Storm Water Management Model

New Mill Creek Watershed MDPU

(New Mill 3&4)

Master Drainage Plan

November 2011

Chesapeake VIRGINIA
Department of Public Works

URS
URS Corporation

Table of Contents

Executive Summary 1
Background 2
Citizen Input 3
Methodology 4
Treatment of Nodal Flooding 4
Vertical Datum 5
Modeling Configurations 5
Modeling Results 6
Master Drainage Plan Improvements 8
Master Drainage Plan Caveats 10
Items to Be Considered or Addressed in Future Development 11
Contact Information 11

Figures

Figure 1. New Mill Creek 3&4 Watershed MDPU Map 12
Figure 2. Soils with Wetlands Overlay 13
Figure 3. Existing Conditions Subcatchments with Shaded Imperviousness 14
Figure 4. Future Conditions Subcatchments with Shaded Imperviousness 15
Figure 5. Subcatchments with Potential Increase in Imperviousness 16
Figure 6. Link-Node Diagram – Existing Conditions and Surveyed Locations 17
Figure 7. Link-Node Diagram – Future Conditions 18
Figure 8. Flooding for 10-Yr and 50-Yr Storms: Existing Hydrology, Existing Drainage 19
Figure 9. Improvements with Wetlands Underlay 20
Figure 9a. Improvements (Close-up) 21
Figure 10. Flooding for 10-Yr and 50-Yr Storms: Existing Hydrology, Existing Drainage with Improvements 22

Tables

Table C-1. Maximum Water Surface Elevations: Existing Conditions C-1
Table C-2. Maximum Water Surface Elevations: Existing Conditions with Improvements C-9
Table D-1. Peak Discharge: Existing Conditions D-1
Table D-2. Peak Discharge: Existing Conditions with Improvements D-8
Table E-1. Existing Total Nodal Inflow Volumes E-1

Appendices

A. Photographs A-1
B. Survey Data B-1
C. Maximum Water Surface Elevations C-1
D. Peak Discharges D-1
E. Total Inflow Volumes E-1

Storm Water Management Model

New Mill Creek Watershed MDPU

(New Mill 3&4)

Chesapeake, VA

URS Nos. 11657980

Executive Summary

The City of Chesapeake (City) and URS Corporation (URS) have completed a drainage study of the New Mill 3&4 Watershed 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 potential 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 estimated existing and anticipated future land use, and locations and volumes of computed flooding are identified in the modeling.

After analyzing existing and potential problems in this watershed, the engineering team has identified two specific projects that can alleviate existing flooding in the subject watershed.

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 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 existing-with-improvements 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.

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 on the area of New Mill 3&4 Watershed covering approximately 1855 acres.

The New Mill 3&4 Watershed is located in western Chesapeake and is bordered on the north by Deep Creek watershed, on the west by New Mill Creek 1&2 watershed, on the east by Camden Mills Watershed, and on the south and southeast by Bells Mill Creek watershed. Runoff from the New Mill 3&4 Watershed discharges into the Southern Branch of the Elizabeth River.

This watershed (New Mill Creek 3&4) is hydraulically connected to the New Mill Creek 1&2 and Bells Mill Creek watersheds at New Mill Creek and Herring Ditch, respectively. Because studies of these two watersheds had been completed and updated previously, URS engineers and City engineers combined the three watersheds into one comprehensive SWMM model encompassing all three of these watersheds.

The New Mill 3&4 Watershed was delineated into 110 subcatchments in order to compute and distribute runoff throughout the entire watershed. The drainage system was assigned with 283 nodes and more than 290 links, providing sufficient detail and modeling resolution for master drainage planning purposes. Overall, the New Mill 3&4 Watershed is largely agricultural and contains several large, undeveloped tracts of land that are expected to be developed in the future. This study primarily addresses existing drainage and stormwater issues, as well as it will help City Engineers evaluate potential future developments.

Three drainage studies, Dominion Commons (2004), New Mill Basin (2004), and Grassfield Outfall NM_3 (2006, updated in 2008), were previously completed within this watershed, as summarized below.

The Dominion Commons Study was completed in September of 2004 by Engineering Services, Inc. The study concentrated on the proposed development of approximately 75 acres. The study concluded that the Dominion Commons development with its onsite retention and detention systems does lower the hydraulic grade lines for the design storms. The detention systems proposed within the development are in accordance with the requirements set in the Master Drainage Study. The improvements downstream of the outfall points from Dominion Commons were improved in accordance with the Master Drainage Plan.

The New Mill Basin Study was completed in November of 2004 by Engineering Services, Inc. This study focused on combining subbasins 930, 935, 940, 945, 950, and 955 into one single basin with an adequately-sized outfall and drainage system which would allow for logical development in the future. The study suggested that improvements should include widening and deepening the ditch system along the west side of Shillelagh Road, and eliminating numerous driveway culverts.

The Grassfield Outfall NM_3 Study was conducted by Aquarius Engineering. The study was originally completed in March of 2006 focusing on the development of approximately 375 acres, and then revised in December, 2008 to accommodate the addition of 60 acres of the Majestic Estates Subdivision Plan and a modification of the outfall channel at Cedar Road. According to the analytical result, no improvement was required.

In addition to the previous studies, the City of Chesapeake provided URS with plan sets for projects within the New Mill 3&4 Watershed—some of which have been approved for construction but have yet to be 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 make its near-future development likely.

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 invert elevations, pipe type and size, and channel characteristics, throughout the watershed.

Citizen Input

In addition to providing plan sets, past studies, and surveys, the City also conducted several meetings (at City Hall and in the field) with local farmers who have experienced significant drainage and flooding problems in recent years. The farmers provided valuable input about specific events and the response of the drainage system, as well as the hydrology of the watershed.

- Several farmers reported frequent flooding from moderate rainfall events. They all reported that this flooding did not occur prior to the development of the WalMart property, which they believe has caused drainage to back up onto their properties. The New Mill 3&4 Watershed is very flat, so reduced outfall capacity can exacerbate channel and property flooding far upstream.
- Several farmers reported that the extent of the flooding is widespread and prolonged enough to drown crops. They provided photographs taken from Shillelagh Road on 14 June 2006, and marked the photo locations on a large map.
- They all reported that it can take several days for the heavy flooding from moderate to intense storms to dissipate along Shillelagh Road.
- The farmers are aware of vegetation and maintenance issues and their impacts on drainage. One problem is that these tracts are largely rented out, and the rental farmers till and plant too close to the ditch banks.
- Mr. Pearce reports that a contractor installed four culverts to drain his property to the ponds at Grassfield High School (with his permission). Mr. Pearce reports that the culverts did not work, and he must block the ditches to protect his farmland, because the flows backing up from these culverts are drowning and killing his crops.
- Mr. Spruill reported that during a recent heavy rain he went to the culvert behind the WalMart property and noticed that the ditch on the north side of Cahoon Parkway was dry, and that there was a substantial backup of flow in the ditch south of Cahoon Parkway. The farmers believe this outfall is too high (and filled with sediment). Even small rainfalls fill this shallow ditch.
- Mr. Spruill also noted frequent flooding on his property, as the drainage has nowhere to go (due to the shallow ditch).
- Several farmers indicated it can take 7 to 10 days for these fields to dry out after a heavy rainfall.
- Several farmers indicated that they believe the outfall culvert under Dominion Boulevard near the intersection with Shillelagh Road is blocking flows and causing backups in the upstream direction (to the south). They reported a Christmas tree blocking the culvert in the past, and believe the culvert is too high.

- Several farmers indicated that a storm in October 2010 resulted in heavy flooding on Vincek Way and caused street closure.
- Mr. Collins reported that flows from Herring Ditch back up to the north.
- Mr. Collins said that dry soils in the farm fields shed runoff almost like clay rather than infiltrating as might otherwise be expected.

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 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 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 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.

Vertical Datum

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

Modeling Configurations

Three modeling configurations—Existing Hydraulics with Existing Hydrology (Scenario 1), Future Hydraulics (without recommendations) with Future Hydrology (Scenario 2), and Existing Hydraulics (with recommendations) with Existing Hydrology (Scenario 3)—were developed for this study as described below.

Scenario 1 — Existing watershed hydrology with the drainage system configured as it existed in 2011. Channels are modeled using their existing (2011) conditions as well. URS field inspections confirmed that many channels are not in a well-maintained state, so where appropriate, adjustments were made in the modeling to reflect actual conditions. 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 are accounted for 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. Grassfield Outfall NM_3 Drainage Update
2. New Mill Basin Drainage Study
3. Dominion Commons Drainage Study
4. New High School in Grassfield Area
5. Majestic Estates
6. Dominion Commerce Park Phase 1
7. Roadway Plans of Dominion Commerce Park Phase 2
8. Grassfield Parkway & Dominion Blvd Improvements
9. Bald Cypress Quay
10. Cahoon Plantation Ph.2

Scenario 2 — Future watershed hydrology with the added future drainage system as it is anticipated by the City. For the most part, channels and conduits are configured as they exist in 2011 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. Plantation Greens
2. Future proposed Lakes 3, 4, and 5

Scenario 3 Existing watershed hydrology with an improved existing drainage system in a well-maintained state. This is the "Scenario 3" model. This scenario incorporates the drainage from Scenario 1 along with any recommendations from the engineering team to help reduce flooding on a Master Drainage Facility level (i.e. facilities serving 320 acres or more). (See the section on Master Drainage Plan Caveats below for additional clarifications about the Scenario 3 configuration used for this study.)

The recommended improvements should reduce flooding at key locations, where feasible, for existing conditions. These improvements were developed during this study, are highlighted in Figures 9 and 9a, and specifically include the following projects:

1. Upper Shillelagh Road Drainage Improvements
2. Dominion Commerce Park Lakes Outfall Improvements

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

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 (Scenario 1) and existing with improvements (Scenario 3) conditions.

Stable SWMM runs were obtained for all modeling scenarios. Continuity errors ranged from low to very low. URS engineers used PCSWMM to review dynamic hydraulic grade line results, checking the hydraulic routing for potential stability problems or any type of flow anomaly. This QA/QC procedure aids in producing reliable modeling results.

Boundary conditions (water surface elevations) at the downstream outfall were specified by the City of Chesapeake, Department of Public Works, as stated in the *Public Facilities Manual*. In all cases, for all return periods, the hydraulic boundary condition was modeled as a constant water surface elevation of 3.60 feet (NAVD88) in the Southern Branch of the Elizabeth River. Due to the natural topography and designed drainage systems, major portions of this watershed are sensitive to the downstream boundary water surface elevation used in these models.

The GIS analysis prepared in support of this modeling indicates that the New Mill Watershed will increase from **23.65** to **49.38** 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.

During the process of determining imperviousness, URS engineers, with agreement from City engineers, visually adjusted the percentage of imperviousness of each subbasin based on aerial imagery. This step is necessary because the City currently does not have imperviousness mapped in its GIS.

Figures 8 and 10 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, 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 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 both existing and existing with improvements 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 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). 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 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, C-2, D-1, and D-2, as well as the flooding figures in this report.

The maintenance condition of channels and drainage structures plays a big role in the routing of runoff and flood flows. If debris builds up to block drainage structures, or channels are allowed to fill with silt, flooding will likely be more severe than what is modeled. Debris can be a significant problem in natural channel outfall systems, and should be monitored carefully to ensure that these systems function properly. Likewise, heavy buildup of vegetation can significantly worsen local flooding. Channels that are relatively free from vegetation in the winter months can have significantly less conveyance capacity in the summer months when vegetation thickens. Depending upon the type of plant growth, the change in conditions can be dramatic. Observations from field visits and surveys indicated many channels and culverts are not in a well-maintained condition. For this reason URS engineers, with agreement from City staff, used professional judgment to adjust channel and pipe roughness coefficients in selected locations. For Scenarios 2 and 3, the models were built based on the assumption that the drainage and stormwater systems will be well maintained.

In evaluating the flooding computed by these models, the importance of Mr. Collins' comments about the soils shedding water rapidly (like clay) became quite apparent. In discussing the soil conditions, several farmers reported that these fields flooded quickly, held water for extended periods of time, and exhibited "mud cracking" phenomena as they dried. When URS engineers adjusted the Green Ampt soils parameters in the models to account for Mr. Collins' comments, the models produced hydrologic and hydraulic results that closely mirrored the flooding that the farmers had reported. URS engineers suspect that soil amendments applied to these fields over a long period of time could have caused these soils to produce the reported response to rainfall. This citizen input was extremely important in getting the modeling right.

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.

Two specific projects were conceived and incorporated into the modeling during the course of this study. The backbone drainage system of the New Mill Creek 3&4 watershed consists of two major systems; the Shillelagh Road system and the Commerce Park Lakes system. Recent reports and field observations on heavy rains indicated that stormwater backed up in these two main systems which resulted in localized flooding at many locations in the upper portion of the watershed, especially the farmlands. Field surveys and inspections indicated that ditches and culverts along Shillelagh Road are not in a well-maintained condition, and that many of them have sediment and heavy vegetation blocking flows. As some farmers reported that water would not completely leave the system for several days after the storm, this phenomenon indicates there must be significant blockages in the drainage system. Also, pipes connecting some lakes and retention basins are undersized, preventing stormwater from being conveyed fast enough to downstream locations during extreme storm events.

Another concern involves the single culvert connections between the retention basins at the Dominion Commerce Park. Debris can easily block the connecting culverts, and when it does there is no place for the flooding to escape. Citizens and City inspectors reported that blockages have occurred from storm debris in the past—one example involving a large plastic sandbox that floated down and blocked a culvert during a large storm event. Separately, several farmers reported a blockage in a downstream culvert caused by a Christmas tree. To minimize the potential failure of single pipe outfalls, URS recommends constructing a parallel culvert or drainage path at each retention basin outfall along the Dominion Commerce Park. These redundant culverts should be spaced sufficiently far apart from the existing culverts to reduce the potential to have two culverts blocked simultaneously.

The City and URS engineers worked closely together to develop two projects to alleviate flooding in the watershed. The main goal of these two projects is to lower the water surface elevations in the Shillelagh Road ditches and in the Dominion Commerce Park Lakes in order to provide more flood storage. These two projects are shown in Figures 9 and 9a, and are included in modeling Scenario 3. Refer to Figures 6, 9 and 9a 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. Upper Shillelagh Road Drainage Improvements

The idea of these improvements is to divert major stormwater in the upper portion of New Mill Creek 3&4 Watershed to the Dominion Commerce Parks Lakes system via a new ditch. These improvements, along with the Dominion Commerce Park Lakes Outfall Improvements, will help carry the runoff load in the Shillelagh Road system. Recommended improvements to this area include:

1. Node 525: Lower invert to 5.25 ft. (Surveyed existing elev. 5.86 ft.)
2. Node 401: Lower invert to 4.62 ft. (Surveyed existing elev. 4.94 ft.)
3. Node 203: Lower invert to 4.00 ft. (Assumed existing elev. 8.50 ft.)
4. Node 205: Lower invert to 3.50 ft. (Assumed existing elev. 7.50 ft.)
5. From Nodes 365 to 399: Clean and restore all ditches to their original designed conditions. Enlarge all driveway culverts to double 48-in pipes or equivalent.
6. From Nodes 399 to 401: Enlarge driveway culvert to double 54-in pipes or equivalent.
7. From Nodes 525 to 401: Replace existing 24-in culvert with double 42-in culverts or equivalent.
8. From Nodes 401 to 403: Clean and restore ditches to their original designed conditions. Enlarge driveway culvert to double 54-in pipes or equivalent.
9. From Nodes 403 to 205: Re-grade and widen existing channel bottom to 4 ft. with side slopes equal to 2H:1V.

10. From Nodes 205 to 225: Replace existing 15-in pipe with a 4-ft. channel bottom having side slopes equal to 2H:1V. This new channel should outfall to Lake 225 at elevation 3.40 ft.

2. Dominion Commerce Park Lakes Outfall Improvements

Street elevations in the Vincek Way and Grassfield High School vicinity are lower than the bank elevations of the lakes, allowing street flooding to occur before the lakes are overtopped. The goal for these improvements is to lower water surface elevations in the Dominion Commerce Park lakes system to approximately 8.00 feet for the 100-year design storm. Recommended improvements to this area include:

1. From Nodes 199 to 225: Add one (1) 48-in pipe to the existing 48-in pipe connecting to the lakes.
2. From Nodes 225 to 245: In addition to existing 36-in pipe, create a spillway (riprap channel) connecting the two lakes. The channel should have an 8-ft. bottom width, 2H:1V side slopes, and starting invert at 4.00 ft. Alternatively, a 72-in pipe can be substituted for the spillway.
3. From Nodes 245 to 267: Create one (1) 48-in outfall pipe connecting Lake 245 (at 4.20 ft. elevation) to Node 267.
4. Node 301: Lower invert to 3.20 ft. (Assumed existing elev. 6.50 ft.)
5. Node 303: Lower invert to 3.10 ft. (Surveyed existing elev. 6.13 ft.)
6. Node 305: Lower invert to 3.00 ft. (Surveyed existing elev. 5.23 ft.)
7. From Nodes 245 to 303: Create an outfall channel connecting Lake 245 (at 4.50 ft. elevation) to Node 303. The channel should have a 6-ft bottom width and 2H:1V side slopes.
8. From Nodes 303 to 305: Add one (1) 48-in culvert at new inverts. Note: The existing 48-in culvert should remain in place and will be used as an overflow pipe.
9. From Nodes 305 to 307: Re-grade the channel holding the new invert at node 305.
10. From Nodes 319 to 837: Clean the channel and create a 10-ft. wide bench, set 1 ft. vertically up from the channel bottom.

Master Drainage Plan Caveats

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 stormwater systems are neither required nor designed to accommodate flooding from extreme events such as the 50-year storm. As indicated above, recommended improvements in this report are to lower system's water surface elevations in order to alleviate flooding and to create extra storage. Private land owners will need to clean out their private drainages, remove any blockages, and enlarge culverts to make way for runoff in order to resolve localized flooding.

One important caveat to keep in mind is that 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.

Compared to previous Master Drainage Plans completed by URS for the City, the New Mill 3&4 Watershed has substantial tracts of undeveloped land that have high development potential (they are currently farm fields). In the previous studies, the histograms for Scenario 3 (future hydrology with future drainage and stormwater improvements in place) are based upon the assumption that future development can occur without on-site BMPs. In this regard, these scenarios are conservative, and lead to better flood protection. However, in this case, because there is so much undeveloped acreage, such an assumption becomes less useful. In other words, where we have large farm tracts showing significant flood volumes in the histograms, these histograms are pinpointing private property flooding (that is not easy or cost effective for the City to address). After discussing this issue with URS, the City requested that for the New Mill 3&4 study, Scenario 3 histograms should be based upon existing land cover conditions for the farm tracts and remaining watershed. Where it appears that future improvements will not decrease flooding on private property, in fact, the City has very little control over these tracts. The hydraulic results however provide lower water surface elevations at the outfalls from these tracts, so that private landowners can better drain their properties if they choose to make improvements. URS made undocumented model runs to confirm that these parcels could indeed achieve better drainage with the two proposed Master Drainage Plan projects in place.

Items to Be Considered or Addressed in Future Development

Because the New Mill 3&4 Watershed consists of large, undeveloped tracts of land, and because there are existing drainage and stormwater management problems, the potential impacts from future development must be evaluated very carefully.

After years of regulatory activity, Virginia recently promulgated new Stormwater Management Act regulations that became effective in September, 2011. One key change in the new regulations is the introduction of "Runoff Reduction" measures to manage stormwater. The basic idea is that developers must address (and limit) the total quantity of runoff produced from their projects. In the past, new development could produce and release increased volumes of runoff as long as certain conditions were met, including ensuring that the post-development discharge rates did not exceed the pre-development rates for prescribed design storms, and that the increased runoff did not damage (or threaten) downstream drainage areas. Under the new regulations, the focus has shifted to limiting the total runoff volume.

Table E-1 is provided in this report to help the City with future watershed planning. This table lists the total computed inflow volume for every junction in this watershed model under existing (2011) conditions. One simple application could be to limit the runoff volume from future developments to the values listed in Table E-1. The likely result will be the construction of additional outfalls and drainage systems in the future, incorporating additional on-site detention or retention basins

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.

Contact Information

Mr. Sam Sawan, PE (757.382.6101) served as the project manager for the City of Chesapeake on this project. Mr. 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 Brad Alger and Libby Ludwig (757.873.0559).