Storm Water Management Model

Butts Station Road / Kemp Woods Outfall (NS-2) Watershed MDPU

Master Drainage Plan

November 2005

US Army Corps of Engineers
Norfolk District

Chesapeake VIRGINIA
Department of Public Works

URS
URS Corporation

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Chesapeake, VA

URS No. 11656363

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Executive Summary

Engineers from the U.S. Army Corps of Engineers, City of Chesapeake and URS Corporation have completed a drainage study of the Butts Station Road / Kemp Woods Outfall Drainage Basin using the Storm Water Management Model (SWMM) computer program.

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 three specific projects that can alleviate future flooding in the subject watershed. Preliminary cost opinion computations, provided in a separate Cost Appendix, indicate that all three projects 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. Two of the projects can probably be constructed as part of private development projects with little or no cost to the City.

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 D for both existing and future conditions.

This watershed has received a significant amount of attention from the City over the past several years. Several 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 substantiates that the prescribed improvements are or will be effective in reducing storm water flooding in the area.

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

The Butts Station Road / Kemp Woods Outfall drainage basin has experienced significant development in the past and is currently undergoing much new development. Although this watershed is well developed, it still contains several large, undeveloped tracts of land that can be expected to be developed in the future. This study addresses existing drainage and storm water issues, as well as expected future conditions.

An overall Master Drainage Plan study for this watershed was completed in October of 1985 by Gannett Fleming Corddry & Carpenter. The Gannett Fleming study recommended two crossing upgrades; replace the 54-inch diameter pipe under Elbow Farms Road with triple 5x5 foot box culverts and upgrade the triple 5x5 foot box culverts under Butts Station Road. Both recommendations were adopted by the city. The triple 5x5 foot box culverts under Butts Station Road were deemed to be inadequate to handle upstream runoff from future development. This 1985 study suggested that the City adopt one of three options: 1) Install another 5x5 foot box culvert; 2) Reduce the design storm requirement for this crossing; or 3) Provide additional detention facilities within the study area. It was also the recommended that the City widen the bottom of the natural channel from downstream of Kemp Woods subdivision to about 3,200 feet downstream of Butts Station Road. The City subsequently required developers to provide on-site detention to account for their increased runoff and to make improvements to the main channel for sections adjacent to their properties. Since the completion of the 1985 master drainage study the following development projects have been approved and or completed within the subject watershed:

1. Kemp Crossing Subdivision (1985)
2. Kemp Woods Subdivision (1987)
3. Hunningdon Woods Subdivision (1987)
4. Clearfield Estates Subdivision (1989)
5. Kemp Woods South Subdivision (1993)
6. Warrington Hall Subdivision (1999)
7. VDOT / Kempsville Road Improvements (2000)
8. Subdivision of Greystone (2002)
9. Ruth's Glen Subdivision (2004)

10. The Commons at Hunningdon Lakes (2004)
11. Sommerton Condominiums (2005)
12. Subdivision of Kemp Bridge (2005)

In addition to the 1985 Master Drainage Study, drainage studies for two of the neighborhoods within the subject watershed have also been completed. A drainage study for Norcova subdivision was completed in October of 2000 and it was determined that insufficient pipe sizes needed upgrading. A drainage study was also completed for the Kemp Woods Subdivision in December of 1999, following the flooding produced by hurricanes Floyd and Irene. The Kemp Woods Study was undertaken in response to citizen complaints about flooding.

Prior to the construction of Kemp Woods subdivision and according to the Master Drainage Plan, 55 acres of this neighborhood (located on the east side of the subdivision) drained to the Stumpy Lake Watershed. At the time of design of Kemp Woods subdivision approval was attained for the low-lying 55 acres to drain within the subject watershed, with the majority of this area going to Lake No. 2. During the 1999 study, conducted by the City of Chesapeake, it was found that the criteria used for designing the ponds within Kemp Woods (performed in 1986/87) was a 50-year, 6-hour duration storm. In 1991 the design return period for this type of facility was increased to a 50-year, 24-hour duration storm. This more stringent criterion produces a significantly larger quantity of storm water runoff and would call for larger lakes connecting to a larger outfall pipe. Due to space limitations for increasing lake sizes, the only real solution for alleviating the flooding in Kemp Woods lies with the design of the outfall which is to the south of the neighborhood. It was recommended during the 1999 study that the outfall from Kemp Woods subdivision be modified by separating incoming pipes, from different drainage areas, from that of the pipe discharging Kemp Woods Lakes. It was also recommended that future developments take into consideration the lake levels within Kemp Woods when designing their projects such that the future lake levels not exceed the existing lake levels.

Since these studies have been completed, there has been much new development in the subject watershed. Pipe upgrades within Norcova subdivision were constructed by the City resulting in better conveyance of storm water flows from this area. Just downstream of Kemp Woods subdivision, the pipe carrying the discharge from Kemp Woods Lakes has been separated from other incoming pipes. In addition, due to new subdivisions along the natural channel downstream of Kemp Woods subdivision, approximately 3,500 feet of channel and pipe improvements have been made. These changes alone have significantly reduced the high water levels in the area of Kemp Woods subdivision.

The east bank of the natural channel just downstream of Butts Station Road, referred to as "Butts Station Outfall," has low-lying contours that creating excess flooplain storage for this watershed. URS modeled the existing conditions utilizing this 'true' storage. In the future conditions modeling, URS modeled this section as if the east bank would be filled in to create a trapezoidal channel with side slopes of 2 horizontal to 1 vertical. There are no immediate plans for the City of Chesapeake to apply this fill, however, the City wanted to make sure that the trapezoidal channel would be sufficient to convey the necessary flow due to increased runoff from future development. If this area is filled it will reduce floodplain storage that currently is available. If the developer of the property on the east side of the outfall channel downstream of Butts Station Road is able to attain the proper permits to fill in this area, he/she may do so but will need to dedicate drainage easements along the ditch in order for the city to maintain the outfall channel.

The City of Chesapeake provided URS with several plan sets for projects that have been approved for construction but have not yet been constructed. 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' since the approval of the project assures its near-future

development. Furthermore, the City provided to URS several plan sets to be considered in the future conditions. These plans are still in the design phase and have not received an approval prior to the commencement of this study.

The City of Chesapeake surveyed selected points in the subject watershed at the request of URS. Part of the survey request was for current water surface elevations in existing lakes and ponds. URS evaluated the survey data and found three locations where the water surface elevations were higher than the invert of the discharge pipe for the respective lake. This indicated to URS that these locations might contain an outlet structure of sorts. After discussing these findings with the City, it was determined that the elevated lake levels were due to downstream sediment buildup or debris.

The first location was at the outfall of the Hunningdon Lake Subdivision (node 186). The outlet pipe at this location is a circular 36-inch reinforced concrete pipe. The City indicated that maintenance will be performed in this area to remove the cause of blockage. Another location of concern is at the Norcova lakes outfall (node 224). Double 24-inch by 38-inch horizontal elliptical pipes comprise the outfall, which was constructed as one of the Norcova (2000) study recommendations. City officials offered the explanation of known sediment build-up at the downstream end of these pipes as the cause of this downstream blockage. The City stated that maintenance needs to be continuous in this area due to this problem and that perhaps cleaning the downstream ditch should help longer term. The third location of concern is at the Kemp Woods Subdivision outfall lake (node 354). The discharge pipe out of this lake is a 34-inch by 53-inch horizontal elliptical pipe. The explanation for high water surface elevations in this area come from an eye-witness account of sediment dams downstream of this outfall. A citizen of Kemp Woods subdivision reported seeing rock check dams in the downstream channel. These dams have been temporarily placed due to the construction of Sommerton Condominiums and the subdivision of Kemp Bridge. Upon completion of all channel improvements downstream of Kemp Woods subdivision, the rock check damns should be removed, thus allowing runoff to flow normally.

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

Two modeling configurations, Existing and Future, were developed for this study as described below.

Existing — Existing watershed hydrology with the drainage system configured as it exists in 2005. Channels are modeled using their existing (2005) conditions as well. This is the "existing conditions" model. Several approved development plans were considered in the existing conditions model even though construction of these projects has not necessarily been completed prior to this study. The City of Chesapeake requested that the following plan sets be considered as 'existing' because they have been approved prior to the start of this study:

1. The Commons at Hunningdon Lakes
2. Ruth's Glen Subdivision
3. Sommerton Condominiums
4. Subdivision of Kemp Bridge
5. Warrington Hall Subdivision
6. Subdivision of Greystone

Future — Future watershed hydrology with the future drainage system configuration as envisioned by the City of Chesapeake. This is the "future conditions" model. Several development plans, still in the design phase, were added to the future conditions model and are listed below:

A. Stony Run Manor Subdivision
B. Subdivision of Westchester Estates
C. Arlington Meadows Subdivision
D. Hilltop Terrace Subdivision

Additional improvements were also added (largely to eliminate flooding at key locations, where feasible) to the future conditions. These improvements were developed during this study, are highlighted in Figure 8, and specifically include the following projects:

E. Warrington Hall Channel Improvements
F. Stony Run Manor / Westchester Estates Channel Improvements
G. Butts Station Road Outfall Channel Improvements

This configuration 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

In order to determine an appropriate starting water surface elevation for the hydraulic modeling, a hydrologic frequency analysis was performed on water surface elevations in the A&C Canal. 18 years of electronically recorded data was provided by the Norfolk District Corps of Engineers, dating back to 1988. This data was reduced to obtain an annual maximum series, which was analyzed using the HydroStat computer program (described on the web at http://www.cahh.com). The results of this analysis indicate that a starting water surface elevation of 2.3 feet (NAVD88) is appropriate for the hydraulic modeling.

Stable RUNOFF and EXTRAN runs were obtained for all modeling scenarios, with EXTRAN continuity errors well below 0.5 percent.

The GIS analysis prepared in support of this modeling indicates that the Butts Station Road / Kemp Woods Outfall (NS-2) watershed will increase from **34.03** to **38.34** 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 7 and 9 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 does not have to 'fix' all of the flooding represented by the histograms in the figures. Areas such as 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 do so. 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.

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.

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 D for both existing and future conditions. The blue shading in Tables D-1 and D-2 indicates locations where the maximum computed water surface meets or exceeds the ground elevation for the 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 D-1 and D-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 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 D-1 and D-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 D-1 and D-2, and 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. The City is aware of a few maintenance issues that are being corrected, such as the presence of erosion control check dams installed during construction projects downstream from the Kemp Woods subdivision, and siltation in some older drainage ditches.

One of the specific concerns addressed in this study is potential flooding in Kemp Woods Lake No. 2—an area where citizens have had several complaints about flooding. Due to the expense and complexity of SWMM modeling, the City has focused on existing and future conditions for this Master Drainage Plan Update. Past flooding resulting from drainage system configurations that no longer exist was not evaluated in this study. Computed peak water surface elevations at Lake No. 2 for existing and future conditions are presented in Table 1.

Table 1. Peak Water Surface Elevation, Kemp Woods Lake No. 2

Modeling Configurations	Peak Water Surface Elevations (ft)	
	10-yr	**50-yr**
Existing	11.00	12.21
Future	10.92	12.03

Notes:
1. Water surface elevations computed at node 340 (i.e. Lake No. 2).
2. Vertical datum NAVD88.
3. The minimum roadway elevation within Kemp Woods subdivision is 11.60 which can be found at the end of Skyline Circle. Other low elevations of 12.10 can be found throughout the subdivision.

As indicated in the table, the peak 10-year water surface elevations are below the lowest roadway grade of 11.60 feet, which can be found at the end of Skyline Circle. The modeling also indicates that other than for a few low-lying lots in this vicinity, Lake No. 2 is adequate to provide flooding protection from the 50-year storm.

The City of Chesapeake has flood storage requirements relating to back-to-back storms. Simply stated, detention and retention facilities must recover a substantial portion of the available flood storage 48 hours after a 10-Year Type II design storm event. A special SWMM analysis was constructed and run to produce the results indicated in Table E-1. As shown in the table, all of the storm water basins in the

watershed should recover flood storage capacity adequately within 48 hours after the onset of a 10-year Type II storm.

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. Three specific projects were conceived and incorporated into the modeling during the course of this study to reduce the effects of flooding within the subject watershed. These projects are by no means exhaustive, but 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 three projects are shown in Figure 8, and are included in the future modeling.

1. Warrington Hall Channel Improvements

This project is estimated to cost approximately **$ 670,495** in 2005 dollars, if constructed after surrounding land improvements are in place. If constructed as part of adjacent development projects, the cost to the City could be minimal or insignificant.

Construct improvements to the east side of the ravine adjacent to Warrington Hall. Improvements to the ravine, starting just south of Miriam Drive (node 418) and continuing along ravine for approximately 2,350 linear feet (node 470), include widening the channel bottom to 20 feet while maintaining a side slope of 2 horizontal to 1 vertical. The channel shall be maintained so as to create a Manning roughness factor of 0.04. These channel improvements will provide increased conveyance capacity and flood storage in the ravine.

2. Stony Run Manor / Westchester Estates Channel Improvements

This project is estimated to cost approximately **$ 549,094** in 2005 dollars, if constructed after surrounding land improvements are in place. If constructed as part of adjacent development projects, the cost to the City could be minimal or insignificant.

Construct improvements to both sides of the natural ravine that travels between the future developments of Stony Run Manor and Westchester Estates. Improvements to the ravine, starting at the end of Warrington Hall Channel Improvements (node 470) and continuing along ravine for approximately 1,100 linear feet to Butts Station Road (node 488), include widening the channel bottom to 20 feet while maintaining side slopes of 2 horizontal to 1 vertical. The channel shall be maintained so as to create a Manning roughness factor of 0.04. These channel improvements will provide increased conveyance capacity and flood storage in the ravine.

3. Butts Station Road Outfall Channel Improvements

This project is estimated to cost approximately **$ 521,829** in 2005 dollars. The cost to the City can be reduced if coordinated and constructed as part of adjacent development projects.

Construct improvements to the natural ravine downstream of the Butts Station Road outfall. Limits of improvements include the east side of the ravine from Butts Station Road (node 490) to approximately 1,200 linear feet downstream (node 508) and the west side of the ravine starting at Butts Station Road (node 490) to approximately 550 linear feet downstream. The improvements to the ravine include widening the channel bottom to 25 feet while maintaining side slopes of 2 horizontal to 1 vertical. Channel shall be maintained so as to create a Manning roughness factor of 0.04. These channel improvements will provide increased conveyance capacity and flood storage in the ravine.

The goal of this type of study is not to relive *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.

Contact Information

Mr. Sam Sawan, PE (757.382.8267) served as the project manager for the City of Chesapeake on this project. Mr. Bryant Wilkins was the Section 22 contract manager for the Corps of Engineers, Norfolk District. Mr. Michael Barbachem, PE, DEE, CFM (757.499.4224) was the project manager for URS. The modeling evaluations and report were produced by Stephanie Hood, EIT and John Paine, PE, PH, CFM (757.873.0559).