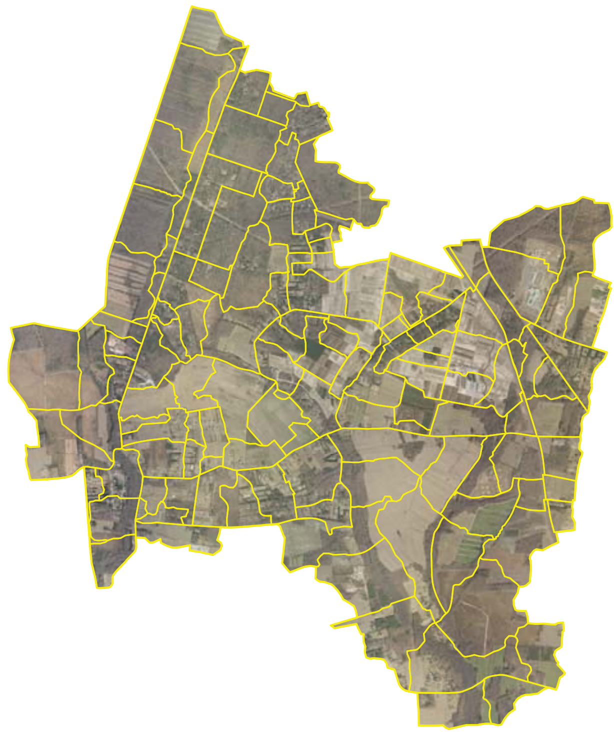
Storm Water Management Model

Southern Chesapeake Watershed MDPU
(Study Areas 2 & 3)



Master Drainage Plan

April 2007

US Army Corps of Engineers
Norfolk District

Chesapeake VIRGINIA
Department of Public Works

URS
URS Corporation

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(Study Areas 2 & 3)
Chesapeake, VA

URS No. 11656563

April 2007

Executive Summary

Engineers from the U.S. Army Corps of Engineers, City of Chesapeake and URS Corporation have completed a drainage study of the Southern Chesapeake Watershed, Study Areas 2 and 3, using the Storm Water Management Model (SWMM) computer program. It is important to state that any reference to the Southern Chesapeake Watershed herein will be limited to Study Areas 2 and 3 only, unless indicated otherwise.

The analytical procedure is based on computing localized flood volumes resulting from design rainfall events such as the 2-, 5-, 10-, 25-, 50- and 100-year storms. The watershed is analyzed using modeling configurations to quantify flooding associated with both existing and future watershed conditions. Drainage improvement alternatives are carefully evaluated with respect to their potential impact to the entire watershed. The improvement alternatives are then given further consideration based on construction feasibility and financing constraints, with the focus on the entire watershed rather than on a few individual components. The advantage of this approach is that the entire drainage system can be evaluated on a consistent, system-wide basis.

The process of identifying candidate drainage improvement projects is based on trial-and-error modeling techniques. The watershed is analyzed using anticipated future land use and imperviousness, and locations and volumes of computed flooding are identified in the modeling.

After analyzing existing and potential problems in this watershed, URS has identified twelve specific projects that can alleviate future flooding in the subject watershed. Eight of the twelve projects are not considered Master Drainage Facilities (MDF's) because their contributing drainage area is less than 320 acres. Preliminary cost opinion computations, provided in a separate Cost Appendix, indicate that the four Master Drainage Facilities are financially feasible. These projects can be carried forward as Capital Improvements Projects with some assurance that the impacts on the watershed as a whole have already been adequately considered. Portions of some projects can potentially be constructed as part of private development initiatives with little or no cost to the City. For example, the Middle Homestead Tributary Improvements project could be constructed by the City, or could be done as part of future development proffers. A third option for this project could be to strictly require on-site stormwater management for

future development so that little or no improvements would be required to the outfall channel (this option would need to address the existing flooding that is occurring—which would be a problem if home sites are developed—as well as future increases in storm water runoff).

There are many combinations of drainage improvements that can be evaluated in any watershed. While a substantial effort has been applied to develop this study, it is by no means exhaustive. The intent of this undertaking was not only to develop sound alternatives for watershed improvements, but also to leave the underlying data files and computer models so that they can be used in a straightforward manner in the future.

The peak computed water surface elevations at each modeled node are presented in Appendix C for existing conditions and future conditions.

Portions of this watershed associated with roadway or development projects have been evaluated by the City over the past several years. Some studies have been completed to address specific problems as described elsewhere in this report. The modeling conducted as part of this Master Drainage Plan Update incorporates the previously prescribed improvements where possible, either directly or with modifications. In some cases, previously recommended improvements can be eliminated or reduced in scale, as detailed later in this report.

As part of the cost sharing agreement between the City of Chesapeake and the U.S. Army Corps of Engineers, improvements to the Southern Chesapeake watershed must include features that provide valuable habitat restoration or creation opportunities that may also provide ancillary flood damage reduction benefits. This study was authorized by Resolution of the Committee of Transportation and Infrastructure of the U.S. House of Representatives, Docket 2674, Dismal Swamp and Dismal Swamp Canal, Chesapeake, Virginia, adopted 22 May 2002, which states in part "…*to determine whether modifications to the existing project are advisable to address flooding problems, environmental restoration and protection, and related water resources needs in the vicinity of the Dismal Swamp Canal in Chesapeake, Virginia."*

The City of Chesapeake worked closely with URS to develop restoration and protection concepts that could be applied in this watershed to enhance environmental resources. These conceptual improvements were reviewed with Norfolk District Corps of Engineers staff, who also offered ideas for implementation of wetland and riparian habitat corridors. After field screening, Corps staff identified four potential environmental protection and restoration projects that can be used to meet the requirements of Docket 2674. These projects involve constructing wetlands and/or riparian habitat corridors.

FEMA flood insurance studies and rate maps are the definitive source of floodplain limits and elevations. The SWMM models developed for this drainage study are specific design scenarios based on 2-, 5-, 10-, 25-, 50-, and 100-year rainfall events—THEY ARE NOT TO BE CONSTRUED AS INDICATIVE OF EXPECTED WATER SURFACE ELEVATIONS FOR THE PURPOSES OF FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS. The SWMM models developed for this study could be adapted for use in the National Flood Insurance Program and submitted to FEMA for approval, but until they are subjected to that process the published flood insurance studies and rate maps remain fully in effect.

Background

URS was directed by the City of Chesapeake and the U.S. Army Corps of Engineers to conduct a study on the area of Southern Chesapeake Watershed (Study Areas 2 and 3) covering approximately 8,881 acres.

The Southern Chesapeake Watershed is located just south of central Chesapeake. Two separate outfalls, which are hydraulically linked to one another, discharge runoff towards the south and into the Northwest River. In addition to these two outfalls, the subject watershed is also hydraulically linked to the Cooper's Ditch Watershed located to the north. The connections between these two major watersheds occur along their adjacent borders in two separate areas identified as Edinburgh Lake and the Caroon Farms Subdivision. Edinburgh Lake was constructed so that during small storm events the lake discharges towards the south into Southern Chesapeake Watershed, and during larger storm events excess flow discharges to the north into Cooper's Ditch Watershed. A local high point in the Caroon Farms Subdivision, south of New Zealand Reach, flows both north to Cooper's Ditch and south to Southern Chesapeake, thus creating a hydraulic link between the two watersheds. These connections between the two watersheds complicate the hydraulic modeling process, and require that the two watersheds be modeled in a single hydraulic model.

The subject watershed was delineated into 131 subbasins in order to distribute point sources for inflow throughout the entire watershed. The Southern Chesapeake Watershed consists mostly of rural property and contains several large, undeveloped tracts of land, very few of which are targeted for future land use modification. This study addresses existing drainage and storm water issues, as well as expected future conditions. The Cooper's Ditch model is combined with the Southern Chesapeake model. There are two reports—one for each watershed, but only one underlying set of SWMM models. The entire SWMM model has over 700 nodes and over 800 links, making it an extremely large and complicated model for this region.

Chesapeake citizens who live in or around the Southern Chesapeake Watershed attended meetings with URS and City staff. The citizens provided URS with useful information. One citizen noted that ongoing flooding problems occur in the Caroon Farms Subdivision, stating that floodwaters remain at select intersections, including the areas of Cobble Scott Way, Tiki Way, and Water Oak Street, "up to two days following a storm event." This is a significant statement indicating potential problems with maintenance, because storm runoff would flow unimpeded through these outfall channels in much less time than two days. Downed trees across the outfall channels or debris in the channels or culverts would be the most likely cause of the lag. Another citizen pointed out his findings regarding the St. Brides Outfall. He stated that there are blockages within this channel due to previous activity across the power line right-of-way. In addition, make-shift bridges, created for the passage of all terrain vehicles (ATV's), have been placed across the channel. It is this citizen's opinion that these disturbances to the St. Brides Outfall contribute greatly to the flow problems in this area. The City believes that this outfall is currently limited to handling up to a 5-yr storm event.

Two drainage studies, Saint Brides Outfall Study and Homestead Outfall Study, completed in late 1988, included both of the watershed's southern outfalls. The following is a brief description of each of the two studies.

In November of 1988, the City of Chesapeake concluded a study of the Saint Brides Outfall. This study consisted of the main channel, Saint Brides Ditch, along with two of its tributaries, Hickory Ditch and Hickory Ditch North. Approximately 6,861 acres drain into these channels before being released into the Northwest River. During the course of this study several deficiencies were discovered throughout the channel system. The City devised two alternative recommendations to be considered in the improvements for this outfall. Alternative 1 proposed to replace all drainage structures with larger passages and make improvements to the natural channels. Alternative 2 was similar to Alternative 1 with some differences in drainage structure sizes. In addition, Alternative 2 incorporated a series of reservoirs along the natural channel for storm water retention. Details of each alternative along with the existing drainage and the locations are presented in Table 1.

Table 1. St. Brides Outfall — 1988 Proposed Drainage Alternatives

	Location	Existing Drainage	Proposed Drainage	
			Alternative 1	**Alternative 2**
Saint Brides Ditch (main channel)	1,600 ft. south of St. Brides Road	Swampland	Floodplain w/ 20-ft pilot channel	Floodplain w/ 20-ft pilot channel
	St. Brides Road (south crossing)	30-ft wooden bridge	140-ft conc. bridge	80-ft conc. bridge
	5,600 ft. north of St. Brides Road	Swampland	325-ft bot. channel w/ 20-ft pilot channel	325-ft bot. channel w/ 20-ft pilot channel
	4,100 ft. south of Benefit Road	55-ft bot. channel	120-ft bot. channel w/ 20-ft pilot channel	120-ft bot. channel w/ 20-ft pilot channel
	Immediately south of Benefit Road	55-ft bot. channel	110-ft bot. channel w/ 20-ft pilot channel	88-ft sharp crested weir
	Benefit Road	30-ft wooden bridge	60-ft conc. bridge	60-ft conc. bridge
	Private driveway, 1,300 ft. north of Benefit Road	Single 30-in x 60-in CMP & double 18-in RCPs	Double 6-ft x 6-ft box culverts	Double 6-ft x 6-ft box culverts
	2,000 ft. north of Benefit Road	Channel	110-ft bot. channel w/ 20-ft pilot channel	Reservoir
Saint Brides Ditch (main channel)	Private driveway, 1,000 ft. south of St. Brides Road	Double 72-in CMPs	60-ft conc. bridge	40-ft conc. bridge
	St. Brides Road (north crossing)	Double 48-in x 72-in CMPs	50-ft conc. bridge	30-ft conc. bridge
	Private road, 2,400 ft. north of St. Brides Road	Double 60-in CMPs	40-ft conc. bridge	30-ft conc. bridge
	Private road, 4,100 ft. north of St. Brides Road	Double 48-in pipes	30-ft conc. bridge	30-ft conc. bridge
	Caroon Farms, Section 4	20-ft bot. channel	30-ft bot. channel w/ 5-ft pilot channel	Reservoir
	Caroon Farms, Section 4	20-ft bot. channel	30-ft bot. channel w/ 5-ft pilot channel	Reservoir
	Caroon Farms, Section 4	20-ft bot. channel	30-ft bot. channel w/ 5-ft pilot channel	Reservoir
Hickory Ditch	Junction of St. Brides Ditch and Hickory Ditch	Swampland	Swampland w/ 20-ft pilot channel	Swampland w/ 20-ft pilot channel
	Private road 3,100 ft south of Benefit Road	Double 36-in RCPs	60-ft conc. bridge	60-ft conc. bridge
	Junction of Hickory Ditch and Hickory Ditch North	Swampland	300-ft bot. channel w/ 100-ft pilot channel	100-ft sharp crested weir
	Benefit Road	16-ft wooden bridge	40-ft conc. bridge	40-ft conc. bridge
	1,200 ft north of Benefit Road (Greenbrier Nursery)	Double 48-in RCPs w/ metal weir	275-ft bot. channel w/ 20-ft pilot channel	20-ft conc. bridge

	Location	Existing Drainage	Proposed Drainage	
			Alternative 1	Alternative 2
	1,100 ft south of Hickory Road	8-ft bot. channel	30-ft bot. channel	Reservoir
	Hickory Road	Single 18-in RCP		
	Battlefield Boulevard	Single 24-in RCP		
Hickory Ditch North	1,500 ft south of Benefit Road	6-ft bot. channel	30-ft bot. channel	Reservoir
	Benefit Road	Triple 48-in x 76-in HECP & single 48-in RCP	Five 76-in x 48-in & one 48-in RCPs	30-ft conc. bridge
	Battlefield Boulevard	Single 4-ft x 6-ft box culvert	Triple 4-ft x 6-ft box culverts	30-ft conc. bridge
	Hickory Road	Single 30-in & single 27-in RCPs	Four 3-ft x 5-ft box culverts	20-ft conc. bridge
	Immediately north of Hickory Road	8-ft bot. channel	10-ft bot. channel	Reservoir

In December of 1988, the City of Chesapeake concluded a study of the Homestead Outfall. This study area included the Homestead and Pine Ridge Subdivisions as well as the western half of Johnstown Road, totaling approximately 2,500 acres. Deficiencies were found throughout this system and the recommendations presented in Table 2 were offered to improve the drainage in this area.

Table 2. Homestead Outfall — 1988 Proposed Drainage Alternatives

	Location	Existing Drainage	Proposed Drainage
Homestead (main channel)	Buskey Road	Double 48-in & single 42-in RCPs	40-ft bridge
	Channel from Buskey Road to Benefit Road	Floodplain	55-ft bot. Channel
	Benefit Road	Triple 48-in RCPs	20-ft bridge
	Channel north of Benefit Road	Combination of marsh and roadside ditches	40-ft bot. channel w/ 10-ft pilot channel
Homestead (tributary)	Buskey Road	Triple 36-in RCPs	Double 5-ft x 10-ft box culverts

Although both of these studies were completed in 1988, none of the recommendations for either study area were implemented.

In addition to the previous two studies, the City of Chesapeake provided URS with several plan sets for projects within the subject watershed, some of which have been approved for construction but have not yet been completed. As directed by the City, URS modeled these as ‘existing’ conditions. While some of these developments were not expected to be complete by the end of this study, they were considered existing conditions because the approval of the project assures its near-future development. The City of Chesapeake surveyed selected points in the subject watershed at the request of URS. These selected survey points are presented in Appendix B. The City also provided URS with GIS-related topographic data. URS utilized these four main sources—past studies, plan sets, survey data, and GIS data to extract channel and infrastructure information, such as inverts, pipe type and sizes, and channel characteristics, throughout the subject watershed.

The City also provided an XP-SWMM model completed by Engineering Services Inc. completed in June 2006, and requested that URS incorporate this model into the Southern Chesapeake Master Drainage Plan Update as “existing conditions.” Details contained in that model are now inherent in the current model. The XP-SWMM model provided by Engineering Services Inc. contained over 100 nodes. After some discussion of preliminary results with City staff, URS made additional field investigations to make sure that outfall channel geometry and Manning roughness coefficients used in the new models are correct. Adjustments were made to better reflect actual channel bottom widths and roughness coefficients found in the field. In response to citizen wishes, the City has adopted a policy of not clearing vegetation from the channel banks in this area. The results are that the channel banks are rougher than they would be if maintained in a more clear-cut state, and this roughness tends to retard storm water flows and produce higher water surface elevations than it would otherwise. South of Caroon Farms, the effect on computed water surface elevations is approximately one vertical foot higher compared to what was initially incorporated from the Engineering Services Inc. model.

Methodology

The engineering methodology applied in this study is summarized in a separate document, submitted by URS to the City of Chesapeake in April of 2005, entitled *Master Drainage Plan Methodology*. SWMM modeling is typically used for relatively large-scale studies. It is not generally intended to be used as a design tool for individual projects, due to its complexity and data requirements. Its strength lies in the application of very advanced hydrologic and hydraulic routing computational routines, fed with data from a geographic information system (GIS) and from plans for future roadway and parcel development projects.

This Master Drainage Plan Update Report presents the findings of the application of this methodology to the subject watershed.

Modeling Configurations

Three modeling configurations—Existing Hydraulics with Existing Hydrology, Existing Hydraulics with Future Hydrology, and Future Hydraulics with Future Hydrology—were developed for this study as described below.

Scenario 1 Existing watershed hydrology with the drainage system configured as it existed in 2006. Channels are modeled using their existing (2006) conditions as well. This is the “Scenario 1” model. The City of Chesapeake requested certain plan sets be considered as ‘existing’ because they have been approved prior to the start of this study. The following is a list of plan sets and studies, provided by the City, that were used in the existing conditions model (the list includes completed past studies, projects that have been constructed, as well as approved projects not yet constructed):

1. Benefit Road Outfall Ditch
2. Caroon Farms Sections 1, 2, 3, 4, 5, 6, & 7
3. Cooper's Ditch Subbasin Map

4. Country Mill Run
5. Delia Drive Outfall Improvement
6. Dewald Rd. Drainage Improvement
7. Hickory Ridge Section 2
8. Hickory Station Estates
9. Hickory Station Estates Phase 2
10. Homestead Outfall Study Area
11. Hunters Ridge
12. Jury Rd. Drainage Improvement
13. Lexington Place
14. Northwset River Weir Drainage Evaluation
15. Pine Ridge
16. Pleasant Ridge North
17. Pleasant Ridge Phase 1
18. Sign Pine Rd. Drainage Improvement
19. St. Brides Outfall Study Area
20. Taft Rd Drainage
21. Village Farms
22. Study of Caroon Farms North and South

Scenario 2 Future watershed hydrology with the drainage system configured as it existed in 2006. Channels are modeled using their existing (2006) conditions as well. This is the "Scenario 2" model. This scenario will show the flooding effects of the existing drainage system due to future land use development. In other words, if no improvements are made to the current drainage system and the remainder of the watershed is constructed as described by the City's 2005 Adopted Land Use Plan, these are the locations and volumes of flooding that can be expected.

Scenario 3 Future watershed hydrology with the future drainage system configured as envisioned by the City of Chesapeake and URS. This is the "Scenario 3" model. This scenario incorporates the drainage from Scenarios 1 and 2 along with any recommendations from URS to help eliminate flooding on a master drainage facility level (i.e. areas serviced by 320 acres or greater).

The recommended improvements should largely reduce flooding at key locations, where feasible, in the future conditions. These improvements were developed during this study, are highlighted in Figure 10, and specifically include the following projects:

1. Upper Homestead Tributary Improvements
2. Middle Homestead Tributary Improvements
3. Johnstown Road Outfall Improvements
4. Lexington Place Outfall Improvements
5. Village Farms Outfall Improvements
6. Caddie Street Outfall Improvements (abandoned)
7. Edinburgh Parkway BMP
8. Sign Pine Road BMP
9. Hickory High School BMP
10. Expressway BMP Expansion and Outfall Improvements
11. Benefit Road Drainage Improvements
12. Saint Brides Outfall Maintenance and Improvements

This scenario depicts future conditions with strategic drainage and storm water improvements in place. Additional details and descriptions regarding the improvements are presented elsewhere in this report. Cost opinions are presented in a separate Cost Appendix.

Modeling Results

Stable RUNOFF and EXTRAN runs were obtained for all modeling scenarios. EXTRAN continuity errors ranged from low to very low.

Boundary conditions (water surface elevations) at the downstream outfall were set in accordance with Chapter 5, Section Q of the City of Chesapeake Public Facilities Manual (July 2001 Edition). In all cases, for all return periods, the hydraulic boundary condition was modeled as a constant water surface elevation of 0.93 feet (NAVD88) in the Northwest River. Due to the natural topography, the water surface elevations in the upper portions of the Southern Chesapeake Watershed are not very sensitive to the downstream boundary water surface elevation used in these models.

The GIS analysis prepared in support of this modeling indicates that the Southern Chesapeake Watershed will increase from **8.81** to **12.61** percent imperviousness in the future, as indicated in Figures 3 and 4. The procedures used to determine this increase are explained in the *Master Drainage Plan Methodology* (April 2005) report submitted previously. This increase in impervious cover produces greater volumes of storm water runoff, which have been incorporated into the future conditions models.

Figures 8, 9, and 11 depict street and property flooding volumes for the 10- and 50-year design storm events. The histograms are not drawn to any scale, but they are proportional, and serve to graphically identify where flooding can be expected under each modeling configuration.

The City reviewed, at separate times, preliminary *existing* and *future* modeling results provided by URS. In 2006 a severe rainfall event occurred in the Southern Chesapeake Watershed, producing a measured water surface elevation at Node 476 near Lexington Place of 13.70 feet. City staff checked weather records and estimated that this event was approximately a 50-year rainfall event. The City questioned URS preliminary results which were indicating computed 50-year water surface elevations several tenths of a foot below this measured level. URS made subsequent field investigations and made the discoveries and adjustments noted in the Background section earlier in this report. The computed 50-year existing water surface (using a Type II design hyetograph) became 13.67 feet after these adjustments, which represents remarkably close agreement to the measured value of 13.70 feet. The model was not calibrated in any fashion to achieve this agreement—rather the agreement resulted from making straightforward adjustments based on field investigation.

The City requested that the 50-year design storm adequacy of the 30-foot bridge on St. Brides Road over the lower St. Brides outfall be noted in this report. This bridge is represented between Nodes 910 and 912 in the modeling. **The overtopping elevation at this bridge is 5.40 feet**, which is significantly higher than the 50-year water surface elevations summarized in Table 3.

Table 3. St. Brides Road Bridge (Nodes 910 – 912) 50-Year Water Surface Elevations

Modeling Scenario	50-Year Water Surface Elevation	
	Node 910	Node 912
Scenario 1 (Existing Conditions)	3.05	2.91
Scenario 2 (Future Hydrology, Existing Drainage)	3.26	3.10
Scenario 3 (Future Hydrology w/ Improvements)	3.65	3.44

The City does not have to 'fix' all of the flooding represented by the histograms in the figures. Areas such as woodlands, deep ravines, large open spaces, ball fields and parks, and along railroad rights of way often do not require improvements unless there is a specific reason to construct them. It is also important to bear in mind that a 50-year design storm is an extreme event, and that neighborhood drainage systems are typically not required to accommodate 50-year storms.

Flooding complaints, particularly those in residential neighborhoods, often result from maintenance problems such as a clogged pipe or debris in a ditch. In considering whether or not drainage improvements might be required to correct an *existing* deficiency, the model results should indicate a flooding problem, and there should be some flooding history to support the need for improvements. If both of these conditions are not met, then the system maintenance should be reviewed or the computer models should be carefully checked.

As noted in the Background section above, maintenance is a significant issue with respect to flooding in and along the major outfall channels. During field inspections, and as attested to by local residents, trees have fallen across the outfall channel in multiple locations. These fallen trees are either catching debris or have the potential to catch debris during large storm events. These MDPU models are based on realistic assumptions as to the conditions of the existing and proposed channels—good maintenance practices must be followed to keep the system functioning properly.

It is also important to understand when reviewing these results that there can be low-lying structures in the watershed that have finished floor elevations below the maximum water surface elevations computed in the SWMM models. In order to estimate whether or not a particular structure will be subject to flooding for a given storm condition, maximum hydraulic grade line elevations in the vicinity should be checked against the finished floor elevation. For example the maximum computed water surface elevation (CWSE) at Node 290 (Benefit Road) appears to be higher than the ground surrounding the house to the northeast. As a result of further survey or field inspection it may be determined that there is no direct access for the flooding waters at Node 290 to reach this property. Areas such as this may require additional field verification to evaluate the impacts of flooding nodes on adjacent properties.

As with all models of this size and complexity there is a great deal of detailed information required. Because it is not feasible to collect *all* of the required data, in some locations it is necessary to make educated guesses about inverts and pipe and channel dimensions and geometries. Where future designs and studies will be based on these models, engineers are strongly encouraged to field-verify all items that may critically impact their designs.

The peak computed water surface elevations at each model node are presented in Appendix C for both existing and future condition scenarios. The blue shading in Tables C-1 and C-2 indicates locations where the maximum computed water surface meets or exceeds the ground elevation for that node. Many of these nodal flooding locations are very small quantity or short duration events. In the SWMM EXTRAN models, the volume of water leaving the node during flooding is computed and summarized for continuity purposes (which allows for a reasonable accounting of flood volume at the node) *but the flooded water is not re-introduced into the model for subsequent routing*. If flooding occurs at a choke point in the system, downstream nodes may have computed maximum water surface elevations less than what can actually be expected due to the volume of water being 'held' upstream. At nodes in Tables C-1 and C-2 where this phenomenon is probably occurring the maximum computed water surface is indicated in ***bold, red, italic*** type. The patterns of flooding can appear to be somewhat counter-intuitive due to the complexity of hydraulic routing. For example, a given node can flood for the 10-year event, but not for the 25-year event. This could be due to computed upstream flooding, or it could be due to the timing of flooding along other hydraulic pathways.

The figures that indicate nodal flood volumes in this report have been filtered so that nodal flood volumes less than 10,000 cubic feet are not represented (because less than 10,000 cubic feet of flooding cannot be practically discerned on the ground—it simply appears as heavy runoff or sheet flow in most cases). Tables C-1 and C-2 have not been filtered at all; where nodal flooding is indicated in many cases the duration and quantity of flooding can be very minor.

The PCSWMM modeling platform contains a very helpful dynamic hydraulic grade line tool that allows the user to view animations of the computed water surface elevations. This dynamic hydraulic grade line tool takes input from a digital interface file at *a specified sampling interval*, for example every 3 minutes in these models. The EXTRAN routing computations are performed at one-second intervals, and the EXTRAN output (*.out) file contains summary information based on *every* time step. If the dynamic hydraulic grade line tool is used to view the results the user should bear in mind that it is based on a sample (one out of every 180 seconds), and therefore the 'peak' values listed by the dynamic hydraulic grade line tool are peaks as sampled using a three-minute interval. The EXTRAN output data on the other hand contains a summary of the *exact* peak values. The EXTRAN output file summaries are used to prepare Tables C-1 and C-2, as well as the flooding figures in this report.

The modeling results presented in this report are based on the assumption that the drainage and storm water systems will be well maintained. If debris builds up to block drainage structures, or channels are allowed to fill with silt, flooding will likely be more severe than computed and represented in this report.

FEMA flood insurance studies and rate maps are the definitive source of floodplain limits and elevations in all cases. The SWMM models developed for this drainage study are specific design scenarios based on 2-, 5-, 10-, 25-, 50-, and 100-year rainfall events—THEY ARE NOT TO BE CONSTRUED AS INDICATIVE OF EXPECTED WATER SURFACE ELEVATIONS FOR THE PURPOSES OF FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS. The SWMM models developed for this study could be adapted for use in the National Flood Insurance Program and submitted to FEMA for approval, but until they are subjected to that process the published flood insurance studies and rate maps remain fully in effect.

Master Drainage Plan Improvements

The City of Chesapeake utilizes a 320-acre threshold for candidate Master Drainage Facility (MDF) improvements. If a project services less than 320 acres, it will generally not be constructed as part of the City's Master Drainage Plan.

Twelve specific projects were conceived and incorporated into the modeling during the course of this study, eight of which are not considered MDF improvements due to their contributing areas being less than 320 acres. These projects are by no means exhaustive, but they seem to provide a reasonable amount of flooding relief at reasonable costs. All of the projects appear to be feasible from a preliminary planning standpoint, but issues such as future wetlands delineations and the ability to successfully acquire rights-of-way or parcels of land may necessitate some modifications as these projects move forward. The twelve projects are shown in Figure 10 and are included in the future modeling scenario. Refer to Figures 6, 7, and 10 of this report to find node and link numbers and to view the locations of improvements that are referenced in the following project summaries.

1. Upper Homestead Tributary Improvements

This project is not considered a master drainage improvement project because the contributing drainage area is less than 320 acres. For this reason, a cost opinion is not provided. However, URS evaluated this improvement to support the City's continuing efforts to relieve excessive flooding and to determine whether implementing the project would cause flooding at downstream locations. The purpose of the improvements is to increase stormwater conveyance through the upper portion of the tributary. The recommended improvement is:

From nodes 100 to 106: Increase channel depth to 5.5 feet and widen the channel bottom to 8 feet with side slopes equal to 2H:1V.

The flooding that occurs at Nodes 102 and 106 under existing conditions is expected to worsen under future conditions. This project would alleviate the flooding at Nodes 102 and 106. Rather than implementing, or requiring developers to implement, this project, the City could require on-site stormwater management for future development projects to reduce expected future flooding. Implementation of this project without completing the recommended Middle Homestead Tributary Improvements (discussed as item 2 of this section) would likely result in increased flooding downstream.

2. Middle Homestead Tributary Improvements

This project is estimated to cost approximately $\underline{\$ 1,489,464}$ in 2007 dollars if constructed after the surrounding land improvements are in place. If constructed as part of adjacent development projects, the cost to the City could be reduced.

The improvements within Middle Homestead Tributary will increase the conveyance of storm water as well as provide extra storage to alleviate flooding due to excess runoff. Improvements have been sized to accommodate the increased flows that would result from the Upper Homestead Tributary Improvements. Recommended improvements to this area include:

1. From Nodes 106 to 110: Increase channel depth to 5 feet and widen the channel bottom to 8 feet with side slopes equal to 2H:1V.
2. From Nodes 110 to 114: Widen channel bottom to 10 feet with side slopes equal to 2H:1V.
3. From Nodes 114 to 116: Replace two 12-in plastic pipes with two 48-in RCPs.
4. From Nodes 116 to 120: Widen channel bottom to 8 feet with side slopes equal to 2H:1V.
5. From Nodes 120 to 124: Replace 36-in CMP with two 48-in RCPs.
6. From Nodes 124 to 126: Widen channel bottom to 8 feet with side slopes equal to 2H:1V.
7. From Nodes 126 to 128: Replace 24-in CMP with two 36-in RCPs or CMPs.
8. From Nodes 128 to 130: Widen channel bottom to 8 feet with side slopes equal to 2H:1V.

3. Johnstown Road Outfall Improvements

The contributing area for this project is less than 320 acres and, therefore, it is not considered a master drainage improvement project. For this reason, a cost opinion is not provided for this project. However, URS evaluated this improvement to support the City's continuing efforts to relieve excessive flooding and to determine how much water would be transferred downstream if these improvements were implemented.

The improvements within this area will increase the conveyance of storm water as well as provide extra storage to alleviate flooding due to excess runoff. Recommended improvements to this area include:

1. From Nodes 104 to 118: Increase channel depth to 4 feet and widen channel bottom to 8 feet with side slopes equal to 2H:1V.
2. From Node 160 to 122: Increase channel depth to 5.9 feet and widen channel bottom to 8 feet with side slopes equal to 2H:1V.
3. From Nodes 122 to 136: Replace 18-in RCP with two 48-in RCPs.
4. From Nodes 136 to 142: Increase channel depth to 5.5 feet and widen channel bottom to 6.5 feet with side slopes equal to 2H:1V.
5. From Nodes 142 to 146: Replace 18-in RCP with 4-ft x 12-ft box culvert.
6. From Nodes 146 to 148: Increase channel depth to 6 feet and widen channel bottom to 6 feet with side slopes equal to 2H:1V.
7. From Nodes 148 to 152: Replace 18-in RCP with 4-ft x 12-ft box culvert.
8. From Nodes 152 to 166: Increase channel depth to 5.2 feet and widen channel bottom to 6 feet with side slopes equal to 2H:1V.
9. From Nodes 166 to 156: Replace 18-in RCP with 4-ft x 12-ft box culvert.
10. From Nodes 156 to 158: Increase channel depth to 5.1 feet and widen channel bottom to 11 feet with side slopes equal to 2H:1V.
11. From Nodes 158 to 162: Replace 18-in RCP with 4-ft x 12-ft box culvert.
12. From Nodes 162 to 178: Increase channel depth to 5.5 feet.
13. From Nodes 178 to 180: Increase channel depth to 6 feet and widen channel bottom to 6 feet with side slopes equal to 2H:1V.
14. From Nodes 180 to 184: Widen channel bottom to 6 feet with side slopes equal to 2H:1V.
15. From Nodes 184 to 188: Replace 18-in RCP with 4-ft x 12-ft box culvert.
16. From Nodes 188 to 168: Widen channel bottom to 6 feet with side slopes equal to 2H:1V.
17. From Nodes 188 to 168: Widen channel bottom to 8 feet with side slopes equal to 2H:1V.

An alternative recommendation to these improvements is to implement on-site BMPs. However, because flooding occurs even under existing conditions, BMPs would have to address flows from both existing and proposed development to alleviate the problem.

4. Lexington Place Outfall Improvements

This project will increase capacity to convey stormwater flows downstream. The City has considered enlarging the bottom width of the channel at Lexington Place from its existing 20-ft width to a 50-ft width. The channel was modeled with a bottom width of 15 to 20 feet to reflect existing conditions. The recommended infrastructure has been sized to accommodate increased flows from the recommended Johnstown Road Outfall Improvement project (discussed as item 3 of this section). URS has worked with the City to determine the best strategy to improve this outfall, and identified three alternatives:

Alternative 1

1. From Node 452 to 468: Widen channel bottom width to 80 feet with side slopes equal to 2H:1V.
2. From Node 468 to 474: Leave as 20-ft bottom width channel to create a choke at outfall of 80-ft channel and control mass flow to downstream.
3. From Node 474 to 476: Widen channel bottom width to 25 feet with side slopes equal to 2H:1V.
4. From Node 496 to 498: Add two additional 48-in CMPs parallel to the two existing 48-in CMPs.

Alternative 2

1. From Node 474 to 476: Widen channel bottom width to 50 feet with side slopes equal to 2H:1V.
2. From Node 476 to 478: Add one additional 48-in x 76-in elliptical pipe parallel to the two existing 48-in x 76-in elliptical pipes.
3. From Node 478 to 496: Widen channel bottom width to 50 feet with side slopes equal to 2H:1V.
4. From Node 496 to 498: Add one additional 48-in CMP parallel to the two existing 48-in CMPs.
5. From Node 498 to 620: Widen channel bottom width to 30 feet with side slopes equal to 2H:1V.

Alternative 3

1. From Node 474 to 476: Widen channel bottom width to 50 feet with side slopes equal to 2H:1V.
2. From Node 476 to 478: Add one additional 48-in x 76-in elliptical pipe parallel to the two existing 48-in x 76-in elliptical pipes.
3. From Node 478 to 496: Lower invert at node 478 by 2.9 feet, deepen the channel with 0.02 percent slope. Also, widen channel to 50-ft bottom width with side slopes equal to 2H:1V.
4. From Node 496 to 498: Add one additional 48-in CMP parallel to the two existing 48-in CMPs.
5. From Node 498 to 534: Lower invert at node 498 by 1.4 feet, deepen the channel with 0.02 percent slope. Also, widen channel to 30-ft bottom width with side slopes equal to 2H:1V.
6. From Node 534 to 644: Continue to deepen the channel with 0.02 percent slope (no widening is necessary at this portion).

The City indicated that Alternative 3 is the preferred option. Alternative 3 is reflected in Scenario 3 models. Therefore, a cost opinion is provided for this alternative. **The project is estimated to cost approximately <u>$ 2,414,951</u> in 2007 dollars**, if constructed after the surrounding land improvements are in place. Including all or portions of the improvements as part of adjacent development projects could reduce or even eliminate the cost to the City.

<u>5. Village Farm Outfall Improvements</u>

This project is not considered a master drainage improvement project because the contributing drainage area is less than 320 acres. For this reason, a cost opinion is not provided. However, URS has evaluated the improvement to this area to support the City's continuing effort to relieve excessive flooding and to evaluate whether implementing the improvements would cause flooding at downstream locations. No increased downstream flooding is expected to occur as a result of this project. Recommended improvements include:

1. From Nodes 622 to 624: Increase channel depth to 3 feet and widen channel bottom to 5 feet with side slopes equal to 1.5H:1V.
2. From Nodes 624 to 626: Add one additional 30-in RCP parallel to the existing 30-in RCP.
3. From Nodes 630 to 632: Add one additional 36-in RCP parallel to the existing 36-in RCP.
4. From Nodes 632 to 634: Add one additional 36-in RCP parallel to the existing 36-in RCP.
5. From Nodes 634 to 636: Replace existing 12-in RCP with two 30-in RCPs.

6. Caddie Street Outfall Improvements

Because the City is not considering future improvements in this area, this potential project has been omitted from further consideration. It is noted here only to ensure that previous e-mails and discussions on all of the potential projects maintain the same alternative number from cradle to grave.

7. Edinburgh Parkway BMP

This project is not considered a master drainage improvement project because the contributing drainage area is less than 320 acres. For this reason, a cost opinion is not provided. This BMP involves creating a retention pond and improving stormwater conveyance. The project is expected to reduce flooding of downstream culverts by detaining peak storm flows. While a cost estimate was not performed, the cost of constructing the BMP is expected to be lower than the cost of upgrading downstream culverts and channels to convey stormwater flows. The Edinburgh Parkway BMP will also create habitat for environmental purposes and improve water quality. Recommended improvements include:

1. From Nodes 544 to 546: Increase channel depth to 6 feet and widen channel bottom to 30 feet with side slopes equal to 1H:1V.
2. From Node 546 to 548: Replace 36-in RCP with 4-ft x 6-ft box culvert.
3. Convert channel parallel to Edinburgh Parkway to a linear retention pond with dimensions of 200-ft x 2050-ft and side slopes equal to 3H:1V. (Note: Top of bank at elevation 20 ft., water surface elevation at 15 ft., and bottom at elevation 14 ft., all in NAVD 88 Vertical Datum).
4. Place 35 linear feet of 30-in RCP at retention outfall of pond with invert elevation at 15 ft. (NAVD 88).
5. From Nodes 554 to 558: Replace existing 18-in RCP with two 36-in RCPs. (Note: This improvement is downstream of the proposed retention pond and could be completed as a separate project.)

8. Sign Pine Road BMP

A detention pond is recommended to detain stormwater flows and to improve water quality. The pond will be designed to provide habitat by incorporating wetlands. **This project is estimated to cost approximately <u>$ 1,322,043</u> in 2007 dollars**, if constructed after the surrounding land improvements are in place. Including all or portions of the improvements as part of adjacent development projects could reduce or even eliminate the cost to the City. The cost of constructing this BMP is expected to be lower than the cost of improving downstream culverts and channels to convey increased stormwater flows. The recommended BMP includes:

At Node 590: Construct a linear detention pond (from existing channel) parallel to Sign Pine Road. Pond dimensions should be 120-ft x 1350-ft with side slopes equal to 3H:1V. The top-of-bank elevation should be 14 feet with the bottom at elevation 9.2 feet (NAVD 88 Vertical Datum).

9. Hickory High School BMP

Because the contributing area for this project is less than 320 acres, it is not considered a master drainage improvement project. Therefore, a cost opinion is not provided for this project. This BMP will involve expanding a retention pond and improving channel conveyance capacity. The project will reduce anticipated future flooding of downstream culverts by detaining peak stormwater flows. While a cost estimate was not performed, expansion of the retention pond is expected to cost less than upgrading downstream culverts and channels to convey increased stormwater flows. This BMP will also create habitat for environmental purposes and improve water quality. Recommended improvements include:

1. At Node 722: Expand natural retention pond to a linear retention pond utilizing the existing channel from Node 730 to 722. The expansion should have dimensions of 240-ft x 1800-ft and side slopes equal to 4H:1V. Elevations should match those in the existing natural pond.
2. From Node 730 to 722: Increase channel depth to 4.6 feet and widen channel bottom to 15 feet with side slopes equal to 2H:1V. (Note: the existing channel is shortened due to this expansion of the pond.)

10. Expressway BMP Expansion and Outfall Improvements

The contributing area for this project is less than 320 acres and, therefore, it is not considered a master drainage improvement. For this reason, a cost opinion is not provided for this project. However, URS recommends improvements to this area due to significant expected increases in flooding resulting from an anticipated future increase in total impervious area in Subbasins 95941 and 96001 (See Figures 3 and 4). Recommended improvements to this area include:

1. At Node 600: Expand existing BMP to a top-of-bank area of 5.0 acres with side slopes equal to 4H:1V. Elevations should match those in the existing BMP.
2. From Nodes 594 to 596: Add one 4-ft x 7-ft box culvert parallel to the two existing 36-in RCPs.
3. From Nodes 602 to 604: Add one 3-ft x 6-ft box culvert to the existing 30-in RCP.
4. From Nodes 604 to 610: Widen channel bottom to 6 feet with side slopes equal to 2H:1V.
5. From Nodes 610 to 714: Replace the 24-in RCP with 3-ft x 6-ft box culvert.
6. From Nodes 716 to 718: Add one 48-in RCP parallel to the existing 48-in RCP.

Flooding in this area under existing conditions is minor. Because the majority of flooding is a result of future conditions, Chesapeake could also address flooding in this area through on-site stormwater management in future developments.

11. Benefit Road Drainage Improvements

This project is estimated to cost approximately $ 244,112 in 2007 dollars, if constructed after the surrounding land improvements are in place. Constructing the project as part of adjacent development projects could reduce the cost to the City.

1. From Nodes 780 to 782: Replace 15-in CMP with two 24-in RCPs.
2. From Nodes 784 to 786: Add three 48-in RCPs to the three existing 48-in RCPs.

This area experiences flooding under existing conditions due to low-lying topography. However, flooding is expected to increase significantly under future conditions. The City could mitigate the increase in flooding by requiring on-site stormwater management for future development projects.

12. Saint Brides Outfall Maintenance and Improvements

Because the contributing area for this project is less than 320 acres, it is not considered a master drainage improvement project. Therefore, a cost opinion is not provided for this project. However, URS recommends improvements to this area to support the City's continuing efforts to relieve flooding in the tributaries upstream of the project. Recommended improvements, which will increase the conveyance of storm water, include:

1. Node 890: Lower invert to elevation 10.00 (NAVD 88).
2. Node 914: Lower invert to elevation 9.60 (NAVD88).

3. Node 916: Lower invert to elevation 9.58 (NAVD88).
4. From Nodes 890 to 914: Clean and re-grade channel to create positive flow.
5. From Nodes 914 to 916: Place existing 30-in RCP at the new invert elevations.

The goal of this type of study is not to relieve *all* flooding, but rather to identify Master Drainage Facility improvements that can be feasibly constructed. It is also important to consider that neighborhood and commercial parcel drainage and storm water systems are neither required nor designed to accommodate flooding from extreme events such as the 50-year storm.

Environmental Restoration and Protection Opportunities

As part of the cost sharing agreement between the City of Chesapeake and the U.S. Army Corps of Engineers, improvements to the Southern Chesapeake 2 & 3 Watersheds must include features that provide valuable habitat restoration or creation opportunities that may also provide ancillary flood damage reduction benefits. This study was authorized by Resolution of the Committee of Transportation and Infrastructure of the U.S. House of Representatives, Docket 2674, Dismal Swamp and Dismal Swamp Canal, Chesapeake, Virginia, adopted 22 May 2002, which states in part "*…to determine whether modifications to the existing project are advisable to address flooding problems, environmental restoration and protection, and related water resources needs in the vicinity of the Dismal Swamp Canal in Chesapeake, Virginia.*"

There are five categories under which potential restoration opportunities are evaluated: scarcity, connectivity, special species status, plan recognition, and self-sustainability.

The Corps identified four potential projects in the Southern Chesapeake 2 & 3 Watersheds for habitat creation, as shown in Figure 13:

A. Lower Sign Pine Road BMP Habitat Corridor (incorporated into Improvement 8 above)
B. Edinburg BMP Habitat Corridor (incorporated into Improvement 7 above)
C. East Edinburgh Habitat Corridor (also incorporated into Improvement 7 above)
D. Hickory High School BMP Habitat Corridor (incorporated into Improvement 9 above)

Contact Information

Mr. Sam Sawan, PE (757.382.6101) served as the project manager for the City of Chesapeake on this project. Mr. Mark Mansfield, Chief Planning and Policy Branch; Mr. Bryant Wilkins, Project Manager; Mr. Tom Yancey, Senior Technical Reviewer; Mr. Walter Trinkala, Engineering Technical Specialist; and Mr. Greg Steele, Planning Technical Team Leader represented the Corps of Engineers, Norfolk District. Mr. John Paine, PE, PH, CFM (757.873.0559) was the project manager for URS. The modeling evaluations and report were produced by Hai Tran, EIT, Stephanie Hood, EIT, and John Paine (757.873.0559).