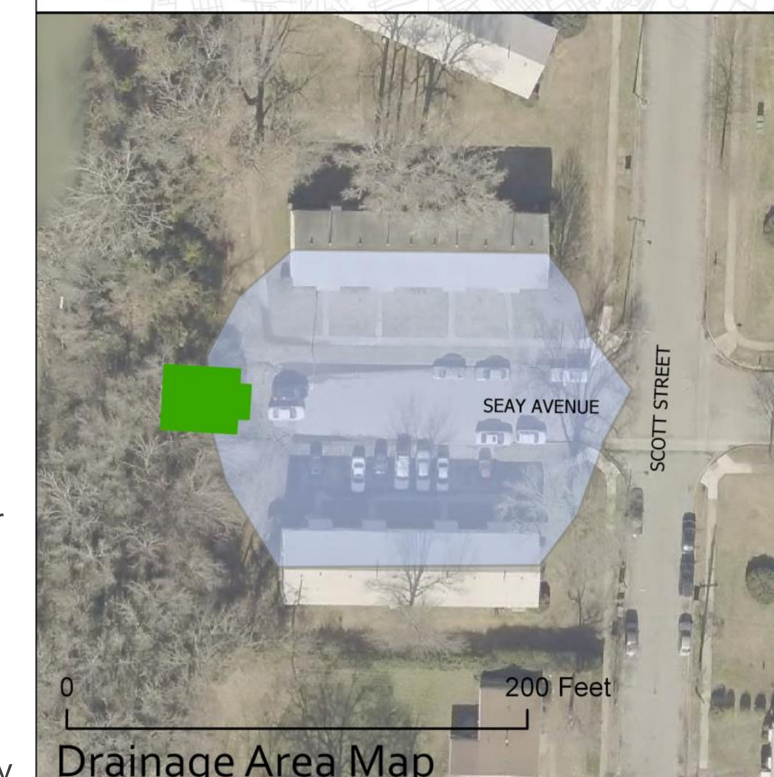


Proposed Site



Infiltration Basin





SA – Seay Ave.
Infiltration Basin

Existing Conditions

The west end of Seay Ave. has had repeated reports of flooding after intense wet weather events. The roadway currently has no existing infrastructure for ponding relief. At the west end of the street, there is open space in the right of way with signs of standing water. The sheet flow directed towards the right-of-way space at the west end of the street has a drainage area of 0.49 acres with 60% impervious. The next page provides additional site photographs.

Proposed Improvement

The proposed infiltration basin will be on the west end of Seay Ave. beyond the east end of the street. The feature will have a pretreatment sediment forebay for collection of sediment and trash to prevent clogging of the infiltration basin. The infiltration basin with a surface ponding area and below grade stone storage with an underdrain. The practice will have the potential to manage 0.49 acres of drainage in the area, providing stormwater storage capacity to relieve persistent flooding issues that occur on this end of Seay Ave. Subsurface utility relocation or coordination may be required within the practice footprint location.

Type: Infiltration Basin
Address: 3494 Seay Ave.
Area Managed: 0.49 acres

Conceptual Level Estimates:

Construction Cost: $35,000
TN Load Reduction: 2.3 lb/yr
TP Load Reduction: 0.4 lb/yr
TSS Load Reduction: 160 lb/yr

WQ Treatment Volume: 1,750 ft^3
Cost/Storage Volume: $20/$ft^3$
TN Reduction Cost: $15,000/lb/yr
TP Reduction Cost: $92,000/lb/yr
TSS Reduction Cost: $220/lb/yr

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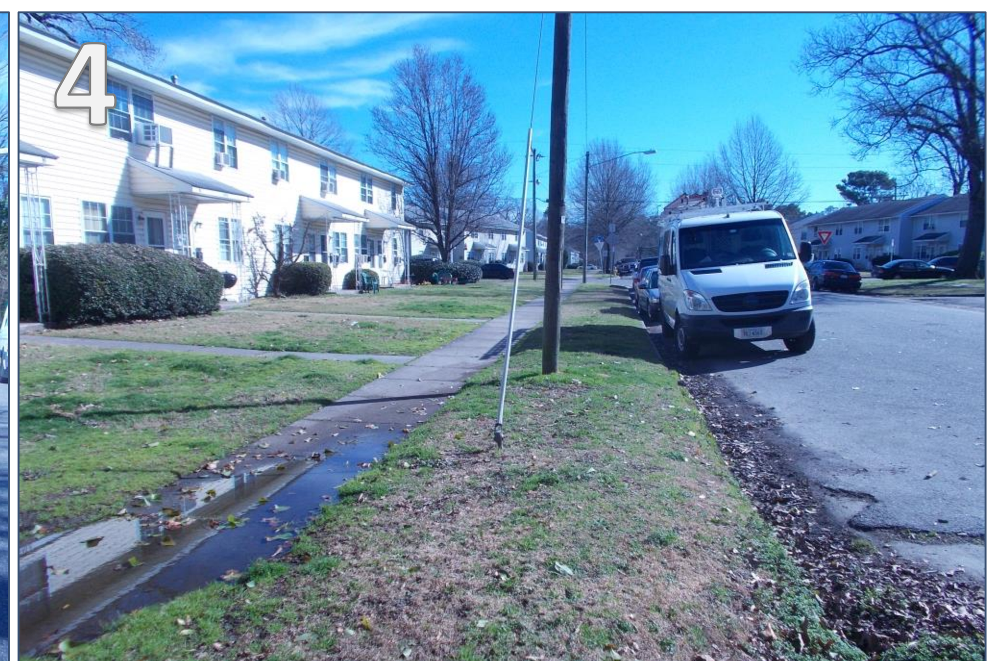
Conceptual Design – Not for Construction

Seay Avenue
Concept Overview

Facing east on south side of Seay Ave.

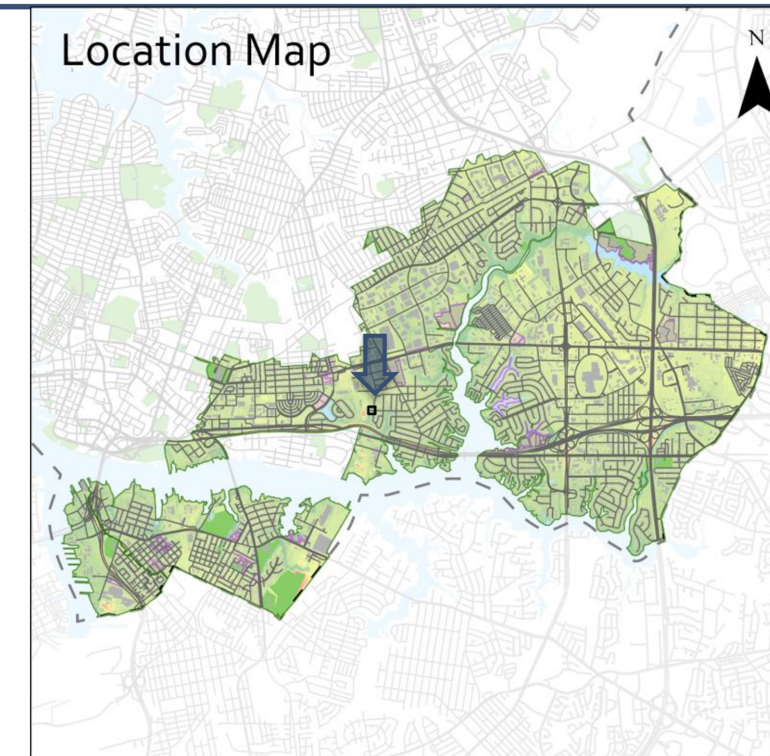
Facing west at west end of Seay Ave.

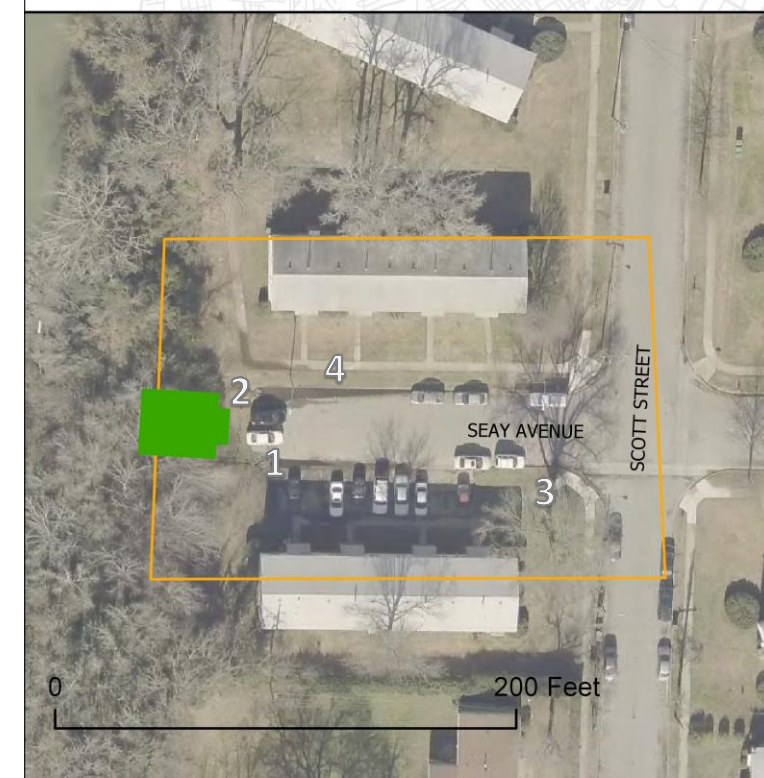
Facing southwest towards parking area



Facing east from west end of Seay Ave.

See inset map on the right for photograph locations





SA – Seay Ave.
Infiltration Basin

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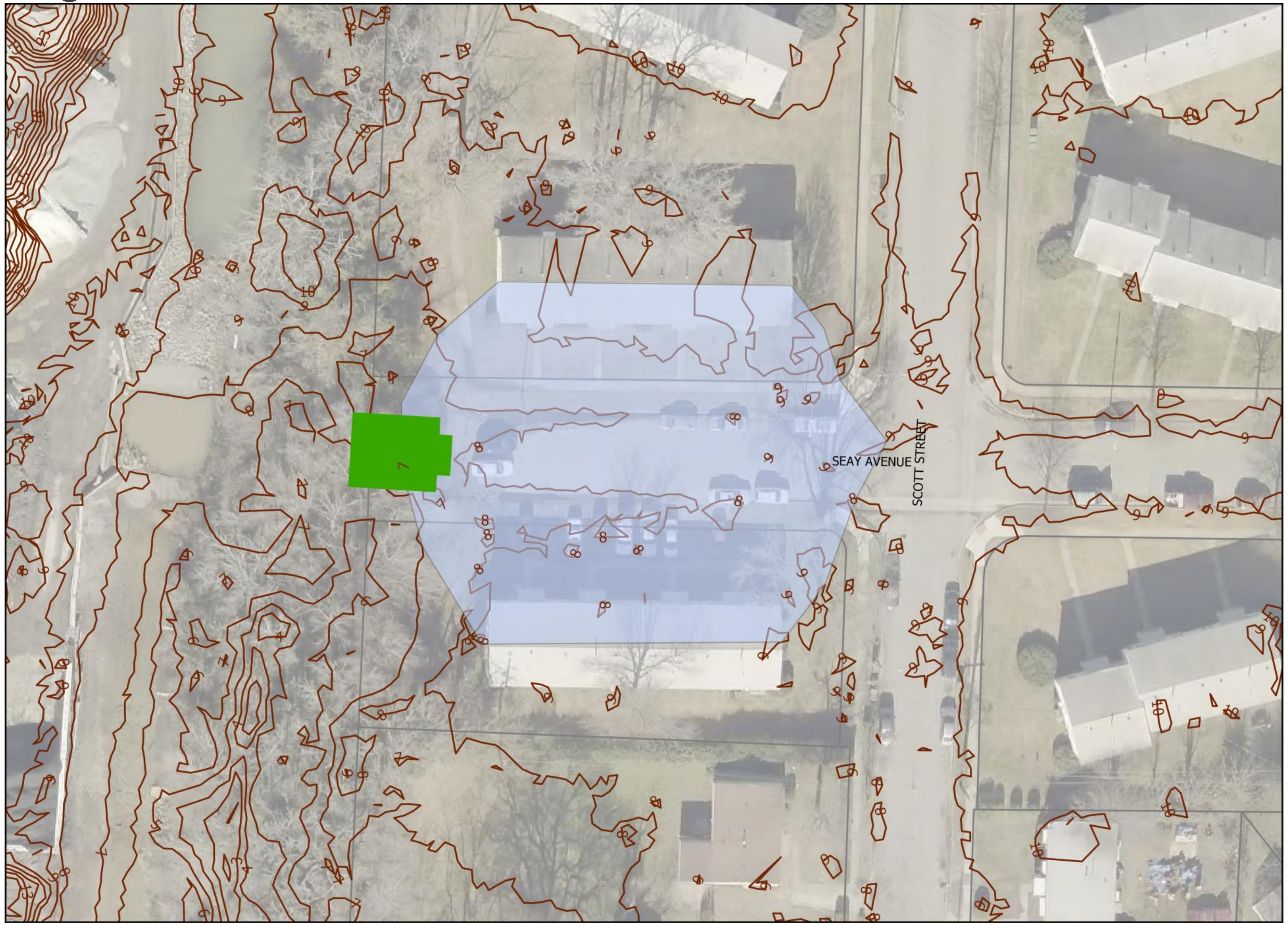
Seay Avenue

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

Alternative Design Options:
- Right-of-way bioretention on the north side of Seay Avenue
- Grasses swale past the east end of the roadway with a stone pretreatment area
- Underdrain from bioretention would tie into the swale and sheet flow would also reach the swale feature

SA – Seay Ave. Infiltration Basin	
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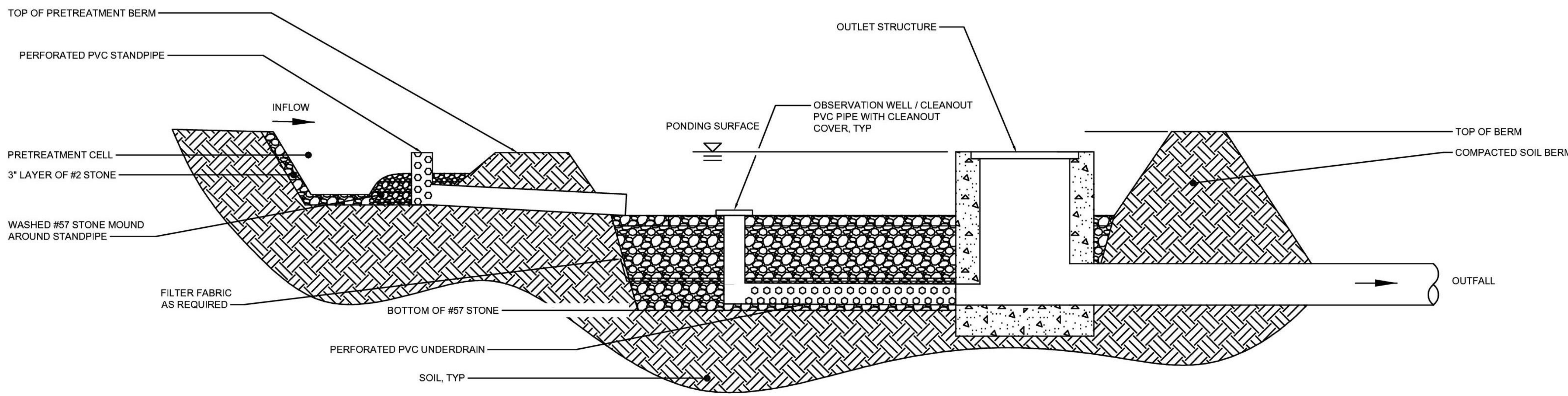
Seay Avenue
Infiltration Basin Standard Detail



INFILTRATION BASIN
(NOT TO SCALE)

SA – Seay Ave. Infiltration Basin	
THE CITY OF NORFOLK	Hazen
Sheet 4 of 5	03/22/19

Conceptual Design – Not for Construction

Seay Avenue
Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 60\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.59 in$
  - $A = 21,180 ft^2$
- $WQ_V = 1{,}041\ ft^3$

Calculate full water quality treatment volume

- $Vol_{treatment} = (Area_{ponding} + Area_{subsurface})\frac{1}{2} \times D_{ponding} + Area_{subsurface}(D_{stone} \times Porosity_{stone})$
  - $Area_{ponding} = 1{,}041 ft^2$
  - $Area_{subsurface} = 520 ft^2$
  - $D_{ponding} = 1\ ft$
  - $D_{stone} = 5\ ft$
  - $Porosity_{stone} = 0.4$
- $Vol_{treatment} = 1{,}750\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = .49\ ac$
  - $\%_{impervious} = 60\%$
  - $\%_{pervious} = 40\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**0.6 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**4.1 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**217 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	63%[2]	**0.4 lb/yr**
TN	57%[2]	**2.3 lb/yr**
TSS	70%[3]	**160 lb/yr**

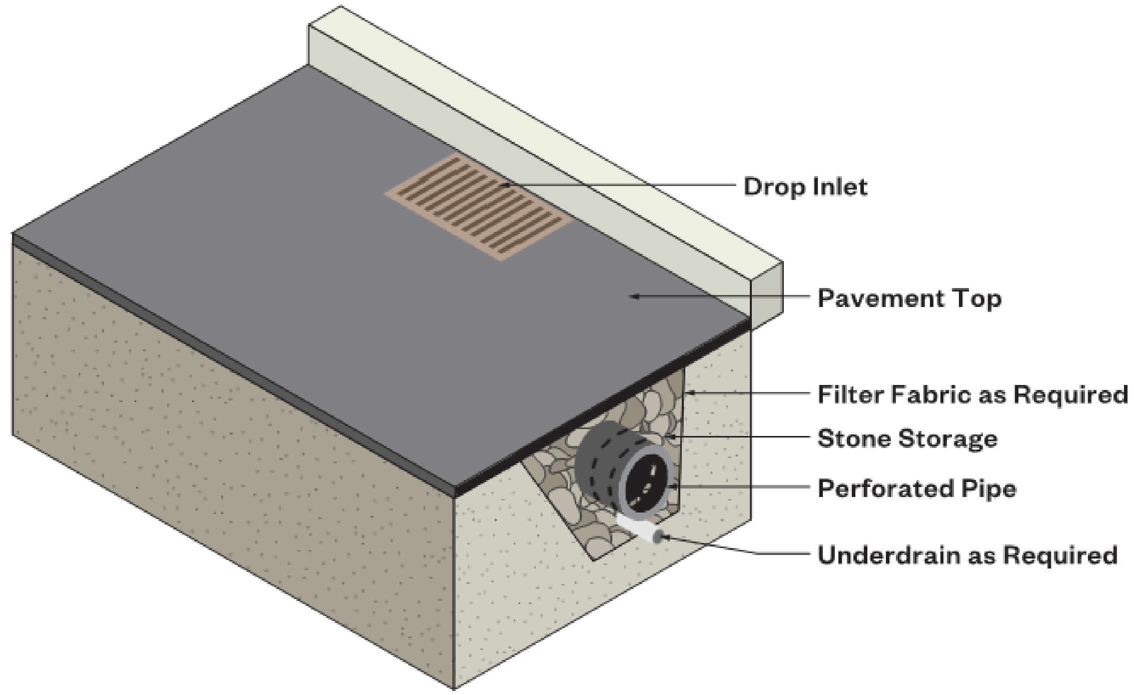
[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Infiltration Feature Specification No. 8, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 93%, TN: 92%, TSS: 70%)

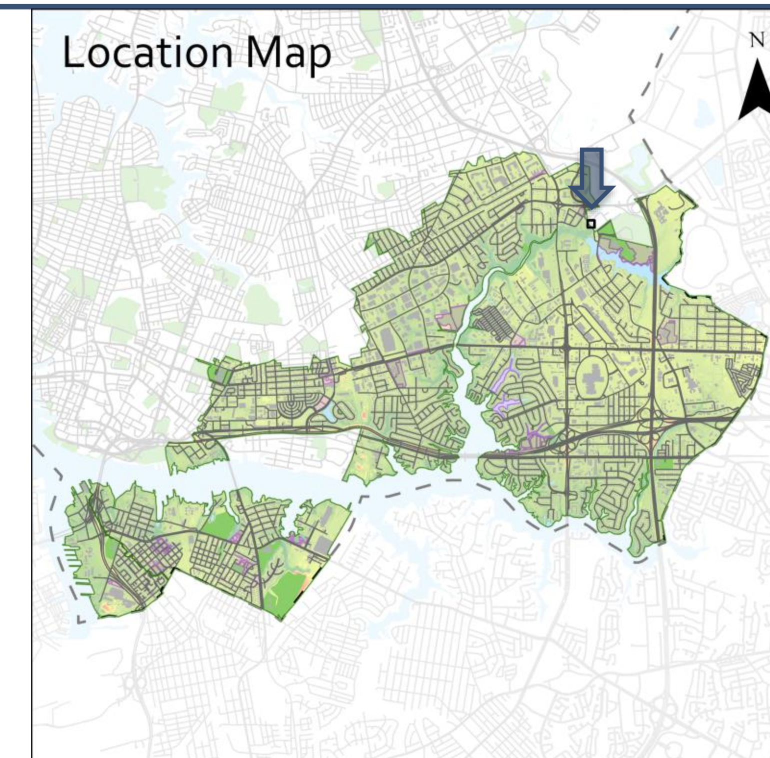
Town and Country Day School
Concept Overview

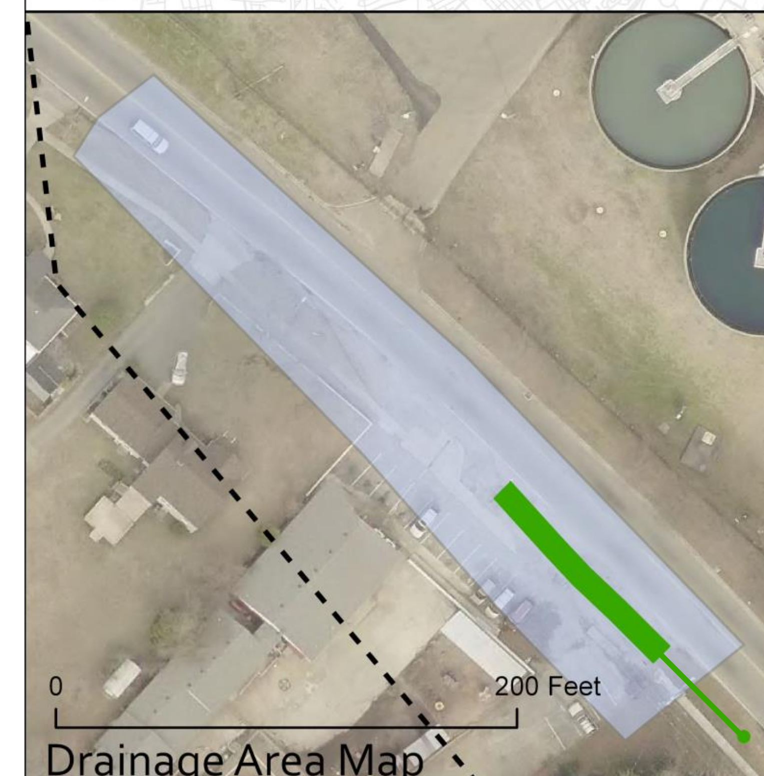
Proposed Site

Proposed Site



Pipe Detention





TCD – Town and Country Day School
Right-of-Way Pipe Detention

Existing Conditions

This right-of-way space is off of Kempsville Rd. at the entrance of the Town and Country Day School. The roadway is prone to frequent flooding and persistent ponding after intense rainfall. During the site visit, there was evidence of ponding issues in the entrance to the school's parking lot with standing water and water lines. The existing stormwater infrastructure is on the northeast side of the roadway and the grading of the road sheds water to settling in the private parking lot of the school. The sheet flow directed towards the right-of-way space in front of the school is 0.49 acres which is 85% impervious. The next page provides additional site photographs.

Proposed Improvement

The proposed right-of-way pipe detention will capture sheet flow from the drainage area with a series of drop inlets. The inlet will be sized during detailed design. The pipe detention feature will consist of a stone storage, a perforated pipe for increased storage volume, and an outlet structure. Downstream of the pipe detention will be a new run of conveyance pipe reconnecting to the existing stormwater network, just upstream of an outfall. The practice will have the potential to manage at least 1" of runoff from up to 0.49 acres of drainage in the area, providing stormwater storage capacity to relieve persistent flooding issues that occur on Kempsville Rd. Subsurface utility relocation or coordination may be required within the practice footprint location.

Type: Pipe Detention
Address: 3801 E. Princess Anne Rd.
Area Managed: 0.49 acres

Conceptual Level Estimates:

Construction Cost: $115,000
TN Load Reduction: 2.5 lb/yr
TP Load Reduction: 0.5 lb/yr
TSS Load Reduction: 195 lb/yr

WQ Treatment Volume: 1,610 ft^3
Cost/Storage Volume: $71/$ft^3$
TN Reduction Cost: $45,000/lb/yr
TP Reduction Cost: $242,000/lb/yr
TSS Reduction Cost: $590/lb/yr

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Town and Country Day School
Concept Overview

Facing SE from NW side of parking lot

Parking area ponding

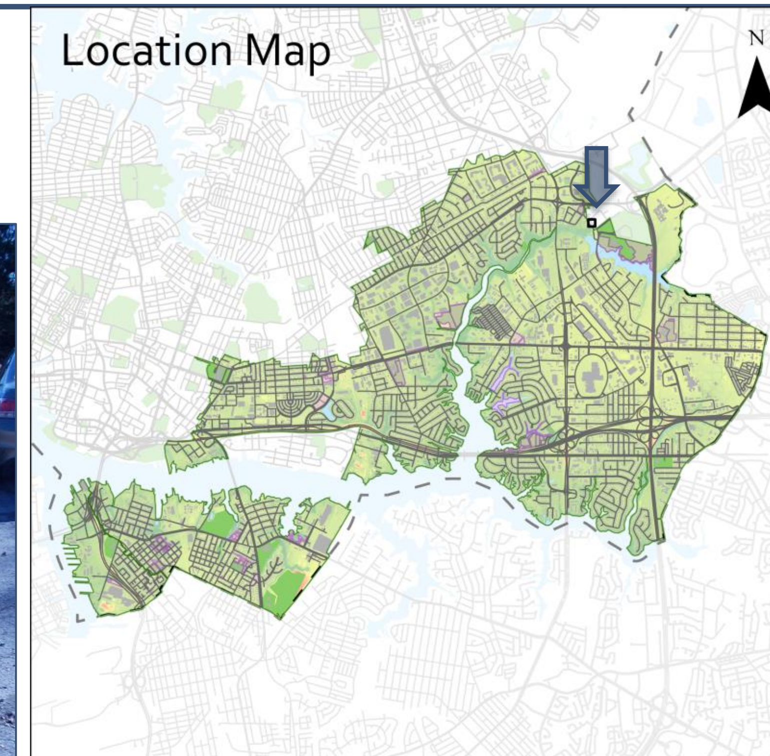
Facing SE from ponding area

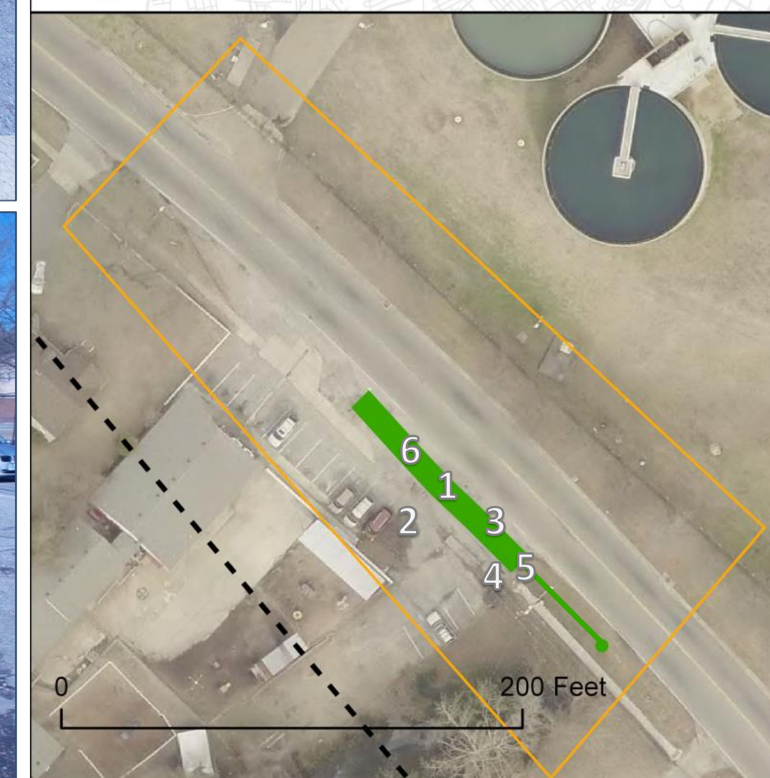
Existing ditch for ponding relief

Right-of-way space near SW outfall

Facing NW in parking lot

See inset map on the right for photograph locations





TCD – Town and Country Day School
Right-of-Way Pipe Detention

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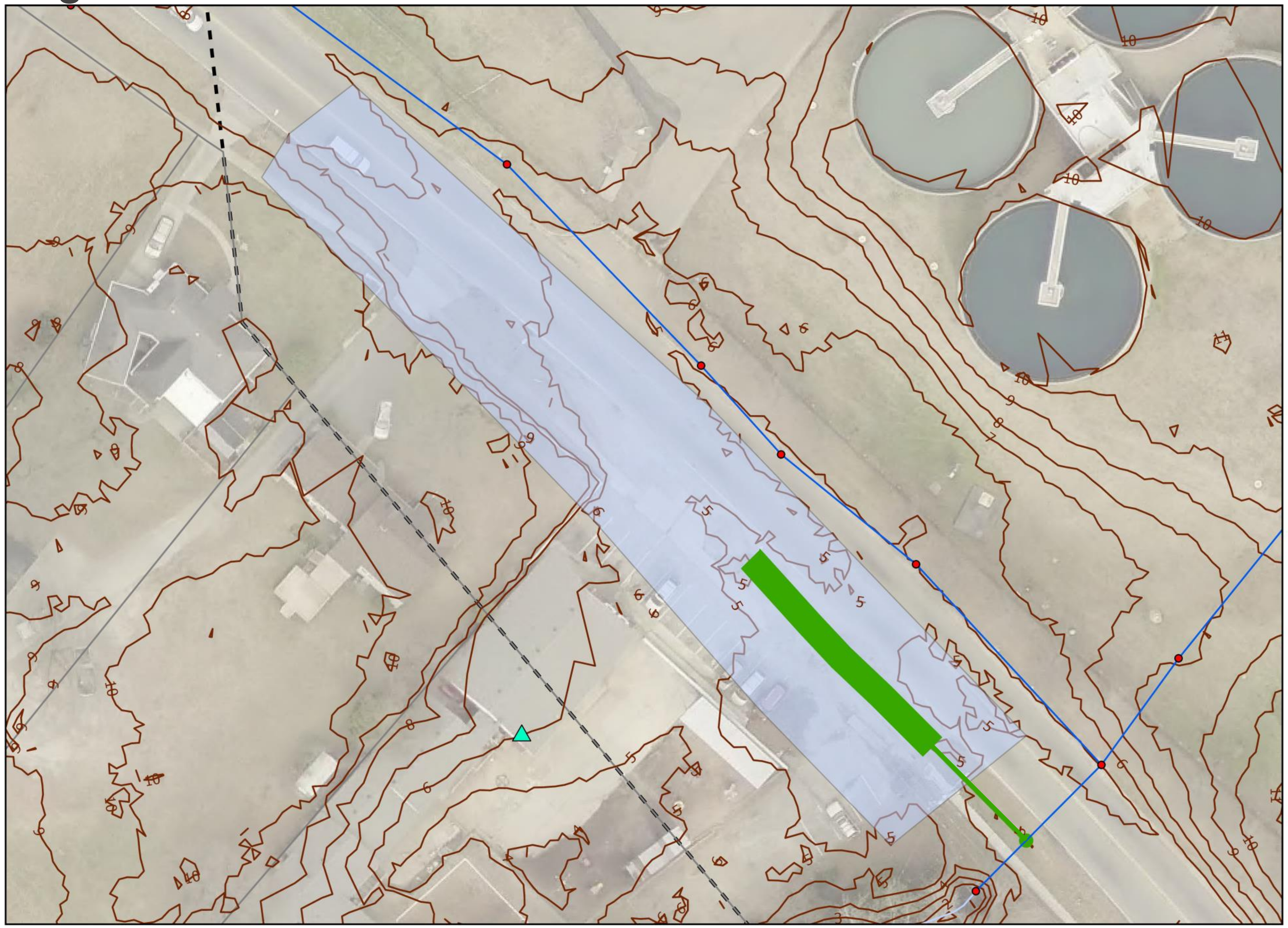
Conceptual Design – Not for Construction

Town and Country Day School

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

TCD – Town and Country Day School
Right-of-Way Pipe Detention

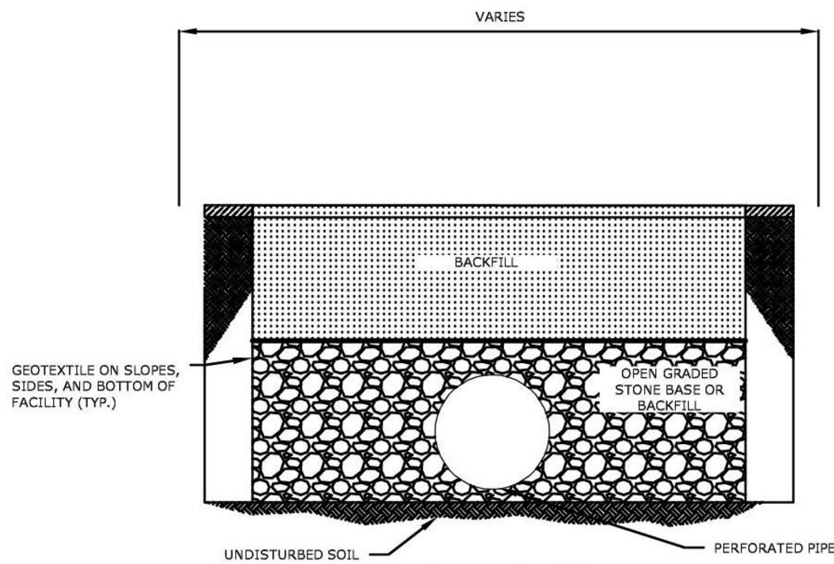
THE CITY OF NORFOLK Hazen

Sheet 3 of 5	03/22/19

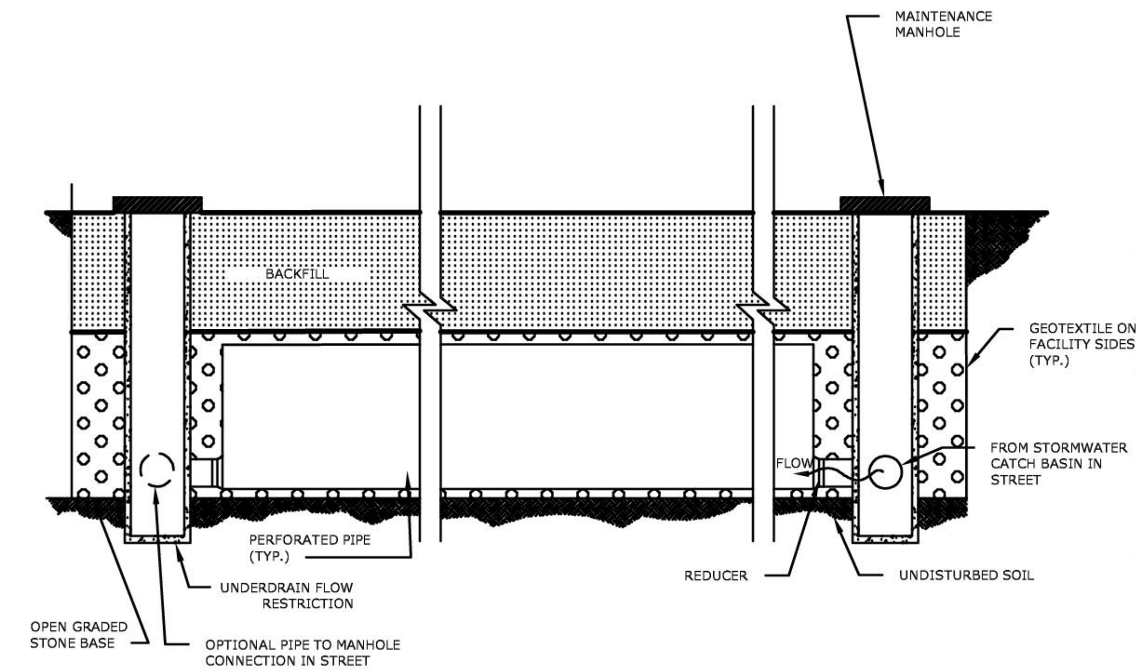
Conceptual Design – Not for Construction

Town and Country Day School

Pipe Detention Standard Details



PIPE DETENTION
(NOT TO SCALE)



PIPE DETENTION
(NOT TO SCALE)

TCD – Town and Country Day School
Right-of-Way Pipe Detention

THE CITY OF NORFOLK Hazen

Sheet 4 of 5 | 03/22/19

Conceptual Design – Not for Construction

Town and Country Day School
Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times A$
  - $\%_{impervious} = 80\%$
  - $WQ_{Depth} = (1.00\ in \times \left(.05 + \%_{impervious}(.9)\right) = 0.77 in$
  - $A = 21{,}344\ ft^2$
- $WQ_V = 1{,}370\ ft^3$

Estimate median stormwater chamber footprint

- $Footprint = 900 ft^2$

Calculate full water quality treatment volume

- $Vol_{treatment} = (Area \times D_{stone} - Vol_{chamber}) \times (Porosity_{stone}) + Vol_{chamber}$
  - $Area = 900 ft^2$
  - $D_{stone} = 4\ ft$
  - $Porosity_{stone} = 0.4$
  - $Vol_{chamber} = 283 ft^3$
- $Vol_{treatment} = 1{,}610\ ft^3$

Estimate annual pollutant load reduction

- $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
  - $A = .49\ ac$
  - $\%_{impervious} = 80\%$
  - $\%_{pervious} = 20\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**0.8 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**4.4 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**279 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

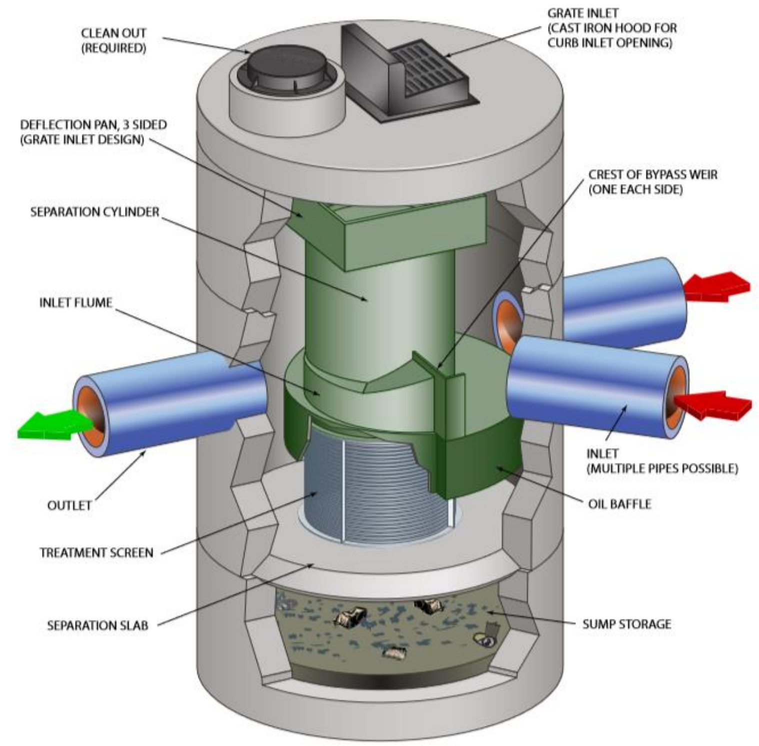
- $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	63%[2]	**0.5 lb/yr**
TN	57%[2]	**2.5 lb/yr**
TSS	70%[3]	**195 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Infiltration Practices, Design Specification No. 8, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

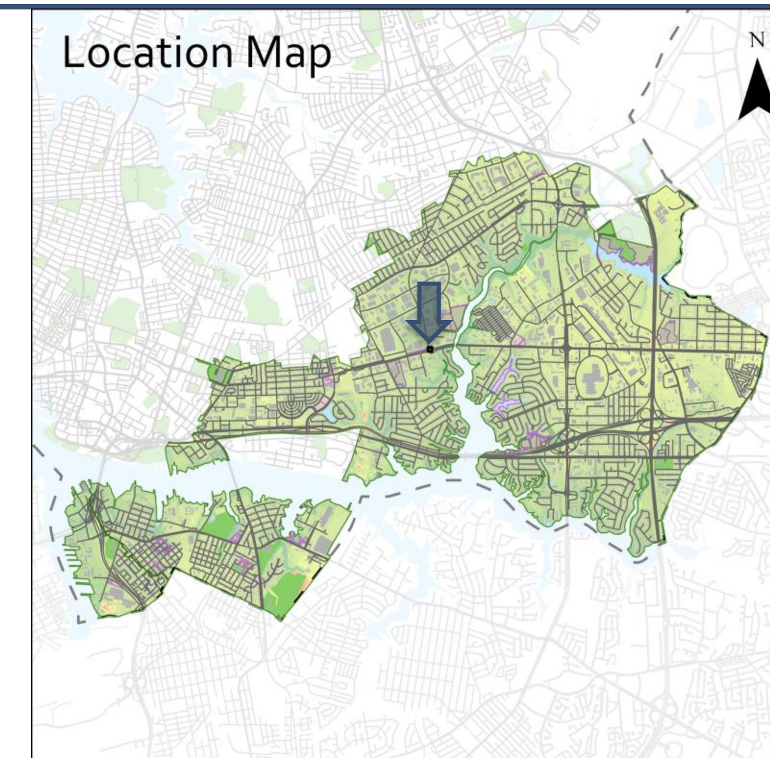
Calculations and footprints are based on Level 1 designs. Level 2 designs will have added benefits including increased pollutant load reductions; however, Level 2 designs may have slightly higher construction costs due to additional media depth or storage volume requirements. Note that Level 2 designs are contingent upon site specific factors including (but not limited to) soil infiltration rates, groundwater levels, and space constraints. Level 2 Reductions (TP: 93%, TN: 92%, TSS: 70%).

Virginia Beach Blvd. Right-of-Way
Concept Overview



Hydrodynamic Separator

*graphic from Contech Engineered Solutions LLC



VBB – Virginia Beach Blvd. Right-of-Way
Catch Basin & Hydrodynamic Separator

Existing Conditions

This right-of-way space is on the corner of Virginia Beach Blvd. and Azalea Garden Rd. The roadway is prone to frequent flooding and persistent ponding after intense rainfall. The existing grading of the roadway sheds water to the northeast corner of the intersection with no stormwater structure to capture the flow. Existing stormwater piping runs along the north side of Virginia Beach Blvd. with no inlet at this ponding location. The sheet flow directed towards the right-of-way space in front of the Fire Department is 0.37 acres with 80% impervious. The next page provides additional site photographs.

Proposed Improvement

The proposed catch basin will be on the northeast corner of the intersection in front of the Fire Department. The curb inlet will be sized during detailed design. The catch basin will convey flow to an in-line hydrodynamic separator for pretreatment and trash removal before reconnecting to the existing stormwater network with a manhole connection. The practice will have the potential to manage at least 1" of runoff from up to 0.37 acres of drainage in the area, providing stormwater storage capacity to relieve persistent flooding issues that occur on this Virginia Beach Blvd. intersection. Subsurface utility relocation or coordination may be required within the practice footprint location.

Type: Catch Basin & Hydrodynamic Separator
Address: 3777 E. Virginia Beach Blvd.
Area Managed: 0.37 acres

Conceptual Level Estimates:

Construction Cost: $38,000
TN Load Reduction: 0.0 lb/yr
TP Load Reduction: 0.1 lb/yr
TSS Load Reduction: 153 lb/yr

WQ Treatment Volume: 1,040 ft^3
Cost/Storage Volume: $37/$ft^3$
TN Reduction Cost: $0/lb/yr
TP Reduction Cost: $328,000/lb/yr
TSS Reduction Cost: $250/lb/yr

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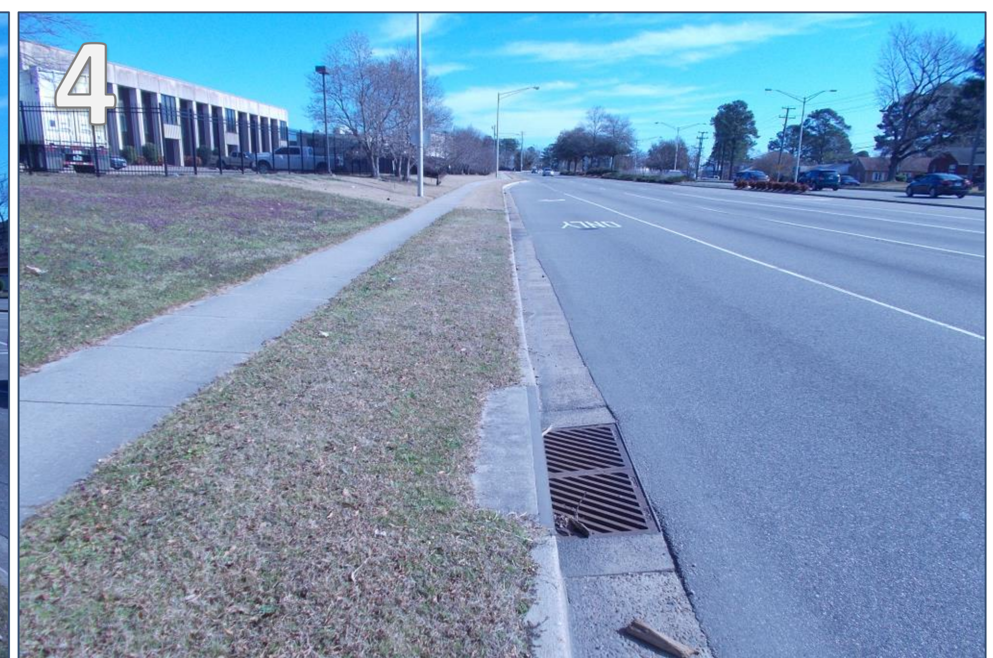
Conceptual Design – Not for Construction

Virginia Beach Blvd. Right-of-Way
Concept Overview

Facing SE at the west corner of site

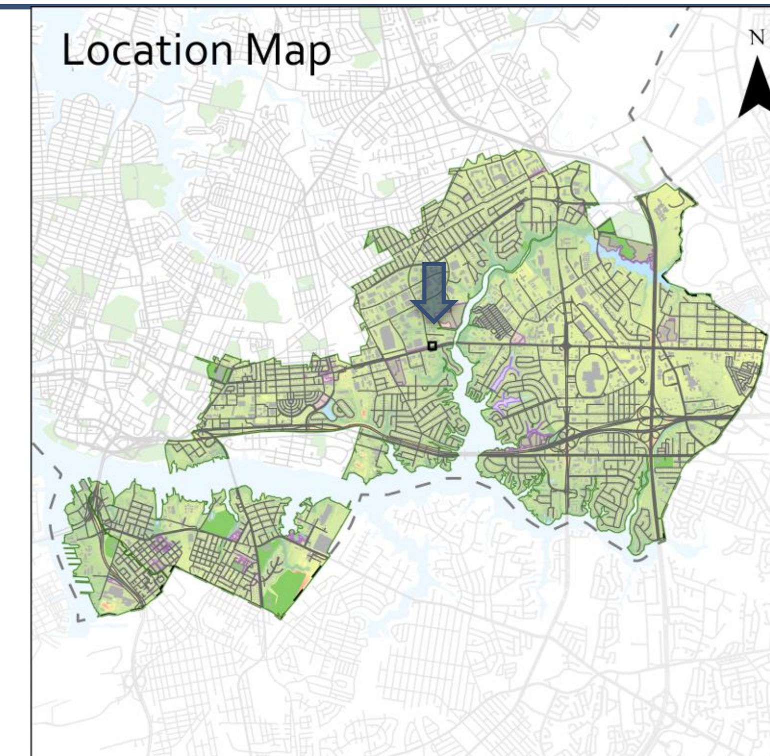
Facing west on north side of VB Blvd.

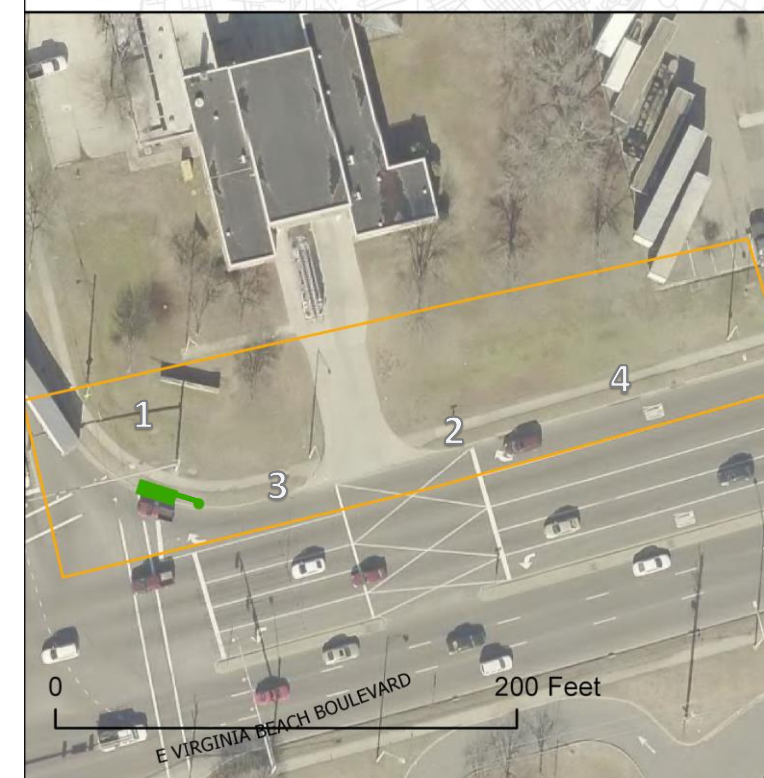
Facing east on north side of VB Blvd.



Existing catch basin on north side of VB Blvd.

See inset map on the right for photograph locations





VBB – Virginia Beach Blvd. Right-of-Way
Catch Basin & Hydrodynamic Separator

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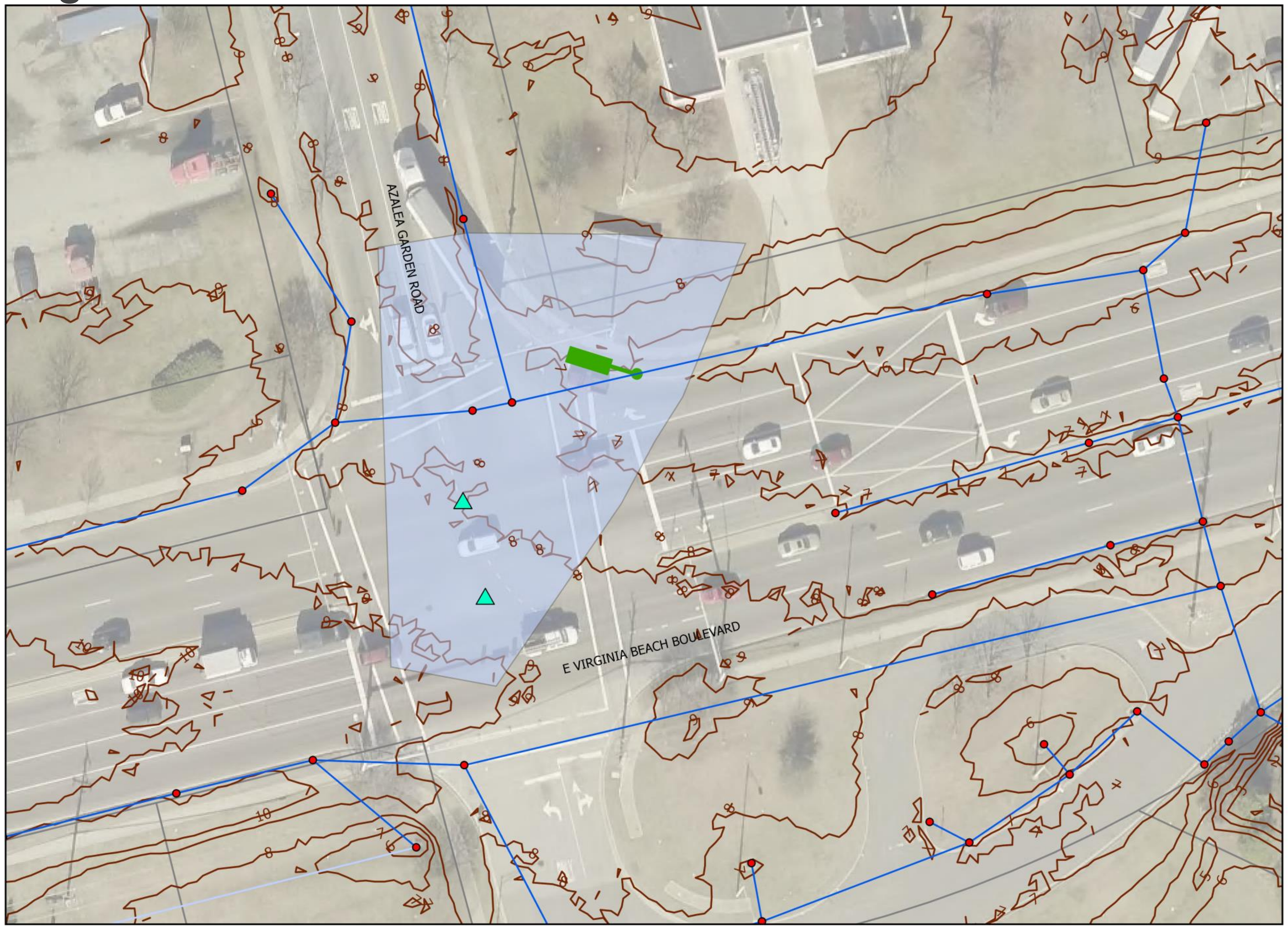
Conceptual Design – Not for Construction

Virginia Beach Blvd. Right-of-Way

Drainage Area Plan View



LEGEND
- EX STORM STRUCTURE
- EX STORM DITCH
- EX STORM PIPE
- EX PROPERTY LINE
- GENERAL WATERSHED BOUNDARY
- REPORTED FLOOD COMPLAINT
- DRAINAGE AREA
- PRACTICE SURFACE FOOTPRINT
- PRACTICE SUBSURFACE FOOTPRINT

Note: Landscaping, utility structures, signs, and existing storm drainage structure location approximated from aerial imagery. Exact locations must be field verified and surveyed during detailed design.

N

0 25 50 100 Feet

VBB – Virginia Beach Blvd. Right-of-Way
Catch Basin & Hydrodynamic Separator

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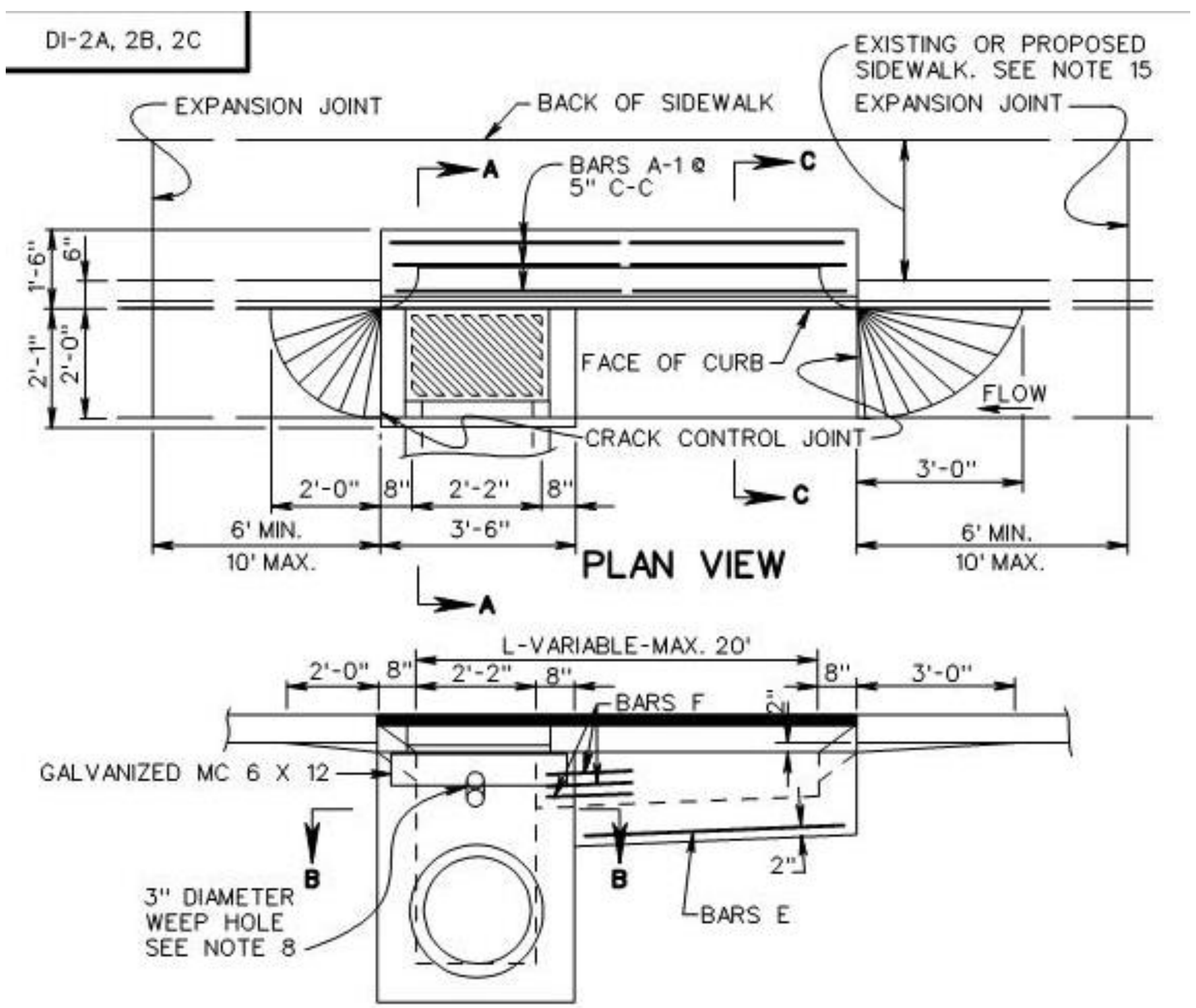
Sheet 3 of 5 | 03/22/19

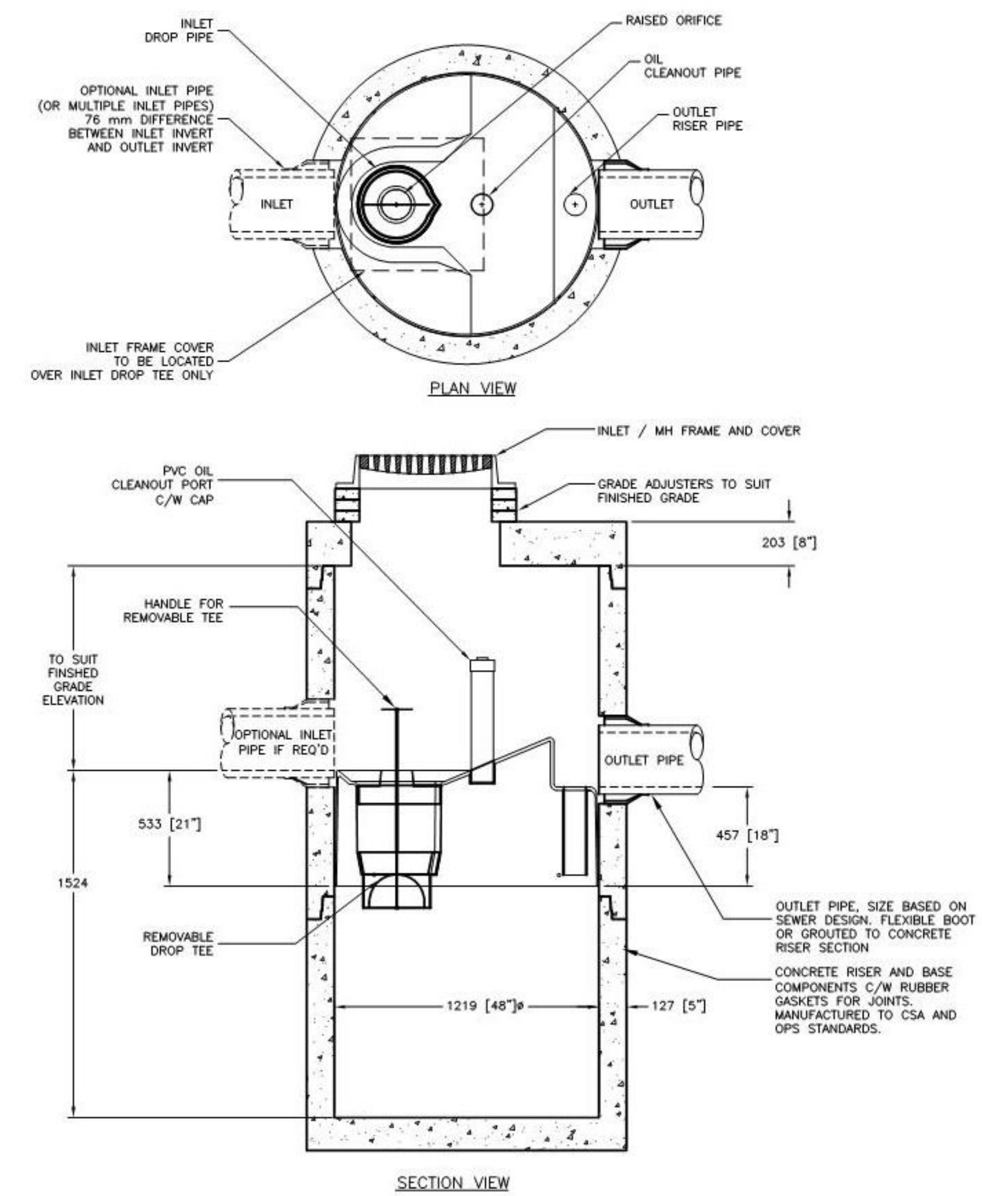
Conceptual Design – Not for Construction

Virginia Beach Blvd. Right-of-Way

Catch Basin and Hydrodynamic Separator Section



CATCH BASIN
(NOT TO SCALE)



HYDRODYNAMIC SEPARATOR
(NOT TO SCALE)

VBB – Virginia Beach Blvd. Right-of-Way Catch Basin & Hydrodynamic Separator	
THE CITY OF NORFOLK	Hazen
Sheet 4 of 5	03/22/19

Virginia Beach Blvd. Right-of-Way
Design Calculations

Calculate water quality volume

- $WQ_V = \frac{WQ_{Depth}}{12} \times Area_{impervious}$
  - $WQ_{Depth} = 1.00\ in$
  - $Area_{impervious} = 16{,}210\ ft^2$
- $WQ_V = 1{,}040\ ft^3$

Hydrodynamic Separator

- **Estimate treatment volume peak discharge**
  - $q_{pTv} = q_u \times A \times Q_a$
    - $A = 0.37ac$
    - $q_u = 1000\ (\frac{\frac{cfs}{mi^2}}{in})$
    - $Q_a = 0.77in$
  - $q_{pTv} = 0.45cfs*$

*treatment volume peak discharge, drainage area, and % impervious were given to manufacturer for sizing the structure

- **Estimate annual pollutant load reduction**
  - $Load_{annual} = (A \times \%_{impervious} \times Loading\ Rate_{imp}) + (A \times \%_{pervious} \times Loading\ Rate_{per})$
    - $A = .37\ ac$
    - $\%_{impervious} = 80\%$
    - $\%_{pervious} = 20\%$

Pollutant	$Loading\ Rate_{impervious}$	$Loading\ Rate_{pervious}$	$Load_{annual}$
TP	1.76 lbs/acre/yr[1]	0.5 lbs/acre/yr[1]	**0.6 lb/yr**
TN	9.39 lbs/acre/yr[1]	6.99 lbs/acre/yr[1]	**3.4 lb/yr**
TSS	676.94 lbs/acre/yr[1]	101.08 lbs/acre/yr[1]	**219 lb/yr**

[1] 2009 EOS Loading Rate (lbs/acre/yr) in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

  - $Load\ Reduction = Load_{annual} \times \%_{load\ removal}$

Pollutant	$\%_{load\ reduction}$	$Load\ Reduction$
TP	20%[2]	**0.1 lb/yr**
TN	0%	**0.0 lb/yr**
TSS	70%[3]	**153 lb/yr**

[2] Load Removal from Virginia DCR Stormwater Clearinghouse, Hydrodynamic Separator, Design Specification No. 16, Version 2.0 January 1, 2013
[3] BMP Characterization for Nutrient Curves and Retrofit Pollutant Removal Adjustor Curve for TSS in Chesapeake Bay TMDL Special Condition Guidance, May 18, 2015

VBB – Virginia Beach Blvd. Right-of-Way
Catch Basin & Hydrodynamic Separator

THE CITY OF NORFOLK Hazen

03/22/19

Conceptual Design – Not for Construction

Appendix D. Final Prioritization Spreadsheet

METRIC EVALUATION NOTES

#	Factor	Proposed Metric	Explanation	+ or - Scoring	Scoring Responsibility	Questions and Comments
	Flood Control:					
1	Proximity to Flooding Studies/Trunk Line Analysis	0, 1, or 2	0 = outside flooding area; 1 = marginally in or close to flooding area; 2 = in critical capacity, flood prone area	-	City of Norfolk	City will score based on distance to flooding studies/ trunk line analysis. Score reflects level of flooding within the DA.
2	Proximity to Known Flood Complaint	0, 1, or 2	0 = No recorded flooding, 1 = Near flood complaint, 2 = City recommended location	+	Hazen Calculated	This is similar to above but focuses on complaints (public concern) in the immediate vicinity of the practice.
3	Practice Storage Volume	WQ Storage Volume (cf)	Larger storage volume is top score	+	Hazen Calculated	Based on storage volume from concept design.
	Water Quality Benefits:					
4	TP Removed	Lbs/Year Removed	Greatest lb removal per pollutant is the top score	+	Hazen Calculated	Weighting for the different pollutants can be varied based on specific pollutants of concern, as appropriate.
5	TN Removed	Lbs/Year Removed		+		
6	TSS Removed	Lbs/Year Removed		+		
	Maintenance and Maintainability Based on City Experience:					
7		1 through 5	Routine Maintenance Frequency (times per year)	-	Hazen Populated	Based on DEQ recommended maintenance frequency.
	Estimated Cost					
8		Estimated Construction Cost ($)	Lowest cost is top score	-	Hazen Calculated	Can choose to use actual cost estimate, or categorize estimated cost. #1 < $500,000; $500,000 < #3 > $1M; #5 > $1M
	Public Perception					
9		1, 3, or 5	1 = No knowledge of neighborhood 3 = known, active and positive community members 5 = More than one active community champion, supporting flood control	+	City of Norfolk	Better public acceptance will receive a higher score.
	Known Existing Infrastructure Condition					
10		0,1,2	Qualitative assessemnt of known nearby infrastructure issues. 0 = no previous maintenance in area 1 = some maintenance in area 2 = frequent maintenance in area	+	City of Norfolk	This factor will act like a BONUS. Based on infrastructure failures or repairs within the

EASTERN BRANCH WATERSHED ASSESSMENT: Prioritization Tool

	Potential Flood Control			Water Quality Benefits			Maintenance	Cost	Public	Known Infrastructure Condition		
	Proximity to Flooding Studies/Trunk Line Analysis	Number of Complaints Nearby Complaints	Practice WQ Storage Volume	TN Removed	TP Removed	TSS Removed	Maintenance and Maintainability	Concept Level Construction Cost	Qualitative Evaluation of Known Public Interests	Does Nearby Infrastructure Need Improvement?		
Factor #	1	2	3	4	5	6	7	8	9	10		
Category Weights	36%			9%			25%	15%	5%	10%	100%	
Global Weights	5%	16%	15%	3%	3%	3%	25%	15%	5%	10%		
Units	0, 1, or 2	0, 1, or 2	cf	lbs/year	lbs/year	lbs/year	1 through 5	$	1, 3, or 5	0, 1, or 2		
Concept	**RAW SCORES**										**WEIGHTED TOTAL SCORE**	**FINAL RANKING**
011 - Poplar Hall Park	0	0	2,600	4.5	0.7	310	2	$151,000	3	0	-0.072320909	12
070 - Ballentine Blvd Near Virginia Beach Blvd	2	0	5,000	3.8	1.3	694	2	$231,000	3	2	-0.024566665	10
087 - Campostella Park	0	1	47,000	25.0	8.3	4,325	2	$760,000	3	0	0.03826687	7
0AA - Arlington Avenue	0	2	140	0.5	0.1	20	5	$23,000	0	0	-0.090732474	14
174R - Fairlawn Recreational Center	0	0	3,620	3.6	0.7	41	1	$282,000	3	2	0.066532918	5
EBA - E Berkley Ave	0	1	2,200	3.5	0.7	270	1	$353,000	3	0	0.041621678	6
EPA - E Princess Anne Rd	2	1	2,970	5.0	0.9	388	1	$214,000	0	2	0.074652395	4
MAJ - Majestic Ave	2	2	1,900	3.8	0.7	284	5	$179,000	0	0	-0.14535641	15
SA - Seay Ave	2	2	1,750	2.3	0.4	160	1	$35,000	1	2	0.172197686	3
TCD - Town and Country Day School	0	2	1,610	2.5	0.5	195	1	$115,000	5	2	0.256961448	1
VBB - Virginia Beach Blvd	2	1	1,040	0.0	0.1	153	1	$38,000	0	0	-0.021554175	9
069 - Industrial Park Azalea Little League	0	0	9,200	4.9	1.1	1,274	5	$163,000	0	0	-0.245849058	18
099 - Lake Taylor Schools	0	0	83,600	31.3	6.1	8,255	1	$2,043,000	1	1	-0.03235997	11
038 - Princess Anne Park	1	1	850	1.5	0.2	117	5	$155,000	3	2	-0.073534331	13
104 - Corner Lot at E Virginia Beach Blvd	2	1	840	1.4	0.2	119	5	$69,000	0	0	-0.222311727	16
073 - Ballentine Blvd at NSU Entrance	0	0	2,600	5.6	0.7	3	5	$216,000	0	0	-0.257153769	19
136 - Berkley Park	0	0	2,060	1.3	0.3	233	1	$410,000	3	1	0.003704926	8
142 - Diggs Town Recreation Center	1	0	2,300	6.1	0.5	285	5	$582,000	3	1	-0.228337586	17
045 - Park Ave	2	0	1,600	2.0	0.3	164	5	$294,000	0	0	-0.317498834	20
ML - Meadow Lake	1	2	490,000	0.0	0.0	0	4	$150,000	5	2	0.223986784	2

Key

<-- Update these cells to reflect the City of Norfolk's weighting

Concept	WEIGHTED TOTAL SCORE	Rank
TCD - Town and Country Day School	0.256961448	1
ML - Meadow Lake	0.223986784	2
SA - Seay Ave	0.172197686	3
EPA - E Princess Anne Rd	0.074652395	4
174R - Fairlawn Recreational Center	0.066532918	5
EBA - E Berkley Ave	0.041621678	6
087 - Campostella Park	0.03826687	7
136 - Berkley Park	0.003704926	8
VBB - Virginia Beach Blvd	-0.021554175	9
070 - Ballentine Blvd Near Virginia Beach Blvd	-0.024566665	10
099 - Lake Taylor Schools	-0.03235997	11
011 - Poplar Hall Park	-0.072320909	12
038 - Princess Anne Park	-0.073534331	13
0AA - Arlington Avenue	-0.090732474	14
MAJ - Majestic Ave	-0.14535641	15
104 - Corner Lot at E Virginia Beach Blvd	-0.222311727	16
142 - Diggs Town Recreation Center	-0.228337586	17
069 - Industrial Park Azalea Little League	-0.245849058	18
073 - Ballentine Blvd at NSU Entrance	-0.257153769	19
045 - Park Ave	-0.317498834	20