# Cooper's Ditch Watershed

# Technical Memorandum

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# Technical Memorandum

# Cooper's Ditch Watershed SWMM Conversion

**Chesapeake, VA**

**URS No. 11657815**

## Executive Summary

Engineers from the City of Chesapeake and URS Corporation have converted the Cooper's Ditch Watershed computer models to run under the latest version of EPA's Storm Water Management Model (SWMM). The original SWMM 4 models were completed by URS (with assistance from City of Chesapeake and U.S. Army Corps of Engineers) in 2007.

EPA's SWMM model has been continually developed and refined over the past 40 years, and is well suited for analyzing urban stormwater management and drainage issues. After updating SWMM's FORTRAN code progressively for 30 years, the developers of the EPA SWMM engine decided to recode the entire program in the C+ programming language. The conversion involved writing tens of thousands of lines of computer code from the ground up.

In practical terms, the two biggest differences between the older and newer versions of SWMM are:

- Flooding is no longer assumed to leave the drainage system when the computed water surface elevations are higher than the ground elevations (this was a significant limitation in SWMM Version 4 that required considerable attention to accommodate), and
- The new PCSWMM shell has simplified data preparation and analysis capabilities, and is much better integrated with Geographic Information Systems (GIS) than older versions.

The City has a considerable investment in its SWMM models and studies, and uses these tools to solve flooding problems, identify Master Drainage Plan (MDP) improvement projects, set Capital Improvements Project budgets, negotiate with private-sector developers, and help meet certain regulatory criteria in its existing and forthcoming stormwater management permits.

In order to extend the useful life of these models and make them available to users who are only familiar with the most current software tools, the City asked URS to convert older SWMM models to current versions of SWMM. The process also involved preparing figures and tables representing modeling conditions and results to match the formats that have become standardized in recent years.

Recently the City requested that URS incorporate additional plan sets information—that became available after the original study was completed—into the existing and future conditions models. The addition of these new plans alters the results of the original study. These alterations led to changes in recommended improvements that have been incorporated into this updated study.

This Technical Memorandum contains updated figures and tables, and should be viewed as an update and supplement to (rather than a replacement of) the original 2007 report. The original report contains photographic documentation, as well as other useful information, that is not duplicated in this document.

The analytical procedure is still based on computing localized flood volumes resulting from design rainfall events such as the 2-, 5-, 10-, 25-, 50-, and 100-year storms. Alternatives for improvements are then given further consideration based on construction feasibility and financing constraints which the City understands as of 2012.

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

Maintaining these models is particularly challenging because development and changes in the watershed are ongoing and endless. All models are prepared with limited information. As new projects, studies, and plans are undertaken, additional details become available—that were not available when the original master drainage plans were prepared. These models and documents require considerable effort and lead time to produce, and represent snapshots of conditions at a particular time. The deliverables for this assignment include all the SWMM modeling and GIS files completed for this assignment. Engineers should easily be able to use this data in the future, but must use good judgment in verifying modeling details that may be critical to their particular projects.

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 has converted all of the Cooper's Ditch Watershed Master Drainage Plan Update (MDPU) models to run using EPA SWMM Version 5—specifically Version 5.0.18. URS has also incorporated new plan sets, provided by the City and listed elsewhere in this report, in order to create an updated, existing conditions version of the 2007 study.

The original MDPU was completed in April 2007. Although a few drainage projects have been either completed or initiated within the watershed since then, the major storm water routing configuration remains essentially the same as it was in 2007.

Three scenarios are modeled:

**Scenario 1** – (Updated for 2012 using the 2007 SWMM model) <u>Existing land cover</u> conditions <u>with the existing drainage</u> system in a well-maintained state. The City of Chesapeake requested certain plan sets be included for this SWMM conversion process. The following is a list of plan sets and studies, provided by the City for this update, that were used in the existing conditions model:

1. Chapel Hill Estates Phase 1
2. Edinburgh Erosion and Sediment Control Plans
3. Edinburgh CC2 - Phase One

4. Edinburgh Commons - East (E8)
5. Edinburgh Commons West
6. Edinburgh PUD REGIONAL COMMERCIAL (RC)
7. Edinburgh Self Storage
8. The Home Depot at Edinburgh (Subdivision)
9. The Home Depot at Edinburgh (Site)
10. Final Site Plan Wal-Mart
11. Final Subdivision Plan Wal-Mart
12. Fentress Outfall
13. Great Bridge Marketplace
14. Glenwood Shopping Center Option 5 Map
15. Glenwood Shopping Center 10 Year Storm Conditions Map
16. Great Bridge / Hickory YMCA
17. Sutherlyn Estates
18. Windlesham Plantation
19. Glenwood for Hodges Farm Associates
20. Commercial Property of Glennwood Subdivision
21. United States Post Office (Great Bridge Station)
22. Great Bridge Commerce Center
23. Great Bridge Commerce Center (exist and propose drainage)
24. Three Intermediate School
25. Berkshire Estates

**Scenario 2 –** Future watershed hydrology with the added future drainage system as it is anticipated by the City. The watershed imperviousness, from the 2012 Scenario 1 model, was increased as outlined by the City's 2010 Adopted Land Use Plan. For the most part, channels and conduits are configured as they exist in 2012 in a well-maintained state, however, the addition of two future plan sets, identified by the City, have been added this scenario. This is the "Scenario 2" model. This scenario will show the flooding effects of the existing drainage system (with the added future plan sets in place) due to future land use development. The following plan sets, provided by the City, have been added to this Scenario 2:

1. Hanbury Manor Subdivision
2. Jordan Hall @ Johnstown Subdivision

**Scenario 3** – <u>Future land cover</u> conditions, allowing for increases in imperviousness due to future development, <u>with an improved drainage</u> system in a well-maintained state. Some of the improvements identified in the 2007 study have now been either constructed or designed, and for that reason—coupled with the new plan data—the 2012 scenarios are significantly different from the 2007 scenarios. Scenario 3 comprises the future watershed hydrology with the future drainage system configured as envisioned by the City of Chesapeake and URS in 2012. This scenario incorporates the drainage from Scenario 2 along with any recommendations from the engineering team to help eliminate flooding on both Local and Master Drainage Facility levels. Local Drainage facilities serve less than 320 acres, whereas Master Drainage facilities serve 320 or more acres.

The recommended improvements should significantly reduce flooding at key locations, where feasible, for future conditions. These improvements were developed during this study, are highlighted in Figures 10, 10a, 10b, 10c, and 10d, and specifically include the following projects:

1. Battlefield Blvd Drainage Improvements,
2. Caroon Farms Tributary Drainage Improvement,
3. Hillwell Road Outfall Improvements, and

4. Poplar Ridge Lake Outfall Improvements.

This scenario depicts future conditions with strategic drainage and stormwater improvements in place. Additional details and descriptions regarding the improvements are presented elsewhere in this report.

Flooding at node 343 could result from future development—which increases imperviousness—*if* additional stormwater controls are not constructed. This potential future flooding should be offset by new state stormwater management regulations that incorporate runoff reduction methodology, and by required on-site stormwater management facilities, particularly between nodes 149 and 151.

## Conversion from SWMM Version 4 to 5

URS engineers went through the following steps to complete the conversions:

- Transfer SWMM 4 models and related GIS data from original folder to new project folder.
- Convert old models into EPA SWMM 5 using SWMM Conversion tool.
- Open files with PCSWMM version 5.0.018.
- Import X, Y coordinates for nodes, links, and subcatchments using GIS data. Carefully examine input files for new data that must be added manually (the new SWMM software requires more data than the original software to take advantage of new software features).
- Change dynamic wave options to take advantage of new ponding options (ponding settings, initial terms, variable time steps, etc.).
- Run new models, check and fix errors and warnings.
- Check continuity of models (runoff and routing) to make sure models are numerically stable, and that there are no convergence/oscillation problems.
- Thoroughly check and revise input data for weirs and orifices, to accommodate differences between SWMM versions 4 and 5.
- Final QA/QC all models.

## Treatment of Nodal Flooding in SWMM 5

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 new 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. 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. This approach serves as an economical screening, in that most nodes do not have nodal ponding or flooding.

## Vertical Datum

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

## Modeling Results from the Conversions

In general there is very good agreement between the Version 4 and Version 5 SWMM model results for this watershed. Appendix C presents an "apples-to-apples" comparison of the differences that result purely from the upgrade (The addition of plan sets, as listed in the description under Scenario 1 above, have NOT been incorporated in the results shown in Appendix C). The biggest differences—as expected—are at locations where the ground is low (compared to surrounding ground elevations), and the maximum computed water surface exceeds the localized ground elevation. In these locations the Version 5 SWMM results should be more accurate than the prior results, for reasons described in the "Treatment of Nodal Flooding in SWMM 5" section above.

There is a 98.9-percent agreement between the SWMM 4 and 5 model runs for this watershed (see Table C-1). Generally speaking this represents good agreement between the old and new models. A visual appreciation of the similarities and differences between the SWMM 4 and 5 results can be seen by comparing the flood histogram in figures C-1 through C-4 in Appendix C.

## Master Drainage Plan Improvements (2012 Update)

Over the years, since the original (2007) study was completed, several drainage and stormwater management projects have been completed, are under design, or are being constructed. Those projects, and the impact of some private developments, afford the City an opportunity to update the Master Drainage Plan based on more recent conditions and information.

The City and URS engineers worked closely together to develop four projects to alleviate flooding in the watershed. These four projects are shown in Figures 10 through 10d, and are included in modeling Scenario 3. Refer to Figures 6, 7, and 10 through 10d of this report to find node and link numbers and to view the locations of improvements that are referenced in the following project summaries. Due to the large amount of nodes and links, as well as label text size, please refer to the GIS files provided with this submittal to better view all of the Node and Link details.

## 1. Battlefield Blvd Drainage Improvements

The following recommended improvements are based on the conveyance of a 10-Year design storm:

1. Node 263.1: Construct a dry basin with a top-of-bank area equal to 0.85 acres and side slopes equal to 3H:1V. Depth from the bottom elevation to the top-of-bank should be 4.0 feet (effective storage), and the total storage volume should be approximately 3.0 acre-feet.
2. From Node 263 to 263.1: Construct one (1) 36-inch diameter RCP connecting junction node 263 to the dry basin. This dry basin will serve as relief storage for the drainage system at Battlefield Boulevard.
3. Node 263.2: Lower the invert to 14.00 feet. (Exist. Elev. 14.66 feet.)
4. From Node 263.2 to 263.5: Replace existing 18-inch pipe with one 30-inch RCP.

## 2. Caroon Farms Tributary Drainage Improvement

The following recommended improvements are based on the conveyance of a 50-Year design storm:

From Node 149 to 151: Increase channel depth to 4 feet and widen the channel bottom to 10 feet with side slopes equal to 2H:1V.

Flooding at node 343 could result from future development—which increases imperviousness—*if* additional stormwater controls are not constructed. This potential future flooding should be offset by new state stormwater management regulations that incorporate runoff reduction methodology, and by required on-site stormwater management facilities, particularly between nodes 149 and 151.

## 3. Hillwell Road Outfall Improvements

The following recommended improvements are based on the conveyance of a 50-Year design storm:

1. Node 559: Increase total detention storage to 8.0 acre-feet (estimated existing storage is 2.9 acre-feet).
2. Node 559: Lower the invert to 15.58 ft. (Exist. Elev. 16.58 ft.)
3. Node 681: Lower the invert to 15.00 ft. (Exist. Elev. 15.68 ft.)
4. Node 561: Lower the invert to 14.50 ft. (Exist. Elev. 15.21 ft.)
5. From Node 559 to 681: Replace existing three 22-inch x 34-inch elliptical pipes with three 36-inch RCPs.
6. From Node 681 to 561: Re-grade and maintain channel bottom width of 4 feet, with side slopes 2H:1V.
7. From Node 561 to 643: Replace existing 30-inch RCP with two 42-inch RCPs.

8. From Node 643 to 565: Replace existing 36-inch RCP with two 42-inch RCPs.
9. From Node 565 to 567: Replace existing 36-inch RCP with two 42-inch RCPs.

### 4. <u>Poplar Ridge Lake Outfall Improvements</u>

The following recommended improvements are based on the conveyance of a 50-Year design storm:

1. From Node 913 to 917: Add two 36-inch RCPs parallel to the existing 30-inch RCP at the outfall from Poplar Ridge Lake (Node 913).
2. From Node 917 to 919: Add two 36-inch RCPs parallel to the existing 36-inch RCP.

## Items to Be Considered or Addressed in Future Modeling

Unless clearly indicated otherwise, one important caveat to keep in mind is that the system as modeled for this study assumes a well-maintained system. Debris, sediment, pipe collapses and other maintenance issues can cause very real flooding that must be addressed. In this respect, this study highlights capacity issues rather than maintenance issues (which are best resolved from inspection or citizen reports). There is good reason to create the models in this manner. If poor maintenance conditions are modeled, the capacity problems could easily be masked to the extent that public funds could be spent unnecessarily. For this and other practical reasons, FEMA requires that drainage systems be modeled in a well-maintained state.

These models should also be useful for obtaining starting hydraulic grade line elevations for design purposes on smaller development projects, and for designing stormwater management BMPs on specific sites. URS is providing the models completed for this study to the City in the hope that future engineering efforts will build upon this effort. Engineers should not assume that the data contained in these models and GIS files is correct, and must verify all data that could be critical to their specific projects.

*Findings or recommendations contained herein do not constitute Corps of Engineers approval of any project(s) or eliminate the need to follow normal regulatory permitting processes.*

## Contact Information

Sam Sawan, PE, CSM and Rachel Friend, PE (757.382.6101) served as the project manager and project engineer for the City of Chesapeake on this project. John Paine, PE, PH, CFM was the project manager for URS. The modeling evaluations were produced by Hai Tran, PE. Report writing and QA/QC was provided by John Paine and Stephanie Hood, PE. Additional production assistance was provided by Libby Ludwig (757.873.0559).