Storm Water Management Model

St. Julian Creek Watershed

Master Drainage Plan

April 2005

US Army Corps of Engineers
Norfolk District

Chesapeake VIRGINIA
Department of Public Works

URS
URS Corporation

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1. EXECUTIVE SUMMARY

Note: This document is printed in 8.5x11-inch format. It contains several graphics that have more detail than can be printed at this scale. These graphics are produced in vector form, and can be zoomed to very high levels of detail using Adobe Acrobat Reader to view the electronic version of this document (pdf file). Large-format working plots can be obtained using Adobe Acrobat Reader.

This Master Drainage Plan document describes a storm water management model (SWMM) study that was completed in April 2005 for the St. Julian Creek watershed in the City of Chesapeake. The purposes of the study are to update the City's watershed models to reflect the significant amount of development that has occurred in this watershed since the original models were completed, and to improve the models by taking advantage of GIS technology and improvements in the SWMM model itself.

This document summarizes the methodology, data sources and approach used in the modeling. It also provides complete documentation regarding the construction of the models and parameterization of the modeling data.

The updated models comprising the technical basis of this study have greater resolution than the original models and constitute a new modeling baseline based on 2004 land and infrastructure conditions. Future conditions were also analyzed using proposed site plans to build the models based on likely development scenarios considered in the aggregate.

These modeling results were obtained subject to limitations on available data. In this respect these models represent "best guess" modeling. They should however be quite sufficient for use in watershed planning applications and can easily be enhanced with additional detailed surveying data, as it becomes available. An extensive field survey was performed by the City of Chesapeake in support of this study to verify critical invert elevations and channel and culvert configurations and dimensions. Compared to other SWMM studies in the region, this study is very detailed and has undergone a great deal of digital data validation during the construction and checking of the models.

After preparing and running the future conditions models, the St. Julian Creek watershed increased from 40.0 to 43.5 percent impervious cover. This increase in impervious cover produces greater volumes of storm water runoff, which have been incorporated into the future conditions models. For the 2-year design storm, St. Julian Creek produces 1.309 inches of runoff in 2004, which increases to 1.418 inches in the future — comprising an 8.3 percent increase.

The previous version of the St. Julian Creek Watershed Master Drainage Plan—completed in 1986—called for several million dollars worth of storm water and drainage improvements, some of which have already been constructed in conjunction with road improvements. The current study reviewed all of the previous recommendations and considered a number of additional options aimed at improving drainage conditions within the watershed. This study recommends three significant improvements, two of which will only be required if the City of Portsmouth increases flows under the CSX Railroad. Specifically these improvements are:

- Bypass outlet for Camelot Lake, and channel and culvert improvements to provide capacity for bypass flows between Camelot Lake and Deep Creek Boulevard (estimated to cost $1,407,588 in 2005 dollars),
- Culvert and channel improvements to provide additional flood conveyance capacity from Gust Lane at the CSX Railway to Deep Creek Boulevard, (estimated to cost $906,056 in 2005 dollars), and
- Culvert and channel improvements west of U.S. 17 to provide additional flood conveyance capacity from the CSX Railway to St. Julian Creek, (estimated to cost $613,148 in 2005 dollars).

As described in Section 4.2.8, the FEMA flood insurance models are the definitive source of floodplain limits and elevations in all cases. The City's SWMM models described herein 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 PURPOSE OF FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS.

All documentation and computer modeling files associated with this study are available for review from the City of Chesapeake, Department of Public Works.

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 (757.499.4224) was the project manager for URS. The modeling evaluations and report were produced by William K. Walker, PE, CFM and John Paine, PE, PH, CFM.

2. INTRODUCTION

The City of Chesapeake's Master Drainage Plan models form the basis for planning and design of regional BMPs, are instrumental in setting the capital improvements projects (CIP) budget, and provide hydraulic grade line elevations for use by private-sector engineers in designing new developments.

In the time since the models were first coded, some City watersheds have experienced prolific development—altering the landscape and drainage infrastructure to the degree that the original watershed models are increasingly in need of updates. While these watersheds were developing, so was computer modeling capability, primarily due to gains in processing power and data processing technology. In 1986, SWMM modeling on desktop computers using the DOS operating system was a painstakingly slow process, and many workarounds—such as the use of equivalent length conduits to allow larger computational time steps—were commonplace. A one-second computational increment was unthinkable for desktop modeling on microcomputers. Likewise, there was no desktop Geographic Information System (GIS) platform that could be used to process the model input data. Data reduction was performed using manual methods on paper prints. Watersheds and drainage networks were discretized in somewhat bulky but effective fashion to develop working models. The limitations of 1980s computing technology had an undeniable bearing on the approach to modeling at the time.

The City is committed to maintaining its master Drainage Plan models, and has decided to update the modeling in those watersheds that have experienced the heaviest development since 1986. The St. Julian Creek watershed has experienced significant development during this period, and is expected to incur additional development in the near future.

Not only has engineering and computing technology changed since the original watershed management plans were completed, but so have expectations about the format and distribution of the final study documents. In the past, there was little or no link between the watershed data and the computer models, most of which were completed using very large-scale paper maps. In this respect it was difficult to obtain detailed input data, and empirical models were developed and employed in part to compensate for the lack of detailed information. Now, with the advent of advanced desktop computer system and software platforms, engineers expect a substantial amount of digital backup data to be delivered with a detailed drainage study. The study deliverables now include not only the computer input and output data files and report documentation, but also a robust set of GIS coverages that can be used to work with the models in the future. The reports themselves are set up for on-screen viewing, and contain complete, full-size CAD and GIS plots for instantaneous use by the reader. The use of portable document file (.pdf) formats also enables those users who do not have CAD or GIS software to easily review the plots.

This report contains several highly detailed GIS plots in pdf format that can be printed on standard 8.5x11 printers, along with the regular-sized pages. If the user has access to a large-format printer/plotter, clear large-format plots can easily be obtained, which will make it easier to follow the model layout and construction by referring to the node and link identifiers labeled in these figures. If the user does not have a large format plotter, the freely available Adobe Acrobat Reader software program can be used to zoom in on these plots to reveal the tiniest details and labels, because the figures are produced in vector formats.

One of the greatest advantages today's engineers enjoy is high-resolution aerial imagery. The aerial imagery used in this study — and presented throughout this report — was provided by the Commonwealth of Virginia, Copyright ©2002.

The modeling performed for this Master Drainage Plan update was completed using PCSWMM. This software package is available for approximately $400 and is an excellent low-cost SWMM modeling platform. All of the SWMM files were provided to the City of Chesapeake Department of Public Works as part of the project deliverables. Engineers can easily find important detailed hydraulic information by using any text editor to review the output files, as explained in Section 5. With PCSWMM there are several additional tools that allow the hydraulic results to be reviewed dynamically, that aid in developing an appreciation and feel for how the system behaves. One of these is the Dynamic Hydraulic Grade Line tool, which shows the hydraulic heads changing over time through selected portions of the drainage system.

Figure 2-1 shows a screen capture taken during a review of the 50-year existing (2004) conditions hydraulic response near Deep Creek Boulevard.

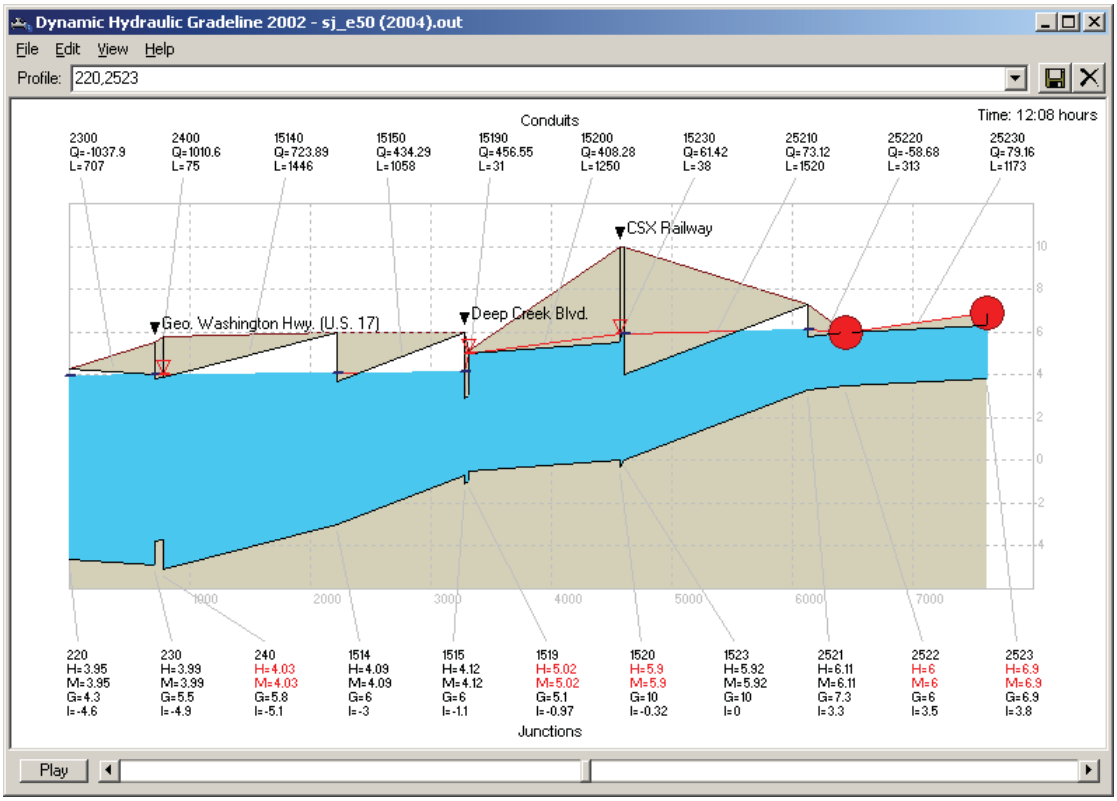

Figure 2-1. 50-Year Existing (2004) Conditions Dynamic Hydraulic Grade Line Through Deep Creek Boulevard

The engineer can check the link-node diagrams presented in this report, then pull up PCSWMM and easily review the hydraulics in this manner using PCSWMM.

3. WATERSHED ISSUES & BACKGROUND

As of 1986, a majority of the St. Julian Creek watershed had been developed, primarily as residential and commercial/light industry parcels. Over the past 18 years or so, the watershed has continued to fill in. While several large tracts of marketable land remain, those along the creek are not ideally suited to accommodate development pressure, particularly given the low-lying, flat topography and tidally influenced drainage outfalls.

Heavy rainfalls, tides and storm surges have always created flooding problems in this watershed. Flooding in neighborhoods has been commonplace, and the City has considered several Master Drainage Plan improvements to lower the hydraulic profiles.

A previous Master Drainage Plan study of the St. Julian Creek watershed, completed in 1986, recommended six major drainage and storm water management improvements, including a bypass for Camelot Lake, and channel and culvert crossing improvements.

To date, the only storm water BMP constructed in this watershed was the improved culvert crossing at Deep Creek Boulevard (near Gilmerton Road), which was installed when the road was realigned.

St. Julian Creek, a tributary to the Southern Branch of the Elizabeth River, has elevations as low as 2 feet (NGVD88) extending 11,500 feet west from its confluence with the Elizabeth River back to Deep Creek Boulevard—roughly two-thirds of the effective length of the watershed. This low-lying topography contributes to frequent flooding but also provides well-defined outfall discharge locations for upland drainage areas.

The drainage and storm water management improvements suggested in the 1986 Master Drainage Plan are expensive and have been carefully considered by the Department of Public Works. Several million dollars worth of recommended improvements have not yet been completed under the 1986 plan, including:

- New double 5x5 box culverts at the CSX Railraod crossing near Gust Lane,
- New double 6x5 box culverts at Deep Creek Boulevard,
- New triple 6x6 box culverts at Romaron Street,
- New bypass weir at Camelot Lake, and
- Channel improvements between the new Camelot Lake weir and Deep Creek Boulevard.

As development pressures increased and flooding continued to be a problem in the Camelot neighborhood, the City decided to revisit the Master Drainage Plan for St. Julian Creek, specifically to update the plan and reassess whether or not the improvements recommended 18 years ago are still required.

In part, the new study described in this document benefits from a considerably greater amount of watershed and drainage information —primarily in the form of aerial imagery and GIS data—and from substantial improvements in stormwater modeling and computer technology that have occurred since 1986.

4. COMPUTER MODELING

Section 2 of the Master Drainage Plan Methodology report (submitted separately) describes data sources and computer model requirements in detail. Each watershed presents its own unique challenges in preparing the Master Drainage Plan, and the St. Julian Creek watershed is no exception. Any modifications or additions to the approach described in the Methodology report are described below.

4.1 Data Sources & Processing

The City of Portsmouth provided Master Drainage sheets for only the easternmost portion of the St. Julian Creek watershed within their City limits. These data sheets were scanned and georeferenced in GIS, and they contain the following information:

- Streets
- Parcels
- Building footprints
- Storm water items

The City of Portsmouth also provided two-foot contours in GIS. These contours matched fairly well, though not identically, to the City of Chesapeake's contours where they overlapped along the CSX Railway.

4.2 Model Development & Selection of Parameters

4.2.1 Rainfall Hyetographs

Table 4-1 lists the rainfall depths and return periods used in Chesapeake based on an analysis of rainfall historical records. For the purposes of this study, the 2-, 5-, 10-, 25-, 50-, and 100-year rainfall events were modeled. Due to temporal discretization and the sharp peak of the design hyetographs, the rainfall volumes used in the models may differ very slightly from these values.

Table 4-1. 24-Hour Rainfall Depths

Return Period (years)	24-Hour Rainfall Depth (inches)
2	3.4
5	5.0
10	5.9
25	6.9
50	8.0
100	9.0

4.2.2 Subarea Delineation

The subcatchments, also referred to as 'subareas,' were delineated entirely using ArcView GIS software. The new subarea delineation deviated somewhat from the old, as new grading and development drainage was considered, and contour data was available for the City of Portsmouth. The difference between the old and new delineations is shown in Figure 4-1—the green shading represents the old delineation, and the new subxatchments are outlined in yellow.

The data described in Section 4.1 was used to piece together the available watershed information and resulted in an existing (2004) conditions model that has 128 subcatchments, as shown in Figure 4-2. The delineation is unchanged for the future conditions model. (This figure can be zoomed and printed to very large formats using Adobe Acrobat Reader software.) This is a very fine level of detail for this type of

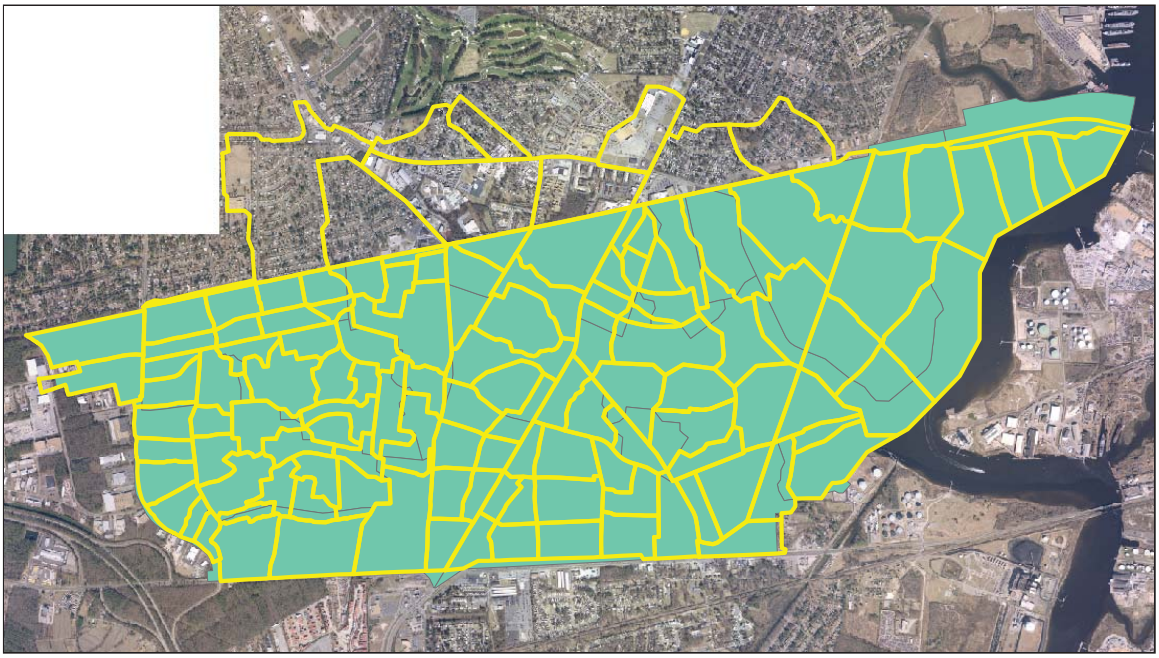

Figure 4-1. 1986 Delineation (Green) and 2004 Delineation (Yellow Outline)

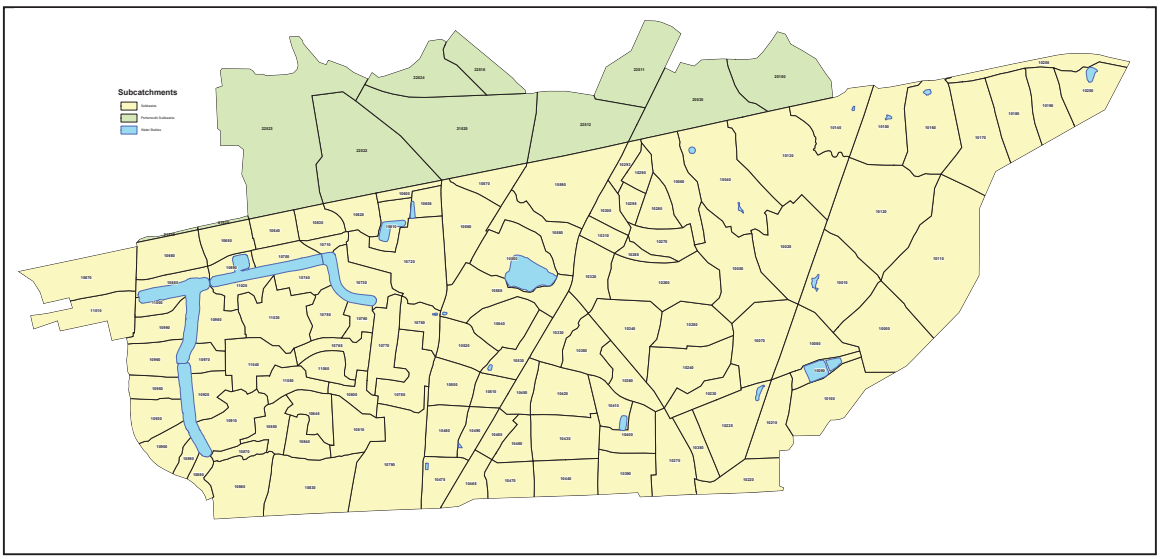

Figure 4-2. Subcatchment Delineation

modeling. Heavy weight was given to site plan drawings and aerial imagery in performing the digitizing, as these data sources represented the most up-to-date information on the watersheds.

This process was time consuming, due to the size of the data files involved, and the need to constantly re-order the themes in the GIS to see critical information in different combinations of overlays. An extraordinary amount of computer processing time was consumed regenerating the screen images during zooming to perform the required snap digitizing that defines the subcatchments.

4.2.3 Subcatchment Imperviousness, Roughness & Depression Storage

To determine the imperviousness of each subcatchment, a GIS frequency analysis was performed to categorize and measure the land use in each subcatchment. The land use coverage employed was obtained directly from the 1999 Regional Stormwater Loading Study prepared by CH2M-Hill consultants for the Hampton Roads Planning District Commission (HRPDC). By overlaying this land use data on the newly delineated subcatchments, the actual area of each land use category within each subcatchment was directly measured in the GIS. The percentage imperviousness of each subcatchment was then calculated entirely within GIS in a two-step process using Chesapeake-specific values of imperviousness for each land use category provided by HRPDC, as shown in Appendix A. The GIS land use coverage was provided by the City of Chesapeake, as shown in Figure 4-3.

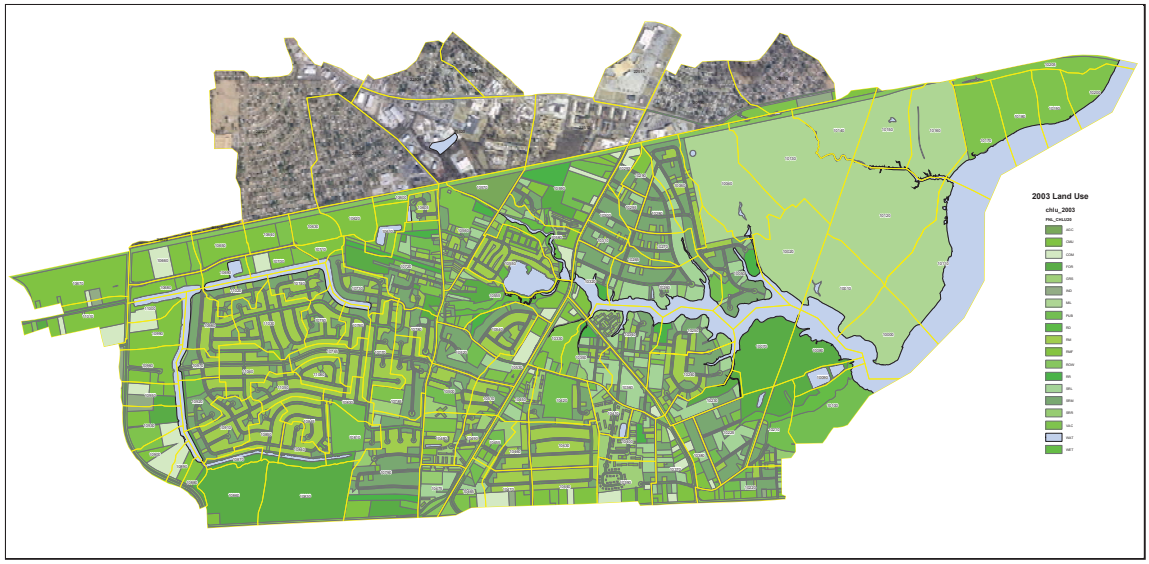

Figure 4-3. Existing (2003) Conditions Land Use

The Manning overland roughness coefficients for impervious and pervious land cover were taken from tables that are widely available in engineering literature, as were the depression storage depths. These provisional values are widely published for applications where there is no calibration data that can be used. For the future conditions models, future imperviousness was based on estimates of future development, as described in Section 5.3 of this document. Tables depicting the imperviousness and soils parameters for each subcatchment are also presented in Appendix A.

4.2.4 Subcatchment Basins

URS digitized storm water management basins and ponds into new polygon coverages from the aerial imagery and site data in the GIS. The St. Julian Creek watershed generally has not been subjected to a proliferation of storm water management basins, however the Virginia Storm Water Management Act now stipulates that detention BMPs must be used if the downstream channel from a proposed development is inadequate.

Outfall structures for major facilities were surveyed, and the facilities were represented using an EXTRAN storage junction. The bottom area and top area of all identifiable ponds was digitized and measured in the GIS, and modeled carefully with SWMM. All other detention facilities were accounted for by land use only (i.e., water as 100% impervious), either because they discharged directly to the tidal estuary or because their area was small compared to the overall subbasin. This approach should adequately account for the storage effects within each subcatchment, without making the model overly complex.

4.2.5 Green-Ampt Soils Parameters

At the time the hydrology data for this project was prepared, the NRCS soil texture update was not yet ready digitally, so infiltration parameters were estimated as described in the Methodology report. Figure 4-4 shows a georeferenced hand drawing of soils textures to the GIS SSURGO soils data. The used values for the SWMM RUNOFF infiltration parameters, SUCT, HYDCON and SMDMAX, were tabulated in a spreadsheet as presented in Table A-3 in Appendix A.

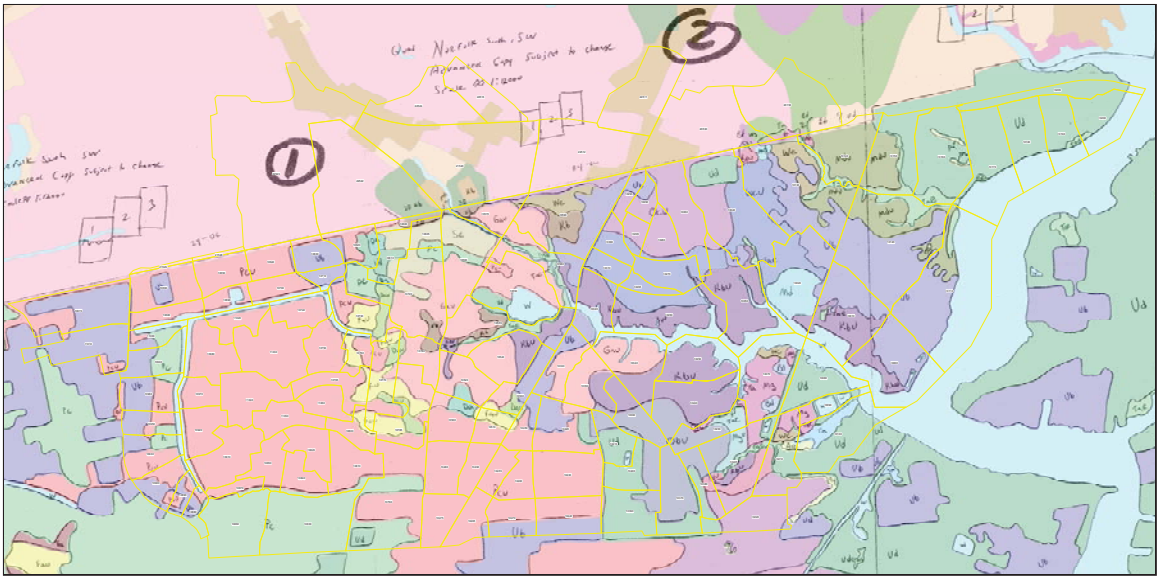

Figure 4-4. Soil Texture Mapping

4.2.6 Drainage Network Discretization (Links and Nodes)

The model links and nodes were discretized after the subarea delineation task was completed (see Section 4.2.2). The existing (2004) conditions and future conditions link-node diagrams are presented in Figures 4-5 and 4-6, respectively.

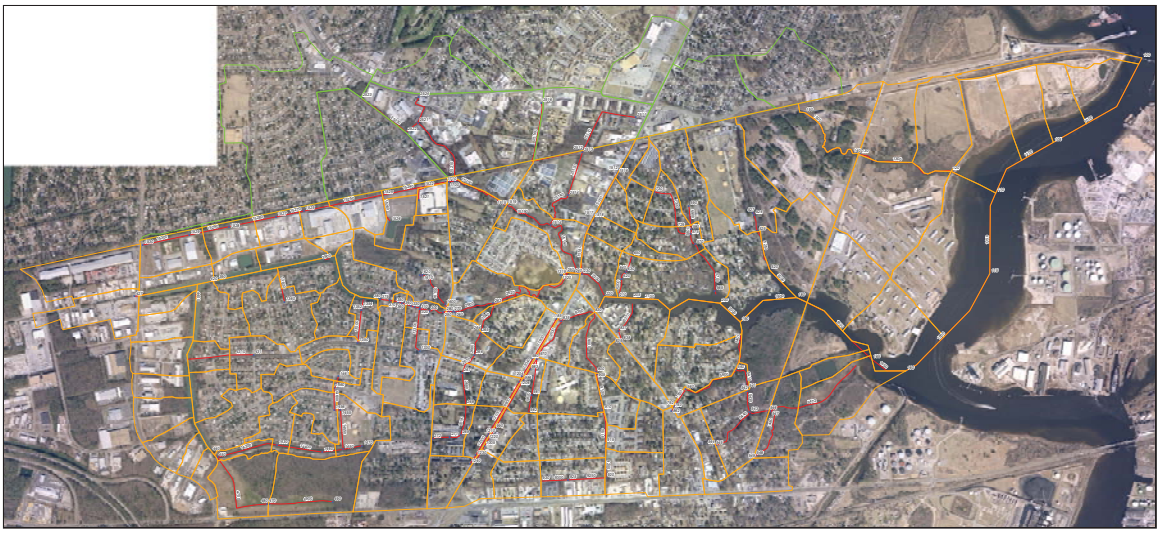

Figure 4-5. Existing (2004) Conditions Link-Node Diagram

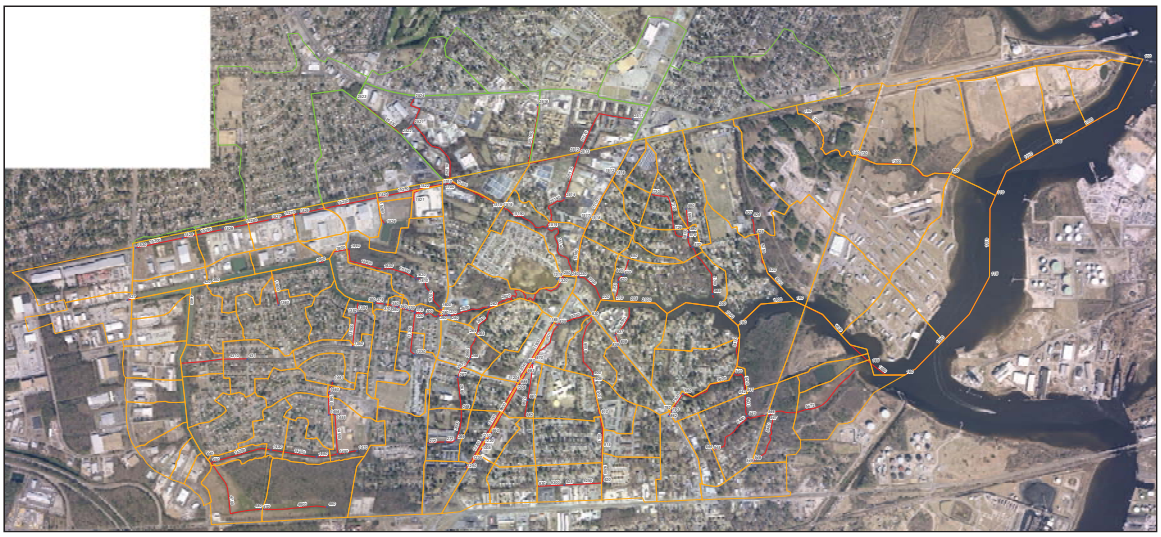

Figure 4-6. Future Conditions Link-Node Diagram

As in all stormwater models, there is some missing pipe and channel configuration data that had to be guessed. The pipe configurations and dimensions in these areas should be field-verified before constructing any improvements based on these models.

4.2.7 Open Channel Approximations

All open channels in the St. Julian Creek watershed master drainage plan models are represented as trapezoidal channels. Left and right side slopes were estimated in e GIS by examining the City's two-foot contour data. Invert elevations were obtained from the City's survey for this project. For deep channels (e.g. St. Julian Creek downtream of U.S. 17, and the South Elizabeth River), where the invert is significantly below the normal waterline, trapezoid bottom widths were set so that the channel width at zero feet NAVD would match the width apparent in the aerial photographs within a reasonable tolerance.

Because the linear pond that makes up the southern arm of Camelot Lake is fairly uniform in both width and side slope, the pond was also approximated using trapezoidal channels.

4.2.8 Important Considerations and Implications Regarding Boundary Conditions and Return Periods

According to National Flood Insurance Rate Map Panel 5100340015C, Revised 2 May 1999, the 100-year flood elevation in St. Julian Creek is 7.7 feet (NAVD88).

The FEMA flood insurance models are the definitive source of floodplain limits and elevations in all cases. The City's SWMM models are design scenarios based on 2-, 5-, 10-, 25-, 50-, and 100-year rainfall events — THEY ARE NOT TO BE CONSTRUED AS INDICATIVE OF THE EXPECTED WATER SURFACE ELEVATIONS FOR THE PURPOSE OF FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS.

5. MODELING SCENARIOS & COMPUTER FILES

See Section 4.2.8 for important information regarding boundary conditions and return periods.

The SWMM files generated for this study are available from the City of Chesapeake, Department of Public Works. All of the modeling files are contained in a single zip file. The RUNOFF and EXTRAN files contained in this zip file have the following nomenclature:

md_Brt (cond)

where:

md = St. Julian Creek Watershed identifier
B = SWMM block (R for RUNOFF, X for EXTRAN)
rt = return period of design storm (in years)
cond = date of conditions being modeled

For example, "sj_E50 (2004)" is the 50-year EXTRAN model for St. Julian Creek Watershed based on 2004 conditions, and "sj_R2 (2004)" is the 2-year RUNOFF model for St. Julian Creek Watershed based on 2004 conditions. Open the file "sj_R2 (2004).out" with PCSWMM, a text editor, or word processor to view the output file for the sj_R2 (2004) modeling scenario. Input data files have a "dat" extension.

The PCSWMM files are related as shown in Figures 5-1 and 5-2 for the 2004 and future conditions models respectively.

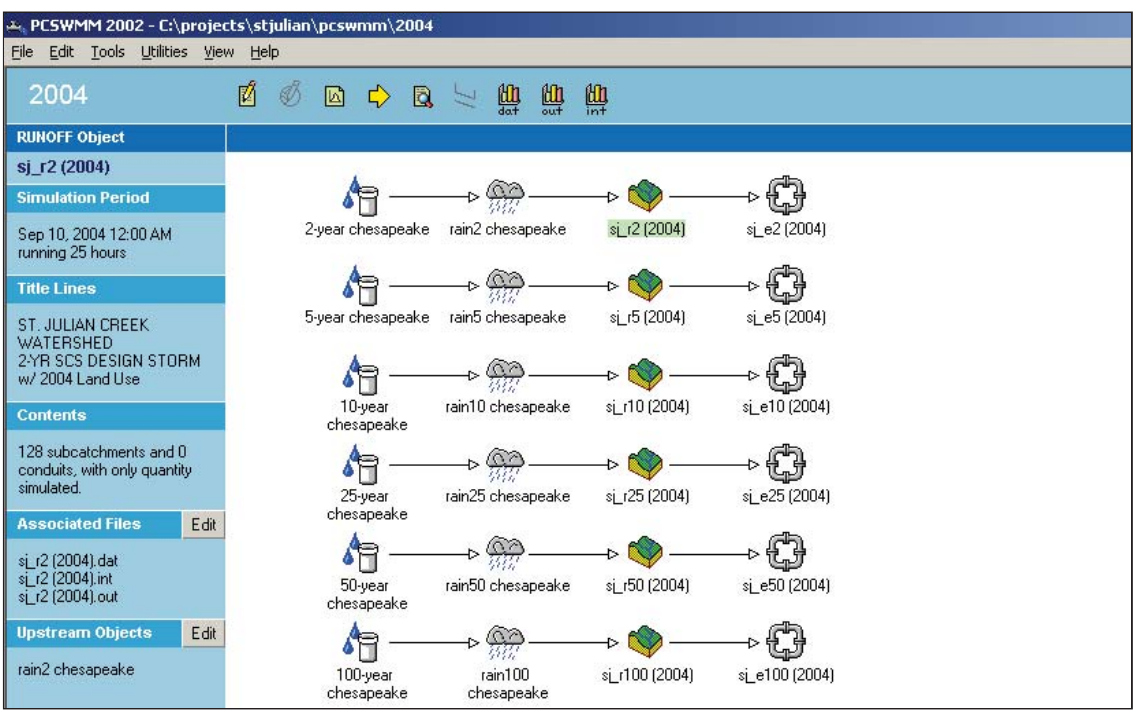

Figure 5-1. SWMM File Relationships for Existing (2004) Conditions Models

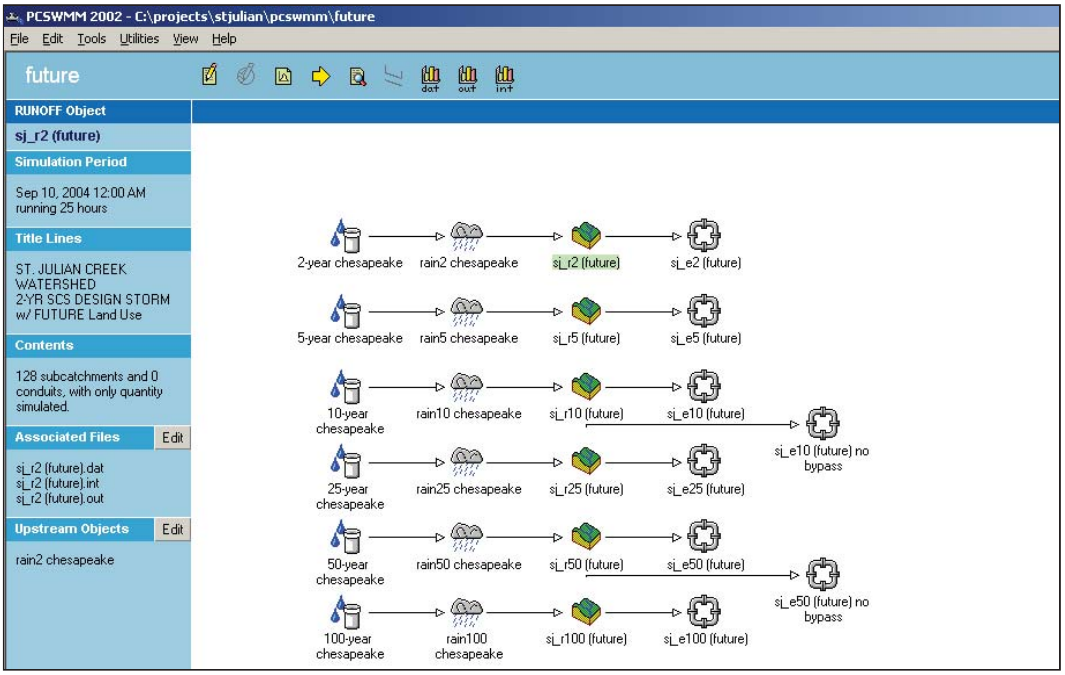

Figure 5-2. SWMM File Relationships for Future Conditions Models

To work with any of these files using the PCSWMM editor, simply click on the appropriate icon, and follow the software prompts to review the input or output files for the selected scenario. PCSWMM also contains tools for reviewing the dynamic hydraulic grade line of the EXTRAN runs, and provides an excellent editor to work with any of the input files. The SWMM model may be run directly by selecting an icon or group of icons and pressing the RUN button (that appears after selecting the icons).

5.1 Vertical Datum

For the purposes of this Master Drainage Plan study, all vertical information was either collected in or converted to the NAVD88 vertical datum. All elevations listed in the modeling data and in the GIS files are on the NAVD88 datum.

5.2 Existing (2004) Conditions Models

The existing conditions models were constructed largely from available GIS data and site plans that had been previously approved by the City. The GIS data contains very little usable invert and culvert attribute data in the St. Julian Creek watershed, so City surveyors collected invert and channel and culvert information at key locations identified by URS, and the field information was incorporated into the existing conditions models.

Much of the available watershed and drainage information was produced at different times, with different levels of accuracy for different purposes. URS engineers made several site visits to verify the drainage system configuration, and spent many hours trying to resolve conflicting information among various site plans, the GIS and data other data sources.

The City identified three development projects that were substantially through the site plan approval process, or nearly complete with their construction. These site plans included:

- Gilmerton Road culvert addition,
- Channel improvements downstream of Gilmerton Road, and

- Norfolk Equipment.

All of these site plans were scanned and geo-referenced into the GIS, and included in the modeling as if they existed in 2004.

As with all models of this size and complexity, there is a great deal of detailed information, much of which has been supplemented with 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 the results.

5.3 Future Conditions Models

After the existing (2004) conditions models were constructed and successful results were obtained, a series of future conditions models was constructed using the 2004 models as a starting point. The entire watershed was evaluated for development potential, and the RUNOFF block data files were modified to reflect the increased imperviousness that would result from future development.

The City provided several site plans that are in various stages of consideration for development of future parcels in the St. Julian Creek watershed, including plans for:

- Canal Drive improvements, including a major outfall along Deaton Drive,
- Chesapeake Fire Station,
- Deep Creek Condos,
- Hambaz gas station,
- Walgreens, and
- Willow Bend (residential development).

Parcels at these sites are clearly identified in the "Future SWMM" GIS files submitted as part of this Master Drainage Plan study by the "fXXX" land use category, where "f" represents future conditions, and "XXX" represents the City's three-letter land use code. Some of these plans did not have design details, such as storm water management basin configurations, available at the time of this study, and some lacked sufficient detail to incorporate directly. These site plans were incorporated into the future conditions models as much as was possible.

In addition to these plans, URS identified 20 additional parcels that appear to be prime candidates for future development in the watershed. All of the parcels considered for future development are shaded in yellow in Figure 5-3. There are other parcel sites available, but they were not considered likely candidates primarily due to topographic and/or wetlands constraints. The subcatchment delineations are the same for both the existing and future conditions models.

After adjusting the future conditions models to account for future developments, the St. Julian Creek watershed increased from 40.0 to 43.5 percent impervious cover. This increase in impervious cover produces greater volumes of storm water runoff, which have been incorporated into the future conditions models. For the 2-year design storm, St. Julian Creek produces 1.309 inches of runoff in 2004, which increases to 1.418 inches in the future — comprising an 8.3 percent increase.

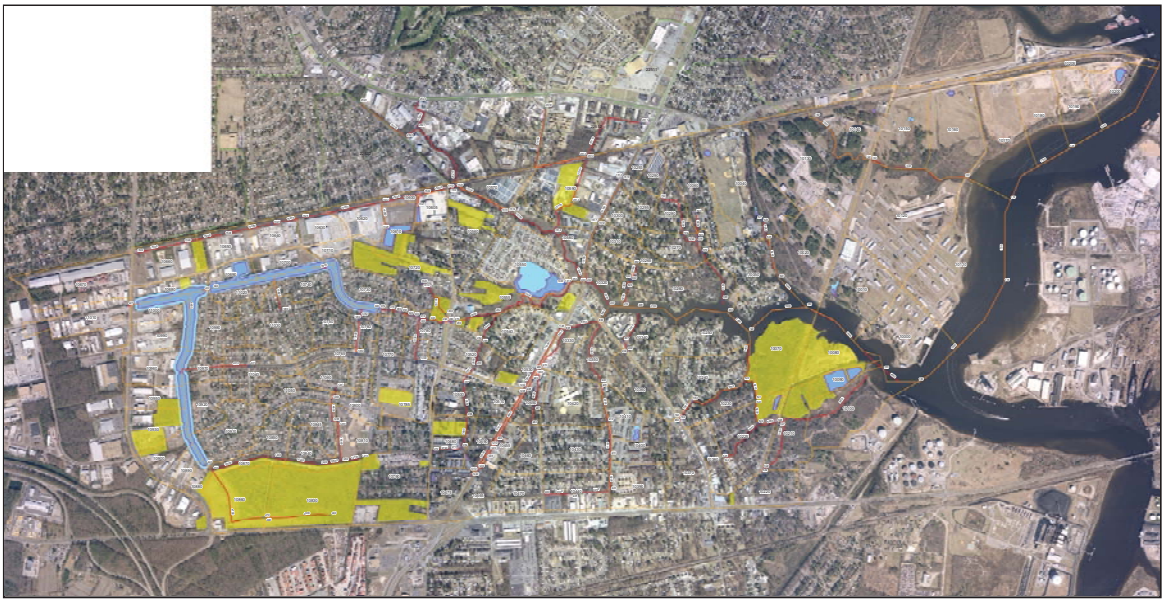

Figure 5-3. Potential Future Site Developments Considered in the Future Conditions Models

6. MODELING RESULTS

Stable RUNOFF and EXTRAN runs were obtained for all modeling scenarios, with EXTRAN continuity errors well below one percent in each case.

St. Julian Creek is a low-lying watershed that incurs frequent street flooding in many locations. Figures 6-1 and 6-2 depict street and property flooding volumes for the 50-year design storm event as modeled for this study. The circular orange symbols in these figures indicate problem areas in the watershed models. The symbols are not drawn to any scale, but they are proportional. It is easy to see that the most significant existing flooding problems are along the CSX Railway. The railroad chokes the flow draining from the City of Portsmouth, so flooding complaints along these drainages within the City of Chesapeake are few. The previous Master Drainage Plan study in 1986 recognized the undersized railroad culverts and recommended significant improvements at these locations.

As shown in Figures 6-1 and 6-2, there are several areas where the SWMM models indicate property and ditch flooding will occur for the 50-year design storm, most notably along the CSX Railway, and in the City of Portsmouth. Although the models indicate that flooding will occur in these areas, there is not a lot of complaint history to justify making Master Drainage Plan improvements at these locations. Flooding is also evident in the Bowden, Boxwood, and Camelot neighborhoods, and the model results are corroborated by complaints. In these locations, flooding creates temporary surface ponding on low-lying. If the City decides that flooding complaints and/or other issues warrant large-scale improvements, these models can easily be used to design the improvements.

It is important to bear in mind that a 50-year design storm event is an extreme event, and that most drainage systems are not required to accommodate 50-year return periods.

All of the models run for this study assume that the drainage system is maintained in sound working condition. Often flooding complaints—particularly those in residential neighborhoods—result from maintenance conditions such as a clogged pipe. In considering whether or not large-scale drainage improvements might be required at a given location, 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.

Figure 6-1. Existing (2004) Conditions Significant 50-year Flooding

Figure 6-2. Future Conditions Significant 50-year Flooding (Shown on 2002 Aerial Imagery)

These SWMM models are prepared knowing that many future changes will be made to the data files. The SWMM output files contain a great deal of meaningful engineering data that is too voluminous to summarize in the body of this document. However, Sections 6.1 and 6.2 contain tables that summarize the existing and future conditions hydraulic grade line elevations throughout the St. Julian Creek watershed, at the time this study was completed. It is anticipated that these models will undergo frequent changes, so the City of Chesapeake Department of Public Works should be consulted to obtain the latest version of these models.

It is also important to understand when reviewing these results that there are several low-lying structures in this watershed that have finished floor elevations below the hydraulic grade lines computed in the SWMM models. In order to estimate whether or not a particular structure will be subject to flooding for a given design condition, the maximum hydraulic grade line elevation at that location should be checked against the finished floor elevation. An example of this situation can be found at Michael Drive — where ground elevations at certain structures are within two feet of the starting water surface elevation used in the models.

The FEMA flood insurance models are the definitive source of floodplain limits and elevations in all cases. The City's SWMM models are 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 PURPOSE OF FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS.

6.1 Existing (2004) Conditions Maximum Water Surface Elevations

Table 6-1. Existing (2004) Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
100	3.55	3.55	3.55	3.55	3.55	3.55
105	3.56	3.57	3.57	3.58	3.58	3.59
110	3.57	3.58	3.58	3.59	3.59	3.60
115	3.57	3.58	3.59	3.60	3.60	3.61
120	3.57	3.59	3.59	3.60	3.61	3.62
130	3.91	4.06	4.15	4.25	4.35	4.46
140	3.94	4.11	4.20	4.31	4.42	4.53
150	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**
160	3.58	3.59	3.60	3.61	3.62	3.63
165	3.58	3.60	3.61	3.62	3.63	3.64
180	3.64	3.68	3.71	3.74	3.76	3.79
190	3.66	3.72	3.75	3.79	3.82	3.86
200	3.67	3.74	3.77	3.81	3.85	3.88
205	3.71	3.79	3.84	3.89	3.92	3.97
210	3.72	3.80	3.84	3.90	3.93	3.98
220	3.73	3.81	3.86	3.92	3.96	4.00
230	3.75	3.84	3.90	3.95	3.99	4.04
240	3.76	3.87	3.93	3.99	4.04	4.09
250	3.78	3.91	3.97	4.04	4.09	4.15
260	4.22	4.60	4.79	4.90	4.99	5.08
262	4.16	4.50	4.67	4.77	4.84	4.92
264	4.24	4.61	4.69	4.72	4.74	4.76
265	4.27	4.65	**4.70**	**4.70**	**4.70**	**4.70**
266	4.36	4.74	4.80	4.83	4.85	4.85
267	7.78	9.67	**10.00**	**10.00**	**10.00**	**10.00**
268	8.81	9.87	10.25	10.41	**10.50**	**10.50**
269	9.69	10.15	10.42	10.53	10.63	10.71

Table 6-1. Existing (2004) Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
270	4.24	4.63	4.84	4.96	5.06	5.16
271	10.59	**11.20**	**11.20**	**11.20**	**11.20**	**11.20**
272	10.59	**11.20**	**11.20**	**11.20**	**11.20**	**11.20**
280	4.25	4.65	4.86	4.98	5.08	5.18
290	4.25	4.65	4.86	4.98	5.08	5.18
300	4.27	4.67	4.89	5.03	5.14	5.24
310	5.46	6.54	7.33	8.16	8.95	**9.93**
320	4.28	4.73	4.97	5.11	5.22	5.33
330	4.29	4.76	5.02	5.17	5.28	5.39
340	4.29	4.77	5.03	5.22	5.29	5.40
350	4.31	4.83	5.10	5.30	5.39	5.51
360	4.32	4.87	5.15	5.35	5.44	5.57
370	5.56	6.30	6.70	7.11	7.59	7.98
379	5.68	6.61	7.08	7.56	8.13	8.60
380	5.95	6.72	7.16	7.68	8.26	8.72
390	5.95	6.72	7.16	7.68	8.26	8.72
420	5.95	6.73	7.17	7.70	8.27	8.75
427	5.95	7.26	8.20	9.64	11.34	**12.00**
431	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
440	5.95	6.73	7.17	7.70	8.27	8.75
450	6.71	7.13	7.37	7.70	8.27	8.75
470	9.22	9.49	9.64	9.80	9.92	10.00
480	9.61	10.31	10.97	11.09	11.56	12.11
490	10.20	10.64	10.88	11.26	11.68	12.18
520	3.64	3.68	3.71	3.74	3.76	3.79
525	3.97	4.14	4.15	4.18	4.19	4.22
526	4.40	4.64	4.65	4.65	4.66	4.67
527	5.31	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
540	3.67	3.75	3.79	3.84	3.89	3.93
541	3.70	3.78	3.83	3.89	3.94	3.99
542	4.12	4.43	4.62	4.77	4.93	4.95
543	4.16	4.49	4.69	4.84	**5.00**	**5.00**
544	4.17	4.51	4.69	4.85	5.01	5.06
545	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
546	4.16	4.49	4.68	4.84	5.00	5.01
547	4.18	4.56	**4.70**	**4.70**	**4.70**	**4.70**
548	5.88	5.88	5.88	5.88	5.88	5.88
549	**6.70**	**6.70**	**6.70**	**6.70**	**6.70**	**6.70**
560	4.81	5.28	5.51	5.73	5.82	5.90
565	3.67	3.74	3.78	3.82	3.85	3.89
570	3.73	3.84	3.90	3.98	4.06	4.14

Table 6-1. Existing (2004) Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
575	3.74	3.85	3.93	4.01	4.09	4.18
580	3.74	3.85	3.93	4.01	4.09	4.18
590	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**
620	3.72	3.80	3.85	3.90	3.94	3.98
630	4.00	4.07	4.07	4.07	4.07	4.07
640	6.45	**7.26**	**7.26**	**7.26**	**7.26**	**7.26**
650	7.71	7.89	8.00	8.12	8.24	8.34
729	4.00	4.25	4.38	4.52	4.66	4.78
730	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**
760	3.73	3.82	3.87	3.92	3.96	4.01
792	6.64	7.93	8.85	9.49	9.54	9.55
793	6.54	8.46	9.59	10.40	10.43	10.44
830	4.15	4.44	4.61	4.76	5.40	5.56
835	4.15	4.46	4.64	4.81	5.43	5.59
837	3.73	3.82	3.87	3.94	4.00	4.05
838	4.96	5.85	6.68	7.77	8.74	8.79
839	5.81	6.45	7.50	8.97	**10.27**	**10.27**
862	6.82	8.93	10.26	**11.20**	**11.20**	**11.20**
900	4.36	4.71	4.89	5.02	5.51	5.64
905	5.11	5.69	**6.00**	**6.00**	**6.00**	**6.00**
910	6.74	6.94	7.04	7.16	7.32	7.44
915	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
920	10.47	10.87	**11.00**	**11.00**	**11.00**	**11.00**
925	10.49	10.78	10.90	10.90	10.90	10.89
930	**10.30**	**10.30**	**10.30**	**10.30**	**10.30**	**10.30**
970	4.85	5.05	5.14	5.22	5.54	5.69
980	5.07	5.32	5.43	5.54	5.67	5.77
981	9.14	**10.10**	**10.10**	**10.10**	**10.10**	**10.10**
982	9.31	10.13	10.24	10.33	10.42	10.47
983	7.44	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**
984	7.48	8.03	8.04	8.05	8.06	8.07
986	8.07	9.02	9.29	9.56	9.83	**10.00**
990	9.19	9.50	9.61	9.76	10.00	10.19
1005	10.54	11.64	11.67	11.69	11.69	11.68
1010	10.70	**11.70**	**11.70**	**11.70**	**11.70**	**11.70**
1185	4.16	4.49	4.68	4.86	5.46	5.65
1190	4.63	4.63	4.77	4.96	5.53	5.73
1200	7.62	7.62	7.62	7.62	7.62	7.62
1204	7.93	7.93	7.93	7.93	7.93	7.93
1206	**10.50**	**10.50**	**10.50**	**10.50**	**10.50**	**10.50**
1210	10.92	10.92	10.92	10.92	10.92	10.92

Table 6-1. Existing (2004) Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
1220	**11.23**	**11.23**	**11.23**	**11.23**	**11.23**	**11.23**
1230	**11.40**	**11.40**	**11.40**	**11.40**	**11.40**	**11.40**
1240	**11.60**	**11.60**	**11.60**	**11.60**	**11.60**	**11.60**
1319	3.80	3.96	4.06	4.19	4.32	4.46
1320	4.50	4.65	4.74	4.85	4.96	5.06
1330	**7.82**	**7.82**	**7.82**	**7.82**	**7.82**	**7.82**
1350	**8.33**	**8.33**	**8.33**	**8.33**	**8.33**	**8.33**
1352	6.08	6.72	7.16	7.69	8.26	8.49
1354	6.04	6.74	7.16	7.68	8.26	**8.50**
1360	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
1430	6.71	7.13	7.38	7.70	8.27	8.75
1440	6.72	7.14	7.38	7.70	8.27	8.75
1450	6.72	7.14	7.38	7.70	8.28	8.75
1455	8.93	10.18	10.49	10.53	10.57	10.60
1456	9.31	10.72	**11.02**	**11.02**	**11.02**	**11.02**
1460	11.54	**11.96**	**11.96**	**11.96**	**11.96**	**11.96**
1461	**9.85**	**9.85**	**9.85**	**9.85**	**9.85**	**9.85**
1470	6.72	7.14	7.38	7.70	8.28	8.75
1512	9.15	**9.70**	**9.70**	**9.70**	**9.70**	**9.70**
1514	3.79	3.91	3.97	4.04	4.10	4.15
1515	3.80	3.93	4.00	4.07	4.13	4.18
1516	9.06	**9.55**	**9.55**	**9.55**	**9.55**	**9.55**
1517	8.53	**9.60**	**9.60**	**9.60**	**9.60**	**9.60**
1518	8.41	**9.60**	**9.60**	**9.60**	**9.60**	**9.60**
1519	4.08	4.42	4.60	4.81	5.03	**5.10**
1520	4.70	5.15	5.39	5.64	5.91	6.17
1521	9.94	10.36	10.67	11.08	11.55	12.00
1522	9.94	10.10	10.19	10.22	10.30	10.38
1523	4.74	5.19	5.43	5.67	5.94	6.18
1524	10.96	11.19	11.30	11.46	11.63	11.78
1525	**12.00**	**12.00**	**12.00**	**12.00**	**12.00**	**12.00**
1526	10.30	10.66	10.89	11.12	11.38	**11.50**
1527	13.30	13.70	13.92	**14.00**	**14.00**	**14.00**
1528	**14.00**	**14.00**	**14.00**	**14.00**	**14.00**	**14.00**
1529	**16.00**	**16.00**	**16.00**	**16.00**	**16.00**	**16.00**
1530	**16.70**	**16.70**	**16.70**	**16.70**	**16.70**	**16.70**
1600	4.64	5.53	6.07	**6.14**	**6.14**	**6.14**
1610	5.85	6.30	6.55	6.71	6.71	6.71
1620	6.76	7.29	7.99	**8.00**	**8.00**	**8.00**
1700	4.70	5.15	5.40	5.65	5.92	6.18
1710	9.93	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**

Table 6-1. Existing (2004) Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
2511	9.26	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
2512	8.06	**9.10**	**9.10**	**9.10**	**9.10**	**9.10**
2513	7.01	7.49	7.51	7.50	7.50	7.48
2514	3.81	3.94	4.02	4.10	4.16	4.23
2516	8.75	9.76	**10.00**	**10.00**	**10.00**	**10.00**
2521	5.79	5.94	6.01	6.05	6.11	6.24
2522	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
2523	**6.90**	**6.90**	**6.90**	**6.90**	**6.90**	**6.90**
2524	8.77	9.20	9.40	9.61	9.83	**10.00**

6.2 Future Conditions Maximum Water Surface Elevations

Table 6-2. Future Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
100	3.55	3.55	3.55	3.55	3.55	3.55
105	3.56	3.57	3.57	3.58	3.58	3.59
110	3.57	3.58	3.58	3.59	3.60	3.60
115	3.57	3.59	3.59	3.60	3.61	3.61
120	3.57	3.59	3.60	3.61	3.62	3.63
130	3.91	4.06	4.15	4.25	4.35	4.46
140	3.94	4.11	4.20	4.31	4.42	4.53
150	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**
160	3.58	3.60	3.60	3.61	3.62	3.63
165	3.59	3.60	3.61	3.62	3.63	3.64
180	3.64	3.70	3.72	3.76	3.79	3.82
190	3.67	3.74	3.77	3.82	3.87	3.91
200	3.68	3.76	3.80	3.85	3.90	3.95
205	3.73	3.82	3.88	3.94	4.01	4.07
210	3.74	3.83	3.89	3.95	4.03	4.10
220	3.75	3.85	3.92	3.99	4.07	4.14
230	3.78	3.90	3.97	4.05	4.14	4.22
240	3.79	3.94	4.02	4.13	4.23	4.32
250	3.82	3.98	4.07	4.17	4.29	4.38
260	4.33	4.84	5.01	5.18	5.30	5.34
262	4.24	4.67	4.78	4.88	5.04	5.14
264	4.33	4.70	4.72	4.75	4.79	4.82
265	4.36	**4.70**	**4.70**	**4.70**	**4.70**	**4.70**

Table 6-2. Future Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
266	4.46	4.90	4.83	4.84	4.84	4.82
267	8.62	9.03	**10.00**	**10.00**	**10.00**	**10.00**
268	8.92	9.39	10.43	**10.50**	**10.50**	**10.50**
269	9.85	9.95	10.55	10.64	10.73	10.77
270	4.36	4.92	5.14	5.38	**5.50**	**5.50**
271	10.98	**11.20**	**11.20**	**11.20**	**11.20**	**11.20**
272	10.98	**11.20**	**11.20**	**11.20**	**11.20**	**11.20**
280	4.37	4.95	5.17	5.42	5.56	5.57
290	4.38	4.95	5.19	5.44	5.60	5.62
300	4.39	4.97	5.20	5.45	5.63	5.67
310	5.69	6.96	7.79	8.51	9.75	**9.93**
320	4.42	5.03	5.26	5.51	5.69	5.73
330	4.43	5.07	5.30	5.55	5.73	5.77
340	4.43	5.08	5.31	5.56	5.74	5.78
350	4.46	5.13	5.37	5.63	5.81	5.87
360	4.48	5.17	5.41	5.66	5.84	5.92
370	5.50	6.04	6.35	6.69	7.08	7.36
379	5.61	6.26	6.62	6.98	7.35	7.65
380	5.85	6.38	6.70	7.05	7.40	7.73
390	5.85	6.38	6.70	7.05	7.40	7.72
420	6.00	6.81	7.26	7.77	8.30	8.77
427	6.01	7.44	8.43	9.80	11.51	**12.00**
431	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
440	6.00	6.81	7.26	7.77	8.30	8.77
450	7.27	7.80	8.08	8.38	8.70	8.98
470	10.09	10.09	10.09	10.09	10.09	10.09
480	12.99	12.99	**13.00**	**13.00**	**13.00**	**13.00**
490	**13.00**	**13.00**	**13.00**	**13.00**	**13.00**	**13.00**
520	3.65	3.70	3.72	3.76	3.79	3.83
525	3.97	4.15	4.17	4.19	4.22	4.24
526	4.40	4.64	4.65	4.66	4.67	4.68
527	5.31	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
540	3.68	3.76	3.81	3.87	3.93	3.98
541	3.72	3.81	3.86	3.92	3.98	4.04
542	4.23	4.58	4.72	4.88	4.95	4.97
543	4.28	4.64	4.79	4.95	**5.00**	**5.00**
544	4.30	4.65	4.80	4.96	5.05	5.08
545	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
546	4.28	4.64	4.79	4.95	5.01	5.03
547	4.37	**4.70**	**4.70**	**4.70**	**4.70**	**4.70**
548	5.88	5.88	5.88	5.88	5.88	5.88

Table 6-2. Future Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
549	**6.70**	**6.70**	**6.70**	**6.70**	**6.70**	**6.70**
560	4.83	5.31	5.54	5.76	5.86	5.94
565	3.69	3.76	3.80	3.85	3.90	3.96
570	3.74	3.85	3.92	4.00	4.09	4.18
575	3.75	3.87	3.94	4.03	4.12	4.21
580	3.75	3.87	3.94	4.03	4.12	4.21
590	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**
620	3.74	3.84	3.89	3.96	4.03	4.10
630	4.00	4.07	4.07	4.07	4.08	4.15
640	6.45	**7.26**	**7.26**	**7.26**	**7.26**	**7.26**
650	7.71	7.89	8.00	8.12	8.24	8.34
729	4.00	4.25	4.38	4.52	4.66	4.78
730	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**
760	3.75	3.86	3.92	3.99	4.07	4.15
792	6.64	7.93	8.85	9.49	9.54	9.55
793	6.54	8.46	9.58	10.40	10.43	10.44
830	4.50	4.91	5.11	5.28	5.46	5.63
835	4.51	4.93	5.13	5.31	5.50	5.66
837	3.74	3.85	3.91	3.98	4.06	4.14
838	4.96	5.84	6.65	7.72	8.70	8.76
839	5.81	6.45	7.46	8.92	**10.27**	**10.27**
862	6.82	8.93	10.25	**11.20**	**11.20**	**11.20**
900	4.64	5.08	5.28	5.42	5.56	5.69
905	5.29	5.94	**6.00**	**6.00**	**6.00**	**6.00**
910	6.74	6.94	7.04	7.18	7.32	7.44
915	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
920	10.47	10.87	**11.00**	**11.00**	**11.00**	**11.00**
925	10.49	10.78	10.90	10.90	10.90	10.89
930	**10.30**	**10.30**	**10.30**	**10.30**	**10.30**	**10.30**
970	4.85	5.11	5.26	5.42	5.59	5.74
980	5.07	5.32	5.43	5.54	5.67	5.77
981	9.14	**10.10**	**10.10**	**10.10**	**10.10**	**10.10**
982	9.31	10.13	10.24	10.33	10.42	10.47
983	7.44	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**
984	7.48	8.03	8.04	8.05	8.06	8.07
986	8.07	9.02	9.29	9.56	9.83	**10.00**
990	9.19	9.50	9.61	9.76	10.00	10.19
1005	10.54	11.64	11.67	11.69	11.69	11.68
1010	10.70	**11.70**	**11.70**	**11.70**	**11.70**	**11.70**
1185	4.52	4.95	5.15	5.34	5.53	5.73
1190	4.63	5.02	5.22	5.40	5.60	5.81

Table 6-2. Future Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
1200	7.62	7.62	7.62	7.62	7.62	7.62
1204	7.93	7.93	7.93	7.93	7.93	7.93
1206	**10.50**	**10.50**	**10.50**	**10.50**	**10.50**	**10.50**
1210	10.92	10.92	10.92	10.92	10.92	10.92
1220	**11.23**	**11.23**	**11.23**	**11.23**	**11.23**	**11.23**
1230	**11.40**	**11.40**	**11.40**	**11.40**	**11.40**	**11.40**
1240	**11.60**	**11.60**	**11.60**	**11.60**	**11.60**	**11.60**
1319	3.84	4.04	4.16	4.33	4.52	4.69
1320	4.50	4.65	4.74	4.85	4.96	5.07
1330	**7.82**	**7.82**	**7.82**	**7.82**	**7.82**	**7.82**
1350	**8.33**	**8.33**	**8.33**	**8.33**	**8.33**	**8.33**
1352	6.13	6.60	6.89	7.23	7.58	7.86
1354	5.96	6.46	6.77	7.15	7.52	7.82
1360	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
1430	7.28	7.81	8.09	8.39	8.71	9.00
1440	7.28	7.81	8.09	8.39	8.72	9.00
1450	7.28	7.81	8.09	8.40	8.72	9.00
1455	9.21	10.49	10.59	10.64	10.70	10.75
1456	9.58	10.96	**11.02**	**11.02**	**11.02**	**11.02**
1460	11.67	**11.96**	**11.96**	**11.96**	**11.96**	**11.96**
1461	**9.85**	**9.85**	**9.85**	**9.85**	**9.85**	**9.85**
1470	7.28	7.81	8.10	8.40	8.72	9.00
1512	9.16	**9.70**	**9.70**	**9.70**	**9.70**	**9.70**
1514	3.83	4.02	4.13	4.26	4.39	4.50
1515	3.85	4.05	4.18	4.32	4.46	4.57
1516	9.07	**9.55**	**9.55**	**9.55**	**9.55**	**9.55**
1517	8.55	**9.60**	**9.60**	**9.60**	**9.60**	**9.60**
1518	8.42	**9.60**	**9.60**	**9.60**	**9.60**	**9.60**
1519	3.91	4.20	4.42	4.65	4.84	4.99
1520	4.30	4.96	5.34	5.71	5.92	6.10
1521	10.06	10.38	10.68	11.09	11.58	12.03
1522	10.03	10.15	10.19	10.23	10.30	10.38
1523	4.34	5.07	5.56	6.10	6.26	6.40
1524	10.96	11.17	11.30	11.46	11.63	11.78
1525	**12.00**	**12.00**	**12.00**	**12.00**	**12.00**	**12.00**
1526	10.39	10.77	11.00	11.27	**11.50**	**11.50**
1527	13.30	13.70	13.91	**14.00**	**14.00**	**14.00**
1528	**14.00**	**14.00**	**14.00**	**14.00**	**14.00**	**14.00**
1529	**16.00**	**16.00**	**16.00**	**16.00**	**16.00**	**16.00**
1530	**16.70**	**16.70**	**16.70**	**16.70**	**16.70**	**16.70**
1600	4.38	4.96	5.20	5.46	5.64	5.67

Table 6-2. Future Conditions, Maximum Computed Water Surface Elevations

Junction Number	Maximum Junction Elevation (FT, NGVD88) Bold Indicates Surface Flooding					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
1610	4.47	5.14	5.44	5.78	6.04	6.14
1620	4.50	5.25	5.64	6.11	6.50	6.73
1630	4.71	5.52	5.84	6.20	6.55	6.81
1640	5.66	6.47	6.77	7.09	7.42	7.65
1700	4.32	4.97	5.35	5.72	5.93	6.10
1710	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**
2511	7.02	7.65	7.96	8.28	8.62	9.06
2512	4.87	5.83	6.37	6.92	7.36	7.74
2513	4.61	5.27	5.62	6.04	6.47	6.75
2514	3.86	4.06	4.19	4.35	4.51	4.65
2516	7.52	7.98	8.21	8.45	8.71	9.04
2521	5.36	6.33	6.82	**7.30**	**7.30**	**7.30**
2522	5.62	6.64	7.16	7.72	**8.00**	**8.00**
2523	6.07	7.14	7.67	8.34	8.50	8.50
2524	6.77	7.19	7.40	7.61	7.87	8.05

7. MASTER DRAINAGE PLAN IMPROVEMENTS

This study has been prepared to facilitate the modeling and consideration of future improvements in this watershed. The level of detail is sufficient for a large watershed, establishing a good baseline for future modeling. Modelers building upon this effort should bear in mind the amount of guessing that was necessary to make up for missing information. As future models are constructed, they should be submitted to the City for review and possible incorporation into future updates of this study. Any new field surveying data would be of particular interest to the City.

The prior Master Drainage Plan study of the St. Julian Creek watershed—completed in 1986—resulted in recommendations for three major watershed drainage improvements. URS carefully evaluated the 1986 recommendations using the modeling results of the current study.

Only part of one of the prior recommendations has been largely accomplished over time—specifically installation of a larger culvert at Deep Creek Boulevard downstream of Camelot Lake. This culvert was installed at the time Deep Creek Boulevard was widened and realigned.

The 1986 recommendations were used as starting points to evaluate future improvements in the St. Julian Creek watershed. After considerable trial-and-error design modeling, recommendations for three improvements were identified and validated. One of the final recommendations is similar to those described in the 1986 study. One of the final recommendations combines the other two 1986 recommendations as part of a more extensive effort. A third recommendation is to improve the drainage east of St. Julian Creek and just downstream of the CSX Railway. The three recommended improvements are shown in Figure 7-1 and described below.

Figure 7-1. Recommended Watershed Improvements

Inherent in these recommended improvements is the assumption that Chesapeake will continue to follow State storm water management and erosion control regulations and guidelines. It is also required that the hydraulic storage capacity and conveyance properties of major drainage system components be maintained as modeled for this study. Specifically, future development plans must not reduce the flood storage that was modeled in this study, and channels and culverts must be maintained to have the hydraulic characteristics as modeled.

In producing the final recommendations, many computer runs were made in an attempt to minimize the cost of the future improvements.

7.1. Camelot Lake Bypass

The need for this improvement was identified in the previous study and validated in the current models. Camelot Lake does not currently meet the City's detention basin storage recovery requirement.

After considerable trial and error, the bypass recommendation consists of the following components:

- A new 4'H x 10'W box culvert 348 feet long, with upstream and downstream inverts of 4.9 and 3.4 feet NAVD, respectively;
- An improved channel with 8-foot bottom width and 2:1 sideslopes, and upstream and downstream inverts of 3.4 and 1.6 feet NAVD, respectively;
- A replacement 3'H x 8'W box culvert under Romaron Street, with upstream and downstream inverts of 1.6 and 1.3 feet NAVD, respectively;
- An improved channel with 8-foot bottom width and 2:1 sideslopes, and upstream and downstream inverts of 1.3 and 0.0 feet NAVD, respectively; and

The proposed bypass is composed of Links 16500 – 16000 in the future conditions model, from Node 1650 to Node 290. The bypass is sized so that 48 hours after the start of a 10-year storm for future conditions land use, Camelot Lake recovers 90% of the storage volume needed for a 50-year storm at existing conditions (i.e., 2004 land use with no bypass).

Figure 7-2 shows the 50-year peak hydraulic grade line values through the bypass from Node 390 to Node 262.

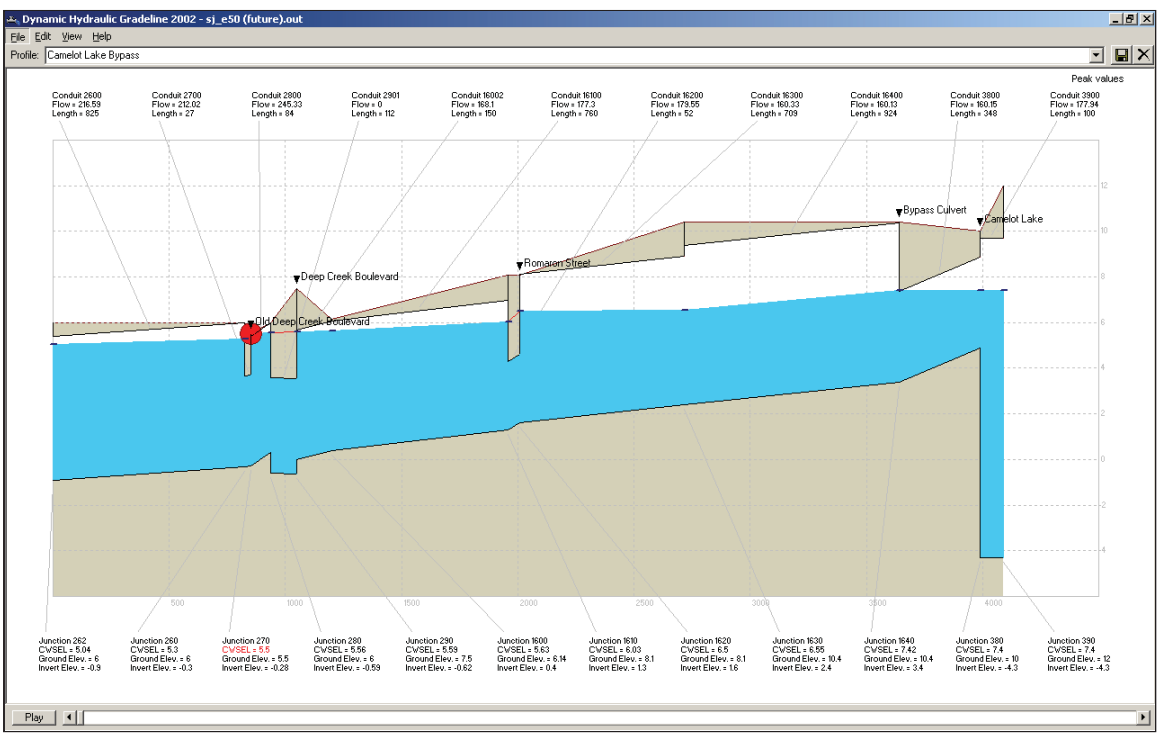

Figure 7-2. 50-Year Peak Hydraulic Grade line From Node 390 Through Node 262

7.2. Portsmouth Outfall – Gust Lane to Deep Creek Boulevard

The next two facility recommendations are required only if the City of Portsmouth opens up the crossings under the CSX Railway, although the models indicate that Deep Creek Boulevard almost floods for the 50-year event under existing conditions. The recommendation consists of the following:

- An additional 72" RCP culvert 40 feet long under the CSX Railway, with upstream and downstream inverts of 0.0 and -0.3 feet NAVD, respectively;
- An improved channel with 30-foot bottom width and 2:1 sideslopes, and upstream and downstream inverts of -0.3 and -1.0 feet NAVD, respectively;
- Two additional 4'H x 6'W box culverts under Deep Creek Boulevard, with upstream and downstream inverts of -1.0 and -1.1 feet NAVD, respectively; and
- Dredging the channel downstream of Deep Creek Boulevard to an elevation of -1.1 feet NAVD so that the culverts are not sumped.

Widening the channel to have a 30-foot bottom width in this location has several benefits, including increased conveyance capacity for upstream flows, and increased flood storage within the channel. The modeling effort indicated that without this additional conveyance capacity and storage, flows will overtop the existing channel banks, and nodal flooding will occur. Several different widths were tried, and a 30-foot bottom just barely provides the needed hydraulic capacity. Given the lot line configurations and available remaining land after existing and future development is considered, a 30-foot bottom should fit well on the site.

The proposed 72" RCP culvert is Link 15232, from Node 1523 to Node 1520. The proposed 30-foot wide channel is Link 15200 in the future conditions model, from Node 1520 to Node 1519. The proposed 4'H x 6'W box culverts are Links 15192 and 15193, from Node 1519 to Node 1515. The proposed dredging is on the upstream end of Link 15150, between Node 1515 and Node 1514.

Figure 7-3 shows the 50-year peak hydraulic grade line values through St. Julian Creek from Node 2521 to Node 1514.

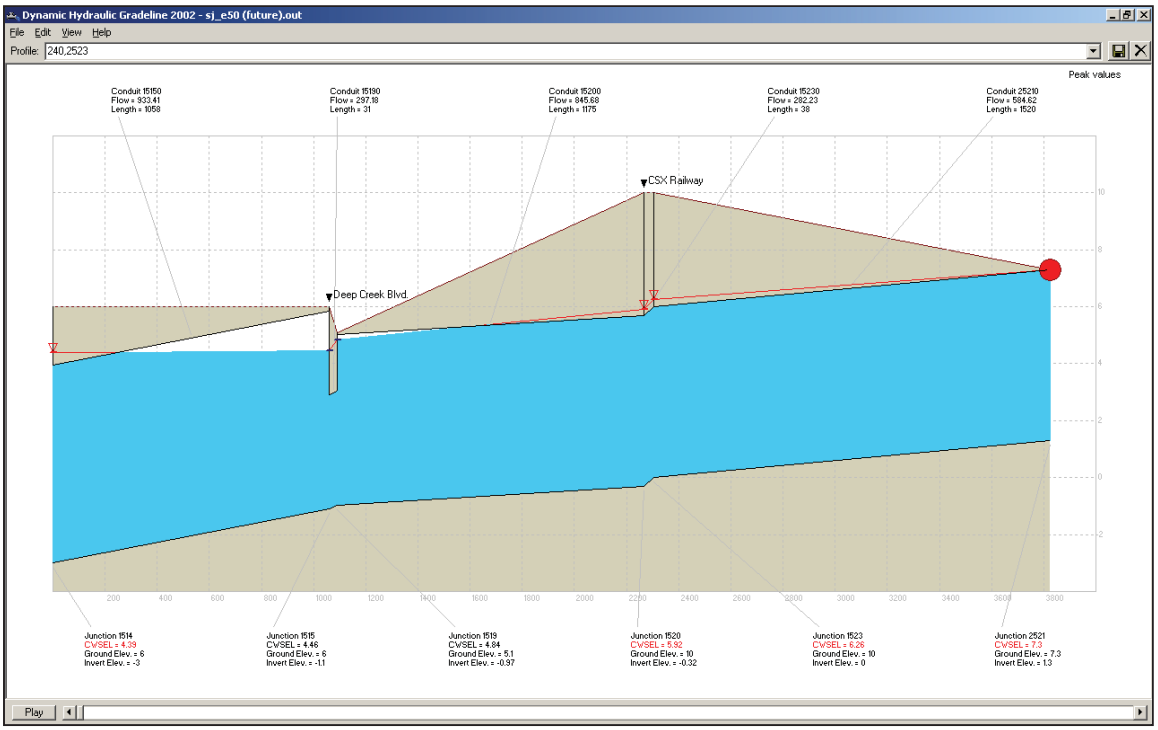

Figure 7-3. 50-Year Peak Hydraulic Grade line From Node 2521 Through Node 1514

7.3. Portsmouth Outfall – West of U.S. 17

As with the previous facility, this project is required only if the City of Portsmouth opens up the crossing under the CSX Railway. The recommendation consists of the following:

- An additional 60" RCP culvert 40 feet long under the CSX Railway, with upstream and downstream inverts of 1.87 and 1.76 feet NAVD, respectively;
- An improved channel with 15-foot bottom width and 2:1 sideslopes, and upstream and downstream inverts of 1.76 and 0.5 feet NAVD, respectively; and
- Dredging the channel downstream of the improved channel to an elevation of 0.5 feet NAVD.

The proposed 60" RCP culvert is Link 25122 in the future conditions model, from Node 2512 to Node 2513. The inverts are set to those assumed for the existing culvert, whose geometric properties were visually estimated during a field visit and tied to the City's GIS spot elevation nearby on the CSX Railway. The improved channel is Link 25130, from Node 2513 to Node 2514. The proposed dredging is on the upstream end of Link 25140, between Node 2514 and Node 1514.

Figure 7-4 shows the 50-year peak hydraulic grade line values through the Portsmouth Crossing west of U.S. 17 from Node 2511 to Node 1514.

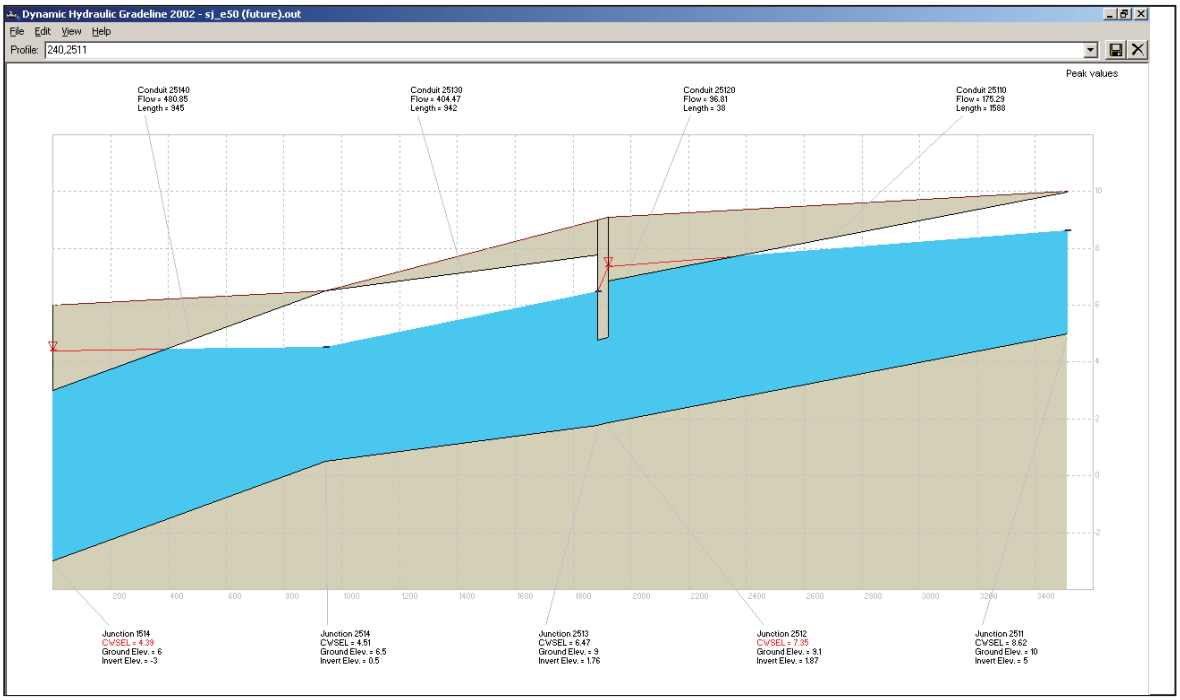

Figure 7-4. 50-Year Peak Hydraulic Grade line From Node 2511 Through Node 1514

APPENDIX A. SUBCATCHMENT IMPERVIOUSNESS & SOILS PARAMETERS

Table A-1. Percent Imperviousness by Land Use

Source: HRPDC "Regional Stormwater Loading Study," September 1999, by CH2M-Hill

LUCODE	Land Use	Percent Imperviousness
RR	Single-Family Residential - Rural	5
SRR	Single-Family Residential - Semi-Rural	10
SRL	Single-Family Residential - Suburban Low	15
SRM	Single-Family Residential - Suburban Medium	25
RM	Single-Family Residential - Urban	40
RMF	Multi-Family Residential	50
CMU	Office/Light Industrial	60
COM	Commercial	85
MIL	Military	30
PUB	Schools, Government Buildings	25
IND	Industrial	85
RD	Roads	90
ROW	Right-of-Ways	1
VAC	Vacant	1
GRS	Open Space - Grass	1
FOR	Forest	1
AGC	Agricultural - Cropland	1
AGP	Agricultural - Pasture	1
WET	Wetlands	100
WAT	Water Features	100

Table A-2. Imperviousness Computations by Land Use
St. Julian Creek Watershed
12/2/2004
Note: These computations were performed in GIS using the City's land use data.

The actual imperviousness used in the SWMM modeling may be adjusted to reflect conditions that are not otherwise reflected in the GIS land use coverage.

From GIS		Percent Imperviousness	
ID	Acres	2003 Land Use	Future Land Use
10000	49.83	60.45	60.45
10010	45.31	42.18	42.18
10020	48.03	34.30	34.30
10040	62.60	29.86	29.86
10050	45.49	42.65	42.65
10060	30.46	29.42	29.42
10070	39.29	23.63	53.71
10080	28.05	34.29	60.17
10090	9.80	60.23	75.89
10100	39.72	49.98	51.73
10110	93.08	70.15	70.15
10120	82.66	30.91	30.91
10130	74.53	29.11	29.11
10140	32.50	29.50	29.50
10150	35.57	30.52	30.52
10160	44.11	31.10	31.10
10170	46.84	43.14	43.14
10180	31.57	33.76	33.76
10190	22.97	30.21	30.21
10200	27.14	49.09	49.09
10205	17.31	9.39	9.39
10210	25.18	27.59	37.98
10220	21.73	34.49	34.70
10225	38.84	23.10	28.52
10230	16.39	18.29	20.63
10240	35.32	30.32	30.35
10250	27.66	47.39	47.39
10260	47.39	39.62	39.62
10265	5.81	28.52	28.52
10270	16.89	26.80	26.80
10280	14.63	28.35	28.35
10290	8.17	37.04	37.04
10293	7.05	42.65	42.65
10295	7.38	28.22	28.22

Table A-2. Imperviousness Computations by Land Use
St. Julian Creek Watershed
12/2/2004
Note: These computations were performed in GIS using the City's land use data.

The actual imperviousness used in the SWMM modeling may be adjusted to reflect conditions that are not otherwise reflected in the GIS land use coverage.

From GIS		Percent Imperviousness	
ID	Acres	2003 Land Use	Future Land Use
10300	10.66	26.84	26.84
10310	9.45	28.26	28.26
10320	21.99	42.46	42.46
10330	18.17	25.43	25.43
10340	33.23	35.96	35.96
10350	21.03	15.94	15.94
10360	17.69	25.18	25.18
10370	28.04	37.42	37.42
10380	13.88	36.05	36.05
10390	23.50	27.38	27.38
10400	19.34	16.99	16.99
10410	14.22	22.46	22.46
10420	27.84	27.63	27.63
10430	30.01	39.44	39.44
10440	23.20	46.23	46.23
10450	11.84	27.38	27.38
10455	9.90	20.74	20.74
10460	12.13	31.29	31.29
10465	14.77	31.31	31.31
10470	16.88	52.80	52.80
10475	16.93	23.29	23.32
10480	18.63	23.45	34.79
10490	11.73	23.14	23.14
10500	19.44	27.90	27.90
10510	11.06	33.45	33.45
10520	20.23	25.66	25.66
10530	16.64	47.17	54.39
10540	24.22	33.39	33.64
10550	39.20	66.38	66.38
10555	36.13	38.77	48.44
10560	35.16	19.72	27.05
10570	15.41	6.11	6.11
10580	26.77	57.55	57.55
10590	55.04	25.93	32.80
10600	4.72	21.00	21.00
10605	8.60	37.28	37.28

Table A-2. Imperviousness Computations by Land Use
St. Julian Creek Watershed
12/2/2004
Note: These computations were performed in GIS using the City's land use data.

The actual imperviousness used in the SWMM modeling may be adjusted to reflect conditions that are not otherwise reflected in the GIS land use coverage.

From GIS		Percent Imperviousness	
ID	Acres	2003 Land Use	Future Land Use
10610	14.05	51.61	59.84
10620	14.65	49.79	49.79
10630	13.02	53.05	53.05
10640	13.35	35.40	35.40
10650	16.19	46.60	50.75
10660	24.36	52.20	57.39
10670	40.94	54.15	54.15
10680	12.32	61.71	66.81
10690	9.88	67.00	67.00
10700	13.96	58.25	58.25
10710	6.04	61.97	61.97
10720	53.00	17.34	30.85
10730	21.67	42.80	42.80
10740	16.17	49.41	49.41
10750	17.83	43.52	43.52
10760	9.85	45.24	45.24
10765	16.47	36.59	36.59
10770	23.15	40.49	40.74
10780	13.99	32.85	36.98
10785	28.31	23.82	29.88
10790	61.58	27.14	36.24
10800	10.96	34.92	34.92
10810	21.92	27.41	32.24
10830	48.40	2.24	58.39
10840	13.71	36.72	49.28
10845	16.17	40.94	40.94
10850	14.70	39.13	42.91
10860	34.70	4.73	58.89
10870	6.62	36.63	61.73
10880	7.07	38.16	53.30
10890	6.63	70.85	70.85
10900	14.76	62.97	69.68
10910	27.77	38.99	38.99
10920	18.09	36.80	36.80
10930	19.34	31.42	62.04
10950	13.09	53.01	62.72

Table A-2. Imperviousness Computations by Land Use
St. Julian Creek Watershed
12/2/2004
Note: These computations were performed in GIS using the City's land use data.

The actual imperviousness used in the SWMM modeling may be adjusted to reflect conditions that are not otherwise reflected in the GIS land use coverage.

From GIS		Percent Imperviousness	
ID	Acres	2003 Land Use	Future Land Use
10960	20.02	56.99	56.99
10970	10.96	37.61	37.61
10980	24.14	45.23	45.23
10990	18.07	65.40	65.40
11000	10.02	76.28	76.28
11010	28.49	59.97	59.97
11020	12.67	47.38	47.38
11030	36.11	40.81	40.81
11040	24.82	39.84	39.84
11050	15.27	39.16	39.16
11060	12.22	39.88	39.88

Table A-3. Subcatchment Soil Texture
St. Julian Creek Watershed
12/02/2004

ID	ACRES	Soil_Type	SUCT	HYDCON	SMDMAX
10000	49.83	Sandy Loam	4.33	0.86	0.246
10010	45.31	Loamy Sand	2.41	2.35	0.312
10020	48.03	Sandy Loam	4.33	0.86	0.246
10040	62.61	Sandy Loam	4.33	0.86	0.246
10050	45.49	Sandy Loam	4.33	0.86	0.246
10060	30.46	Sandy Loam	4.33	0.86	0.246
10070	39.29	Sandy Loam	4.33	0.86	0.246
10080	28.05	Sandy Loam	4.33	0.86	0.246
10090	9.80	Water-Clay	12.45	0.02	0.079
10100	39.72	Sandy Loam	4.33	0.86	0.246
10110	93.08	Sandy Loam	4.33	0.86	0.246
10120	82.67	Sandy Loam	4.33	0.86	0.246
10130	74.53	Sandy Loam	4.33	0.86	0.246
10140	32.50	Sandy Loam	4.33	0.86	0.246
10150	35.57	Sandy Loam	4.33	0.86	0.246
10160	44.11	Sandy Loam	4.33	0.86	0.246
10170	46.84	Sandy Loam	4.33	0.86	0.246
10180	31.57	Sandy Loam	4.33	0.86	0.246
10190	22.97	Sandy Loam	4.33	0.86	0.246
10200	27.14	Sandy Loam	4.33	0.86	0.246
10205	17.31	Sandy Loam	4.33	0.86	0.246
10210	25.18	Sandy Loam	4.33	0.86	0.246
10220	21.74	Sandy Loam	4.33	0.86	0.246
10225	38.84	Sandy Loam	4.33	0.86	0.246
10230	16.39	Sandy Loam	4.33	0.86	0.246
10240	35.32	Loamy Sand	2.41	2.35	0.312
10250	27.66	Loamy Sand	2.41	2.35	0.312
10260	47.39	Loamy Sand	2.41	2.35	0.312
10265	5.81	Loamy Sand	2.41	2.35	0.312
10270	16.89	Loamy Sand	2.41	2.35	0.312
10280	14.63	Loamy Sand	2.41	2.35	0.312
10290	8.18	Loamy Sand	2.41	2.35	0.312
10293	7.05	Loamy Sand	2.41	2.35	0.312
10295	7.38	Loamy Sand	2.41	2.35	0.312
10300	10.66	Loamy Sand	2.41	2.35	0.312
10310	9.45	Loamy Sand	2.41	2.35	0.312
10320	21.99	Loamy Sand	2.41	2.35	0.312
10330	18.17	Loamy Sand	2.41	2.35	0.312
10340	33.23	Loamy Sand	2.41	2.35	0.312
10350	21.03	Loamy Sand	2.41	2.35	0.312

Table A-3. Subcatchment Soil Texture
St. Julian Creek Watershed
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ID	ACRES	Soil_Type	SUCT	HYDCON	SMDMAX
10360	17.69	Sandy Loam	4.33	0.86	0.246
10370	28.04	Sandy Loam	4.33	0.86	0.246
10380	13.88	Sandy Loam	4.33	0.86	0.246
10390	23.50	Sandy Loam	4.33	0.86	0.246
10400	19.34	Sandy Loam	4.33	0.86	0.246
10410	14.22	Sandy Loam	4.33	0.86	0.246
10420	27.84	Sandy Loam	4.33	0.86	0.246
10430	30.01	Sandy Loam	4.33	0.86	0.246
10440	23.20	Sandy Loam	4.33	0.86	0.246
10450	11.84	Sandy Loam	4.33	0.86	0.246
10455	9.90	Sandy Loam	4.33	0.86	0.246
10460	12.13	Sandy Loam	4.33	0.86	0.246
10465	14.77	Sandy Loam	4.33	0.86	0.246
10470	16.88	Sandy Loam	4.33	0.86	0.246
10475	16.93	Sandy Loam	4.33	0.86	0.246
10480	18.63	Sandy Loam	4.33	0.86	0.246
10490	11.73	Sandy Loam	4.33	0.86	0.246
10500	19.44	Sandy Loam	4.33	0.86	0.246
10510	11.06	Sandy Loam	4.33	0.86	0.246
10520	20.23	Loamy Sand	2.41	2.35	0.312
10530	16.64	Sandy Loam	4.33	0.86	0.246
10540	24.22	Loamy Sand	2.41	2.35	0.312
10550	39.20	Loamy Sand	2.41	2.35	0.312
10555	36.13	Loamy Sand	2.41	2.35	0.312
10560	35.16	Loamy Sand	2.41	2.35	0.312
10570	15.41	Loamy Sand	2.41	2.35	0.312
10580	26.78	Loamy Sand	2.41	2.35	0.312
10590	55.04	Loamy Sand	2.41	2.35	0.312
10600	4.72	Loamy Sand	2.41	2.35	0.312
10605	8.60	Loamy Sand	2.41	2.35	0.312
10610	14.05	Loamy Sand	2.41	2.35	0.312
10620	14.65	Sandy Loam	4.33	0.86	0.246
10630	13.02	Sandy Loam	4.33	0.86	0.246
10640	13.35	Sandy Loam	4.33	0.86	0.246
10650	16.19	Sandy Loam	4.33	0.86	0.246
10660	24.36	Sandy Loam	4.33	0.86	0.246
10670	40.94	Sandy Loam	4.33	0.86	0.246
10680	12.32	Sandy Loam	4.33	0.86	0.246
10690	9.88	Sandy Loam	4.33	0.86	0.246
10700	13.96	Sandy Loam	4.33	0.86	0.246
10710	6.04	Sandy Loam	4.33	0.86	0.246
10720	53.00	Loamy Sand	2.41	2.35	0.312

Table A-3. Subcatchment Soil Texture
St. Julian Creek Watershed
12/02/2004

ID	ACRES	Soil_Type	SUCT	HYDCON	SMDMAX
10730	21.67	Loamy Sand	2.41	2.35	0.312
10740	16.17	Sandy Loam	4.33	0.86	0.246
10750	17.83	Sandy Loam	4.33	0.86	0.246
10760	9.85	Sandy Loam	4.33	0.86	0.246
10765	16.47	Sandy Loam	4.33	0.86	0.246
10770	23.15	Loamy Sand	2.41	2.35	0.312
10780	13.99	Loamy Sand	2.41	2.35	0.312
10785	28.31	Loamy Sand	2.41	2.35	0.312
10790	61.58	Sandy Loam	4.33	0.86	0.246
10800	10.96	Sandy Loam	4.33	0.86	0.246
10810	21.92	Sandy Loam	4.33	0.86	0.246
10830	48.40	Sandy Loam	4.33	0.86	0.246
10840	13.71	Sandy Loam	4.33	0.86	0.246
10845	16.17	Sandy Loam	4.33	0.86	0.246
10850	14.70	Sandy Loam	4.33	0.86	0.246
10860	34.70	Sandy Loam	4.33	0.86	0.246
10870	6.62	Sandy Loam	4.33	0.86	0.246
10880	7.07	Sandy Loam	4.33	0.86	0.246
10890	6.63	Sandy Loam	4.33	0.86	0.246
10900	14.76	Sandy Loam	4.33	0.86	0.246
10910	27.77	Sandy Loam	4.33	0.86	0.246
10920	18.09	Sandy Loam	4.33	0.86	0.246
10930	19.34	Sandy Loam	4.33	0.86	0.246
10950	13.09	Sandy Loam	4.33	0.86	0.246
10960	20.02	Sandy Loam	4.33	0.86	0.246
10970	10.97	Sandy Loam	4.33	0.86	0.246
10980	24.14	Sandy Loam	4.33	0.86	0.246
10990	18.08	Sandy Loam	4.33	0.86	0.246
11000	10.02	Sandy Loam	4.33	0.86	0.246
11010	28.50	Sandy Loam	4.33	0.86	0.246
11020	12.67	Sandy Loam	4.33	0.86	0.246
11030	36.11	Sandy Loam	4.33	0.86	0.246
11040	24.82	Sandy Loam	4.33	0.86	0.246
11050	15.27	Sandy Loam	4.33	0.86	0.246
11060	12.22	Sandy Loam	4.33	0.86	0.246
Portsmouth Subcatchments					
21529	1.73	Sandy Loam	4.33	0.86	0.246
21528	1.75	Sandy Loam	4.33	0.86	0.246
22511	40.51	Sandy Loam	4.33	0.86	0.246
22512	56.84	Sandy Loam	4.33	0.86	0.246
22522	84.37	Sandy Loam	4.33	0.86	0.246
22523	141.05	Sandy Loam	4.33	0.86	0.246

Table A-3. Subcatchment Soil Texture
St. Julian Creek Watershed
12/02/2004

ID	ACRES	Soil_Type	SUCT	HYDCON	SMDMAX
21520	106.54	Sandy Loam	4.33	0.86	0.246
20150	50.49	Sandy Loam	4.33	0.86	0.246
20530	59.89	Sandy Loam	4.33	0.86	0.246
22524	33.79	Sandy Loam	4.33	0.86	0.246
22516	22.30	Sandy Loam	4.33	0.86	0.246
128 Subcatchments					