Total Maximum Daily Loads of Bacteria for Poquoson River and Back Creek in the City of Poquoson and in York County, Virginia

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

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List of Abbreviations

BMP	Best Management Practice
CFR	Code of Federal Regulations
CWA	Clean Water Act
DGIF	Department of Game and Inland Fisheries
DSS	Virginia Division of Shellfish Sanitation
EFDC	Environmental Fluid Dynamics Computer Code
EPA	Environmental Protection Agency
FA	Future Allocation
GIS	Geographic Information System
HRSD	Hampton Roads Sanitation District
IP	Implementation Plan
LA	Load Allocation
LSPC	Loading Simulation Program C++
MDL	Maximum Daily Load
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
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VA-DCR	Virginia Department of Conservation and Recreation
VA-DEQ	Virginia Department of Environmental Quality
VA-DGIF	Virginia Department of Game and Inland Fisheries
VDH	Virginia Department of Health
VDOT	Virginia Department of Transportation
VPDES	Virginia Pollutant Discharge Elimination System
WLA	Wasteload Allocation
WQAIR	Water Quality Assessment Integrated Report
WQC	Water Quality Criteria
WQLS	Water Quality Limited Segments
WQMIRA	Water Quality Monitoring, Information, and Restoration Act
WQMP	Water Quality Management Plans
WQS	Water Quality Standard
WWTP	Wastewater Treatment Plant

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 (WQSs). TMDLs represent the total pollutant loading that a waterbody can receive without violating WQSs. 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.

A TMDL of the Poquoson River was completed in 2006 using a volumetric method for eleven shellfish harvesting impaired sites and one recreational impaired site (VA-DEQ, 2006). Since 2006, new listings have been added to the TMDL list. In addition, three MS4 permits held within the Poquoson River watershed require allowable waste loads to be determined during the TMDL process. However, the previous TMDLs were not developed based on the watershed approach and did not have sufficient spatial resolution to estimate waste loads allocation from each jurisdiction for MS4 permits. York County and the City of Poquoson have expended millions of dollars in recent years providing public sewer and taking septic systems offline. Starting in 2007, both York County and the City of Poquoson have been performing aggressive "find and fix" programs, including inspection of all gravity sewers, upgrade of pump stations, and elimination of pipe leaks. They have also lined and capped manholes to prevent storm and tidal water from entering the system due to overflows. These efforts have improved the current water quality condition. Since late 2007 VDH-DSS has applied the new mTEC direct plate counting method to measure fecal coliform concentration instead of the MPN method. The new method reduces statistical uncertainty and provides more accurate measures of bacterial concentration. In order to fulfill TMDL requirements and reflect the current condition, a new TMDL development using a watershed-based approach is needed for this watershed.

The Poquoson River watershed is located along the Western Shore of the Chesapeake Bay about 4 km south of the York River mouth in the City of Poquoson and in York County, Virginia. Based on the water quality assessment, it does not support the primary contact recreation (e.g., swimming and fishing) and shellfish consumption designated uses. The Back Creek watershed is located north of the Poquoson watershed and drains to the Chesapeake Bay. It does not support its shellfish harvesting designated use. The TMDLs presented in this report have been developed to meet bacterial standards for the following impaired segments of the Poquoson River:

Assessment Unit	Water name	Location Description	Cause Category	Cause Name	Size (miles)
VAT-C07E_LMC 01A04	Lambs Creek - Poquoson River	South shore tributary to Poquoson R, west of Poquoson Shores. On border of Poquoson/York boundary. Between Moores Cr. and Roberts Cr to east. CBP Segment MOBPH. DSS Shellfish condemnation # 053-137 C (effective 20080320).	4A	Fecal Coliform	0.16
VAT-C07E_PTC 01A04	Patricks Creek - Poquoson River	North shore trib to Poquoson River south of Dare area. CBP Segment MOBPH. DSS Shellfish condemnation # 053-137 D (eff. 20090323).	4A	Fecal Coliform	0.10
VAT-C07E_ROB 01A04	Roberts Creek - Upper	South of mouth of Poquoson R., between Hunts Pt. and Griffins Beach areas. CBP Segment MOBPH. DSS Shellfish condemnation # 053-222 A (effective 20080320).	4A	Fecal Coliform	0.10
VAT-C07E_WH H01A06	White House Cove - Bennett Cr. Area	Located in York Haven Anchorage area, south of mouth of Poquoson R, CBP segment MOBPH. Portion of DSS Shellfish condemnation # 053-222 C (effective 20090302).	4A	Fecal Coliform	0.14
VAT-C07E_POQ 01A06	Poquoson River - Upper [TMDL-CD]	From Rt 17 crossing @ reservoir dam (RM 5.7) downstream to past confluence of Quarter March Cr (RM 2.7) @ Calthrop Neck. Including Moores & Quarter March Creeks. CBP Segment MOBPH. DSS shellfish condemn # 053-137 B (effective 20080320).	4A	Fecal Coliform Enterococ -cus	0.40
VAT-C07E_CHS 01A06	Chisman Creek-Upper & Goose Cr	From end of tidal waters (upper 2/3 of creek), downstream to area of Evergreen Shores (approx. RM 0.9). CBP Segment MOBPH. DSS condemnation # 053-221 B (effective 20100302).	4A	Fecal Coliform	0.47

VAT-C07E_HOD 01A08	Hodges Creek - Upper	North shore trib to Poquoson R. @ Fish Neck. CBP Segment MOBPH. Portion of DSS shellfish condemnation # 053-137 A (effective 20090323).	5B	Fecal Coliform, Enterococ -cus	0.04
VAT-C07E_LYO 01A06	Lyons Creek - Upper (DSS_06-IR)	South shore tributary to Poquoson R, in area of York Haven Anchorage. East of Roberts Cr. and north of White House Cove. CBP Segment MOBPH. Portion of DSS Shellfish condemnation # 053-222 B (effective 20100302).	5B	Fecal Coliform, Enterococ -cus	0.04
VAT-C07E_FLY 01A06	Floyds Bay	Located in southeast corner of Bennett Cr, trib to Poquoson River. Area of York Haven Anchorage. Portion of DSS shellfish condemnation # 053-222 D (effective 20100302). CBP Segment MOBPH.	5B	Fecal Coliform	0.04
VAT-C07E_CAB 01A08	Cabin Creek - Upper	Cabin Creek upstream portion (N of Poquoson R mouth) tributary to Poquoson River. From end of tidal waters downstream approx. 1/2 creek's length. CBP Segment MOBPH. DSS shellfish condemnation # 053-221 (effective 20100302).			
VAT-C07E_POQ 01B08	Poquoson River - Upper [No TMDL]	From Pilney Point Estates downstream to end of Calthrop Neck. CBP Segment MOBPH. Portion of DSS shellfish condemn # 053-137 B (20080320) outside of TMDL for Poquoson R. TMDL (25403).	5B	Fecal coliform, Enterococ -cus	0.121
VAT-C07E_POQ 02B08	Unnamed Cove @ Crane [No TMDL]	North shore trib to Poquoson R (incl. area adjacent to mouth of Patricks Cr.) at Crane. CBP Segment MOBPH. Portion of DSS shellfish condemnation # 053-137 D (effective 20080320). Outside TMDL for Patricks Creek [31196].	5B	Fecal coliform	0.021

Additionally, included in this report is the bacteria TMDL for one impaired segment of Back Creek:

Assessment Unit	Water name	Location Description	Cause Category	Cause Name	Size (miles)
VAT-C07E_BCK01A00	Back Creek - Upper	Back Creek (S of York R mouth) tributary to The Thorofare and Chesapeake Bay. From end of tidal waters downstream to point upstream of Dandy (RM 1.6). CBP Segment MOBPH. DSS shellfish condemnation # 053-151 A (effective 20080320).	5B	Fecal coliform	0.222

Sources of Bacteria

The watershed approach using information of landuse, survey, and observations was applied to conduct the source assessment. There is no point source, such as a wastewater treatment plant (WWTP), in the Poquoson River watershed that discharges bacteria to the River. Three MS4 permits are held within the Poquoson River TMDL watershed. The potential sources of bacteria in the watershed include MS4 regulated areas, nonpoint sources such as livestock, wildlife, pets, human activities, failing septic systems, and Sanitary Sewer Overflows (SSOs).

Modeling Approach

A system of numerical models was applied to simulate the loadings of fecal coliform bacteria from the Poquoson River watershed, and the resulting response of in-stream fecal coliform concentrations. The watershed model, Loading Simulation Program in C^{++} (LSPC), developed by the USEPA, was selected to simulate the watershed hydrology and fecal coliform load to the Poquoson River. The Environmental Fluid Dynamics Computer Code (EFDC) was used to simulate the transport and fate of fecal coliform bacteria in the receiving water. The models were calibrated using 2008-2012 data to reflect the large effort to reduce pollutants in the watershed in recent years and under the current condition. In order to take into account seasonal and hydrological variations, the period 2000-2007 was selected to compute the TMDL as this 8-year period covers both extreme dry and wet years over the last 30-year period, which is representative of the hydrological cycle of the watershed.

Endpoints

The fecal coliform criteria for the shellfish designated use are more stringent than the enterococcus criteria for the recreation designated use. Therefore the endpoint selected for these TMDLs was based upon the fecal coliform bacteria since this will be protective of both designated uses. The numerical criteria for fecal coliform are a *Geometric Mean* of 14 MPN /100mL and a *90th percentile* of 49 MPN/100mL for a 30-month assessment period. As the 90th percentile criterion is more stringent of these two criteria, it is used as the endpoint. For recreation areas, the enterococci criterion was applied. The numerical criteria for enterococci is that no more than 10% of the total samples in the assessment period shall exceed 104 cfu/100 ml and the monthly geometric mean does not exceed 35 cfu/100ml. The endpoints were established based on the designated uses of shellfish harvesting and recreation uses with respect to each listed area. The stringent criteria are applied for the waterbody impaired by both pathogens.

Load Allocation Scenarios

For the shellfish and recreational use impairments, the appropriate water quality standard is a monthly *geometric mean* value of 14 MPN/100mL and a *90th percentile* value of 49 MPN/100mL for fecal coliform bacteria. Results from calibrated model simulation were used to establish the existing load in the system. The allowable load was calculated using the water quality standard criteria to establish the TMDLs. The difference between the TMDL and the existing loading (annual based loading) represents the necessary level of reduction. In order to take into account future growth in the watershed, one percent (1%) of the TMDL load is allocated to future growth (FA). There are three Phase II MS4 permits in the watershed: York County (VAR040028), the City of Poquoson (VAR040024), and VDOT (VAR040115). Waste Loads (WLA) are allocated to these MS4s based on urbanized land within the regulated area of the watershed. The Technical Advisory Committee (TAC) recommended that the aggregation of the VDOT MS4 WLA with Poquoson and York's MS4 WLA was the best course of action. The remaining loads are nonpoint source loads and are allocated as Load Allocation (LA).The maximum reductions required to meet fecal coliform and enterococcus water quality standards are approximately 39% and 10% for the Poquoson River and Back Creek watersheds, respectively. The fecal coliform TMDL (counts/day) for the Poquoson and Back Creek watersheds are summarized below:

Impairment	WLA	LA	MOS	TMDL
Poquoson River	**6.63E+11**	**2.23E+12**	Implicit	**2.89E+12**
MS4 Poquoson (VAR040024)	*2.88E+11*			
MS4 York (VAR040028)	*3.46E+11*			
VDOT (VAR040115)				
Future Load	*2.89E+10*			
Back Creek	**7.10E+10**	**3.10E+11**	Implicit	**3.81E+11**
MS4 York (VAR040028)	*6.72E+10*			
VDOT (VAR040115)				
Future Load	*3.81E+09*			

*York County municipality MS4 loads have been aggregated with a portion of the adjacent VDOT MS4 load due to the continuity of the system.

Where:

TMDL =Total Maximum Daily Load (counts/day)

LA = Load Allocation (nonpoint source) (counts/day)
WLA =Wasteload Allocation (MS4) (counts/day)
MOS =Margin of Safety

The Total maximum annual loadings (Counts per year) are as follows:

Impairment	WLA	LA	MOS	TMDL
Poquoson River	**1.12E+14**	**3.85E+14**	Implicit	**4.97E+14**
MS4 Poquoson (VAR040024)	*4.70E+13*			
MS4 York (VAR040028)	*6.03E+13*			
VDOT (VAR040115)				
Future Load	*4.97E+12*			
Back Creek	**1.41E+13**	**6.14E+13**	Implicit	**7.54E+13**
MS4 York (VAR040028)	*1.33E+13*			
VDOT (VAR040115)				
Future Load	*7.54E+11*			

*York County municipality MS4 loads have been aggregated with a portion of the adjacent VDOT MS4 load due to the continuity of the system.

The maximum daily fecal coliform existing and allowable loads for York County and the City of Poquoson are summarized below:

Waterbody Name	Jurisdiction	Existing Counts/Day	TMDL Counts/Day	Reduction
Poquoson River	City of Poquoson	1.75E+12	1.00E+12	42.7%
	York County	2.99E+12	1.89E+12	36.7%
	Sum	4.73E+12	2.89E+12	39.0%
Back Creek	York County	4.22E+11	3.81E+11	9.8%

The annual fecal coliform existing and allowable loads for York County and the City of Poquoson are summarized below:

Waterbody Name	Jurisdiction	Existing Counts/Year	TMDL Counts/Year	Reduction
Poquoson River	City of Poquoson	2.85E+14	1.64E+14	42.4%
	York County	5.30E+14	3.32E+14	37.3%
	Sum	8.16E+14	4.97E+14	39.1%
Back Creek	York County	8.36e+13	7.54e+13	9.8%

The load allocation (LA) was partitioned to the nonpoint sources within the watershed based on the TMDL endpoint and modeling scenarios of source reduction to meet water quality standards. A complete reduction of controllable loads including human-derived fecal coliform (septic, SSO, and marina), livestock, and pets is applied to the load allocation scenario to show the influence of humans on impairments. Reduction for wildlife is considered when the reduction of controllable loads does not achieve the water quality standards for the estuary. A scenario to provide a starting point of designing an implementation plan (combining LA and WLA) is summarized below:

Waterbody Name	Category	Current Load (Counts/Day)	Allocation (Counts/Day)	Reduction Needed (%)
Poquoson River	Wildlife	3.10E+12	2.89E+12	6.8
	Pets	1.07E+12	0.00E+00	100.0
	Livestock	2.34E+11	0.00E+00	100.0
	Septic	2.61E+09	0.00E+00	100.0
	SSO	2.21E+11	0.00E+00	100.0
	Marina	1.03E+11	0.00E+00	100.0
	Total	4.73E+12	2.89E+12	39.0
Back Creek	Wildlife	3.36E+11	3.36E+11	0.0
	Pets	8.65E+10	4.55E+10	47.4
	Livestock	3.39E+08	0.00E+00	100.0
	Septic	7.71E+07	0.00E+00	100.0
	SSO	0	0	
	Marina	0	0	
	Total	4.22E+11	3.81E+11	9.8

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 an eight-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 90th percentile standards.

Recommendations for TMDL Implementation

The goal of this TMDL is to establish the maximum daily load for developing an allocation plan that achieves water quality standards 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." The allocation presented above is for providing a starting point for designing implementation strategies. An iterative approach to TMDL implementation can be implemented, which first addresses the controllable sources that have the largest impacts on water quality and create the greatest risks to human health. 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.

Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. Public meetings were organized for this purpose. The first public meeting was held on March 18, 2013 at the Sandy Bottom Nature Park (1255 Big Bethel Road, Hampton, VA), to inform the stakeholders of the TMDL development process and to obtain feedback. Results of the hydrologic calibration, bacteria source estimates, and TMDL development were discussed at the public meeting. Two Technical Advisory Committee (TAC) meetings were held at this location during the TMDL development processes. At both TAC meetings, held on May 1 and June 26 of 2013, stakeholders reviewed TMDL development processes and methodology, and provided comments and suggestions. Stakeholders also provided available data for the TMDL development. Input from these meetings was utilized in the development of the TMDL and improved confidence in the allocation scenarios and TMDL process. The second public meeting was held on July 30, 2013, again at the Sandy Bottom Nature Park. Updated bacterial loading distribution and TMDL results were presented and discussed in the public meeting.

The draft TMDL report was posted for review during the period from July 31 to August 31, 2013. Stakeholders have provided many valuable comments and suggestions. These comments and suggestions have been carefully reviewed and incorporated into the revision of this TMDL report.

1.0 INTRODUCTION

1.1 Background

Section 303(d) of the Clean Water Act 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 (WQSs). TMDLs represent the total pollutant loading that a waterbody can receive without violating WQSs. The TMDL process establishes the allowable loadings of pollutants for a waterbody that the waterbody can receive without violating WQSs. 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.

The Poquoson River watershed is located along the Western Shore of the Chesapeake Bay about 4 km south of the York River mouth (Figure 1.1). The Poquoson River drains northeast to the mainstem of the Bay, which then drains directly southeast to the Atlantic Ocean. A total of 12 segments of Poquoson River and 1 segment of Back Creek are listed on the 2006 Virginia 305(b)/303(d) Water Quality Assessment Integrated Report (VA-DEQ, 2006) as an impaired waterbody due to violation of the State's water quality standards for fecal coliform and enterococcus (see Table in Exec Summary). Based on the water quality assessment, it does not support its designated use of primary contact recreation (e.g., swimming and fishing) and providing shellfish growing areas. Figure 1.2 illustrates the delineation of the thirteen impaired segments. A TMDL has been developed to meet the fecal coliform standards. This document, upon approval of EPA, establishes fecal coliform TMDLs for these 13 impaired segments. A TMDL of the Poquoson River and Back Creek was completed in 2006 using a volumetric method for eleven shellfish harvesting impaired sites and one recreational impaired site (VA-DEQ, 2006). Since 2006, new listings have been added to the TMDL list. In addition, three MS4 permits held within the Poquoson River watershed require allowable waste loads to be determined during the TMDL process. However, the previous TMDLs were not developed based on the watershed approach and did not have sufficient spatial resolution to estimate waste loads from each jurisdiction for MS4 permits. York County and the City of Poquoson have expended millions of dollars in recent years to provide public sewer and thereby take septic systems offline. Starting in 2007, both York County and the City of Poquoson have performed aggressive "find and fix" programs, including inspection of all gravity sewers, upgrade of pump stations, and elimination of pipe leaks. They have also lined and capped manholes to prevent storm and tidal water from entering the system due to overflows. These efforts have improved the current water quality condition. Since late 2007 VDH-DSS has applied the new mTEC direct plate counting method, instead of the MPN method, to measure fecal coliform concentration. The new method reduces statistical uncertainty and provides more accurate measures of bacterial concentration. In order to fulfill TMDL requirements and provide a starting point for implementation based on the current condition, TMDL development using a watershed-based approach is needed for this watershed.

1.2 Listing of Waterbodies under the CWA

WQSs are regulations based on federal or state law that set numeric or narrative limits on pollutants. Water quality monitoring is performed to measure pollutants and determine if the measured levels are within the bounds of the limits set for the uses designated for the waterbody. Waterbodies with pollutant levels that exceed the designated standards are considered impaired for the corresponding designated use (e.g. swimming, drinking, shellfish harvesting, etc.). Under the provisions of §303 (d) of the Clean Water Act (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.

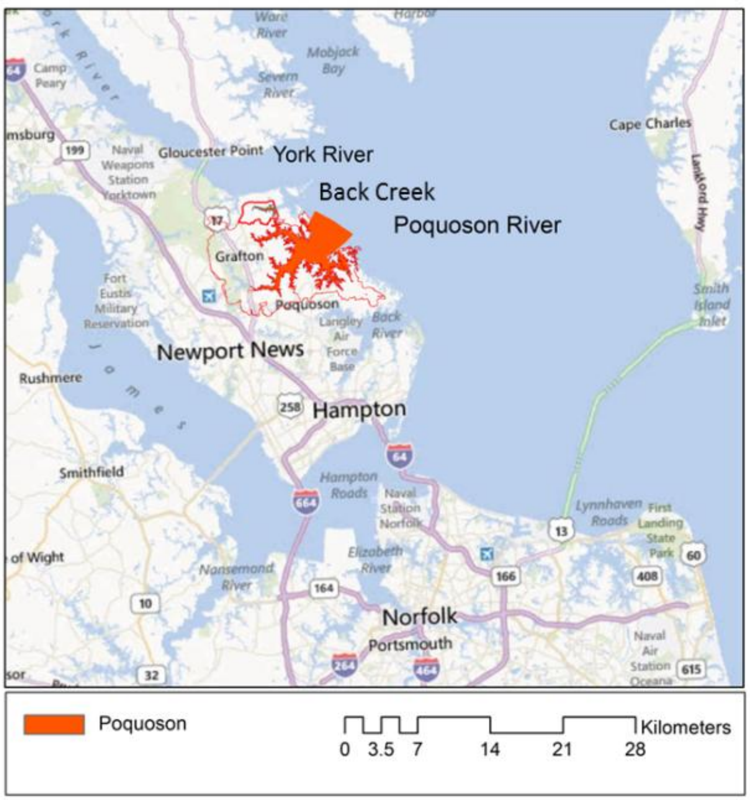


Figure 1.1: Location Map of the Poquoson River

1.3 Watershed Location and Description

The Poquoson River is located along the Western Shore of the Chesapeake Bay about 4 km south of the York River mouth (Figure 1.1). The watershed is low in elevation and is characterized by nearly flat terrain, terraces, tidal marshes, and ponds. Brackish wetlands are common and serve as habitat for fish and shellfish and wildlife (Woods *et al.*, 1999). The watershed area for Poquoson River is 83.5 km^2 (20,630 acres) in size. The Poquoson River watershed is mainly wetlands, forested, and urban, which are 32%, 31%, and 29%, respectively, accounting for approximately 92% of the watershed area. The Back Creek is located north of the Poquoson watershed and drains to the Chesapeake Bay. The soil characteristics of the watershed are the same as the Poquoson River watershed. For the Back Creek watershed, wetland, forest, and urban landuses account for 48%, 19%, and 16%, respectively.

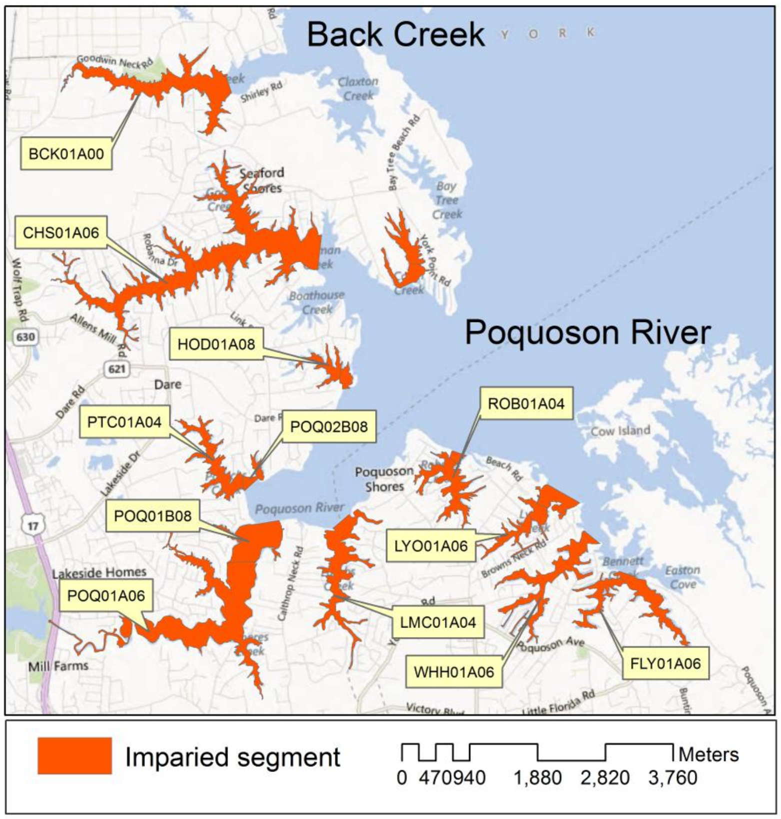


Figure 1.2: Delineation of the Poquoson River and Back Creek Impaired Segments

1.4 Designated Uses and Applicable Water Quality Standard

1.4.1 Designation of Uses

According to Virginia WQSs (9VAC25-260-10):

"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 WQSs, certain standards are assigned by water class, while other standards are assigned to specifically described waterbodies/waterways to protect the 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. Poquoson River is considered as a Class II water, "Estuarine Water (Tidal Water-Coastal Zone to Fall Line)" (9VAC25-260-50).

1.4.2 Bacteria Standard

Effective February 1, 2010, VADEQ specified new bacteria standards in 9 VAC 25-260-170.A. These standards replaced the existing fecal coliform standard of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreation in a saltwater or transition zone, the current criteria are 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."

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 oceanic 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 or restriction classifications are 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) of 14 per 100 milliliters. The 90th percentile shall not exceed an MPN of 43 for a 5-tube, 3-dilution test or 49 for a 3-tube, 3-dilution test.

These standards are calculated using a 30-month window, which means that every consecutive 30-month data group must have a *geometric mean* of 14 MPN/100mL or less and a *90th percentile* of 49 MPN/100mL or less to meet both standards.

1.5 Impairment Listing

Both the Virginia Department of Health - Division of Shellfish Sanitation (VDH-DSS) and the Department of Environmental Quality (VA-DEQ) conducted long-term observations. These data were used for assessing impairment and for supporting model development.

1.5.1 VDH-DSS monitoring data

The VDH-DSS state agency has occupied 70 fecal coliform measurement stations in the Poquoson River and Back Creek during the period 1990-2012. The locations of these stations are shown in Figure 1.3 and time series for all stations are provided in Appendix B of this report.

Sufficient exceedances of Virginia's WQSs for fecal coliform bacteria criteria were recorded at numerous stations to assess the segments of Poquoson River and Back Creek as not supporting of the CWA's shellfish harvesting area use support goal. The percentage of exceedances of the fecal coliform criteria for both the geometric mean and the 90th percentile are tabulated in Table 1.1 for all 70 VDH-DSS stations. The designated uses, impairments, and criteria for Poquoson River segments are summarized in Table 1.2.

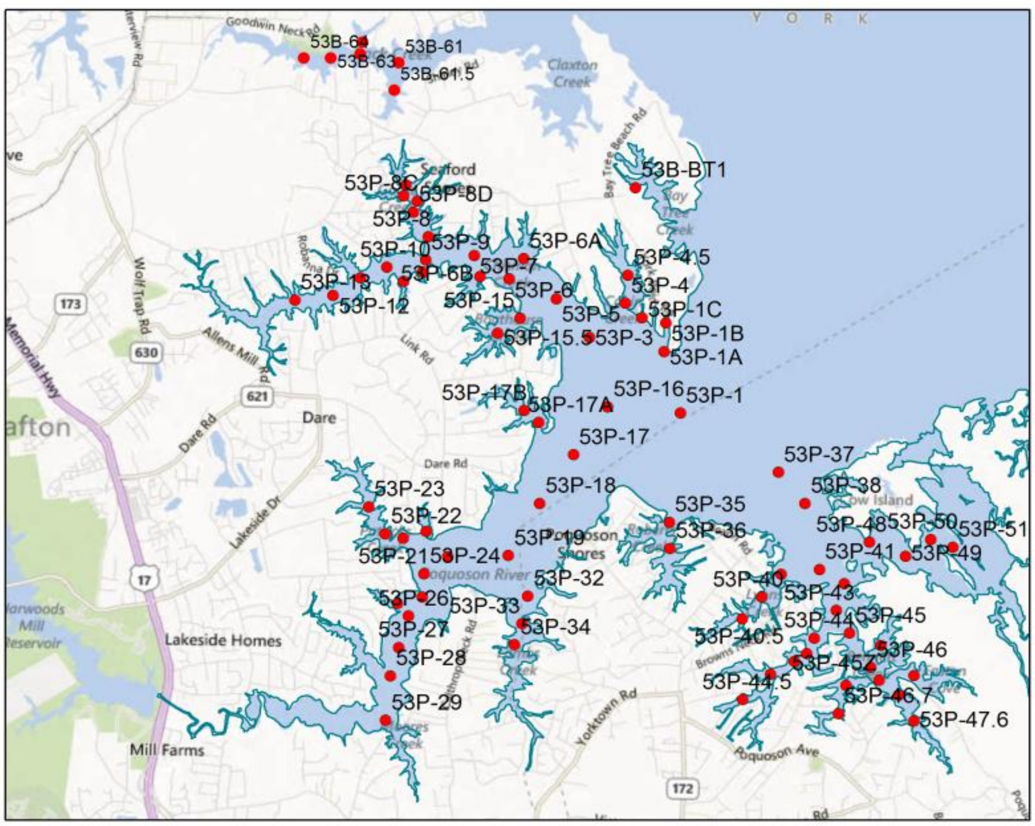


Figure 1.3: Locations of VDH-DSS Stations in the Poquoson River

Table 1.1: Exceedances of the Fecal Coliform Criteria (1990-2012) of Poquoson River DSS Monitoring Stations

Stream Name	Station ID	Number of Samples	Geomean Criterion MPN/100 ml	Geomean Exceedance Percentage	90th Percentile Criterion MPN/100 ml	90th Percentile Exceedance
Cabin Cr.	53P-1A	256	14	0.0%	49	5.4%
Cabin Cr.	53P-1B	37	14	0.0%	49	0.0%
Cabin Cr.	53P-1C	10	14	0.0%	49	0.0%
Chisman Cr.	53P-3	257	14	0.0%	49	4.3%
Chisman Cr.	53P-4	256	14	0.0%	49	5.0%
Chisman Cr.	53P-4.5	92	14	0.0%	49	5.4%
Chisman Cr.	53P-5	257	14	0.0%	49	16.6%
Chisman Cr.	53P-6	257	14	0.0%	49	41.3%
Chisman Cr.	53P-6A	91	14	0.0%	49	1.2%
Chisman Cr.	53P-6B	91	14	0.4%	49	11.6%
Chisman Cr.	53P-7	257	14	23.6%	49	53.7%
Chisman Cr.	53P-8	257	14	40.1%	49	57.9%
Goose Cr.	53P-8D	67	14	1.2%	49	15.8%
Goose Cr.	53P-9A	90	14	8.5%	49	27.0%
Goose Cr.	53P-9B	90	14	8.1%	49	31.3%
Goose Cr.	53P-10	256	14	51.4%	49	80.7%
Goose Cr.	53P-11	256	14	58.7%	49	82.6%
Poquoson R.	53P-15	257	14	0.0%	49	22.0%
Poquoson R.	53P-15.5	90	14	3.1%	49	13.1%
Poquoson R.	53P-17	241	14	0.0%	49	0.0%
Hodges Cove	53P-17A	155	14	0.0%	49	6.2%
Hodges Cove	53P-17B	86	14	0.4%	49	27.4%
Poquoson R.	53P-18	257	14	0.0%	49	4.2%
Poquoson R.	53P-19	258	14	0.0%	49	12.7%
Patricks Cr.	53P-20	258	14	0.0%	49	13.5%
Patricks Cr.	53P-20A	147	14	39.8%	49	57.5%
Patricks Cr.	53P-21	258	14	32.0%	49	83.4%
Patricks Cr.	53P-22	259	14	71.4%	49	88.8%
Qtr. March	53P-24	257	14	1.2%	49	14.7%
Qtr. March	53P-25	256	14	9.7%	49	43.2%
Qtr. March	53P-26	257	14	7.7%	49	44.8%
Qtr. March	53P-26.5	91	14	3.1%	49	17.0%
Qtr. March	53P-27	258	14	3.1%	49	76.8%
Qtr. March	53P-28	259	14	56.4%	49	86.9%
Qtr. March	53P-29	258	14	80.3%	49	88.8%
Lambs Cr.	53P-33	253	14	68.0%	49	88.8%
Lambs Cr.	53P-34	254	14	80.7%	49	88.8%
Roberts Cr.	53P-35	164	14	0.0%	49	7.3%
Roberts Cr.	53P-36	126	14	0.0%	49	32.0%
Bennett Cr.	53P-37	238	14	0.0%	49	0.0%
Whitehouse	53P-38	255	14	0.0%	49	0.0%

Whitehouse	53P-39	253	14	0.8%	49	15.4%
Whitehouse	53P-40	250	14	13.1%	49	67.2%
Whitehouse	53P-40.5	35	14	5.4%	49	54.1%
Whitehouse	53P-41	256	14	0.0%	49	0.0%
Whitehouse	53P-42A	256	14	0.0%	49	0.0%
Whitehouse	53P-43	256	14	0.0%	49	10.4%
Whitehouse	53P-44	259	14	13.9%	49	60.2%
Whitehouse	53P-44.1	255	14	37.1%	49	71.4%
Whitehouse	53P-44.2Z	255	14	54.1%	49	86.5%
Whitehouse	53P-44.3	89	14	5.4%	49	29.7%
Whitehouse	53P-45	255	14	0.0%	49	3.5%
Whitehouse	53P-45Z	149	14	0.0%	49	2.7%
Floyds Bay	53P-46	255	14	2.7%	49	36.3%
Floyds Bay	53P-46.5	255	14	0.0%	49	13.1%
Floyds Bay	53P-46.5Z	249	14	5.0%	49	56.8%
Floyds Bay	53P-46.6	89	14	0.0%	49	13.9%
Floyds Bay	53P-46.7	45	14	0.8%	49	11.2%
Floyds Bay	53P-47.5	256	14	5.8%	49	53.7%
Floyds Bay	53P-47.6	58	14	0.0%	49	9.3%
Bennett Cr.	53P-48	253	14	0.0%	49	0.0%
Bennett Cr.	53P-49	237	14	0.0%	49	0.0%
Bennett Cr.	53P-50	254	14	0.0%	49	0.0%
Bennett Cr.	53P-51	254	14	0.0%	49	0.0%
Back Creek	53B-61	322	14	9.5%	49	45.0%
Back Creek	53B-61.5	94	14	0.3%	49	10.4%
Back Creek	53B-62	321	14	10..7%	49	52.0%
Back Creek	53B-62.5	94	14	4.0%	49	15.6%
Back Creek	53B-63	322	14	38.2%	49	67.0%
Back Creek	53B-64	320	14	37.9%	49	85.9%

Table 1.2: The Water Types, Designated Uses, Impairments, WQC, and List Years for the Poquoson River Impaired Segments

Stream Name	Water Type	Designated Use	Impairment	Criteria (MPN/100ml)	List Year
Lambs Creek	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2008
Patricks Creek	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2009
Roberts Creek	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2008
White House Cove	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2009
Poquoson River Upper	Tidal	Recreation, Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49 Sample max 104	2009

Stream Name	Water Type	Designated Use	Impairment	Criteria (MPN/100ml)	List Year
Chisman Creek-upper	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2009
Hodges Creek-upper	Tidal	Recreation, Shellfish Harvesting	Fecal coliform	Geomean <35 Sample max 104	2010
Lyons Creek-upper	Tidal	Recreation, Shellfish Harvesting	Fecal coliform	Geomean <35 Sample max 104	2009
Floyds Bay	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2010
Cabin Creek-Upper	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2010
Poquoson River - Upper	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2010
Unnamed Cove @ Crane	Tidal	Shellfish Harvesting	Fecal coliform	Geomean <14 90th percentile<49	2010

1.5.2 VA-DEQ monitoring data

In the Poquoson River, the VA-DEQ state agency has occupied 8 stations for the measurement of fecal coliform and 8 stations for the measurement of enterococci. Locations of these stations are shown in Figure 1.4. Table 1.3 shows the number of fecal coliform measurements and their average values for each station. Table 1.4 summarizes enterococci measurements by showing the number of samples at each station and the exceedance percentages based on the instantaneous criterion of 104 MPN/100 ml.

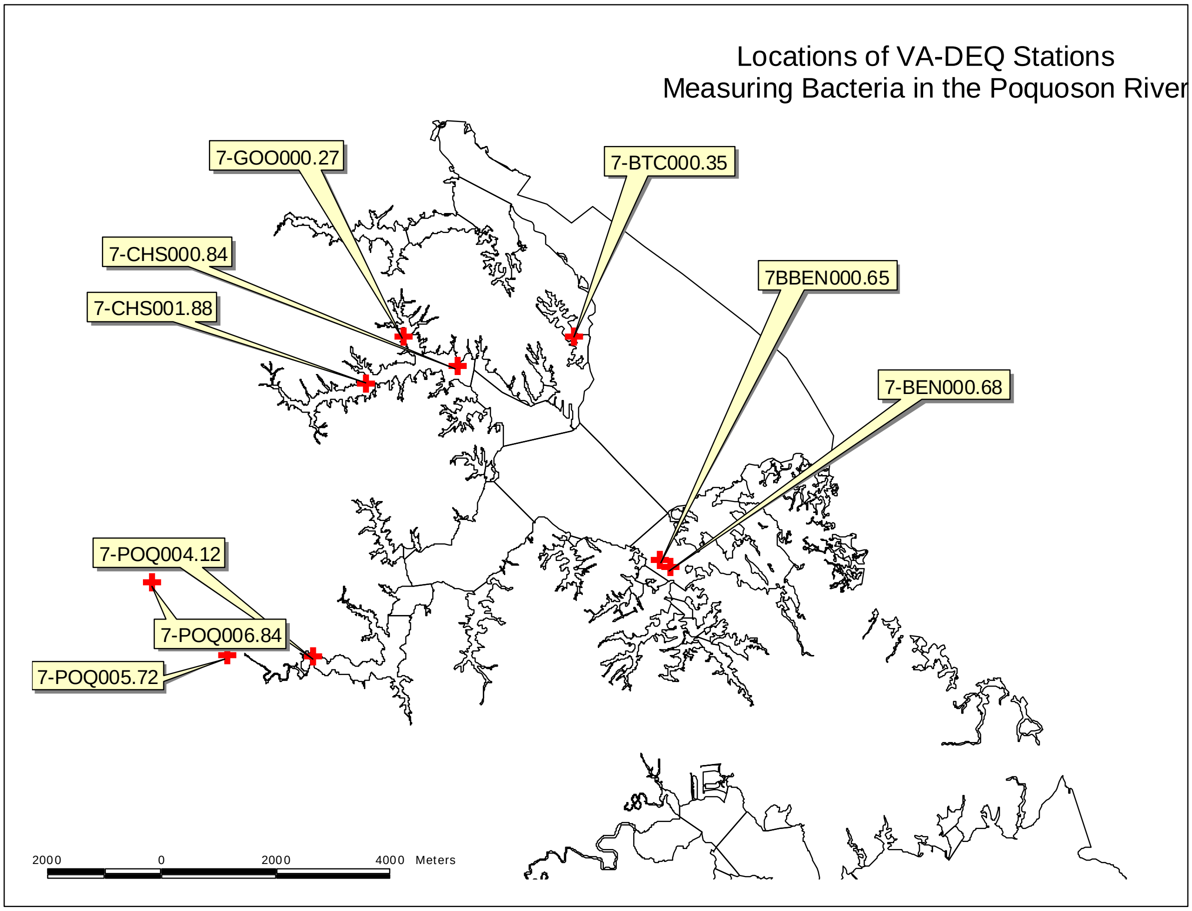


Figure 1.4: Locations of VA-DEQ Stations in the Poquoson River

Table 1.3: VA-DEQ Measurements of Fecal Coliform in the Poquoson River

Station	Number of Observations	Fecal Coliform Average (MPN/100 ml)
7-BEN000.68	1	25
7-CHS000.84	112	55
7-CHS001.88	1	25
7-GOO000.27	1	25
7-POQ004.12	107	299
7-POQ005.72	14	25
7-POQ006.84	13	25
7BBEN000.65	1	25

Table 1.4: VA-DEQ Measurements of Enterococci in the Poquoson River

Station	Number of Observations	Enterococci Average (MPN/100 ml)	Percentage in Violation*
7-BEN000.68	1	10	0%
7-CHS000.84	60	228	12%
7-CHS001.88	1	10	0%
7-GOO000.27	1	10	0%
7-POQ004.12	61	522	66%
7-POQ005.72	7	13	0%
7-POQ006.84	7	11	0%
7BBEN000.65	1	10	0%

*For Enterococci, the criterion for violation is above an instantaneous value of 104 MPN/100 ML

2.0 WATERSHED CHARACTERIZATION

2.1 Topology, Soil, and Climate

The Poquoson River watershed is categorized as Ecoregion 63b and 63c. The watershed is low in elevation and is characterized by nearly flat terrain, terraces, tidal marshes, and ponds. Brackish wetlands are common and serve as habitat for fish and shellfish and wildlife (Woods *et al.*, 1999). Typical soil profiles are loamy fine sand, fine sandy loam, and sand. Large portions of soil are characterized as hydrologic soil group C, which have moderately high runoff potential (USDA, http://websoilsurvey.sc.egov.usda.gov/app/HomePage.htm). As part of the Tidewater Climate Region, the Poquoson River region experiences average January temperatures of 41˚F and average July temperatures of 79˚F. Average January precipitation is 4.7 inches and average July precipitation is 4.7 inches. Annual precipitation ranges from 26.48 to 64.96 inches with a mean precipitation of 45.1 inches (Fig. 2.1). It is influenced by stream discharge, groundwater seepage, and surface runoff.

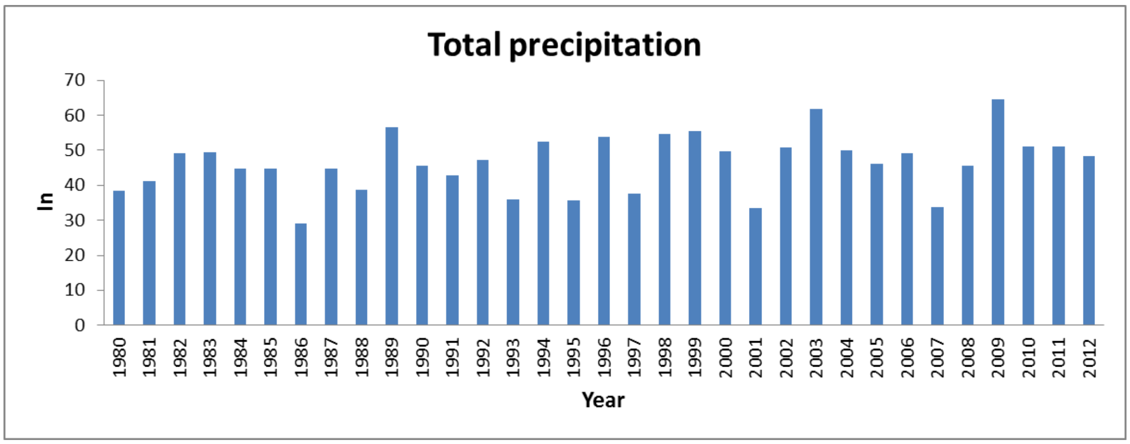


Figure 2.1: Total Annual Precipitation in the Poquoson River Watershed (Norfolk Airport)

2.2 Landuse

The land use characterization for the entire Poquoson River watershed was based on land cover 2006 data from the NOAA Coastal Change Analysis Program (C-CAP) (http://www.csc.noaa.gov/digitalcoast/data/ccapregional/). The landuse is shown in Figure 2.2. The classification matches part of the National Land Cover Database (NLCD) with more detailed land use for wetlands. Brief descriptions of land use classifications and the percentages of landuse in the Poquoson River watershed areas are presented in Tables 2.1 and 2.2, respectively. For analysis purposes, landuse was divided into eight groups shown in Figure 2.3. Dominant land uses in the watershed were found to be forest (32%), wetlands (31%), and urban and open space (30%), which account for 93% of the total area in the watershed. For Back Creek, the dominant landuses are wetland (48%), forest (19%), and urban (16%).

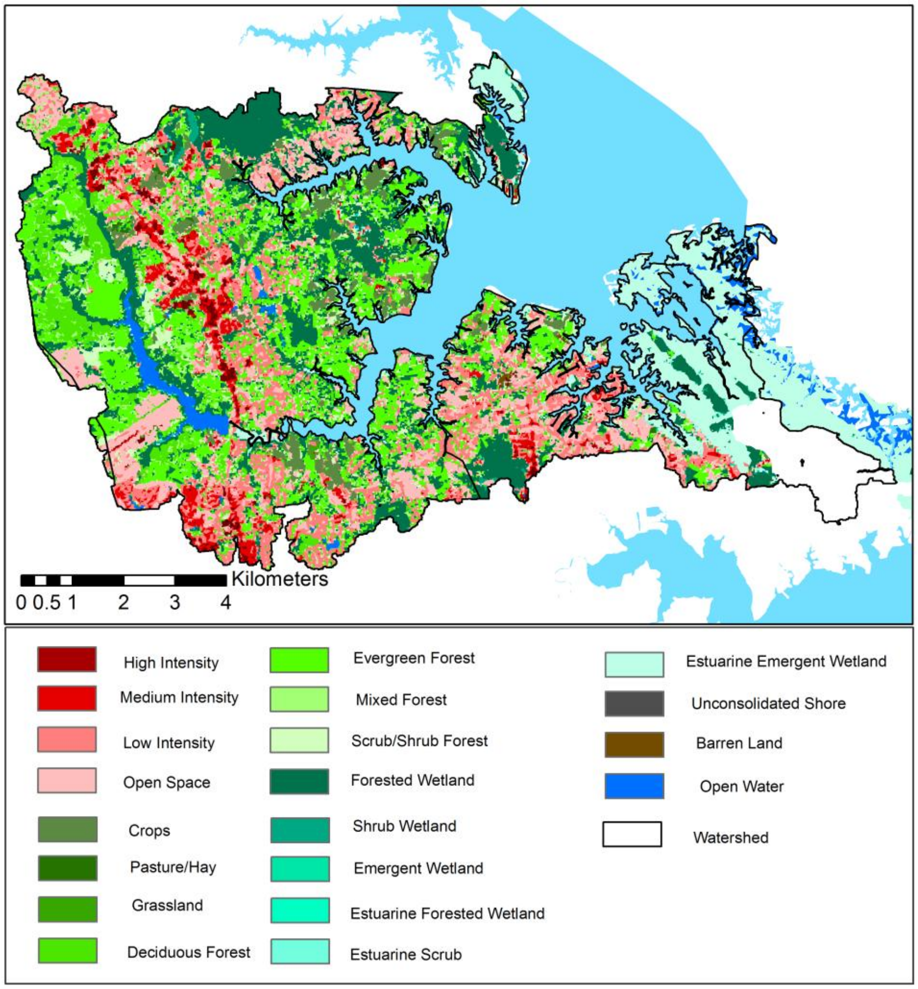


Figure 2.2: Land Use of the Poquoson River Watershed

Table 2.1: Descriptions of Landuse

Description of Landuse
High Intensity Residential: Includes significant land area covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies less than 20% of the landscape. Constructed material accounts for 80-100% of the total cover.
Median Intensity Residential: Includes areas with a mixture of constructed materials and vegetation or other cover. Constructed materials account for 50 to 79% of total area.
Low Intensity Residential: Includes areas with a mixture of constructed materials and

vegetation. Constructed materials account for 30-80% of the cover. Vegetation may account for 20-70% of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

Open Space: Includes areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes.

Row Crops: Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

Pasture/Hay: Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

Grassland: Includes areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation.

Deciduous Forest: Areas dominated by trees where 75% or more of the tree species shed foliage simultaneously in response to seasonal change.

Evergreen Forest: Areas characterized by trees where 75% or more of the tree species maintain their leaves all year; Canopy is never without green foliage.

Mixed Forest: Areas dominated by trees where neither deciduous nor evergreen species represent more than 75% of the cover present.

Emergent Herbaceous Wetlands: Areas where perennial herbaceous vegetation accounts for 75-100% of the cover and the soil or substrate is periodically saturated with or covered with water.

Estuarine Forested Wetland: Areas where woody vegetation accounts for 25-100% of the coverage and this vegetation exceeds 5 m in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation cover is greater than 20%.

Estuarine Shrub: Includes tidal wetlands dominated by woody vegetation less than 5 meters in height.

Estuarine Emergent Wetland: Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Total vegetation cover is greater than 80%.

Barren land (unconsolidated shore): Includes materials such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable.

Open Water: Areas of open water, generally with less than 25% or greater cover of vegetation or soil.

Table 2.2: Landuse Descriptions and Percentages of the Poquoson River Watershed

	York County		City of Poquoson		Totals	
Landuse Name	**Acres**	%	**Acres**	%	**Acres**	%
High Intensity	222.4	1.5	29.1	0.6	251.4	1.3
Medium Intensity	590.8	4.0	123.8	2.4	714.6	3.6
Low Intensity	1,897.4	12.9	672.4	12.8	2,569.8	12.9
Open Space	1,718.9	11.7	606.6	11.6	2,325.5	11.7
Crops	617.9	4.2	65.1	1.2	683.0	3.4
Pasture	45.4	0.3	11.3	0.2	56.7	0.3
Grassland	41.7	0.3	6.2	0.1	47.9	0.2
Deciduous Forest	1,866.3	12.7	176.3	3.4	2,042.6	10.3
Evergreen Forest	2,224.2	15.2	270.1	5.2	2,494.3	12.5
Mixed Forest	854.7	5.8	42.2	0.8	897.0	4.5
Scrub/Shrub Forest	831.9	5.7	197.1	3.8	1,029.0	5.2
Forested Wetland	2,897.3	19.8	680.6	13.0	3,577.9	18.0
Shrub Wetland	111.2	0.8	43.9	0.8	155.1	0.8
Emergent Wetland	46.8	0.3	19.4	0.4	66.2	0.3
Estuarine Forested Wetland	0.9	0.0	0.0	0.0	0.9	0.0
Shrub Wetland	5.9	0.0	49.4	0.9	55.2	0.3
Estuarine Emergent	336.5	2.3	1,991.2	38.0	2,327.7	11.7
Unconsolidated Shore	3.8	0.0	7.7	0.1	11.5	0.1
Barren Land	10.1	0.1	15.2	0.3	25.2	0.1
Open Water	332.8	2.3	231.3	4.4	564.1	2.8
Estuarine Aquatic Bed	4.4	0.0	0.4	0.0	4.8	0.0
Totals	14,661.2	100.0	5,239.3	100.0	19,900.5	100.0

Table 2.3: Landuse Descriptions and Percentages of the Back Creek Watershed

Landuse Name	Acres	%
High Intensity	32.0	2.2
Medium Intensity	64.7	4.4
Low Intensity	140.4	9.6
Open Space	83.2	5.7
Crops	19.7	1.4
Pasture	2.7	0.2
Grassland	3.8	0.3

Deciduous Forest	82.4	5.7
Evergreen Forest	118.3	8.1
Mixed Forest	29.2	2.0
Scrub/Shrub Forest	49.5	3.4
Forested Wetland	640.8	43.9
Shrub Wetland	19.4	1.3
Emergent Wetland	6.9	0.5
Estuarine Forested Wetland	0.4	0.0
Shrub Wetland	0.0	0.0
Estuarine Emergent	32.5	2.2
Unconsolidated Shore	3.5	0.2
Barren Land	0.0	0.0
Open Water	127.9	8.8
Estuarine Aquatic Bed	1.3	0.1
Sum	1458.8	100.0

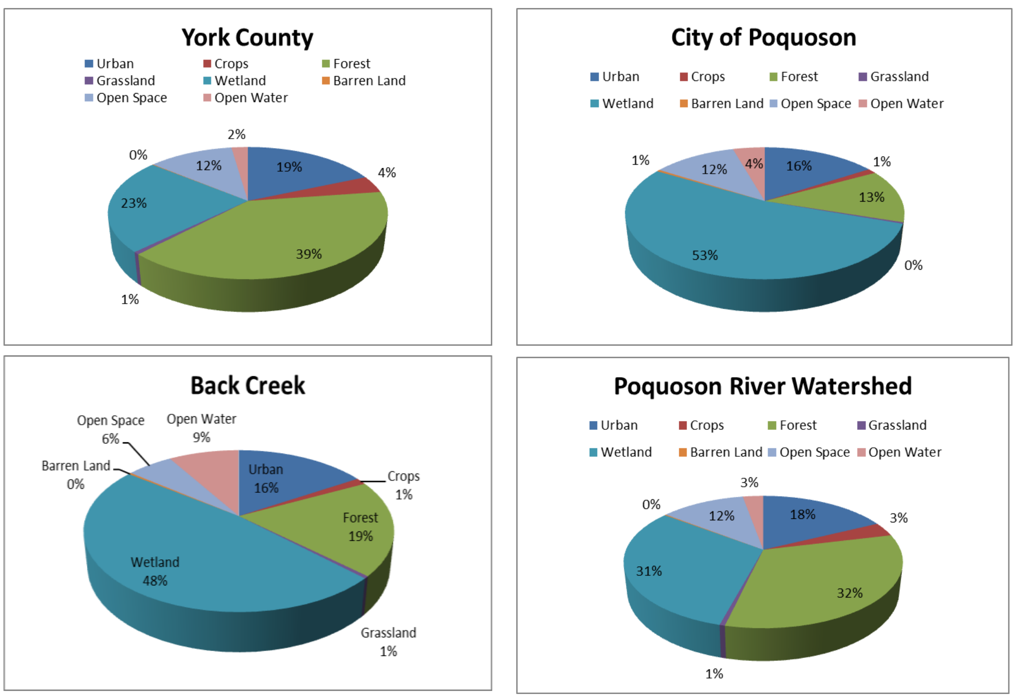


Figure 2.3: Percentage Landuses of the Poquoson River and Back Creek Watersheds

2.3 Water Quality Conditions

The VA-DEQ performs water quality monitoring throughout Virginia to determine if WQSs are being met for the designated uses of the corresponding waters. Samples have been taken at the water quality monitoring stations in Poquoson River (Figure 1.4). VDH-DSS also performs long-term monitoring in shellfish growing areas in the River. A summary of the data is listed in Tables 1.3 and 1.4.

Fecal bacteria, *E. coli*, and enterococci, have been used as indicator organisms for predicting human health impacts in TMDL studies. A statistical analysis found that the highest correlation to gastrointestinal illness was linked to elevated levels of *E. coli* and enterococci in freshwater (enterococci in salt water). Currently VA-DEQ analyzes the fecal coliform, enterococci, and *E. coli* concentrations in water samples by using the membrane filtration method. This method usually has a maximum detection limit of 8,000 counts/100 ml, but the upper limit can be increased to 16,000 counts/100 ml if concentrations are expected to be high. The minimum detection limits for fecal coliform, enterococci, and *E. coli* are 100, 10, and 25 counts/100 ml, respectively. The VDH-DSS state agency has occupied 64 fecal coliform measurement stations in the Poquoson River during the period 1990-2012 (Figure 1.3 and Table 1.1). The routine measurements are conducted monthly. Figure 2.4 shows the annual mean fecal coliform concentration from 1990 to 2012. It can be seen that fecal coliform concentrations varied from year to year. High concentrations often occurred in wet hydrological years of 1998, 1999, and 2004, but not always following the precipitation variation. Monthly bacterial distribution is shown in Figure 2.5. Mean daily high concentrations occur in spring (March to May) and fall (August to November). Large variations occur in March, August, and September.

Figure 2.6 shows all observed fecal coliform data in the River. Note that VDH-DSS has applied the new mTEC direct plate counting method, instead of the MPN method, since late 2007. The new method reduces statistical uncertainty and provides more accurate measures of bacterial concentration. Meanwhile, York County and the City of Poquoson have expended millions of dollars providing public sewer and taking septic systems offline since 2007 while completing a series of implementation projects. This series of projects have been applied in the watershed to reduce the bacterial loading since late 2007. These efforts can greatly improve water quality conditions. It can be seen that bacterial concentrations observed overall have decreased starting in late 2007. There are no concentrations above 1000 cfu/100ml and concentrations higher than 100 cfu/100ml occurred less frequently from late 2007. The 90th percentile values decrease as well (Appendix B). Figure 2.7 compares the empirical cumulative distribution function of observations between 2000-2007 and 2008-2012. It can be seen that current concentration is much lower for the 90th percentile than that during the 2000-2007 period. The large uncertainty associated with measurements is reduced. More observations are needed to confirm this trend.

Table 2.4 lists statistics of both the mean 90th percentile values and the maximum 90th percentile values from 2008 to 2012. Only fourteen stations have maximum 90th percentile values that exceed the water quality standard. The mean 90th percentile value that exceeded the water quality standards was 54%. Both Roberts Creek (VAT-C07E_ROB01A04) and Cabin Creek upper (VAT-C07E_CAB01A08) show no violations.

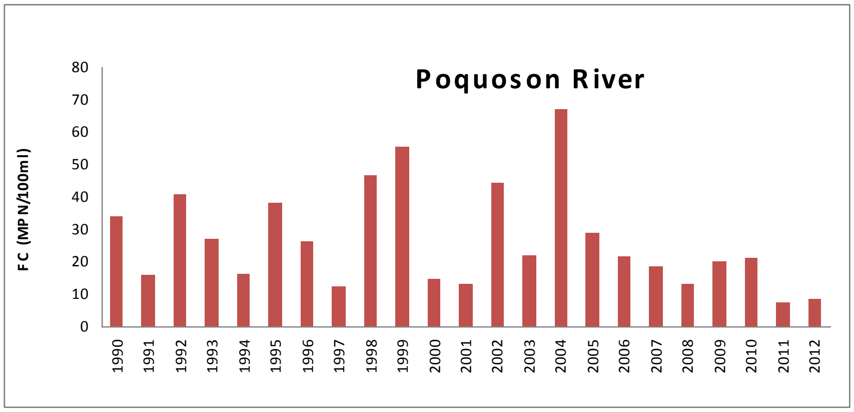


Figure 2.4: Annual Distribution of Mean Fecal Coliform Concentration

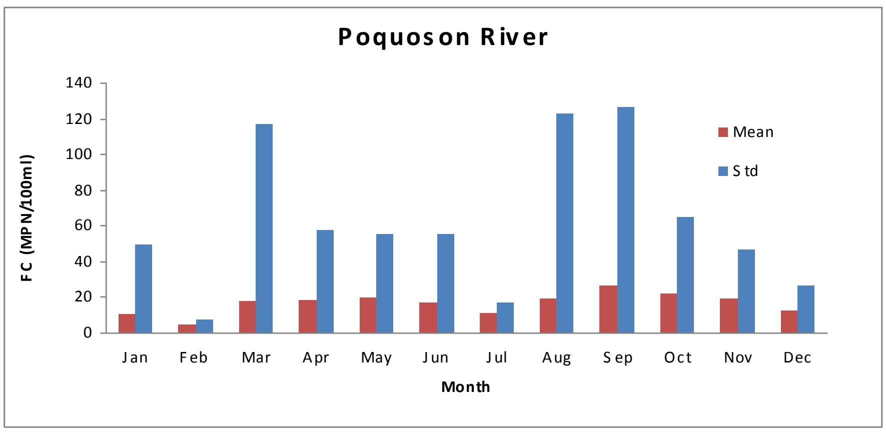


Figure 2.5: Monthly Mean and Standard Deviation of Fecal Coliform Concentration

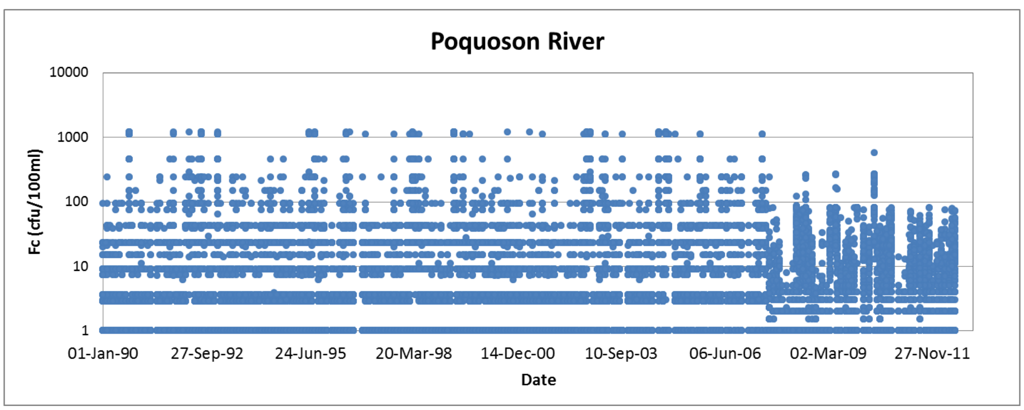


Figure 2.6: Observations of Fecal Coliform Concentration Distribution since 1990

Table 2.4: Statistics of Mean and Maximum of 90th Percentile Values from 2008-2012 (cfu/100ml)

Station	Mean 90th	Max. 90th	% exceeding standard	Station	Mean 90th	Max. 90th	% exceeding standard	Station	Mean 90th	Max. 90th	% exceeding standard
1A	6.0	8.9		17	7.2	10.4		40	52.2	72.2	47.3
1B	20.5	31.7		17A	31.0	41.1		40_5	66.8	88.5	80.7
1C	1.5	2.3		17B	55.9	74.9		41	13.7	22.1	
3	9.6	13.9		18	10.1	15.0		42A	14.4	24.1	
4	10.1	14.1		19	16.9	26.2		43	19.2	33.6	
4_5	14.3	19.7		20	17.6	25.4		44	31.8	48.4	
5	19.1	27.4		20A	74.9	100.8	105.7	44_1	39.9	58.4	19.1
6	22.3	31.4		21	54.9	75.3	53.6	44_2Z	55.6	75.2	53.5
6A	14.9	24.0		22	61.7	89.9	83.4	44_3	53.9	81.0	65.2
6B	26.8	36.2		24	18.7	23.4		45	16.3	26.9	
7	32.0	42.4		25	33.3	46.7		45Z	16.7	26.6	
8	30.0	46.5		26	41.1	55.4	13.0	46	20.0	30.6	
8A	1.3	5.2		26_5	31.4	50.3	2.6	46_5	18.9	31.8	
8C	1.2	4.1		27	55.4	68.8	40.4	46_5Z	25.0	44.8	
8D	41.1	61.2		28	73.9	92.9	89.6	46_6	39.8	56.9	16.2
9	48.9	73.9	50.8	29	93.9	118.8	142.4	46_7	75.8	96.2	96.3
9A	47.6	58.5	19.4	32	38.6	58.2	18.7	47_5	28.6	42.4	
9B	90.5	126.8	158.8	33	62.9	82.5	68.3	47_6	56.4	79.7	62.6
10	48.5	66.6	35.8	34	92.5	122.4	149.8	48	5.2	8.1	
11	49.6	68.2	39.1	37	6.8	8.9		49	4.7	6.0	
15	19.6	25.4		38	8.9	13.2		50	3.7	4.8	
15_5	43.4	53.5	9.1	39	25.5	43.2		51	3.7	4.9	

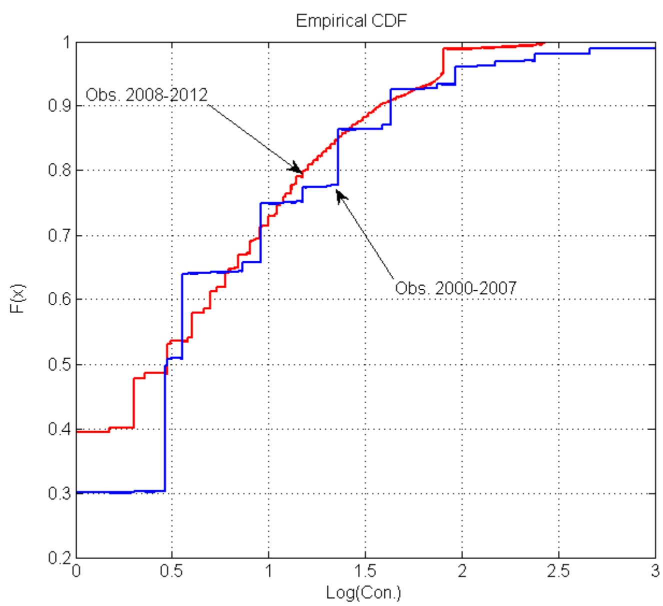


Figure 2.7: Comparison of Cumulative Distribution Functions of Observations between 2000-2007 and 2008-2012

3.0 SOURCE ASSESSMENT

3.1 General

A primary component of pathogens TMDL development for Poquoson River is the evaluation of potential sources of bacteria in the watershed. 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. York County and the City of Poquoson provided GIS data, including septic information and impervious landuse that were used for source assessment.

3.2 Point Sources and MS4s

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. Based on data obtained from the VA-DEQ, there are 24 individual and general permitted facilities in the Poquoson and Back River watersheds. However, no permitted point sources within the Poquoson River watershed discharge fecal coliform into the River.

In addition to the individual and general permits**,** Municipal Separate Storm Sewer System (MS4) permits have been issued to cities and other facilities within the Poquoson watershed. Overall, there are three Phase II MS4 permits held in the Poquoson River TMDL watershed. The areas covered by each of the MS4 permits based on the 2010 census of urbanized area are depicted in Figure 3.1. Urban landuse is comprised of the sum of High Intensity Residential, Median Intensity Residential, and Low Intensity Residential areas based on NOAA C-CAP 2006 landuse data. Table 3.1 lists the MS4 permit holders located within the Poquoson River watershed. The TAC recommended that the VDOT MS4 WLA be aggregated with the Jurisdiction MS4, the acreage associated with VDOT is not listed explicitly.

Table 3.1: MS4 Permit Holders and the Area Occupied by Each MS4 Locality per TMDL Watershed

MS4 Permit Holder	Phase	Permit Number	Jurisdiction	Total Area (ac)	Urban (ac)
York County	II	VAR040028	York County	11,098	2,618
VDOT	II	VAR040115	York County	-	
City of Poquoson	II	VAR040024	City of Poquoson	2,692	750

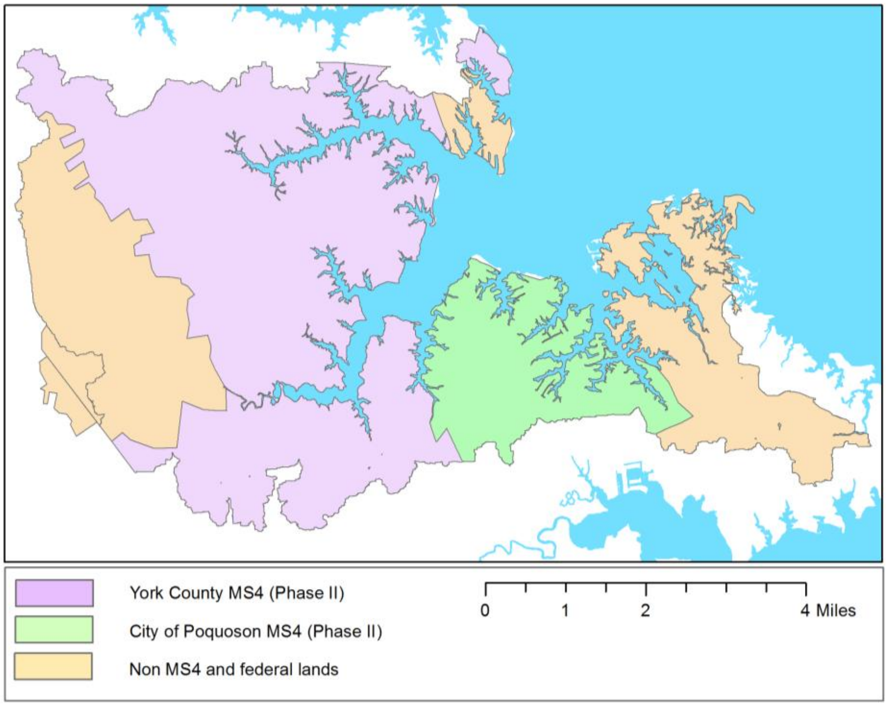


Figure 3.1: MS4 Phase II in York County and City of Poquoson (based on the 2010 census of urbanized area)

3.3 Nonpoint sources

Nonpoint sources are from various sources over a relatively large land area, which are the dominant pollutant sources in the watershed. Nonpoint sources include human-related sources that are mainly through failures of septic systems, SSOs, and pets, livestock, and wildlife.

Human Population

Nonpoint sources related to humans are derived from information about the human population in a region. Population numbers for humans and households are derived from US Census Bureau data (USCB, 2011). As only a portion of York County is located within the watershed, the human population of York County within the watershed is estimated based on its area for urban landuses within the Poquoson River watershed with respect to the county watershed area for urban landuse. The estimated population and the number of households are listed in Table 3.2.

Pets

Dogs are the predominant contributors of fecal coliform. The dog population was often calculated using a formula for estimating the number of pets from national percentages, reported by the American Veterinary Association: number of dogs = number of households * 0.58. This number is much higher than the number of licenses registered in the County and the City. The current number of licenses for the City of Poquoson was obtained. This number was divided by urban landuse acreage to obtain the number of dog per acre of urban landuse area. This rate is used to estimate the total number of dogs in the Poquoson River watershed for both the City of Poquoson and York County. According to a previous study in the Chesapeake Bay region, about 23%-30% of dog wastes are assumed to be subject to runoff. A rate of 23% was used to estimate loading. The estimated dog number is listed in Table 3.2.

Table 3.2: Human Population, Households, and Pets in the Poquoson R. Watershed

		City of Poquoson	York County	Total
Poquoson River	Population (2011)	7,331	24,470	31,801
	Households	2,758	9,113	11,871
	Dogs	907*	2924	3832
Back Creek	Population (2011)		1650	1650
	Households		660	660
	Dogs		207	207

*The number of dogs is based on the number of licenses issued by the City of Poquoson and the urban landuse areas for the watershed.

Septic Systems

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 City of Poquoson currently is on a public sewer system. Some areas of York County are still using septic systems – there are 1,031 septic tanks in the watershed. The septic tank locations in York County are shown in Figure 3.2. Note that septic systems located inside the watershed of Harwood Mills Reservoir do not direct influence to the downstream, which discharge mainly to the reservoir. The estimated failure rate is assumed to be 12% based on data from the Tidewater region. The estimated average number of persons for each septic tank is assumed to be 2.7 and each person is assumed to discharge 70 gal/day with a fecal coliform concentration of 1.0×10^4 MPN/100ml (EPA, 2001a).

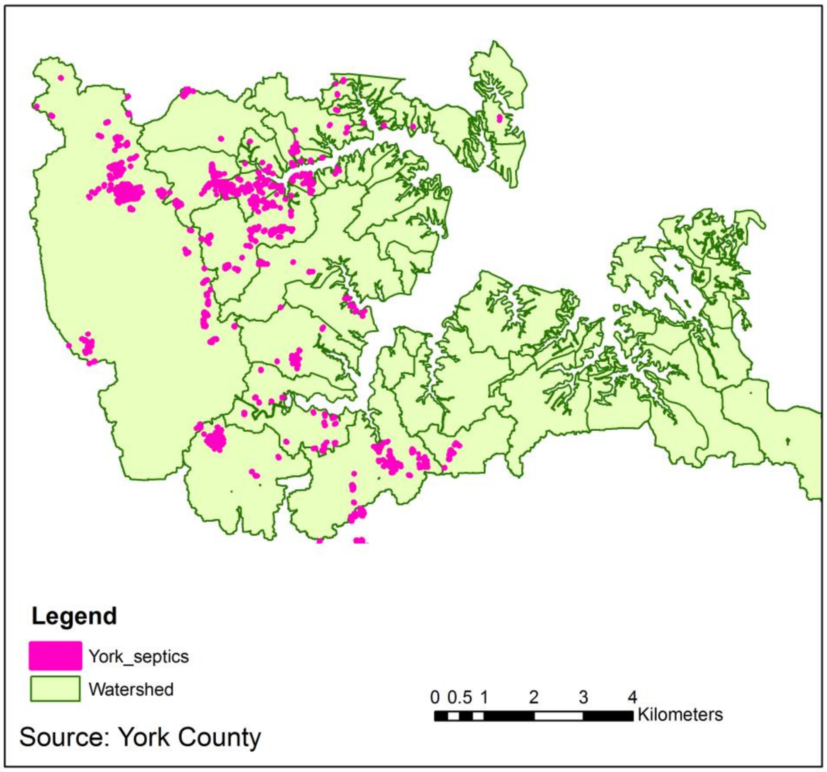


Figure 3.2: Septic System Locations in the Poquoson River Watershed

Sanitary Sewer Overflows (SSOs)

Sanitary Sewer Overflows (SSOs) are discharges of raw sewage from municipal and non-municipal sanitary sewer systems. SSOs can release untreated sewage into basements or out of manholes and onto city streets, playgrounds, and into streams before this sewage can reach a treatment facility (VA-DEQ, 2010). SSOs are often caused by blockages in sewer lines and breaks in the sewer lines.

Based on the data recorded from 2008-2012 provided by VA-DEQ, the SSO locations in the watershed are identified (Figure 3.3). The accumulative spillage distribution is shown in Figure 3.4. The loading corresponding to a 95^{th}-percentile spillage volume is estimated as 25% raw sewage and 75% non-raw sewage. The fecal coliform concentrations for raw sewage and non-raw sewage are listed in Table 3.3. It can be seen that SSO spills occurred less than 11 times each year, and they do not contribute significantly on a daily basis. However, when spillage occurs, it can cause a short-term increase of fecal coliform concentration in the receiving waters. A summary of spillage is listed in Table 3.3.

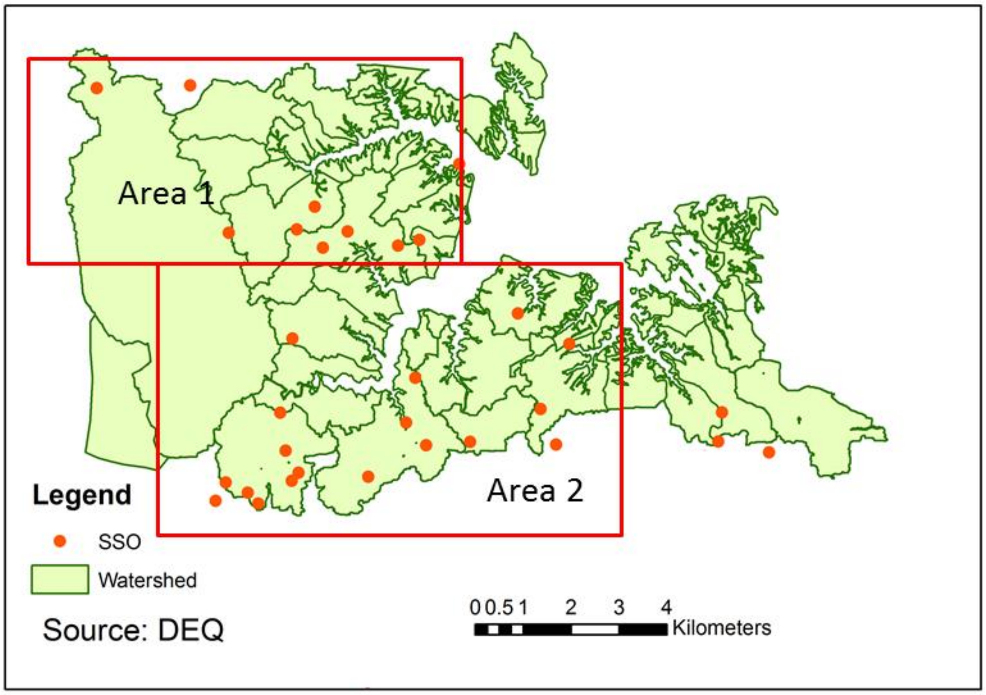


Figure 3.3: Distribution of SSO Locations in the Poquoson River Watershed

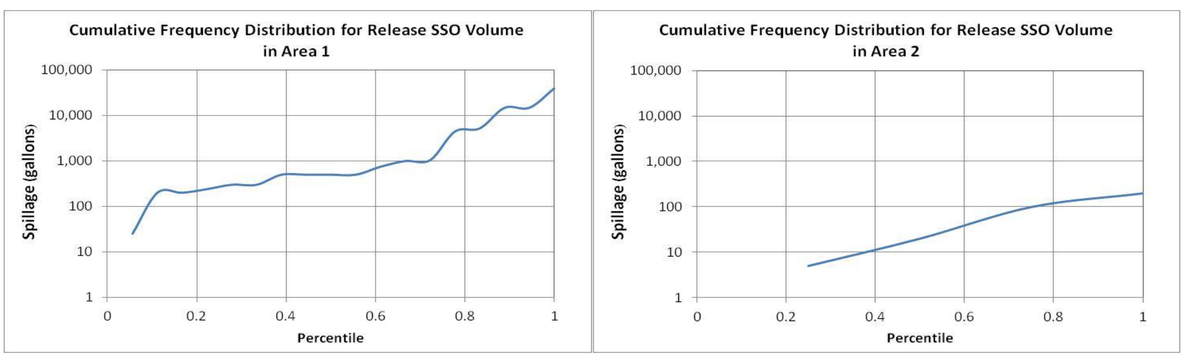


Figure 3.4: Cumulative Frequency Distributions of SSOs in the Poquoson River Watershed

Table 3.3: Fecal Coliform Information for SSOs in the Poquoson River Watershed

Area	Number of Spills	95% Volume (Gallons)	Raw Sewage Concentration (MPN/100ml)	Non-Raw Sewage Concentration* (MPN/100ml)	m^3	Fecal Coliform (Counts/Day)
1	18	18,750	2,700,000	500,000	70.98	7.453E+11
2	4	185	2,700,000	500,000	0.70	7.353E+09

- The concentration is based on published value.

Wildlife

The wildlife inventory for the Poquoson watershed was developed based on a number of information and data sources, including habitat availability, Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and stakeholder comments and observations. The number of animals in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat, which were generated based on GIS data of land use and streams. According to a field survey and the UVA population model, the deer population is much higher in this watershed than its averaged density in the region. Therefore, high acreage densities of 0.094 animals per acre were used to estimate the deer population.

Plum Tree Island National Wildlife Refuge is situated on the eastern side of the City of Poquoson adjacent to the Chesapeake Bay. It consists of 3,501 acres of saltmarsh, shrub-scrub, and wooded habitats that provide a haven for waterfowl, marsh-birds, and shorebirds. Waterfowl and migration bird populations are much higher in this watershed. The survey of bird population density in a similar wildlife refuge of Blackwater National Wildlife Refuge in Maryland shows a very high density with 1.85 birds per acre compared to the typical density of 0.02 birds per acre. In order to more accurately estimate the bird population, a tidal prism model was used to inversely estimate the fecal coliform loading from the Plum Tree Island National Wildlife Refuge based on observations in Floyds Bay and Lloyd Bay. This approach was applied for bacterial TMDLs in Maryland and Virginia (MDE, 2010; Shen and Zhao, 2010). The tidal prism model was developed for the Lloyd Bay and Eastern Cove where dominant loadings are from the Plum Tree Island National Wildlife Refuge with sufficient observations. Based on the tidal prism model, the loading can be computed from the observations as follows:

$$Q_{in}C_{in}-Q_{out}C+L_0-k_cVC=0 \qquad \text{(Eq. 1)}$$

$$L_0= k_cVC+ Q_{out}C- Q_{in}C_{in} \qquad \text{(Eq. 2)}$$

where Q_{in} and Q_{out} are water fluxes (m^3 per tidal cycle) in and out of the model segment, which can be computed as αVin and α(Vin+R), where α is return ratio, Vin is the tidal prism, and R is the runoff. C_{in} and C_{out} are observed fecal coliform concentrations at the boundary and inside of the segment, respectively. k_c is the decay rate of fecal coliform. The value of the decay rate varies from 0.7 to 3.0 per day in saltwater (Mancini, 1978;

Thomann and Mueller, 1987). A decay rate of 1.0 per day (0.52 per tidal circle) was used as a conservative estimate in the TMDL calculation (MDE, 2010). L_0 is the loading from the watershed (counts per tidal cycle) and V is the volume of the model segment. Using tidal range, surface area, and return ratio, water fluxes can be computed. The model parameter of return ratio was based on the previous study in this area (Kuo et al., 1998; Shen et al., 2002a). By using observed fecal coliform concentrations, the loading can be estimated. The decay rate for marsh areas can be expected to be lower than that for in-stream areas. Using a decay rate of 0.5 per day, about 60% of the bacteria will remain on the marsh. We expect that the bacteria will be transported to the stream during high tide, which means that about 50% of the remaining bacteria can be transported into the embayment. Therefore, we assumed that 30% of the loading is subject to runoff. Using a fecal coliform production rate of 4.9×10^9 bacteria counts per day (USEPA, 2001a), an estimated mean density of about 0.77 birds per acre is determined. This rate is much larger than a commonly used rate of 0.02 birds/ac. Note that the assumption that 30% of the loading is subject to runoff only affects the estimation of the bird population. It does not affect the loading estimation as it is estimated based on observations. A fraction (25%) of this density (or 25% per ac loading) was applied to the watershed that is not inside or adjacent to the wildlife refuge, which gives a rate of 0.2 birds/ac (ten times larger than the mean value). This rate was used to compute bacterial daily production and applied to the watershed model for forest, wetland, and urban lands. The value was used as a baseline value for model input and further verified by the watershed model simulations that yield good agreement between model predictions and observations to account for the variation of each subwatershed (Appendix A). Typical wildlife densities are presented in Table 3.4.

Table 3.4: Typical Wildlife Densities and Wildlife Habitat

Wildlife Type	Population Density	Habitat Requirements
Deer	0.094 animals/acre	Entire watershed, except open water and urban development
Raccoon	0.078 animals/acre	Forest and Wetland within 600 feet of streams and ponds
Raccoon	0.016 animals/acre	Upland Forest
Muskrat	50/mile	Streams and Rivers
Nutria	18.5/mile	Streams and Rivers
Duck/birds	1.53 animals/acre*	Entire Watershed
*0.77 animals/acre is applied to Plum Tree Island National Wildlife Refuge and 25% of this density is applied to the rest of the Poquoson River watershed.		

Livestock

The shoreline survey data of the Shellfish Sanitation Division of VDH, together with National Agriculture Statistics Survey data were used to estimate the livestock values. VDH Shellfish Sanitation Division conducted a detailed survey of the watershed and identified pollutant sources. The sanitation survey data were exclusively used to estimate livestock contributions. A summary of livestock in the watershed is listed in Table 3.5.

Table 3.5: A Summary of Livestock in the Poquoson River Watershed

Animal Name	Number	Direct Access
Horses	17	No
Cattle	26	Yes/No
Caged chickens	20	No
Pastured goats	1	No
Caged ducks	5	No

Marinas

Marinas and boating activities can contribute bacteria loading when their wastes are not adequately collected in pump stations or the pump stations do not work properly. A summary of marina and boat information is listed in Table 3.6 (VDH-DSS, shoreline survey).

A total loading contribution from boating slips was estimated based on estimated totals of boats at marinas in the watershed and the number of people occupying each boat and daily bacteria production for each person. For the current calculation, an average of 3 persons per slip is assumed and only 10% of the slips contribute to the loading.

Table 3.6: Total Number of Slips by Marina in the Poquoson River Watershed

Location	Slips/Moorings	Existing
Poquoson Marina End of Rens Rd., Poquoson	156 moorings 34 dry storage spaces	Wet: 14 < 26 ft, 51 > 26 ft
Islander Marina 127 East River Road, Poquoson	32	Wet: 10 < 26 ft, 4 > 26 ft
York Haven Marina, 100 Mingee St., Poquoson	71	Wet: 37<26 ft, 24>26 ft
Dare Marina Incorporated 821 Railway Rd, Grafton	53 moorings 204 dry storage	
Thomas Marina 300 Presson Road, Yorktown	39	
Aqua Marine 512 Wildey Rd., Seaford	26	
Seaford Scallop Company 509 Shirley Rd., Seaford	17	
Mills Marina Incorporated 1742 Back Creek Road, Seaford	63	
Seaford Yacht Club 584 Goodwin Neck Rd., Yorktown	60	
Rens Road Pier end of Rens Rd., Poquoson	4	
E. T. Firth Wholesale Seafood 114A Brown's Neck Rd., Poquoson	3	
259 Mingee St., Poquoson	4	

Chesapeake Watch at… 808 Ship Point Rd., Grafton	8	
Smith's Marine Railway Inc. 810 Railway Road, Grafton	5	
Robanna Shores Community Assn. end of Thomas Road, Seaford	12	
424 Crockett Road, Seaford	12	
Southeast Rope and Rigging End of Shirley Rd., Seaford	2	
1008 Dandy Loop, Yorktown	8	
1310 Dandy Loop, Yorktown	2	

3.4 Summary of Source Assessment

Based on information from landuse, human population, field survey, and observation data, nonpoint sources of bacteria were estimated for each subwatershed based on landuse and livestock distribution. A summary of distribution over the entire watershed is listed in Table 3.7. Note that the SSO is estimated based on the 95th-percentile loading. As spillage occurred less than 11 times per year, it does not contribute significantly on a daily basis. Table 3.8 lists the loading from each source category as a percentage of the total. Loadings from septic systems, SSOs, and marinas are grouped as human. Overall, wildlife and pets contribute 88% of the total loading.

Table 3.7: Summary of Source Distribution in the Poquoson River Watershed

	Source	Animal	Number	Loading (Counts/Day)	Percent
Poquoson River	Wildlife	Deer	1801	9.00E+11	5.6%
		Ducks/Birds	14752	8.96E+12	56.2%
		Muskrat	563	1.41E+11	0.9%
		Nutria	1289	3.22E+11	2.0%
		Raccoon	967	1.21E+11	0.8%
		Total Wildlife	19371	1.04E+13	65.5%
	Pets	Dogs	3832	3.60E+12	22.6%
	Septic		1023 (tanks)	8.79E+09	0.1%
	SSO			7.45E+11	4.7%
	Livestock			7.87E+11	4.9%
	Marinas		579 (slips)	3.47E+11	2.2%
	Totals			1.59E+13	100.00%
Back Creek	Wildlife	Deer	125	6.26E+10	6.6%
		Ducks/Birds	1024	6.23E+11	66.1%
		Muskrat	65	1.63E+10	1.7%
		Nutria	149	3.73E+10	4.0%
		Raccoon	76	9.55E+09	1.0%

		Total Wildlife	1440	7.48E+11	79.4%
	Pets	Dogs	207	1.93E+11	20.5%
	Septic		20	1.72E+8	<1%
	SSO				0
	Livestock		6	7.56E+08	<1%
	Marinas		0		0
	Totals			9.42E11	100%

Table 3.8: Loadings from Source Categories as Percentage of Total

Waterbody	Name	Loading (Counts/Day)	Percent
Poquoson River	Wildlife	1.04E+13	65.5%
	Human (septics, SSOs, marinas)	1.10E+12	6.9%
	Livestock	7.87E+11	4.9%
	Pet	3.60E+12	22.6%
	Total	1.59E+13	100.00%
Back Creek	Wildlife	4.11E+11	79.44
	Human (septics, SSOs, marinas)	9.45E+07	<1%
	Livestock	4.16E+08	<1%
	Pet	1.06E+11	20.5%
	Total	5.18E+11	100.0%

4.0 TMDL DEVELOPMENT

4.1 Overview

A TMDL is the total amount of a pollutant that a waterbody can receive and still meet WQSs. 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 WQSs. 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 the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody, and in the scientific and technical understanding of water quality in natural systems. In addition, where applicable, the TMDL may include a future allocation (FA) as necessary. This definition is denoted by the following equation:

TMDL = WLAs + LAs + MOS + (FA, where applicable)

This section documents the detailed fecal coliform TMDLs and LA development for Poquoson River.

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. Most impaired segments are within shellfish growing areas delineated by the VDH-DSS. Examples of the condemned areas are shown in Figures 4.1 and 4.2. Two segments are listed for both shellfish harvesting and primary contact. The most stringent criterion was selected as the endpoint for the impaired area. According to WQS 9VAC25-260-50, the numerical criteria for fecal coliform for the shellfish harvesting use of Poquoson River impaired sites is a *Geometric Mean* of 14 MPN/100mL and a *90thpercentile* of 49 MPN/100mL for a 30-month assessment period. All bacteria are quantified by fecal coliform. To compute enterococci, the following translator equation (VA-DEQ 2003, 2008) was used to convert fecal coliform concentrations to enterococci concentrations:

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

Using this conversion, the criteria of geometric mean and 90th percentile of fecal coliform correspond to 11.5 and 24.3 cfu/100ml, respectively, which are both lower than the geometric mean criterion of enterococci of 43 cfu/100ml. Because the *90th Percentile* value of 49 MPN/100ml is more stringent, it was used as the endpoint for fecal coliform to determine the TMDL. For impairments designated for recreational use, the enterococci criteria were applied. The numerical criteria for enterococci is that no more than 10% of the total samples in the assessment period shall exceed 104 cfu/100 ml and that the monthly geometric mean does not exceed 43 cfu/100 ml. If the upstream recreational impairment connects a downstream shellfish growing area, the more stringent shellfish criteria will be applied.

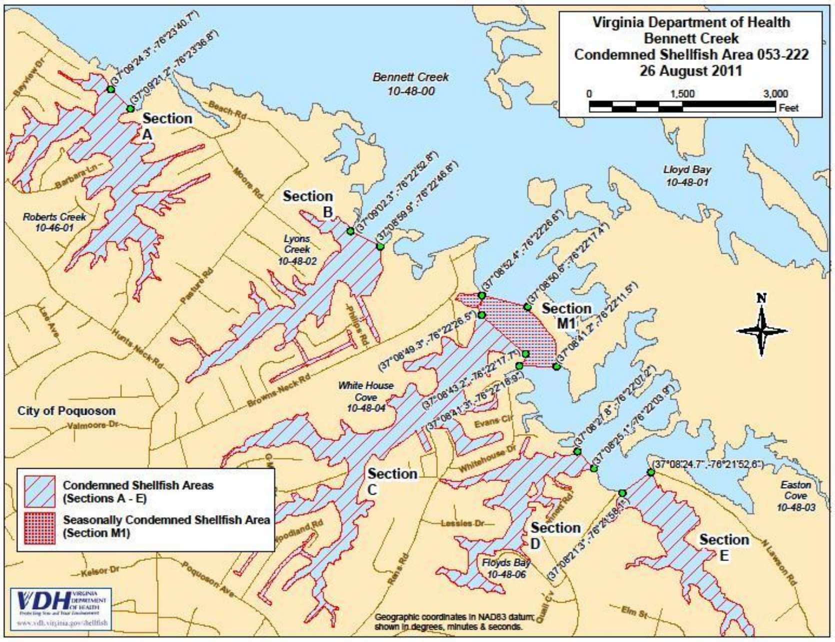


Figure 4.1: Condemnation Shellfish Area 053-222 of the Poquoson River

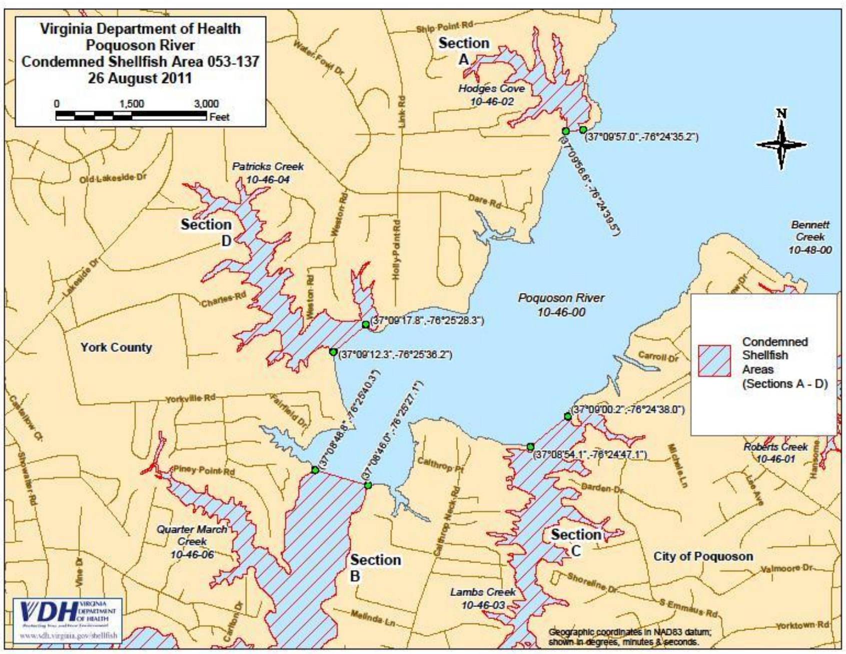


Figure 4.2: Condemnation Shellfish Area 053-137 of the Poquoson River

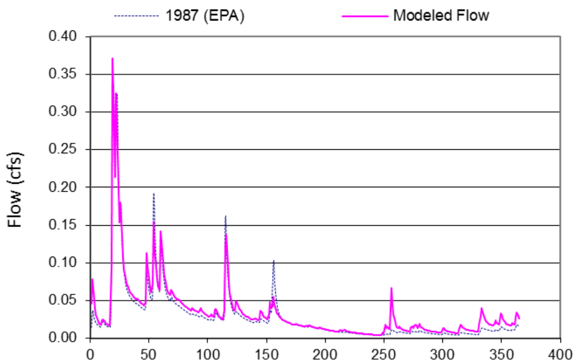
4.3 Model Development for Computing TMDL

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 River. Because the Back Creek is a small creek that directly drains to the Chesapeake Bay, the tidal prism model was used to compute the current and allowable loads (Eq. 2) (MDE, 2010; Shen and Zhao, 2010). The watershed model was only used for establishing long-term annual maximum loading for this watershed. The current observation data (2008-2012) were used to estimate the existing condition and the averages of maximum 90^{th} percentile values of Stations 53B-63 and 53B-64 were used for the model. The parameters used for Back Creek are shown below:

Surface Area (m^2)	Volume (m^3)	Tidal Range (m)	Tidal Prism (m^3)	FC Conc. (2008-2012) (cfu/100ml)	Decay (1/day)
517,796.60	569,576.26	0.72	372,813.55	53.8	1.0

There are no USGS flow measurements in this watershed. The flow simulated by the watershed model was calibrated using USGS gauging data at Gage 01670000 in Beaverdam Swamp near Ark, VA, located approximately 20 miles north of the Poquoson River watershed. The measurement period is between 1980 and 1989. This is the only USGS gauging station located in this region. The USGS data were used for model calibration mainly for non-urban landuses, as both watersheds are located in the same eco-region. The EPA Chesapeake Bay Program conducted a watershed model simulation in the Bay region. The model simulation was also compared to the Bay Program output in Poquoson area for urban landuse (acreage flow). A comparison of model results against the EPA watershed model at the selected subwatershed and USGS station of flow is shown in Figure 4.3. Detailed modeling processes and calibration procedures are presented in Appendix A.



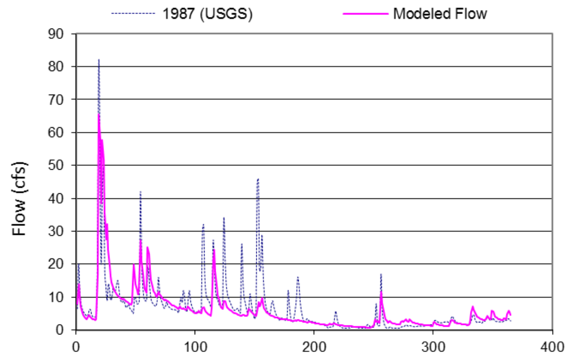


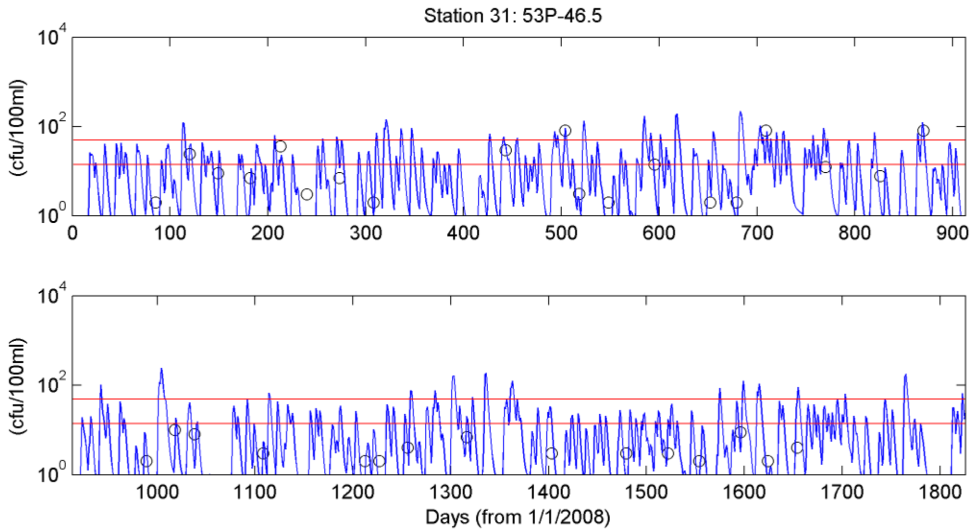
Figure 4.3: Time Series Comparison of Daily Stream Flow between Model Simulation and EPA Watershed Model (Left Panel) and Observations from USGS Stream Gage 01670000 in 1987

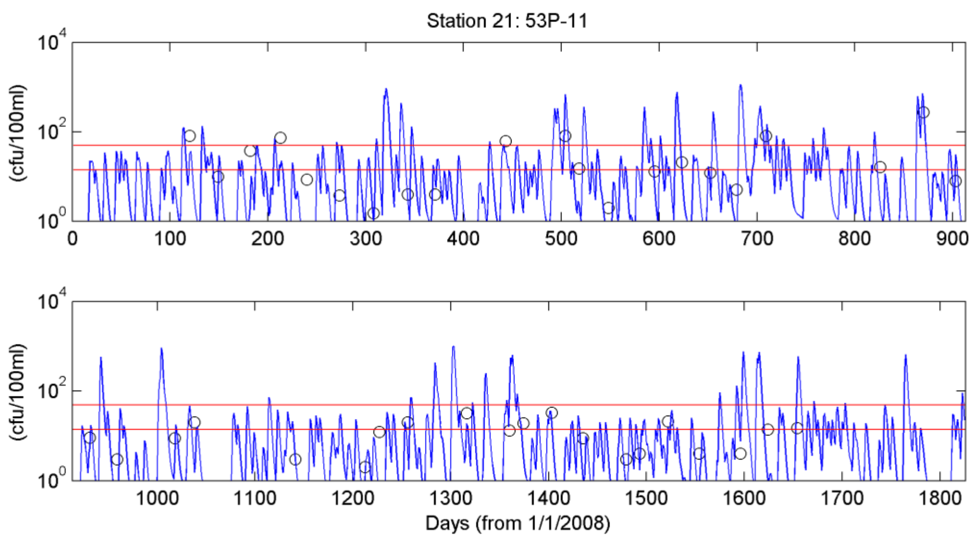
Numerical model calibration of fecal coliform was conducted for the period of 2008-2012. The model was calibrated at DSS and DEQ stations. A constant decay of 1.0 per day was used for the bacterial loss in the stream. Once the model was calibrated, the model simulation was extended from 2000-2007 to develop TMDLs. The selection of period for TMDL development is based on the hydrological cycle in the watershed. The period of 2000-2007 is comprised of extreme low (i.e., 2001), mean, and extreme high (i.e., 2003) precipitation for a 30-year period. This period represents a typical hydrological cycle.

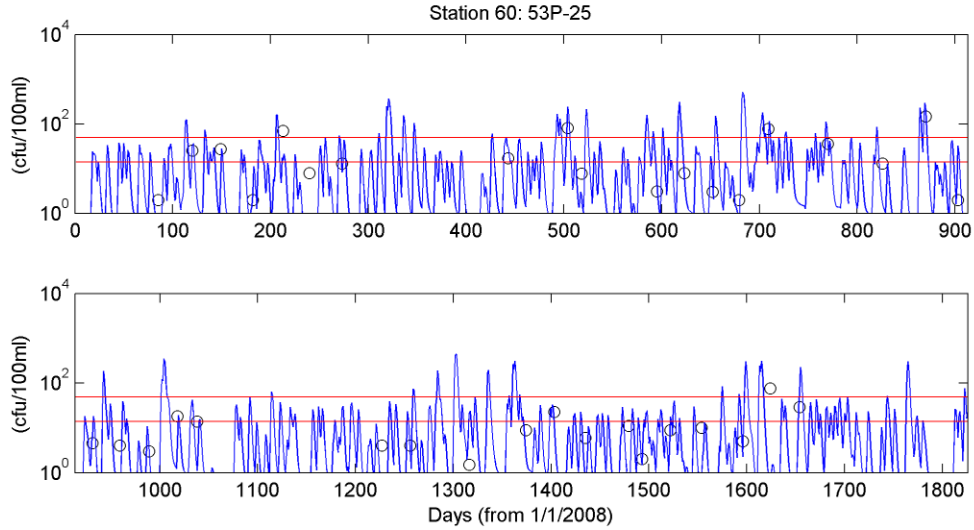
Because the flow from Harwood Mills Reservoir is mainly overflow from the spillway and bacterial concentration inside the reservoir meets the water quality standard, it has minor influence on the downstream. Therefore, the loading from the watershed of Harwood Mills Reservoir was estimated based on the observation flow and mean bacterial concentration of measurements instead of using output from the watershed model.

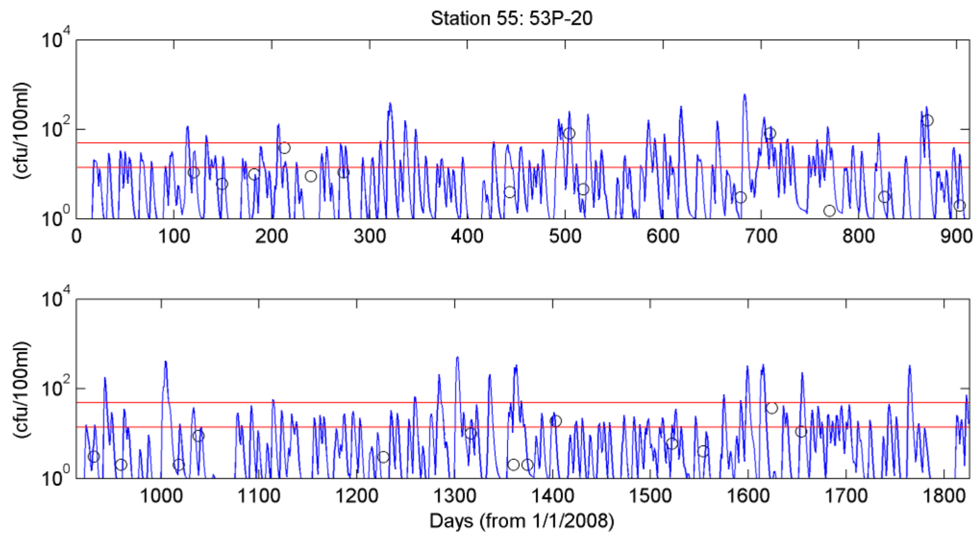
The waterbodies near the wildlife refuge are not listed as impairment of bacteria, nor the waterbody near the Poquoson River mouth. The loadings from subwatersheds 95 and 96 are discharged to the Chesapeake Bay. Loadings from subwatersheds 97, 99 (including Cow Island), 98, 94, 90, and 88 mainly are discharged to Lloyd Bay, which flows to the waterbody near the mouth of Poquoson River. The loadings from these subwatersheds have minor influence on listed segments of LYO01A06, LMC01A04, WHH01A06, and FLY01A06).

Model results at 6 selected stations are shown in Figure 4.4. Calibration results for other stations are shown in Appendix A. Because of many random events are unknown, the model calibration focuses on the general seasonal variation rather than to match individual events. Another method of comparison of the model results and observations is to view the accumulative fecal coliform concentrations at all observation stations to ensure that the 90th percentile concentration is correctly modeled. Figure 4.5 shows the comparison of accumulative distribution of modeled and observed concentrations. It can be seen that the model matches observations very well. The model results are also compared to the observations from 2000 to 2007. It can be seen that predicted 90th percentile values are lower than observation values, indicating a decrease in recent years of bacterial concentration in this system. These results suggest that there is good agreement between observed data and simulated data during the calibration period, indicating that the model has the ability to simulate bacteria in the Poquoson River and can be applied in the development of the TMDL. Bacteria variations over an eight-year period are consistent. The detailed model calibration and TMDL development are presented in Appendix A.






Station 60: 53P-25
(cfu/100ml)
10^4
10^2
10^0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
Days (from 1/1/2008)


Station 55: 53P-20
(cfu/100ml)
10^4
10^2
10^0
0
100
200
300
400
500
600
700
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1100
1200
1300
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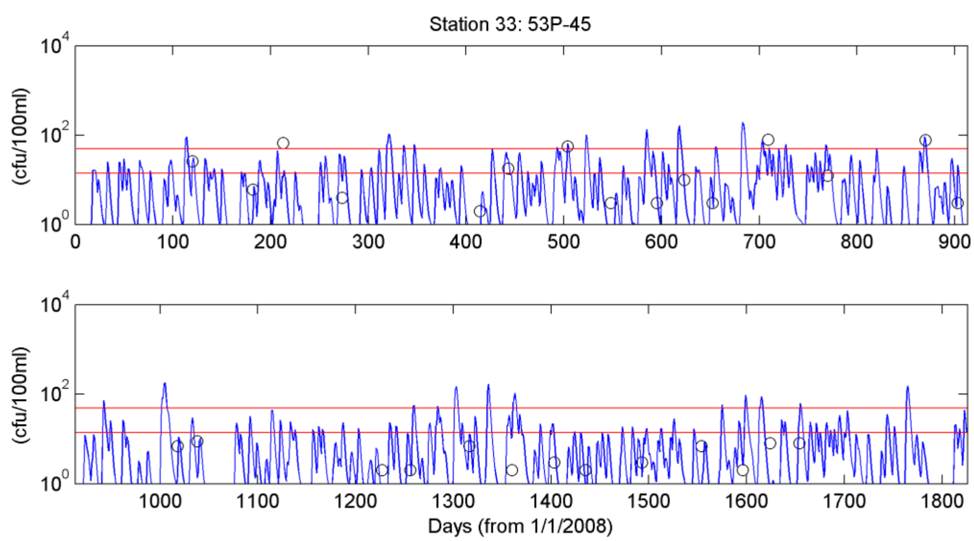
1500
1600
1700
1800
Days (from 1/1/2008)


Station 33: 53P-45
(cfu/100ml)
10^4
10^2
10^0
0
100
200
300
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1200
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1600
1700
1800
Days (from 1/1/2008)

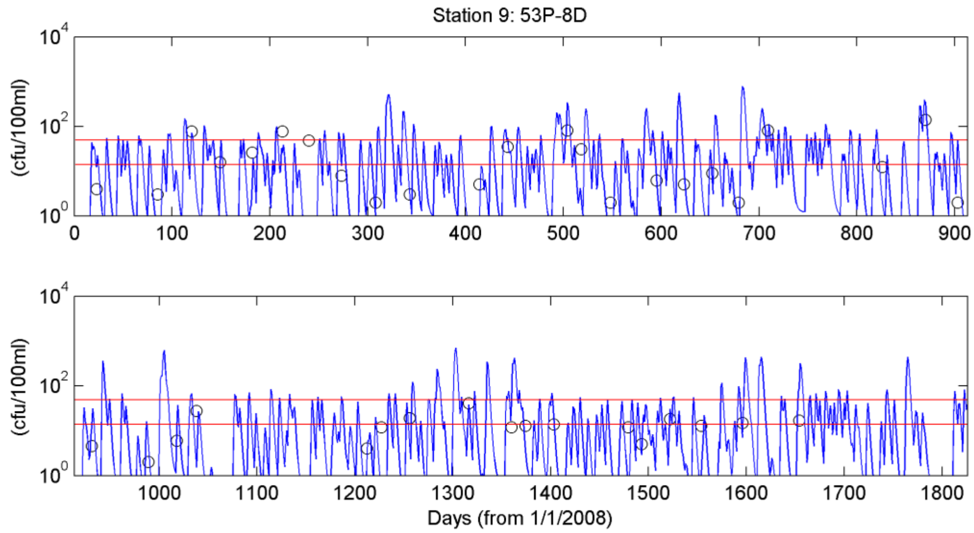

Figure 4.4: Time Series Comparison of Fecal Coliform Concentration between Model Simulation (Blue Lines) and Observations (Circles) from 2008 to 2012. The Red Lines Denote the Geometric Mean and 90th Percentile Criteria.

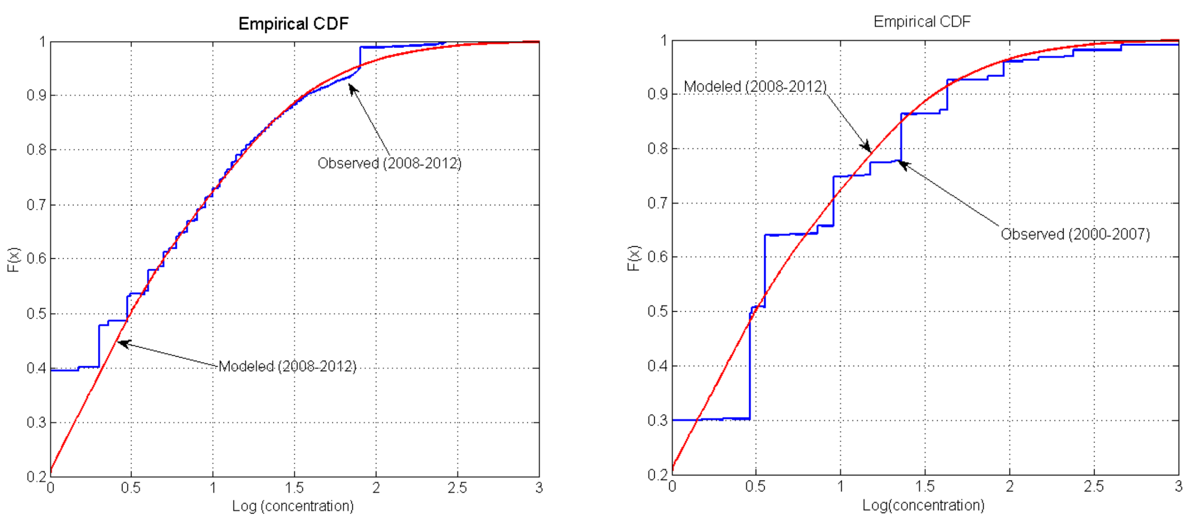

Figure 4.5: Comparison of Cumulative Distribution of Modeled and Observed Fecal Coliform at all Stations (left panel compares 2008-2012 observations and right panel compares 2000-2007 observations)

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 WQSs and help to identify the actions that may have to be undertaken to meet WQSs.

The seasonal variation of bacterial concentration varies from embayment to embayment. Although high concentrations of bacteria often occur during high precipitation, the critical period does not follow a typical high and low flow pattern. It depends on both the duration and intensity of rainfall and bacterial accumulation on the land. To better address the critical period for the River, a long-term simulation was applied to the model to include different hydrological cycles and rainfall events. The current loadings to the waterbody were determined using a long-term record of water quality monitoring (observation) data. The period of record for the data was 1990 to 2012, which spans different flow regimes and temperatures. An 8-year model simulation (2000-2007) was conducted, which includes extreme wet and dry years over the last 30 years. Results from this simulation show that high concentrations of bacteria variations occurred more often over this 8-year period than during the model calibration period of 2008-2012 due to the variation of the hydrological cycle. 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

To allocate loads while protecting the aquatic environment, a MOS needs to be considered. A MOS is typically expressed either as unallocated assimilative capacity or as conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed controls). In the TMDL calculation, the MOS can either be explicitly stated as an additional separate quantity, or implicitly stated, as in conservative assumptions. The assessment of impairment is based on the monthly observations, while the timestep of simulation is every minute, which enables one to simulate high bacterial variations. In many instances, the model simulates much higher bacterial concentration than observations as these values are often unobservable during monthly surveys. Therefore using continuous model results to address attainment is more conservative. The model used a bacterial decay rate of 1 per day, which accounts for the die-off of bacteria. For the Poquoson River, long-term model simulations were conducted to account for a large range of variation. Therefore, the MOS was implicitly incorporated in this TMDL that allocation scenarios were designed to meet the fecal coliform standards for *geometric mean* of 14 MPN/100mL and for *90^{th} percentile* of 49 MPN/100mL.

4.6 TMDL Computation

The TMDL development was based on an 8-year simulation between 2000-2007 using the calibrated model for the current condition between 2008 and 2012. The TMDL for each impairment was computed based on model simulation results of long-term annual mean loading with the consideration of the probability of being exceeded in a daily basis. The EPA-recommended method to convert long-term annual mean loading to daily maximum loading is applied (Appendix A). According to the endpoints for fecal coliform for the established pollutant reduction target, the allowable fecal coliform loading reduction to meet the criteria can be computed. A reduction of loadings from watersheds is needed. 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 A. The results of maximum daily loading for Poquoson River and Back Creek were listed in Table 4.1. The results of load and load reduction for each jurisdiction are listed in Table 4.2.

The annual load was computed as multiple year mean annual load, or mean daily load times 365.25 day. As the Back Creek 90th percentile loading was computed based on the tidal prism model, the mean annual load was derived from the watershed model simulation. The results and reduction expressed as annual loads are listed in Tables 4.3 and 4.4.

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

Waterbody	Pollutant	Criterion (MPN/100ml)	Current Load (Counts/Day)	Allowable Load (Counts/Day)	Required Reduction (%)
Poquoson River	Fecal Coliform	90th Percentile: 49	4.73E+12	2.89E+12	39.0%
Back Creek	Fecal Coliform	90th Percentile: 49	4.22E+11	3.81E+11	9.8%

Table 4.2: Estimated Daily Loads and Load Reductions for Jurisdictions

Waterbody Name	Jurisdiction	Existing Counts/Day	TMDL Counts/Day	Reduction
Poquoson River	City of Poquoson	1.75E+12	1.00E+12	42.7%
	York County	2.99E+12	1.89E+12	36.7%
	Sum	4.73E+12	2.89E+12	39.0%
Back Creek	York County	4.22E+11	3.81E+11	9.8%

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

Waterbody	Pollutant	Criterion (MPN/100ml)	Current Load (Counts/Year)	Allowable Load (Counts/Year)	Required Reduction (%)
Poquoson River	Fecal Coliform	90th Percentile: 49	8.16E+14	4.97E+14	39.1%
Back Creek	Fecal Coliform	90th Percentile: 49	8.36E+13	7.54E+13	9.8%

Table 4.4: Estimated Annual Loads and Load Reductions for Jurisdictions

Waterbody Name	Jurisdiction	Existing Counts/Year	TMDL Counts/Year	Reduction
Poquoson River	City of Poquoson	2.85E+14	1.64E+14	42.4%
	York County	5.30E+14	3.32E+14	37.3%
	Sum	8.16E+14	4.97E+14	39.1%
Back Creek	York County	8.36E+13	7.54E+13	9.8%

4.7 Summary of TMDL and Load Allocation

There are no wastewater treatment facilities in the watershed of the Poquoson River that have permits to discharge bacteria to the River. In order to consider future growth in the region, one percent of TMDL loading is allocated to future growth (FA). There are three MS4 permits for York County, City of Poquoson, and VDOT. The loading is estimated based on urban landuse in the MS4 regulated area within the watershed. The waste loads for permits are determined based on partitioning of the total loading between total landuse and urban landuse within regulated areas. The urban area of the MS4 regulated area is comprised of the sum of High Intensity Residential, Median Intensity Residential, and Low Intensity Residential areas based on NOAA C-CAP 2006 landuse data and 2010 census of urbanized area. In addition, the potential loadings from SSOs and marinas are included in load allocation as they are not regulated by MS4s discharge. The TMDLs are summarized in Table 4.5. The total maximum annual loads are listed in Table 4.6.

Table 4.5: Bacterial TMDLs for Poquoson River and Back Creek (Counts/Day)

Impairment	WLA	LA	MOS	TMDL
Poquoson River	**6.63E+11**	**2.23E+12**	Implicit	**2.89E+12**
MS4 Poquoson (VAR040024)	*2.88E+11*			

MS4 York (VAR040028)	*3.46E+11*			
VDOT (VAR040115)				
Future Load	*2.89E+10*			
Back Creek	**7.10E+10**	**3.10E+11**	Implicit	**3.81E+11**
MS4 York (VAR040028)	*6.72E+10*			
VDOT (VAR040115)				
Future Load	*3.81E+09*			

**York County* municipality MS4 loads have been aggregated with a portion of the adjacent VDOT MS4 load due to the continuity of the system.

Where:

TMDL =Total Maximum Daily Load;
LA = Load Allocation (nonpoint source)
WLA =Wasteload Allocation (MS4)
MOS =Margin of Safety

Table 4.6: Annual Total Maximum Loads for Poquoson River and Back Creek (Counts/Year)

Impairment	WLA	LA	MOS	TMDL
Poquoson River	**1.12E+14**	**3.85E+14**	Implicit	**4.97E+14**
MS4 Poquoson (VAR040024)	*4.70E+13*			
MS4 York (VAR040028)	*6.03E+13*			
VDOT (VAR040115)				
Future Load	*4.97E+12*			
Back Creek	**1.41E+13**	**6.14E+13**	Implicit	**7.54E+13**
MS4 York (VAR040028)	*1.33E+13*			
VDOT (VAR040115)				
Future Load	*7.54E+11*			

**York County* municipality MS4 loads have been aggregated with a portion of the adjacent VDOT MS4 load due to the continuity of the system.

The loadings for each bacterial source were determined based on the source assessment and adjusted based on the model calibration against current observations. Load allocation was determined based on percent of source contribution and model simulations with respect to the reduction of source categories. The percent reduction needed to attain the water quality criterion was allocated to each source category and listed in Table 4.7. Allocation of source distribution for nonpoint source (LA) is listed in Table 4.8. Because the source contribution for each subwatershed was proportionally adjusted based on the model calibration, the results provide a general guideline. The TMDL seeks to eliminate all human-derived fecal components through the allocation process. Human-derived fecal coliform is a serious concern in the estuarine environment and both state and federal law preclude the discharge of human waste. A 100% reduction of human-derived fecal coliform was applied in the allocation to provide a probable scenario for implementation. According to the preceding analysis, reduction of the controllable loads, human (septic, SSOs, and boating activities), livestock and pets, may not result in achievement of the water quality standard. Therefore, an additional reduction is allocated to wildlife. Although SSO incidence does not occur daily, it can contribute to the short-term increase of bacterial loading in the watershed. Therefore, it is considered as controllable loading. The estimation is based on the 95th percentile, which is considered the worst-case scenario. The allocations presented a scenario how the TMDLs could be implemented to achieve water quality standards; however, the state reserves the right to allocate differently, as long as consistency with the achievement of water quality standards is maintained.

Table 4.7: Reduction of Potential Sources

Waterbody Name	Category	Current Load (Counts/Day)	Percentage	Allowable Load (Counts/Day)	Reduction Needed (%)
Poquoson River	**Wildlife**	3.10E+12	65.54	2.89E+12	6.8
	Pets	1.07E+12	22.62	0.00E+00	100.0
	Livestock	2.34E+11	4.94	0.00E+00	100.0
	Septic	2.61E+09	0.06	0.00E+00	100.0
	SSO	2.21E+11	4.68	0.00E+00	100.0
	Marina	1.03E+11	2.18	0.00E+00	100.0
	Total	4.73E+12	100.0	2.89E+12	39.0
Back Creek	**Wildlife**	3.36E+11	79.44	3.36E+11	0.0
	Pets	8.65E+10	20.47	4.55E+10	47.4
	Livestock	3.39E+08	<1	0.00E+00	100.0
	Septic	7.71E+07	<0	0.00E+00	100.0
	SSO	0	0	0	
	Marina	0	0	0	
	Total	4.22E+11	100	3.81E+11	9.8

* Note that the loads listed in the table include both WLA and LAs

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Table 4.8: Reduction of Potential Non-point Source

Waterbody Name	Category	Current Load (LA) (Counts/Day)	Percentage	Allowable Load (LA) (Counts/Day)	Reduction Needed (%)
Poquoson River	Wildlife	2.39E+12	87.6	2.23E+12	6.8
	Pets	0.00E+00	0.0	0.00E+00	
	Livestock	2.34E+11	8.6	0.00E+00	100.0
	Septic	0.00E+00	0.0	0.00E+00	
	SSO	0.00E+00	0.0	0.00E+00	
	Marina	1.03E+11	3.8	0.00E+00	100.0
	Total	2.73E+12	100.0	2.23E+12	18.3
Back Creek	Wildlife	3.10E+11	99.9	3.10E+11	0.0
	Pets	0.00E+00	0.0	0.00E+00	
	Livestock	3.39E+08	<1	0.00E+00	100
	Septic	0.00E+00	<0	0.00E+00	100
	SSO	0	0	0	
	Marina	0	0	0	
	Total	3.11E+11	100.0	3.10E+11	0.1

5.0 IMPLEMENTATION AND PUBLIC PARTICIPATION

5.1 General

Once the EPA has approved a TMDL, 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/tmdl/implans/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 River. It will be beneficial 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.

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 WQSs.

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

The SSOs evaluated in this report are associated with the sanitary sewer collections systems of the HRSD and the municipalities within the Poquoson watershed. Prior to the development of this TMDL, consent orders were issued requiring HRSD and municipalities to evaluate their collection system and develop plans to eliminate SSOs. This TMDL will not affect the execution of these orders. A summary of these orders and their requirements are described below.

The State Water Control Board issued HRSD and thirteen satellite municipal collection systems (the cities of Chesapeake, Hampton, Newport News, Poquoson, Portsmouth, Suffolk, Virginia Beach and Williamsburg; the counties of Gloucester, Isle of Wight, and York; the James City Service Authority; and the town of Smithfield) a special order by consent effective September 26, 2007. The overarching goal of the order is to reduce the occurrence of sanitary sewer overflows in the regional sanitary sewer system.

In general, the order provides for conducting a regional sanitary sewer system evaluation including flow, pressure, and rainfall monitoring and conducting Sanitary Sewer Evaluation Studies (SSES) in identified basins pursuant to the Regional Technical Standards (the regional Technical Standards are incorporated into the order as Attachment 1 and provide detailed requirements to ensure a consistent regional approach for completion of the work required by the order). Data obtained from the studies will be used in the development of a regionally integrated, calibrated and dynamic flow model. System maintenance is addressed by the development of Management, Operations, and Maintenance Programs for HRSD and each municipality. Deficiencies identified by the SSES must be considered and if appropriate, scheduled for rehabilitation or replacement in the development of Rehabilitation Plans. In addition, to address adequate capacity to collect, convey, and treat peak flows in the regional sanitary sewer system during wet weather, a Regional Wet Weather Management Plan will be developed and implemented to define improvements in the regional system necessary to meet wastewater transmission and treatment needs to 2030.

5.3 Reasonable Assurance for Implementation

This section provides the basis for reasonable assurance that the bacteria TMDLs will be achieved and maintained. The appropriate measures to reduce pollution levels at the area include, where appropriate, the use of better treatment technology or installation of best management practices. Details of these methods are to be described in the implementation plan.

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load. With respect to these potential reductions in bacteria loads attributed to wildlife, Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. However, if bacteria levels remain high and localized overabundant populations of wildlife are identified as the source, then measures to reduce such populations may be an option if undertaken in consultation with the Department of Game and Inland Fisheries (DGIF) or the United States Fish and Wildlife Service (USFWS). While managing such overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

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 when 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 WQSs, 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.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting WQSs 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 WQSs, monitoring plans and milestones for attaining WQSs.

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 addressing at a minimum the WQMIRA requirements will be developed. An exception is the municipal separate storm sewer systems (MS4s), which are both covered by NPDES permits and expected to be included in TMDL implementation plans. 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 WQSs. 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.state.va.us/tmdl/pdf/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 inputs from stakeholders and to apprise the stakeholders of the progress made. Public meetings were organized for this purpose. The first public meeting was held on March 18, 2013 at the Sandy Bottom Nature Park (1255 Big Bethel Road, Hampton, VA), to inform the stakeholders of the TMDL development process and to obtain feedback. Results of the hydrologic calibration, bacteria source estimates, and TMDL development were discussed at the public meeting. Two Technical Advisory Committee (TAC) meetings were held at this location during the TMDL development processes. At both TAC meetings, held on May 1 and June 26 of 2013, stakeholders reviewed TMDL development processes and methodology, and provided comments and suggestions. Stakeholders also provided available data for the TMDL development. Input from these meetings was utilized in the development of the TMDL and improved confidence in the allocation scenarios and TMDL process. The second public meeting was held on July 30, 2013, again at the Sandy Bottom Nature Park. Updated bacterial loading distribution and TMDL results were presented and discussed in the public meeting.

The draft TMDL report was posted for review during the period from July 31 to August 31, 2013. Stakeholders have provided many valuable comments and suggestions. These comments and suggestions have been carefully reviewed and incorporated into the revision of this TMDL report.

REFERENCES

CFR (Code of Federal Regulations), 2006. 40 CRF 122.26. http://www.gpoaccess.gov/off/index.html

Hamrick, J. M. 1992a. A three-dimensional environmental fluid dynamics computer code: Theoretical and computational aspects. Special Report in Applied Marine Science and Ocean Engineering. No. 317. The College of William and Mary, VIMS, 63 pp.

Hamrick, J. M. 1992b. Estuarine environmental impact assessment using a three-dimensional circulation and transport model. Estuarine and Coastal Modeling, Proceedings of the 2nd International Conference, M. L. Spaulding et al., eds., ASCE, New York, 293-303.

Kuo, A., Butt, A., Kim, S., and J. Ling. 1998. Application of a tidal prism water quality model to Virginia Small Coastal Basins. VIMS SRAMSOE No. 348.

Mancini, J.L. 1978. Numerical Estimates of Coliform Mortality Rates Under Various Conditions. Journal, WPCF, November, 2477-2484.

Maryland Department of the Environment (MDE) 2010. Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in Monie Bay in Somerset County, Maryland.

Park, K., A. Y. Kuo, J. Shen, and J. M. Hamrick. 1995. A three-dimensional hydrodynamic eutrophication model (HEM-3D): description of water quality and sediment process submodels. Special Report in Applied Marine Sci. and Ocean Engin. No. 327, pp. 102, Virginia Institute of Marine Sci., Gloucester Point, VA 23062.

Shen, J., A. Parker, and J. Riverson. 2005. A new approach for a windows-based watershed modeling system based on a database-supporting architecture. Environmental modeling and software 20: 1127-1138.

Shen, J., H. Wang, and G. M. Sisson. 2002a. Application of an integrated watershed and tidal prism model to the Poquoson coastal embayment. Special Report in Applied Marine Science and Ocean Engineering, No. 380, Virginia Institute of Marine Science, Gloucester Pt. VA.

Shen, J., N. Sullines, and A. Park. 2002b. Mobile Bay TMDL development, linking inland and estuarine systems. Coastal Water Resources, American Water Resources Association, 2002 Spring Specialty Conference, May 13–15, 2002, New Orleans, LA, pp. 313–318.

Shen, J. and Y. Zhao. 2010. Combined Bayesian Statistics and Load Duration Curve Method for Bacteria Nonpoint Source Loading Estimation. Water Research, 44, 77-84.

Thomann, R. V. and J. A. Mueller. 1987. Principles of surface water quality modeling and control. Harper and Row, Publishers, NY. 644 pp.

US Census Bureau (USCB). 2010. Census of Population, Public Law 94-171 Redistricting Data File. http://factfinder2.census.gov.

United States Environmental Protection Agency (USEPA). 1998. Nutrient tool “NutrientTool.xls” program.

USEPA. 2001a. Total Maximum Daily Load for Pathogens, Flint Creek Watershed.

USEPA. 2001b. Total Maximum Daily Load (TMDL) For Metals, Pathogens and Turbidity in the Hurricane Creek Watershed, Tuscaloosa County, Alabama. USEPA, Atlanta, GA.

USEPA. 2004. Loading Simulation Program in C++. http://www.epa.gov/ATHENS/wwqtsc/LSPC.pdf.

USEPA. 2007. *Options for expressing daily loads in TMDLs*. U.S. Environmental Protection Agency, Office of Wetland, Ocean &Watersheds.

VA-DEQ. 2003. HSPF Model Calibration and Verification for Bacteria TMDLs (http://www.townhall.virginia.gov/l/GetFile.cfm?File=E:%5Ctownhall%5Cdocroot%5CGuidanceDocs%5C440%5CGDoc_DEQ_3322_v1.pdf).

VA-DEQ. 2006. Total maximum daily load (TMDL) report for shellfish areas listed due to bacterial contamination: Poquoson River and Back Creek.

VA-DEQ. 2008. Bacteria Total Maximum Daily Load Development for Mill Creek and Powhatan Creek (http://www.deq.virginia.gov/tmdl/apptmdls/jamesrvr/millpowec.pdf).
VA-DEQ. 2010. Virginia Water Quality Assessment Integrated Report.

VA-DEQ. 2010. Bacteria Total Maximum Daily Load (TMDL) Development for the Elizabeth River Watershed.

Woods, A. J., M. James, J. M. Omernik, and D. D. Brown. 1999. Level III and IV ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. U.S. Environmental Protection Agency National Health and Environmental Effects Research Laboratory.

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 the Poquoson River watershed. The EFDC model (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, 2001a, b). Like other watershed models, LSPC is a precipitation-driven model and requires necessary meteorological data as model input.

LSPC was configured for the Poquoson River watershed to simulate this watershed of 56 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 pathogen 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 (livestock, 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 that are 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. Sources of bacteria assessment were described in Section 3. The dominant bacterial sources are from urban landuse, wetlands, and forest. Wildlife contributions from different animals were summed together to obtain total loading as counts per day and were applied to forest and wetland. For urban landuse, contributions from wildlife (birds/duck), pets, failures of septic systems are summed together and then applied to the urban landuse. As wildlife and pets are dominant bacterial sources, urban landuse contributes highest bacterial loading. Contribution from livestock was applied only to the subwatershed(s) where these sources are located. For the current model simulation, SSOs were not simulated by the watershed model, as the incidences occurred less than 3% of the time within a given year. A loading estimation was conducted for each subwatershed and each landuse so that spatial loading variations can be simulated. The final loads discharged to the stream were estimated based on model simulation results to minimize the uncertainty of source variations in different subwatersheds. 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 (Shen et al., 2005). 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.

Because the flow from Harwood Mills Reservoir is mainly overflow from the spillway and bacterial concentration inside the reservoir meets the water quality standard, it has minor influence on the downstream. Therefore, the loading from the watershed of Harwood Mills Reservoir was estimated based on the observation flow and mean bacterial concentration of measurements instead of using output from watershed model. The watershed model output was only used to estimate the loading in this watershed.

The waterbodies near the wildlife refuge are not listed as impairment of bacteria, nor the waterbody near the Poquoson River mouth. The loadings from subwatersheds 95 and 96 are discharged to the Chesapeake Bay. Loadings from subwatersheds 97, 99 (including Cow Island), 98, 94, 90, and 88 mainly are discharged to Lloyd Bay, which flows to the waterbody near the mouth of Poquoson River. The loadings from these subwatersheds have minor influences on the listed segments of LYO01A06, LMC01A04, WHH01A06, and FLY01A06.

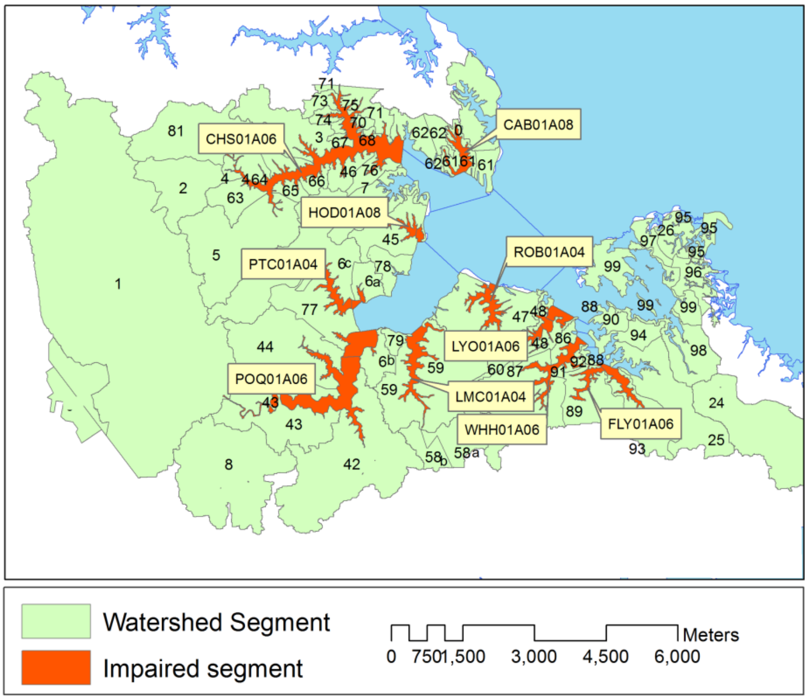


Figure A.1: Subwatersheds Model Segmentation

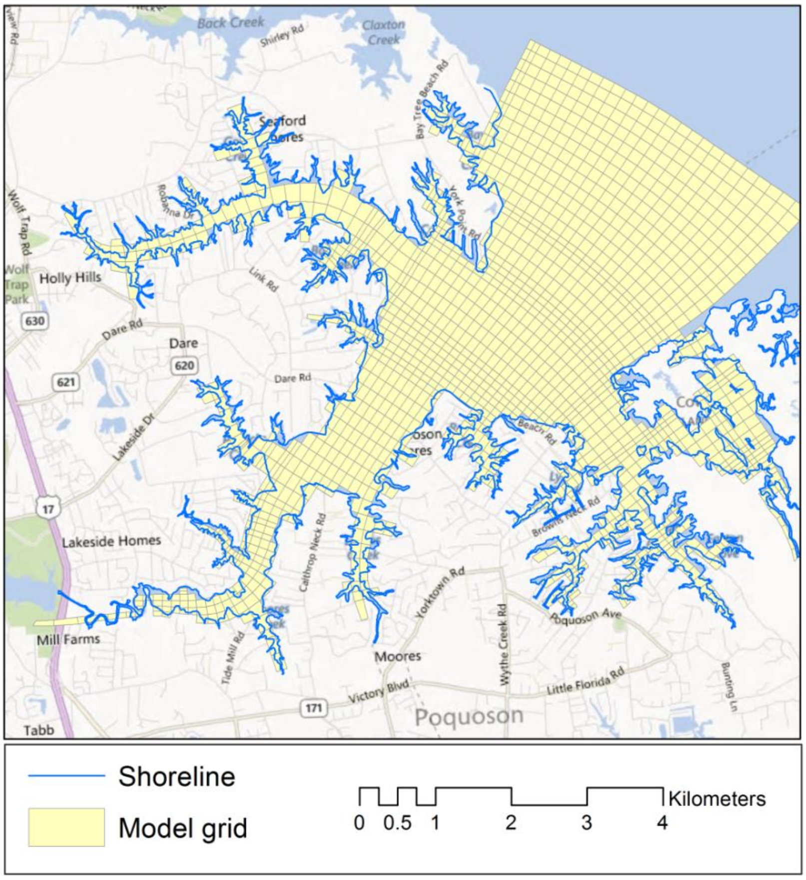


Figure A.2: A Diagram of Estuarine Model Grid

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 Poquoson River 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/athens/wwqtsc/html/hydrodynamic_models.html).

Inputs to the EFDC model for the Poquoson River include:

- Bathymetry
- Freshwater inputs (lateral and upstream) from watersheds
- Surface meteorological parameters such as wind
- Bacteria loadings from watershed
- Tide and salinity at the open boundary

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 the Poquoson River was developed based on the high-resolution shoreline digital files from USEPA and USGS topographic maps. The bathymetry used NOAA bathymetry data (http://www.ngdc.noaa.gov/mgg/bathymetry/). The grid covers the entire River so that the mouth of the River can be used to set the boundary condition. Setting the model boundary well outside the model area of interest increases the model accuracy by reducing the influence of the boundary condition. There are a total of 1593 cells in the horizontal surface grid and three vertical layers. Long-term mean salinity at the surface and the bottom and harmonic tidal constituents were used for the model open boundary. Daily flow and bacteria loading were discharged to the River for the simulations.

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. Since there is no USGS gage or any other continuous flow data available in the Poquoson River watershed, a reference watershed was used for calibration. The USGS Gage 01670000 in Beaverdam Swamp near Ark, VA, located approximately 20 miles north of the Poquoson River watershed, was used to calibrate the model parameters for hydrology simulation. This is the only gage station in this region. The observation period was from 1980-1989. The landuses of forest and wetland and soil types are similar to those of the Poquoson River watershed, but it has less urban land. The USGS flow was used mainly for calibration non-urban land. The US-EPA conducted a watershed simulation for tidal water region. The EPA model results were also used for the model calibration as the LSPC and the EPA models are similar watershed models.

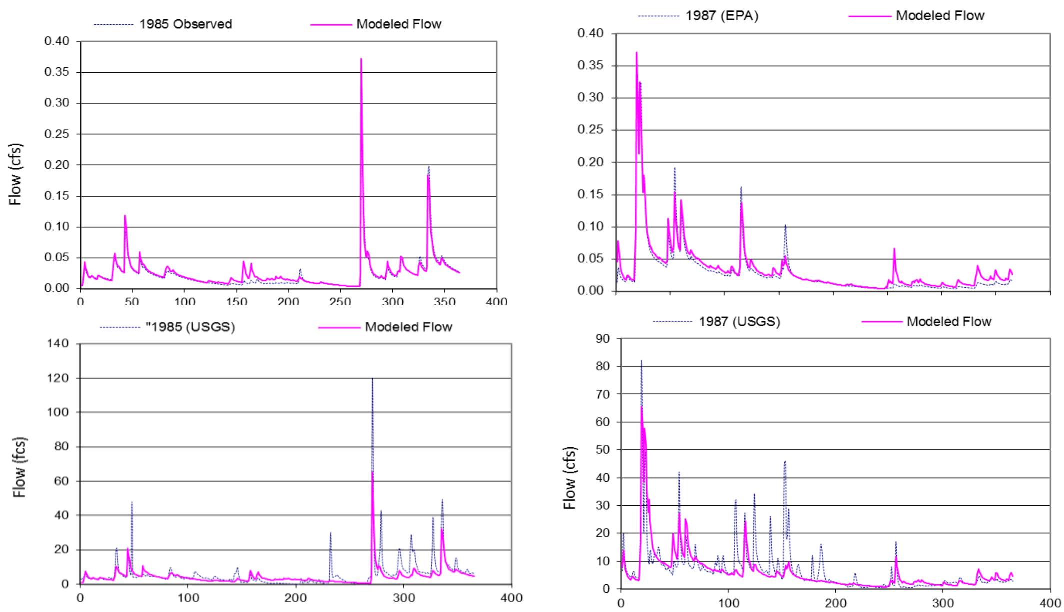


Figure A.3: Time Series Comparison of the Daily Stream Flow between Model Simulation and Observed Data from USGS Stream Gage 01670000 in 1985 and 1987

Figure A.3 shows the time series comparison of daily stream flow for years 1985 and 1987 for the watershed of Beaverdam Swamp using USGS data and a selected urban subwatershed in the Poquoson River watershed using EPA data. It can been seen that model results matches the EPA model results very well as the precipitation data used for this watershed are similar. Figure A.4 shows the long-term daily stream flow frequency comparison between the model results and field data collected by the USGS gage. Based on this comparison, it can be seen that the LSPC model has reasonably reproduced the observations.

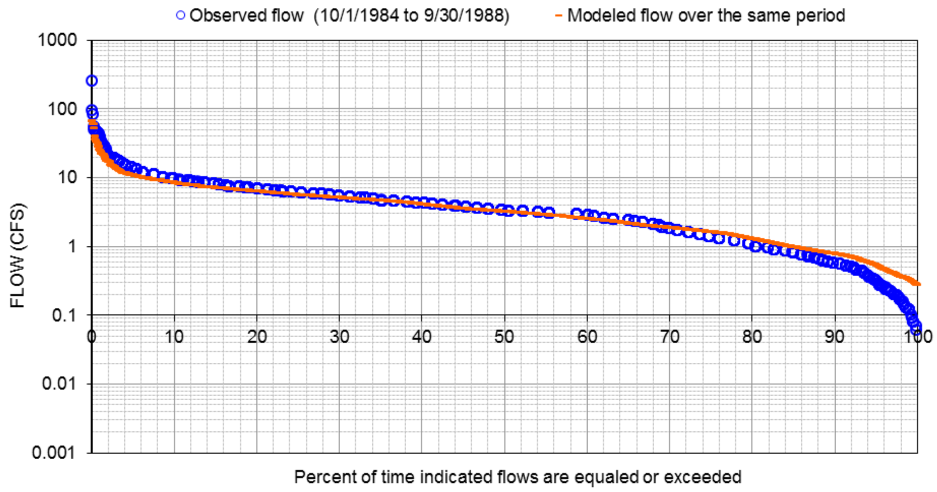
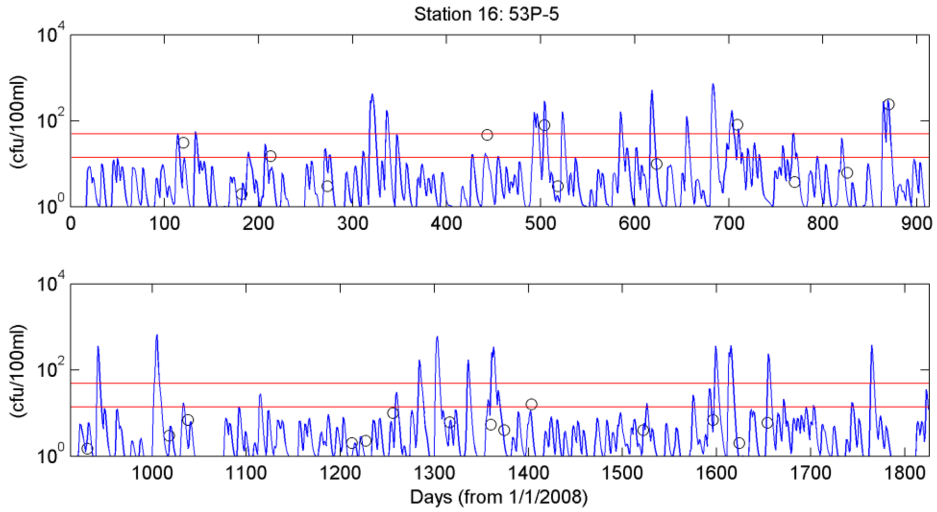
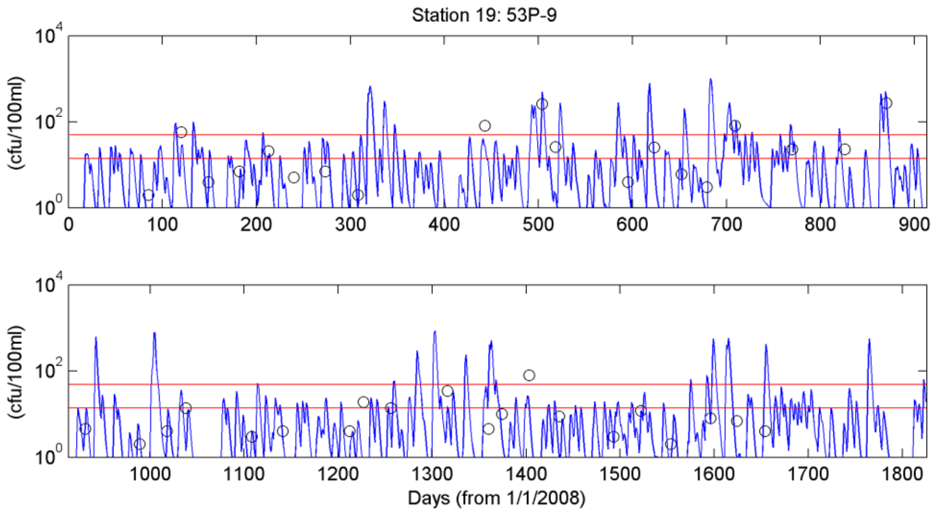


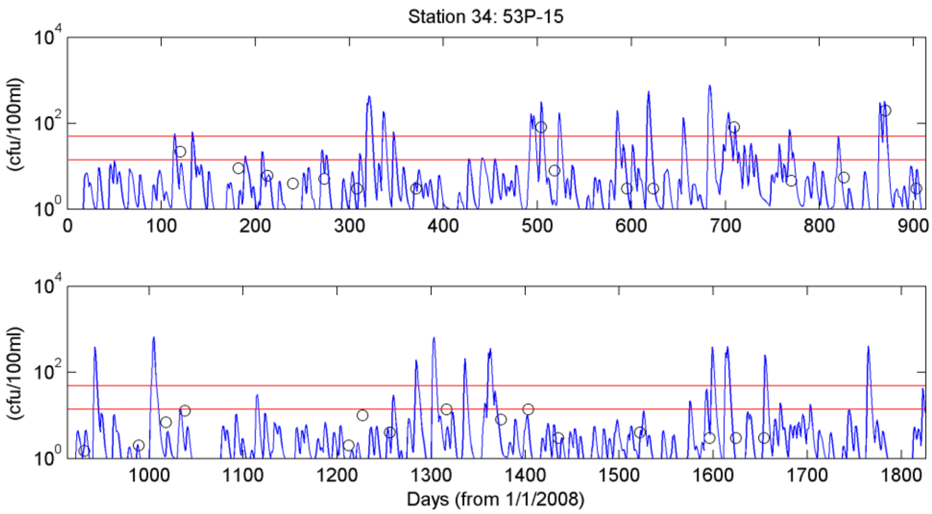
Figure A.4: Long-term Accumulated Daily Stream Flow Comparison between Model Simulation and the Reference Flow Station USGS 01670000

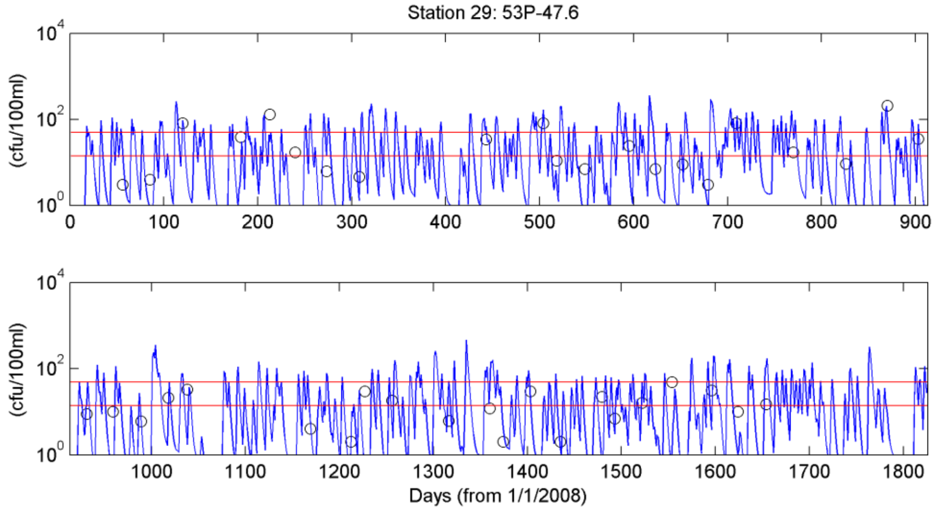
A.1.2.2 Estuarine Model

Calibration of the bacteria transport model is typically performed using water quality measurements from the watershed. Absent the necessary data from the Poquoson River watershed, the calibration was performed on the observation data in the Poquoson River receiving water using an iterative approach between the watershed model and the receiving water model. 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. The approach is similar to that used in USEPA-recommended loading production rates (USEPA, “FecalTool.xls” program, 1998) (Section:3.3). The loading distribution estimated in Section 3 only provides a background value and loading distribution is not uniform over entire watershed. Some of unknown sources in a watershed also exist and are not observed. Therefore, these loading parameters were adjusted proportionally for each source during model calibration to account for uncertainty in the loading estimation. The model was calibrated from 2008-2012. A constant bacteria decay rate of 1.0/day is used, which was derived based upon observations and literature review (MDE, 2010). Figure A.5 shows 15 selected stations of impaired segments. It can be seen that the model simulated the observed data quite well. As bacterial concentrations in the River are highly driven by events, i.e., SSOs and boating activities, as well as direct access of wildlife, some discrepancies can be expected. In particular, the model can miss some observations of high concentration, as the causes of these events are unknown. Overall, model simulations are satisfactory.





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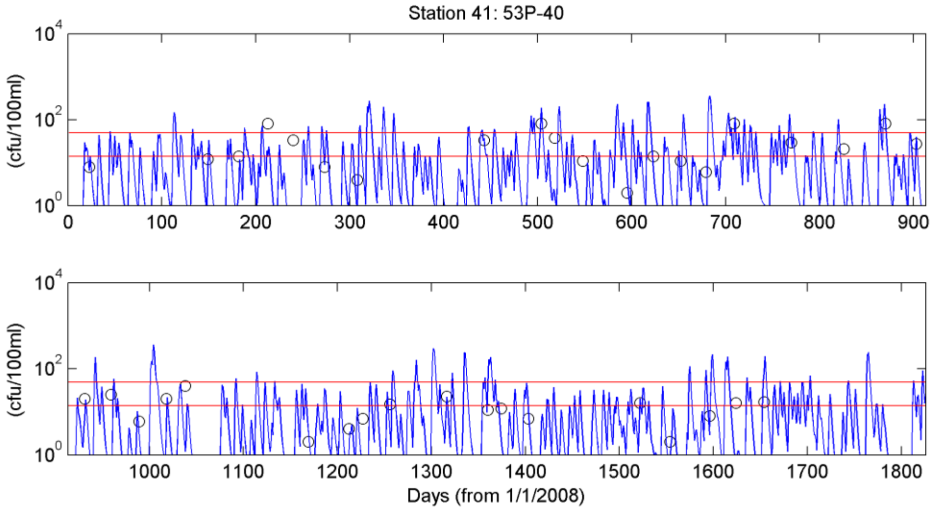
Days (from 1/1/2008)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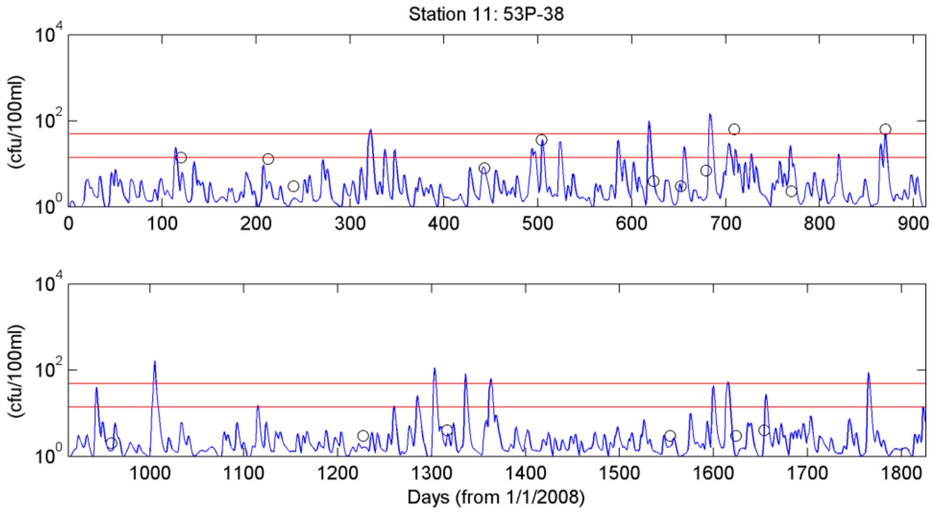
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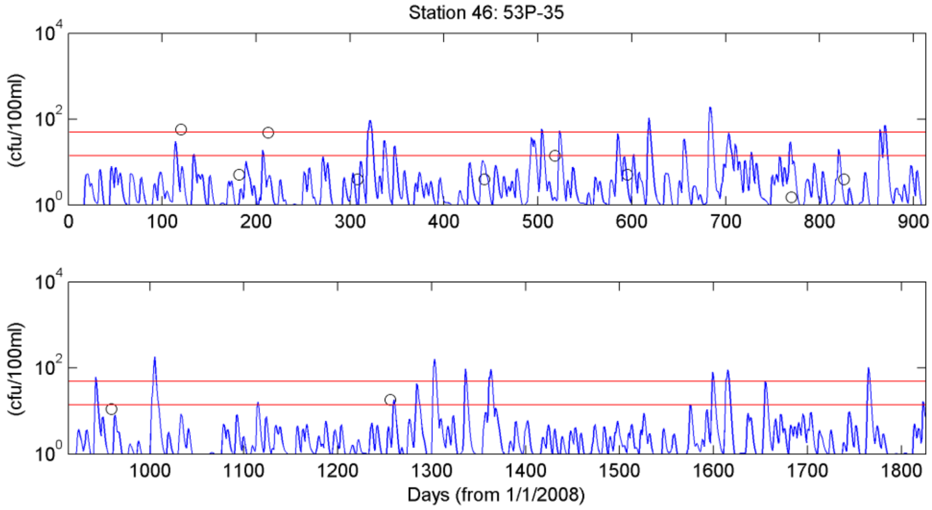
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10^2
10^0
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100
200
300
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500
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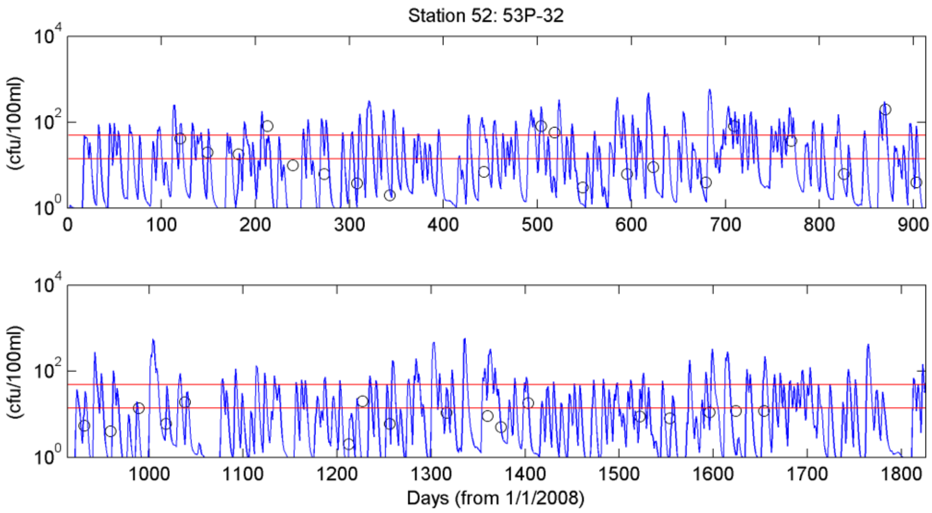
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
Days (from 1/1/2008)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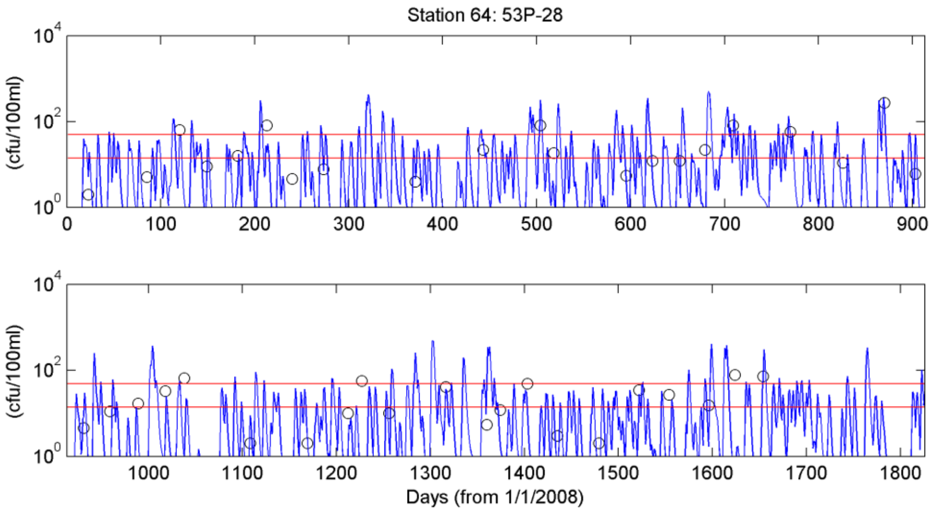
(cfu/100ml)
10^4
10^2
10^0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
Days (from 1/1/2008)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10^2
10^0
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100
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1000
1100
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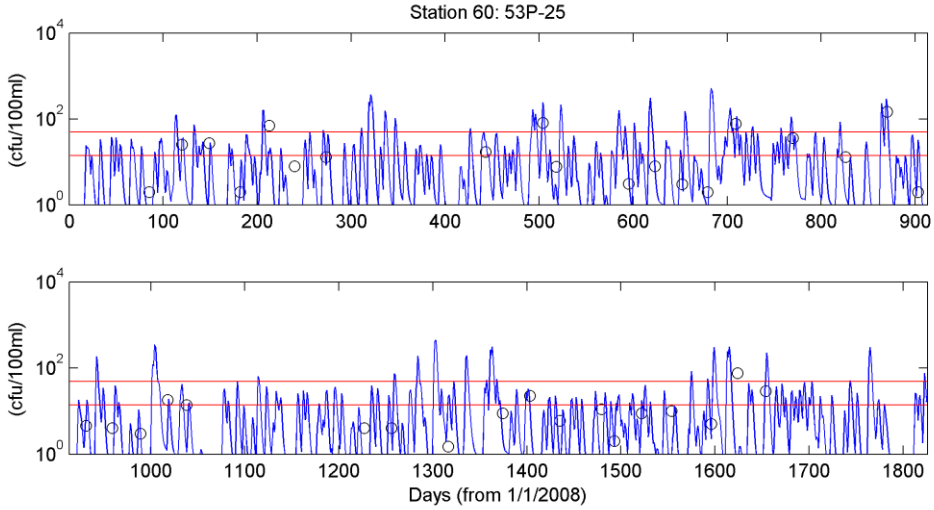
1300
1400
1500
1600
1700
1800
Days (from 1/1/2008)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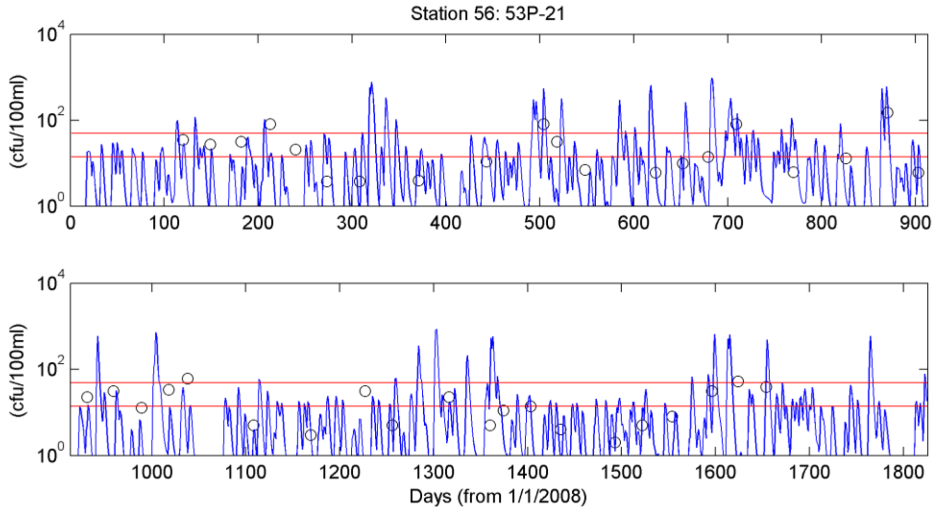
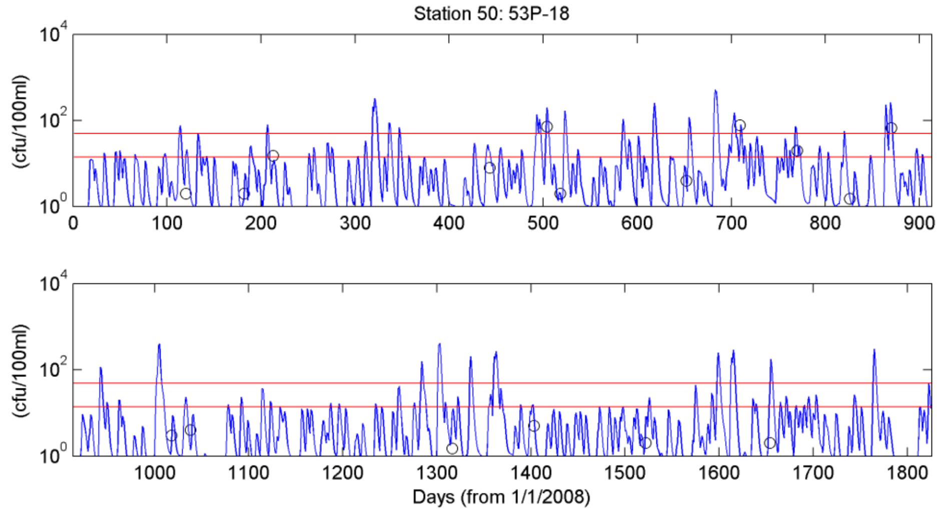
Days (from 1/1/2008)


Station 56: 53P-21
(cfu/100ml)
Days (from 1/1/2008)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Days (from 1/1/2008)

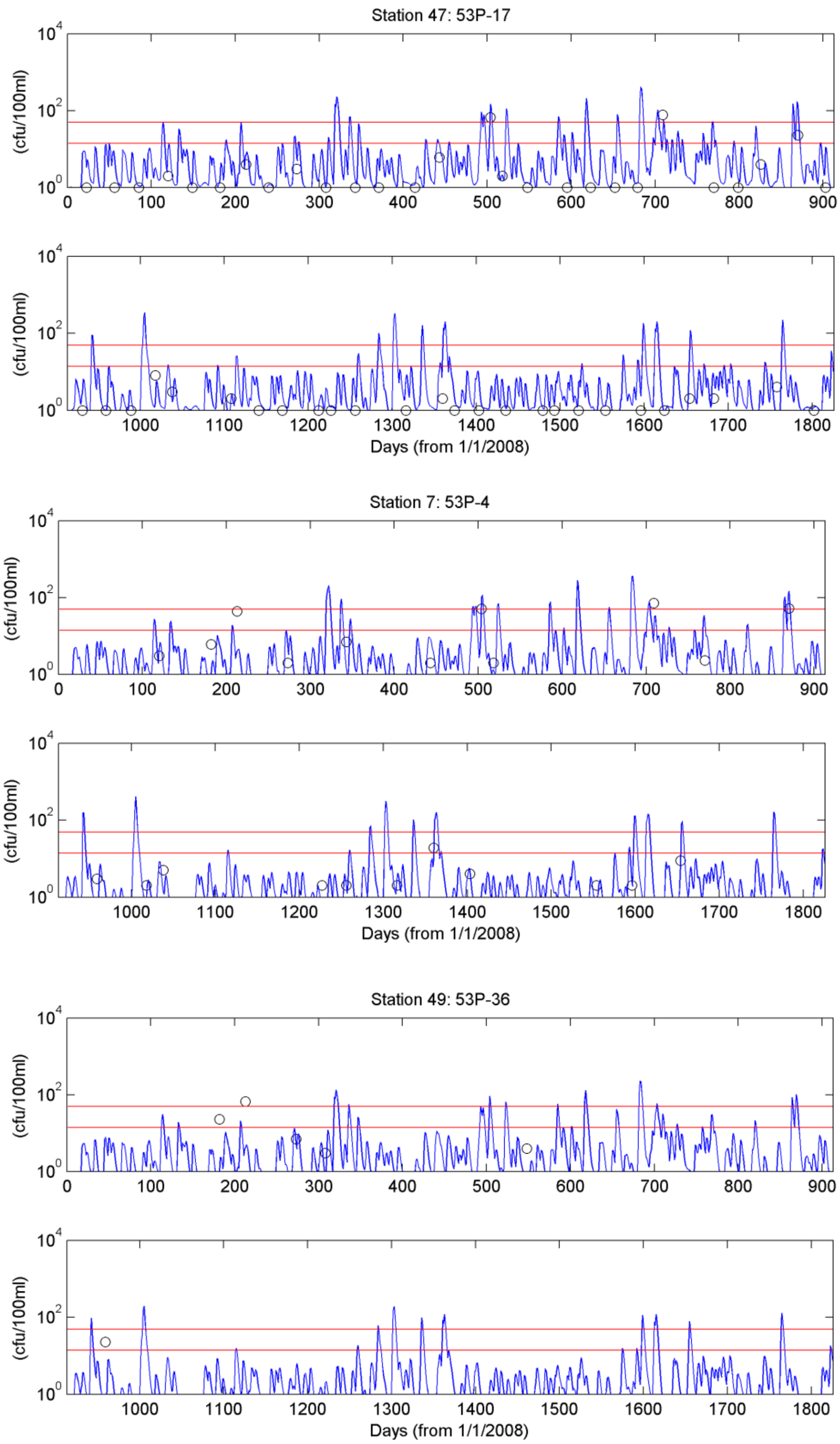


Figure A.5: Model Calibration of Bacteria at Selected Stations in the Impaired Segments

A.2 TMDL Development

A.2.1 Allowable Load

The TMDL was computed for an eight-year period from 2000-2007. The selection of the TMDL development period is based on the available data and hydrological variation in the watershed. The period of 2000-2007 is comprised of extreme low (i.e., 2001), mean, and extreme high (i.e., 2003) precipitation for a 30-year period. This period represents a typical hydrological cycle. According to the bacteria endpoint, a series of loading reductions were conducted to find the allowable loads to evaluate the attainment of acceptable in-stream water quality. With about 24-58% reduction of fecal coliform loadings from different subwatersheds, the water quality standards can be attained.

The attainment of water quality standards was based on 30-month statistics of geometric mean and 90th percentile concentrations. Fecal coliform concentrations at each observation station were assessed to ensure that water quality standards were met. There are two segments (VAT-C07E_LYO01A06 and VAT-C07E_HOD01A08) that violate both primary contact and shellfish criteria. As the 90th percentile shellfish standard is the most stringent criterion, it is used to determine the load reduction. The distribution of 30-month moving geometric mean and 90th percentile concentrations of modeled daily fecal coliform at each assessment station (Table 1.1) was examined to be below the standards. The impaired segments of Roberts Creek (VAT-C07E_ROB01A04) and Cabin Creek upper (VAT-C07E_CAB01A08) have no violation based on current data from 2008-2012. Therefore, the existing loading is used as the TMDL.

A.2.2 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 water quality standard. Absent any other sources, the reduction is allocated to wildlife. The allocations presented demonstrate how the TMDLs could be implemented to achieve water quality standards; however, the state reserves the right to allocate differently, as long as consistency with the achievement of water quality standards 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 Poquoson River, 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 standard deviation divided by the mean.

Using the method described above, *LTA* is the mean daily loading from 2000-2007 for each subwatershed. The daily mean loading and standard deviations with respect to loads were computed. The maximum daily load of fecal coliform was calculated using the above equations. The results of the maximum daily loading were listed in Table 4.1 for Poquoson River. The loading distribution between York County and the City of Poquoson is listed in Table A.2 and the loading distributions by impaired segments are listed in Table A.3. The fecal coliform TMDLs for Impaired Segments are listed in Table A.4. Note that future allocation is not implemented in load and wastewater load allocation.

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

Waterbody	Pollutant	Criterion (MPN/100ml)	Current Load (Counts/Day)	Allowable Load (Counts/Day)	Required Reduction (%)
Poquoson River	Fecal Coliform	90th Percentile: 49	4.73E+12	2.89E+12	39.0%

Table A.2: Estimated Loads and Load Reductions for Fecal Coliform by City and County

Waterbody Name	Jurisdiction	Existing Counts/Day	TMDL Counts/Day	Reduction
Poquoson River	City of Poquoson	1.75E+12	1.00E+12	42.7%
	York County	2.99E+12	1.89E+12	36.7%
	Sum	4.73E+12	2.89E+12	39.0%

Table A.3: Estimated Loads and Load Reductions for Fecal Coliform by Impaired Segments

List ID	Name	Current Load (Counts/Day)	Allowable Load (Counts/Day)	Reduction (%)
VAT-C07E_LMC01A04	Lambs Creek - Poquoson River	1.38E+12	5.84E+11	57.6
VAT-C07E_PTC01A04	Patricks Creek - Poquoson River	1.25E+11	8.55E+10	31.4
VAT-C07E_ROB01A04	Roberts Creek - Upper	8.84E+10	8.84E+10	0.0
VAT-C07E_WHH01A06	White House Cove - Bennett Cr. Area	4.78E+11	3.42E+11	28.5
VAT-C07E_POQ01A06*	Poquoson River - Upper [TMDL-CD]	1.03E+12	7.82E+11	24.0
VAT-C07E_CHS01A06	Chisman Creek-Upper & Goose Cr	1.00E+12	6.11E+11	39.1
VAT-C07E_HOD01A08	Hodges Creek - Upper	2.98E+11	1.57E+11	47.2

VAT-C07E_LYO01A06	Lyons Creek - Upper (DSS_06-IR)	1.10E+11	7.24E+10	34.5
VAT-C07E_FLY01A06	Floyds Bay	1.36E+11	1.02E+11	24.9
VAT-C07E_CAB01A08	Cabin Creek - Upper	3.35E+10	3.35E+10	0.0
VAT-C07E_POQ01B08	Poquoson Upper downstream POQ01A06	4.36E+10	2.32E+10	46.7
VAT-C07E_POQ02B08	Unnamed Cove @Crane	1.34E+10	9.17E+09	31.4
Sum		4.73E+12	2.89E+12	39.0

*Loading includes the watershed of Harwood Mills Reservoir although it has minor influence to the downstream due to dilution and bacterial die-off.

Table A.4: The fecal coliform TMDLs for Impaired Segments

List ID	TMDL	LA	WLA	MOS
VAT-C07E_LMC01A04	5.84E+11	4.45E+11	1.39E+11	Implicit
VAT-C07E_PTC01A04	8.55E+10	7.39E+10	1.16E+10	Implicit
VAT-C07E_ROB01A04	8.84E+10	7.37E+10	1.47E+10	Implicit
VAT-C07E_WHH01A06	3.42E+11	1.95E+11	1.47E+11	Implicit
VAT-C07E_POQ01A06	7.82E+11	6.19E+11	1.63E+11	Implicit
VAT-C07E_CHS01A06	6.11E+11	4.91E+11	1.21E+11	Implicit
VAT-C07E_HOD01A08	1.57E+11	1.53E+11	4.41E+09	Implicit
VAT-C07E_LYO01A06	7.24E+10	5.19E+10	2.05E+10	Implicit
VAT-C07E_FLY01A06	1.02E+11	8.81E+10	1.43E+10	Implicit
VAT-C07E_CAB01A08	3.35E+10	3.09E+10	2.55E+09	Implicit
VAT-C07E_POQ01B08	2.32E+10	2.14E+10	1.84E+09	Implicit
VAT-C07E_POQ02B08	9.17E+09	7.93E+09	1.25E+09	Implicit
Sum	2.89E+12	2.25E+12	6.40E+11	

A.3 Source Distribution and Load Allocation

Finally, the results of the fecal coliform loading for each source category estimated by the watershed approach and model simulations were used to partition the load allocation that would meet water quality standards according to sources. Although an SSO does not occur very often, it is considered as a controllable source. The activities of boating (marinas) are considered as well and allocated to the entire area. Because the source contribution for each subwatershed was adjusted proportionally to each source during the model calibration process in order to account for the uncertainty of loading estimation and unknown sources, the allocation provides a general guideline for the source distribution. These sources cannot be addressed without public understanding of, and support for, the implementation process. An allocation is summarized in Table A.5. The 100% reduction scenario for human related sources is to show probable human influence to the impairment.

Table A.5: Reduction of Potential Sources

Waterbody Name	Category	Current Load (Counts/Day)	Percentage	Allowable Load (Counts/Day)	Reduction Needed (%)
Poquoson River	**Wildlife**	3.10E+12	65.54	2.89E+12	6.8
	Pets	1.07E+12	22.62	0.00E+00	100.0
	Livestock	2.34E+11	4.94	0.00E+00	100.0
	Septic	2.61E+09	0.06	0.00E+00	100.0
	SSO	2.21E+11	4.68	0.00E+00	100.0
	Marina	1.03E+11	2.18	0.00E+00	100.0
	Total	4.73E+12	100.0	2.89E+12	39.0
Back Creek	**Wildlife**	3.36E+11	79.44	3.36E+11	0.0
	Pets	8.65E+10	20.47	4.55E+10	47.4
	Livestock	3.39E+08	<1	0.00E+00	100.0
	Septic	7.71E+07	<0	0.00E+00	100.0
	SSO	0	0	0	
	Marina	0	0	0	
	Total	4.22E+11	100	3.81E+11	9.8

The distribution of source distribution, current load, and reduction required for each listed area are summarized in Table A.6. The sources from humans are the sum of failing septic systems, boating activities, and potential SSOs. As SSOs only occurred less than 11 times over in a year, they do not contribute significantly to daily loading. The estimation of SSOs was based on the 95th percentile flow of incidents that occurred in that watershed. The estimation can be considered as a worst-case scenario. The contributions of marinas (boating activities) were not included in the allocations to each subwatershed of the impaired area.

Table A.6: Load Allocation and Required Reduction for Fecal Coliform

Area	Name	Percent	Current Load (Counts/Day)	Load Allocation (Counts/Day)	Reduction (%)
Lambs Creek	Human	63.0%	8.676E+11	7.578E+10	91.3
	Livestock	0.0%	5.500E+08	0	100.0
	Pet	11.9%	1.644E+11	1.644E+11	0.0
	Wildlife	25.0%	3.437E+11	3.437E+11	0.0
	Total	100.0%	1.376E+12	5.838E+11	57.6
Patricks Creek/unnamed Cove @ Crane*	Human	2.4%	3.348E+09	0	100.0
	Livestock	16.2%	2.230E+10	0	100.0
	Pet	13.7%	1.895E+10	1.344E+09	92.9
	Wildlife	67.7%	9.336E+10	9.336E+10	0.0
	Total	100.0%	1.380E+11	9.47E+10	31.4

Roberts Creek	Human	0.0%	0.000E+00	0	0.0
	Livestock	0.0%	0.000E+00	0	0.0
	Pet	24.4%	2.156E+10	2.156E+10	0.0
	Wildlife	75.6%	6.681E+10	6.681E+10	0.0
	Total	100.0%	8.837E+10	8.837E+10	0.0
White House Cove	Wildlife	0.0%	0.000E+00	0	0.0
	Human	0.0%	0.000E+00	0	0.0
	Livestock	44.1%	2.108E+11	7.458E+10	64.6
	Pet	55.9%	2.672E+11	2.672E+11	0.0
	Total	100.0%	4.780E+11	3.418E+11	28.5
Poquoson River-Upper /Poquoson Upper downstream*	Human	10.0%	1.069E+11	0	100.0
	Livestock	0.0%	1.771E+08	0	100.0
	Pet	26.2%	2.815E+11	1.21E+11	56.9
	Wildlife	63.8%	6.841E+11	6.841E+11	0.0
	Total	100.0%	1.073E+12	8.05E+11	24.9
Chisman Creek-upper	Human	0.2%	2.421E+09	0	100.0
	Livestock	20.3%	2.036E+11	0	100.0
	Pet	21.6%	2.165E+11	3E+10	86.1
	Wildlife	57.9%	5.813E+11	5.813E+11	0.0
	Total	100.0%	1.004E+12	6.113E+11	39.1
Hodges River-upper	Human	0.0%	0.000E+00	0	0.0
	Livestock	0.0%	0.000E+00	0	0.0
	Pet	5.2%	1.540E+10	0	100.0
	Wildlife	94.8%	2.823E+11	1.572E+11	44.3
	Total	100.0%	2.977E+11	1.572E+11	47.2
Lyons Creek-upper	Human	0.0%	0.000E+00	0	0.0
	Livestock	0.0%	0.000E+00	0	0.0
	Pet	37.3%	4.116E+10	3.1E+09	92.5
	Wildlife	62.7%	6.925E+10	6.925E+10	0.0
	Total	100.0%	1.104E+11	7.235E+10	34.5
Floyds Bay	Human	0.0%	1.581E+07	0	100.0
	Livestock	0.0%	0.000E+00	0	0.0
	Pet	24.0%	3.272E+10	0	100.0
	Wildlife	76.0%	1.036E+11	1.024E+11	1.2
	Total	100.0%	1.363E+11	1.024E+11	24.9
Cabin Creek-upper	Human	0.0%	0.000E+00	0	0.0
	Livestock	0.0%	0.000E+00	0	0.0
	Pet	12.4%	4.158E+09	4.158E+09	0.0
	Wildlife	87.6%	2.930E+10	2.93E+10	0.0
	Total	100.0%	3.346E+10	3.346E+10	0.0

*Watershed at the downstream is influenced by the upstream and the loading distributions of both the upstream and downstream are reported together.

Appendix B: Fecal coliform data collected by the Virginia Department of Health, Division of Shellfish Sanitation (VDH-DSS) in the Poquoson River

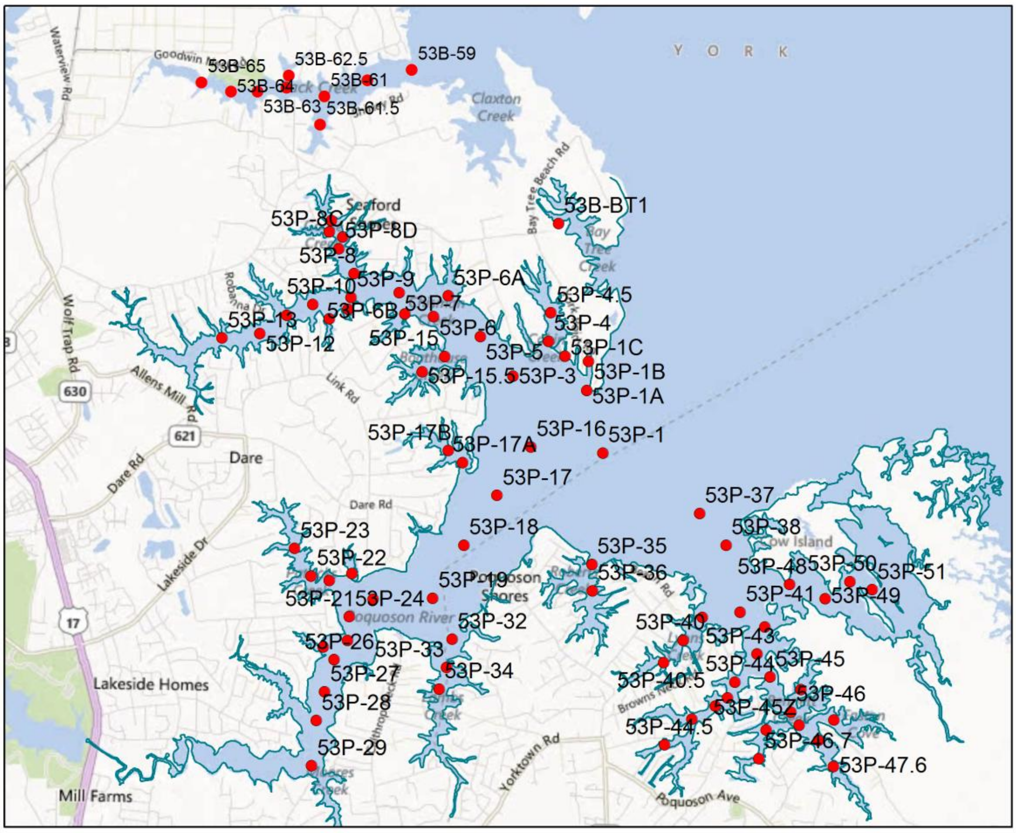
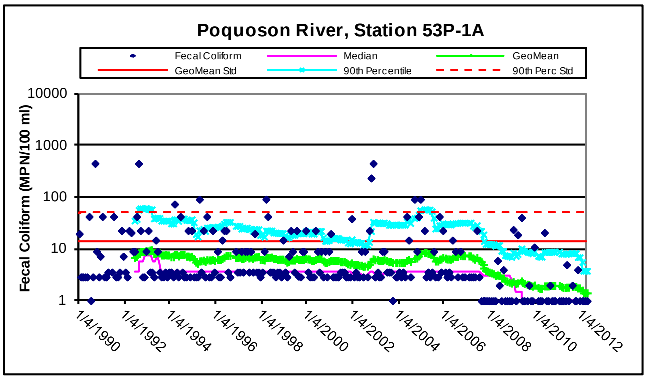
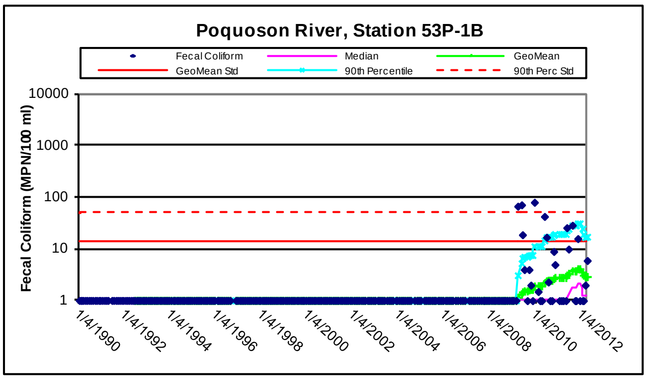
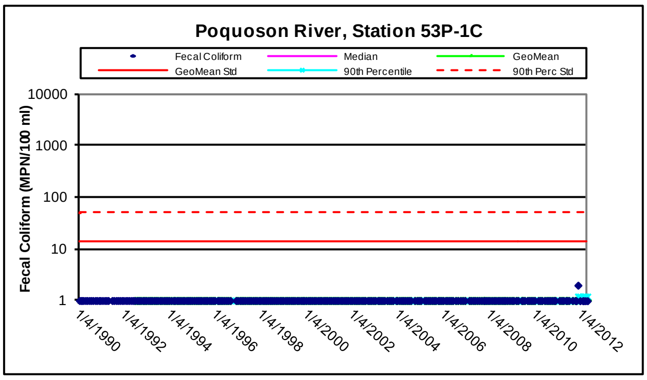
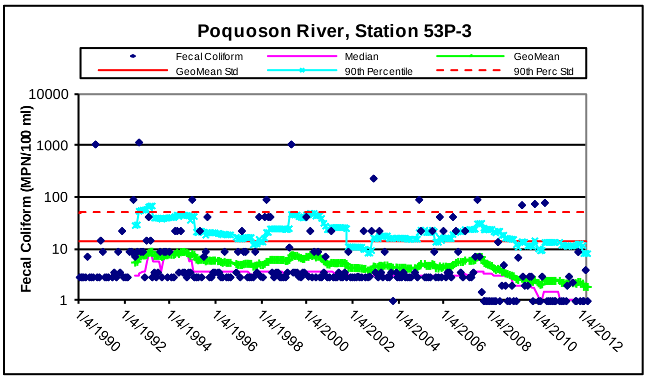


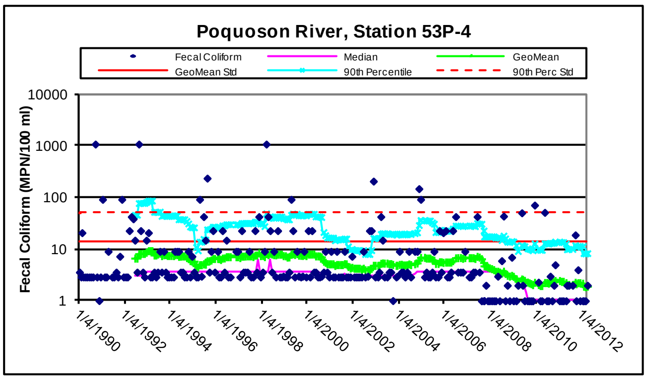
Figure B.1: Locations of VDH-DSS stations monitored in the Poquoson River (1990-2012)

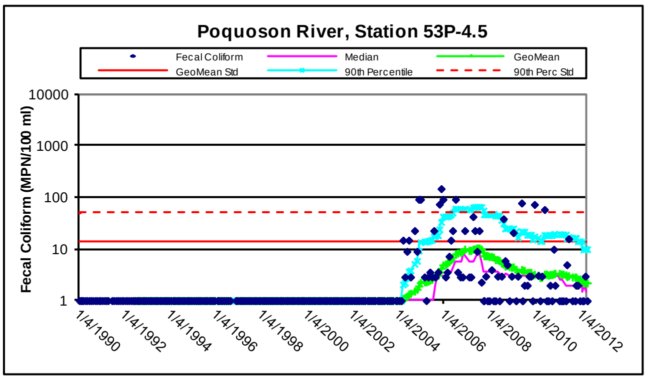

Poquoson River, Station 53P-1A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

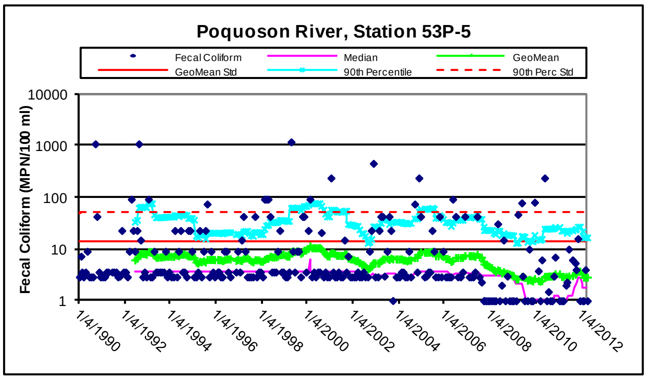

Poquoson River, Station 53P-1B
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

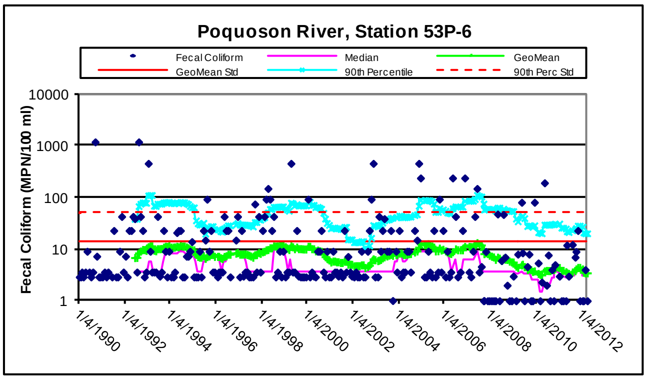

Poquoson River, Station 53P-1C
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

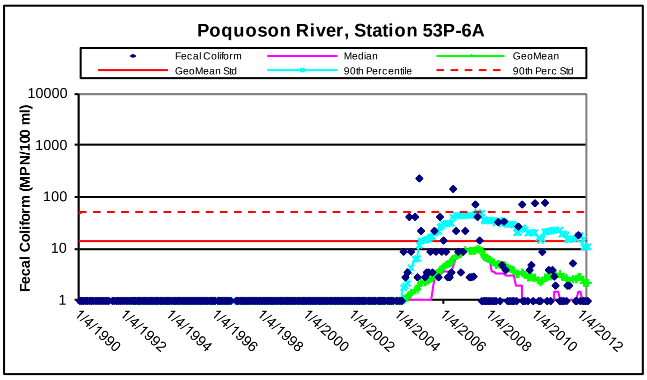

Poquoson River, Station 53P-3
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

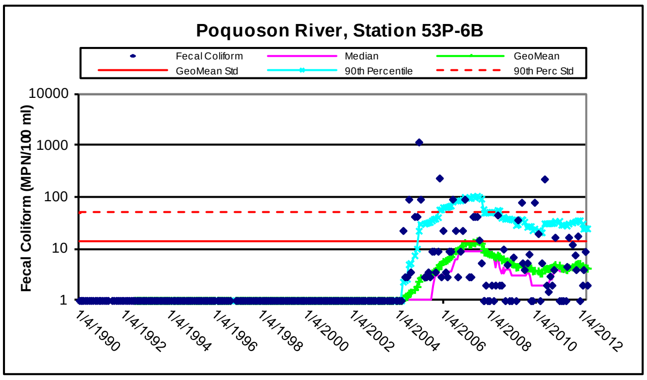

Poquoson River, Station 53P-4
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

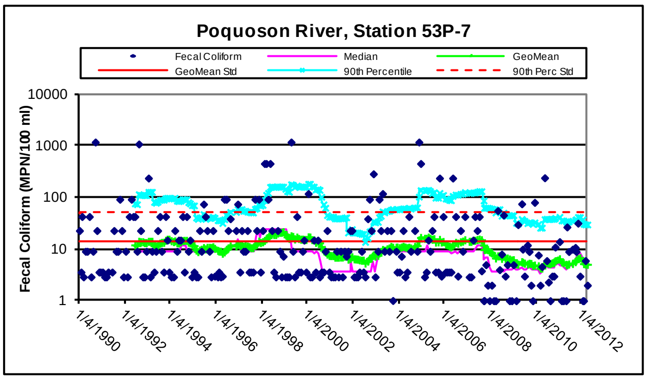

Poquoson River, Station 53P-4.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

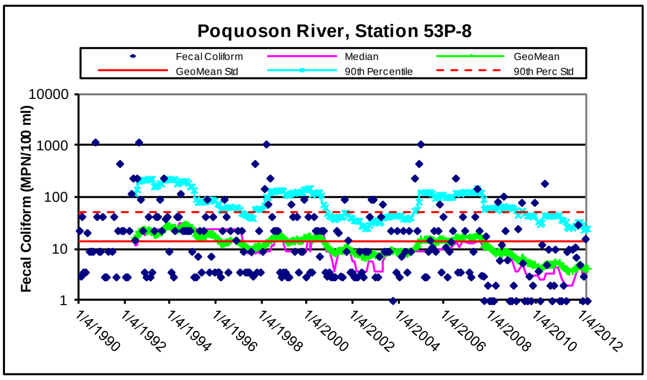

Poquoson River, Station 53P-5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

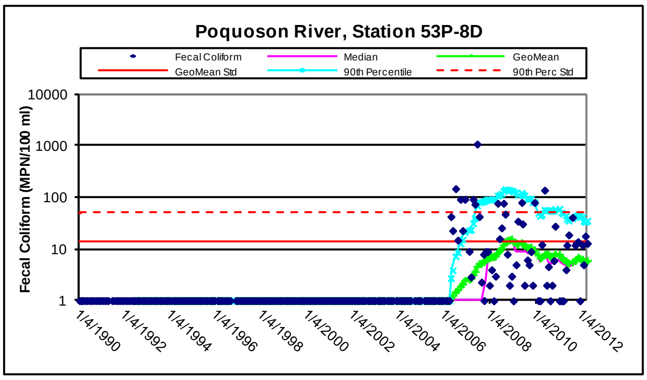

Poquoson River, Station 53P-6
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

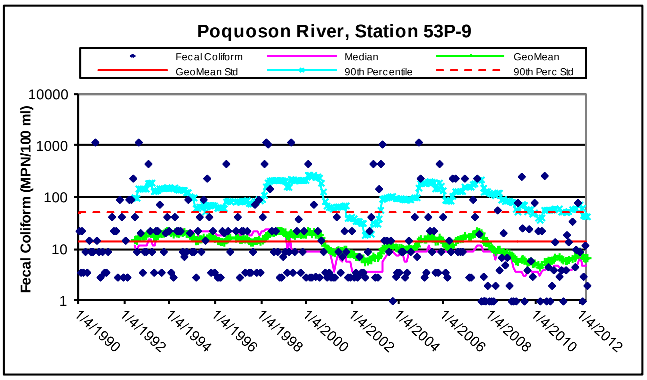

Poquoson River, Station 53P-6A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

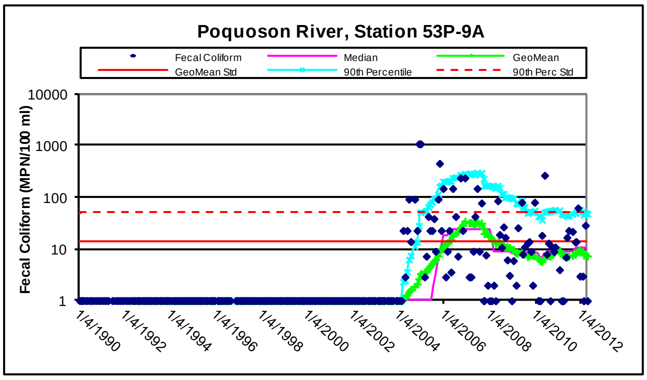

Poquoson River, Station 53P-6B
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

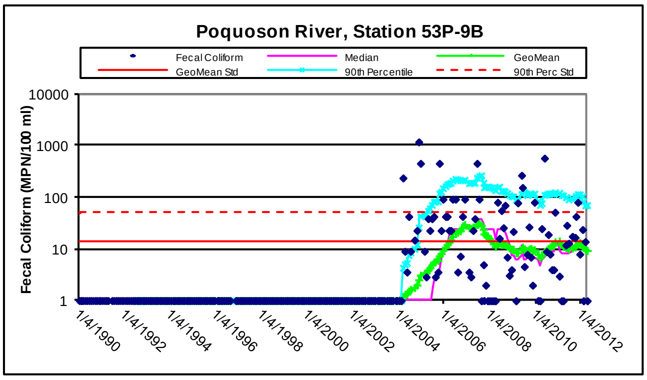

Poquoson River, Station 53P-7
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

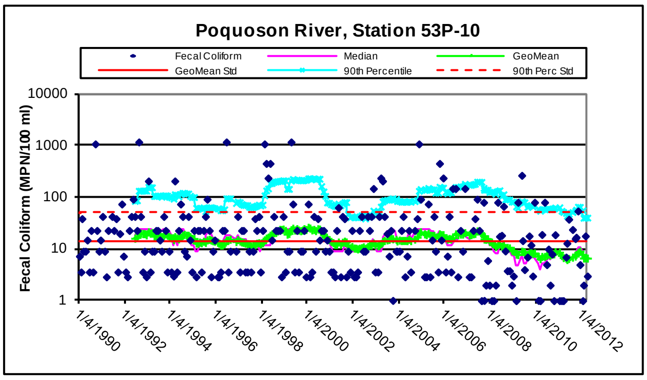

Poquoson River, Station 53P-8
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

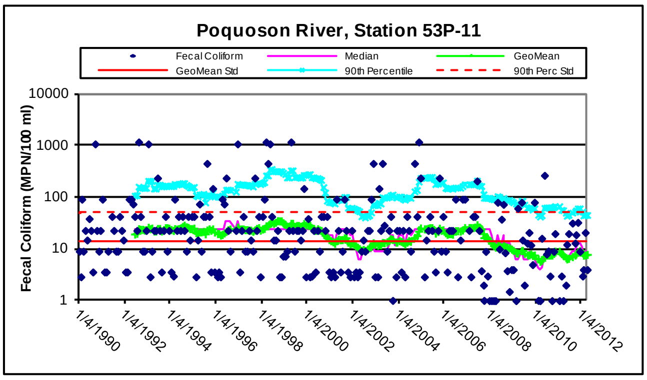

Poquoson River, Station 53P-8D
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

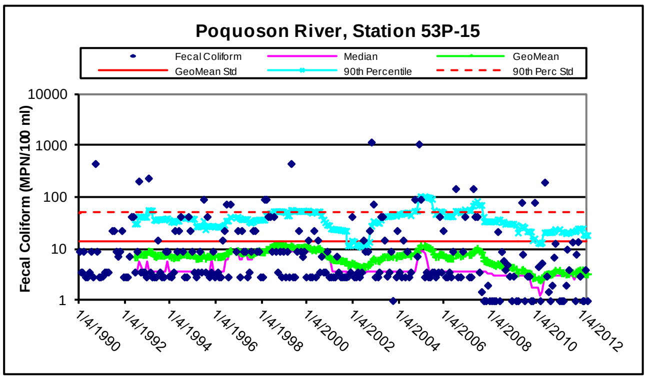

Poquoson River, Station 53P-9
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

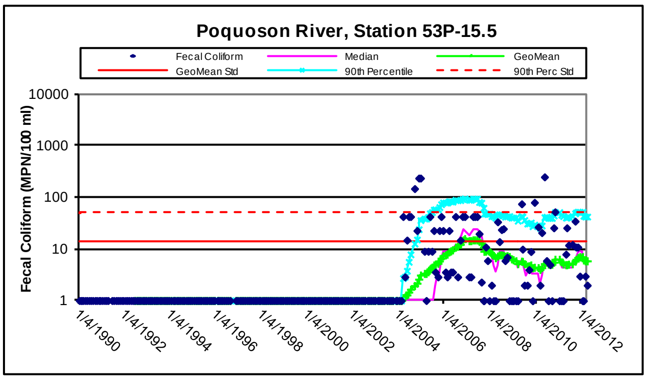

Poquoson River, Station 53P-9A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

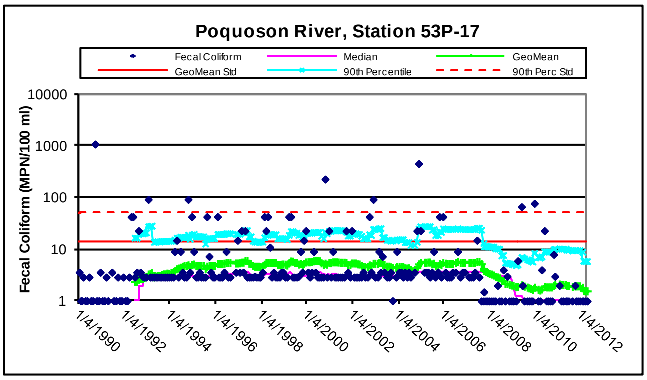

Poquoson River, Station 53P-9B
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

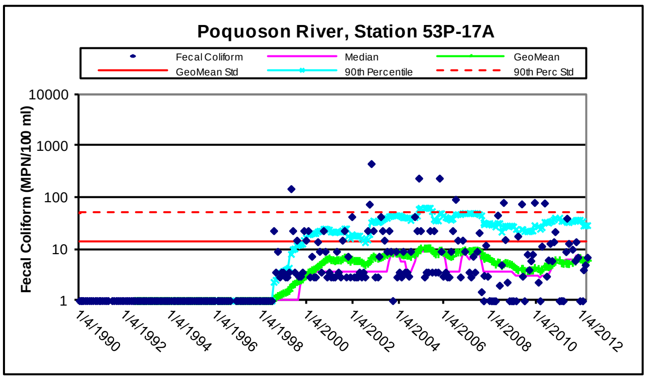

Poquoson River, Station 53P-10
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

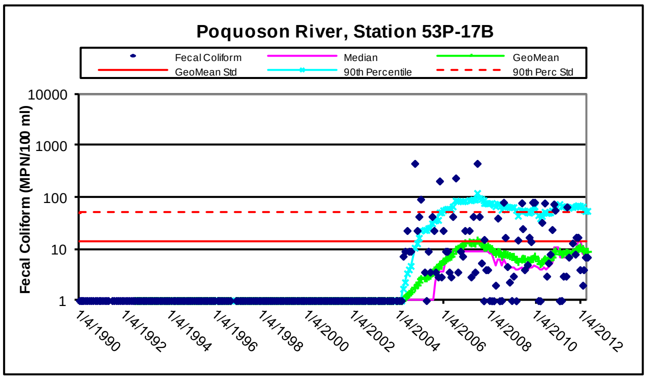

Poquoson River, Station 53P-11
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

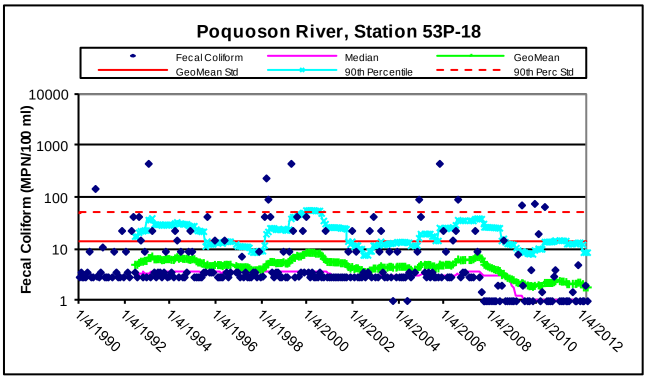

Poquoson River, Station 53P-15
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

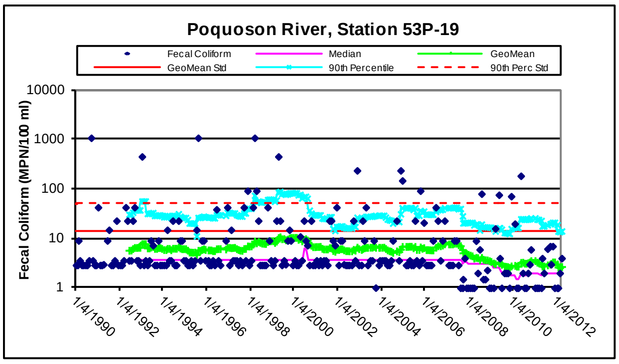

Poquoson River, Station 53P-15.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

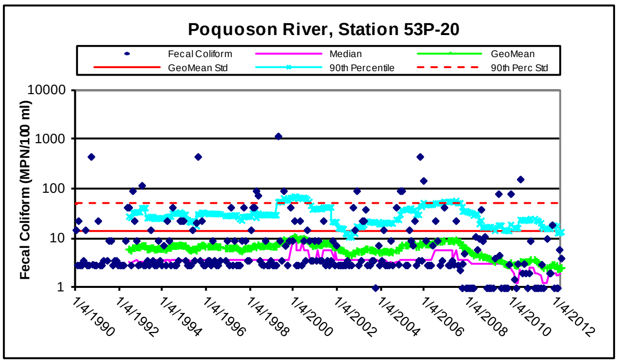

Poquoson River, Station 53P-17
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

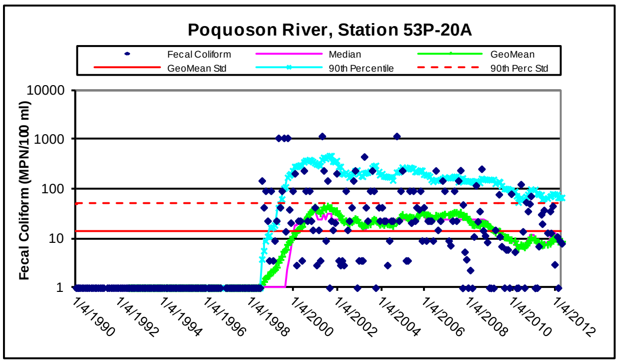

Poquoson River, Station 53P-17A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

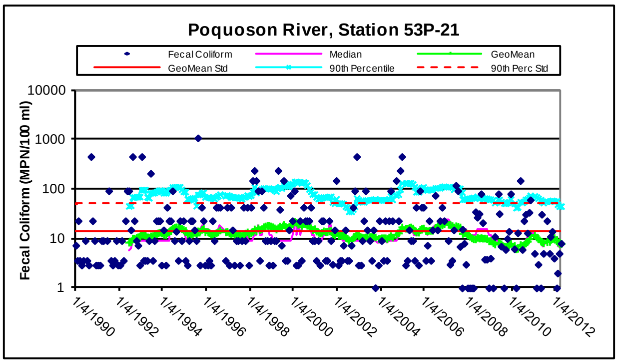

Poquoson River, Station 53P-17B
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

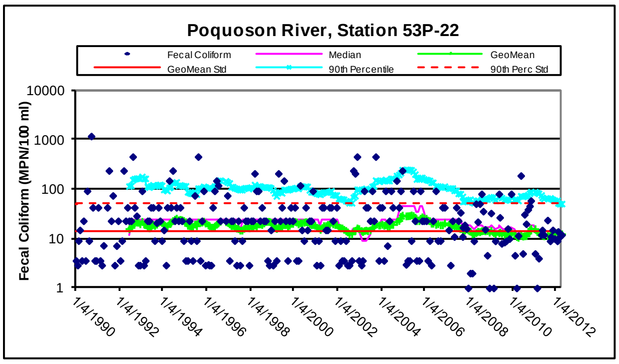

Poquoson River, Station 53P-18
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

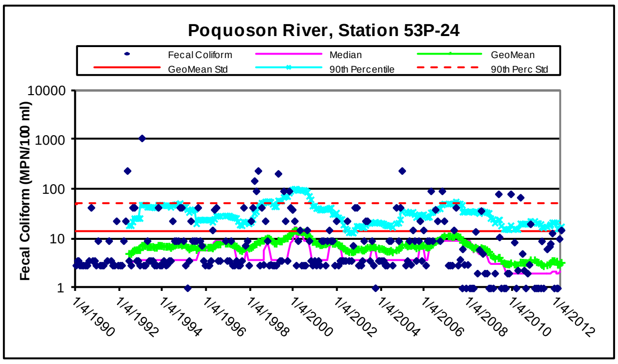

Poquoson River, Station 53P-19
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

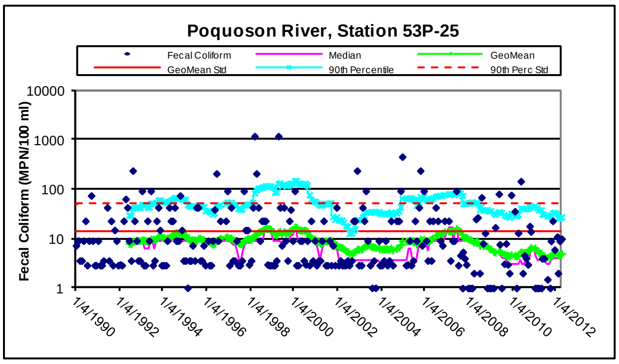

Poquoson River, Station 53P-20
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

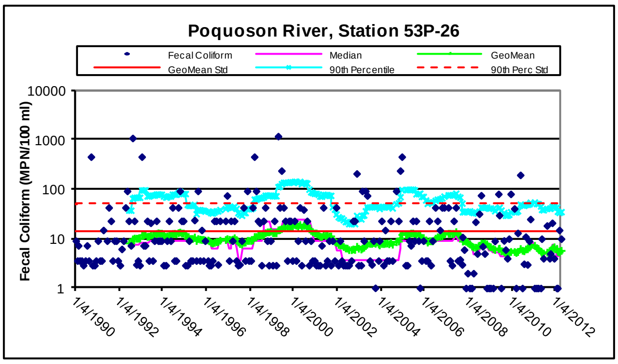

Poquoson River, Station 53P-20A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

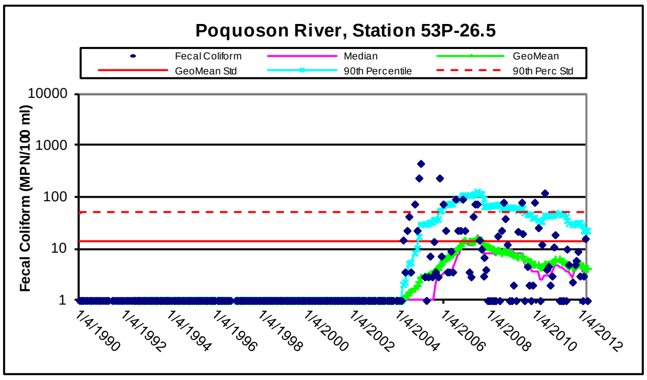

Poquoson River, Station 53P-21
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

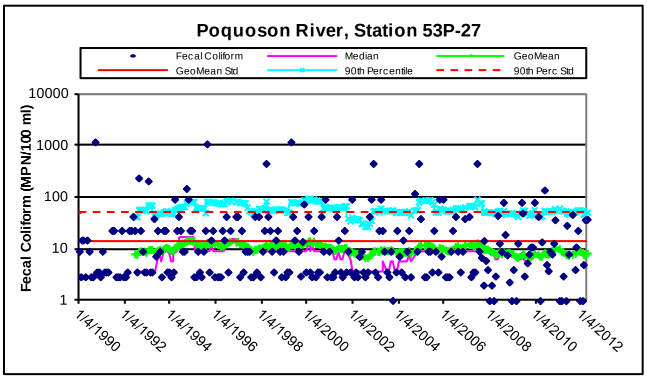

Poquoson River, Station 53P-22
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

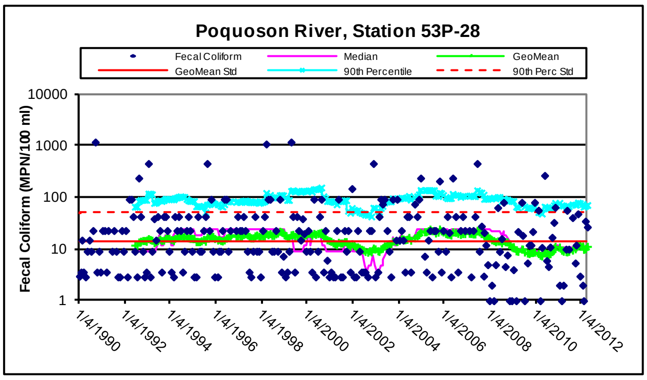

Poquoson River, Station 53P-24
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

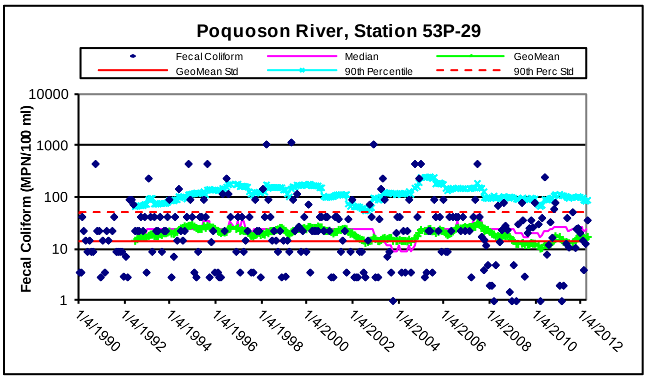

Poquoson River, Station 53P-25
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

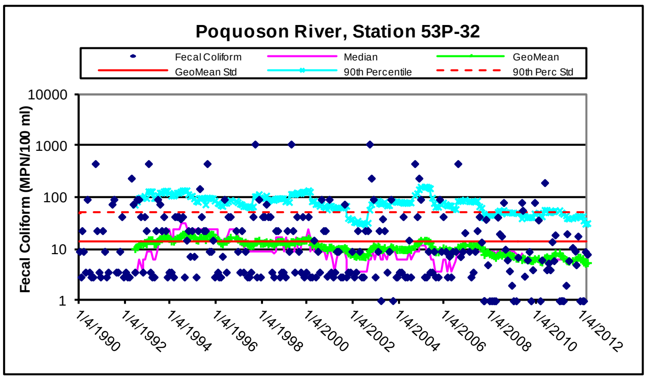

Poquoson River, Station 53P-26
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

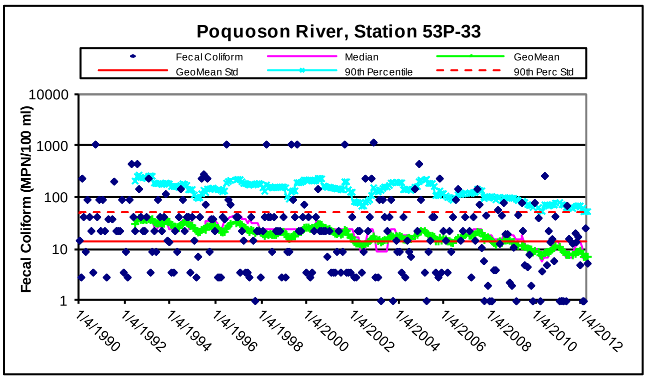

Poquoson River, Station 53P-26.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

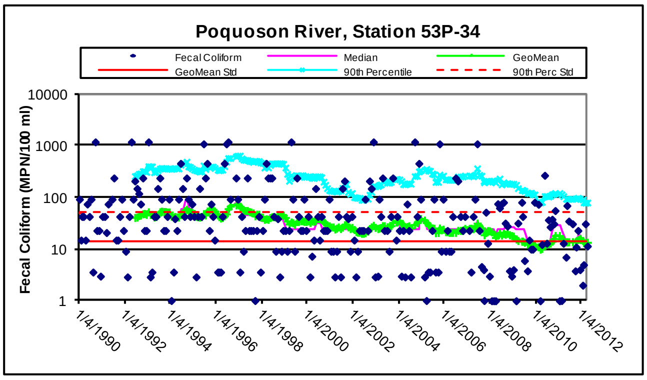

Poquoson River, Station 53P-27
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

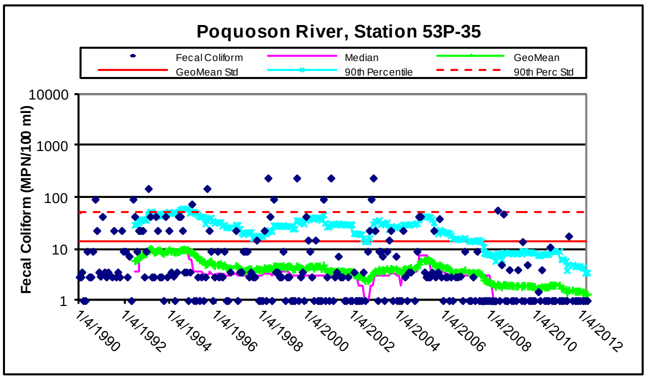

Poquoson River, Station 53P-28
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

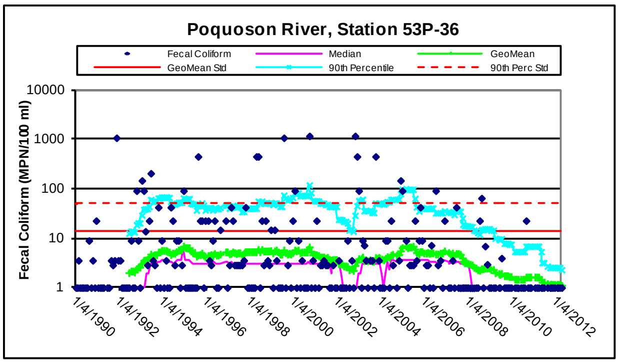

Poquoson River, Station 53P-29
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

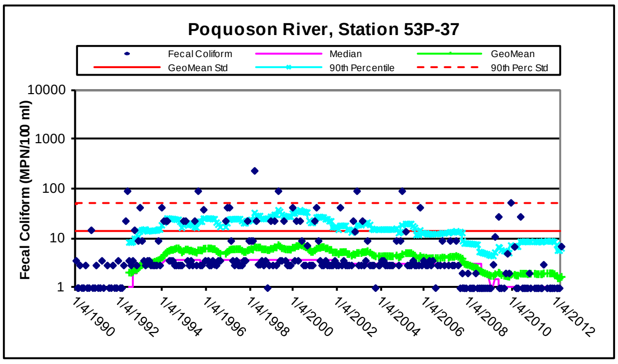

Poquoson River, Station 53P-32
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

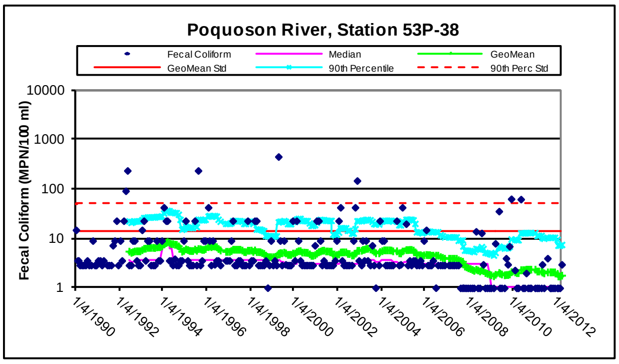

Poquoson River, Station 53P-33
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

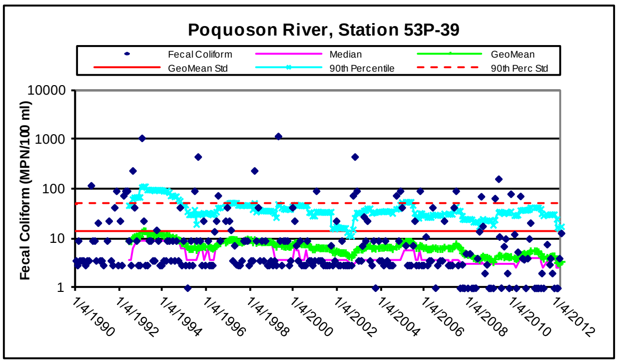

Poquoson River, Station 53P-34
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

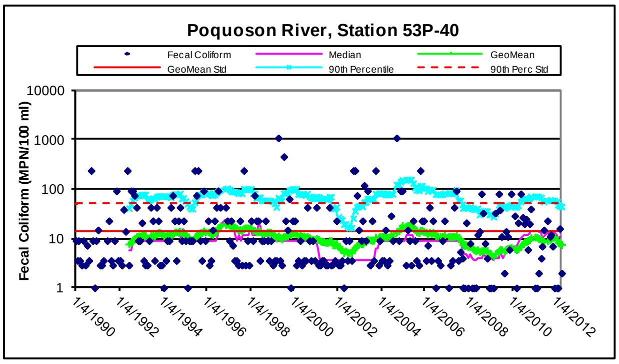

Poquoson River, Station 53P-35
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

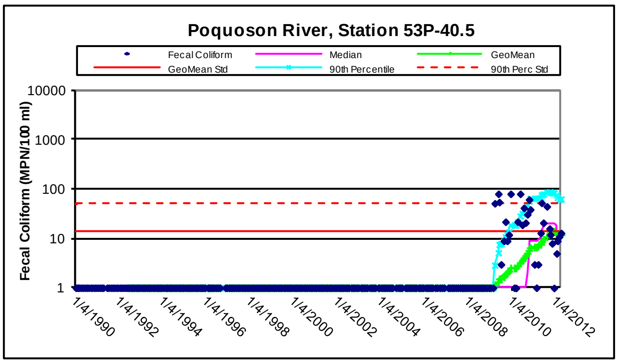

Poquoson River, Station 53P-36
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

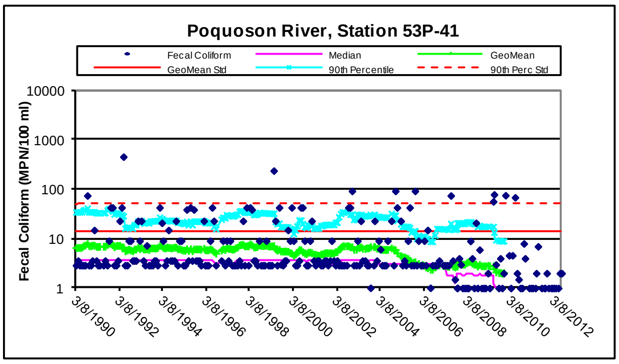

Poquoson River, Station 53P-37
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

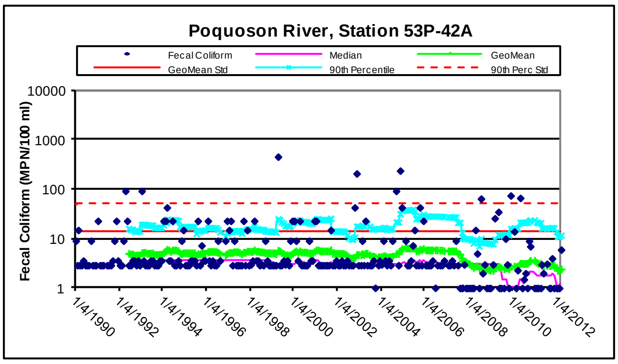

Poquoson River, Station 53P-38
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

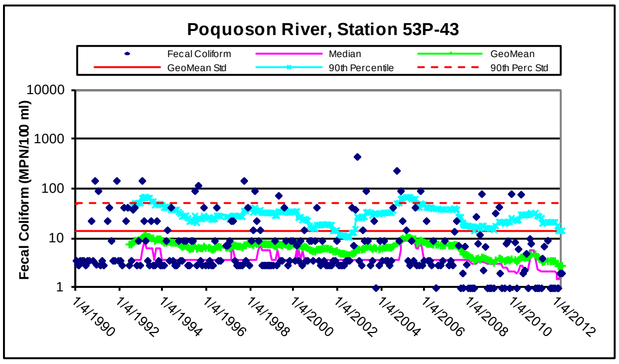

Poquoson River, Station 53P-39
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

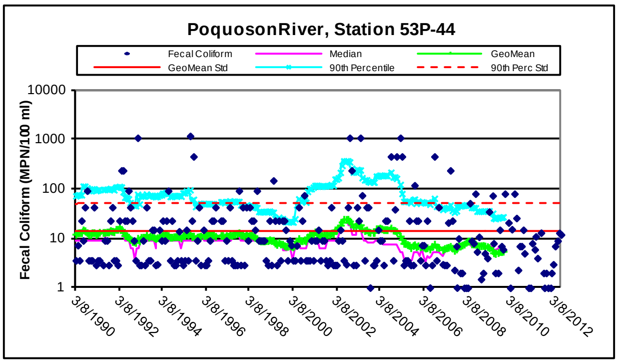

Poquoson River, Station 53P-40
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

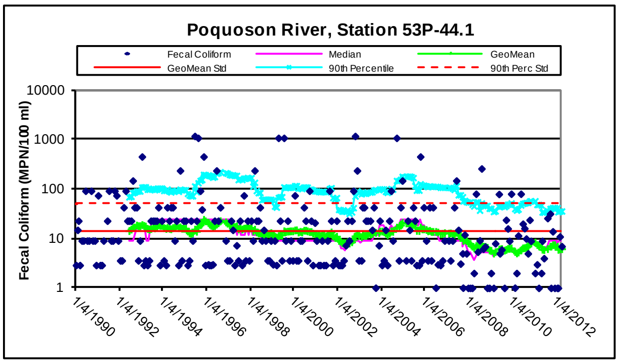

Poquoson River, Station 53P-40.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

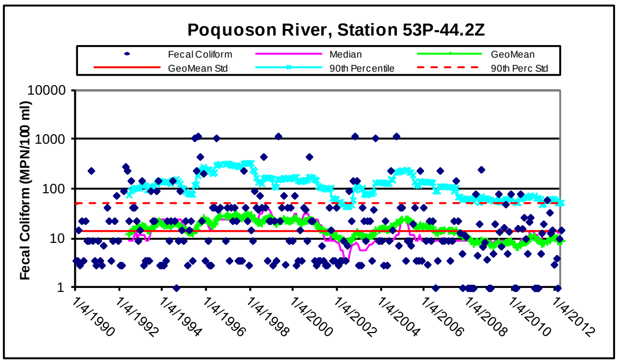

Poquoson River, Station 53P-41
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
3/8/1990
3/8/1992
3/8/1994
3/8/1996
3/8/1998
3/8/2000
3/8/2002
3/8/2004
3/8/2006
3/8/2008
3/8/2010
3/8/2012

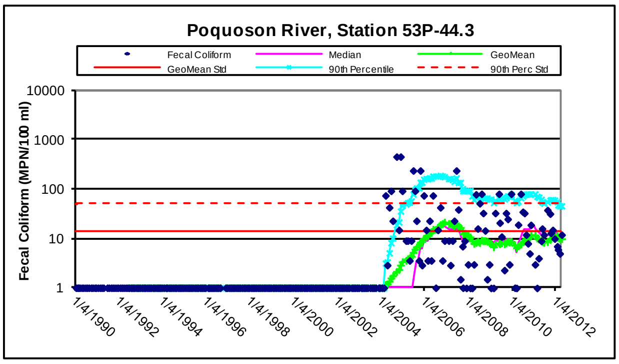

Poquoson River, Station 53P-42A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

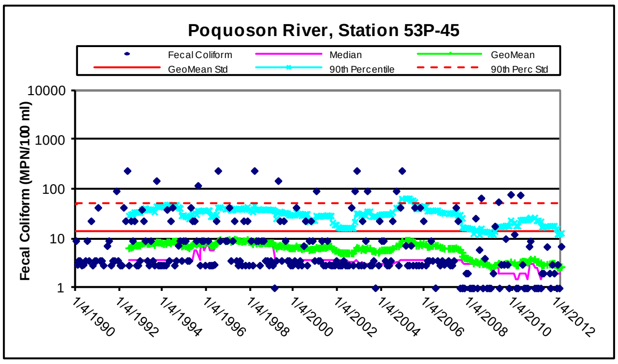

Poquoson River, Station 53P-43
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

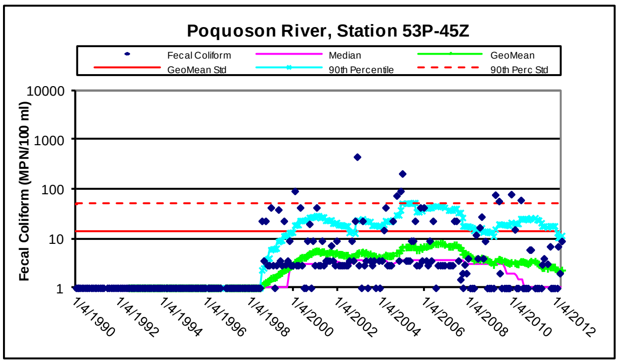

PoquosonRiver, Station 53P-44
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
3/8/1990
3/8/1992
3/8/1994
3/8/1996
3/8/1998
3/8/2000
3/8/2002
3/8/2004
3/8/2006
3/8/2008
3/8/2010
3/8/2012

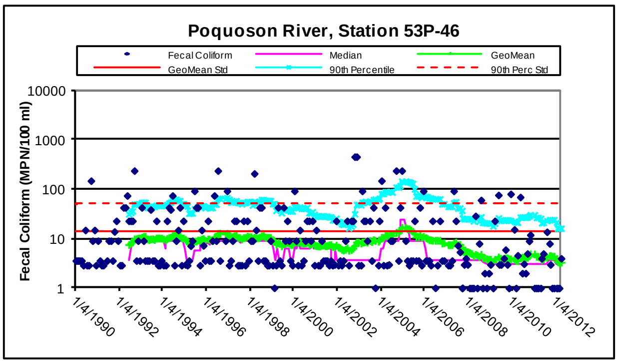

Poquoson River, Station 53P-44.1
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

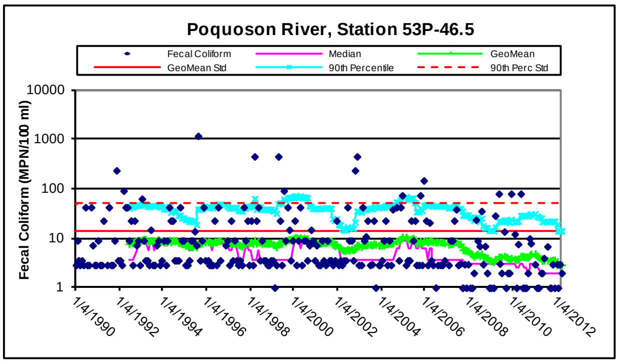

Poquoson River, Station 53P-44.2Z
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

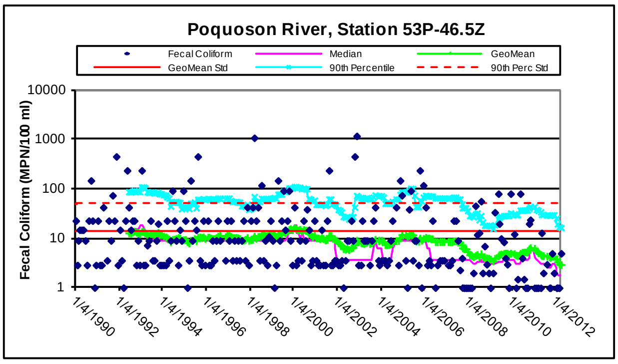

Poquoson River, Station 53P-44.3
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

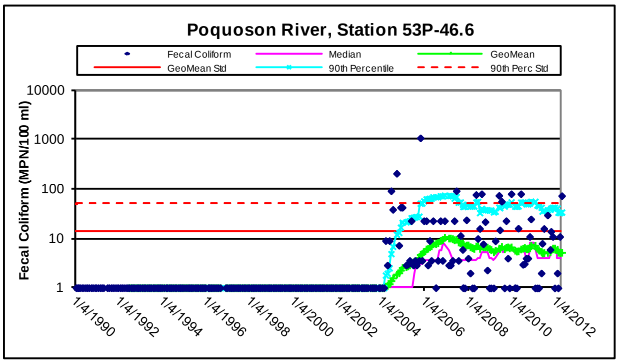

Poquoson River, Station 53P-45
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

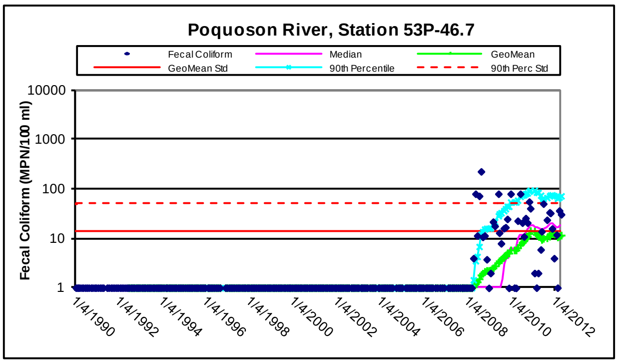

Poquoson River, Station 53P-45Z
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

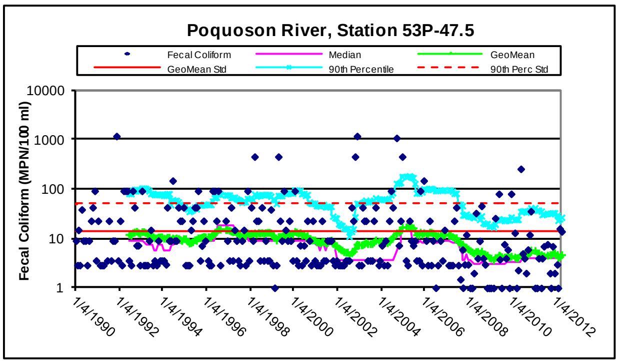

Poquoson River, Station 53P-46
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

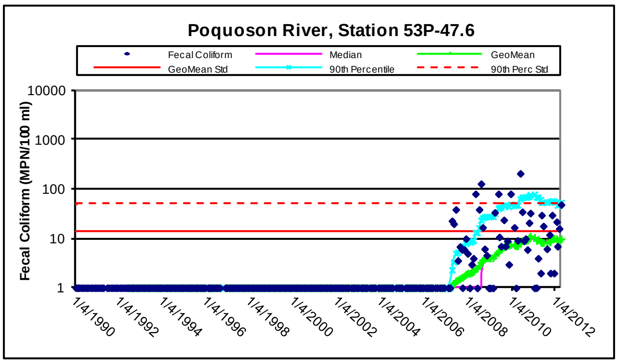

Poquoson River, Station 53P-46.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

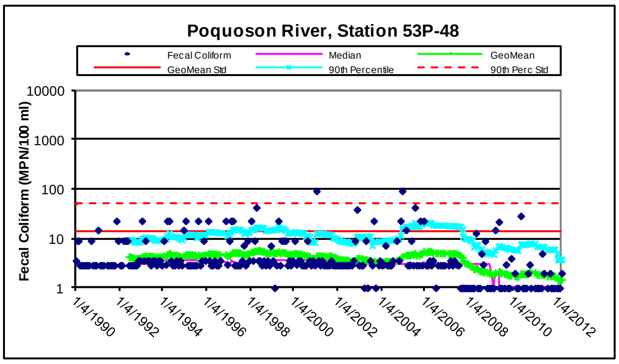

Poquoson River, Station 53P-46.5Z
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

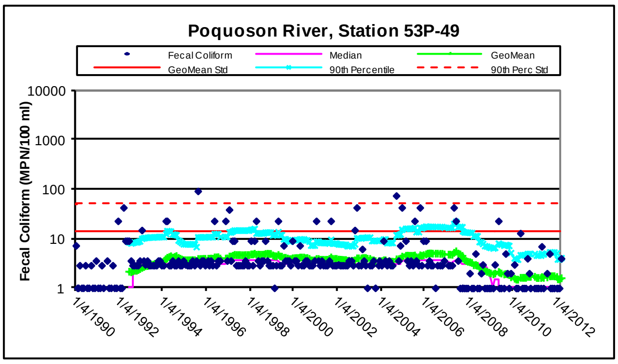

Poquoson River, Station 53P-46.6
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

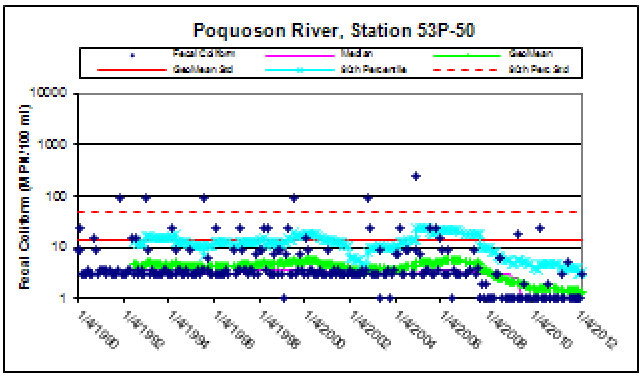

Poquoson River, Station 53P-46.7
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

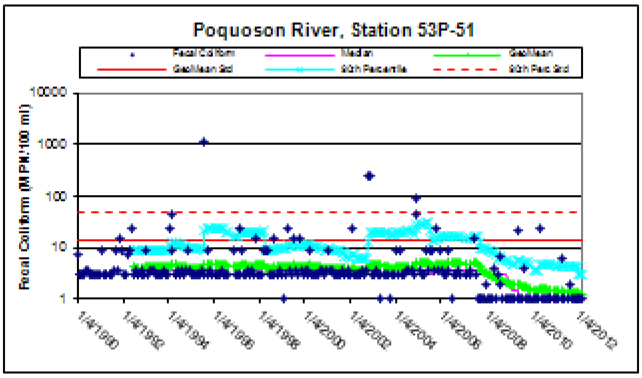

Poquoson River, Station 53P-47.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

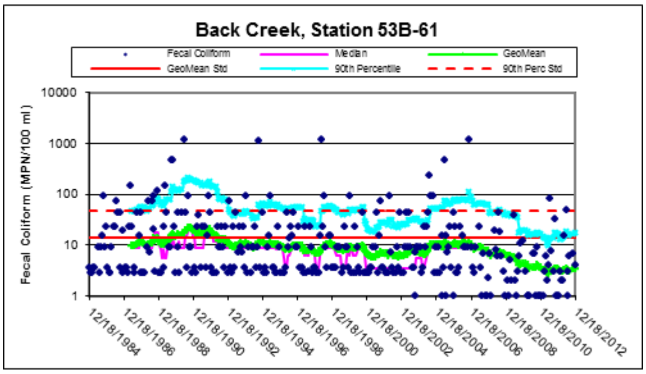

Poquoson River, Station 53P-47.6
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

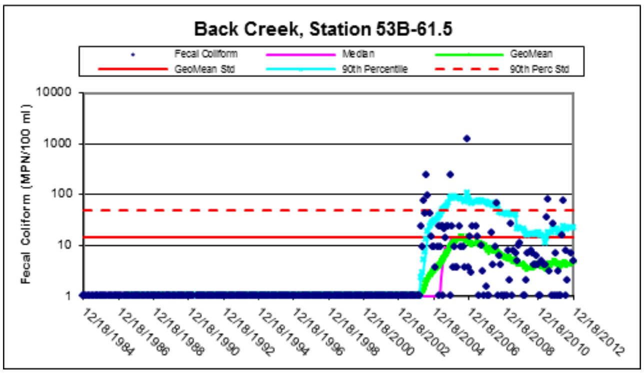

Poquoson River, Station 53P-48
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

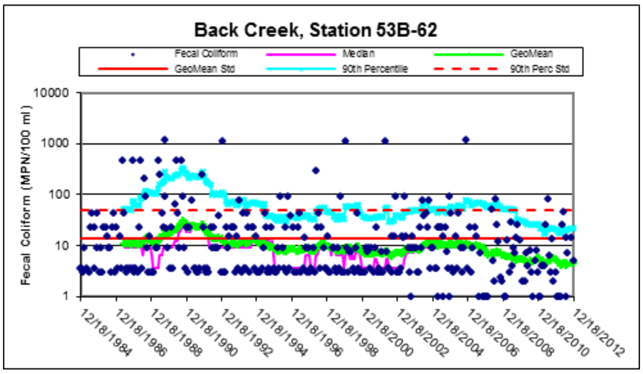

Poquoson River, Station 53P-49
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

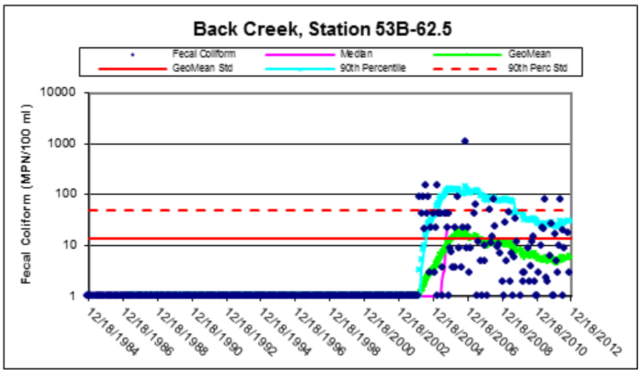

Poquoson River, Station 53P-50
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

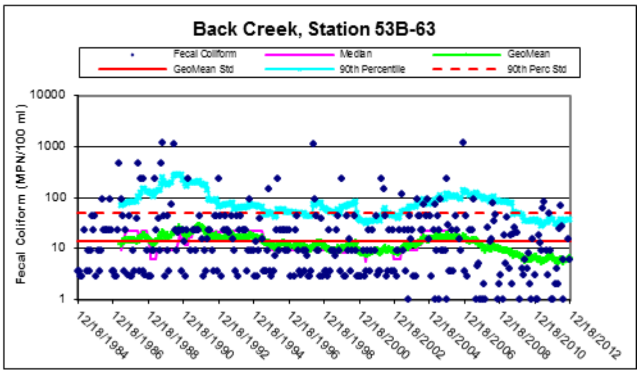

Poquoson River, Station 53P-51
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/4/1990
1/4/1992
1/4/1994
1/4/1996
1/4/1998
1/4/2000
1/4/2002
1/4/2004
1/4/2006
1/4/2008
1/4/2010
1/4/2012

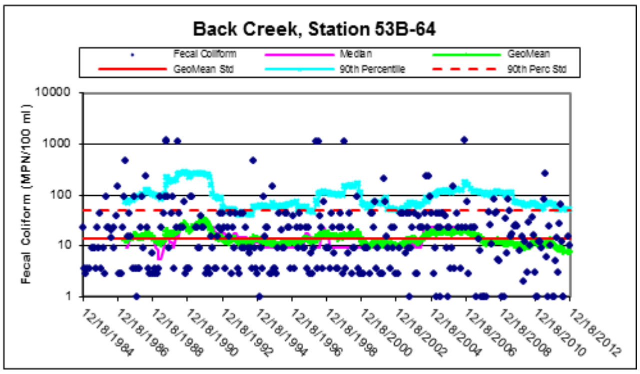

Back Creek, Station 53B-61
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
12/18/1984
12/18/1986
12/18/1988
12/18/1990
12/18/1992
12/18/1994
12/18/1996
12/18/1998
12/18/2000
12/18/2002
12/18/2004
12/18/2006
12/18/2008
12/18/2010
12/18/2012


Back Creek, Station 53B-61.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
12/18/1984
12/18/1986
12/18/1988
12/18/1990
12/18/1992
12/18/1994
12/18/1996
12/18/1998
12/18/2000
12/18/2002
12/18/2004
12/18/2006
12/18/2008
12/18/2010
12/18/2012


Back Creek, Station 53B-62
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
12/18/1984
12/18/1986
12/18/1988
12/18/1990
12/18/1992
12/18/1994
12/18/1996
12/18/1998
12/18/2000
12/18/2002
12/18/2004
12/18/2006
12/18/2008
12/18/2010
12/18/2012


Back Creek, Station 53B-62.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
12/18/1984
12/18/1986
12/18/1988
12/18/1990
12/18/1992
12/18/1994
12/18/1996
12/18/1998
12/18/2000
12/18/2002
12/18/2004
12/18/2006
12/18/2008
12/18/2010
12/18/2012


Back Creek, Station 53B-63
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
12/18/1984
12/18/1986
12/18/1988
12/18/1990
12/18/1992
12/18/1994
12/18/1996
12/18/1998
12/18/2000
12/18/2002
12/18/2004
12/18/2006
12/18/2008
12/18/2010
12/18/2012


Back Creek, Station 53B-64
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
12/18/1984
12/18/1986
12/18/1988
12/18/1990
12/18/1992
12/18/1994
12/18/1996
12/18/1998
12/18/2000
12/18/2002
12/18/2004
12/18/2006
12/18/2008
12/18/2010
12/18/2012