Total Maximum Daily Loads of Bacteria for Nassawadox Creek & Tributaries and Westerhouse Creek in Northampton County, Virginia

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TABLE OF CONTENTS

TABLE OF CONTENTS i
List of Figures ii
List of Tables iii
List of Abbreviations iv
EXECUTIVE SUMMARY v
1.0 INTRODUCTION 1
1.1 Background 1
1.2 Listing of Waterbodies under the CWA 2
1.3 Watershed Location and Description 4
1.4 Designated Uses and Applicable Water Quality Standard 5
1.5 Impairment Listing 6
2.0 WATERSHED CHARACTERIZATION 10
2.1 Topology, Soil, and Climate 10
2.2 Landuse 10
2.3 Water Quality Conditions 13
3.0 SOURCE ASSESSMENT 21
3.1 General 21
3.2 Population Number Summaries 21
3.3 Septic System Inputs 23
3.4 Point Sources 25
3.5 Livestock 26
4.0 TMDL DEVELOPMENT 27
4.1 Overview 27
4.2 Selection of a TMDL Endpoint 27
4.3 Model Development for Computing TMDL 27
4.4 Consideration of Critical Conditions and Seasonal Variation 32
4.5 Margin of Safety 32
4.6 TMDL Computation 33
4.7 Summary of TMDL and Load Allocation 36
5.0 IMPLEMENTATION AND PUBLIC PARTICIPATION 38
5.1 General 38
5.2 Staged Implementation 38
5.3 Reasonable Assurance for Implementation 39
5.4 Public Participation 42
REFERENCES 42
Appendix A: Model Development A1
A.1 Model Development A1
A.2 Allowable Load Calculation A20
A.3 Total Maximum Daily Load A26
A.4 Load Allocation A29
Appendix B: Calculation of Population Numbers B1

List of Figures

Figure E1: Location of TMDL Area xii
Figure E2: Delineation of Impaired Segments and Corresponding Subwatersheds (Purple color shows impaired shellfish segments. Orange color denotes primary contact impairment.) xiii
Figure 1.1a: Location of TMDL Area 3
Figure 1.1b: Delineation of Impaired Segments and Corresponding Subwatersheds (Purple color shows impaired shellfish segments. Orange color denotes primary contact impairment.) 4
Figure 1.2: Observation Stations in the Nassawadox Creek and Westerhouse Creek Watersheds 7
Figure 2.1: Land Use of the Nassawadox Creek and Westerhouse Creek Watersheds 11
Figure 2.2: Percentage Landuses of the Nassawadox Creek and Westerhouse Creek Watersheds 12
Figure 2.3: Observation of Enterococci at Station 7-NSS004.33 in Nassawadox Creek 13
Figure 2.4: Spatial Distribution of Mean Fecal Coliform Concentration in Nassawadox Creek and Westerhouse Creek 14
Figure 2.5: Observations of Fecal Coliform in the Nassawadox Creek watershed (blue lines are 30-sample geo-mean, black lines are 30-sample 90th percentile, and red lines are water quality standards of 14 and 31 cfu/100mL). 16
Figure 2.6: Temperature, Salinity, and Rainfall Variations at Station 7-FNC002.43 Located in the Middle Portion of Nassawadox Creek 17
Figure 2.7: Correlation Analysis of Salinity and Rainfall and Fecal Coliform 18
Figure 2.8: Comparison of Observed Mean Fecal Coliform and Empirical Model Prediction 18
Figure 2.9: Seasonal Variation of Fecal Coliform Concentration at Selected Stations in Nassawadox Creek 19
Figure 2.10: Seasonal Variation of Mean Fecal Coliform Concentration in Nassawadox Creek 20
Figure 3.1: Septic System Locations in the Nassawadox Creek and Westerhouse Creek Watersheds .. 24
Figure 3.2: Measured Fecal Coliform Bacterial Concentration at Riverside Shore Memorial Hospital 25
Figure 3.3: Distribution of Livestock in the Watersheds (dots represent possible locations of livestock, and number are subwatershed ID) 26
Figure 4.1: Time Series Comparison of Daily Stream Flow between Model Simulation and Observations from USGS Stream Gage 01484800 in 1994 28
Figure 4.2: Time Series Comparison of Fecal Coliform between Model Simulation and Observations from 2007-2012 30
Figure 4.3: Comparison of Seasonal Variation of Model Predictions and Observations from 2007-2012 (box shows the first and third quartile of the observation data, red line is the median, circles are model results, circles with + show the maximum and minimum) 31
Figure 4.4: Comparison of the Cumulative Distribution of Model Predictions and Observations 32
Figure A-1: Subwatersheds of Nassawadox Creek A3
Figure A-2: Receiving Water Model Grid A4
Figure A-3: Time Series Comparison of the Daily Stream Flow between Model Simulation and Observed Data from USGS Stream Gage 01484800 in 1993 and 1994 ..... A5
Figure A-4: 10-year Accumulated Daily Stream Flow Comparison between Model Simulation and the Reference Flow Station USGS 01484800 ..... A6
Figure A-5: Comparison of Modeled (Blue Line) and Observed (Red Dots) Salinity at the Upper, Middle, and Downstream Portions of the Creek A7
Figure A-6: Model Calibration of Fecal Coliform at All Violation Stations in the Estuary A15
Figure A-7: Comparison of Seasonal Variation of Fecal Coliform in Different Creeks and in the Entire Estuary (box shows the first and third quartile of the observation data, red line is the median, circles are model results, circles with + show the maximum and minimum) A19
Figure A-8: Comparison of Cumulative Distribution of Averaged Fecal Coliform Concentration in Nassawadox Creek A20
Figure A-9: Distribution of Fecal Coliform and Running 90th Percentile at the Violation Stations in the Nassawadox Creek A24

Figure A-10: Distribution of Enterococci in the Middle of Nassawadox Creek A25
Figure A-11: Distributions of Fecal Coliform and Running 90th Percentile at Violation Stations in Westerhouse Creek A26

List of Tables

Table 1.1: List of Impaired Segments of Nassawadox Creek and Westerhouse Creek 1
Table 1.2: Violations of the Water Quality Criteria (Fecal Coliform (cfu/100mL)) from 2007-2014 in Nassawadox Creek 8
Table 2.1: Landuse and Percentages of the Nassawadox Creek and Westerhouse Creek Watersheds .. 12
Table 3.1: Humans, Dogs, Livestock, and Wildlife Populations in the Nassawadox Creek and Westerhouse Creek Watersheds 22
Table 3.2: Densities Used for Estimating Wildlife in the Watersheds* 22
Table 3.3: Distribution of Bacteria Source Deposited to Watershed 23
Table 3.4: Point Sources in Nassawadox Watershed 25
Table 4.1: Estimated Daily Maximum Loads and Load Reductions for Fecal Coliform 34
Table 4.2: Estimated Daily Loads and Load Reductions for Each Listed Segments 34
Table 4.3: Estimated Annual Maximum Loads and Load Reductions for Fecal Coliform 34
Table 4.4: Estimated Annual Maximum Loads and Load Reductions for Each Listed Segment 35
Table 4.5: Estimated Loads Runoff and Load Reductions for Bacteria from Nonpoint Sources 36
Table 4.6: Fecal Coliform Bacteria Daily TMDLs in Nassawadox Creek and Westerhouse Creek (Counts/Day) 36
Table 4.7: Fecal Coliform Bacterial Annual TMDLs in Nassawadox Creek and Westerhouse Creek (Counts/Year) 37
Table A-1: Estimated Daily Loads and Load Reductions for Fecal Coliform A28
Table A-2: Estimated Annual Loads and Load Reductions for Fecal Coliform (Each Listed Segment) A29
Table A-3: Load Allocation and Required Reduction for Bacteria Based on 90th Percentile A30
Table A-4: Existing and Allowable Load to Meet Enterococci WQS A32
Table A-5: Load Allocation for Each Source to meet Enterococci WQS A32
Table B-1: Densities Used for Estimating Wildlife in the Nassawadox Creek B2

List of Abbreviations

BMP	Best Management Practice
CFR	Code of Federal Regulations
CWA	Clean Water Act
EFDC	Environmental Fluid Dynamics Computer Code
EPA	Environmental Protection Agency
FA	Future Allocation
GIS	Geographic Information System
LA	Load Allocation
LSPC	Loading Simulation Program C++
MGD	Million Gallons Per Day
MOS	Margin of Safety
MOU	Memorandum of Understanding
MS4s	Municipal Separate Storm Sewer Systems
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
SWCB	State Water Control Board
TMDL	Total Maximum Daily Load
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA-DCR	Virginia Department of Conservation and Recreation
VA-DEQ	Virginia Department of Environmental Quality
VADGIF	Virginia Department of Game and Inland Fisheries
VDH	Virginia Department of Health
VPDES	Virginia Pollutant Discharge Elimination System
WLA	Wasteload Allocation
WQAIR	Water Quality Assessment Integrated Report
WQC	Water Quality Criteria
WQMIRA	Water Quality Monitoring, Information, and Restoration Act
WQMP	Water Quality Management Plans
WQS	Water Quality Standard

EXECUTIVE SUMMARY

Introduction

Section 303(d) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for waterbodies that are exceeding water quality standards (WQS). TMDLs represent the total pollutant loading that a waterbody can receive without violating WQS. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish controls based on water quality conditions to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources.

Nassawadox Creek and tributaries and Westerhouse Creek are located in Northampton County, Virginia, along the west side of the Eastern Shore of the Delmarva Peninsula. The Creeks drain west to the Chesapeake Bay (see Figure E1). Six sub-embayments in the Nassawadox Creek and three segments of the Westerhouse Creek were listed on the 2006 Virginia 305(b)/303(d) Water Quality Assessment Integrated Report (VA-DEQ, 2006) as impaired waterbodies due to violation of the State's WQS for fecal coliform for shellfish consumption designated use. One segment in Nassawadox Creek is also listed as impaired for not meeting the recreation designated use due to violations of the enterococcus WQS (see Figure E2). The listing information for each impaired segment is listed below. Based on the water quality assessment, they do not support their designated uses of shellfish consumption and recreation.

In 2007, a shellfish bacteria TMDL (http://www.deq.virginia.gov/portals/0/DEQ/Water/TMDL/apptmdls/shellfish/nassa.pdf) was completed for 6 impairments in the Nassawadox Creek watershed. This new TMDL report differs from the 2007 TMDL in two important ways. The original TMDL was done using a simplified volumetric model with limited spatial resolution. The new TMDL was modeled using a system of numerical models: a watershed model and a hydrodynamic-transport model. Also, the fecal coliform data used for the previous TMDL were measured using the Most Probable Number (MPN) method. In 2008, the Virginia Department of Health – Division of Shellfish Sanitation (VDH-DSS) began using a new mTEC plate counting method for fecal coliform measurements. The new method reduces statistical uncertainty and provides more accurate measures. The new TMDL uses fecal coliform data measured using this new method. This document, upon approval by the State Water Control Board and EPA, establishes bacteria (fecal coliform and enterococcus) TMDLs for Nassawadox Creek and Westerhouse Creek for the following ten segments:

Assessment Unit	Water Name	Location Description	Cause Category	Cause Name	Size (miles^2)
1 VAT-C13E_ CHC01A00	Church Creek-Upper	In area of Elliotts Neck. Tributary to Nassawadox Creek. Portion of CBP segment CB7PH. DSS shellfish direct harvesting condemnation # 085-185 B (effective 20100629).	5A	Fecal Coliform	0.100
2 VAT-C13E_ CHC01C10	Church Creek - Middle	In area of Elliotts Neck. Tributary to Church Creek - Middle, UT North Cove. Portion of CBP segment CB7PH. DSS shellfish harvesting condemnation # 085-185 A	5A	Fecal Coliform	0.026
3 VAT-C13E_ HGC01A06	Holly Grove Cove- Upper	Located near Wellington Neck. From end of tidal waters downstream to end of DSS Condemnation. Portion of CBP segment CB7PH. DSS shellfish direct.	5A	Fecal Coliform	0.082
4 VAT-C13E_ KLL01A06	Kelley Cove	From end of tidal waters downstream to confluence with Nassawadox Cr. (area of TMDL-bact 6/07). Portion of CBP segment CB7PH. Portion of DSS shellfish	5A	Fecal Coliform	0.026
5 VAT-C13E_ NSS01A06	Nassawadox Creek – Upper	From end of tidal waters downstream to confluence with Kelly Cove (RM 5.2) area of TMDL-bact 6/07. Portion of CBP segment CB7PH. Portion of DSS shellfish direct harvesting condemnation # 085-110 D (effective 20100629).	5A	Fecal Coliform	0.178
6 VAT-C13E_ NSS02A06	Nassawadox Creek – Lower	Mainstem of lower portion of creek to mouth. Portion of CBP segment CB7PH. DSS (OPEN) shellfish direct harvesting condemnation # 085-110 & 085-185	5A	Enterococcus	2.070
7 VAT-C13E_ NSS03A08	Nassawadox Creek – Middle, N. Shore Tribs.	Mainstem of lower portion of creek to mouth. Portion of CBP segment CB7PH. DSS (OPEN) shellfish direct harvesting condemnation # 085-110 & 085-185 (effective 20100629).	5A	Fecal Coliform	0.140
8 VAT-C14E_ WHS02A06	Westerhouse Creek - Upper South Branch	In Church Neck area, west of Bridgetown. Upper portion of Westerhouse Creek South	5A	Fecal Coliform	0.034

		Branch. Portion of CBP segment CB7PH. Portion DSS shellfish direct			
9 VAT-C14E_ WHS02B10	Westerhouse Creek - Middle Upper	In Church Neck area, west of Bridgetown. Upper portion of Westerhouse Creek South Branch. Portion of CBP segment CB7PH. Portion DSS shellfish direct	5A	Fecal Coliform	0.003
10 VAT-C14E_ WHS01A06	Westerhouse Creek - North Branch	In Church Neck area, west of Bridgetown. Portion of CBP segment CB7PH. DSS shellfish direct harvesting condemnation # 085-199 A (20070605).	5A	Fecal Coliform	0.033

Sources of Bacteria

The watershed approach was applied to conduct the source assessment. There are two point sources (VA0027537 and VAR051805) in the Nassawadox Creek watershed. Riverside Shore Memorial Hospital (VA0027537) has a permit to discharge bacteria with concentration of FC: 200 cfu/100mL and E.coli: 126 cfu/100mL, which are based on WQS. The designed flow is 0.1 MGD and the measured average monthly maximum flow is about 0.068 MGD. This point source discharges to Warehouse Creek. VDH-DSS has administratively closed the upper reach of the Creek. The permanent closure was determined based on potential fecal input from the hospital's water treatment plant discharge. VDH-DSS will commonly close areas such as these to ensure the protection of public health. However, the monthly monitoring data show the bacterial concentration to always be below 10 cfu/100mL, which does not add to the problem in this area. Butch's Car & Parts Inc. (VAR051805) does not discharge bacteria. The dominant sources of bacteria in the watersheds are nonpoint sources, including livestock, wildlife, pets, and failing septic systems.

Modeling Approach

A system of numerical models was applied to simulate the loadings of fecal coliform and enterococci from the Nassawadox Creek and Westerhouse Creek watersheds, and the resulting response of in-stream water quality variables. The watershed model, Loading Simulation Program in C^{++} (LSPC), developed by the USEPA, was selected to simulate the watershed hydrology and bacteria load to Nassawadox and Westerhouse Creeks. The Environmental Fluid Dynamics Computer Code (EFDC) was used to simulate the transport and fate of fecal coliform and enterococci in the receiving waters.

Endpoints

The fecal coliform criteria for the shellfish designated use are used as endpoints for shellfish growing areas. The numerical criteria for fecal coliform are a *Geometric Mean* of *14 MPN /100mL and* a *90th percentile* of 31 cfu/100 mL measured by membrane filtration using the mTEC culture media method.

The enterococci criteria are used as endpoints for the recreation designated use. The numerical criteria for enterococci are a *Geometric Mean* of 35 cfu /100mL and a *Single Sample Maximum* of 104 cfu /100mL.

For TMDL development, the most stringent criteria for fecal coliform and enterococci will be used as the endpoint for the impaired area for both shellfish and recreation uses.

Load Allocation Scenarios

For the shellfish and recreation impairments, the most stringent WQS was determined to be the 90th percentile of 31 cfu/100mL for fecal coliform. Calibrated model simulation results were used to establish the existing loads in the system. The annual maximum loading is computed using long-term mean daily loading. Based on an EPA recommendation, the maximum daily loads is computed from long-term mean daily loading based on a statistical method. The nonpoint source loadings (LA) presented in tables of this report are the runoff of bacteria discharging to the stream. The loads that are necessary to meet WQS were established for the TMDLs. The difference between the TMDL and the existing loading (annual based loading) represents the necessary level of reduction. The maximum reductions required to meet bacterial WQS are approximately 36.4% for the Nassawadox Creek watershed and 46.9% for the Westerhouse Creek watershed. The fecal coliform TMDL (counts per day) and total maximum annual loading (counts per year) for the watersheds are summarized below.

Daily load (counts per day) Summary:

Impairment	**WLA**	**LA**	**MOS**	**TMDL**
Nassawadox	**1.72E+10**	1.70E+12	Implicit	1.72E+12
VA0027537*	*7.57E+07*			
Future load (1%)	*1.72E+10*			
Westerhouse Creek	**5.95E+08****	5.89E+10	Implicit	5.95E+10
Future load (1%)				

* Estimated based on design flow and permit of FC 200 cfu/100mL. No change of current permits

** The WLA reflects 1% of the TMDL for future growth allocation

Annual load (counts per year) Summary:

Impairment	WLA	LA	MOS	TMDL
Nassawadox	***3.04E+12***	2.98E+14	Implicit	3.01E+14
*VA0027537**	*2.77E+10*			
Future load (1%)	*3.01E+12*			
Westerhouse Creek	***1.15E+11***	1.13E+13	Implicit	1.15E+13
Future load (1%)				

* Estimated based on design flow and permit of FC 200 cfu/100mL. No change of current permits
**The WLA reflects 1% of the TMDL for future growth allocation

Where:

TMDL =Total Maximum Daily Load
LA =Load Allocation (nonpoint source)
WLA =Wasteload Allocation (point source)
FA =Future Allocation, which is 1% of allowable load
MOS =Margin of Safety

Finally the results of the fecal coliform loading for each source category estimated by the watershed approach were used to partition the load allocation (LA) as appropriate to meet water quality standards (summarized below).

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek	Human	5.94E+10	0	100.0%
	Pets	2.77E+11	0	100.0%
	Wildlife	1.64E+12	1.643E+12	0.0%
	Livestock	7.05E+11	7.41E+10	89.5%
	Total	2.68E+12	1.72E+12	36.0%
Westerhouse Creek	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
	Human	9.71E+08	0	100.0%
	Pets	4.53E+09	0	100.0%
	Wildlife	1.06E+11	5.95E+10	44.1%
	Livestock	1.23E+08	0	100.0%
	Total	1.12E+11	5.95E+10	46.9%

Margin of Safety

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. This was done by using long-term water quality data that cover different flow regimes, with extreme wet and dry years, and a multiple-year simulation to estimate the current bacteria loads and load reduction targets. An implicit margin of safety (MOS) was incorporated in this TMDL by establishing allocations that would meet both the geometric mean and the 90th percentile standards, or instantaneous standards.

Recommendations for TMDL Implementation

The goal of this TMDL is to develop an allocation plan that achieves WQS during the implementation phase. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states, in Section 62.1-44.19.7, that the "Board shall develop and implement a plan to achieve fully supporting status for impaired waters."

To facilitate the phased IP approach to meet the recreation use while planning to meet the shellfish use as well, the required reduction of runoff is 28.5%. The reduction for each source is listed below.

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek	Human	2.85E+10	0	100.0%
	Pets	1.33E+11	0	100.0%
	Wildlife	7.88E+11	7.881E+11	0.0%
	Livestock	3.38E+11	1.32E+11	60.9%
	Total	1.29E+12	9.20E+11	28.5%

The TMDLs developed for the Nassawadox Creek and Westerhouse Creek watershed impairments provide allocation scenarios that will be a starting point for developing implementation strategies to reduce the runoff of bacteria discharging to the stream. Additional monitoring aimed at targeting the necessary reductions is critical to implementation development. Once established, continued monitoring will aid in tracking success toward meeting water quality milestones.

Public participation is critical to the implementation process. Reductions in non-point source loading are the crucial factor in addressing the problem. These sources cannot be addressed without public understanding of, and support for, the implementation process. Stakeholder input will be critical from the onset of the implementation process in order to develop an implementation plan that will be truly effective.

Reasonable Assurance

The reduction required for the attainment of WQs is based on the model simulations, which considers the seasonal and interannual variation of hydrological processes. The implementation recommendation provides a strategy for load reduction. When the implementation plan is completed, the 28% reduction is achievable for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), and public participation. There is reasonable assurance that the load reductions will be met when the implementation strategies are employed. Following the development of the TMDL, DEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program, and use these data to evaluate reductions in pollutants, the effectiveness of the TMDL in attaining and maintaining WQSs, and the success of implementation efforts.

Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progress made. Public meetings were organized for this purpose. A kick-off Work Group meeting was held on June 23, 2015 at the Accomack-Northampton Planning District Commission to inform the stakeholders of the TMDL development process and to obtain feedback. A second Work Group meeting was held on August 26, 2015 to update source estimates in the watersheds. Results of the hydrologic calibration, bacteria source estimates, and TMDL development were discussed in the first public meeting held on October 22, 2015 at the Exmore Town Hall (on Main Street in Exmore). Updated bacterial loading distribution and final TMDL results were presented and discussed in the second public meeting held on March 10, 2016 at the Accomack-Northampton Planning District Commission.

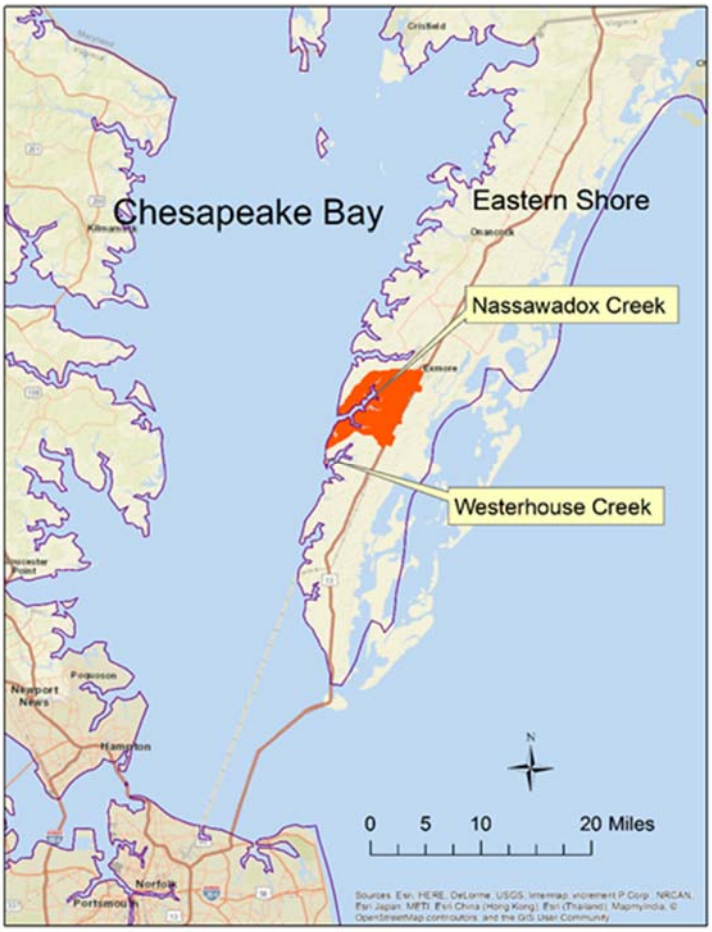


Figure E1: Location of TMDL Area

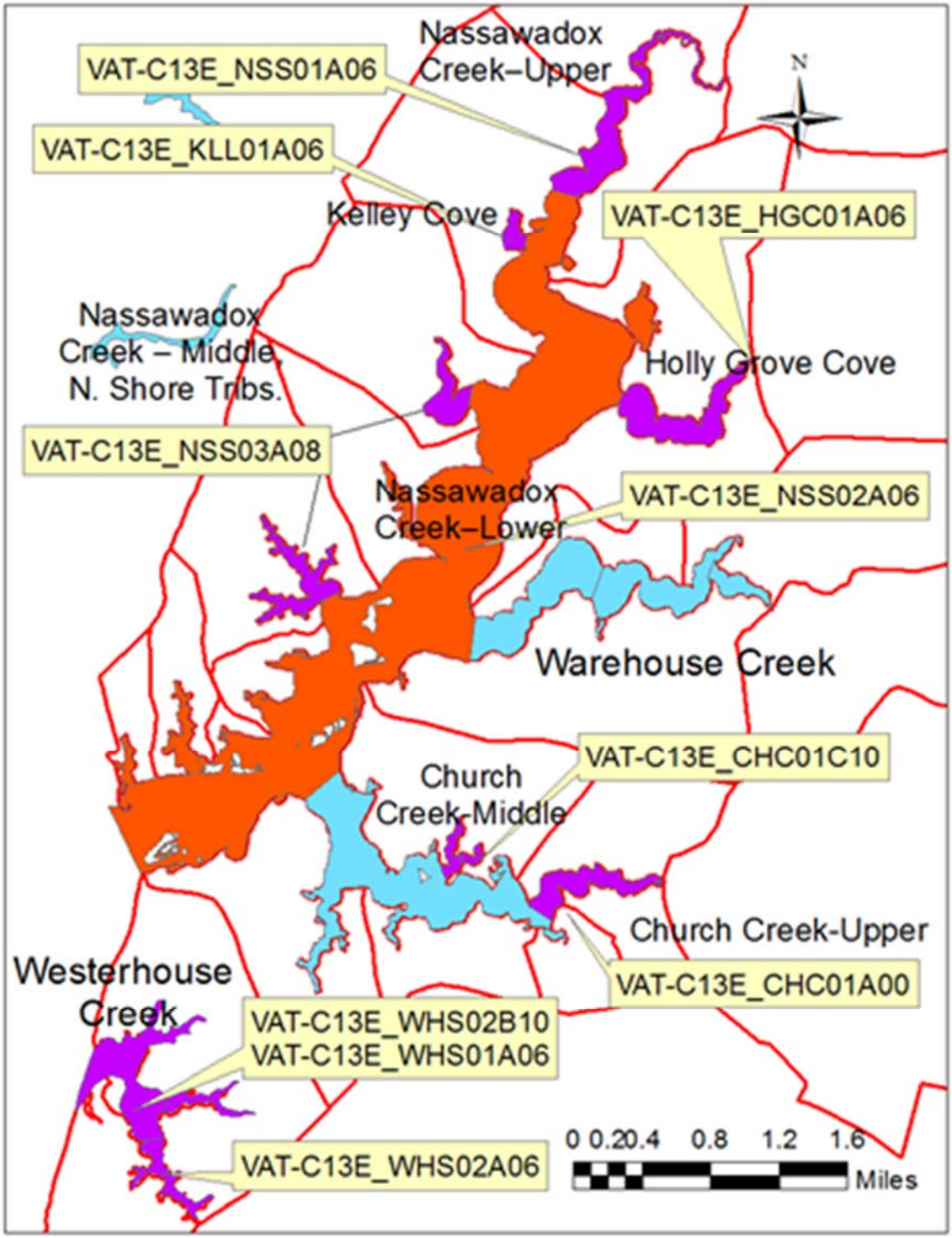


Figure E2: Delineation of Impaired Segments and Corresponding Subwatersheds (Purple color shows impaired shellfish segments. Orange color denotes primary contact impairment.)

1.0 INTRODUCTION

1.1 Background

Section 303(d) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding Water Quality Standards (WQS). TMDLs represent the total pollutant loading that a waterbody can receive without violating WQS. The TMDL process establishes the allowable loadings of pollutants for a waterbody that the waterbody can receive without violating WQS. By following the TMDL process, states can establish controls based on water quality conditions to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources.

Nassawadox Creek and tributaries and Westerhouse Creek are located in Northampton County, Virginia, along the west side of the Eastern Shore of the Delmarva Peninsula (Figure 1.1a). The Creeks drain west to the Chesapeake Bay. Six embayments in the Nassawadox Creek and three segments of the Westerhouse Creek were listed on the 2006 Virginia 305(b)/303(d) Water Quality Assessment Integrated Report (VA-DEQ, 2006) as waterbody impairments due to violations of the State's WQS for fecal coliform for the shellfish designated use. One segment in Nassawadox Creek is also listed as impaired for not meeting the recreation-designated use due to violations of the enterococcus WQS. The listing information for all impaired segments are listed in Table 1.1. Based on the water quality assessment, they do not support their designated uses of shellfish consumption and recreation.

In 2007, a shellfish bacteria TMDL (http://www.deq.virginia.gov/portals/0/DEQ/Water/TMDL/apptmdls/shellfish/nassa.pdf) was completed for 6 impairments in the Nassawadox Creek watershed. This new TMDL report differs from the 2007 TMDL in two important ways. The original TMDL was done using a simplified volumetric model with limited spatial resolution. The new TMDL was modeled using a system of numerical models: a watershed model and a hydrodynamic-transport model. Also, the fecal coliform data used for the previous TMDL was measured using the Most Probable Number (MPN) method. In 2008, the Virginia Department of Health – Division of Shellfish Sanitation (VDH-DSS) began using a new mTEC plate counting method for fecal coliform measurements. The new method reduces statistical uncertainty and provides more accurate measures. The new TMDL uses fecal coliform data measured using this new method. This document, upon approval by the State Water Control Board and EPA, establishes bacteria (fecal coliform and enterococcus) TMDLs for Nassawadox Creek and Westerhouse Creek for the following ten segments:

Table 1.1: List of Impaired Segments of Nassawadox Creek and Westerhouse Creek

Assessment Unit	Water Name	Location Description	Cause Category	Cause Name	Size (miles^2)
1 VAT-C13E_ CHC01A00	Church Creek-Upper	In area of Elliotts Neck. Tributary to Nassawadox Creek. Portion of CBP segment CB7PH. DSS shellfish direct harvesting	5A	Fecal Coliform	0.100

		condemnation # 085-185 B (effective 20100629).			
2 VAT-C13E_ CHC01C10	Church Creek - Middle	In area of Elliotts Neck. Tributary to Church Creek - Middle, UT North Cove. Portion of CBP segment CB7PH. DSS shellfish harvesting condemnation # 085-185 A	5A	Fecal Coliform	0.026
3 VAT-C13E_ HGC01A06	Holly Grove Cove-Upper	Located near Wellington Neck. From end of tidal waters downstream to end of DSS Condemnation. Portion of CBP segment CB7PH. DSS shellfish direct.	5A	Fecal Coliform	0.082
4 VAT-C13E_ KLL01A06	Kelley Cove	From end of tidal waters downstream to confluence with Nassawadox Cr. (area of TMDL-bact 6/07). Portion of CBP segment CB7PH. Portion of DSS shellfish	5A	Fecal Coliform	0.026
5 VAT-C13E_ NSS01A06	Nassawadox Creek – Upper	From end of tidal waters downstream to confluence with Kelly Cove (RM 5.2) area of TMDL-bact 6/07. Portion of CBP segment CB7PH. Portion of DSS shellfish direct harvesting condemnation # 085-110 D (effective 20100629).	5A	Fecal Coliform	0.178
6 VAT-C13E_ NSS02A06	Nassawadox Creek – Lower	Mainstem of lower portion of creek to mouth. Portion of CBP segment CB7PH. DSS (OPEN) shellfish direct harvesting condemnation # 085-110 & 085-185	5A	Enterococcus	2.070
7 VAT-C13E_ NSS03A08	Nassawadox Creek – Middle, N. Shore Tribs.	Mainstem of lower portion of creek to mouth. Portion of CBP segment CB7PH. DSS (OPEN) shellfish direct harvesting condemnation # 085-110 & 085-185 (effective 20100629).	5A	Fecal Coliform	0.140
8 VAT- C14E_ WHS02A06	Westerhouse Creek - Upper South Branch	In Church Neck area, west of Bridgetown. Upper portion of Westerhouse Creek South Branch. Portion of CBP segment CB7PH. Portion DSS shellfish direct	5A	Fecal Coliform	0.034
9 VAT-C13EC14E_ WHS02B10	Westerhouse Creek - Middle Upper	In Church Neck area, west of Bridgetown. Upper portion of Westerhouse Creek South Branch. Portion of CBP segment CB7PH. Portion DSS shellfish direct	5A	Fecal Coliform	0.003
10 VAT- C14E_ WHS01A06	Westerhouse Creek - North Branch	In Church Neck area, west of Bridgetown. Portion of CBP segment CB7PH. DSS shellfish direct harvesting condemnation # 085-199 A (20070605).	5A	Fecal Coliform	0.033

1.2 Listing of Waterbodies under the CWA

WQS are regulations based on federal or state law that establish designated uses for the waterbodies of Virginia and establish numeric or narrative limits on pollutants in order to

protect those designated uses. Water quality monitoring is performed to measure pollutants and determine if measured levels are within the established bounds for a waterbody. Waterbodies with pollutant levels that exceed the designated standards are considered impaired for the corresponding designated use (e.g. swimming, drinking, shellfish harvest, etc.). Under the provisions of §303 (d) of the CWA, impaired waterways are placed on the list reported to the EPA. The impaired water list is included in the biennial 305(b)/ 303(d) Water Quality Assessment Integrated Report (WQAIR, VA-DEQ, 2006). Those waters placed on the list require the development of a TMDL and corresponding implementation plan intended to eliminate the impairment and bring the water into compliance with the designated standards.

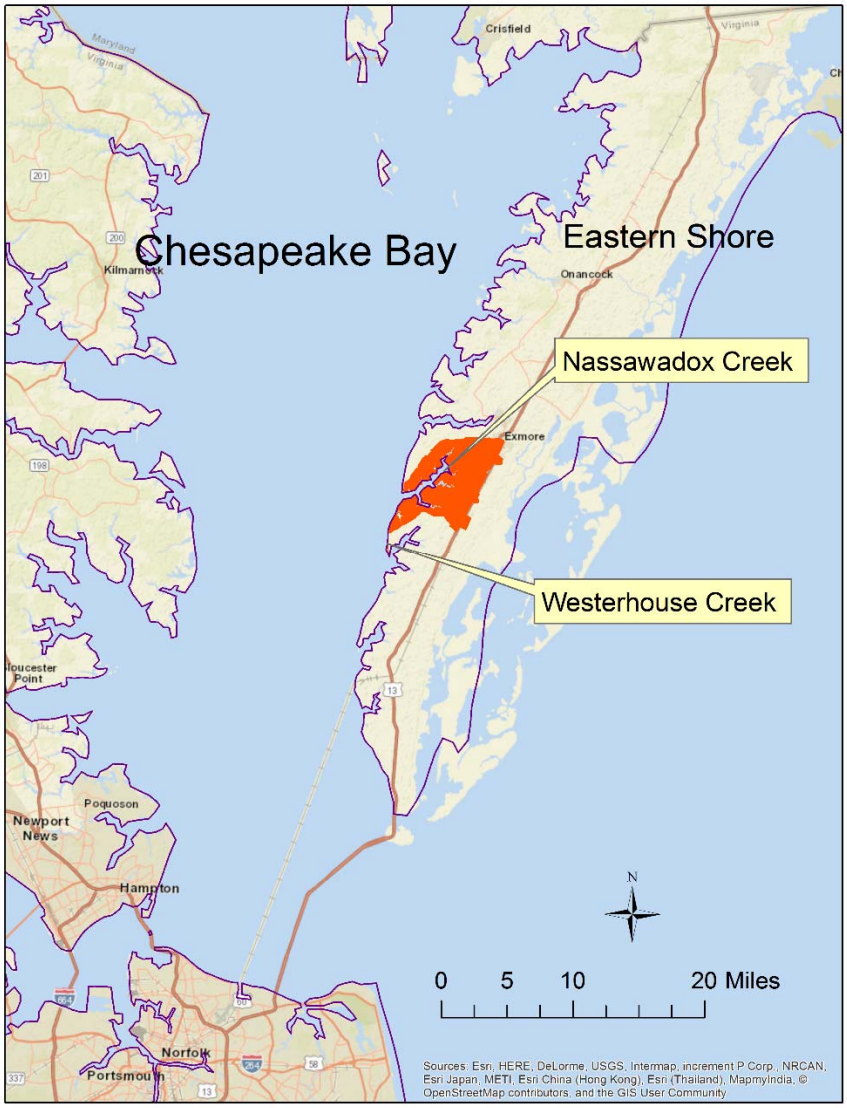


Figure 1.1a: Location of TMDL Area

1.3 Watershed Location and Description

Nassawadox Creek and tributaries and Westerhouse Creek are located in Accomack County, along the Eastern Shore of the Delmarva Peninsula, Virginia (Figure 1.1a). The watershed area for Nassawadox Creek is 76.1 km^2 (18,797 acres) in size. The Nassawadox Creek watershed is mainly forested, agricultural, and wetlands. These land uses account for approximately 88% of the watershed. Westerhouse Creek is about 5.9 km^2 (1453 acres) and urban landuse has 2.43%. Nassawadox Creek and Westerhouse Creek can be delineated to 26 subwatersheds that drain to each of the impaired segments (Figure 1.1b).

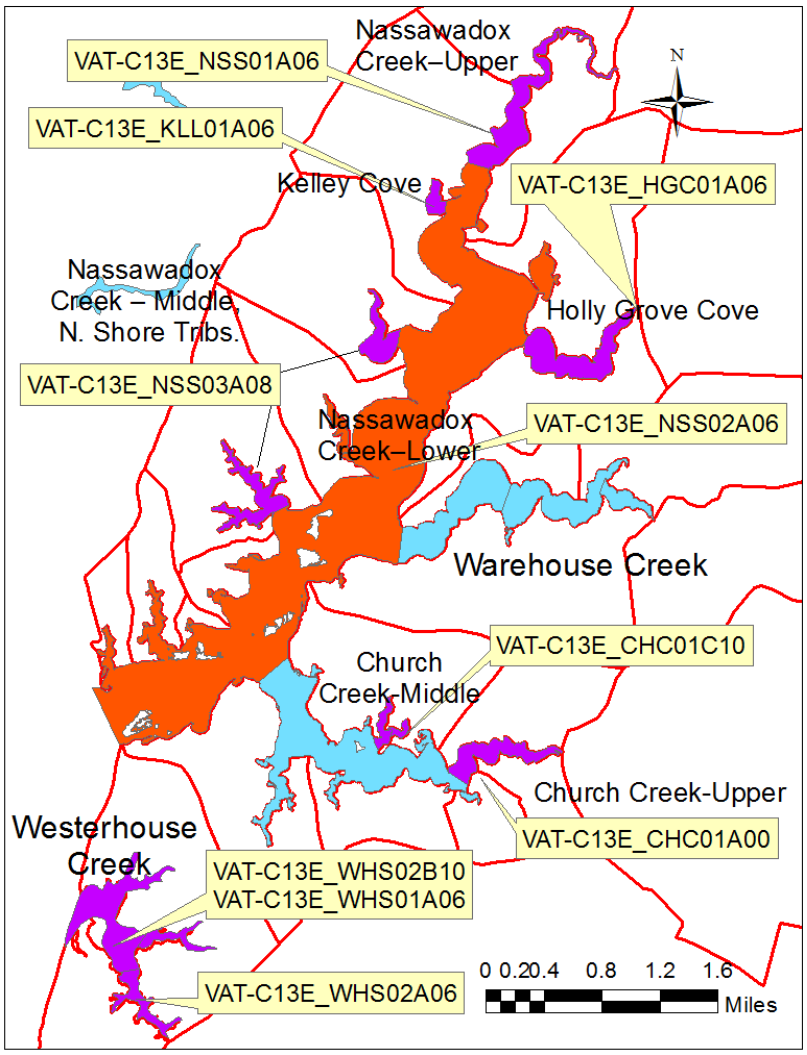


Figure 1.1b: Delineation of Impaired Segments and Corresponding Subwatersheds (Purple color shows impaired shellfish segments. Orange color denotes primary contact impairment.)

1.4 Designated Uses and Applicable Water Quality Standard

1.4.1 Designation of Uses

According to Virginia WQS (9VAC25-260-10A):

"All State waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish."

The state promulgates standards to protect waters to ensure the uses designated for those waters are met. In Virginia's WQS, certain standards are assigned by water class, while other standards are assigned to specifically described waterbodies/waterways to protect designated uses of those waters. Virginia has seven waters classes (I through VII) with DO, pH, and temperature criteria for each class (9VAC25-260-50). The identification of waters by class is found in the river basins section tables. The tables delineate the class of waters to which the basin section belongs in accordance with the class descriptions given in 9VAC25-260-50. By finding the class of waters for a basin section in the classification column and referring to 9VAC25-260-50, the DO, pH, and maximum temperature criteria can be found for each basin section. Nassawadox and Westerhouse Creeks are considered as a Class II water, "Estuarine Water (Tidal Water-Coastal Zone to Fall Line)" (9VAC25-260-50).

1.4.2 Bacteria Standards

For shellfish growing areas, the criteria used for developing TMDLs are outlined in 9 VAC 25-260-160 and read as follows:

In all open-ocean or estuarine waters capable of propagating shellfish or in specific areas where public or leased private shellfish beds are present, and including those waters on which condemnation is established by the State Department of Health, the following criteria for fecal coliform bacteria shall apply:

The geometric mean fecal coliform value for a sampling station shall not exceed an MPN (most probable number) or MF (membrane filtration using mTEC culture media) of 14 per 100 milliliters (mL). The estimated 90th percentile shall not exceed an MPN of 43 per 100 mL for a 5-tube decimal dilution test or an MPN of 49 per 100 mL for a 3-tube decimal dilution test, or MF test of 31 CFU (colony forming units) per 100 mL.

For recreation use, the criteria used for developing TMDLs are outlined in 9 VAC 25-260-

170A and read as follows:

"Enterococci bacteria shall not exceed a monthly geometric mean of 35 cfu/100 mL in transition and saltwater. If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 cfu/100 mL."

1.5 Impairment Listing

The VA-DEQ has 5 monitoring stations in the watershed, however only three stations have ample data. VDH-DSS has routinely monitored the bacterial concentrations at multiple stations in the Nassawadox Creek and Westerhouse Creek watersheds for fecal coliform during 2008-2014. The fecal coliform concentration is measured using the mTEC plate counting method, which provides a more accurate measurement. The data obtained from VDH-DSS will be used for this study. The location map of observation stations is shown in Figure 1.2.

Sufficient exceedances of Virginia's WQS for fecal coliform and enterococci maxima were recorded at multiple stations in the Nassawadox Creek and Westerhouse Creek watersheds to be deemed as not supportive of shellfish consumption and recreational uses. The statistics and violation of geometric mean and 90th percentile values of shellfish criteria for the segments are summarized in Table 1.2.

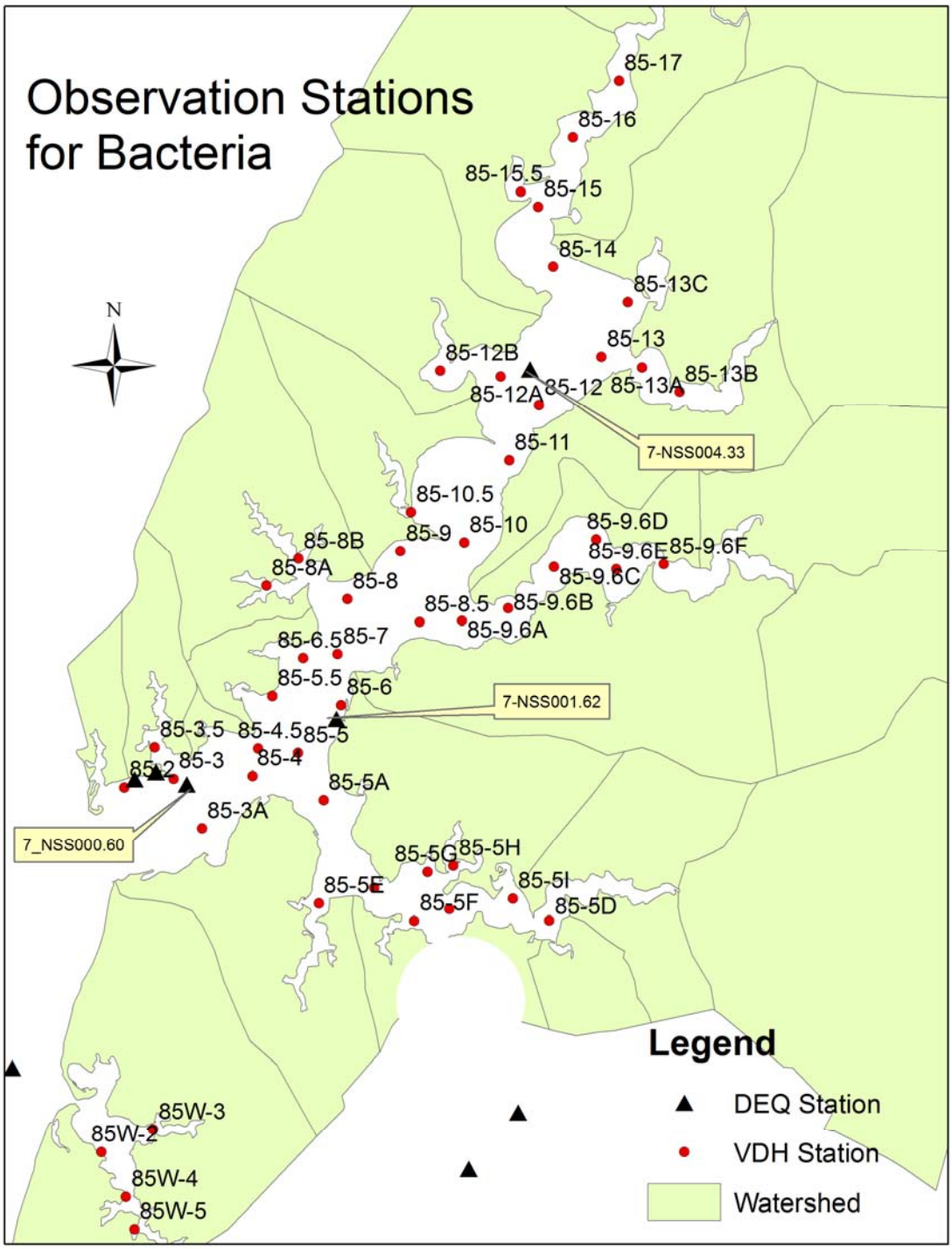


Figure 1.2: Observation Stations in the Nassawadox Creek and Westerhouse Creek Watersheds

Table 1.2: Violations of the Water Quality Criteria (Fecal Coliform (cfu/100mL)) from 2007-2014 in Nassawadox Creek

Station Name	Max. geo-mean	Max. 90th	Mean	Max.	Std Deviation	Violation geo-mean	Violation 90th
'85-2'	1.8	3.7	1.6	5.0	1.0	N	N
'85-3'	2.0	4.6	1.9	17.0	2.2	N	N
'85-3.5'	6.2	35.8	11.1	81.0	15.2	N	Y
'85-3A'	2.4	8.1	3.0	23.0	4.0	N	N
'85-4'	1.9	4.0	2.1	19.0	2.4	N	N
'85-4.5'	2.2	5.5	2.4	10.0	2.3	N	N
'85-5'	2.2	5.4	2.2	11.0	2.0	N	N
'85-5.5'	2.1	4.8	2.4	10.0	2.0	N	N
'85-5A'	2.7	9.4	4.2	43.0	5.8	N	N
'85-5E'	5.4	27.9	9.4	81.0	14.3	N	N
'85-5B'	4.3	16.7	7.1	55.0	10.0	N	N
'85-5G'	9.9	40.9	16.2	150.0	23.9	N	Y
'85-5H'	18.3	89.4	39.1	1100.0	128.0	Y	Y
'85-5F'	5.8	23.5	9.0	93.0	13.6	N	N
'85-5C'	4.9	17.3	6.3	50.0	7.4	N	N
'85-5I'	9.2	39.7	11.6	64.0	13.0	N	Y
'85-5D'	10.8	54.6	16.9	93.0	22.3	N	Y
'85-6'	2.9	10.0	3.2	39.0	5.1	N	N
'85-6.5'	2.5	8.9	3.6	43.0	5.7	N	N
'85-7'	2.9	12.1	5.0	150.0	17.0	N	N
'85-8'	2.7	8.1	3.2	24.0	3.3	N	N
'85-8.5'	3.6	14.5	4.3	43.0	6.1	N	N
'85-8A'	26.1	148.1	55.1	1200.0	145.3	Y	Y
'85-8B'	17.1	134.9	42.2	1100.0	128.9	Y	Y
'85-9'	3.2	10.2	4.1	23.0	4.1	N	N
'85-9.6A'	3.6	9.5	4.0	13.0	3.1	N	N
'85-9.6B'	3.3	11.6	4.6	21.0	4.6	N	N
'85-9.6C'	7.9	27.8	9.5	130.0	15.5	N	N
'85-9.6D'	7.7	36.6	11.2	130.0	18.9	N	Y
'85-9.6E'	7.7	49.7	13.4	163.3	22.9	N	Y
'85-9.6F'	15.8	82.8	30.5	460.0	59.7	Y	Y
'85-10'	2.9	9.3	3.7	28.0	4.1	N	N
'85-10.5'	3.1	12.6	4.4	43.0	6.3	N	N
'85-11'	3.4	13.5	4.2	23.0	5.5	N	N
'85-12'	3.1	11.7	4.2	23.0	4.8	N	N
'85-12A'	3.5	15.3	6.3	93.0	14.2	N	N
'85-12B'	10.5	56.4	16.7	93.0	22.4	N	Y

'85-13'	3.2	12.9	4.8	43.0	7.3	N	N
'85-13A'	7.1	41.2	13.9	240.0	31.1	N	Y
'85-13B'	13.0	94.3	28.1	240.0	45.4	N	Y
'85-13C'	3.5	12.2	5.1	43.0	6.5	N	N
'85-14'	4.3	20.3	7.4	93.0	12.8	N	N
'85-15'	7.1	32.3	11.9	93.0	16.0	N	Y
'85-15.5'	34.2	158.8	44.0	240.0	43.2	Y	Y
'85-16'	15.9	57.9	20.6	93.0	20.7	Y	Y
'85-17'	31.5	186.1	52.1	1200.0	137.1	Y	Y
‘85W-2’	4.4	15.1	5.4	29.0	5.6	N	N
‘85W-3’	8.8	31.3	10.3	51.0	10.5	N	Y
‘85W-4’	7.8	24.6	8.2	32.0	8.9	N	
‘85W-5’	14.1	49.5	17.5	81.0	15.6	Y	Y

2.0 WATERSHED CHARACTERIZATION

2.1 Topology, Soil, and Climate

The Nassawadox Creek and Westerhouse Creek watersheds, located along Virginia's Eastern Shore, are in the lowland sub-province of the Coastal Plain province. Latest Tertiary and Quaternary sand, silt, and clay, which cover much of the Coastal Plain, were deposited during interglacial highstands of the sea under conditions similar to those that exist in the modern Chesapeake Bay and its tidal tributaries (http://www.wm.edu/geology/virginia/provinces/coastalplain/coastal_plain.html). The soils in the watersheds range from moderately drained to slow infiltration rate (USDA, 2006).

As part of the Tidewater Climate Region, the Nassawadox Creek and Westerhouse Creek watersheds experience average January temperatures of 35-48° F and average July temperatures of 71-85° F. Average annual precipitation is 41.3 inches. It is influenced by stream discharge, groundwater seepage, and surface runoff.

2.2 Landuse

The land use characterization for the entire watersheds was based on land cover data from the Virginia National Land Cover Data (NLCD) 2011 Land Use Dataset (Figure 2.1). The land use classifications in the watershed areas, and percentages, are presented in Table 2.1. Dominant land uses in Nassawadox Creek watershed were found to be agriculture (50%), forest (20%), and wetland (18%), which account for 88% of the total area in the watershed. The dominant landuse in Westerhouse Creek watershed are agriculture (49%), forest (26%), and wetland (14%), which combine for 89% of the total area in the watershed. Figure 2.2 shows the percentage land uses in both watersheds.

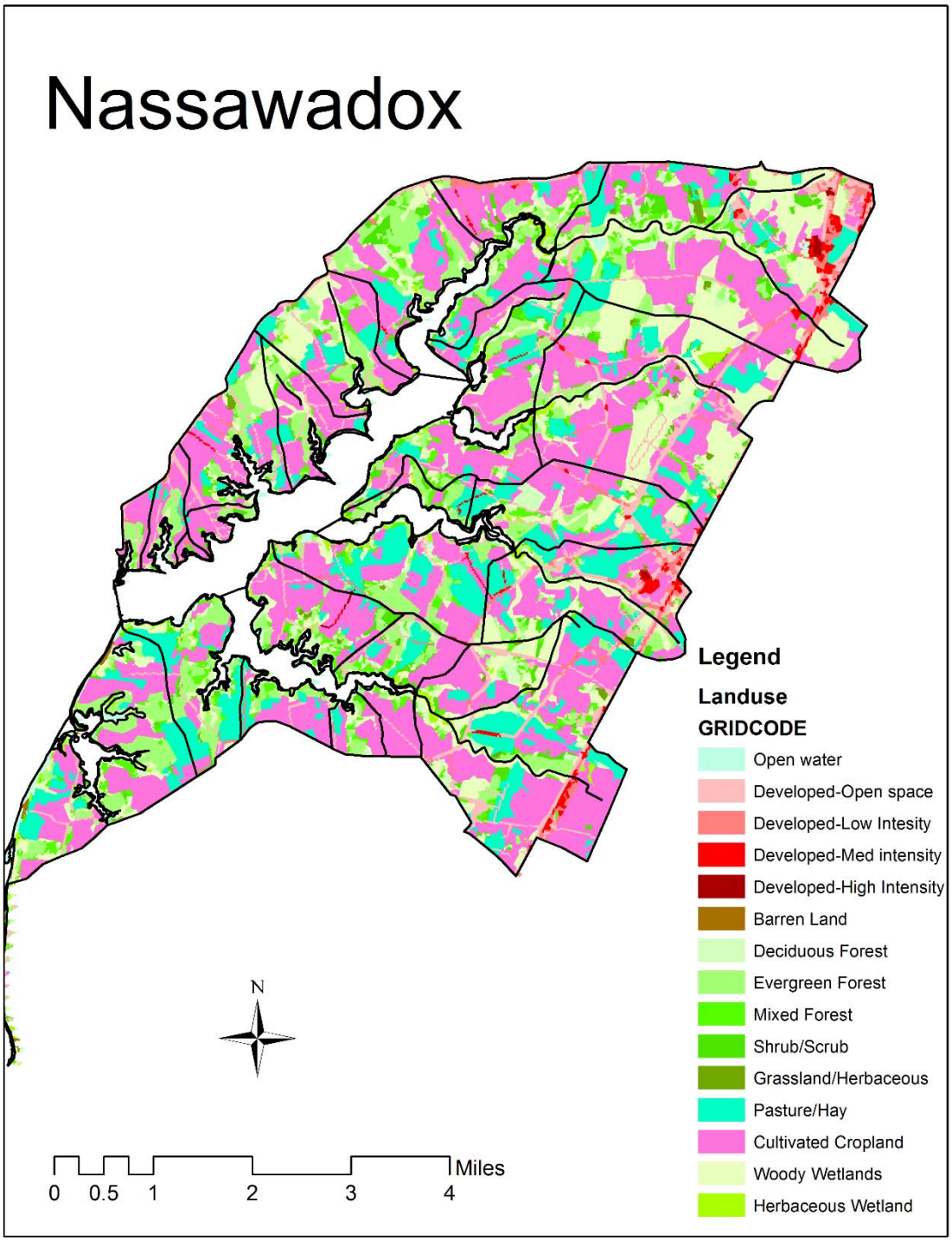


Figure 2.1: Land Use of the Nassawadox Creek and Westerhouse Creek Watersheds

Table 2.1: Landuse and Percentages of the Nassawadox Creek and Westerhouse Creek Watersheds

Landuse Name	Nassawadox Creek		Westerhouse Creek	
	Area (ac)	Percentage	Area (ac)	Percentage
Open water	267.10	1.42	104.30	7.18
Developed-Open space	1353.27	7.20	33.36	2.30
Developed-Low Intensity	429.44	2.28	2.00	0.14
Developed-Med intensity	196.82	1.05	0.00	0.00
Developed-High Intensity	24.69	0.13	0.00	0.00
Barren Land	0.22	0.00	16.46	1.13
Deciduous Forest	488.82	2.60	21.13	1.45
Evergreen Forest	1877.45	9.99	262.42	18.06
Mixed Forrest	723.89	3.85	73.83	5.08
Shrub/Scrub	542.20	2.88	23.80	1.64
Grassland/Herbaceous	90.96	0.48	1.11	0.08
Pasture/Hay	2465.01	13.11	207.94	14.31
Cultivated Cropland	6927.35	36.85	506.39	34.85
Woody Wetlands	3154.44	16.78	158.57	10.91
Herbaceous Wetland	255.31	1.36	41.59	2.86
Total	18796.96	100.00	1452.90	100.00

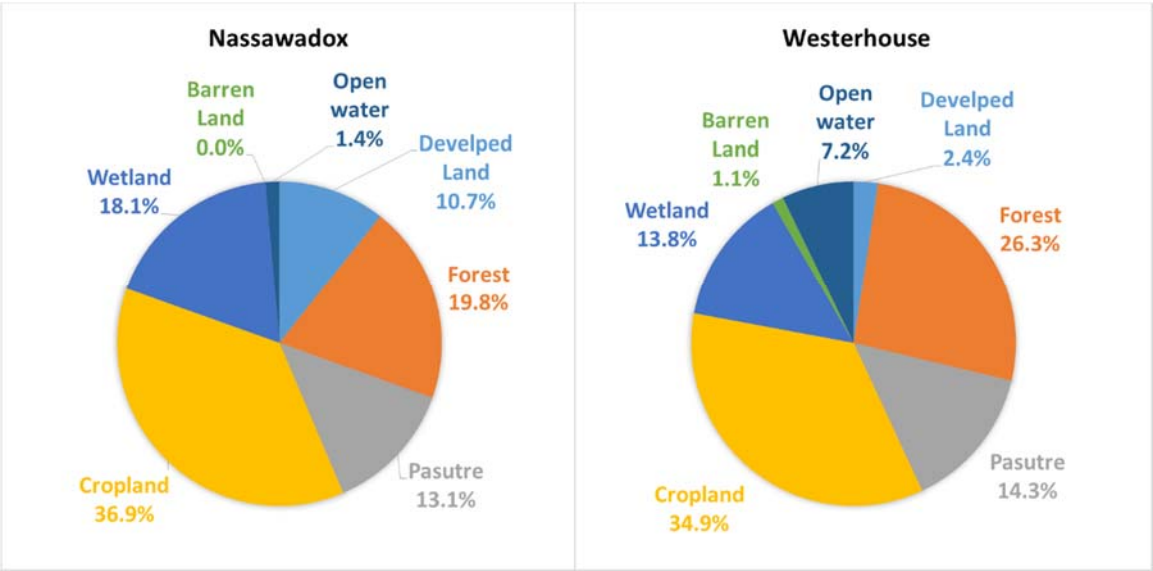


Figure 2.2: Percentage Landuses of the Nassawadox Creek and Westerhouse Creek Watersheds

2.3 Water Quality Conditions

The DEQ performs water quality monitoring throughout Virginia to determine if WQS are being met for the designated uses of the corresponding waters. Samples have been taken at the Nassawadox monitoring stations. It shows that enterococci exceeds the 104 cfu/100mL 8 times from 2007-2014 at Station 7-NSS004.33, which is about 19% (Figure 2.3). VDH-DSS observed fecal coliform bacteria in the Creeks from 2007-2015 at 46 stations. Data collected prior to June 2008 were analyzed using the MPN method and not the mTEC method, and yet this was inconsequential in the analysis. Figure 2.4 shows the spatial distribution of mean fecal coliform concentration in the Nassawadox Creek watershed (2008-2013). It can be seen that high concentrations often occurred in the headwaters of the small embayments of the Creeks. Figure 2.5 shows the time series plot of the observations. Both geometric mean and 90th percentile values are plotted. It can be seen that WQS are exceeded at multiple stations. The violations are mainly from 2007-2011, which are due to hydrological conditions. These years are the focus for model calibration.

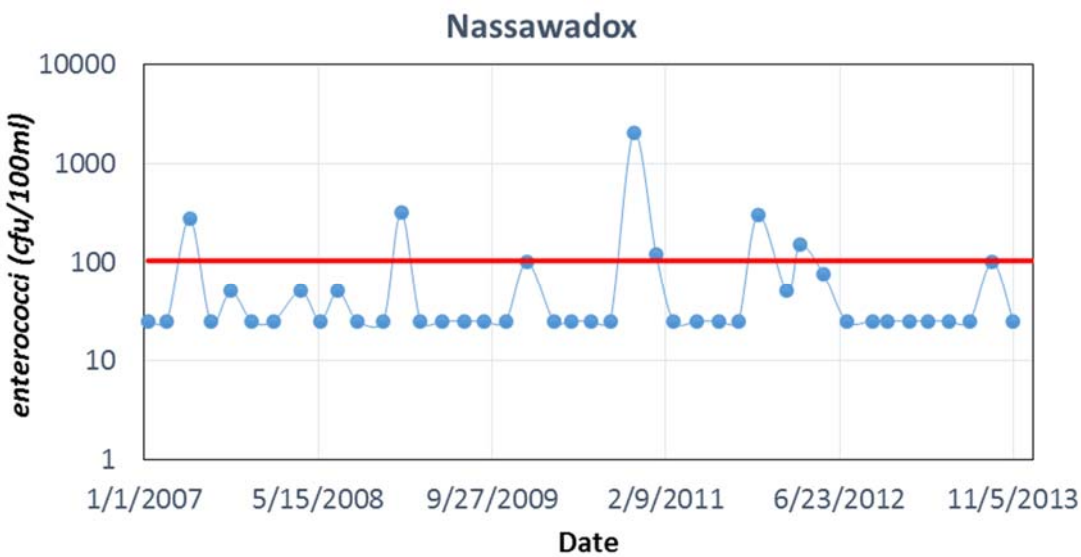


Figure 2.3: Observation of Enterococci at Station 7-NSS004.33 in Nassawadox Creek

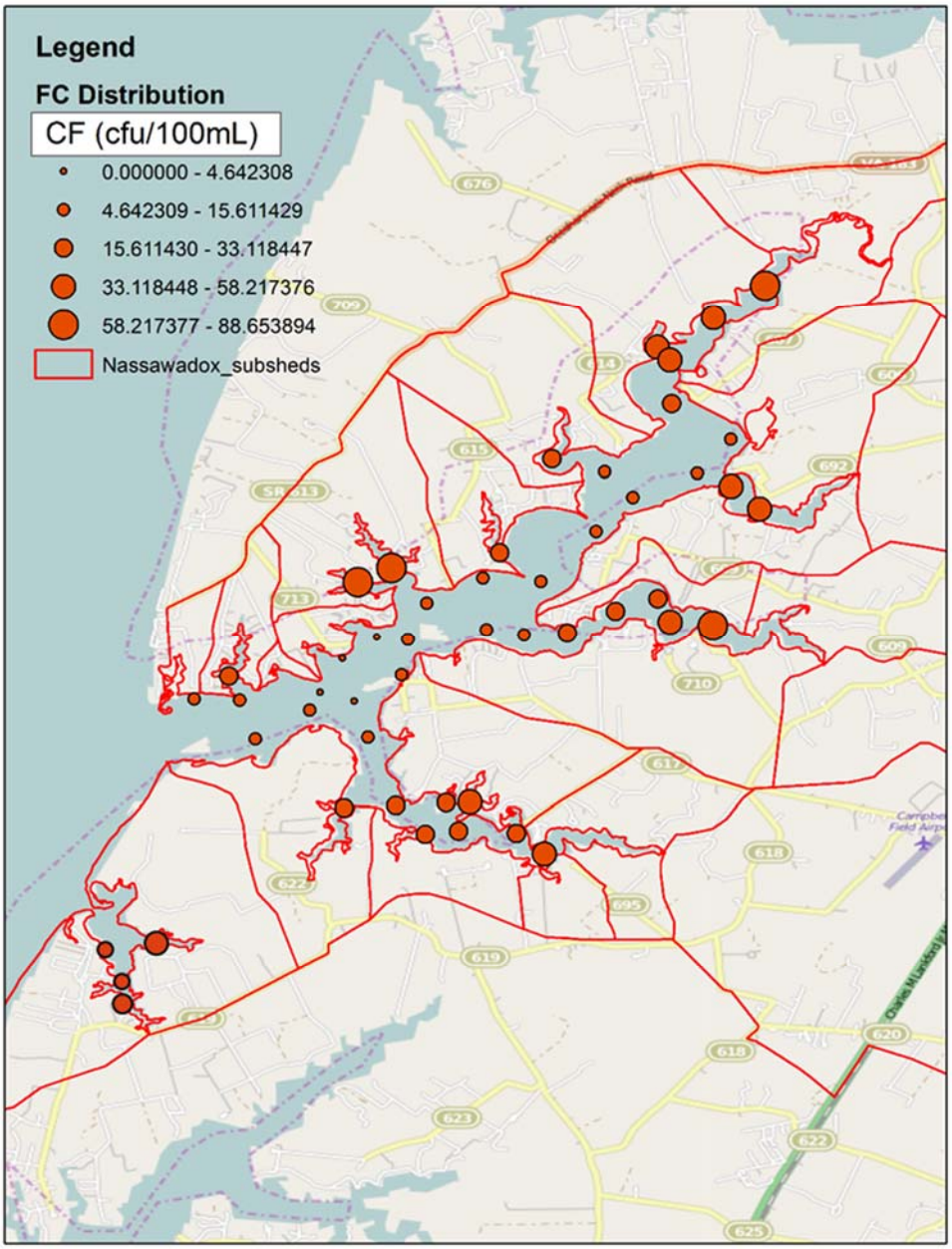
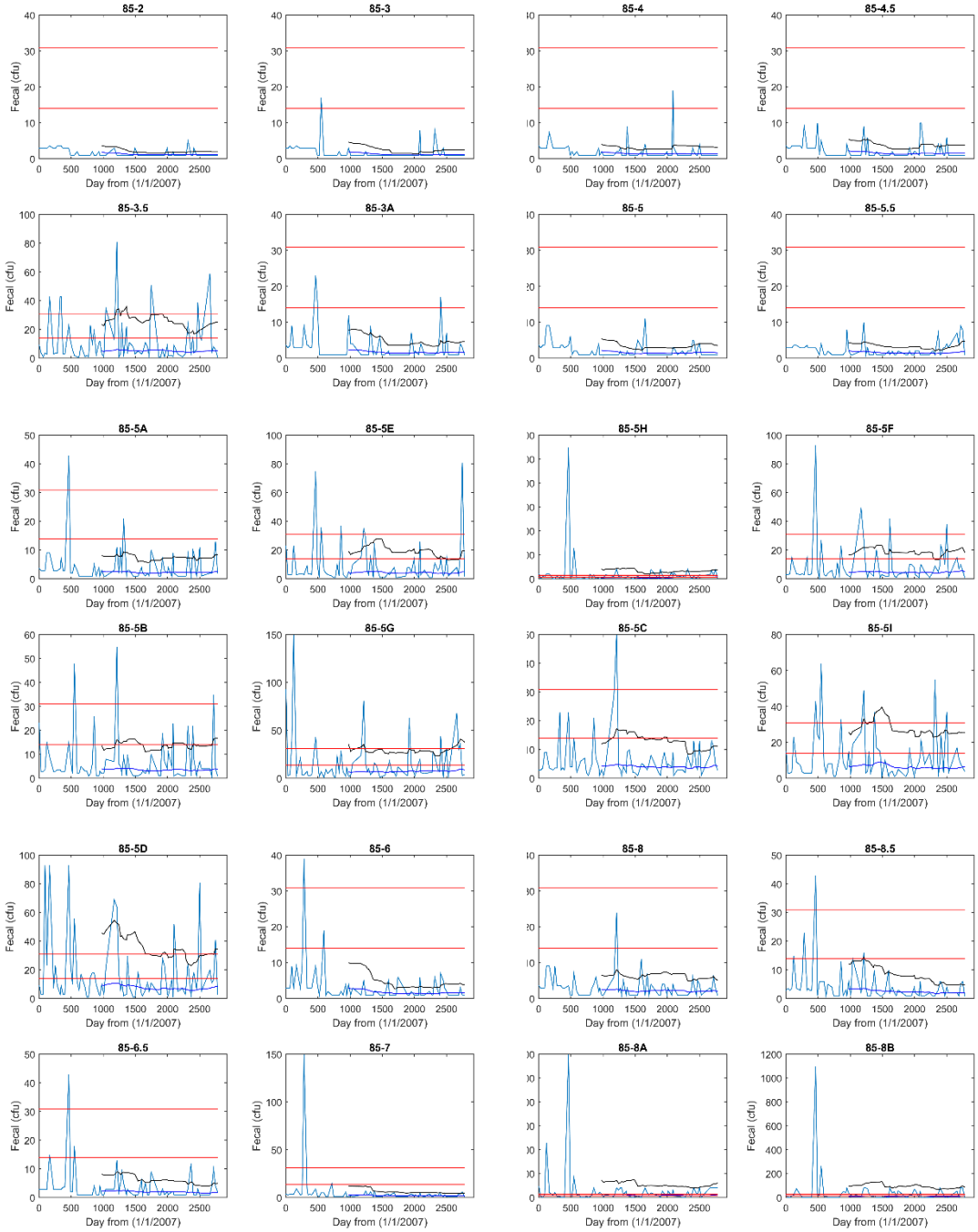


Figure 2.4: Spatial Distribution of Mean Fecal Coliform Concentration in Nassawadox Creek and Westerhouse Creek


85-2
85-3
85-4
85-4.5
85-3.5
85-3A
85-5
85-5.5
85-5A
85-5E
85-5H
85-5F
85-5B
85-5G
85-5C
85-5I
85-5D
85-6
85-8
85-8.5
85-6.5
85-7
85-8A
85-8B
Fecal (cfu)
Day from (1/1/2007)

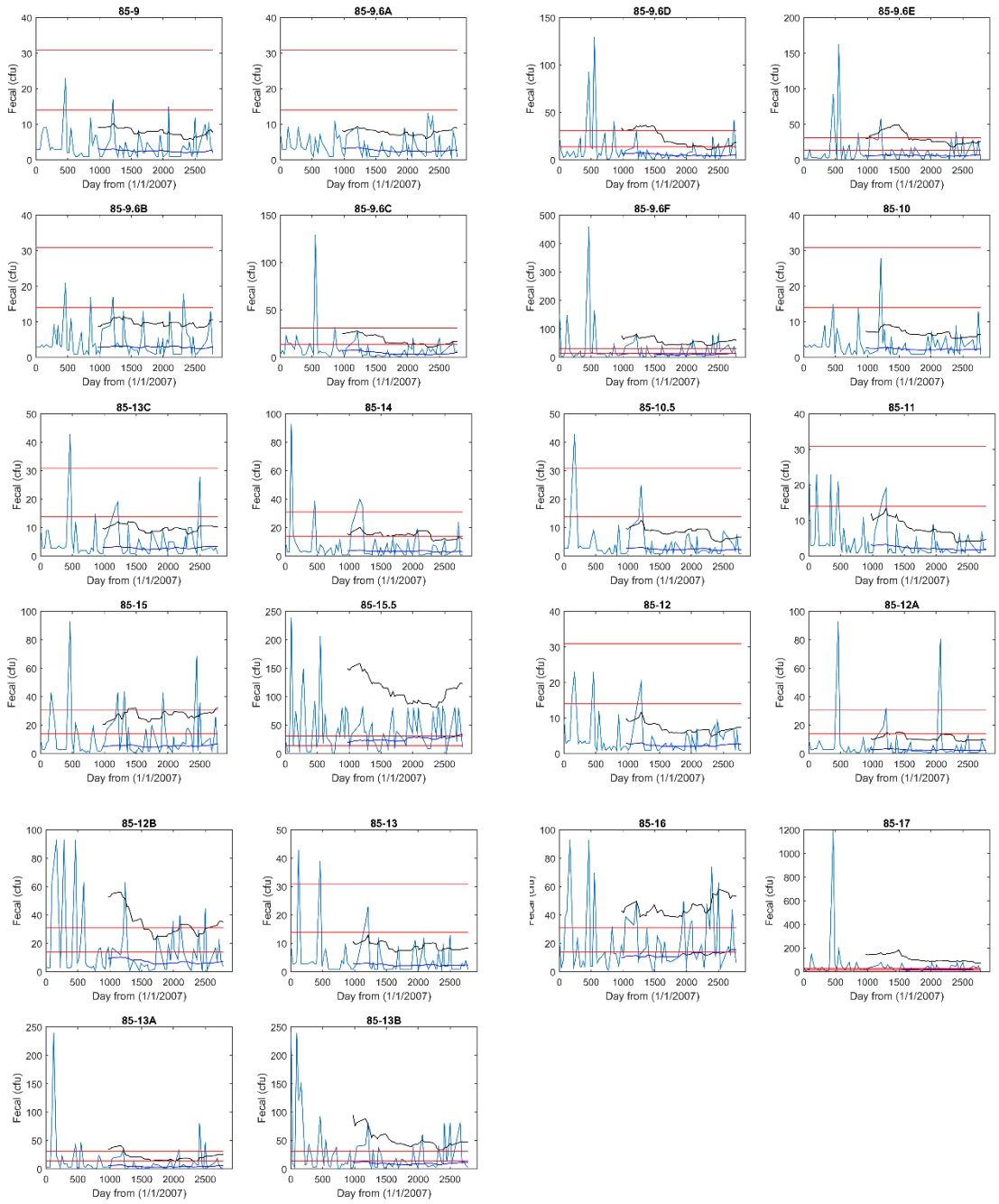


Figure 2.5: Observations of Fecal Coliform in the Nassawadox Creek watershed (blue lines are 30-sample geo-mean, black lines are 30-sample 90th percentile, and red lines are water quality standards of 14 and 31 cfu/100mL).

2.3.1 Temperature, salinity, and seasonal variation

Temperature, salinity, and rainfall during observation of bacteria made in the mid-portions of the Nassawadox and Westerhouse Creeks are shown in Figures 2.6. A wide seasonal temperature variation is typical in the stream. Summer high temperatures reached 30 degrees C and winter low temperatures were about 0 degrees C. In the middle portion to the Nassawadox Creek, most of the salinities ranges from 15-25 psu, indicating that the Creek is highly influenced by both tide and freshwater discharge.

The correlation analysis of averaged fecal coliform in the Nassawadox Creek with salinity, rainfall 24 hours before observation, rainfall 2 days before observation, and rainfall 3 days before observation show that there is no correlation between salinity and fecal coliform. A weak correlation can be found between fecal coliform and rainfall in 24 hours (R=0.51) and rainfall 2 days before observation (R=0.28), which are shown in Figure 2.7. A multiple regression was performed for mean fecal coliform and rainfall 24 hours, 2 days, and 3 days before observation, and temperature. The result is shown in Figure 2.8. The correlation coefficient is 0.66 (p=0.0001). It can be seen that fecal coliform concentration is correlated to rain events, but the regression model does not predict each peak indicating a nonlinear effect.

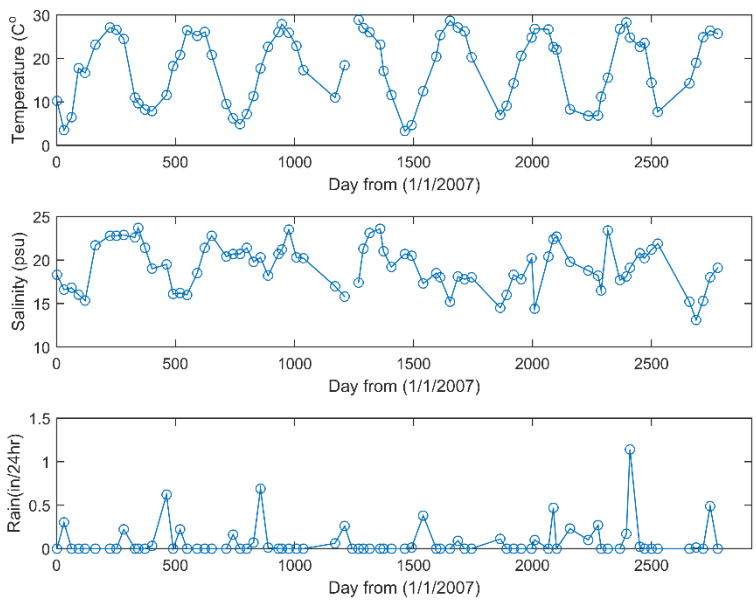


Figure 2.6: Temperature, Salinity, and Rainfall Variations at Station 7-FNC002.43 Located in the Middle Portion of Nassawadox Creek

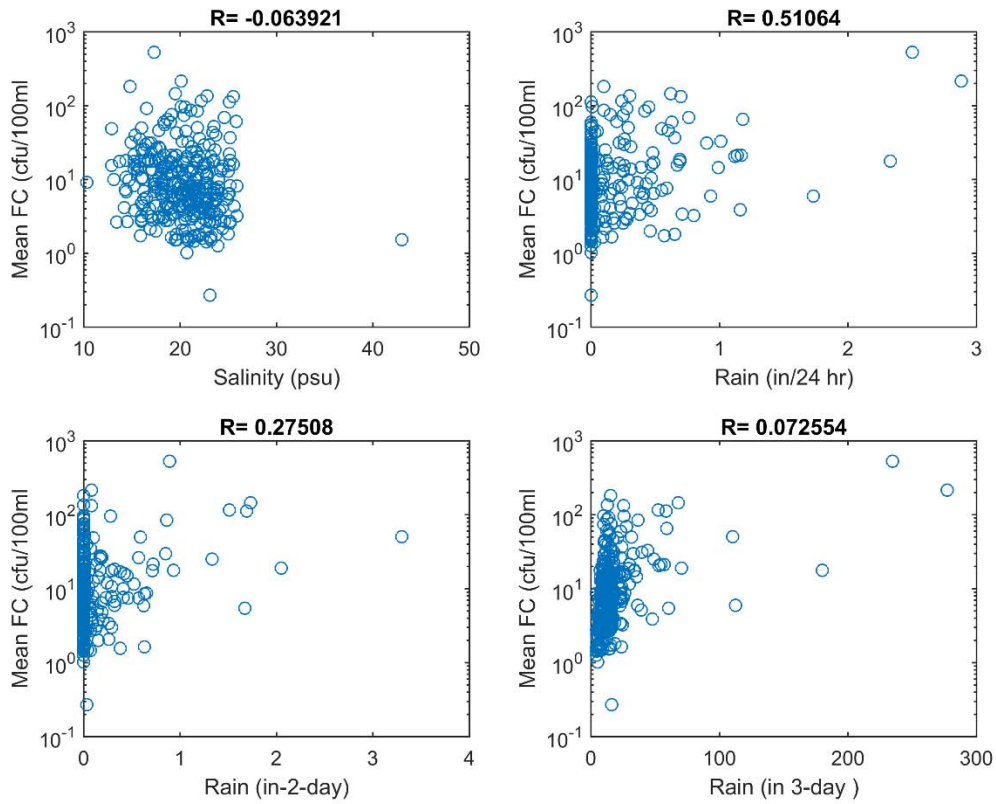


Figure 2.7: Correlation Analysis of Salinity and Rainfall and Fecal Coliform

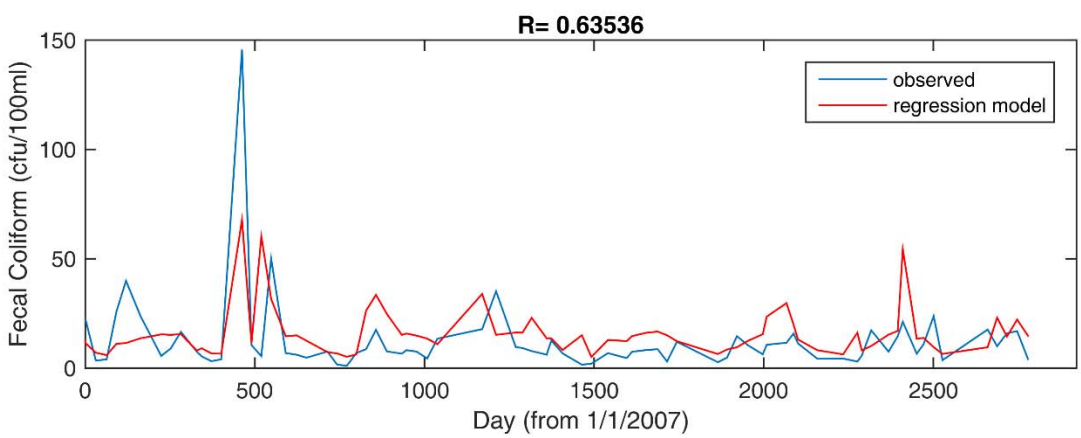


Figure 2.8: Comparison of Observed Mean Fecal Coliform and Empirical Model Prediction

There is a seasonal variation of fecal coliform. But seasonal variations are different at different stations. Figure 2.9 shows seasonal variations for some selected stations. It can be seen that high concentration can occur in different months. By averaging all data in the Creek, it can be shown that April has the highest concentration followed by July and May (Figure 2.10).

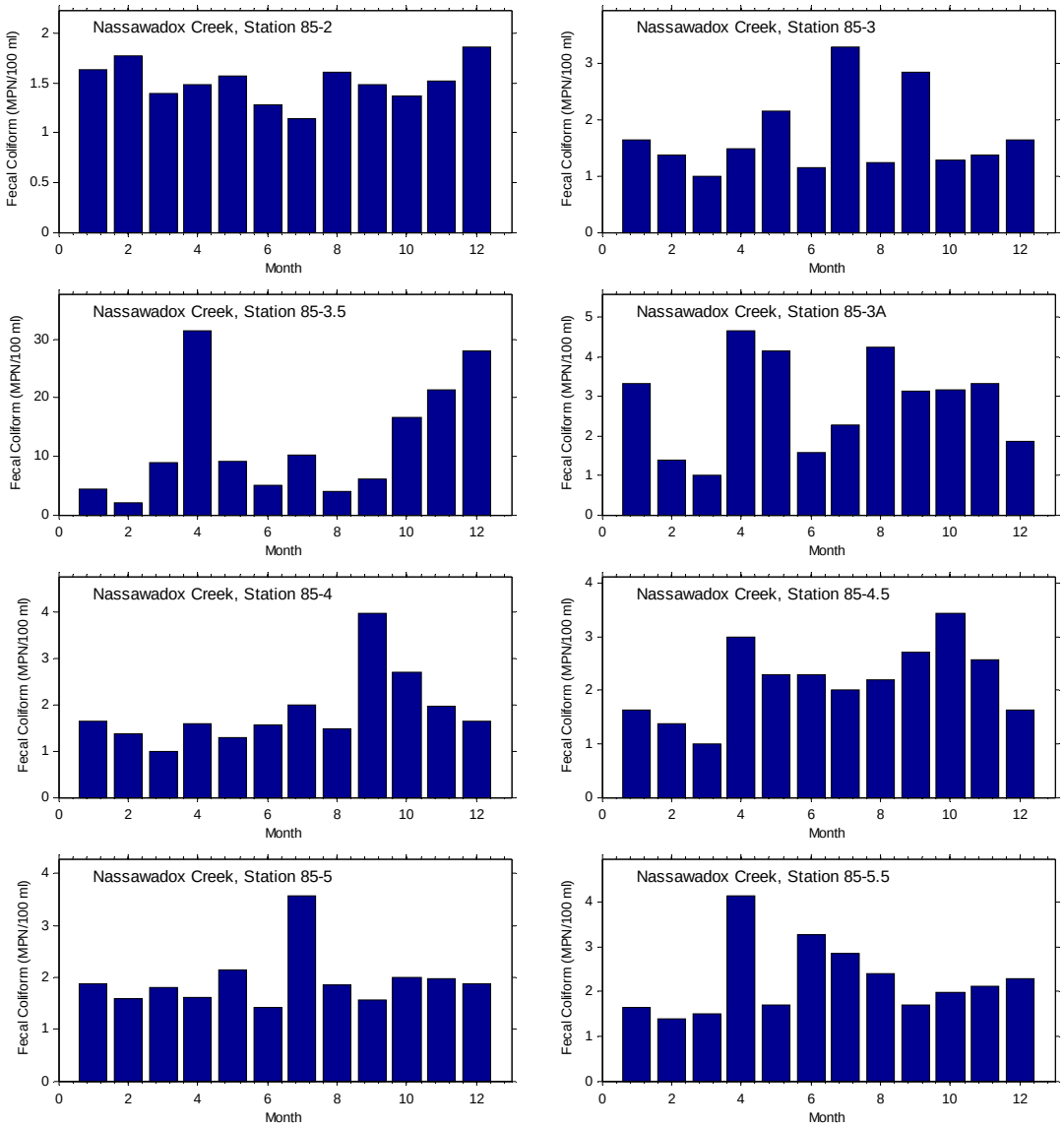


Figure 2.9: Seasonal Variation of Fecal Coliform Concentration at Selected Stations in Nassawadox Creek

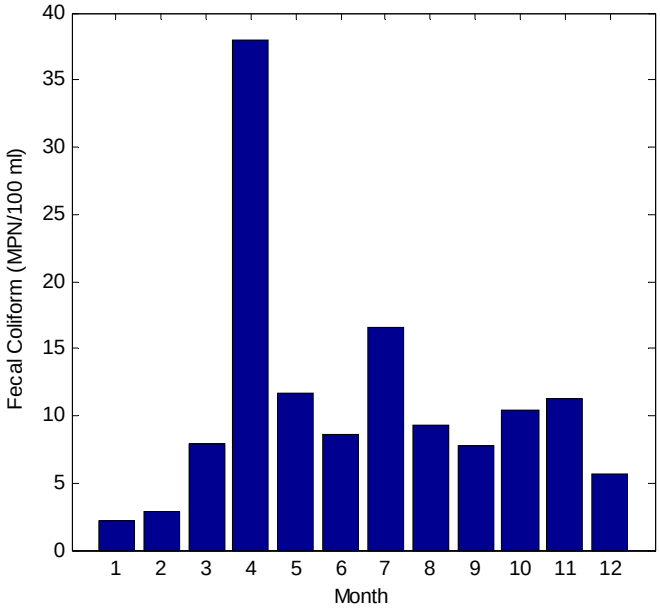


Figure 2.10: Seasonal Variation of Mean Fecal Coliform Concentration in Nassawadox Creek

3.0 SOURCE ASSESSMENT

3.1 General

A primary component of bacteria TMDL development for Nassawadox Creek and Westerhouse Creek is the evaluation of potential sources of bacteria in the watersheds. The watershed approach was applied for the source assessment. Landuse data together with human population, wildlife, manure application, etc. were used for the assessment. Sources of information that were used in evaluating potential pollutant sources included the VA-DEQ, the Virginia Department of Conservation and Recreation (VA-DCR), the Virginia Department of Game and Inland Fisheries (VADGIF), the Virginia Department of Health (VDH), US Department of Agriculture (USDA) agriculture census data, public participation, watershed studies, stream monitoring, published information, and best professional judgment. A substantial amount of information was contributed by local stakeholders.

The potential pollutant sources in the watershed can be broken down into point and nonpoint sources. Point sources are permitted pollutant loads derived from individual sources and discharged at specific locations. There are two point sources within the Nassawadox Creek watershed. Nonpoint sources are from various sources over a relatively large land area, which are the dominant pollutant sources in the watershed.

3.2 Population Number Summaries

Population numbers for humans, dogs, livestock, and wildlife are shown in Table 3.1. The human population can be derived from US Census Bureau data (USCB, 2010) and estimated based on watershed area and landuses for the Nassawadox Creek watershed with respect to the county watershed area for urban landuse. We used the dataset of 911 addresses to estimate the household numbers, and the county average number of persons (2.32/household) in each household to estimate the population, which provides a more accurate estimation of the population. There are 2,026 and 42 households in the watersheds of Nassawadox Creek and Westerhouse Creek, respectively. National Agriculture Statistics Survey data were used to calculate the livestock numbers. Bacteria source distribution is estimated based on the number of animals, typical animal weights, and daily bacteria production rates. According to field surveys, deer and geese populations are much higher in this watershed than the averaged density in Virginia. Therefore, high acreage densities were used, and are listed in Table 3.2. These numbers are derived from inputs from stakeholders and the Hungars-Mattawoman TMDL Implementation Plan (http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ImplementationPlans/Mattawoman_TMDL_IP_Public.pdf). Although a large number of chickens was estimated based on landuse and the agriculture census, there is no manure application in this watershed, based on DEQ's survey. Therefore, leaking from manure storage or a farm operation would be the only contribution from chicken farms and it is expected that this would result in only a small percentage of the total contribution. No manure source is estimated from this watershed. The source distributions are listed in Table 3.3. It can be seen that a large portion of bacteria sources is from wildlife.

Table 3.1: Humans, Dogs, Livestock, and Wildlife Populations in the Nassawadox Creek and Westerhouse Creek Watersheds

		Nassawadox Creek watershed	Westerhouse Creek watershed
Human	**Population**	4700	97
	Septic system	2026	42
	Dogs*	1183	25
	Cats* (unused)	1293	27
Livestock	**Horse**	46	0
	Cattle	65	0
	Fowl	129	12
	Chickens	5509**	0
	Geese	12	0
Wildlife	**Deer**	1940	150
	Raccoons	1321	102
	Muskrats	2864	236
	Geese	293	24
	Ducks	597	49
	Geese (seasonal peak)	527	44
	Ducks (seasonal peak)	1074	89

* Dogs = (36.5% of houses) × (1.6 dogs/house), Cats = (30.4% of houses) × (2.1 cats/house) (AVMA, 2012)
** The number of chickens varies each year. No permitted manure application occurs in this watershed and chickens do not contribute to the loading significantly in this watershed.

Table 3.2: Densities Used for Estimating Wildlife in the Watersheds*

Wildlife Type	Population Density	Habitat Requirements
Deer	0.1032 animals/acre	Entire watershed
Raccoons	0.0703 animals/acre	Entire watershed
Muskrats	0.3128 animals/acre	300-foot buffer for primary habitat/600 feet buffer for secondary habitat
Geese	0.032 animals/acre	300-foot buffer for primary habitat /600 feet buffer for secondary habit
Ducks	0.0652 animals/acre	300-foot buffer for primary habitat/600 feet buffer for secondary habitat

*Population density derived during Hungars-Mattawoman IP study

Table 3.3: Distribution of Bacteria Source Deposited to Watershed

Waterbody Name	Source	Loads (counts per day)	Percent of Source
Nassawadox Creek	Human	6.23E+11	2.2%
	Pets	2.90E+12	10.3%
	Wildlife	1.72E+13	61.2%
	Livestock	7.38E+12	26.3%
	Total	2.81E+13	100.0%
Westerhouse Creek	Human	1.29E+10	0.87%
	Pets	6.02E+10	4.04%
	Wildlife	1.41E+12	94.98%
	Livestock	1.63E+09	0.11%
	Total	1.49E+12	100.00%

3.3 Septic System Inputs

Conventional septic tank systems are only effective where the soil is adequately porous to allow percolation of liquids, and the groundwater level is low enough to avoid contamination. Leaking pipes or treatment tanks (i.e., leakage losses) can allow wastewater to return to the groundwater, or discharge to the surface, without adequate treatment. Leaking septic systems are a source of nutrients and bacteria. The household numbers derived from 911 addresses are used for estimating septic systems, which provides a more accurate approach. There are a total of 2,026 and 42 septic systems in the Nassawadox Creek and Westerhouse Creek watersheds, respectively (Figure 3.1). Using a failure rate of 5% based on the local VDH and the Hungars-Mattawoman IP report, the number of failed systems is approximately 101 and 2, respectively, in these two watersheds. The septic flow rate of 70 gal/person/day is used (EPA 2001a). MapTech Inc. (2001) did an evaluation of bacteria concentration for septic, which has the concentration of 1.0×10^6 counts/100mL. The concentration of 1.0×10^6 counts/100mL was used for estimating the loading from septic systems.

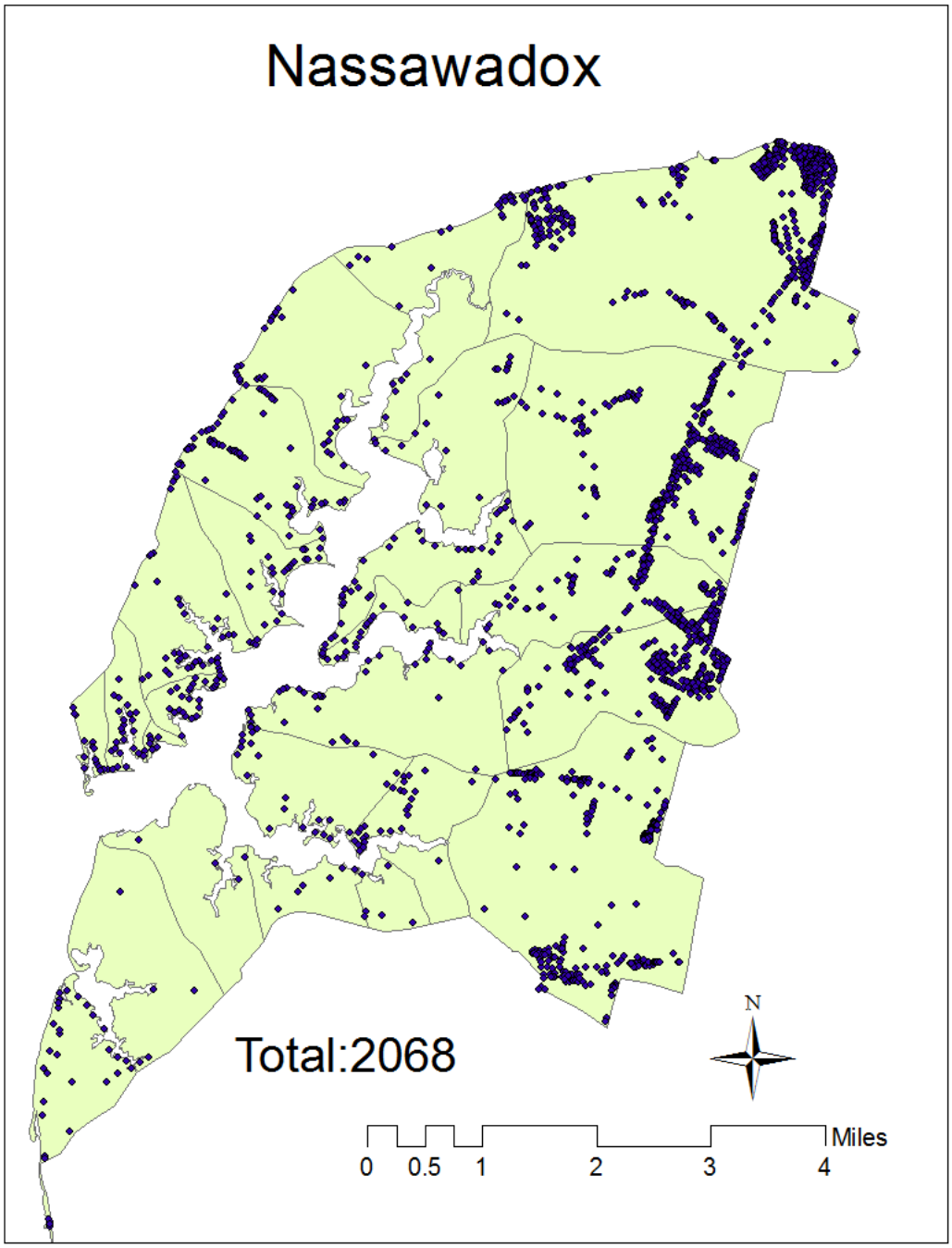


Figure 3.1: Septic System Locations in the Nassawadox Creek and Westerhouse Creek Watersheds

3.4 Point Sources

There are two point sources in the watershed, which are Riverside Shore Memorial Hospital (VA0027537) and Butch's Car & Parts Inc. (VAR051805). The information of the point sources is listed in Table 3.4. There is no bacteria discharge for VAR051805 because it is a stormwater discharge related to industrial activity. The design flow for the Memorial Hospital is 0.1 MGD. Measured average maximum flow is about 0.068 MGD, and discharges to Warehouse Creek. VDH-DSS has administratively closed the upper reach of the Creek. The permanent closure was based on potential fecal input from the hospital's water treatment plant discharge. VDH-DSS will commonly close areas such as these to ensure the protection of public health. Monthly monitoring data show that the bacteria concentration discharged from the Memorial Hospital is low, which does not add to the elevated bacteria levels in this area. A typical concentration distribution is shown in Figure 3.2. The highest concentration is less than 10 cfu/100mL, which corresponds to a loading of 2.59 x 10^6 counts/day.

Table 3.4: Point Sources in Nassawadox Watershed

Permit	Facility name	Permit type	Receiving stream	Design Flow (MGD)	Bacteria limits	Estimated allowable loading (counts/day)*
VA0027537	Riverside Shore Memorial Hospital	Sewage Treatment Plant Individual VPDES	Unnamed tributary to Warehouse Creek	0.1	FC: 200 cfu/100mL E.coli: 126 cfu/100mL	7.57×10^7 (FC) 4.77×10^7(E.coli)
VAR051805	Butch's Car & Parts Inc	Industrial Stormwater General Permit	Nassawadox Creek	NA	NA	NA

*Based on design flow and 200 cfu/100mL for FC and 126 cfu/100mL for E. coli. Current loading is less than 1.82×10^6 counts/day for FC.

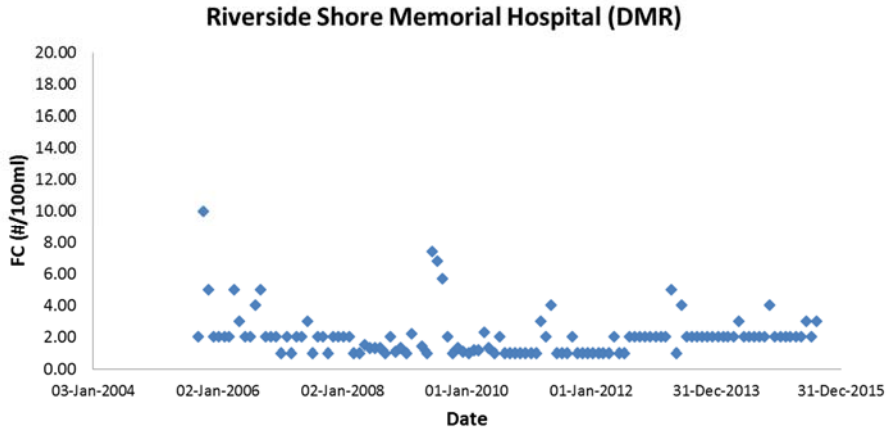


Figure 3.2: Measured Fecal Coliform Bacterial Concentration at Riverside Shore Memorial Hospital

3.5 Livestock

The USDA agriculture census data is one potential source of livestock data. However, the distribution of livestock in each of these subwatersheds is not well-documented in this source. So livestock distributions were determined from an alternative source - Shoreline Surveys (which include livestock counts) from the Virginia Department of Health Division of Shellfish Sanitation (VDH-DSS), Livestock information was then further confirmed by local stakeholders during public meetings. A distribution of the livestock is shown in Figure 3.3.

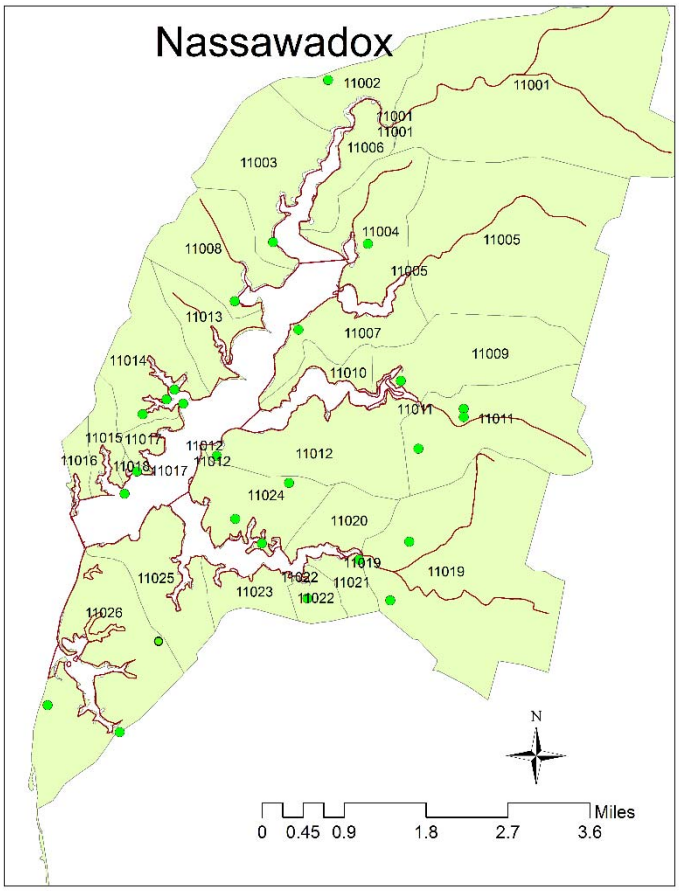


Figure 3.3: Distribution of Livestock in the Watersheds (dots represent possible locations of livestock, and number are subwatershed ID)

4.0 TMDL DEVELOPMENT

4.1 Overview

A TMDL is the total amount of a pollutant that a waterbody can receive and still meet WQS. A TMDL may be expressed as a "mass per unit time, toxicity, or other appropriate measure" (CFR, 2006). These loads are based on an averaging period that is defined by the specific WQS. A TMDL is the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources, incorporating natural background levels. The TMDL must either implicitly or explicitly include a margin of safety (MOS) that accounts for both the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody, and the uncertainty in the scientific and technical understanding of water quality in natural systems. In addition, when applicable, the TMDL may include a future allocation (FA) as necessary. This definition is denoted by the following equation:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS} + (\text{FA, where applicable})$$

This section documents the detailed fecal coliform and enterococci TMDLs, WLA, and LA development for Nassawadox Creek and Westerhouse Creek. Because the WQS for fecal coliform is more stringent than enterococci, the enterococci attainment is satisfied after reduction of the bacteria source in the watershed to meet WQS for fecal coliform. Therefore, only the TMDL for the fecal coliform is presented.

4.2 Selection of a TMDL Endpoint

An important step in developing the TMDL is the establishment of in-stream numerical endpoints, which are used to evaluate the attainment of acceptable water quality and allowable loading capacity. According to WQS 9VAC25-260-160 and 170, the numerical criteria for enterococci for the recreational use is a *Geometric Mean* of 35 counts/100mL and a *Single Sample Maximum* of 104 counts/100mL. The numerical criteria for fecal coliform are *a Geometric Mean of 14 counts/100mL and a 90th percentile of 31 count/100mL*. The most stringent criteria will be used to compute the TMDLs.

4.3 Model Development for Computing TMDL

Numerical models are a widely used approach for TMDL and other water quality studies. In this study, a system of numerical models was applied to simulate the loadings of bacteria and the resulting response of in-stream bacteria. The modeling system consists of two individual model components: the watershed model and the hydrodynamic-water quality model. The watershed model Loading Simulation Program in C^{++} (LSPC), developed by the USEPA (Shen *et al.*, 2005), was selected to simulate the watershed hydrology and bacteria loadings in the watershed. The Environmental Fluid Dynamics Computer Code (EFDC) (Hamrick, 1992a; Park *et al.*, 1995) was used to simulate bacteria transport in the receiving water. A detailed model description, model setup, model calibration, and scenario runs are presented in Appendix A.

The LSPC model is driven by hourly precipitation and was used to simulate the freshwater flow and its associated nonpoint source pollutants. The simulated freshwater flow and bacteria loadings from each sub-watershed were fed into the adjacent water quality model segments. The EFDC model simulates the transport and fate of bacteria in the Creek.

The flow simulated by the watershed model was calibrated using United States Geological Survey (USGS) gauging data at Gage 01484800 in Guy Creek near the Nassawadox watershed. This is the only USGS gauging station located along the Eastern Shore. An example of model calibration of the flow is shown in Figure 4.1. Detailed modeling processes and calibration procedure are presented in Appendix A.

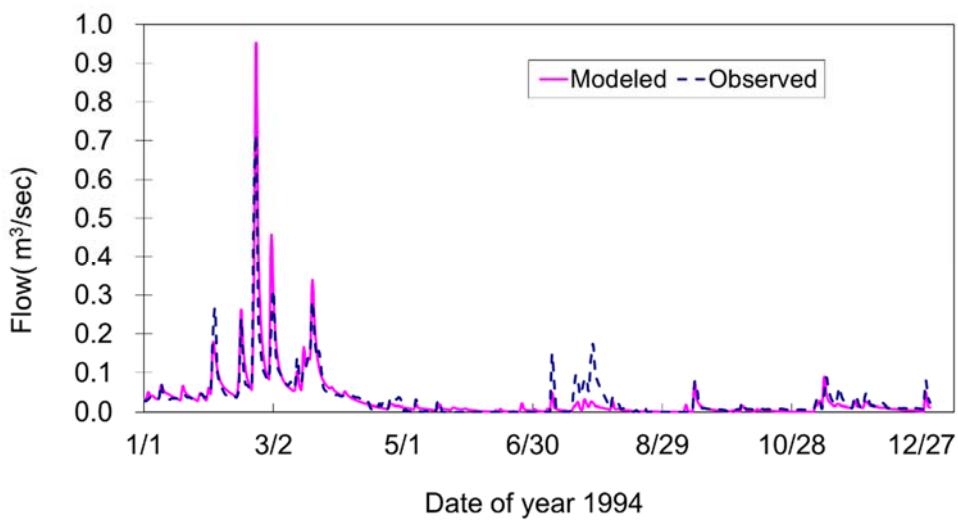


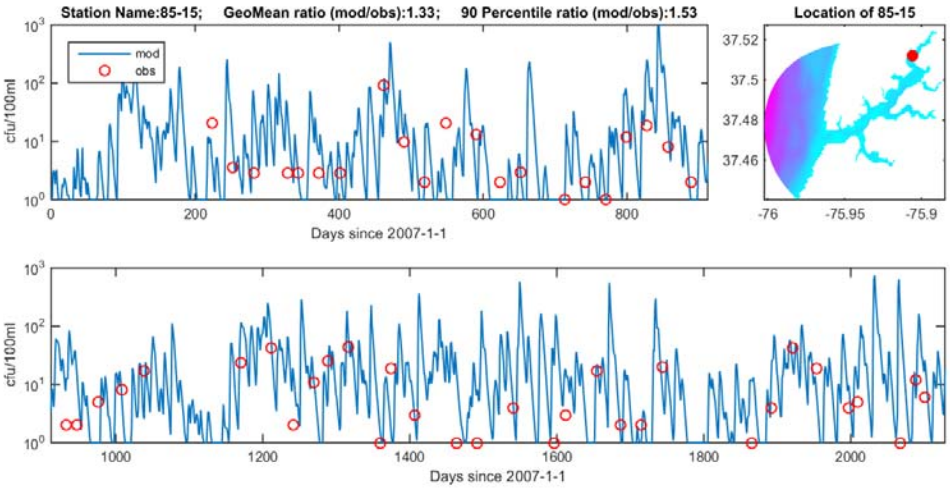
Figure 4.1: Time Series Comparison of Daily Stream Flow between Model Simulation and Observations from USGS Stream Gage 01484800 in 1994

A numerical model calibration of fecal coliform was conducted for the period of 2007-2014. Both the model calibration and assessment were focused on the 2007-2012 period, which corresponded to the highest frequency of violation from 2007 and 2014. The middle section of the Creek is listed for recreational use impairment that uses enterococci as an indicator of water quality. Because bacterial production for difference sources is estimated based on fecal coliform, the bacterial loading discharged from the watershed is quantified by fecal coliform. As there is a good relationship between fecal coliform concentration and enterococci concentration, the transport model only simulates fecal coliform. Both observed fecal coliform concentrations and model results of fecal coliform were converted to enterococci concentration for comparison and assessment of attainment of WQS using the following translator equation (VA-DEQ, 2003, 2008):

$$\log_2(Enterococci) = 1.2375 + 0.59984 \times \log_2(Fecal\ Coliform)$$

Based on this equation, a fecal coliform concentration of 31 cfu/100mL (90th percentile criteria for shellfish consumption use) corresponds to an enterococci concentration of 18.5 cfu/100mL. The recreation designated use single sample maximum value of 104 cfu/100 mL of enterococci concentration corresponds to 551.1 cfu/100mL of fecal coliform concentration. Both water quality criteria were used and the most stringent criteria were used to determine the TMDLs.

Daily watershed run-off discharges to the surface of the Nassawadox Creek and Westerhouse Creek from adjacent watersheds and small creeks connected to them. Because bacteria observations were conducted inside the Nassawadox and Westerhouse Creeks as well as their tributaries, a linked watershed-receiving water model approach was conducted for the model based on observations in all these waterbodies. A constant decay rate of 0.5 per day was used for the bacterial loss in the stream. An example of the model calibration results is shown in Figure 4.2. It can be seen that the model simulates the bacteria variations in the calibration period well, indicating that the model has the ability to simulate bacteria in these waterbodies. The detailed model calibration at all stations that violate the water quality standards is presented in Appendix A.



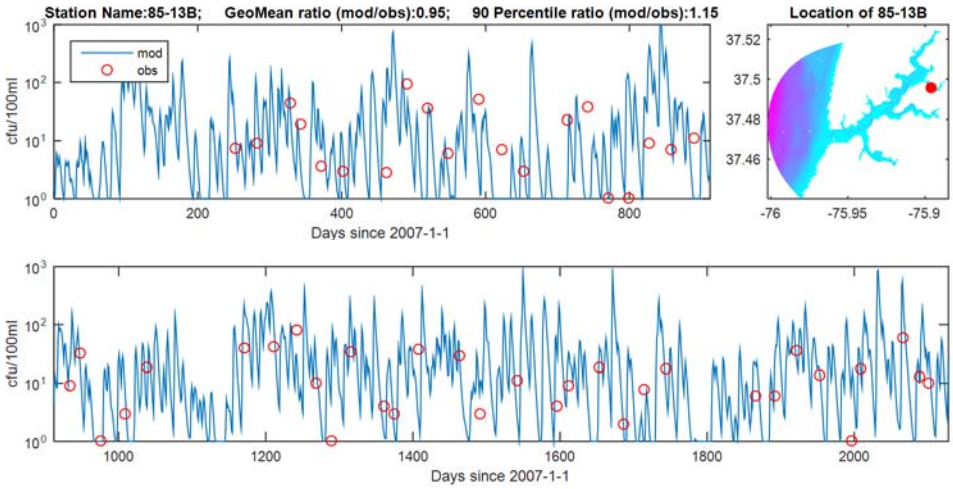


Figure 4.2: Time Series Comparison of Fecal Coliform between Model Simulation and Observations from 2007-2012

Bacterial variations are very large and highly driven by single events and large precipitation events. Therefore, assessments of model skill for seasonal variation and accumulative distribution were performed. Figure 4.3 shows the comparison of the seasonal variation of modeled and observed fecal coliform concentrations for average fecal coliform concentration for the entire Creek. It can be seen that the model simulates seasonal variation well. A comparison of the cumulative distribution of model predictions and observations for all the data in the Creek is shown in Figure 4.4. It can be seen that the model agrees well for the distribution of fecal coliform, indicating that the model has good predictive skill.

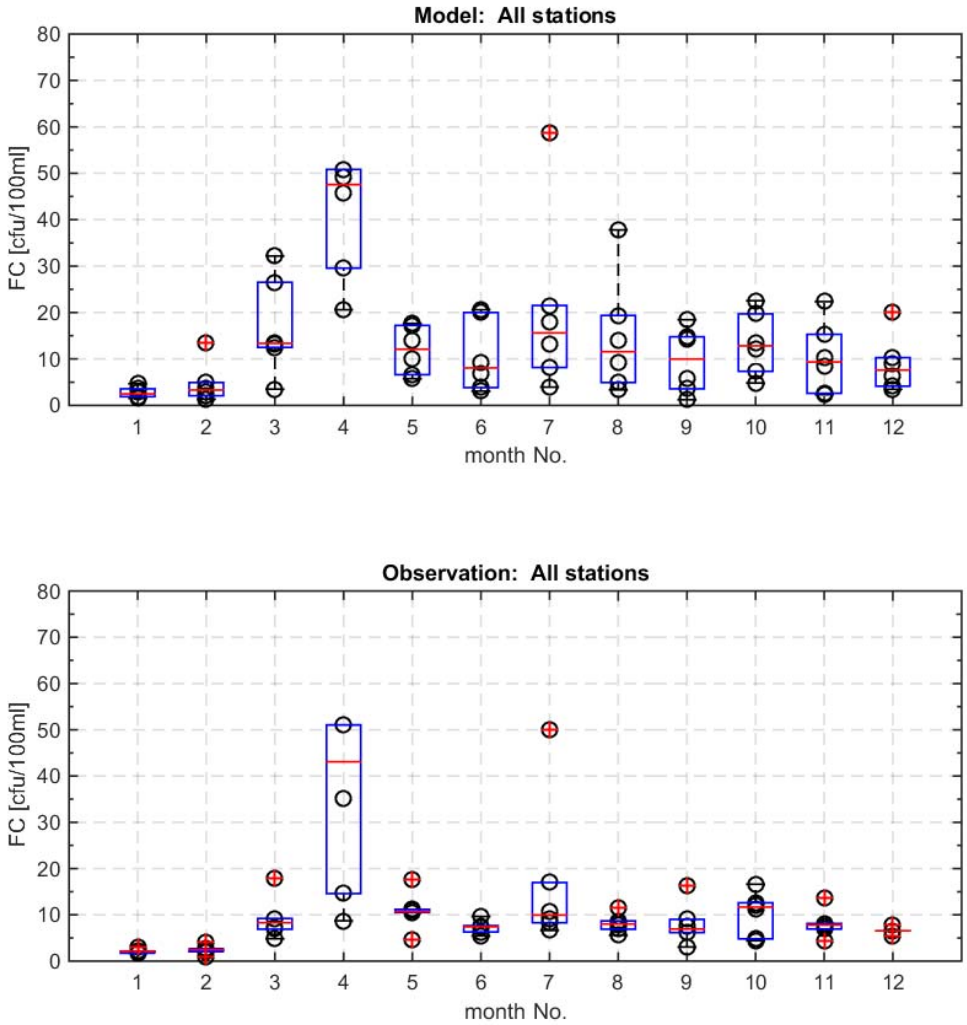


Figure 4.3: Comparison of Seasonal Variation of Model Predictions and Observations from 2007-2012 (box shows the first and third quartile of the observation data, red line is the median, circles are model results, circles with + show the maximum and minimum)

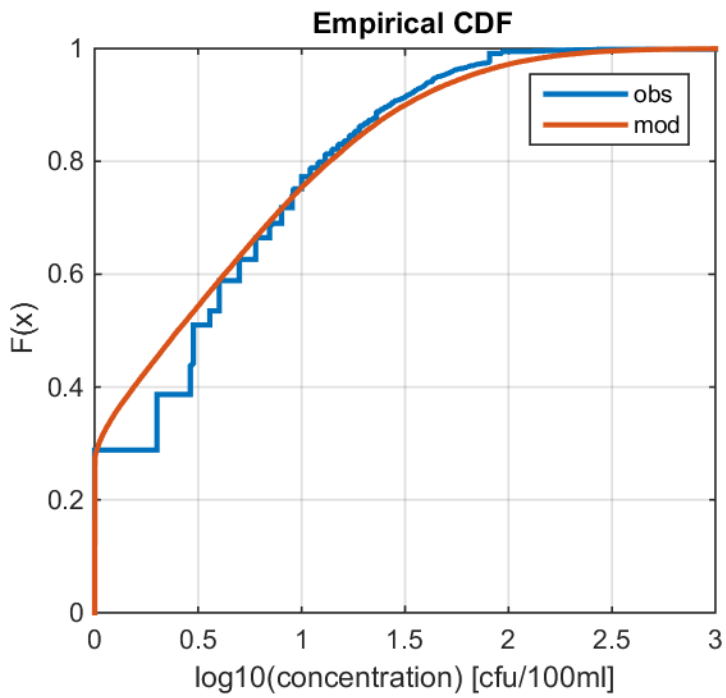


Figure 4.4: Comparison of the Cumulative Distribution of Model Predictions and Observations

4.4 Consideration of Critical Conditions and Seasonal Variation

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when they are most vulnerable. Critical conditions are important because they describe the factors that combine to cause a violation of WQS and help to identify the actions that may have to be undertaken to meet WQS.

The current loadings to the waterbodies were determined using a long-term record of water quality monitoring (observation) data. The period of record for the data was 2007 to 2014, which spans different flow regimes and temperatures, and includes the period that has the highest violation in the Creeks. A 5-year period of model simulation (from 2007-2011) with highest fecal coliform concentration over the entire simulation period was used to develop the TMDL, which is the most stringent period for the attainment of WQS. The resulting estimate is quite robust. Seasonal variations involved changes in surface runoff, stream flow, and water quality as a result of hydrologic and climatologic patterns. These are accounted for by the use of this long-term simulation to estimate the current load and reduction targets.

4.5 Margin of Safety

In order to account for uncertainty in model inputs or outputs and in relationships

between bacterial loadings and in-stream water quality, a margin of safety (MOS) needs to be incorporated into the TMDL development process. A MOS is typically expressed either as an unallocated assimilative capacity (explicit) or as conservative analytical assumptions (implicit) used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed controls). An implicit MOS was used in this TMDL by using long-term water quality data that cover different flow regimes, with extreme wet and dry years, and a multiple-year simulation to estimate the current bacteria loads and load reduction targets. The permitted STP was represented using the design flow and maximum allowable fecal coliform concentration as opposed to the actual discharges. Additionally, the allocations established in the TMDL meet both the geometric mean and the 90th percentile standards, or instantaneous standards.

4.6 TMDL Computation

It is found that the 90th percentile standard for fecal coliform is the most stringent. The 90th percentile endpoint of 31 cfu/100mL is used to establish pollutant reduction, the allowable fecal coliform loading reduction to meet both fecal coliform and enterococci criteria can be computed. The load reduction needed for the attainment of the criteria was determined as follows:

$$\textbf{Load Reduction} = \frac{\textbf{Current Load} - \textbf{Allowable Load}}{\textbf{Current Load}} \times 100\,\%$$

All TMDLs have some probability of being exceeded. That probability is either explicitly specified or implicitly assumed. EPA guidance states that the probability component of a calculated maximum daily load (MDL) from daily simulation should be “based on a representative statistical measure” that is dependent upon the specific TMDL and best professional judgment of the developers (USEPA, 2007). The MDL for this analysis is determined based on a pre-defined probability and long-term simulation. The computed MDL is consistent with achieving the annual cumulative load target. A 90th percentile was selected as the pre-defined probability, which agrees with fecal coliform criteria. The detailed calculation of the MDL is described in Appendix B. The results of maximum daily loadings for Nassawadox Creek and Westerhouse Creek are listed in Table 4.1. The results of load and load reduction for each listed segment are listed in Table 4.2. Note that the loads presented in these tables are the runoff of bacteria discharging to the stream, which are less than 8% of the bacteria deposited on the watershed due to bacterial die-off.

The annual load was computed as multiple year mean annual load, or mean daily load times 365.25 day. The results and reductions expressed as annual loads are listed in Tables 4.3 and 4.4.

Table 4.1: Estimated Daily Maximum Loads and Load Reductions for Fecal Coliform

	Pollutant	Criterion (CFU/100mL)	Current Load (counts/day)	Allowable Load (counts/day)	Required Reduction (%)
Nassawadox Creek	Fecal coliform	90th percentile	2.68E+12	1.72E+12	36.0%
Westerhouse Creek	Fecal coliform	90th percentile	1.12E+11	5.95E+10	46.9%

Table 4.2: Estimated Daily Loads and Load Reductions for Each Listed Segments

	Pollutant	Criterion (CFU/100mL)	Current Load (counts/day)	Allowable Load (counts/day)	Required Reduction (%)
Nassawadox Creek-Upper	Fecal coliform	90th percentile	5.10E+11	2.14E+11	58.0%
Kelly Cove	Fecal coliform	90th percentile	1.83E+11	7.68E+10	58.0%
Holly Grove Cove	Fecal coliform	90th percentile	4.13E+11	2.68E+11	35.0%
Nassawadox Creek-Middle	Fecal coliform	90th percentile	2.90E+11	2.35E+11	19.1%
Church Creek-Upper	Fecal coliform	90th percentile	3.08E+11	2.34E+11	24.0%
Church Creek-Middle	Fecal coliform	90th percentile	1.01E+11	1.01E+11	0.0%
Nassawadox Creek (all)	Fecal coliform	90th percentile	2.68E+12	1.72E+12	36.0%
Westerhouse Creek	Fecal coliform	90th percentile	1.12E+11	5.95E+10	46.9%

Table 4.3: Estimated Annual Maximum Loads and Load Reductions for Fecal Coliform

	Pollutant	Criterion (CFU/100mL)	Current Load (counts/Year)	Allowable Load (counts/Year)	Required Reduction (%)
Nassawadox Creek	Fecal coliform	90th percentile	4.70E+14	3.01E+14	36.0%
Westerhouse Creek	Fecal coliform	90th percentile	2.16E+13	1.15E+13	46.9%

Table 4.4: Estimated Annual Maximum Loads and Load Reductions for Each Listed Segment

	Pollutant	Criterion (CFU/100mL)	Current Load (counts/Year)	Allowable Load (counts/Year)	Required Reduction (%)
Nassawadox Creek-Upper	Fecal coliform	90th percentile	8.78E+13	3.69E+13	58.0%
Kelly Cove	Fecal coliform	90th percentile	3.29E+13	1.38E+13	58.0%
Holly Grove Cove	Fecal coliform	90th percentile	7.31E+13	4.75E+13	35.0%
Nassawadox Creek-Middle	Fecal coliform	90th percentile	5.65E+13	4.57E+13	19.1%
Church Creek-Upper	Fecal coliform	90th percentile	5.38E+13	4.09E+13	24.0%
Church Creek-Middle	Fecal coliform	90th percentile	1.85E+13	1.85E+13	0.0%
Nassawadox Creek (all)	Fecal coliform	90th percentile	4.70E+14	3.01E+14	36.0%
Westerhouse Creek	Fecal coliform	90th percentile	2.16E+13	1.15E+13	46.9%

The loadings for each bacterial source were determined based on source assessment (Appendix B). Load allocations for each source category were determined based on the contribution of each source based on results of source assessment (Table 3.3) and model simulations. The percent reduction needed to attain the water quality criterion was allocated to each source category. Table 4.5 presents the result of bacterial loading associated with runoff. It can be seen that runoff bacterial loading is less than 10% of the loading initially deposited on the land due to bacterial die-off. The results for each listed segment are presented in Appendix A, which provides a start point of the design IP. The TMDL seeks to eliminate 100% of the human-derived fecal component regardless of the allowable load determined through the LA process. Human-derived fecal coliforms are a serious concern in the estuarine environment and discharge of human waste is precluded by state and federal law. If the attainment cannot be achieved, the source from wildlife is reduced.

The point source in the Warehouse Creek watershed (VA0027537) contributes minimal bacteria. The highest concentration measured (<10 cfu/100mL) from this source is below the shellfish geometric mean standard of 14 cfu/100mL.

According to the preceding analyses and model simulations, reduction of the controllable

loads alone (human, livestock, and pets), will not result in achievement of the WQS. Absent any additional sources to which an allocation can be given, a reduction is also allocated to wildlife. The allocations presented demonstrate how the TMDLs could be implemented to achieve WQS; however, the state reserves the right to allocate differently, as long as consistency with the achievement of WQS is maintained.

Table 4.5: Estimated Loads Runoff and Load Reductions for Bacteria from Nonpoint Sources

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek	Human	6.07E+10	0	100.0%
	Pets	2.83E+11	0	100.0%
	Wildlife	1.68E+12	1.68E+12	0.0%
	Livestock	7.20E+11	8.00E+10	88.9%
	Total	2.74E+12	1.76E+12	35.9%
Westerhouse Creek	**Source**	**Current Load (counts/day)**	**Allocation (counts/day)**	**Reduction Needed**
	Human	9.71E+08	0	100.0%
	Pets	4.53E+09	0	100.0%
	Wildlife	1.06E+11	5.95E+10	44.1%
	Livestock	1.23E+08	0	100.0%
	Total	1.12E+11	5.95E+10	46.9%

4.7 Summary of TMDL and Load Allocation

The TMDLs for Nassawadox Creek and Westerhouse Creek are presented in Table 4.6. The loads were allocated to the LA. The annual total maximum load is listed in Table 4.7. The WLA for VA0027537 listed in the tables is estimated based on design flow and permitted bacterial concentration which is based on the WQS. Note that no change to this permit is prescribed.

Table 4.6: Fecal Coliform Bacteria Daily TMDLs in Nassawadox Creek and Westerhouse Creek (Counts/Day)

Impairment	WLA	LA	MOS	TMDL
Nassawadox	1.72E+10	1.70E+12	Implicit	1.72E+12
VA0027537*	*7.57E+07*			
Future load (1%)	*1.72E+10*			
Westerhouse Creek	5.95E+08**	5.89E+10	Implicit	5.95E+10

Future load (1%)				

*Estimated based on design flow and permit of FC 200 cfu/100mL. No change of current permits
**The WLA reflects 1% of the TMDL for future growth allocation

Where:

TMDL = Total Maximum Daily Load;
LA = Load Allocation (nonpoint source)
WLA = Wasteload Allocation (point source)
MOS = Margin of Safety

Table 4.7: Fecal Coliform Bacterial Annual TMDLs in Nassawadox Creek and Westerhouse Creek (Counts/Year)

Impairment	WLA	LA	MOS	TMDL
Nassawadox	**3.04E+12**	2.98E+14	Implicit	3.01E+14
VA0027537*	*2.77E+10*			
Future load (1%)	*3.01E+12*			
Westerhouse Creek	**1.15E+11****	1.13E+13	Implicit	1.15E+13
Future load (1%)				

*Estimated based on design flow and permit of FC 200 cfu/100mL. No change of current permits
**The WLA reflects 1% of the TMDL for future growth allocation

5.0 IMPLEMENTATION AND PUBLIC PARTICIPATION

5.1 General

Once a TMDL has been approved by the EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources in the stream. For point sources, all new or revised Virginia Pollutant Discharge Elimination System (VPDES)/National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ImplementationPlans/ipguide.pdf. With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

5.2 Staged Implementation

In general, Virginia intends for the required pollutant reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, BMP technology can be used to reduce the runoff of bacteria discharging to the surface waters. It will be efficient to remove the livestock impact. Additionally, in both urban and rural areas, reducing the human loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

Additionally, the Nassawadox TMDL provides the opportunity to set a stage 1 goal for Nassawadox that would be based on load reductions that would meet the *Enterococcus* delisting criterion of no more than 10% violation of the 104 cfu/100 ml criterion. Stage 2 would be based on the additional reductions needed to attain the shellfish 90th percentile criterion (meeting the TMDL). The Westerhouse Creek watershed is very small and has a minimal amount of anthropogenic sources so multiple stages would be unnecessary for this watershed.

The iterative implementation of BMPs in the watershed has several benefits:

1. To enable tracking of water quality improvements following BMP implementation through follow-up stream monitoring;

2. To provide a measure of quality control, given the uncertainties inherent in

computer simulation modeling;

3. To provide a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;

4. To help to ensure that the most cost-effective practices are implemented first; and
5. To allow for the evaluation of the adequacy of the TMDL in achieving WQS.

Watershed stakeholders will have the opportunity to participate in the development of the TMDL implementation plan.

5.3 Reasonable Assurance for Implementation

5.3.1 Follow-Up Monitoring

Following the development of the TMDL, DEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining WQS, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in

DEQ's standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established quality assurance/quality control (QA/QC) guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or that they monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bi-monthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.state.va.us/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring.aspx.

To demonstrate that the watershed is meeting WQS for watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, DO, etc.) is bi-monthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

5.3.2 Regulatory Framework

While Section 303(d) of the CWA and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the LAs and WLAs can and will be implemented. EPA also requires that all new or revised NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits, and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain WQS, monitoring plans, and milestones for attaining WQS.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the VPDES program, which typically includes consideration of the

WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater-related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses WQMIRA requirements as well as the nine elements required for an implementation plan under EPA Section 319. An exception is the municipal separate storm sewer systems (MS4s), which are both covered by NPDES permits and may be included in TMDL implementation plans. MS4s are encouraged to participate in local TMDL implementation plan development. Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between the EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the Water Quality Management Plans (WQMPs). Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board for inclusion in the appropriate WQMP, in accordance with the CWA's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the State Water Control Board (SWCB) adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia WQS. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ's website under
http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ppp.pdf

5.3.3 Implementation Funding Sources

Cooperating agencies, organizations, and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans." Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits, and landowner contributions.

The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

5.4 Public Participation

The development of the TMDL would not have been possible without public participation. Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progress made. Public meetings were organized for this purpose. A kick-off Work Group meeting was held on June 23, 2015 at the Accomack-Northampton Planning District Commission to inform the stakeholders of the TMDL development process and to obtain feedback. A second Work Group meeting was held on August 26, 2015 to update source estimates in the watersheds. Results of the hydrologic calibration, bacteria source estimates, and TMDL development were discussed in the first public meeting held on October 22, 2015 at the Exmore Town Hall (on Main Street in Exmore). Updated bacterial loading distribution and final TMDL results were presented and discussed in the second public meeting held on March 10, 2016 at the Accomack-Northampton Planning District Commission.

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Appendix A: Model Development

A.1 Model Development

Numerical models are widely used for TMDLs and other water quality studies. In this study, a system of numerical models was developed to simulate the loadings of bacteria, and the resulting response of in-stream bacteria transport and fate. The modeling system consists of two individual model components: the watershed model and the hydrodynamic-transport model. The watershed model LSPC, developed by the USEPA, was selected to simulate bacteria loads to the receiving waterbody of Nassawadox Creek. The EFDC (Hamrick, 1992a; Park *et al*., 1995) was used to simulate the water quality of the receiving water.

A.1.1 Model Description

A.1.1.1 Watershed Model

The LSPC model is a stand-alone, personal computer-based watershed modeling program developed in Microsoft C^{++} (Shen *et al*., 2005). It includes selected Hydrologic Simulation Program FORTRAN (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land, as well as a simplified stream transport model (USEPA, 2004; Shen *et al*., 2002a, b; USEPA, 2001b, c). Like other watershed models, LSPC is a precipitation-driven model and requires necessary meteorological data as model input.

LSPC was configured for the watershed to simulate this watershed of 26 hydrologically connected subwatersheds (Figure A-1). The subwatersheds were used as modeling units for the simulation of flow and pathogen deposition on the watershed. LSPC was used to simulate the freshwater flow and its associated nonpoint source pollutants. The simulated freshwater flow and bacterial loadings for each subwatershed were fed into the adjacent water quality model segments. In simulating nonpoint source pollutants from the watershed, LSPC uses a traditional buildup and washoff approach. Pollutants from various sources (manure, wildlife, septic systems, etc.) accumulate on the land surface and are subject to runoff during rain events. Different land uses are associated with various anthropogenic and natural processes that determine the potential pollutant load. The pollutants contributed by interflow and groundwater are also modeled in LSPC for each land use category. Pollutant loadings from surface runoff, interflow, and groundwater outflow are combined to form the final loading output from LSPC. In summary, nonpoint sources from the watershed are represented in the model as landuse-based runoff from the landuse categories to account for their contribution (USEPA, 2001a).

For this study, the watershed processes were simulated based on buildup and washoff processes. The final loads were converted to model accumulation rates (ACQOP, units

of counts/acre/day for pathogens). The ACQOP can be calculated for each land use based on all sources contributing nutrients to the land surface. For example, croplands receive manure application and feces from wildlife. Summarizing all these sources together can derive the accumulation rates for croplands. These loading parameters were adjusted accordingly during model calibration. The loads discharged to the stream were estimated based on model simulation results. The other two major parameters governing bacteria simulation, the maximum storage limit (SQOLIM, units in lbs/acre/day for nutrients or counts/acre/day) and the washoff rate (WSQOP, units in inches/hour), were specified based on soil characteristics and land use practices, and further adjusted during the model calibration. The WSQOP is defined as the rate of surface runoff that results in 90% removal of pollutants in one hour. The lower the value, the more easily washoff occurs.

A.1.1.2 Hydrodynamic Model

Hydrodynamic transport is the essential dynamic for driving the movement of dissolved and particulate substances in aquatic waters. Hydrodynamic models are used to represent transport patterns in complex aquatic systems. For the Nassawadox Creek study, the EFDC model was selected to simulate hydrodynamics. EFDC is a general purpose modeling package for simulating 1-, 2-, and 3-dimensional flow and transport in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands, and oceanic coastal regions. It was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications and is considered public domain software (Hamrick, 1992a, 1992b). The model code has been extensively tested and documented. The EFDC model has been integrated into the EPA's TMDL Modeling Toolbox for supporting TMDL development (http://www.epa.gov/exposure-assessment-models/efdc).

Inputs to the EFDC model for Nassawadox Creek and Westerhouse Creek include:

- Bathymetry
- Freshwater inputs (lateral and up-stream) from watersheds
- Surface meteorological parameters such as wind
- Bacteria loadings from watershed

The model uses a grid to represent the study area (Figure A-2). The grid is comprised of cells connected through the modeling process. The scale of the grid (cell size) determines the level of resolution in the model and the model efficiency from an operational perspective. The smaller the cell size, the higher the resolution and the lower the computational efficiency. The model grid used for Nassawadox Creek was developed based on the high-resolution shoreline digital files from USEPA and USGS topographic maps. The grid covered the entire Creek so that the mouth of the Creek can be used to set the boundary condition. Setting the model boundary well outside the model area of interest increased the model accuracy by reducing the influence of the boundary condition.

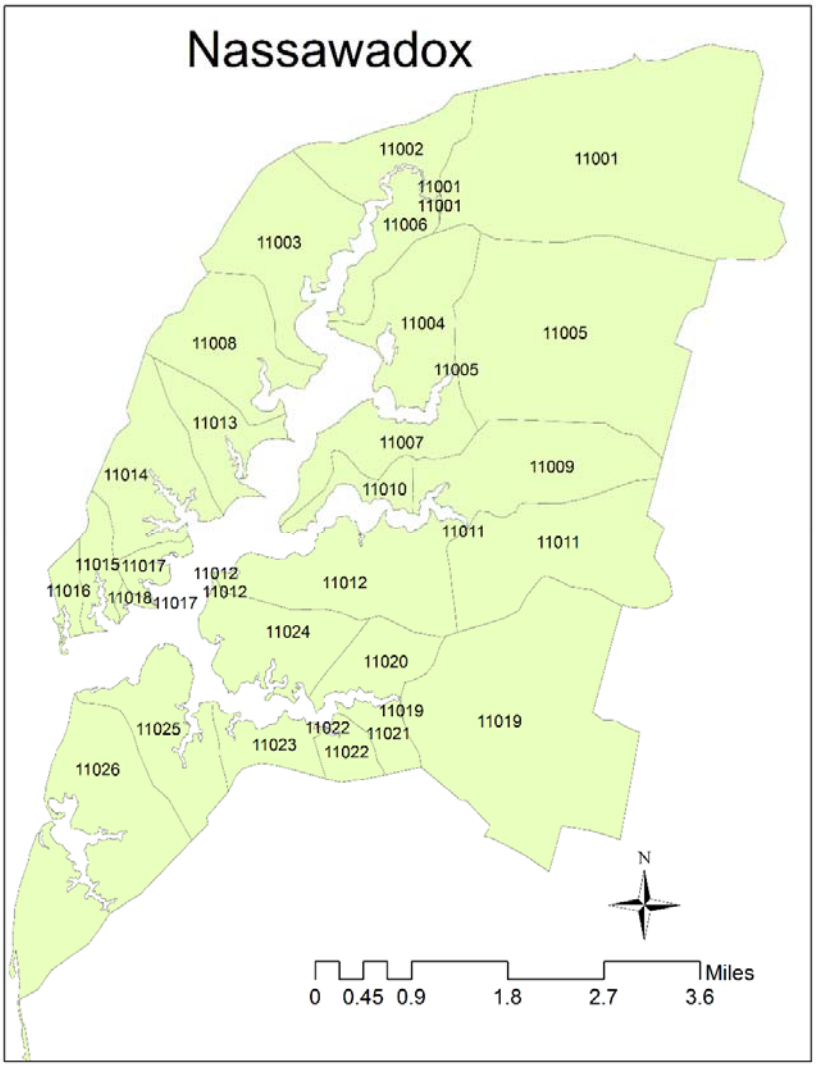


Figure A-1: Subwatersheds of Nassawadox Creek

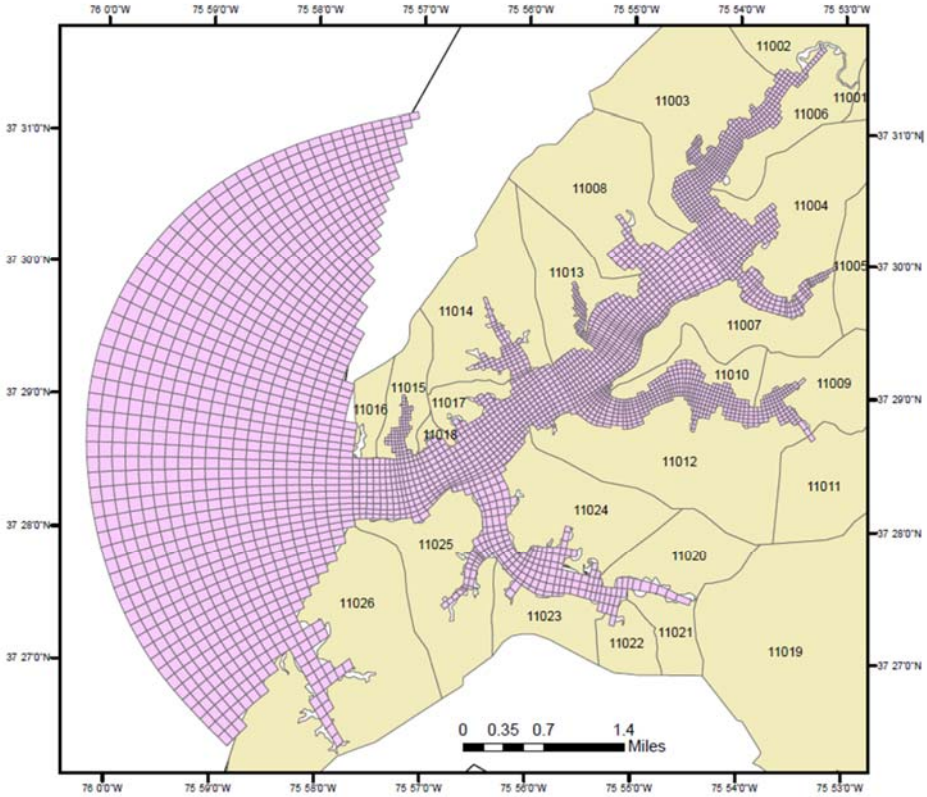


Figure A-2: Receiving Water Model Grid

A.1.2 Model Calibration and Verification

A.1.2.1 Watershed Model

The calibration process involved adjustment of the model parameters used to represent the hydrologic processes until acceptable agreement between simulated flows and field measurements were achieved. The USGS Gage 01484800 in Guy Creek, which is located near the Nassawadox watershed boundary and discharges to the Holly Grove Cove, VA region, was used to calibrate the model parameters for hydrology simulation. The measurement period is from 1986-1996. This is the only USGS station along the Eastern Shore and the observation period is before 2000. The model simulation during the observation period was conducted. The derived parameters were further verified with local flow data collected by the VADEQ in the Onancock Creek watershed. The Onancock Creek watershed has similar landuse, soil, and other characteristics as does Nassawadox Creek. Figure A-3 shows the time series comparison of daily stream flow for years 1993 and 1994. Figure A-4 shows the 10-year daily stream flow frequency comparison between the model result and field data

collected by the USGS gage. It can be seen that the model is only slightly off at very low flow condition (~0.0 cms). Based on the comparison, it can be seen that LSPC has reasonably reproduced the observed flow over a 10-year period.

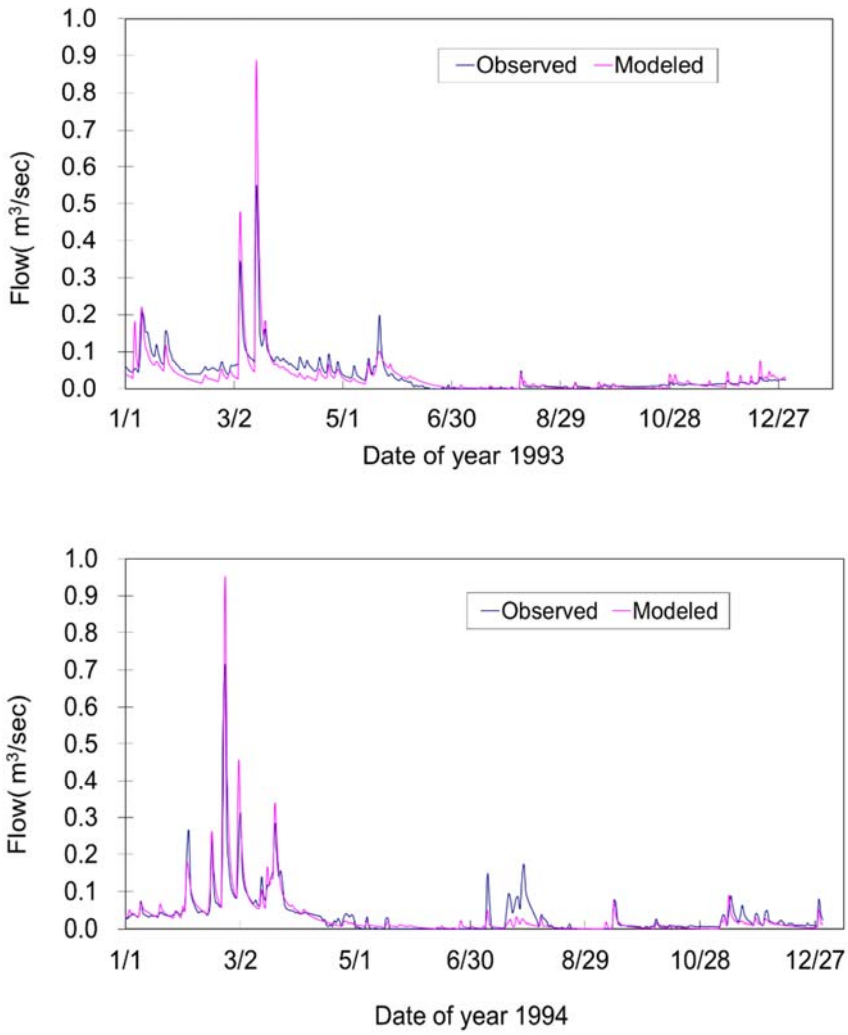


Figure A-3: Time Series Comparison of the Daily Stream Flow between Model Simulation and Observed Data from USGS Stream Gage 01484800 in 1993 and 1994

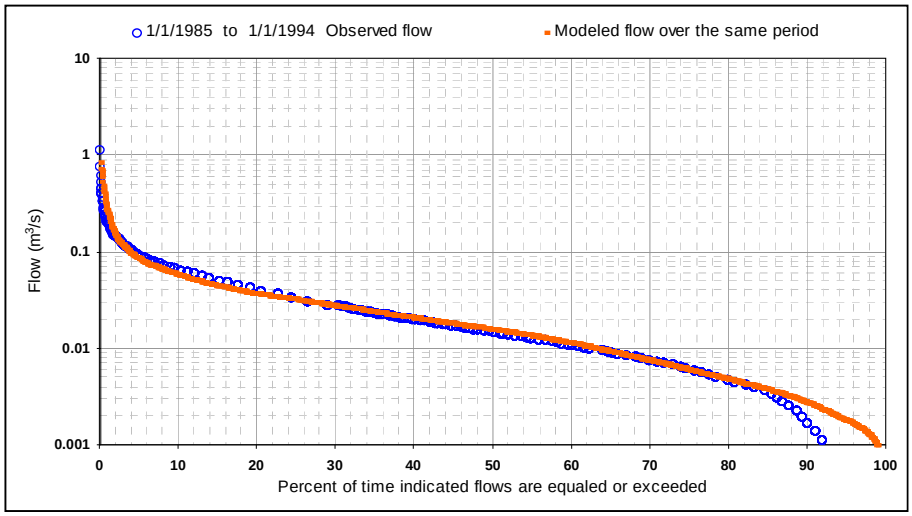
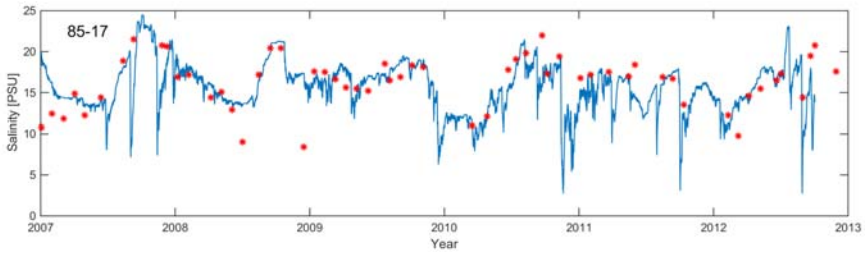


Figure A-4: 10-year Accumulated Daily Stream Flow Comparison between Model Simulation and the Reference Flow Station USGS 01484800

The 3D model was calibrated for salinity. The open boundary was driven by hourly tide output from a large domain Chesapeake Bay model (Du and Shen, 2015). The wind data obtained from the NOAA station at the Chesapeake Bay Bridge Tunnel were used for the model. An accurate simulation of salinity is more important for the model to correctly simulate estuarine circulation and transport processes of bacteria. There are 4 stations inside the Creek that span its domain (85-17, 85-9.6F, 85-3, and 85-5D). These are located in the upstream, in a tributary of Church Creek, and in the downstream of the Creek. The salinity inside the Creek is driven by both freshwater inflow and tide, and wind forcing. When freshwater discharge is large, low salinity can be observed. When tide is dominant, high salinity can be observed. The comparison of modeled and observed salinity is shown in Figure A-5.



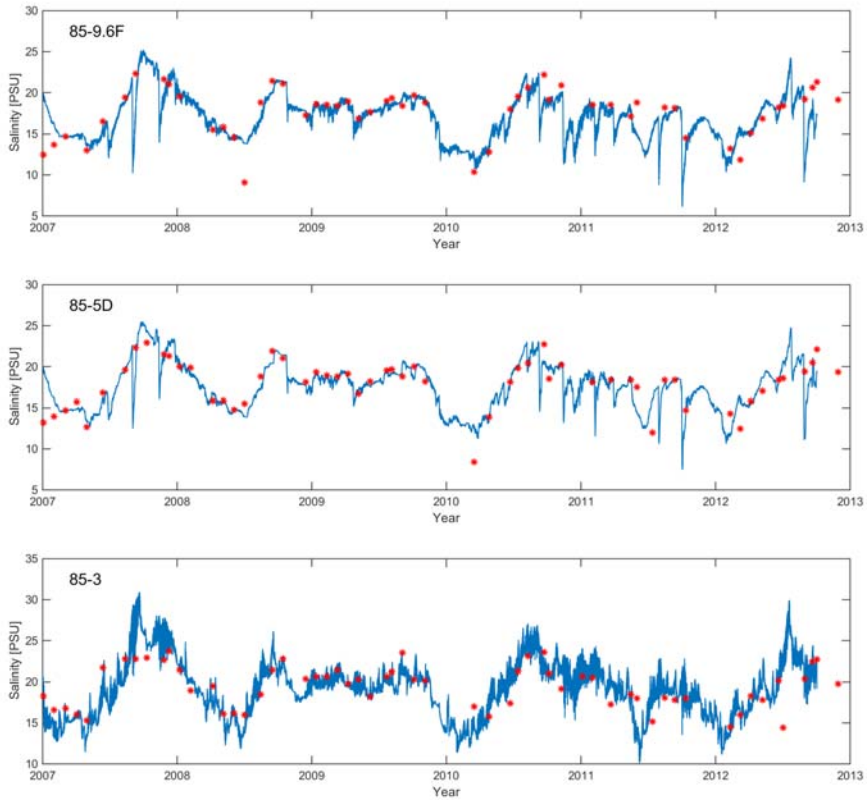
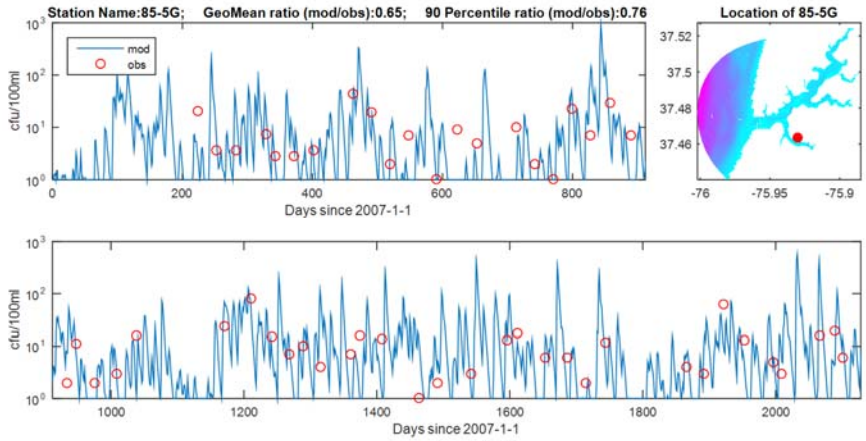


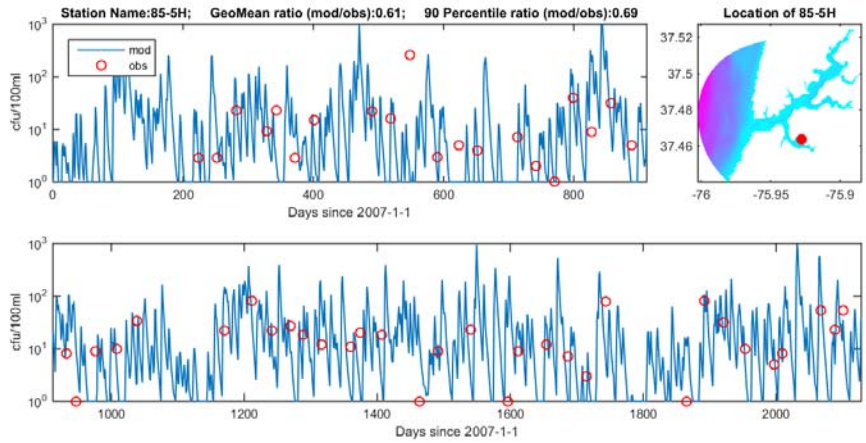
Figure A-5: Comparison of Modeled (Blue Line) and Observed (Red Dots) Salinity at the Upper, Middle, and Downstream Portions of the Creek

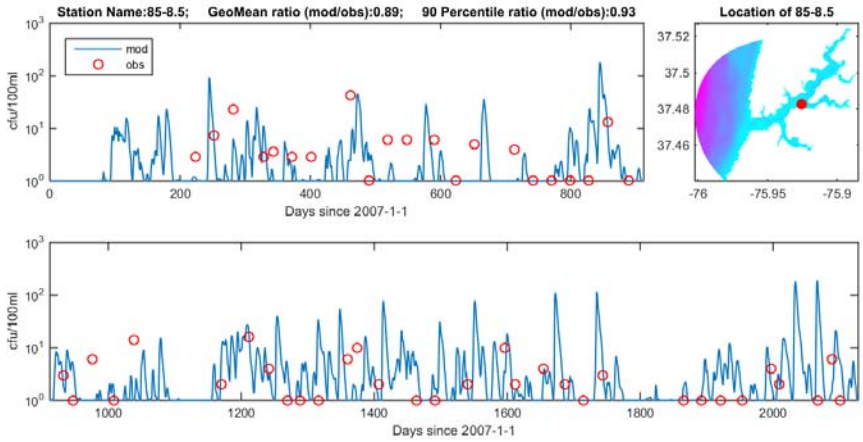
Calibration of the bacteria transport model is typically performed using water quality measurements from the watershed. Absent the necessary data from the Nassawadox Creek watershed, the calibration was performed on the observation data in the Nassawadox Creek receiving water using an iterative approach between the watershed and receiving water models. The watershed model parameters (accumulation and loss rates) for bacteria associated with surface runoff of each land use category were estimated on the basis of all available field survey data using USEPA-recommended loading production rates (USEPA, "FecalTool.xls" program, 1998). A 5-year model simulation (2007-2012), corresponding to the period of highest violation, was presented in Figure A-6 for comparison. A constant bacteria decay rate of 0.5/day is used, which was derived based upon observations, model calibration, and literature review (Shen and Zhao, 2010). The model calibration results for all the stations with violation (either geometric mean or 90th percentile) are presented in Figure A-6. It can be seen that model simulated observations well for both seasonal and interannual variations and peaks of fecal coliform.

The assessment of the model skill for simulating the seasonal variation and the seasonally averaged fecal coliform concentrations are compared to observations by

each embayment for the total estuary as shown in Figure A-7. A comparison of the accumulative distribution for the average concentration of fecal coliform in the Nassawadox is shown in Figure A-8. It can be seen that the model simulated well for the seasonal variation of bacteria and the distribution of the bacteria matches well to the observations, indicating the model has a good predictive skill. Note that the model simulates daily variation and that the observations are only collected once a month and bacterial concentrations are highly event-driven. Therefore, some discrepancies between model and observations can be expected. The model calibration focuses on fecal coliform variation (range) and seasonal variations.



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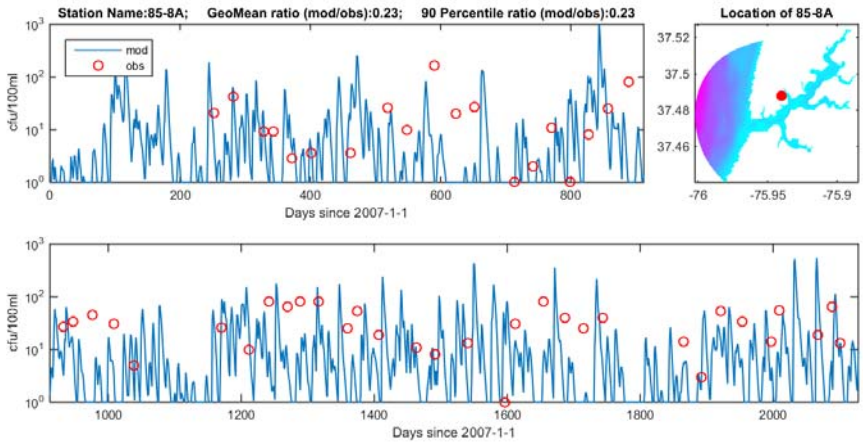
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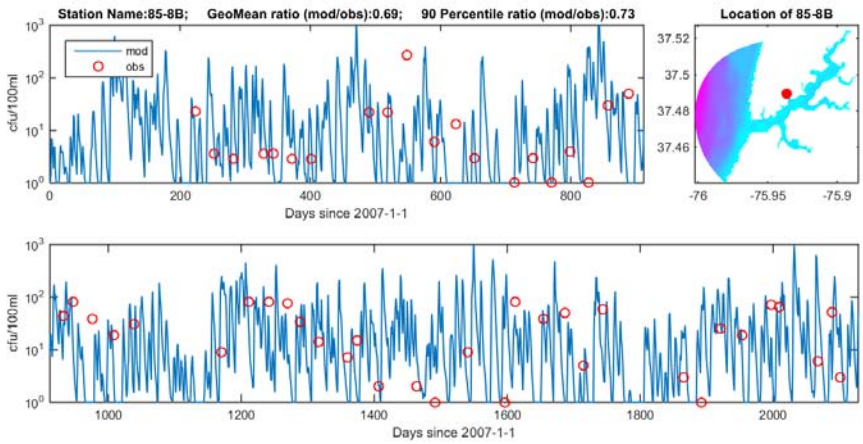
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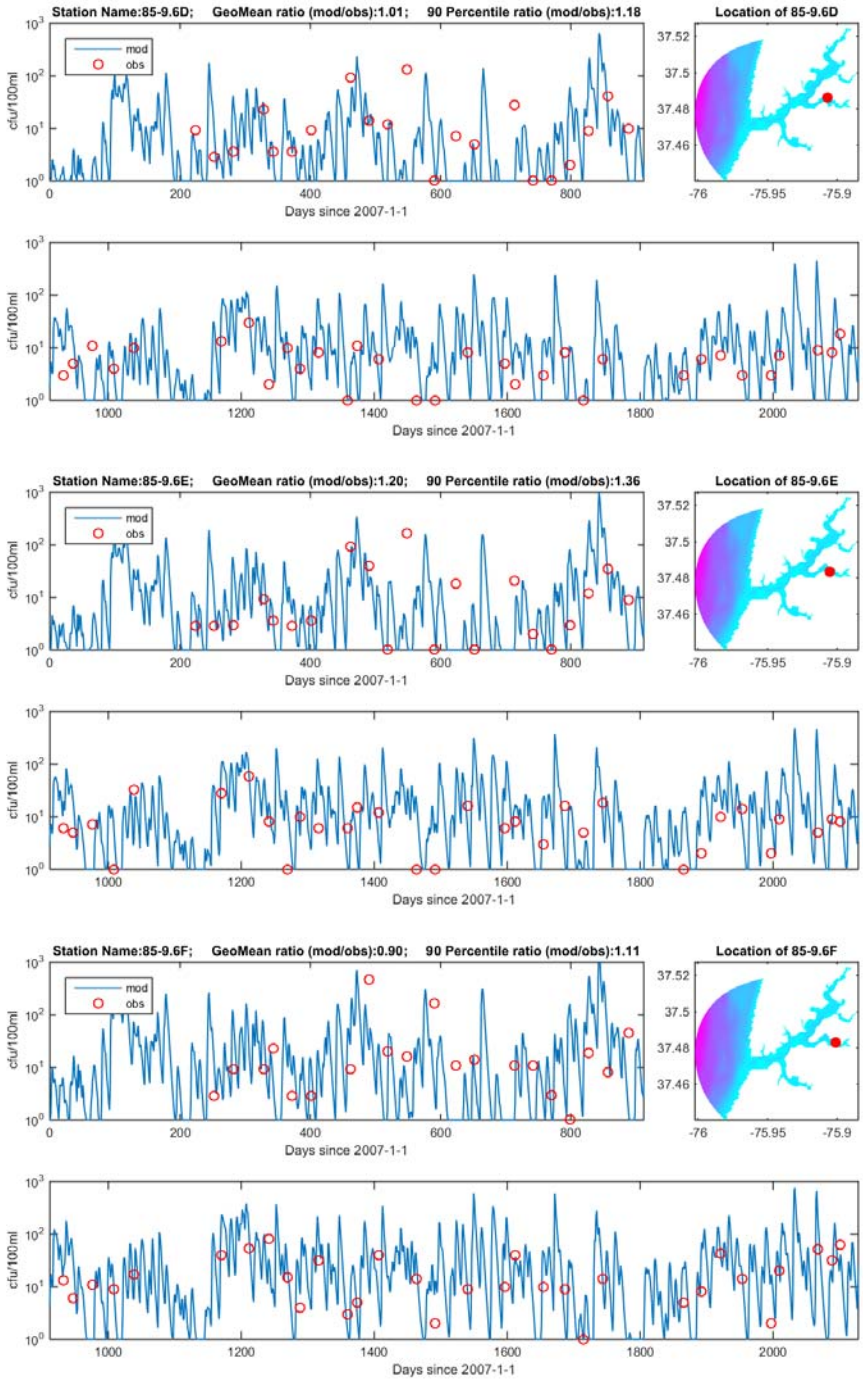
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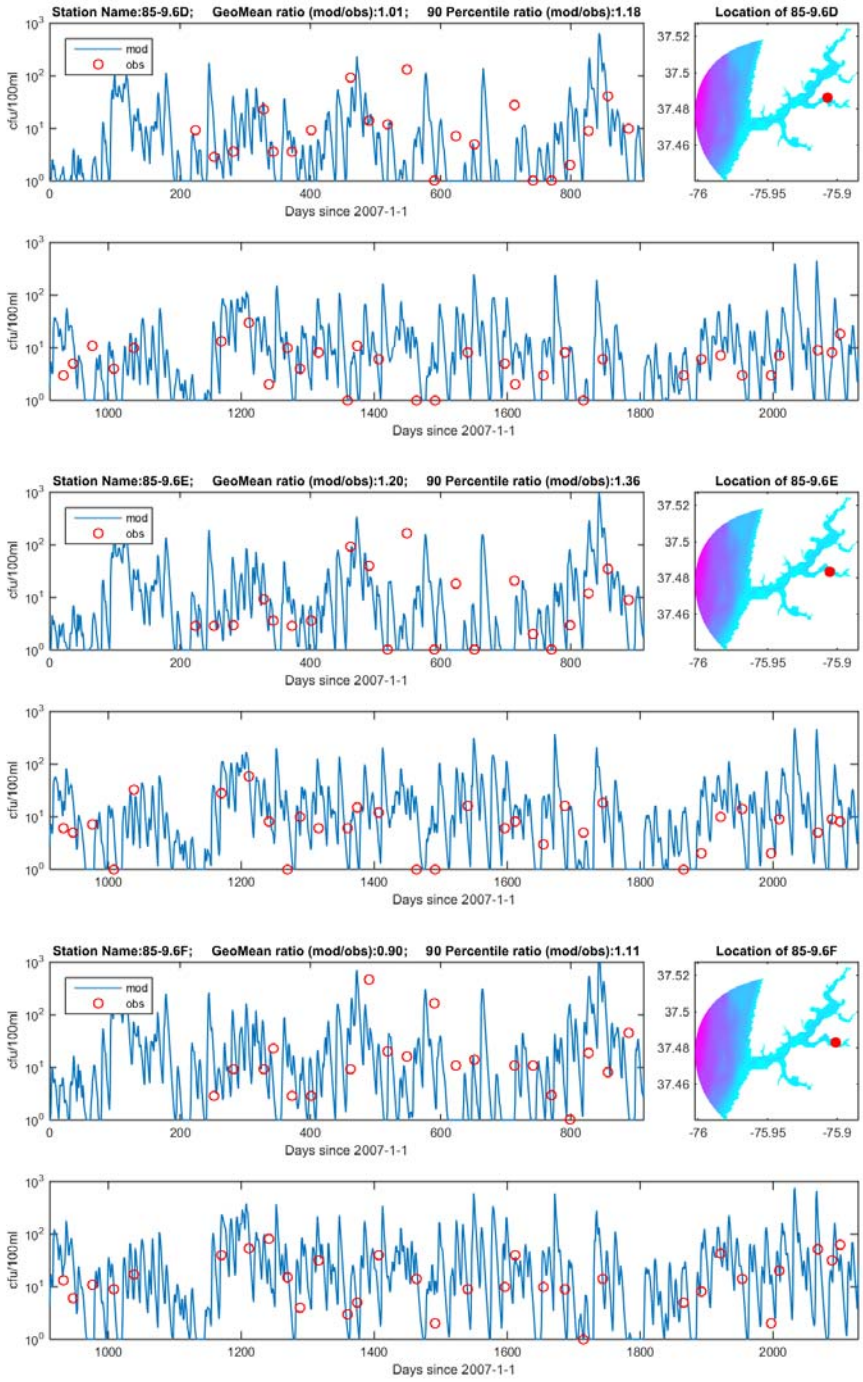
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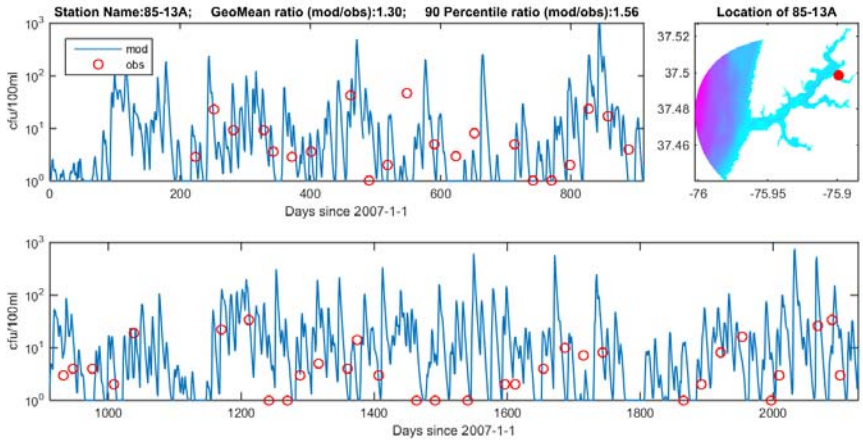
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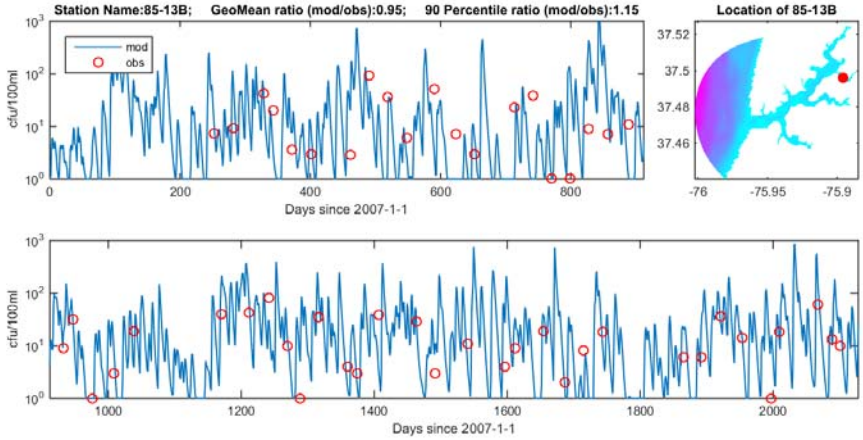
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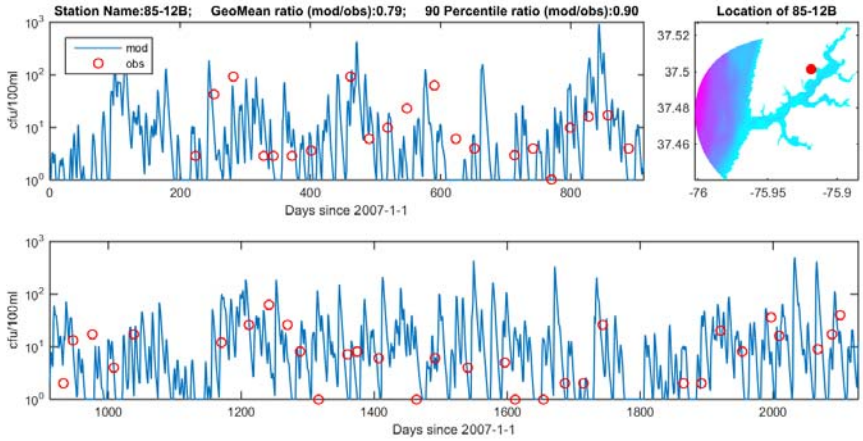
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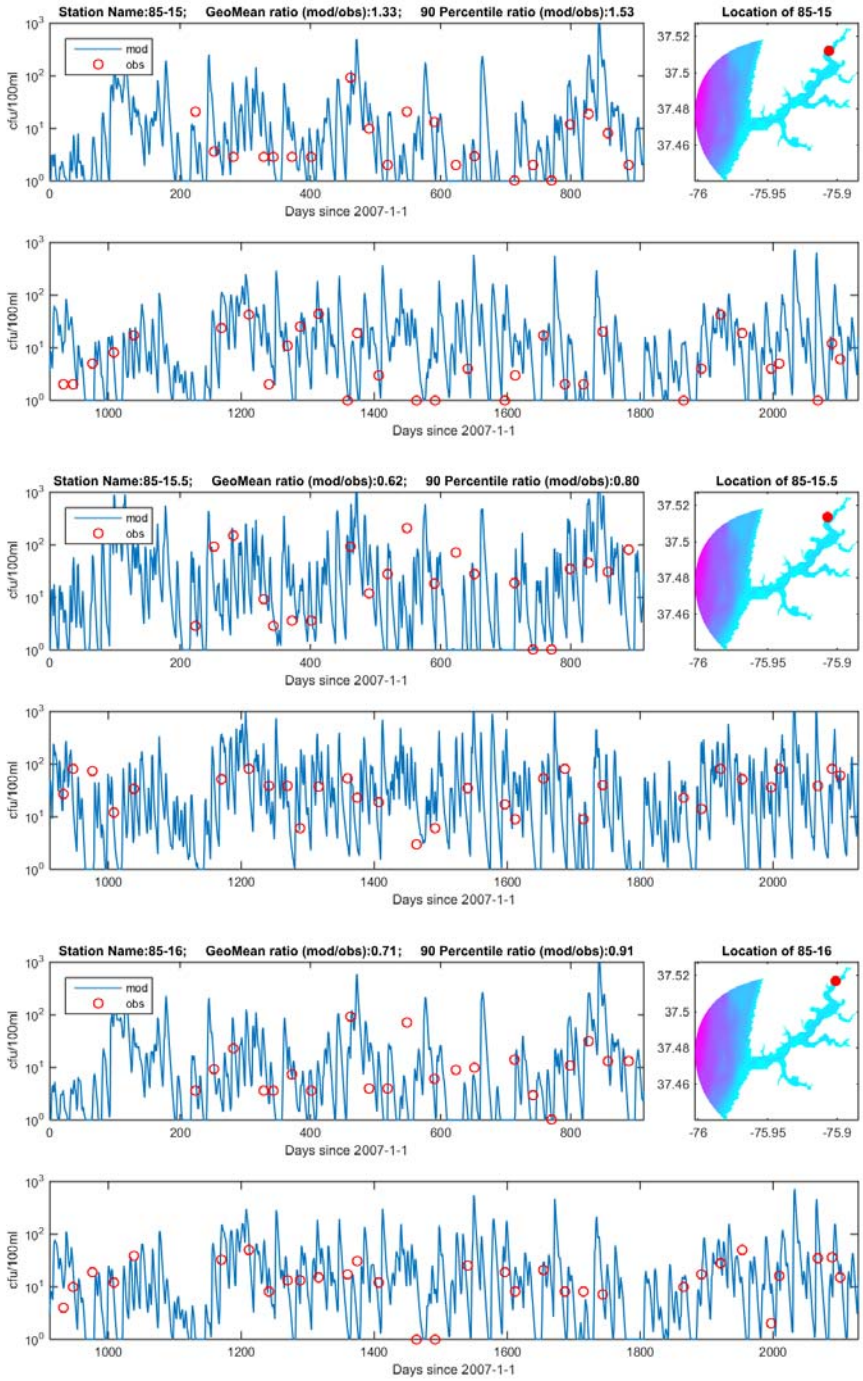
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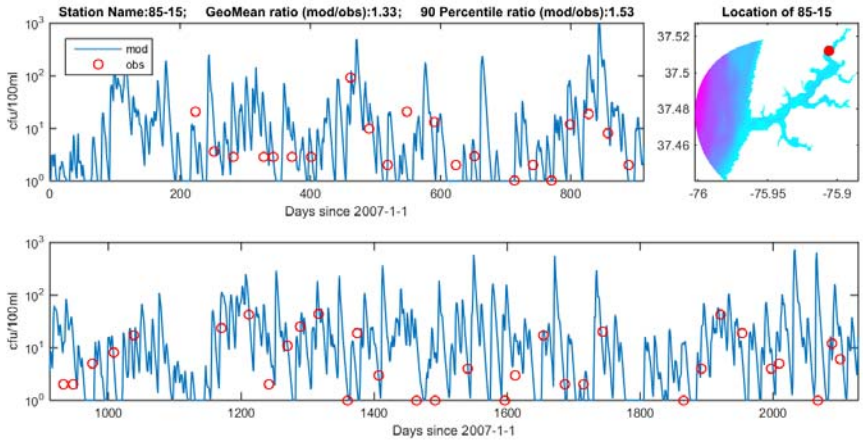
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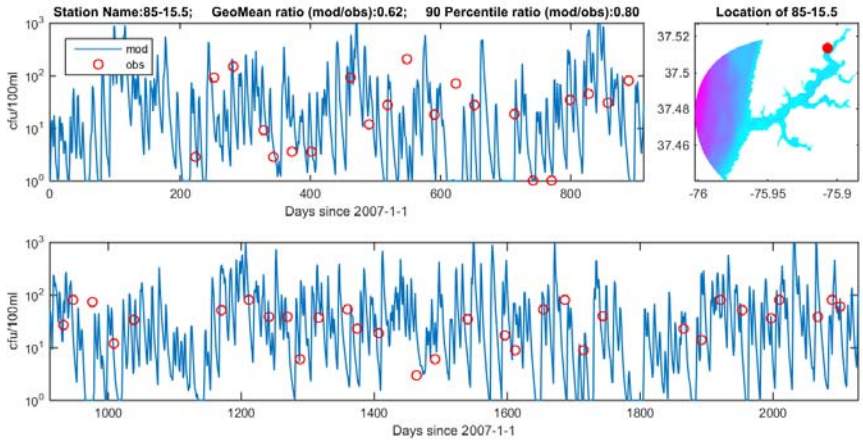
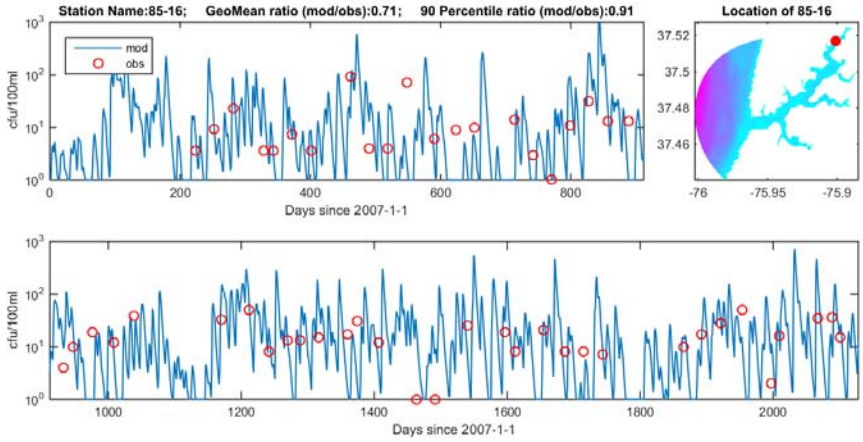
Days since 2007-1-1


Station Name:85-15.5; GeoMean ratio (mod/obs):0.62; 90 Percentile ratio (mod/obs):0.80
Location of 85-15.5
mod
obs
cfu/100ml
Days since 2007-1-1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Location of 85-16
mod
obs
cfu/100ml
Days since 2007-1-1

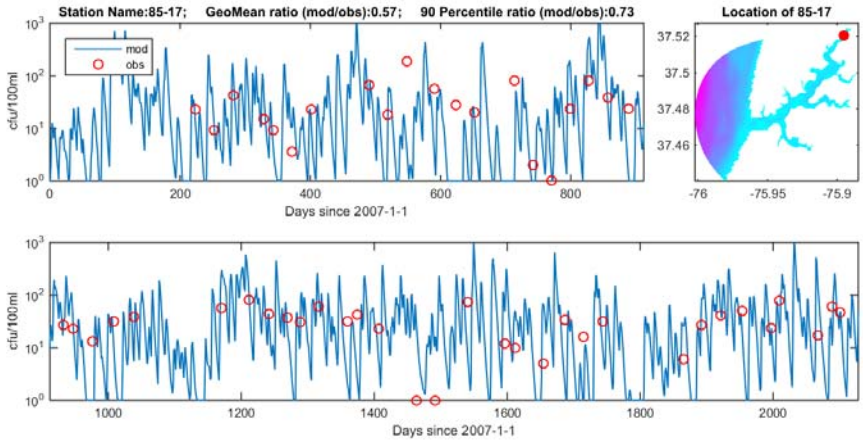
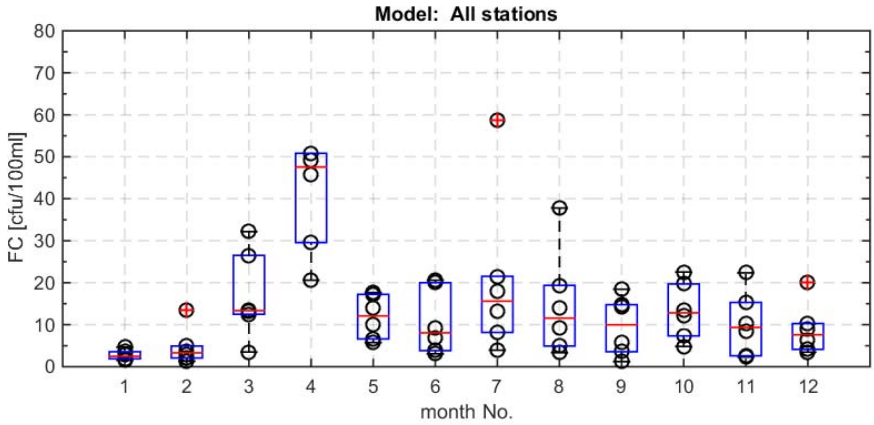
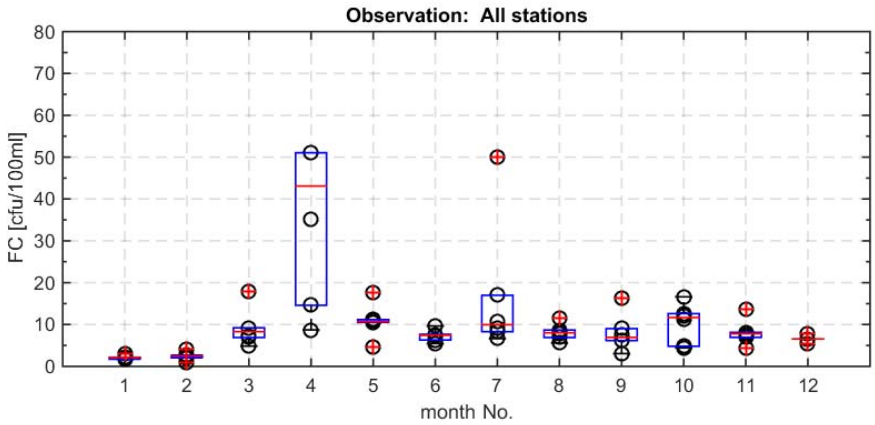
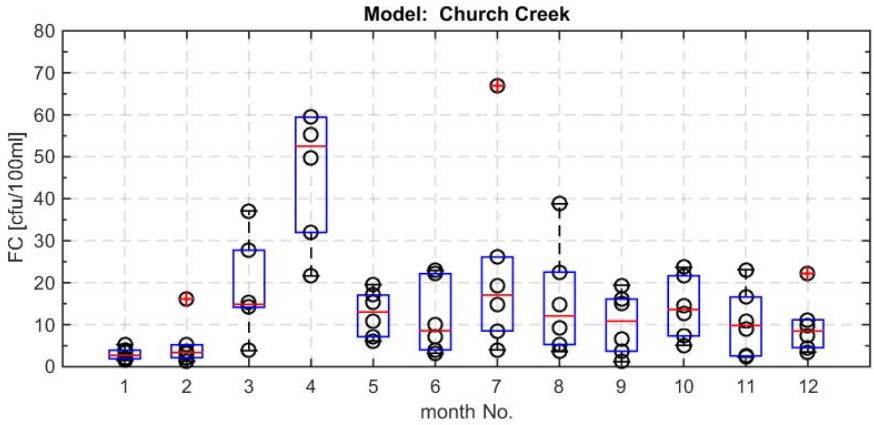
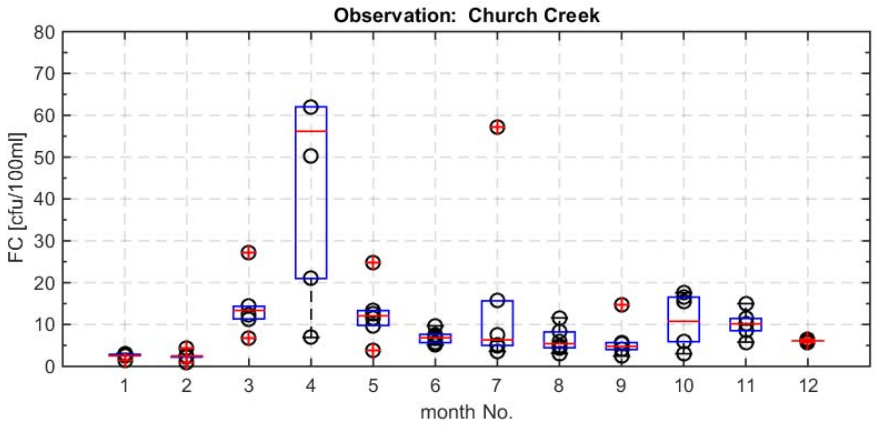


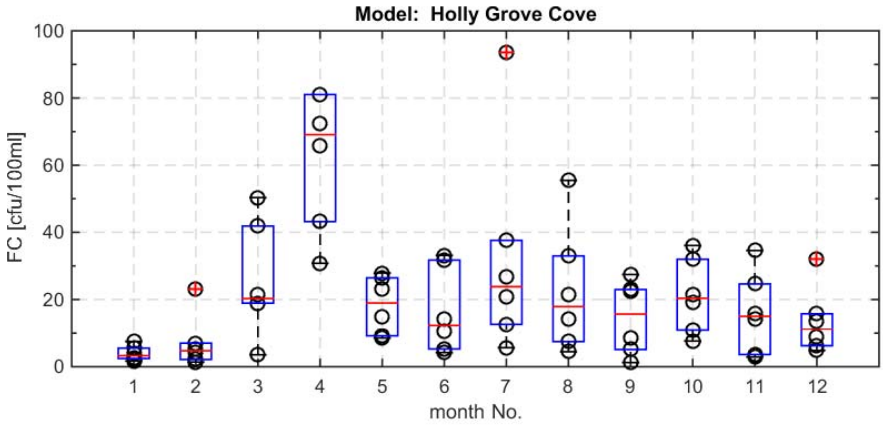
Figure A-6: Model Calibration of Fecal Coliform at All Violation Stations in the Estuary

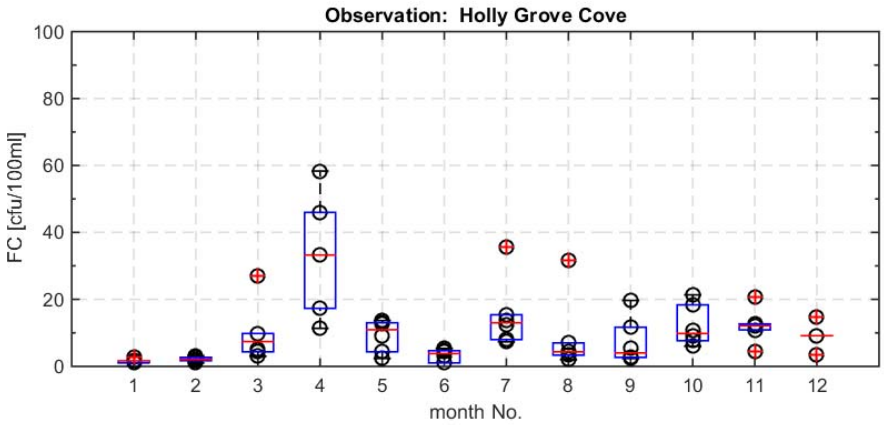

Model: All stations
FC [cfu/100ml]
month No.


Observation: All stations
FC [cfu/100ml]
month No.


Model: Church Creek
FC [cfu/100ml]
month No.


Observation: Church Creek
FC [cfu/100ml]
month No.


Model: Holly Grove Cove
FC [cfu/100ml]
month No.


Observation: Holly Grove Cove
FC [cfu/100ml]
month No.

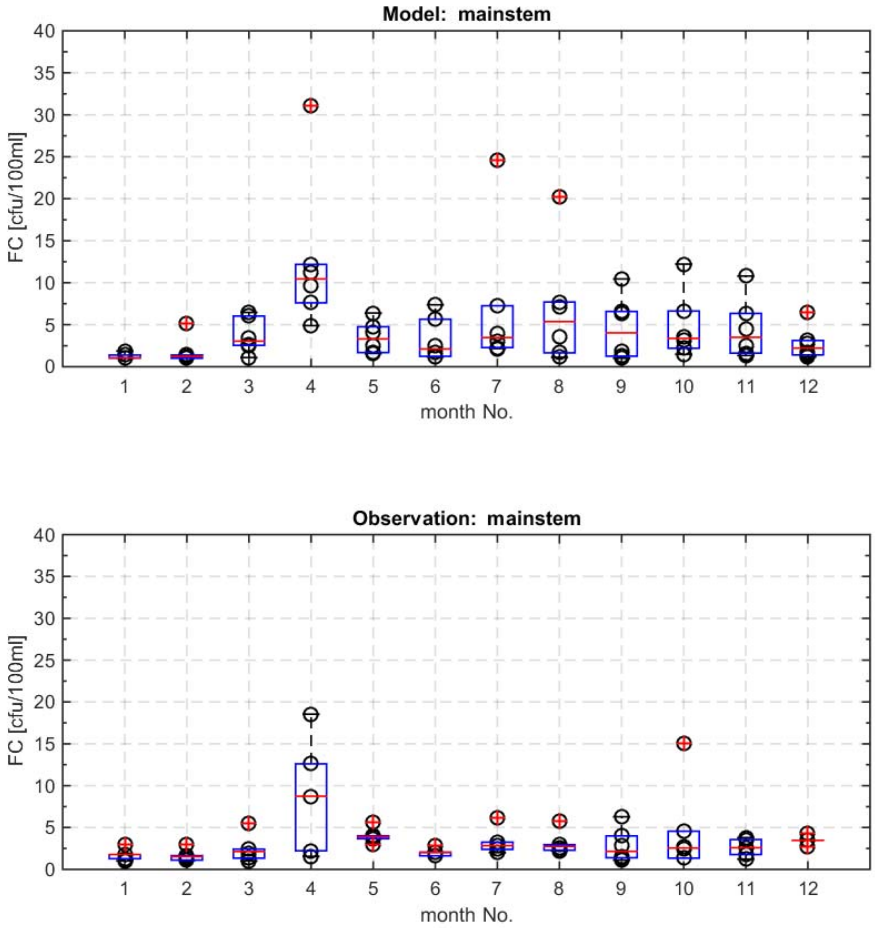


Figure A-7: Comparison of Seasonal Variation of Fecal Coliform in Different Creeks and in the Entire Estuary (box shows the first and third quartile of the observation data, red line is the median, circles are model results, circles with + show the maximum and minimum).

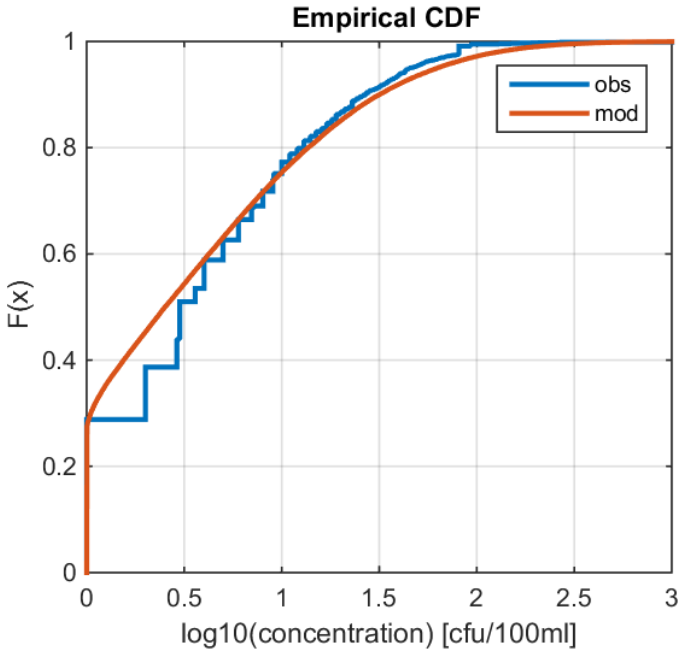
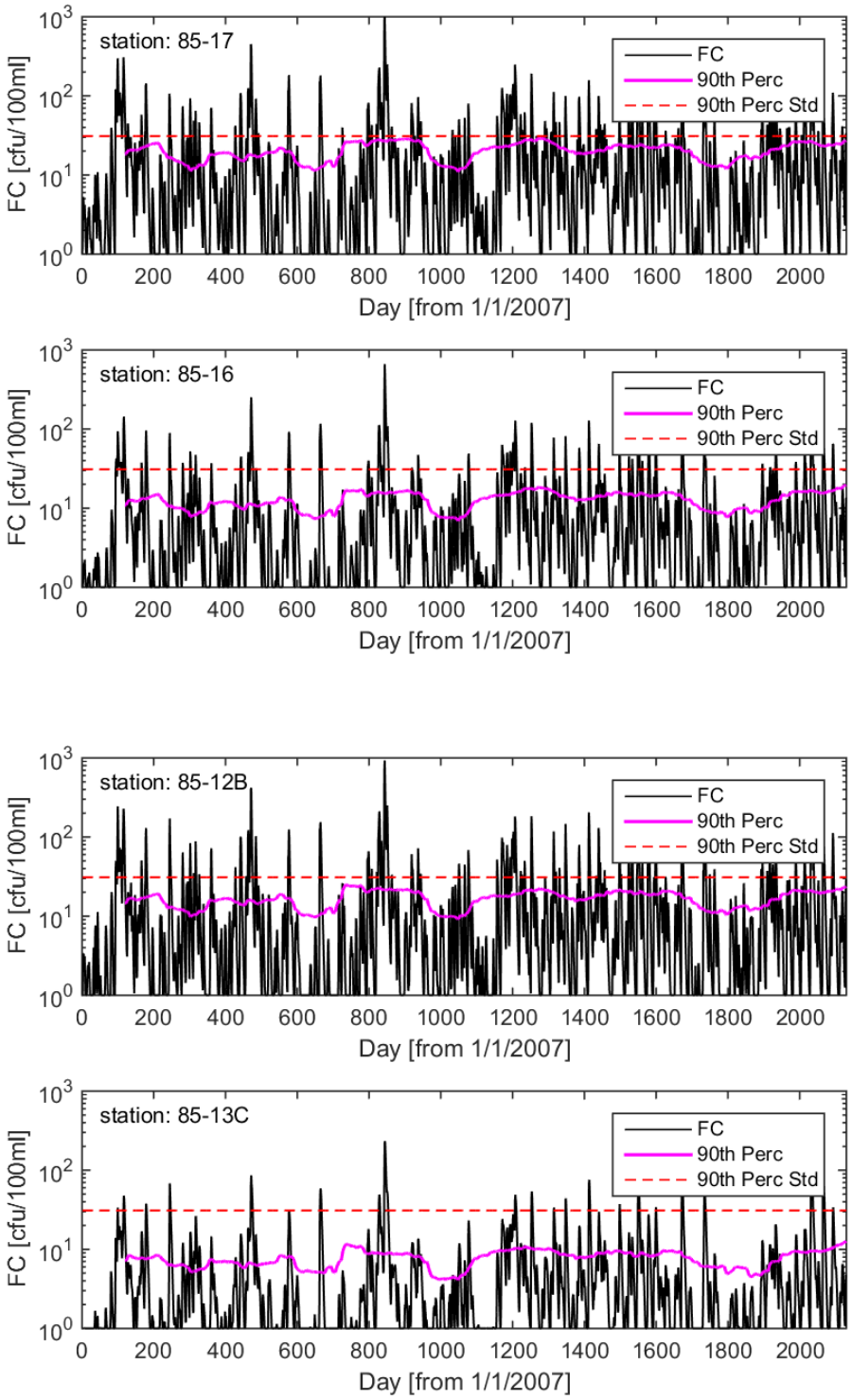


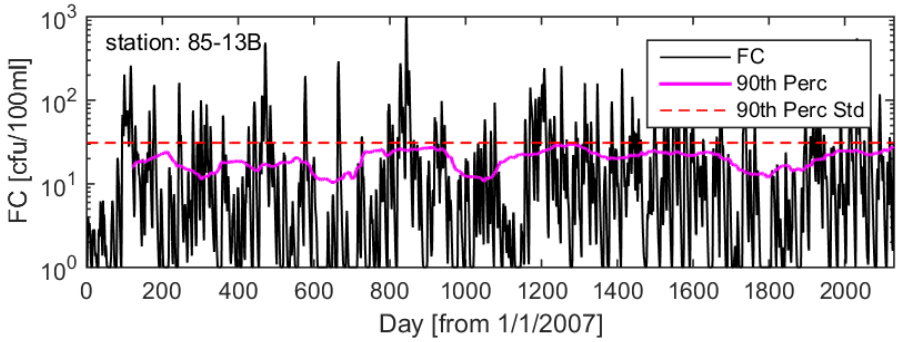
Figure A-8: Comparison of Cumulative Distribution of Averaged Fecal Coliform Concentration in Nassawadox Creek

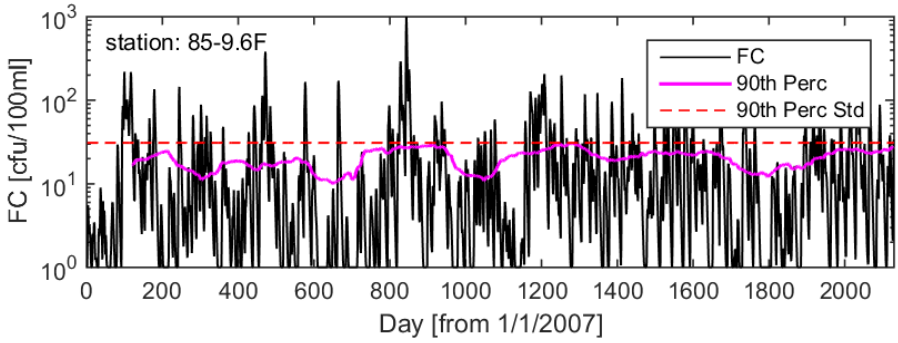
A.2 Allowable Load Calculation

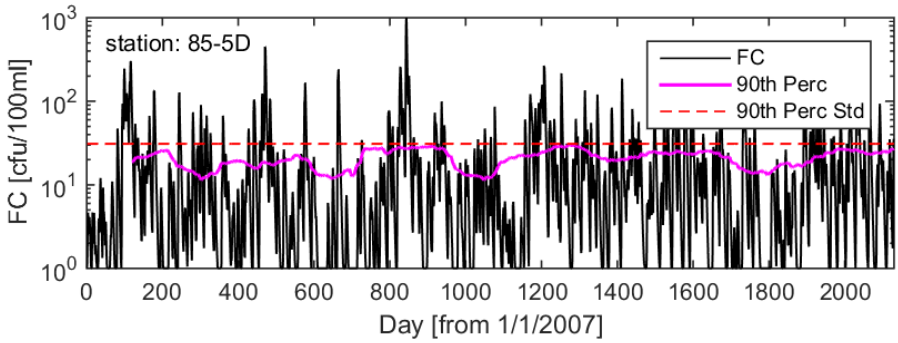
To determine allowable loads and development TMDLs, loading from each subwatershed was reduced so that the receiving water bacterial concentration will meet the water quality criteria endpoints. The model simulation period from 2007-2011 was used to determine the allowable load, which corresponded to the highest violation period for Nassawadox. It is noted that high bacterial concentration occurs in the upstream of the embayment and decreases downstream due to decay and dilution of the tide. The attainment of water quality is assessed at each station for the geometric mean and the 90th percentile of fecal coliform, and for the single sample maximum of 104 cfu/100mL of enterococci. The most stringent criterion is used for determining the reduction. It was found that the 90th percentile is the most stringent criterion in the Creek and, when compliance of the 90th percentile criterion is met, the WQS are met. Note that the amount of loading allowable to the upstream segment determines the total loading. Therefore, the 90th percentile concentration in the downstream of the estuary is generally lower than the upstream when computing the TMDL. The distribution of fecal coliform and the corresponding running 90th percentile in Nassawadox are shown in Figure A-9. The distributions of enterococci in the middle portion of Nassawadox Creek are shown in Figure A-10. The distributions

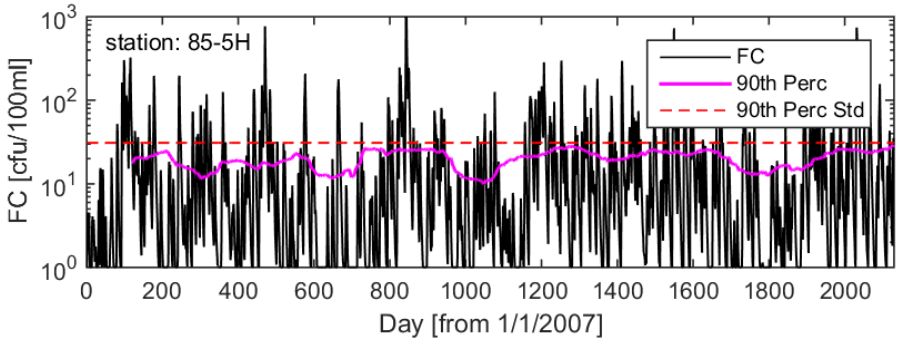
of fecal coliform and the corresponding running 90th percentile in Westerhouse Creek are shown in Figure A-11. It can be seen that the WQS are met after the reductions.

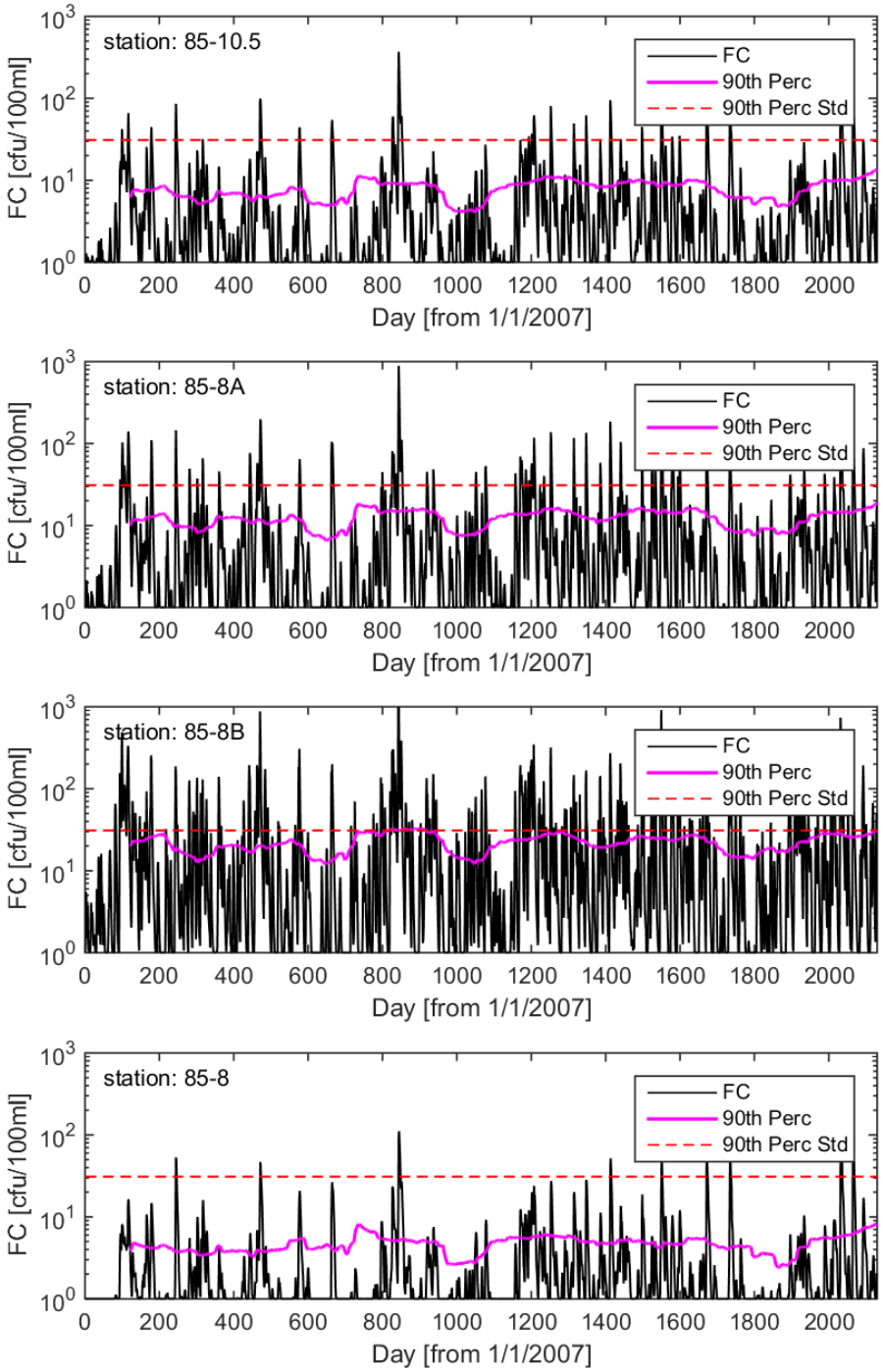



station: 85-13B
FC
90th Perc
90th Perc Std
FC [cfu/100ml]
Day [from 1/1/2007]


station: 85-9.6F
FC
90th Perc
90th Perc Std
FC [cfu/100ml]
Day [from 1/1/2007]


station: 85-5D
FC
90th Perc
90th Perc Std
FC [cfu/100ml]
Day [from 1/1/2007]


station: 85-5H
FC
90th Perc
90th Perc Std
FC [cfu/100ml]
Day [from 1/1/2007]


station: 85-10.5
station: 85-8A
station: 85-8B
station: 85-8
FC
90th Perc
90th Perc Std
FC [cfu/100ml]
Day [from 1/1/2007]
10^0
10^1
10^2
10^3
0
200
400
600
800
1000
1200
1400
1600
1800
2000

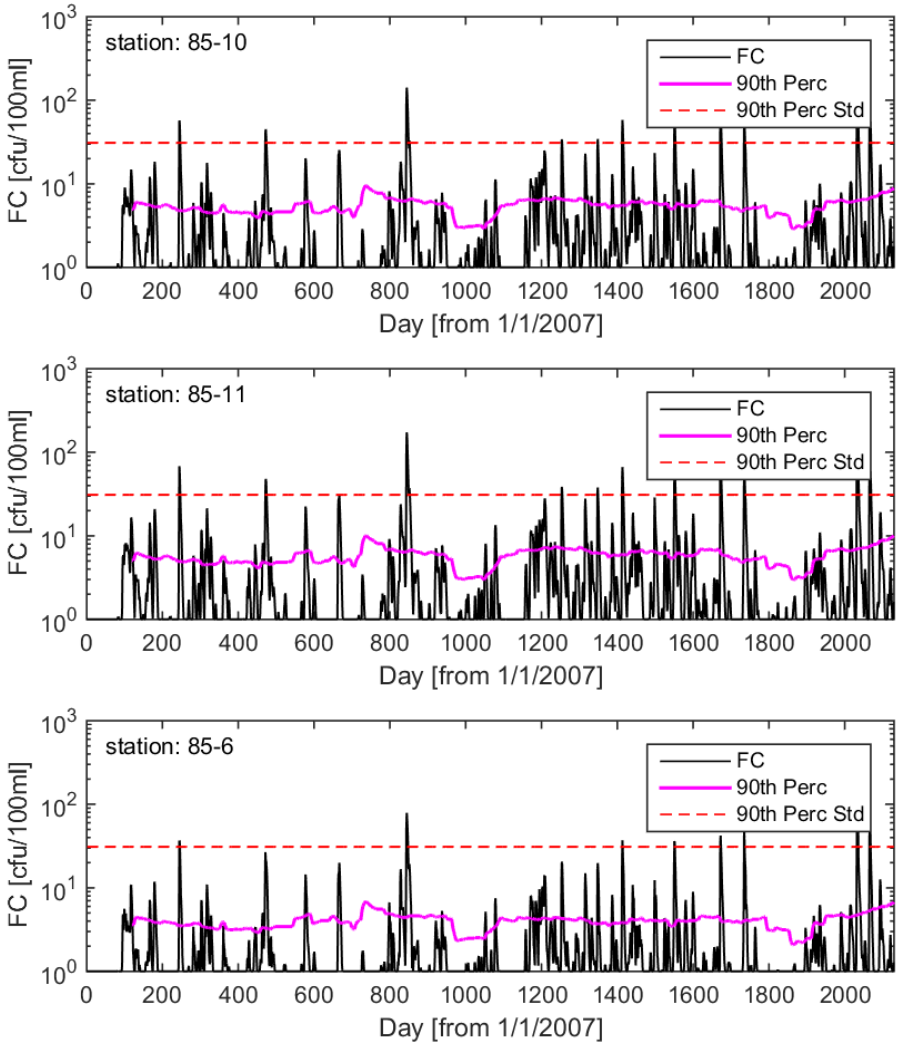
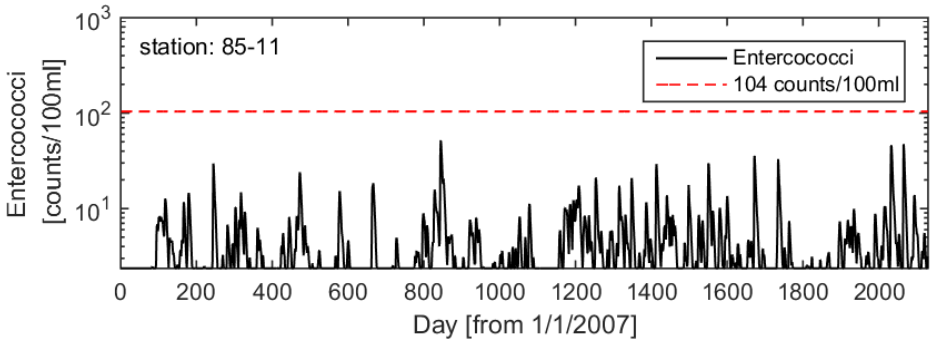


Figure A-9: Distribution of Fecal Coliform and Running 90th Percentile at the Violation Stations in the Nassawadox Creek



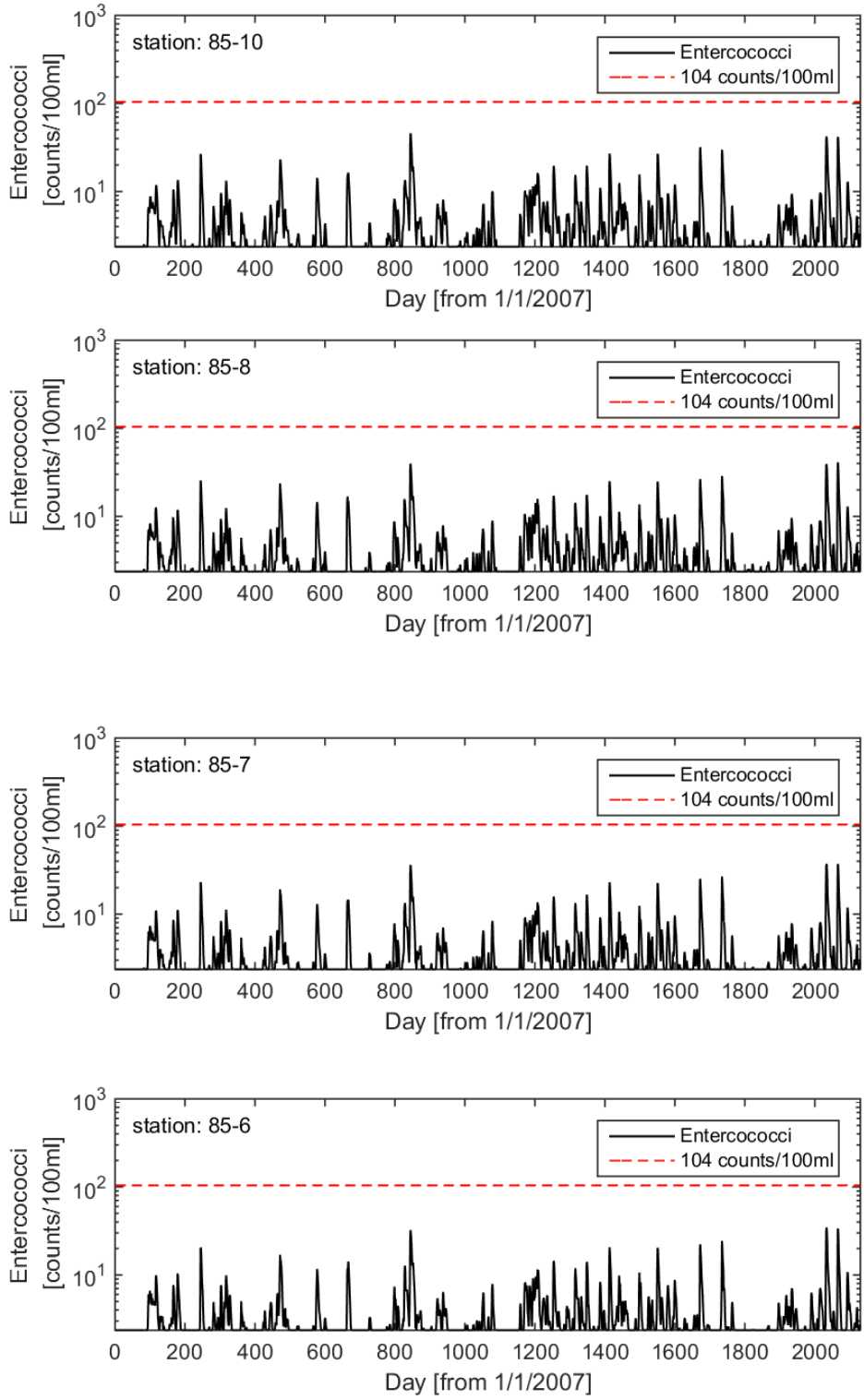


Figure A-10: Distribution of Enterococci in the Middle of Nassawadox Creek

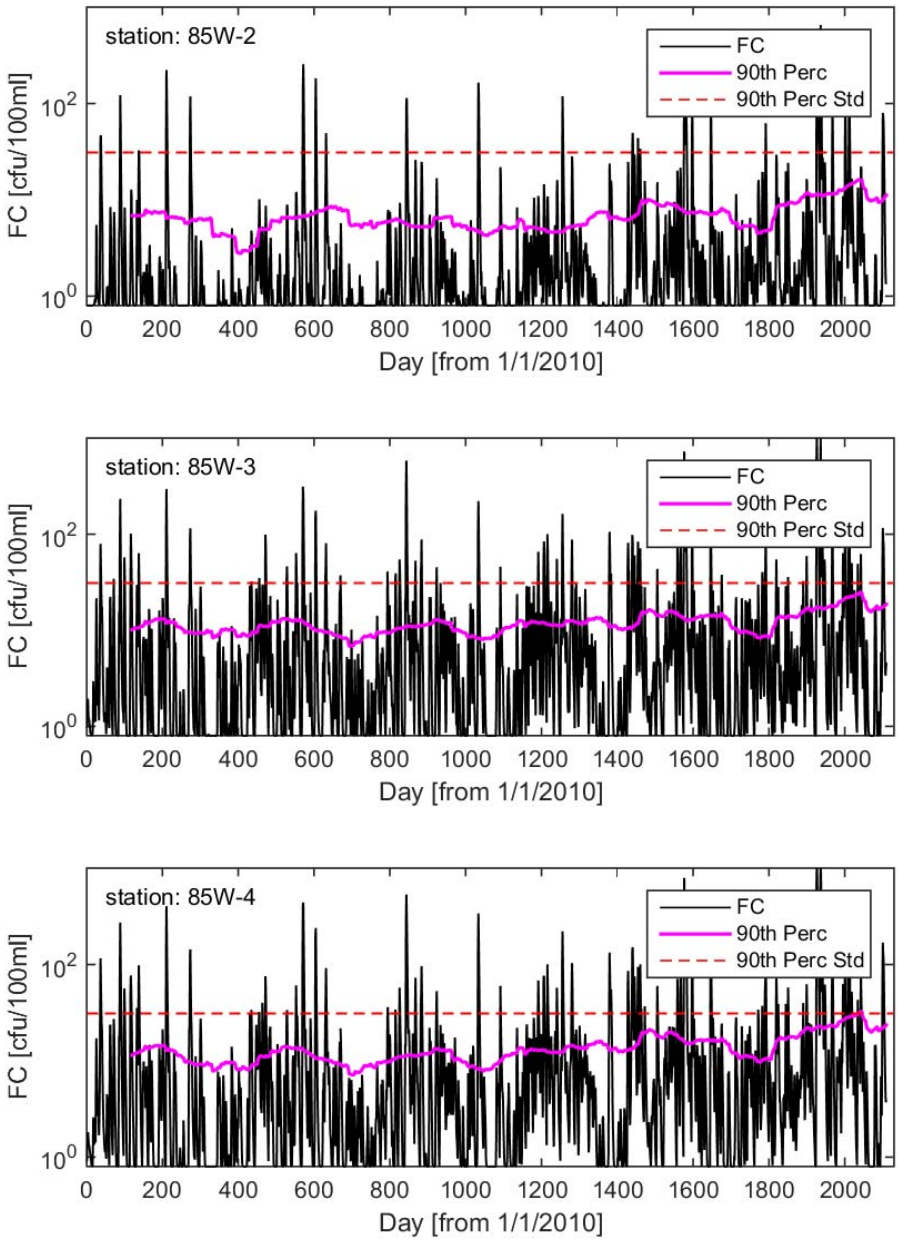


Figure A-11: Distributions of Fecal Coliform and Running 90th Percentile at Violation Stations in Westerhouse Creek

A.3 Total Maximum Daily Load

The TMDL seeks to eliminate 100% of the human-derived fecal component, regardless of the allowable load determined through the LA process. Human-derived forms of fecal coliform are a serious concern in the estuarine environment and both

state and federal law preclude the discharge of human waste. According to the preceding analysis, reduction of the controllable loads, human, livestock and pets, will not result in achievement of the WQS. Absent any other sources, the reduction is allocated to wildlife. The allocations presented demonstrate how the TMDLs could be implemented to achieve WQS; however, the state reserves the right to allocate differently, as long as consistency with the achievement of WQS is maintained.

All TMDLs have some probability of being exceeded, with the probability being either explicitly specified or implicitly assumed. EPA guidance states that the probability component of a calculated maximum daily load (MDL) should be "based on a representative statistical measure" that is dependent upon the specific TMDL and best professional judgment of the developers (USEPA, 2007). This statistical measure represents how often the MDL is expected, or allowed, to be exceeded. The primary options for selecting this level of protection would be:

1. **The maximum daily load reflects some central tendency:** In this option, the maximum daily load is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.
2. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the maximum daily load is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.
3. **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper-bound percentile is selected for the maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in a maximum daily load that would be exceeded 5% of the time.

Because time variable model simulations were conducted, daily loads vary significantly. Daily loading varies both seasonally and annually with respect to different hydrological years. Therefore, the MDL for this analysis is determined based on a pre-defined probability. The computed MDL is consistent with achieving the annual cumulative load target. A 90th percentile was selected as the pre-defined probability, which agrees with fecal coliform criteria. Because loading distribution is better described by a log-normal distribution in the Nassawadox Creek, the MDL is computed as follows (USEPA, 2007):

$$TMDL = LTA \cdot \exp(Z_p \sigma_y - 0.5\sigma_y^2)$$

Where Zp is pth percentage point of the standard normal distribution. For the 95th percentile, Zp = 1.28. LTA is long-term mean daily loading and σ_y is computed as:

$$\sigma_y = \sqrt{\ln(CV^2 + 1)}$$

where CV is coefficient of variation of the untransformed data, which equals to the standard deviation divided by the mean.

Using the method described above, *LTA* is the mean daily loading from 2007-2011 for each listed area. The daily mean loading for Nassawadox Creek and Westerhouse Creek, and for each listed segment, is listed in Table A-1. The allowable annual loads for Nassawadox Creek and Westerhouse Creek are listed in Table A-2.

Table A-1: Estimated Daily Loads and Load Reductions for Fecal Coliform

	Pollutant	**Criterion (CFU/100mL)**	**Current Load (counts/day)**	**Allowable Load (counts/day)**	**Required Reduction (%)**
Nassawadox Creek-Upper	Fecal coliform	90th percentile	5.10E+11	2.14E+11	58.0%
Kelly Cove	Fecal coliform	90th percentile	1.83E+11	7.68E+10	58.0%
Holly Grove Cove	Fecal coliform	90th percentile	4.13E+11	2.68E+11	35.0%
Nassawadox Creek-Middle	Fecal coliform	90th percentile	2.90E+11	2.35E+11	19.1%
Church Creek-Upper	Fecal coliform	90th percentile	3.08E+11	2.34E+11	24.0%
Church Creek-Middle	Fecal coliform	90th percentile	1.01E+11	1.01E+11	0.0%
Nassawadox Creek (all)	Fecal coliform	90th percentile	2.68E+12	1.72E+12	36.0%
Westerhouse Creek	Fecal coliform	90th percentile	1.12E+11	5.95E+10	46.9%

Table A-2: Estimated Annual Loads and Load Reductions for Fecal Coliform (Each Listed Segment)

	Pollutant	Criterion	Current Load	Allowable Load	Required
		(CFU/100mL)	(counts/Year)	(counts/Year)	Reduction (%)
Nassawadox Creek-Upper	Fecal coliform	90th percentile	8.78E+13	3.69E+13	58.0%
Kelly Cove	Fecal coliform	90th percentile	3.29E+13	1.38E+13	58.0%
Holly Grove Cove	Fecal coliform	90th percentile	7.31E+13	4.75E+13	35.0%
Nassawadox Creek-Middle	Fecal coliform	90th percentile	5.65E+13	4.57E+13	19.1%
Church Creek-Upper	Fecal coliform	90th percentile	5.38E+13	4.09E+13	24.0%
Church Creek-Middle	Fecal coliform	90th percentile	1.85E+13	1.85E+13	0.0%
Nassawadox Creek (all)	Fecal coliform	90th percentile	4.70E+14	3.01E+14	36.0%
Westerhouse Creek	Fecal coliform	90th percentile	2.16E+13	1.15E+13	46.9%

A.4 Load Allocation

The loadings for each bacterial source were determined based on source assessment. Load allocations were determined by multiplying the total current and allowable loads by the representative percentage. The percent reduction needed to attain the water quality criterion was allocated to each source category. The results are presented in Table A-3. Note that the loads presented in the tables are the runoff of bacteria discharging to the stream, which are less than 8% of the bacteria deposited on the watershed due to bacterial die-off.

Table A-3: Load Allocation and Required Reduction for Bacteria Based on 90th Percentile

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek-Upper (VAT-C13E_HGC01A06)	Human	1.89E+10	**0**	100.0%
	Pets	8.81E+10	0	100.0%
	Wildlife	4.03E+11	2.141E+11	46.8%
	Livestock	0.00E+00	0.000E+00	0.0%
	Total	5.10E+11	2.14E+11	58.0%

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Kelly Cove (VAT-C13E_KLL01A06)	Human	1.57E+09	**0**	100.0%
	Pets	7.31E+09	0	100.0%
	Wildlife	1.73E+11	7.677E+10	55.7%
	Livestock	4.84E+08	0.000E+00	100.0%
	Total	1.83E+11	7.68E+10	58.0%

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek-Middle (VAT_C13E_NSS03A08)	Human	1.16E+09	**0.00E+00**	100.0%
	Pets	5.42E+09	0.00E+00	100.0%
	Wildlife	4.87E+10	4.87E+10	0.0%
	Livestock	2.35E+11	1.86E+11	20.8%
	Total	2.90E+11	2.35E+11	19.1%

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Church Creek-Upper (VAT-C13_CHC01A00)	Human	8.82E+09	0	100.0%
	Pets	3.88E+10	0	100.0%
	Wildlife	2.43E+11	2.343E+11	3.7%

	Livestock	1.26E+08	0	100.0%
	Total	3.08E+11	2.34E+11	24.0%

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Church Creek-Middle(VAT_C13E_CHC01C10)	Human	7.41E+08	7.41E+08	0.0%
	Pets	3.45E+09	3.45E+09	0.0%
	Wildlife	5.38E+10	5.376E+10	0.0%
	Livestock	4.34E+10	4.34E+10	0.0%
	Total	1.01E+11	1.01E+11	0.0%

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Holly Grove Cove (VAT-C13E_HGC01A06)	Human	1.08E+10	0	100.0%
	Pets	5.05E+10	0	100.0%
	Wildlife	3.51E+11	2.684E+11	23.6%
	Livestock	2.41E+08	0	100.0%
	Total	4.13E+11	2.68E+11	35.0%

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek-Middle (VAT-NSS02A06)	Human	1.04E+10	0	100.0%
	Pets	4.86E+10	3.50E+09	92.8%
	Wildlife	2.31E+11	2.309E+11	0.0%
	Livestock	5.59E+08	5.59E+08	0.0%
	Total	2.90E+11	2.35E+11	19.1%

A.5 Load Allocation

To facilitate the phased IP approach to meet the recreation use while planning to meet the shellfish use as well, a scenario was conducted to determine the load of runoff reduction needed to meet the WQS for the recreation-designated use. The existing load and allowable load to meet the recreation-designated use WQS are listed in Table A-4. The load allocation for each bacteria source is listed in Table A-5. The required reduction is 28.5%.

Table A-4: Existing and Allowable Load to Meet Enterococci WQS

	Pollutant	Criterion (CFU/100ml)	Current Load (counts/day)	Allowable Load (counts/day)	Required Reduction (%)
Nassawadox Creek	Fecal coliform	Geomean/Instantaneous	1.29E+12	9.20E+11	28.52%

Table A-5: Load Allocation for Each Source to meet Enterococci WQS

	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek	Human	2.85E+10	0	100.0%
	Pets	1.33E+11	0	100.0%
	Wildlife	7.88E+11	7.881E+11	0.0%
	Livestock	3.38E+11	1.32E+11	60.9%
	Total	1.29E+12	9.20E+11	28.5%

Appendix B: Calculation of Population Numbers

The process used to generate population numbers used for the nonpoint source contribution analysis for the four source categories (human, livestock, pets, and wildlife) is described for each below.

B.1 Human

The number of people contributing fecal coliform from failing septic tanks were estimated in two ways and then compared to determine a final value.

1) Deficiencies (septic failures) from the DSS shoreline surveys were counted for each watershed and multiplied by 3 (average number of people per household).
2) Numbers of households in each watershed were determined using 911 addresses. The address was obtained for each household and geo-reference for each household was obtained and a Geographic Information System (GIS) layer was created for accounting for the number.

*The septic failure rate was estimated by dividing the number of deficiencies in the watershed by the total households in the watershed. The average septic failure rate was 5% and this was used based on the previous study, public feedback and the Hungars-Mattawoman IP study.

B.2 Livestock

USCB data can be used to calculate the livestock values. The numbers for each type of livestock (cattle, swine, sheep, chickens (big and small), and horses) were reported by county. Each type of livestock was assigned to the landuse(s) it lives on, or contributes to by the application of manure, as follows:

Cattle	Cropland and Pastureland
Swine	Cropland
Sheep	Pastureland
Chickens	Cropland
Horses	Pastureland

The GIS methodology was used to overlay data layers for several steps:

1) The county boundaries and the landuses to get the area of each landuse in each county. The number of animals was divided by the area of each landuse for the county to get an animal density for each county.
2) The subwatershed boundaries and the landuses to get the area of each landuse in each subwatershed.
3) The county boundaries and the subwatershed boundaries to get the area of each county in each subwatershed.

Using the MS ACCESS database, for each type of livestock, the animal density by county was multiplied by the area of each landuse by county in each subwatershed to get the number of animals in each subwatershed. The number of animals in each

subwatershed was summed to get the total number of animals in each watershed.

For this study, a series of public meetings were held and feedback from these public meetings was used to estimate the livestock number. Combining inputs from stakeholders and DSS shoreline survey data, the total number was determined for this study.

B.3 Pets

The dog population was calculated using a formula for estimating the number of pets using national percentages, reported by the American Veterinary Association and previous study:
dogs = # of households ×36.5%× 1.6.
cats = # of households ×30.4%× 2.1.

B.4 Wildlife

For this study the density for wildlife specifically derived from public meeting feedback and results from the Hungars-Mattawoman IP study were used, which are listed in the Table B-1.

Table B-1: Densities Used for Estimating Wildlife in the Nassawadox Creek

Wildlife Type	Population Density	Habitat Requirements
Deer	0.1032 animals/acre	Entire watershed
Raccoons	0.0703 animals/acre	Entire watershed
Muskrats	0.3128 animals/acre	300 feet buffer for primary habitat/600 feet buffer for secondary habitat
Geese	0.032 animals/acre	300 feet buffer for primary habitat /600 feet buffer for secondary habit
Ducks	0.0652 animals/acre	300 feet buffer for primary habitat/600 feet buffer for secondary habitat

B.5 Summary of estimation

The estimation of population, septic system, pets, livestock, and wildlife are summarized in the following tables.

		Source	Counts
Nassawadox Creek-Upper (VAT-C13E_HGC01A06)	**Human**	**Population**	1415
		Septic system	610
		Dogs*	356

		Cats* (unused)	389
	Livestock	**Horses**	0
		Cattle	0
		Fowl	0
		Geese	0
	Wildlife	**Deer**	403
		Raccoons	275
		Muskrats	669
		Geese	68
		Ducks	140
		Geese (peak season)	123
		Ducks (peak season)	251
Kelly Cove (VAT-C13E_KLL01A06)	**Human**	**Population**	72
		Septic system	31
		Dogs*	18
		Cats* (unused)	20
	Livestock	**Horses**	7
		Cattle	0
		Fowl	0
		Geese	0
	Wildlife	**Deer**	91
		Raccoons	62
		Muskrats	178
		Geese	18
		Ducks	37
		Geese (peak season)	33
		Ducks (peak season)	67

Nassawadox Creek-Middle (VAT_C13E_NSS03A08)	**Human**	**Population**	253
		Septic system	109
		Dogs*	64
		Cats* (unused)	70
	Livestock	**Horses**	0
		Cattle	65
		Fowl	100

		Geese	0
	Wildlife	**Deer**	148
		Raccoons	101
		Muskrats	234
		Geese	24
		Ducks	49
		Geese (peak season)	43
		Ducks (peak season)	88

Church Creek-Upper(VAT-C13_CHC01A00)	**Human**	**Population**	626
		Septic system	270
		Dogs*	158
		Cats* (unused)	172
	Livestock	**Horses**	3
		Cattle	0
		Fowl	0
		Geese	0
	Wildlife	**Deer**	325
		Raccoons	222
		Muskrats	399
		Geese	41
		Ducks	83
		Geese (peak season)	73
		Ducks (peak season)	150

Church Creek-Middle(VAT_C13E_CHC01C10)	**Human**	**Population**	77
		Septic system	33
		Dogs*	19
		Cats* (unused)	21
	Livestock	**Horses**	10
		Cattle	0
		Fowl	13
		Geese	12
	Wildlife	**Deer**	94
		Raccoons	64
		Muskrats	121
		Geese	12
		Ducks	25
		Geese (peak season)	22

		Ducks (peak season)	46

Holly Grove Cove (VAT-C13E_HGC01A06)	**Human**	**Population**	712
		Septic system	307
		Dogs*	179
		Cats* (unused)	196
	Livestock	**Horses**	5
		Cattle	0
		Fowl	0
		Geese	0
	Wildlife	**Deer**	320
		Raccoons	218
		Muskrats	511
		Geese	52
		Ducks	107
		Geese (peak season)	94
		Ducks (peak season)	192

Nassawadox Creek-Middle (VAT-NSS02A06)	**Human**	**Population**	1448
		Septic system	624
		Dogs*	364
		Cats* (unused)	398
	Livestock	**Horses**	21
		Cattle	0
		Fowl	16
		Geese	0
	Wildlife	**Deer**	407
		Raccoons	278
		Muskrats	514
		Geese	53
		Ducks	107
		Geese (peak season)	95
		Ducks (peak season)	193