STORM WATER MASTER PLAN FOR THE GREAT DISMAL SWAMP WATERSHED

FINAL REPORT
OCTOBER 2008

CITY of SUFFOLK, VIRGINIA

CLARK • NEXSEN
Architecture & Engineering

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EXECUTIVE SUMMARY

To assist the City of Suffolk in making stormwater decisions to accommodate future development, Clark Nexsen performed a study of the three major watersheds in Suffolk. These watersheds include the James River Basin, the Chowan River/Blackwater River Basin and the Great Dismal Swamp Basin. The watershed studies were performed in two phases. The James River Watershed with an approximate drainage area of 96 square miles was studied under Phase I and submitted to the City in November 2005. The Chowan River / Blackwater River (148 square miles) and the Great Dismal Swamp (72 square miles) Watersheds with an approximate combined drainage area of 220 square miles, have been studied under Phase II. The Chowan River / Blackwater River Watershed Study was submitted to the City in July 2007. The Great Dismal Swamp Watershed study is presented in this report.

The purpose of these studies is to develop a stormwater master planning model to assess existing conditions and the impacts future development will have on these stormwater systems based on the projected 2026 land use condition described in Suffolk's Comprehensive Plan.

The studies require the hydrologic and hydraulic analysis of the existing major drainage systems within the regional watersheds. To facilitate the analysis of a complex stormwater network, Expert System's XP-SWMM (version 10.50) software was used to analyze the model. XP-SWMM is a proprietary software based on the USEPA Stormwater and Wastewaster Management Model (SWMM) computer program. The model represents the primary stormwater conveyances within the watershed to describe and integrate the relationship of the various land uses and hydraulic controls throughout the watershed. The model will be used to create the stormwater master plan from which the existing conditions and proposed future impacts will be evaluated to assist the City of Suffolk in day-to-day development decisions related to stormwater management concerns. The model was developed using the City's comprehensive GIS mapping and field data to define existing conditions and the 2026 Comprehensive Plan to consider future impacts.

The stormwater network was analyzed for the 2-yr, 10-yr, 25-yr and 100-yr 24-hour, Type II rainfall events. The various storm events were evaluated for the following:

- Identify areas prone to flooding for 10-year storm.
- Evaluate culverts for the 10-year and 25-year storms.
- Evaluate bridges and spillways for the 100-year storm.
- Compare existing channel velocities with future development channel velocities based on the 2026 Comprehensive Plan for the 2-year storm.

From the analysis, deficiencies in the stormwater network for the existing condition and 2026 future land use condition were determined and recommendations with conceptual construction cost estimates provided to mitigate the problems.

The model also identified areas that should receive detailed analysis to determine if flood control improvements are warranted. Due to the lack of detailed survey data and the master plan assumptions used, the model should not be used for design applications. Additional data and survey, particularly for roadway culverts, is needed before this model can be used for making specific design decisions and should only be used as a tool preparing the groundwork for more detailed studies and design.

The model indicates that several of the roads within the watershed flood for the 10-yr design storm at culvert crossings. The model results confirm field observations where it appeared that many of the roadway elevations are depressed at culvert crossings allowing flood waters to overtop the road at these localized areas. At this time, only flooded culverts along the Primary Arterial and Minor Arterial roads are recommended for improvements, with the exception of nodes NDS5 (Greenway Rd) and NPOS23 (Hosier Rd) which were added to the list of improvements at the City's request. Table No. ES-1 below summarizes the recommended improvements for the deficiencies discussed under Section 3.0 (Existing Condition Model Results) and Section 4.0 (Future Condition (2026) Model Results) and associated costs for the respective conditions. Most of the improvements recommended were from inadequate culverts that overtopped or had the potential to overtop the roadway for the respective 24-hour, Type II rainfall event. The costs listed show the estimated value of improvements based on the existing condition and the future condition (2026) land uses. For those improvements where only one cost is listed, there were no additional improvements required to address the future condition (2026) land uses. All of the costs shown are based on 2007 dollars and would be greater in the future due to construction cost escalation.

Table No. ES-1 Summary of Erosion and Flood Control Recommendations

Location	Recommendation	Cost
Whaleyville Blvd., 0.47 miles south of intersection with Greenway Rd. (NCOS10)	EXISTING - ADD A 30" RCP TO THE EXISTING 24" RCP. *2026 - ADD AN ADDITIONAL 30" RCP.*	$76,888 $98,049 (2026)
Whaleyville Blvd., 0.25 miles south of intersection with Liberty Spring Rd. (NCOS14)	EXISTING AND 2026 - ADD A 24" RCP TO THE EXISTING 24" RCP.	$62,160 (2026)
Cypress Chapel Rd., 0.11 miles east of intersection with Whaleyville Blvd. (NCOS17)	EXISTING AND 2026 - ADD (2) 24" RCP TO THE EXISTING 24" RCP.	$76,405
Copeland Rd., 0.25 miles west of intersection with Whaleyville Blvd (NCYS12)	EXISTING AND 2026 - REPLACE EXISTING 36" CMP WITH (3) 5'X3' BOX CULVERTS.	$333,588

Table No. ES-1 Summary of Erosion and Flood Control Recommendations		
Location	**Recommendation**	**Cost**
Cypress Chapel Rd., 0.48 miles west of intersection with Carolina Rd. (NCYS29)	EXISTING AND 2026 - REPLACE EXISTING 36" CMP WITH (3) 5'X3' BOX CULVERTS.	$322,652
Carolina Rd., 0.55 miles north of intersection with Copeland Rd. (NCYS44)	EXISTING AND 2026 - ADD (2) 30" RCP TO THE EXISTING (3) 18" RCP.	$97,853
Copeland Rd., 0.10 miles west of intersection with Carolina Rd. (NCYS46)	EXISTING AND 2026 – REPLACE THE EXISTING 12" RCP WITH (2) 24" RCP.	$76,776
Copeland Rd., 0.12 miles west of intersection with Manning Rd. (NCYS48)	EXISTING AND 2026 - ADD (2) 24" RCP TO THE EXISTING 15" CMP.	$76,643
Copeland Rd., 0.11 miles west of intersection with Manning Rd. (NCYS49)	EXISTING - ADD (2) 24" RCP TO THE EXISTING 15" CMP *2026 - ADD AN ADDITIONAL 24" RCP.*	$78,778 $94,633 (2026)
Copeland Rd., 0.34 miles east of intersection with Manning Rd. (NCYS50)	EXISTING AND 2026 - ADD (2) 30" RCP TO THE EXISTING 30" CMP.	$84,546
Copeland Rd., 0.60 miles east of intersection with Jackson Rd. (NCYS8)	EXISTING AND 2026 - ADD (2) 30" RCP TO THE EXISTING 30" CMP	$84,651
Copeland Rd., 0.67 miles east of intersection with Jackson Rd. (NCYS9)	EXISTING - ADD (3) 36" RCP TO THE EXISTING 30" CMP. *2026 – ADD AN ADDITIONAL 36" RCP.*	$236,772 $292,174 (2026)

Table No. ES-1 Summary of Erosion and Flood Control Recommendations

Location	Recommendation	Cost
Greenway Rd., near the intersection with Wedgewood Rd. (NDS5)	EXISTING AND 2026 - REPLACE EXISTING 36" RCP WITH (3) 5'X3' BOX CULVERTS.	$339,324
Cypress Chapel Rd., 0.18 miles east of intersection with Greenway Rd. (NDS13)	EXISTING - ADD A 24" RCP TO THE EXISTING 24" RCP. *2026 – ADD AN ADDITIONAL 24" RCP. (NOTE EXISTING PIPE ASSUMED)*	$69,237 $78,491 (2026)
Cypress Chapel Rd., 0.10 miles west of intersection with Greenway Rd. (NDS17)	EXISTING - ADD (2) 24" RCP TO THE EXISTING 15" CPP. *2026 - ADD AN ADDITIONAL 24" RCP.*	$78,071 $88,326 (2026)
Cypress Chapel Rd., 0.57 miles east of intersection with Greenway Rd. (NDS19)	EXISTING - ADD A 18" RCP TO THE EXISTING 18" RCP	$65,443
Carolina Rd., 0.22 miles south of intersection with Roundtree Cres. (NMOS5)	EXISTING - ADD A 24" RCP TO THE EXISTING 18" RCP. *2026 - ADD AN ADDITIONAL 24" RCP.*	$72,765 $84,511 (2026)
Hosier Rd., near the intersection with Badger Rd. (NPOS23)	EXISTING AND 2026 - REPLACE EXISTING TWIN 48" RCP WITH (3) 5'X3' BOX CULVERTS.	$339,324

Large scale maps of the XP-SWMM model (GIS-01), flooding deficiencies (GIS-02), and recommended improvements (GIS-03) are located after the appendices.

In addition to the recommendations provided in Table No. ES-1, the following recommendations for supplemental analysis and study are provided:

- Detailed channel stability analysis. Because the stormwater master plan model does not focus on variations in channel geometry, roughness, and unique site conditions throughout the channel reach, specific improvement priorities cannot be immediately obtained from the model. At a minimum, outfall channels associated with deficient pipes should be studied in detail. It is assumed that some channel improvement will be necessary where culvert improvements are proposed.

- Impacts of regional best management practices (BMPs). Due to the limitations associated with making decisions on channel stability, the use of regional BMPs was not addressed in detail. A detailed evaluation in concert with the channel stability analysis should be performed for deficient pipes identified in the study recommendations.

- Discussions with the City Public Works Operations revealed that there are several areas throughout the City where localized flooding is caused by beaver activity, which can block culverts and back up stream flow. The dams can be located directly at the culvert or several hundred feet downstream in marshes. The City currently sends crews to remove the dams once they are detected visually or due to an unusual increase in water level. The model does not account for beaver dams in the analysis of the culverts. Mitigation of beaver related flooding is considered a maintenance item.

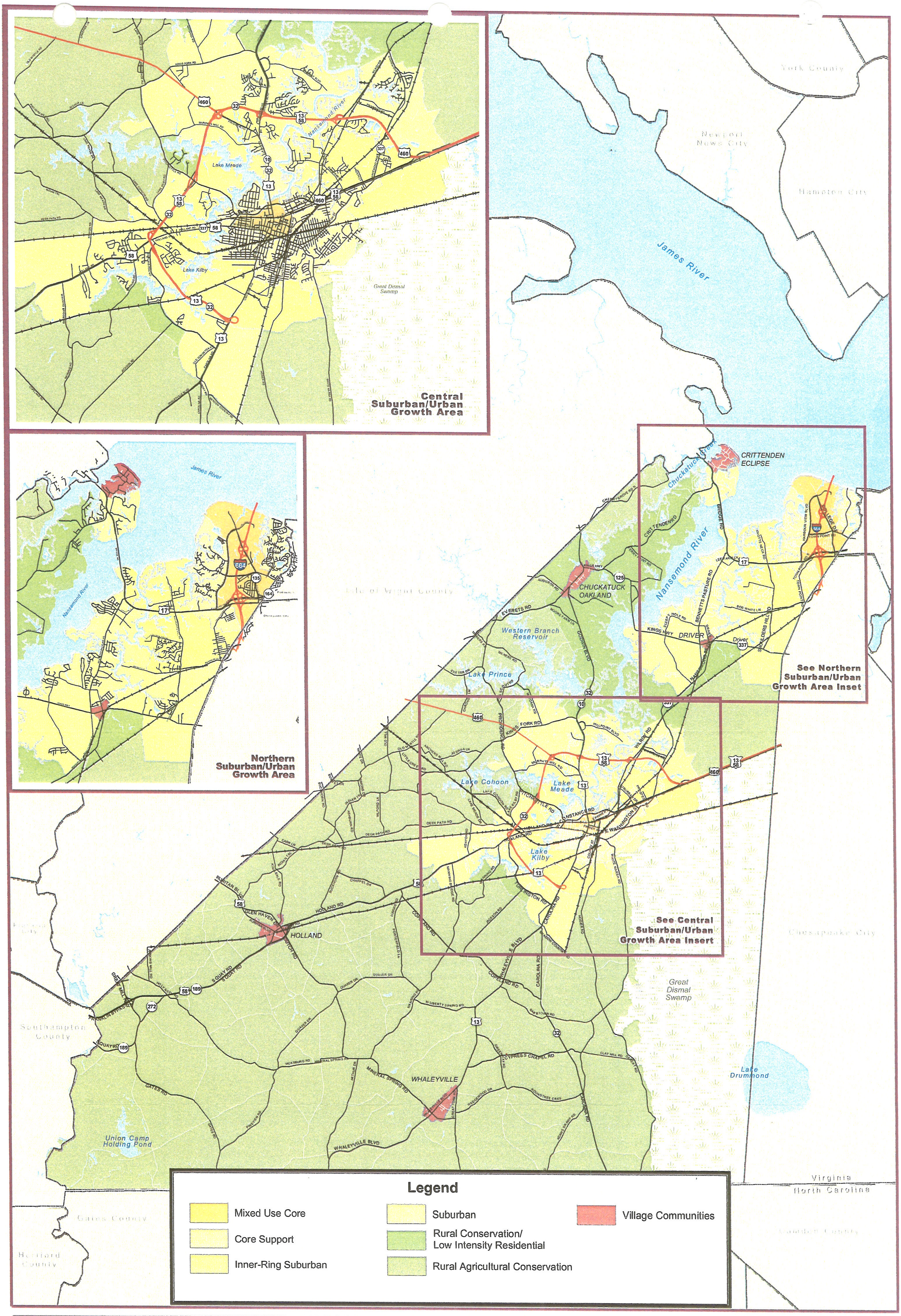
1.0 INTRODUCTION

1.1 City of Suffolk Overview

The City of Suffolk is located in southeastern Virginia and is bordered by Isle of Wight County and Southampton County to the west, the State of North Carolina to the south, the cities of Chesapeake and Portsmouth to the east, and the Lower James and Nansemond Rivers to the north. The city has a land area of approximately 430 square miles, which includes a portion of the Great Dismal Swamp.

The annual precipitation in Suffolk is approximately 50 inches per year. There are variations in the monthly rainfall averages; however, rainfall is generally distributed throughout the year. Snowfall is infrequent and typically melts in a short period of time. Elevations in the city range from sea level to approximately 85 feet.

The City of Suffolk is currently undergoing a period of growth and development. To manage the City's future growth the 2026 Comprehensive Plan was adopted by the City in March 2006. The 2026 Comprehensive Plan established long term (20-yr) development strategies, goals, and policies. A map of the future landuse for the 2026 Comprehensive Plan is provided in Figure 1-1.



City of Suffolk, Virginia

2026 Comprehensive Plan

Focused Growth Areas

0 3
Miles

Figure 1-1
Source: Comprehensive Plan for 2026
City of Suffolk, Virginia

The objectives of the 2026 Comprehensive Plan include, but are not limited to, the following:

- To define and delineate two areas of compact, high-quality urban and suburban development: one around the central city and one in the northeast.
- To allow and promote some low-density, high-quality, large-lot residential development between these two compact areas and in the northwest.
- To preserve the southern half of Suffolk as a rural, agricultural area.
- To make special efforts to protect the watersheds which provide drinking water for Suffolk, Portsmouth, Norfolk, Chesapeake, and Virginia Beach.
- To identify roadway classifications and indicate where major roadway improvements are to be implemented.

To comply with national, state, and local environmental regulations governing water quality, the future development in the 2026 Comprehensive Plan must be implemented in accordance with a variety of existing environmental regulations related to the management of stormwater runoff.

1.2 PROJECT OBJECTIVES

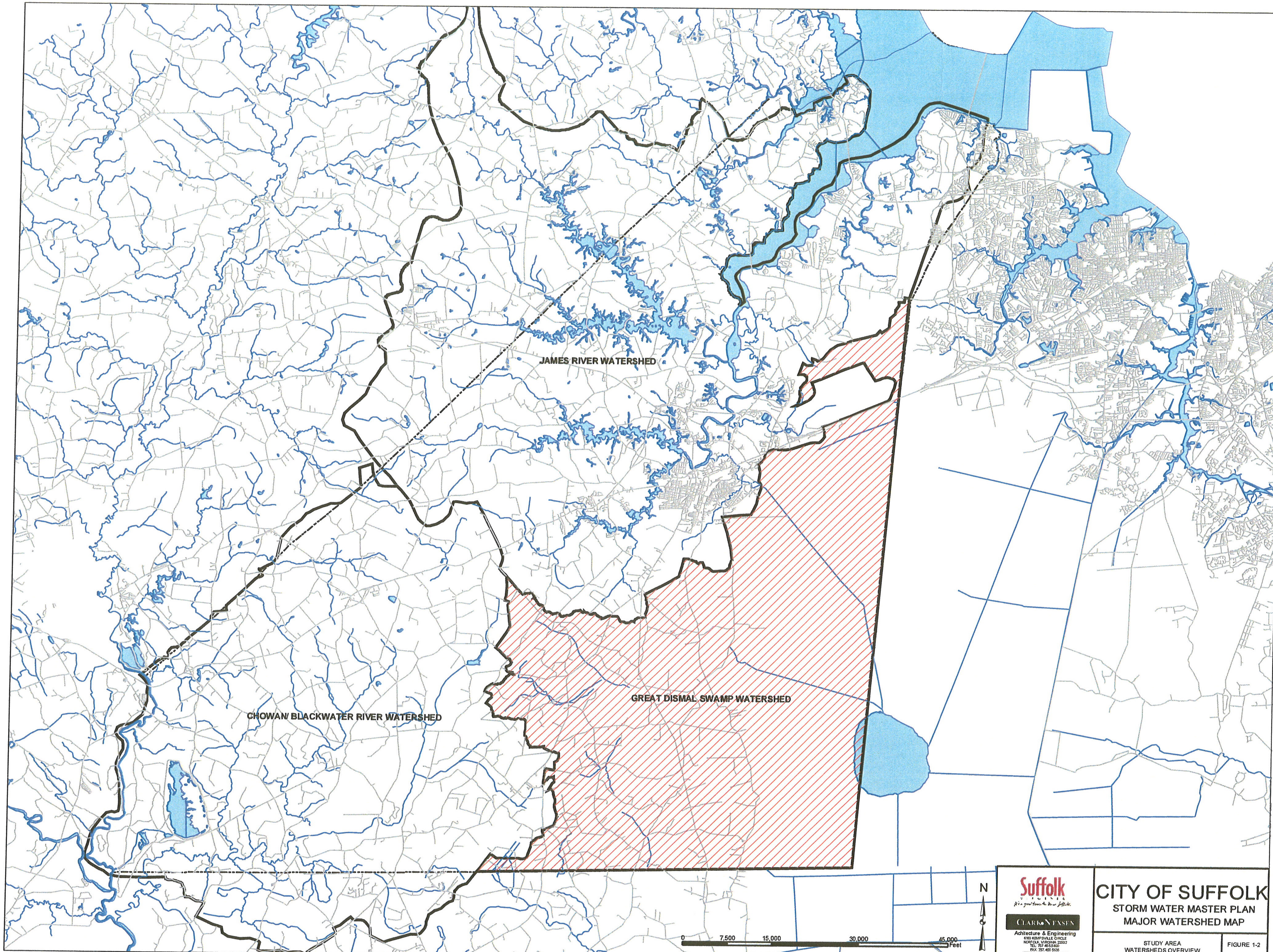
Clark Nexsen performed a study of the three regional watersheds in Suffolk. The watersheds studied include the James River Watershed, Chowan River / Blackwater River Watershed and the Great Dismal Swamp Watershed. The James River Watershed, with an approximate drainage area of 96 sq. mi., was studied under Phase I and submitted to the City in November 2005. The Chowan River / Blackwater River (148 square miles) and the Great Dismal Swamp (72 square miles) Watersheds with an approximate combined drainage area of 220 sq. mi., was studied under Phase II. The watershed studies involve the hydrologic and hydraulic analysis of the existing major drainage systems. A map of the major watersheds within the city is presented in Figure 1-2.

The analysis of the Phase II Study Area for the Great Dismal Swamp Watershed, consisting of approximately 72 square miles, is presented in this report. The study area is located in the southeastern portion of the City. The primary outfall for this watershed is the Great Dismal Swamp to the east.

The hydraulic grade lines within the major conveyances were computed for the existing and future land uses based on current GIS mapping, field observations and the 2026 Comprehensive Land Use Plan to determine the following:

- Identify areas prone to flooding for 10-year storm.
- Evaluate culverts for the 10-year and 25-year storms.
- Evaluate bridges and spillways for the 100-year storm.
- Compare existing channel velocities with future development channel velocities based on the 2026 Comprehensive Plan for the 2-year storm.

Once the flood prone areas were determined, stormwater strategies and associated cost estimates were developed to address the deficiencies.



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CITY OF SUFFOLK
STORM WATER MASTER PLAN
MAJOR WATERSHED MAP

STUDY AREA
WATERSHEDS OVERVIEW

FIGURE 1-2

1.3 REPORT ORGANIZATION

The report is organized as follows:

- Section 1 "Introduction," provides a brief overview of the project objectives and of the report contents.
- Section 2 "Stormwater Modeling Approach" describes methods and assumptions used to develop the XP-SWMM model analysis of the primary drainage system.
- Section 3 "Existing Conditions" summarizes the results of the existing condition XP-SWMM model and the field reconnaissance. Evaluations of areas indicated by the model to be prone to repetitive flooding are provided along with recommendations and cost estimates for potential flood control improvements.
- Section 4 "Future Conditions" summarizes the results of the future condition XP-SWMM model based on the 2026 Comprehensive Plan land use. Evaluations of areas indicated by the model to be prone to repetitive flooding are provided along with recommendations and cost estimates for potential flood control improvements.
- Section 5 "Conclusions and Recommendations" summarizes the report conclusions, recommendations and cost estimates.

2.0 STORMWATER MODELING APPROACH

2.1 HYDROLOGIC/HYDRAULIC MODELING ANALYSIS

A computer model using XP-SWMM was developed to represent the primary stormwater conveyances within the project study area. The model will assist in accomplishing the following objectives:

- Identify areas prone to flooding for 10-year storm.
- Evaluate culverts for the 10-year and 25-year storms.
- Evaluate bridges and spillways for the 100-year storm.
- Compare existing channel velocities with future development channel velocities based on the 2026 Comprehensive Plan for the 2-year storm.
- Evaluate the impact of future development and future projected development.
- Evaluate other stormwater-related issues as determined by the City.

2.2 SOFTWARE

The computer model utilized as the primary tool for modeling the existing and future (2026) land use condition watershed was XP-SWMM version 10.50. The XP-SWMM model was used for both the hydrologic and hydraulic analyses. XP-SWMM generates runoff hydrographs at specific locations within the system based on specified storm events. The model simulates surface runoff within each sub-area and the subsequent routing through the various drainage system components including pipes, channels and reservoirs. Runoff and routing are simulated based on specific input parameters for each component process. Technical information on model formulation and capabilities is available on-line at **www.xpsoftware.com**.

XP-SWMM is a "link-node" model that mathematically represents a drainage system as a series of links and nodes. A "link" represents a hydraulic element for flow transport, such as a pipe, channel, weir, orifice or flow control device. A "node" represents the junction of hydraulic elements (links), as well as a location for input of flow into the drainage system. A node can also represent a storage device such as a lake or pond, or a point junction where link properties change (such as a change in channel slope).

2.3 WATERSHED BOUNDARY DELINEATION

The Great Dismal Swamp Watershed Study Area encompasses approximately 72 square miles consisting of the south eastern portion of Suffolk The majority of the watershed drains southeast through Suffolk toward the Great Dismal Swamp. Agriculture is the predominant land use within the watershed. Other land use activities include residential homes and developments, light commercial and industrial, and conservation areas. The drainage (or sub-catchment) area boundaries within the city for the study area were delineated for primary channels and major streams as shown in Figure GIS-01 at the back of the report.

To construct the model and the associated GIS (ARCInfo 9.1) coverages, various information including current USGS quadrangle maps and City of Suffolk GIS mapping were obtained.

Using the topographic map data, the likely locations (road and rail crossings) of drainage structures (pipe culverts, box culverts, and bridges) serving the primary stormwater conveyances in the delineated watershed boundaries were identified. Clark Nexsen performed field reconnaissance to evaluate and inventory drainage structures to be modeled. Additionally, structure data including material type, shape and dimensions, and photographs were obtained to document existing structures and channel conditions. Several ponding locations (mostly private "farm ponds") were identified on the topographic mapping. Many of these ponds are located on private property or were inaccessible and were not included in the field reconnaissance. Where pond outlet structure data was unavailable, a 4' x 4' box riser was assumed with a crest elevation set at the existing water surface elevation as depicted in the GIS mapping.

As-built survey data (structure inverts and associated roadway elevations) from the Virginia Department of Transportation (VDOT) was generally unavailable for the drainage structures identified in model. Assumptions were made to describe pipe inverts based on field data and GIS mapping. Surveyed channel cross-sections were unavailable. To develop channel sections for the model, Autodesk Civil 3D software was used to cut cross sections from the existing GIS contour surface.

Due to the lack of detailed survey data for hydraulic structures, roadway elevations, and channel cross sections, the results from modeling is approximate and should be refined as more data becomes available.

2.4 NODE NAMING CONVENTION

The naming convention used in the model is consistent with the naming convention outlined in the *Stormwater Master Plan for James River Watershed, Draft Report November 2005*. The naming convention used for identifying catchments was based on link nodes and storage nodes in the hydraulic model. Sub-catchments that discharge to link nodes are designated with the prefix "N" followed by the sub catchment identifier and the link node number (e.g. NCYS6 = inflow from sub catchments to catchment "6" discharging to the Cypress Creek sub watershed). Table 2-1 below summarizes the watershed naming conventions used in the model.

Table 2-1 Summary of Watershed Naming Conventions

Watershed	**Sub-Catchment Identifier**	**Watershed**	**Sub-Catchment Identifier**
Adams Swamp	AS	Moss Swamp	MS
Council Swamp	COS	Pine Swamp	PS
Cypress Swamp	CYS	Pocosin Swamp	POS
Dragon Swamp	DS		

2.5 RAINFALL-RUNOFF MODELING

The RUNOFF module of XP-SWMM was used to generate the runoff from each subcatchment. A 30-minute time step was used for the runoff computations. The 30-minute time step was selected since the rainfall distribution is given in 30-minute segments. Runoff is computed from sub-catchments by describing the drainage areas as idealized rectangular areas with the slope of the subcatchment perpendicular to the width.

If overland flow is visualized as running down-slope off an idealized rectangular catchment, then the width of the subcatchment is the physical width of overland flow. Since real subcatchments will not be rectangular with properties of symmetry and uniformity other procedures are required to approximate the idealized rectangular catchment. The width parameters for catchments with drainage channels off-center, was determined by computing a skew factor:

$$Sk = (A2 - A1) / A$$

$$W = (2 - Sk) * L$$

where

Sk	=	skew factor
A1	=	area to one side of the channel
A2	=	area to other side of the channel
A	=	total area
W	=	subcatchment width
L	=	length of main drainage channel

The width parameter dictates the runoff response time of a sub-catchment and has a significant impact on the size and shape of the hydrograph. A narrower width produces a longer response time, and a wider width produces a shorter runoff response time.

To determine the slope parameter within each sub-area, three measurements were taken at representative locations within each catchment. These measurements were averaged to determine the overall slope for the sub-catchment.

Impervious surface area estimates for existing land use conditions were developed based on field observation and GIS mapping. Each identified land use category was assigned an impervious surface percentage based on information provided in Suffolk's Unified Development Ordinance (UDO). The normal water surface areas of permanent water bodies were modeled as impervious surfaces. From this information, area-weighted averages of impervious surface area were determined for each subcatchment and were used as the approximate baseline percent imperviousness.

For the projected (2026) land use conditions, future zoning mapping for the 2026 Comprehensive Plan was obtained from the Suffolk Department of Planning. The future sub-catchment zoning coverages were assigned impervious surface ratios based on the Suffolk UDO to create area-weighted estimates of projected impervious surface area. The majority of the Study Area is located in the A (Agricultural District) Zone. In order to model the projected 2026 land use conditions a minimum 16% impervious coverage, based on the Suffolk UDO, was used.

2.6 SOILS INFORMATION

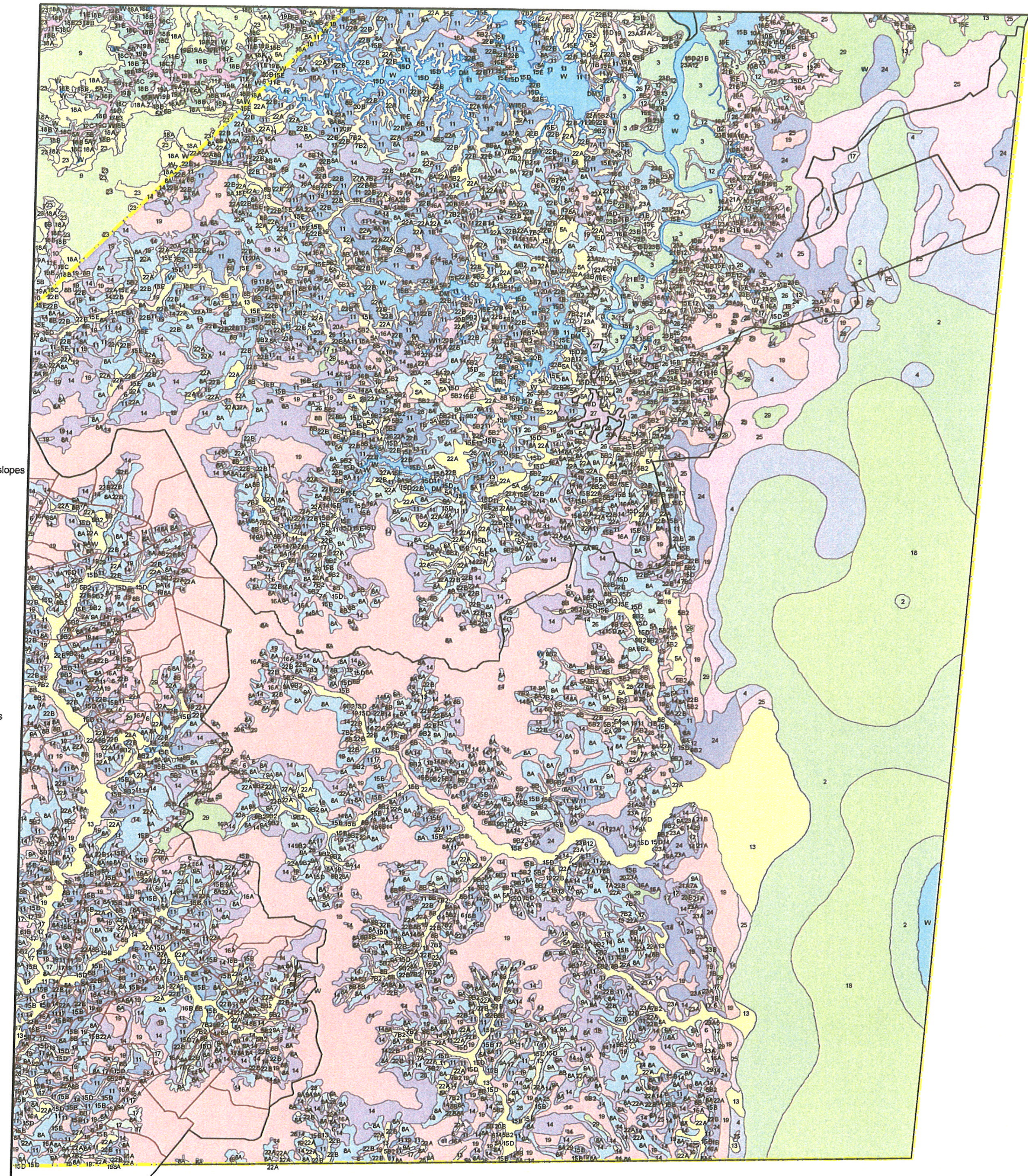
The Soil Survey for the City of Suffolk, published by the United States Department of Agriculture Soil Conservation Service in cooperation with Virginia Polytechnic Institute and State University, provided soil parameters such as hydraulic conductivity, permeability, and initial moisture deficit required for analysis using the Green-Ampt infiltration methodology in XP-SWMM. Additionally, digital soil coverage depicting soil types were obtained from the National Soil Survey Geographic (SSURGO) Database located on-line at **http://www.ftw.nrcs.usda.gov/ssur_data.html**. The SSURGO data, shown in Figure 2-2, was used to develop area-weighted soil parameters for the model. Green-Ampt infiltration parameters were assigned to each soil type. Those soil types were grouped into more generalized parameters to provide a master plan consideration of soil impacts and reduce the time spent developing soil parameters for use in the watershed model.

Legend

- "1" Alaga fine sand
- "10" Nawney loam
- "10A" Kalmia fine sandy loam, wet substratum, 0 - 2 % slopes
- "10B" Kalmia fine sandy loam, wet substratum, 2 - 6 % slopes
- "11" Kenansville loamy sand, 0 - 4 % slopes
- "11E" Nevarc and Remlik soils, 15 - 35 % slopes
- "12" Kenansville loamy sand, wet substratum, 0 - 4 % slopes
- "12A" Peawick silt loam, 0 - 2 % slopes
- "12B" Peawick silt loam, 2 - 6 % slopes
- "12C" Peawick silt loam, 6 - 10 % slopes
- "13" Levy silty clay loam
- "13B3" Peawick clay loam, 2 - 6 % slopes, severely eroded
- "14" Lynchburg fine sandy loam
- "14B" Peawick-Slagle complex, 2 - 6 % slopes
- "15" Rappahannock muck
- "15B" Nansemond loamy fine sand, 0 - 6 % slopes
- "15D" Nansemond loamy fine sand, 6 - 15 % slopes
- "15E" Nansemond loamy fine sand, 15 - 30 % slopes
- "16" Rumford loamy sand
- "16A" Nansemond fine sandy loam, 0 - 2 % slopes
- "16B" Nansemond fine sandy loam, 2 - 6 % slopes
- "17" Pactolus loamy fine sand
- "17B3" Slagle sandy loam, 2 - 6 % slopes, severely eroded
- "18" Pungo muck
- "18A" Slagle fine sandy loam, 0 - 2 % slopes
- "18B" Slagle fine sandy loam, 2 - 6 % slopes
- "18C" Slagle fine sandy loam, 6 - 10 % slopes
- "19" Rains fine sandy loam
- "19A" Uchee loamy sand, 0 - 2 % slopes
- "19B" Uchee loamy sand, 2 - 6 % slopes
- "19C" Uchee loamy sand, 6 - 10 % slopes
- "1B" Alaga loamy sand, wet substratum, 2 - 8 % slopes
- "2" Belhaven muck in Suffolk or Bohicket silty clay loam otherwise
- "20A" Rumford loamy fine sand, 0 - 2 % slopes
- "20B" Rumford loamy fine sand in Suffolk, or Uchee-Peawick complex, 2 - 6 % slopes
- "20C" Uchee-Peawick complex, 6 - 10 % slopes"
- "21" Udorthents, loamy
- "21A" State fine sandy loam, 0 - 2 % slopes
- "21B" State fine sandy loam, 2 - 6 % slopes
- "22A" Suffolk loamy sand, 0 - 2 % slopes
- "22B" Suffolk loamy sand, 2 - 6 % slopes
- "23" Yemassee fine sandy loam
- "23A" Tetotum fine sandy loam, 0 - 2 % slopes
- "23B" Tetotum fine sandy loam, 2 - 6 % slopes
- "24" Tomotley loam
- "25" Torhunta loam
- "26" Udorthents, loamy
- "27" Urban land
- "28" Wahee silt loam
- "29" Weston fine sandy loam
- "3" Bohicket silty clay loam in suffolk, or Chickahominy silt loam
- "4" Deloss mucky loam in Suffolk, or Chipley sand elsewhere
- "5A" Dogue fine sandy loamin Suffolk, or Emporia fine sandy loam, 0 - 2 % slopes
- "5B" Emporia fine sandy loam, 2 - 6 % slopes
- "5B2" Dogue fine sandy loam, 2 - 6 % slopes, eroded
- "6" Dragston fine sandy loam in Suffolk or Kenansville loamy sand elsewhere
- "7" Kinston loam
- "7A" Emporia fine sandy loam, 0 - 2 % slopes
- "7B2" Emporia fine sandy loam, 2 - 6 % slopes, eroded
- "8" Leon-Chipley sands
- "8A" Eunola loamy fine sand, 0 - 2 % slopes
- "8B" Eunola loamy fine sand, 2 - 6 % slopes
- "9" Myatt fine sandy loam
- "9A" Goldsboro fine sandy loam, 0 - 2 % slopes
- "9B2" Goldsboro fine sandy loam, 2 - 5 % slopes, eroded
- "DM" Dam
- "M-W" Industrial waste pond
- "W" Water
- Chowan River Sub-Basins
- Major_Watersheds

N

0 5,000 10,000 20,000 30,000 Feet



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STORM WATER MASTER PLAN

GREAT DISMAL SWAMP WATERSHED

STUDY AREA
SOIL SURVEY DATA

FIGURE 2-1

2.7 STARTING WATER SURFACE CONDITIONS

Starting water surface conditions were developed to model the initial flooding influence on stream sections within the watershed. Hydraulic information for flood elevations within the Dismal swamp was not available, the *Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for the City of Suffolk* dated September 4, 2002 does not provide flood elevations for this area of Suffolk. The starting water surface elevations were estimated using 0.8 x the height of the downstream most culverts or channel. This effect is generally not significant since the upstream hydraulics (pipes, bridges, etc.) control the computed hydraulic grade line.

2.8 DESCRIPTION OF MODEL ACCURACY

Due to the lack of detailed survey data and the master plan assumptions used, the model should not be used for design applications. Additional data and survey should be obtained before this model can be used for purposes other than an approximate analysis and stormwater generalizations. These additional requirements include:

- Detailed survey of hydraulic structure inverts, channel cross sections, elevations of undersides of bridge decking, crown elevations of bridge decking, and adjacent roadway elevations.

- Identification and inventory of existing impoundments (ponds and stormwater management facilities), volumetric measurements of each impoundment, and control structure information such as pipe sizes, inverts of pipes, and invert or crest information of any other control structure at each impoundment.

3.0 EXISTING CONDITION MODEL RESULTS

The existing condition model was analyzed to identify flood prone areas throughout the watershed. The different channel reaches and structures (spillways, culvert crossings and bridges) were analyzed based on the following criteria:

- Existing channel velocities for the 2-yr design storm.
- Roadway culverts for the 10-yr design storm (Minor Arterial, Collector, and Local roadways) and the 25-yr design storm (Principal Arterial roadways).
- Bridges for the 100-year storm.

Improvements and associated costs for the identified flooding and erosion problem areas are recommended based on the model results. Detailed cost estimates for each recommendation are located in Appendix A. Mapping of the flood prone areas and proposed improvements, GIS-03 and GIS-04 respectively, are located in the back of the report.

3.1 DISCUSSION OF FIELD OBSERVATIONS

Clark Nexsen performed a field investigation to identify and document the relevant drainage features within the Study Area. The field study included documenting evidence of erosion at the structures and within the stream channels. Several of the culvert crossings exhibited signs of undermining which caused sumps and sink holes within the roadway and shoulder. Evidence of repaired sumps within the road was also observed in the form of recent pavement patches. Table 3-1 below summarizes locations in the field where erosion, sink holes or sumps were observed.

Table No. 3-1 Field Observations		
Node Name	**Location**	**Field Observations**
NAS15	30" RCP at Adams Swamp Rd	Sump in road
NAS4	18" RCP at Cherry Grove Rd	Filled with Sediment
NCOS8	(3) 36" RCP at Freeman Mill Rd	Sump in road
NCYS10	30" RCP at N. Liberty Spring Rd	Broken pipe at downstream end
NCYS46*	12" RCP at Copeland Rd	Broken Pipe and sump in pavement
NCYS51	36" CMP at Copeland Rd	Sink hole at shoulder
NDS5	36" RCP at Greenway Rd	Beaver dam blocking pipe
NDS8	42" CMP at Greenway Rd	Sump in road
NMOS1	24" RCP at White Marsh Rd	Sump in road
NMOS2	24" RCP at Carolina Rd	Sink hole at shoulder

Most of the deficiencies listed in Table 3-1 above can be considered maintenance items which can be addressed by the Public Works Operations and Maintenance Division. Locations marked with an asterisk (*) are discussed in more detail in section 3-3 below.

3.2 Evaluation of Existing Condition Channel Reaches

Analysis of the channel velocities from the model does not indicate a severe erosion condition exists within the watershed channel cross sections (velocity greater than 2.3 feet per second for the 2-yr design storm). The selection of a velocity of 2.3 feet per second or more is based on the general soil characteristics obtained from SSURGO and comparison with Recommended Maximum Water Velocities and Manning's n as a Function of Soil Depth and Flow Type chart contained in the VDOT Drainage Manual. The majority of the soils are classified as A-2 or A-4, which are gravel and sand with mixtures of silt and clay and silts with mixtures of sand and clay, respectively. This is consistent with what was viewed in the field.

The model shows the velocity within several of the conduits contributes to scour at some pipe outfalls. Due to the limitations of a general stormwater model typical for master planning purposes, channel velocities could vary just as actual conditions along the channel vary but are not explicitly modeled. Therefore, caution is required to determine if a channel is not adequate based on the results.

No specific recommendations for channel stability are provided at this time.

3.3 EVALUATION OF EXISTING CONDITION ROADWAY CULVERTS

The roadway culverts analysis was based on the design criteria in the *VDOT Drainage Manual, Chapter 6, Design Criteria.* The roadway designations were taken from the City Master Thoroughfare Plan for the 2026 Comprehensive Plan. Principal Arterial roadways were evaluated for flooding using the 25-year design storm and Minor Arterial, Collector and Local roadways were evaluated using the 10-year design storm.

The model indicates that several of the roads within the watershed flood for the 10-year design storm at culvert crossings. The model results confirm field observations where it appeared that many of the roadway elevations are depressed at culvert crossings allowing flood waters to overtop the road at these localized areas. At this time, only flooded culverts along the Primary Arterial and Minor Arterial roads are recommended for improvements, with the exception of nodes NDS5 (Greenway Rd) and NPOS23 (Hosier Rd) which were added to the list of improvements at the City's request.

Table No. 3-2 below summarizes the peak design storm flood elevation at each culvert for the Principal and Minor Arterial roads.

Table No. 3-2 Culvert Peak Design Storm Flood Elevations					
Node Name	**Conduit Type**	**Road Name**	**Roadway Designation**	**Approximate Top of Road Elevation (ft)**	**Design Flood Elevation (ft)**
NAS16	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	62.00	60.59
NAS17	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	59.80	59.19
NCOS10	24" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	59.50	59.97
NCOS13	Twin 6'x6' Box Culvert	Whaleyville Blvd (Rt 13)	Principal Arterial	49.00	48.31
NCOS14	24" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	65.50	65.67
NCOS15	24" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	59.00	58.33
NCOS17	(2) 24" RCP	Cypress Chapel (Rt 675)	Minor Arterial	67.50	67.76
NCYS12	36" CMP	Copeland Rd (Rt 647)	Minor Arterial	55.00	55.50
NCYS15	Triple 6'x6' Box Culvert	Whaleyville Blvd (Rt 13)	Principal Arterial	45.00	44.19
NCYS16	18" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	64.60	64.38
NCYS17	(2) 36" RCP	Copeland Rd (Rt 647)	Minor Arterial	47.00	46.89
NCYS29	36" RCP	Cypress Chapel (Rt 675)	Minor Arterial	39.50	40.13
NCYS30	Bridge 1814	Carolina Rd (Rt 32)	Minor Arterial	35.50	33.85
NCYS31	4'x4' Box Culvert	Carolina Rd (Rt 32)	Minor Arterial	44.63	43.78
NCYS44	(3) 18" RCP	Carolina Rd (Rt 32)	Minor Arterial	69.00	69.16
NCYS46	12" RCP	Copeland Rd (Rt 647)	Minor Arterial	64.00	64.25
NCYS48	15" CMP	Copeland Rd (Rt 647)	Minor Arterial	68.70	68.93
NCYS49	15" CMP	Copeland Rd (Rt 647)	Minor Arterial	65.50	66.13
NCYS50	30" CMP	Copeland Rd (Rt 647)	Minor Arterial	63.50	63.70
NCYS51	36" CMP	Copeland Rd (Rt 647)	Minor Arterial	61.50	61.08
NCYS54	4'x4' Box Culvert	Carolina Rd (Rt 32)	Minor Arterial	55.00	54.64
NCYS8	(2) 30" CMP	Copeland Rd (Rt 647)	Minor Arterial	61.00	60.90
NCYS9	30" CMP	Copeland Rd (Rt 647)	Minor Arterial	60.50	61.17

Table No. 3-2 Culvert Peak Design Storm Flood Elevations

Node Name	Conduit Type	Road Name	Roadway Designation	Approximate Top of Road Elevation (ft)	Design Flood Elevation (ft)
NDS5	36" RCP	Greenway Rd (Rt 673)	Local	49.00	49.70
NDS13	24" RCP	Cypress Chapel (Rt 675)	Minor Arterial	67.00	67.23
NDS16	Bridge 8056	Cypress Chapel (Rt 675)	Minor Arterial	40.00	36.50
NDS17	15" CCP	Cypress Chapel (Rt 675)	Minor Arterial	68.50	68.82
NDS18	15" RCP	Cypress Chapel (Rt 675)	Minor Arterial	67.00	66.46
NDS19	18" RCP	Cypress Chapel (Rt 675)	Minor Arterial	65.00	65.21
NMOS2	24" CMP & 18" RCP	Carolina Rd (Rt 32)	Minor Arterial	59.00	58.37
NMOS5	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	59.00	59.30
NMOS8	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	61.00	59.10
NMOS9	24" RCP	Carolina Rd (Rt 32)	Minor Arterial	61.00	59.69
NPOS23	(2) 48" RCP	Hosier Rd (Rt 604)	Local	39.00	39.40
NPOS26	15" RCP	Carolina Rd (Rt 32)	Minor Arterial	71.00	70.97
NPOS28	(3) 15" RCP	Carolina Rd (Rt 32)	Minor Arterial	71.00	70.33
NPOS29	15" RCP	Carolina Rd (Rt 32)	Minor Arterial	71.50	70.68

The table above indicates that the design flood elevation for several culvert crossing overtop their respective roadways.

3.3.1 Recommendations

In order to reduce the design flood elevation for the culverts, the City may wish to consider the following recommendations.

- NCOS10: The existing 24" RCP culvert does not have the required capacity to pass the 25-yr design storm without overtopping Whaleyville Boulevard (Rt. 13). To convey the runoff beneath the road, a 30" RCP should be installed parallel to the existing culvert. The cost of the culvert improvements would be approximately $76,888.

- NCOS14: The existing 24" RCP on Whaleyville Boulevard (Rt. 13) is flooded for the 25-yr design storm. To convey the runoff beneath the road, an additional 24" RCP should be installed to provide additional flood relief for the bridge. The cost of the culvert improvements would be approximately $62,160.

- NCOS17: The (2) 24" RCP crosses beneath Cypress Chapel Road (Rt. 675), the roadway is flooded at the culvert for the 10-yr design storm. Flooding at this elevation is not expected to impact nearby residential structures. Installing two parallel 24" RCP would lower the 10-yr design flood headwater elevation and prevent the road from being overtopped. The cost of the culvert improvements would be approximately $76,405.

- NCYS12: The existing 36" CMP crossing Copeland Rd (Rt. 647) does not have adequate capacity to convey the 10-yr design storm. Flooding at this elevation is not expected to impact nearby residential structures. The existing pipe should be replaced with (3) 5'x3' box culverts to prevent the road from being flooded. The cost of the culvert improvements would be approximately $333,558.

- NCYS29: The 36" RCP at this node crosses Cypress Chapel Road (Rt. 675). The model indicates the roadway is flooded for the 10-yr design storm however; the level of ponding at the culvert is not expected to impact nearby residential structures. Replacing the existing pipe with (3) 5'x3' box culverts would lower the 10-yr peak design flood elevation and prevent the road from being flooded. The cost of the culvert improvements would be approximately $322,652.

- NCYS44: Three 18" RCP cross beneath Carolina Rd (Rt. 32), the roadway is flooded for the 10-yr design storm. Installing two parallel 30" RCP would lower the 25-yr design flood headwater elevation and prevent the road from being overtopped. The cost of the culvert improvements would be approximately $97,853.

- NCYS46: The 12" RCP at this node crosses Copeland Rd (Rt. 647). The model indicates the roadway is flooded for the 10-yr design storm however. Replacing the existing 12" RCP with two 24" RCP would prevent the road from being flooded for the 10-yr design storm. The cost of the culvert improvements would be approximately $76,776.

- NCYS48: The existing 15" CMP culvert does not have the required capacity to convey the 10-yr design storm without overtopping Copeland Rd (Rt. 647). To convey the runoff without overtopping, two 24" RCP should be installed parallel to the existing 15" CMP. The cost of the culvert improvements would be approximately $76,643

- NCYS49: The existing 15" CMP culvert does not have the required capacity to convey the 10-yr design storm without overtopping Copeland Rd (Rt. 647). To convey the runoff without overtopping, two 24" RCP should be installed parallel to the existing 15" CMP. The cost of the culvert improvements would be approximately $78,778.

- NCYS50: The 10-yr design storm elevation existing 30" CMP overtops Copeland Rd (Rt. 647). To convey the runoff beneath the road without overtopping, a twin 30" RCP should be installed parallel to the existing culvert. The cost of the culvert improvements would be approximately $84,546.

- NCYS8: The existing 30" CMP culvert does not have the required capacity to convey the 10-yr design storm without overtopping Copeland Rd (Rt. 647). To convey the runoff without overtopping, two additional 30" RCP should be installed parallel to the existing pipe. The cost of the culvert improvements would be approximately $84,651

- NCYS9: The existing 30" CMP culvert does not have the required capacity to convey the 10-yr design storm without overtopping Copeland Rd (Rt. 647). The level of ponding at the culvert headwaters does not impact nearby residential structures. To convey the runoff without overtopping, three additional 36" RCP should be installed parallel to the existing pipe. The cost of the culvert improvements would be approximately $236,772.

- NDS5: The 36" RCP at this node crosses Greenway Road (Rt. 673). The model indicates the roadway is flooded for the 10-yr design storm. Replacing the existing pipe with (3) 5'x3' box culverts would lower the 10-yr peak design flood elevation and prevent the road from being flooded. The cost of the culvert improvements would be approximately $339,324.

- NDS13: The 10-yr design storm elevation existing 24" RCP overtops Cypress Chapel Road (Rt. 675). To convey the runoff beneath the road without overtopping, an additional 24" RCP should be installed parallel to the existing pipe. The existing pipe could not be located in the field and assumed to be a 24" RCP. The cost of the culvert improvements would be approximately $69,237.

- NDS17: The 10-yr design storm elevation existing 15" CCP overtops Cypress Chapel Road (Rt. 675). To convey the runoff beneath the road without overtopping, two 24" should be installed parallel to the existing pipe. The cost of the culvert improvements would be approximately $78,071.

- NDS19: The 10-yr design storm elevation existing 18" RCP overtops Cypress Chapel Road (Rt. 675). The level of ponding at the culvert headwaters does not impact nearby residential structures. To convey the runoff beneath the road without overtopping, an additional 18" RCP should be installed parallel to the existing pipe. The cost of the culvert improvements would be approximately $65,443.

- NMOS5: The existing 18" RCP does not have the required capacity to convey the 10-yr design storm without overtopping Mineral Spring Rd (Rt. 616). The level of ponding at the culvert does not impact nearby residential structures. To convey the runoff without overtopping, a 24" RCP should be installed parallel to the existing pipe. The cost of the culvert improvements would be approximately $72,765.

- NPOS23: The (2) 48" RCP at this node crosses Hosier Road (Rt. 604). The model indicates the roadway is flooded for the 10-yr design storm. Replacing the existing pipe with (3) 5'x3' box culverts would lower the 10-yr peak design flood elevation and prevent the road from being flooded. The cost of the culvert improvements would be approximately $339,324.

Table No. 3-3 summarizes the existing and proposed improvements peak headwater elevations for the recommendations provided above.

Table No. 3-3 Comparison of Existing and Improved Culvert Peak Headwater Elevations – Existing Condition Model

Node Name	Road Name	Roadway Designation	Approximate Top of Road Elevation (ft)	Existing Culvert Peak Headwater Elevation (ft)	Improved Culvert Peak Headwater Elevation (ft)
NCOS10	Whaleyville Blvd.	Principal Arterial	59.50	59.97	59.26
NCOS14	Whaleyville Blvd.	Principal Arterial	65.50	65.67	64.99
NCOS17	Cypress Chapel Rd.	Minor Arterial	67.50	67.76	66.76
NCYS12	Copeland Rd.	Minor Arterial	55.00	55.50	53.64
NCYS29	Cypress Chapel Rd.	Minor Arterial	39.50	40.19	38.79
NCYS44	Carolina Rd.	Minor Arterial	69.00	69.16	68.69
NCYS46	Copeland Rd.	Minor Arterial	64.00	64.25	63.18
NCYS48	Copeland Rd.	Minor Arterial	68.70	68.93	67.79
NCYS49	Copeland Rd.	Minor Arterial	65.50	66.13	65.13
NCYS50	Copeland Rd.	Minor Arterial	63.50	63.70	62.30
NCYS8	Copeland Rd.	Minor Arterial	61.00	61.30	60.21
NCYS9	Copeland Rd.	Minor Arterial	60.50	61.17	59.67
NDS5	Greenway Rd	Local Rd	49.00	49.70	48.40
NDS13	Cypress Chapel Rd.	Minor Arterial	67.00	67.23	66.19
NDS17	Cypress Chapel Rd.	Minor Arterial	68.50	68.82	68.01
NDS19	Cypress Chapel Rd.	Minor Arterial	65.00	65.21	64.06
NMOS5	Carolina Rd.	Minor Arterial	59.00	59.30	58.91
NPOS23	Hosier Rd	Local Rd	39.00	39.40	37.40

3.4 EVALUATION OF EXISTING CONDITION BRIDGES

The flood elevations at the bridges were evaluated using the 100-yr design storm. Table No. 3-4 below summarizes the 100-yr design flood elevation at the various bridges within the watershed.

Table No. 3-4 Bridge 100-yr Design Storm Flood Elevations

Node	Location	Bridge Number	Low Chord Elevation (ft)	Low Point of Road Elevation (ft)	Bridge Deck Elevation (ft)	100-yr Design Storm Elevation (ft)
NCYS15	Whaleyville Blvd	1804	45.00	45.00	46.50	45.41
NCOS13	Whaleyville Blvd	1805	48.50	49.00	50.00	49.30
NAS4	Cherry Grove Rd	8058	41.00	41.00	43.60	42.11
NCYS30	Carolina Rd	1814	37.00	35.50	38.50	35.15
NCYS43	Desert Rd	8004	32.00	33.00	33.50	30.02
NCYS40	White Marsh Rd	8031	35.00	31.48	37.00	31.45
NPOS24	White Marsh Rd	8027	31.25	32.75	33.92	31.37
NPOS13	Badger Rd	8055	31.00	33.50	37.00	34.12

The existing condition model shows that the 100-yr design flood elevations overtop the roadway near several of the bridges within the watershed.

3.4.1 Recommendations

Many roadways at the bridges within the watershed are flooded for the 100-yr design storm. The majority of those bridges that flood for storm events less than the 100-yr design storm are on local and secondary roads. These roads and the bridges associated with them are generally between 4 and 8 feet above the estimated bottom of the channel or floodplain. Often the adjacent roadway is depressed to provide overflow relief to protect the bridge structure. The current analysis indicates that significant improvements would be required to raise the bridges above the 100-yr flood elevation or to provide pipe crossings to direct flow below the roadway elevation. Individual bridges should have a detailed hydrologic and hydraulic analysis performed to assess the performance of the bridge and to provide appropriate recommendations.

4.0 FUTURE CONDITION (2026) MODEL RESULTS

The existing condition model was modified to reflect the future planned development in the watershed as outlined in the 2026 Comprehensive Plan. The future sub-catchment zoning coverages were assigned impervious surface ratios based on the Suffolk UDO to create area-weighted estimates of projected impervious surface area. The majority of the Study Area is located in the A (Agricultural District) Zone. In order to model the future (2026) land use conditions a minimum 16% impervious coverage, based on the Suffolk UDO, was used for the sub-catchments within the model. The future conditions model was analyzed to identify flood prone areas. The channel reaches and structures (spillways, culvert crossings and bridges) were analyzed based on the following criteria, similar to the existing condition model:

- Future channel velocities for the 2-yr design storm.
- Roadway culverts for the 10-yr design storm (Minor Arterial roadways) and the 25-yr design storm (Principal Arterial roadways).
- Bridges for the 100-year storm.

The improvements for the identified flooding and erosion problem areas recommended in Section 3 of the report were analyzed for the 2026 land use condition. Some of the improvements cited in Section 3 will be adequate for the 2026 land use condition. Detailed cost estimates for each recommendation are located in Appendix A. Mapping of the flood prone areas and proposed improvements, GIS-03 and GIS-04 respectively, are located in the back of the report.

4.1 EVALUATION OF FUTURE CONDITION CHANNEL REACHES

As with the existing condition model, analysis of the channel velocities does not indicate a severe erosion condition exists within most of the watershed channels incorporated into the model. No specific recommendations for channel stability are provided at this time.

4.2 EVALUATION OF FUTURE CONDITION ROADWAY CULVERTS

The future condition roadway culverts were analyzed using the same design criteria as the existing condition model based on the data in the VDOT Drainage Manual. Principal Arterial roadways were evaluated for flooding using the 25-yr design storm and Minor Arterial, Collector, and Local roadways were evaluated using the 10-yr design storm. As with the existing condition model, only flooded culverts at along the Primary Arterial and Minor Arterial roads are recommended for improvements, with the exception of nodes NDS5 (Greenway Rd) and NPOS23 (Hosier Rd) which were added to the list of improvements at the City's request. Table No. 4-1 below summarizes the peak design storm flood elevation at each culvert modeled.

Table No. 4-1 Culvert Peak Design Storm Flood Elevations

Node Name	Conduit Type	Road Name	Roadway Designation	Approximate Top of Road Elevation (ft)	Design Flood Elevation (ft)
NAS16	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	62.00	60.60
NAS17	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	59.80	59.21
NCOS10	24" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	59.50	59.93
NCOS13	Twin 6'x6' Box Culvert	Whaleyville Blvd (Rt 13)	Principal Arterial	49.00	48.44
NCOS14	24" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	65.50	65.68
NCOS15	24" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	59.00	58.42
NCOS17	(2) 24" RCP	Cypress Chapel (Rt 675)	Minor Arterial	67.50	67.77
NCYS12	36" CMP	Copeland Rd (Rt 647)	Minor Arterial	55.00	55.62
NCYS15	Triple 6'x6' Box Culvert	Whaleyville Blvd (Rt 13)	Principal Arterial	45.00	44.34
NCYS16	18" RCP	Whaleyville Blvd (Rt 13)	Principal Arterial	64.60	64.44
NCYS17	(2) 36" RCP	Copeland Rd (Rt 647)	Minor Arterial	47.00	47.07
NCYS29	36" RCP	Cypress Chapel (Rt 675)	Minor Arterial	39.50	40.17
NCYS30	Bridge 1814	Carolina Rd (Rt 32)	Minor Arterial	35.50	33.98
NCYS31	4'x4' Box Culvert	Carolina Rd (Rt 32)	Minor Arterial	44.63	44.04

Table No. 4-1 Culvert Peak Design Storm Flood Elevations

Node Name	Conduit Type	Road Name	Roadway Designation	Approximate Top of Road Elevation (ft)	Design Flood Elevation (ft)
NCYS44	(3) 18" RCP	Carolina Rd (Rt 32)	Minor Arterial	69.00	68.18
NCYS46	12" RCP	Copeland Rd (Rt 647)	Minor Arterial	64.00	64.30
NCYS48	15" CMP	Copeland Rd (Rt 647)	Minor Arterial	68.70	68.56
NCYS49	15" CMP	Copeland Rd (Rt 647)	Minor Arterial	65.50	66.14
NCYS50	30" CMP	Copeland Rd (Rt 647)	Minor Arterial	63.50	63.80
NCYS51	36" CMP	Copeland Rd (Rt 647)	Minor Arterial	61.50	61.17
NCYS54	4'x4' Box Culvert	Carolina Rd (Rt 32)	Minor Arterial	55.00	55.00
NCYS8	(2) 30" CMP	Copeland Rd (Rt 647)	Minor Arterial	61.00	61.38
NCYS9	30" CMP	Copeland Rd (Rt 647)	Minor Arterial	60.50	61.32
NDS5	36" RCP	Greenway Rd (Rt 673)	Local	49.00	49.80
NDS13	24" RCP	Cypress Chapel (Rt 675)	Minor Arterial	67.00	67.34
NDS16	Bridge 8056	Cypress Chapel (Rt 675)	Minor Arterial	40.00	36.65
NDS17	15" CCP	Cypress Chapel (Rt 675)	Minor Arterial	68.50	68.84
NDS18	15" RCP	Cypress Chapel (Rt 675)	Minor Arterial	67.00	66.49
NDS19	24" RCP	Cypress Chapel (Rt 675)	Minor Arterial	65.00	65.23
NMOS2	24" CMP & 18" RCP	Carolina Rd (Rt 32)	Minor Arterial	59.00	58.42
NMOS5	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	59.00	59.31
NMOS8	18" RCP	Carolina Rd (Rt 32)	Minor Arterial	61.00	59.12
NMOS9	24" RCP	Carolina Rd (Rt 32)	Minor Arterial	61.00	59.75
NPOS23	(2) 48" RCP	Hosier Rd (Rt 604)	Local	39.00	39.50
NPOS26	15" RCP	Carolina Rd (Rt 32)	Minor Arterial	71.00	70.98
NPOS28	(3) 15" RCP	Carolina Rd (Rt 32)	Minor Arterial	71.00	70.36
NPOS29	15" RCP	Carolina Rd (Rt 32)	Minor Arterial	71.50	70.71

The table above indicates that the design flood elevation for several culvert crossing overtop their respective roadways. These results are similar to the existing condition model.

4.2.1 Recommendations

The existing condition recommendations for the culverts were analyzed for the 2026 land use condition. ***Improvements recommended under the existing condition were adequate for several of the culverts in the future condition (2026).*** The following summarizes the proposed improvements for the 2026 model.

- NCOS10: In addition to the improvements recommended under Section 3, a second parallel 36" RCP should be installed to convey the 25-yr peak discharge. The adjusted cost of the culvert improvements would be approximately $98,049.

- NCOS14: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCOS17: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCYS12: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCYS29: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCYS44: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCYS48: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCYS49: In addition to the improvements recommended under Section 3, a third parallel 24" RCP should be installed to convey the 10-yr peak discharge. The adjusted cost of the culvert improvements would be approximately $94,633.

- NCYS50: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCYS8: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NCYS9: In addition to the improvements recommended under Section 3, a fourth parallel 36" RCP should be installed to convey the 10-yr peak discharge. The adjusted cost of the culvert improvements would be approximately $292,174.

- NDS5: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NDS13: In addition to the improvements recommended under Section 3, a second parallel 24" RCP should be installed to convey the 10-yr peak discharge. The adjusted cost of the culvert improvements would be approximately $78,491.

- NDS17: In addition to the improvements recommended under Section 3, a third parallel 24" RCP should be installed to convey the 10-yr peak discharge. The adjusted cost of the culvert improvements would be approximately $88,326.

- NDS19: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- NMOS5: In addition to the improvements recommended under Section 3, a second parallel 24" RCP should be installed to convey the 10-yr peak discharge. The adjusted cost of the culvert improvements would be approximately $84,511.

- NPOS23: The improvements proposed under Section 3 are adequate to address the 2026 land use condition.

- Regional Best Management Practices (BMPs): The comparative analysis of constructing a BMP versus making roadway drainage improvements indicates that a significant storage volume is typically required to attenuate sufficient flow to avoid making roadway drainage improvements. Because these costs would far exceed making roadway improvements, no recommendations are made to use storage ponds upstream of roadways. The cost of regional BMPs would be greater than the cost associated with upgrading the roadway culverts. Additionally, construction of regional BMPs reduces the amount of developable land and would require substantial right-of-way to construct and maintain.

Table No. 4-2 summarizes the 2026 unimproved and improved peak headwater elevations for the recommendations provided above.

Table No. 4-2 Comparison of Ultimate (2026) and Improved Culvert Peak Headwater Elevations – Ultimate (2026) Condition Model

Node Name	Road Name	Roadway Designation	Approximate Top of Road Elevation (ft)	2026 Culvert Peak Headwater Elevation (ft)	Improved Culvert Peak Headwater Elevation (ft)
NCOS10	Whaleyville Blvd.	Principal Arterial	59.50	59.93	58.76
NCOS14	Whaleyville Blvd.	Principal Arterial	65.50	65.68	65.22
NCOS17	Cypress Chapel Rd.	Minor Arterial	67.50	67.77	67.48
NCYS12	Copeland Rd.	Minor Arterial	55.00	55.62	54.56
NCYS29	Cypress Chapel Rd.	Minor Arterial	39.50	40.17	38.94
NCYS44	Carolina Rd.	Minor Arterial	69.00	69.18	68.80
NCYS46	Copeland Rd.	Minor Arterial	64.00	64.30	63.65
NCYS48	Copeland Rd.	Minor Arterial	68.70	68.56	67.92
NCYS49	Copeland Rd.	Minor Arterial	65.50	66.14	65.11
NCYS50	Copeland Rd.	Minor Arterial	63.50	63.80	62.99
NCYS8	Copeland Rd.	Minor Arterial	61.00	61.38	60.29
NCYS9	Copeland Rd.	Minor Arterial	60.50	61.32	59.69
NDS5	Greenway Rd	Local Rd	49.00	49.70	48.70
NDS13	Cypress Chapel Rd.	Minor Arterial	67.00	67.34	66.65
NDS17	Cypress Chapel Rd.	Minor Arterial	68.50	68.84	68.25
NDS19	Cypress Chapel Rd.	Minor Arterial	65.00	65.49	64.45
NMOS5	Carolina Rd.	Minor Arterial	59.00	59.31	58.66
NPOS23	Hosier Rd	Local Rd	39.00	39.40	38.20

4.3 EVALUATION OF FUTURE CONDITION BRIDGES

The flood elevations at the bridges were evaluated using the 100-yr design storm for the 2026 condition. Table No. 4-3 below summarizes the 2026 condition 100-yr design flood elevation at the various bridges within the watershed.

Table No. 3-4 Bridge 100-yr Design Storm Flood Elevations

Node	Location	Bridge Number	Low Chord Elevation (ft)	Low Point of Road Elevation (ft)	Bridge Deck Elevation (ft)	100-yr Design Storm Elevation (ft)
NCYS15	Whaleyville Blvd	1804	45.00	45.00	46.50	45.53
NCOS13	Whaleyville Blvd	1805	48.50	49.00	50.00	49.38
NAS4	Cherry Grove Rd	8058	41.00	41.00	43.60	42.23
NCYS30	Carolina Rd	1814	37.00	35.50	38.50	35.31
NCYS43	Desert Rd	8004	32.00	33.00	33.50	30.05
NCYS40	White Marsh Rd	8031	35.00	31.48	37.00	31.55
NPOS24	White Marsh Rd	8027	31.25	32.75	33.92	31.46
NPOS13	Badger Rd	8055	31.00	33.50	37.00	34.16

As previously determined from the existing condition model, the 100-yr design flood elevations overtop the roadway near several of the bridges within the watershed.

4.3.1 Recommendations

As outlined in section 3 above, no recommendations for the bridges are being presented at this time.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The recommendations proposed in the report are summarized in Table No. 5-1 below with associated construction cost estimates. These recommendations are based on model computations and certain conditions discerned from the field investigation. Other conditions could exist that were not modeled due to the scope of the project and the intended usefulness of a stormwater master planning model. The improvements are not in a specific order. Most of the improvements recommended were from inadequate culverts that had the potential to overtop Principal Arterial and Minor Arterial roadways for their respective 24-hour rainfall event. The costs listed show the estimated value of improvements based on the existing condition and the future condition (2026) land uses. For those improvements where only one cost is listed, there were no additional improvements required to address the future condition (2026) land uses. The costs shown are based on 2007 dollars and would be greater in the future due to construction cost escalation.

Table No. 5-1 Summary of Erosion and Flood Control Recommendations

Location	Recommendation	Cost
Whaleyville Blvd., 0.47 miles south of intersection with Greenway Rd. (NCOS10)	EXISTING - ADD A 30" RCP TO THE EXISTING 24" RCP. *2026 - ADD AN ADDITIONAL 30" RCP.*	$76,888 $98,049 (2026)
Whaleyville Blvd., 0.25 miles south of intersection with Liberty Spring Rd. (NCOS14)	EXISTING AND 2026 - ADD A 24" RCP TO THE EXISTING 24" RCP.	$62,160

Table No. 5-1 Summary of Erosion and Flood Control Recommendations		
Location	**Recommendation**	**Cost**
Cypress Chapel Rd., 0.11 miles east of intersection with Whaleyville Blvd. (NCOS17)	EXISTING AND 2026 - ADD (2) 24" RCP TO THE EXISTING 24" RCP.	$76,405
Copeland Rd., 0.25 miles west of intersection with Whaleyville Blvd (NCYS12)	EXISTING AND 2026 - REPLACE EXISTING 36" CMP WITH (3) 5'X3' BOX CULVERTS.	$333,588
Cypress Chapel Rd., 0.48 miles west of intersection with Carolina Rd. (NCYS29)	EXISTING AND 2026 - REPLACE EXISTING 36" CMP WITH (3) 5'X3' BOX CULVERTS.	$322,652
Carolina Rd., 0.55 miles north of intersection with Copeland Rd. (NCYS44)	EXISTING AND 2026 - ADD (2) 30" RCP TO THE EXISTING (3) 18" RCP.	$97,853
Copeland Rd., 0.10 miles west of intersection with Carolina Rd. (NCYS46)	EXISTING AND 2026 – REPLACE THE EXISTING 12" RCP WITH (2) 24" RCP.	$76,776
Copeland Rd., 0.12 miles west of intersection with Manning Rd. (NCYS48)	EXISTING AND 2026 - ADD (2) 24" RCP TO THE EXISTING 15" CMP.	$76,643
Copeland Rd., 0.11 miles west of intersection with Manning Rd. (NCYS49)	EXISTING - ADD (2) 24" RCP TO THE EXISTING 15" CMP *2026 - ADD AN ADDITIONAL 24" RCP.*	$78,778 $94,633 (2026)
Copeland Rd., 0.34 miles east of intersection with Manning Rd. (NCYS50)	EXISTING AND 2026 - ADD (2) 30" RCP TO THE EXISTING 30" CMP.	$84,546

Table No. 5-1 Summary of Erosion and Flood Control Recommendations		
Location	**Recommendation**	**Cost**
Copeland Rd., 0.60 miles east of intersection with Jackson Rd. (NCYS8)	EXISTING AND 2026 - ADD (2) 30" RCP TO THE EXISTING 30" CMP	$84,651
Copeland Rd., 0.67 miles east of intersection with Jackson Rd. (NCYS9)	EXISTING - ADD (3) 36" RCP TO THE EXISTING 30" CMP. *2026 – ADD AN ADDITIONAL 36" RCP.*	$236,772 $292,174 (2026)
Greenway Rd., near the intersection with Wedgewood Rd. (NDS5)	EXISTING AND 2026 - REPLACE EXISTING 36" RCP WITH (3) 5'X3' BOX CULVERTS.	$339,324
Cypress Chapel Rd., 0.18 miles east of intersection with Greenway Rd. (NDS13)	EXISTING - ADD A 24" RCP TO THE EXISTING 24" RCP. *2026 – ADD AN ADDITIONAL 24" RCP.*	$69,237 $78,491 (2026)
Cypress Chapel Rd., 0.10 miles west of intersection with Greenway Rd. (NDS17)	EXISTING - ADD (2) 24" RCP TO THE EXISTING 15" CPP. *2026 - ADD AN ADDITIONAL 24" RCP.*	$78,071 $88,326 (2026)
Cypress Chapel Rd., 0.57 miles east of intersection with Greenway Rd. (NDS19)	EXISTING - ADD A 24" RCP TO THE EXISTING 24" RCP	$65,443
Carolina Rd., 0.22 miles south of intersection with Roundtree Cres. (NMOS5)	EXISTING - ADD A 24" RCP TO THE EXISTING 18" RCP. *2026 - ADD AN ADDITIONAL 24" RCP.*	$72,765 $84,511 (2026)
Hosier Rd., near the intersection with Badger Rd. (NDS5)	EXISTING AND 2026 - REPLACE EXISTING TWIN 48" RCP WITH (3) 5'X3' BOX CULVERTS.	$339,324

The model identified areas within the watershed that require a more detailed analysis to determine what flood control improvements are warranted. Due to the lack of detailed survey data and the master plan assumptions used, the model should not be used for design applications. Additional data and survey, particularly for roadway culverts, is needed before this model can be used for making specific design decisions and should only be used as a tool preparing the groundwork for more detailed studies and design.

Analysis of erosive channel velocities is provided only as general conditions that exist within the model. Since the model does not focus on variations in channel geometry, roughness, and unique site conditions throughout the channel reach, specific improvement priorities cannot be immediately obtained from the model. However, where recommendations for improvements are appropriate from field observations and the analysis of the pipes that show increased velocities at the outfalls, the cost of the channel improvements are included in the cost of the culvert improvements.

Regional best management practices (BMPs) were not closely evaluated at this stage of the model. Due to the limit limitations associated with making decisions on channel stability, the use of regional BMPs was not addressed in detail. Additionally, the cost for constructing a regional BMP would be greater versus the costs of making the pipe improvements. This increased cost is associated with land acquisition and large excavation and disposal hauling costs. The cost of constructing a regional BMP was therefore deemed unwarranted at this time. However, if a more detailed study of channel stability indicates that severe erosive condition exists along a major channel, the use of a regional BMP may be warranted over the cost for making extensive channel improvements and the associated cost in easement acquisition, property impacts and permitting. At this stage, we recommend a more detailed study be performed for those channels downstream of culverts recommended for improvements. This consideration is based on the increased flow volume released with the upgraded pipe systems and may therefore require downstream improvements beyond the distance assumed for initial cost of making the pipe improvements. Only one existing regional pond was modeled in the Dismal Swamp watershed, Node NPOS2 located near the headwaters of the Pocosin Swamp between Hosier Road and White Marsh Road. The pond has a tributary drainage area of 530 acres, a maximum storage capacity of 341 acre-feet and a 10-yr design storm storage volume of 52 acre-feet The outlet was assumed as a 4-ft riser box with a 50-ft emergency spillway. All pond data is based on GIS information, the pond is on private property and was inaccessible during the field investigation.

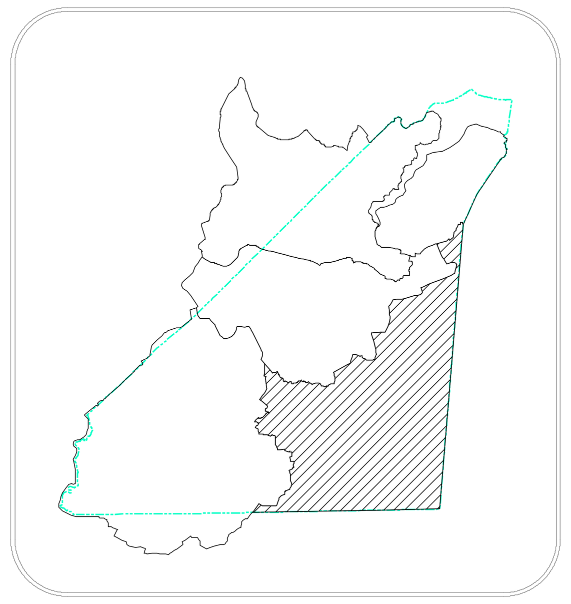
Discussions with the City Public Works Operations revealed that there are several areas throughout the City where localized flooding is caused by beaver activity which can block culverts and back up stream flow. The dams can be located directly at the culvert or several hundred feet downstream in marshes. The City currently sends crews to remove the dams once they are detected visually or due to an unusual increase in water level. The model does not account for beaver dams in the analysis of the culverts. Mitigation of beaver related flooding is considered a maintenance item.

The improvement recommendations were reviewed by City Staff. Table 5-1 below is a listing of the ten (10) most critical points within the Dismal Swamp Watershed based on the City review, field conditions and model results.

Table No. 5-2 10 Most Critical Points in the Dismal Swamp Watershed

Location	Recommendation	Cost
Various	Maintenance concerns noted in Table No. 3-1 of this report.	N/A
Whaleyville Blvd., 0.47 miles south of intersection with Greenway Rd. (NCOS10)	EXISTING - ADD A 30" RCP TO THE EXISTING 24" RCP. *2026 - ADD AN ADDITIONAL 30" RCP.*	$76,888 $98,049 (2026)

Table No. 5-2 10 Most Critical Points in the Dismal Swamp Watershed		
Location	**Recommendation**	**Cost**
Whaleyville Blvd., 0.25 miles south of intersection with Liberty Spring Rd. (NCOS14)	EXISTING AND 2026 - ADD A 24" RCP TO THE EXISTING 24" RCP.	$62,160
Copeland Rd., 0.25 miles west of intersection with Whaleyville Blvd (NCYS12)	EXISTING AND 2026 - REPLACE EXISTING 36" CMP WITH (3) 5'X3' BOX CULVERTS.	$333,588
Cypress Chapel Rd., 0.48 miles west of intersection with Carolina Rd. (NCYS29)	EXISTING AND 2026 - REPLACE EXISTING 36" CMP WITH (3) 5'X3' BOX CULVERTS.	$322,652
Copeland Rd., 0.10 miles west of intersection with Carolina Rd. (NCYS46)	EXISTING AND 2026 – REPLACE THE EXISTING 12" RCP WITH (2) 24" RCP.	$76,776
Copeland Rd., 0.60 miles east of intersection with Jackson Rd. (NCYS8)	EXISTING AND 2026 - ADD (2) 30" RCP TO THE EXISTING 30" CMP	$84,651
Copeland Rd., 0.67 miles east of intersection with Jackson Rd. (NCYS9)	EXISTING - ADD (3) 36" RCP TO THE EXISTING 30" CMP. *2026 – ADD AN ADDITIONAL 36" RCP.*	$236,772 $292,174 (2026)
Greenway Rd., near the intersection with Wedgewood Rd. (NDS5)	EXISTING AND 2026 - REPLACE EXISTING 36" RCP WITH (3) 5'X3' BOX CULVERTS.	$339,324
Hosier Rd., near the intersection with Badger Rd. (NPOS23)	EXISTING AND 2026 - REPLACE EXISTING TWIN 48" RCP WITH (3) 5'X3' BOX CULVERTS.	$339,324



Legend

SUB BASIN BOUNDARY
MAJOR_WATERSHEDS
CITY OF SUFFOLK BOUNDARY

0 3,000 6,000 12,000 18,000 24,000 Feet

1"=6,000'

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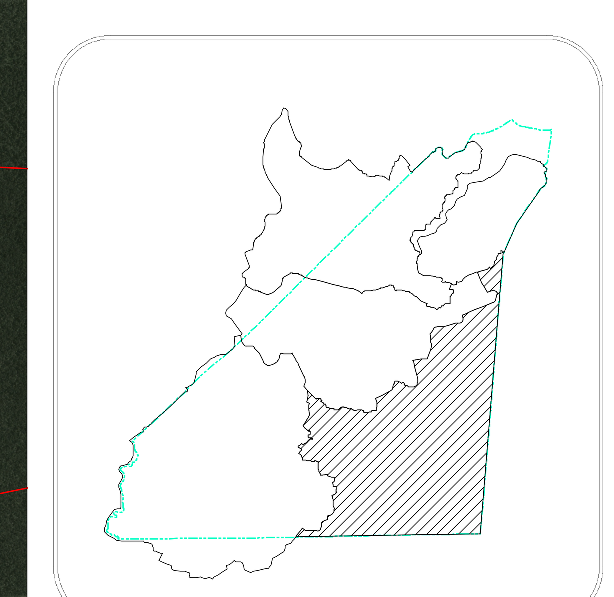
STORM WATER MASTER PLAN
DISMAL SWAMP WATERSHED
STUDY AREA XP-SWMM MODEL

CN NO: N1955.2 E
DATE: 12/12/08
DESIGN: JPP
DRAWN: KRH
REVIEW: RAS
REVISIONS:

NO.	DATE	DESCRIPTION	BY

GIS-01



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DISMAL SWAMP WATERSHED
STUDY AREA XP-SWWM MODEL

CN NO: N1955.2 E
DATE: 12/12/08
DESIGN: JPP
DRAWN: KRH
REVIEW: RAS
REVISIONS:

NO.	DATE	DESCRIPTION	BY

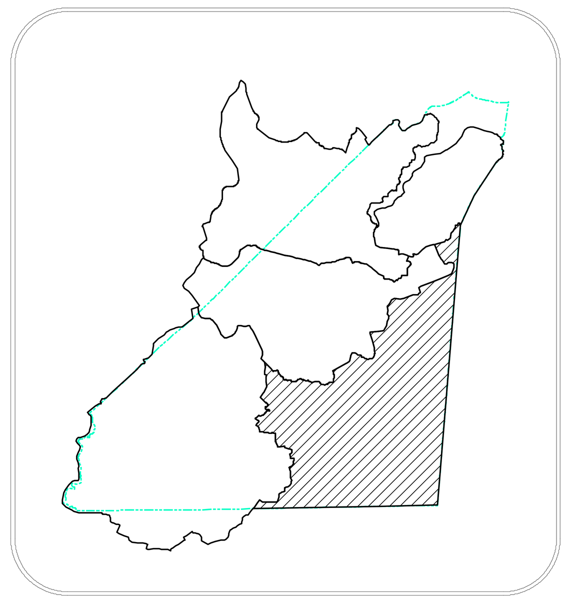
Legend

- SWMM MODEL NODE
- SWMM MODEL LINK
- SUB BASIN BOUNDARY
- MAJOR WATERSHED
- CITY OF SUFFOLK BOUNDARY

0 1,000 2,000 4,000 6,000 8,000 Feet

1"=2,000'

GIS-02



Legend

- DEFFICIENCY_IMPROVEMENT
- MINOR ARTERIAL
- PRINCIPAL ARTERIAL
- MAJOR WATERSHED BOUNDARY
- CITY OF SUFFOLK BOUNDARY

0 1,100 2,200 4,400 6,600 8,800 Feet

1"=2,000'

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STORM WATER MASTER PLAN
DISMAL SWAMP WATERSHED
STUDY AREA - DEFICIENCY AREAS

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DATE: 12/12/08
DESIGN: JPP
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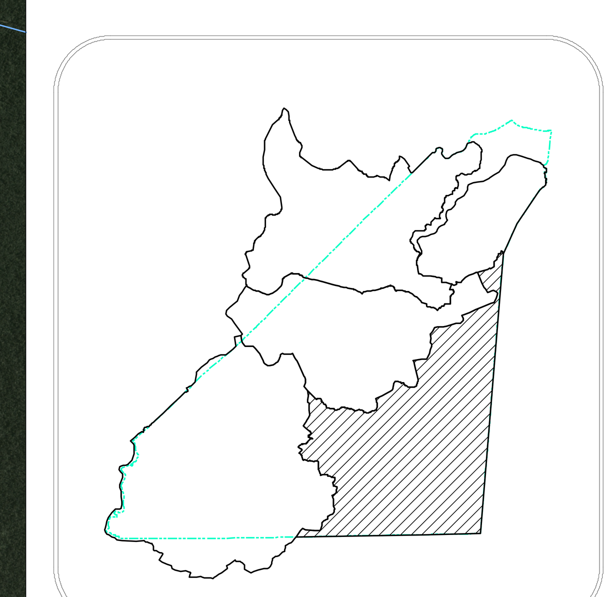
REVIEW: RAS
REVISIONS:

NO.	DATE	DESCRIPTION	BY

GIS-03

SHEET 3 OF 4

3



Legend

- MINOR ARTERIAL
- PRINCIPAL ARTERIAL
- CITY OF SUFFOLK BOUNDARY

0 1,000 2,000 4,000 6,000 8,000 Feet

1"=2,000'

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STORM WATER MASTER PLAN
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DRAWN: KRH
REVIEW: RAS
REVISIONS:

NO.	DATE	DESCRIPTION	BY

GIS-04