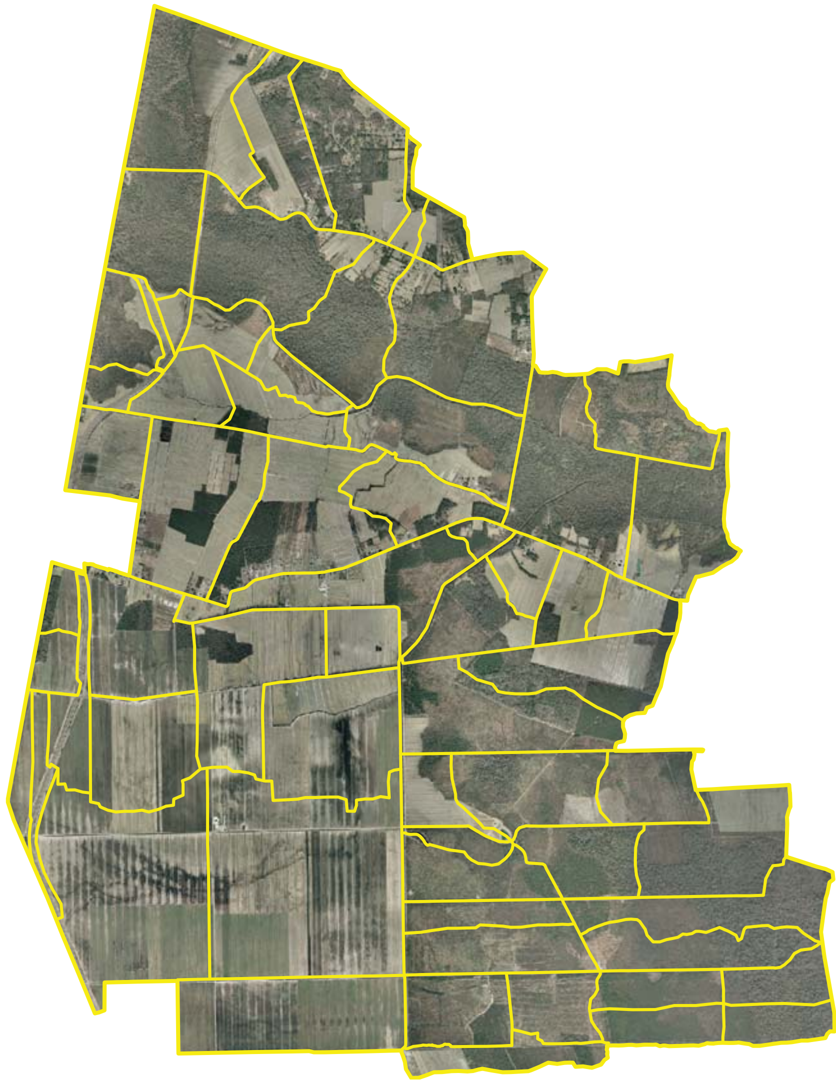
Storm Water Management Model

Southern Chesapeake 4 Watershed Study



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Chesapeake
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URS
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Executive Summary

Engineers from the City of Chesapeake and URS Corporation have completed a drainage study for the Southern Chesapeake 4 Watershed using the Storm Water Management Model (SWMM) computer program.

URS Corporation (URS) has prepared master drainage plan models for numerous watersheds within the City, using PCSWMM computer models. PCSWMM is a desktop software system that facilitates data processing and evaluation based on the EPA SWMM model computational engine. Because the results are based on the EPA computational engine (without modification), they are completely consistent with the EPA version of the model.

Because the SC-4 Watershed consists of very large agricultural, wooded, and wetlands tracts, and because plans for future development are relatively small, a simplified watershed planning approach was used for this study. The Nature Conservancy is purchasing land in this area for conservation. There are large wetland and wooded tracts, and very large farm plots. The drainage infrastructure is simpler than the typical systems that have been modeled elsewhere in the City.

URS prepared large-scale PCSWMM models for this study that will be useful for identifying existing and potential future drainage problems at major culverts and channel locations within the study area. Significant culverts at roadway crossings and major channel cross sections were modeled as in the City's other PCSWMM models, however this model has larger and more generalized components than the other studies. The modeling subcatchments are as large as several hundred acres each. The intent was to model the backbone of the drainage system in the SC-4 watershed, without needlessly over-detailing the study.

The models reflect existing and some future development within the watershed. This study does not provide recommendations for Master Drainage Facility (MDF) improvements, but otherwise follows the Master Drainage Plan methodology that has recently been applied in other Chesapeake watersheds—simplified to reflect the conditions in the watershed and the available budget.

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, although not modeled as part of this abbreviated study, can be carefully evaluated with respect to their potential impact to the entire watershed, 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.

Open channels and ditches in this watershed provide vital floodplain storage that must be carefully protected. The maintenance of floodplain storage along open channels and in low-lying areas is strongly recommended. If floodplain storage is lost through filling or poor maintenance, property and street flooding will increase. The City can protect these areas by enforcing the existing floodplain ordinance and through the acquisition of impoundment easements as future projects are considered.

The maximum computed water surface elevation at each modeled node, and peak computed discharge at each modeled link are presented in Appendices C and D, respectively, for existing and future conditions.

All the data files, including GIS coverages, modeling data and output, and report figures and text, are provided as deliverables for this project. The intent is that competent engineers may use this data in the future to expand upon the SC-4 models, providing a good starting point for future studies.

Engineers must exercise good judgment in how these modeling results are applied in the future. This study comprises an excellent starting point for future analyses, but was conducted with limited funds and with limited data. Future use of these models should involve collecting and verifying critical data based on the intent of the analyses.

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 to conduct a study of the Southern Chesapeake 4 Watershed covering, approximately 16,715 acres. The Southern Chesapeake 4 Watershed is located in southeastern Chesapeake, and is bordered on the south by the State of North Carolina. The majority of runoff from this watershed discharges into the Northwest River, to the east.

The size and extent of the existing land parcels, and the rural character of the watershed and drainage infrastructure (much of which was previously unmapped), made this a difficult study on which to collect surveying and field data. Some of the ‘roads’ extend for miles beyond the nearest access point, and survey crews had to run long level loops and expend considerable effort just to reach certain culvert crossings. Some of the dirt roads had washouts that prevented crews from driving as close to the sites as they would have liked. Despite these challenges, a substantial amount of survey data was collected by City Surveyors, as indicated in Appendix B.

The watershed was delineated into 64 subcatchments in order to adequately distribute point sources for inflow—on average approximately 261 acres per subcatchment. No Master Drainage Plan (MDP) study had been performed previously, and very little data existed for the storm infrastructure prior to this effort.

Approximately half of the Southern Chesapeake 4 Watershed is covered with large, rural farm tracts; the remainder is predominantly forest and heavily wooded tracts. Comparatively speaking, there is little anticipated future development, and conservation interests are buying properties to preserve undeveloped conditions. This study addresses existing drainage and storm water issues, as well as expected future conditions, from a large-scale perspective.

Water quality modeling was not included in the scope for this study.

The City of Chesapeake provided URS with several plan sets for projects within the watershed, some of which have been approved for construction but may not yet have been completed. As directed by the City, URS modeled these as 'existing' conditions. Some of these developments 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 the plan sets, survey data, and GIS data as well as the data retrieved during field inspections to extract channel and infrastructure information, such as pipe inverts, type and sizes, and channel characteristics, throughout the watershed.

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 Watershed Study Report presents the findings of the application of this methodology to the subject watershed.

Treatment of Nodal Flooding

The issue of how to handle nodal flooding is important when using or interpreting any rainfall-runoff model, including SWMM. Loosely speaking, nodal flooding occurs when a computed water surface elevation exceeds the maximum defined depth at a point in the system (referred to as a "node").

In previous versions of SWMM (Versions 4.x and earlier), the water leaving the node was treated as an "escape" from the system. However, the treatment of nodal flooding was enhanced in SWMM Version 5 by introducing "nodal ponding" and "nodal surcharge" capabilities. The nodal ponding option allows the modeler to specify a constant "ponding area" over which nodal surcharges are stored as they escape from the node, then released back into the system as water surface elevations recede. This nodal ponding capability can produce more reliable water surface elevation computations due to the re-introduction of nodal flooding volumes and their continued downstream routing through the drainage system.

The option to compute nodal ponding in SWMM necessitates an approach to treat or develop the ponding area for each node, subject to two considerable limitations. First, the ponding area increases with depth, and in fact at some depth the ponded volume will actually combine with other nearby nodes such that deciding which node has what portion of the surface flooding becomes arbitrary at best. Secondly, it is not feasible to spend the time performing elaborate delineations at each node to compute a constant ponding area that is approximate at best, requires judgment regarding how much area to assign to which node, and ultimately varies with depth. In many locations, the situation is further complicated—when stormwater flows up and out of the ground, it runs down a gutter or downhill flow path to some other location.

SWMM is a one-dimensional model—it can only compute flow depth, discharge and related properties along one-dimensional lines through the drainage network. It cannot compute lateral variations in the flow (such as can be accomplished with two-dimensional surface-flow models). Even if it were possible to precisely compute the ponding area at each node, we are still limited by the use of a one-dimensional model. It is difficult to determine a ponding area with accuracy when the computed water surface elevation exceeds the ground elevation. The problem is further complicated by the difficulty in determining the nominal "ground elevation" in a one-dimensional model.

URS has developed an approach to handle nodal flooding using SWMM Version 5, which we are using on many similar studies. The approach used is to divide the total watershed area by the number of modeling nodes to develop an average ponding area, which is then applied to all nodes that are not directly modeled as storage nodes. This approach is simple, but effective, and because the surface flooding is re-introduced into the drainage system as flood levels decrease, it gives a reliable basis upon which to compute water surface elevations in these models. In some locations, storage nodes are used to make the hydraulic routing results stable, and the nodal ponding area is a function of the storage node characteristics (rather than the average ponding area as described above). For most nodes, the average ponding area is applied in the SWMM models created for this study.

Vertical Datum

Unless specifically stated otherwise, the **North American Vertical Datum of 1988 (NAVD88)** was used throughout this study.

Modeling Configurations

Two modeling configurations—Existing Hydraulics with Existing Hydrology (Scenario 1), and Existing Hydraulics with Future Hydrology (Scenario 2)—were developed for this study as described below.

Scenario 1 Existing watershed hydrology with the drainage system configured as it existed in 2009. Channels are modeled using their existing (2009) 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, provided by the City that was used in the existing conditions model (the list includes projects that have been constructed as well as approved projects not yet constructed):

1. Subdivision Development Plan of Property of Stanley Yeskolske - Blackwater Farms, Inc.
2. Drainage Plan for Patrick D. Propst - Portions of Parcels 'G'
3. Subdivision Development Plan for 2900 Seven Eleven Road Subdivision
4. Subdivision Plan of Property of Dorothy Waller
5. Subdivision Plan of Legends Landing Douglas Road

6. SDMP Subdivision Plan of Lot 7A - Tatem Farm
7. Soil Drainage Management Plan of Lots C & D - James A. Murphy, Jr. Property
8. Douglas Farms Subdivision
9. Subdivision Construction Plan of Glencoe Crossing - Property of Ernestine Lister
10. Soil Drainage Management Plan of Jerry Old Property
11. Drainage Divides for Outfalls & SWM - Route 17
12. U.S. Route 17 - VDOT plans

Scenario 2 Future watershed hydrology with the drainage system configured as it existed in 2009. Channels are modeled using their existing (2009) 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.

Modeling Results

The maximum computed water surface elevations at each modeled node and computed peak discharge at each modeled link are presented in Appendices C and D, respectively, for existing conditions.

Stable SWMM runs were obtained for all modeling scenarios. Continuity errors ranged from low to very low, with essentially zero computed hydrologic continuity for the runoff volumes. As expected, hydraulic routing continuity is higher than typically seen in more detailed models, due to the comparatively large links and subcatchments. URS senior engineers used PCSWMM to review dynamic hydraulic grade lines, checking the hydraulic routing for potential stability problems or any type of flow anomaly. During this QA/QC procedure items were found and addressed, so the final modeling results should be reliable.

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 and wide floodplain environment, the water surface elevations in the upper portions of this 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 4 Watershed will increase from **5.48** to **5.85** 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 stormwater runoff, which have been incorporated into the future conditions models.

Figures 7 and 8 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 woodlands, deep ravines, farm fields, 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 often result from maintenance problems such as a clogged or collapsed 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 preliminary computer models should be carefully scrutinized.

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 maximum computed water surface elevations at each model node are presented in Appendix C for existing conditions. The blue shading in Table C-1 indicates locations where the maximum computed water surface meets or exceeds the ground elevation for that node. Some of these nodal flooding locations are very small quantity (for the total surrounding land area) or short duration events. In these SWMM 5 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) *and the flooded water is re-introduced into the model for subsequent downstream routing,* as explained in the Treatment of Nodal Flooding section above. If flooding occurs at a choke point in the system, downstream (or nearby) nodes may have computed maximum water surface elevations less than what can actually be expected due to the volume of water being 'held' upstream. With the introduction of Nodal Ponding in SWMM 5, this phenomenon is of less concern than it was in older versions of SWMM. Where computed water surface elevations exceed the ground elevation in these models, water surface elevations in the vicinity should be considered 'approximate'. The main purpose of this ponding approach is to account for local flooding volumes and re-introduce stored water back into the drainage system as water surface elevations recede.

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). *Table* C-1 has 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 SWMM routing computations are performed at one-second (or so) intervals, and the output 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 SWMM output data on the other hand contains a summary of the *exact* peak values. The SWMM output file summaries were used to prepare Tables C-1 and D-1, 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 stormwater 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. Debris can be a significant problem in natural channel outfall systems, and should be monitored carefully to ensure that these systems function properly.

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.

Contact Information

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