Total Maximum Daily Loads of Bacteria for Back River in York County and Cities of Hampton, Poquoson, and Newport News, Virginia

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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	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
LA	Load Allocation
LSPC	Loading Simulation Program C++
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
USFWS	US Fish and Wildlife Service
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VA-DCR	Virginia Department of Conservation and Recreation
VA-DEQ	Virginia Department of Environmental Quality
VADGIF	Virginia Department of Game and Inland Fisheries
VDH	Virginia Department of Health
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 Back River was completed in 2006 using a volumetric method for eleven shellfish harvesting impaired sites and one recreational impaired site (VA2006). 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. County and the Cities have expended millions of dollars in recent years providing public sewer and taking septic systems offline. Starting in 2007, both York County and the Cities of Poquoson and Hampton 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. The bacterial concentration is now much lower than during the period from 2000-2008. In order to fulfill TMDL requirements, TMDL development using a watershed-based approach based on observation data since 2008 was needed for this watershed.

The Back River watershed is located along the Western Shore of the Chesapeake Bay about 4 km south of the York River mouth in the Cities of Hampton, Poquoson, and Newport News and in York County, Virginia. Big Bethel Reservoir is located at the upstream of Brick Kiln Creek and discharges to the Back River. The Reservoir drains a portion of the York County watershed and a subwatershed of the City of Newport News. A subwatershed of the City of Newport News drains Newmarket Creek, which passes through the City of Hampton and drains to the Back River. Poquoson County, on the northern side of the Back River, drains the Northwest Branch of the Back River. There are two federal facilities, NASA Langley Research Center and Langley Air Force Base, that are located in the City of Hampton and that drain Back River. Also, there is a portion of the Department of Energy's Thomas Jefferson Accelerator Facility located in the City of Newport News that drains to the Big Bethel Reservoir. Based on the water quality assessment, it does not support its designated use of primary contact recreation (e.g., swimming and fishing) and as a shellfish growing area due to high elevated bacterial concentration. TMDLs have been developed to meet bacterial standards. This document, upon approval of EPA, establishes bacteria (fecal coliform, enterococcus, and *E. coli*) TMDLs for the following impaired segments of the Back River:

Impairment Sites – Back River

Assessment Unit	Water Name	Location Description	Cause Category	Cause Name	Size (miles^2)
VAT-C07E_ LON01A06	Long & Grunland Creeks - Back River	South shore trib. to mainstem Back R. Adjacent to Grandview area. CBP Segment MOBPH. DSS shellfish harvesting condemnation # 054-215 C (effective 20101115).	4A	Fecal Coliform	0.10
VAT-C07E_ HAR01A06	Harris River – Upper	South shore trib. to mainstem Back R. Adjacent to Fox Hill area. DSS shellfish condemnation # 054-215 A (effective 20101115). CBP Segment MOBPH.	4A	Fecal Coliform	0.24
VAT-C07E_ IN101A08	DSS Inlet #1 - Unnamed Inlet at Mouth of SW Branch	South shore trib. to mainstem Back R. Located east of mouth of SW Branch. CBP Segment MOBPH. DSS shellfish harvesting condemnation # 054-021 C (effective 2010115).	4A	Fecal Coliform	0.02
VAT-C07E_ CCR01A06	Cedar & Topping Creeks	Located near City of Poquoson. Cedar & Topping Creeks are tribs to the north shore of the Northwest Branch of Back River. Portion of DSS condemnation # 054-021 B (less NW Br Back R./Brick Kiln Cr. portion) effective 20081119. CBP Segment MOBPH.	4A	Fecal Coliform	0.11
VAT-C07E_ NWB01A06	Northwest Br. Back River - Upper [TMDL-CD]	CBP Segment MOBPH. Headwaters to confluence of Cedar Creek between Cedar Point and Marsh Point. Portion of DSS shellfish condemnation # 054-021 B (less Cedar/Topping & Brick Kiln Creeks, effective 20081119).	4A	Fecal Coliform	0.22
VAT-C07E_ NEW01A02	Newmarket Creek - Upper	South of Blue Bird Gap Farm area. From end of tidal waters at Terrant ES (approx. RM 5.1) downstream to I-64 crossing (RM 3.68). CBP Segment MOBPH. Portion of DSS shellfish condemnation # 054-021 B (effective 20101115).	4A	Fecal coliform & Entero-coccus	0.07

VAT-C07E_ NEW02A02	Newmarket Creek – Lower	South of Blue Bird Gap Farm area. From the I-64 crossing (RM 3.68) downstream to confluence with SW Br. Back R. CBP Segment MOBPH. Portion of DSS shellfish condemnation # 054-021 B (effective 20101115).	4A	Fecal coliform & Entero-coccus	0.08
VAT-C07E_ SWB01A08	SW Br Back River - Incl Tides Mill Cr [TMDL area]	Headwaters of Southwest Branch (incl tidal Tides Mill Cr) downstream to Langley View. CBP segment MOBPH. Portion of DSS shellfish condemnation # 054-021 B (effective 20101115).	4A	Fecal Coliform	1.06
VAT-C07E_ WAT01A06	Watts Creek - (NW Br. Back River)	Located southwest of Poquoson. Watts Cr. trib to Northwest Br. of Back R. CBP segment MOBPH. Portion of DSS condemnation # 054-021 D (effective 20101115).	4A	Fecal Coliform	0.06
VAT-C07E_ BAK01A00	Mainstem Back River	From junction of Northwest and Southwest Branches downstream to mouth of Back River. Portion of CBP Segment MOBPH. DSS Condemnation 054-215 OPEN shellfish condemnations 20101115.	4A	Fecal Coliform	7.05
VAT-C07E_ SWB02A08	Southwest Br. Back River - Mouth [DSS OPEN -No TMDL]	Lower portion to confluence with mainstem Back R. CBP Segment MOBPH. Portion of DSS shellfish (OPEN) condemnation # 054-021 (effective 20081119).	5A	Enteroco ccus	0.23
VAT-C07E_ NWB01B08	Northwest Br. Back River - Upper [TMDL not CD]	Northwest Br. Back River upper portion from confluence of Cedar Creek downstream to confluence Tabbs Cr. Portion DSS shellfish condemnation # 054-021 B (less Cedar/Topping & Brick Kiln Creeks, effective 20081119). CBP Segment MOBPH.	4A	Fecal Coliform	0.26
VAT-C07E_ INX01A10	Unnamed Inlet - Back R South Shore near Wallace Cr	Unnamed Inlet Back R South Shore near Wallace Cr west of Dandy Point. CBP Segment MOBPH. DSS shellfish condemnation # 054-215 D (effective 20081119).	5B	Fecal Coliform	0.01
VAT-C07E_ SWB01B08	SW Br Back River - Outside DSS Inlet #1 & #2 [TMDL area]	At Langley View. CBP segment MOBPH. Portion of DSS shellfish condemnation OPEN # 054-021 (effective 20101115).	4A	Fecal Coliform & Enteroco ccus	0.04
VAT-C07E_ SWB02B10	SW Br Back R - DSS OPEN [TMDL]	Headwaters of Southwest Branch downstream to Langley View. CBP segment MOBPH. Portion of DSS shellfish OPEN condemnation # 054-021 (effective 20101115).	4A	Fecal Coliform & Enteroco ccus	0.36

VAT-C07E_ BRK01A06	Brick Kiln Creek	From 0.3 mi. downstream of Big Bethel Res. dam (approx. RM 5.0, end of tidal waters north of Ebenezer Church) downstream to confluence with Northwest Br. Back R. CBP Segment MOBPH. Portion of DSS shellfish condemnation # 054-021 A (effective 20101115).	4A	Fecal coliform & Entero-coccus	0.09
VAT-C07E_ INB01A04	DSS Inlet #2 - Unnamed Inlet S. Shore of SW Br. Back River	South shore trib. to Southwest Branch Back R. Located near mouth of SW Branch, west of unnamed DSS Inlet #1. DSS condemnation # 054-021 (effective 20101115). CBP Segment MOBPH.	5A	Fecal Coliform	0.07
VAT-C07R_ NEW01A06	Newmarket Creek –Lower Riverine	Lower Riverine, Recreation	5A	E.coli	0.04
VAT-C07E_ BAK01C10	Back River-S Shore at Mouth Wallace Cr.	South Shore Back R. near Grunland Cr. Portion of CBP Segment MOBPH. Portion of DSS shellfish condemnation # 054-215 B	4A	Fecal Coliform	0.039

Sources of Bacteria

The watershed approach using information of landuse, survey, and observations was applied to conduct the source assessment. The Hampton Roads Sanitation District (HRSD) is a VPDES permit holder for a wastewater treatment plant (WWTP) in the Back River watershed. However, HRSD does not discharge bacteria to the Back River. Nine MS4 permits are held within the Back River TMDL watershed. Potential sources of bacteria in the watershed are MS4 regulated areas, nonpoint sources, including livestock, wildlife, pets, human activities, failing septic systems, and Sanitary Sewer Overflows (SSOs).

Endpoints

The fecal coliform criteria of shellfish growing areas are more stringent than the enterococcus criterion for recreation, and thus were selected as endpoints for the shellfish growing areas. 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. *The 90th percentile is the more stringent criterion and is used as the endpoint.* For upstream tributaries impaired with enterococci, the enterococci criterion was applied. The numerical criterion 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. For the riverine segment, the numerical criterion for *E. coli* is that it shall not exceed a monthly geometric mean of 126 cfu/100 ml in freshwater, or no more than 10% of the total samples in the assessment period shall exceed 235 *E. coli* cfu/100 ml. The endpoints were established based on the designated uses of shellfish harvesting and recreation uses.

Modeling Approach

A system of numerical models was applied to simulate the loadings of fecal coliform bacteria from the Back River watershed, and the resulting response of in-stream water quality variables. The watershed model, Loading Simulation Program in C^{++} (LSPC), developed by the USEPA, was selected to simulate the watershed hydrology and fecal coliform load to the Back River. Each jurisdictional area, and each federal land area, is represented by one or more subwatersheds, as is each impaired segment, to account for spatial variations of the watershed. The Environmental Fluid Dynamics Computer Code (EFDC) was used to simulate the transport and fate of fecal coliform and enterococci in the receiving water of the Back River and the Big Bethel Reservoir. The model was calibrated based on field observations and the model simulation spanned a period of five years. 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.

Load Allocation Scenarios

For the shellfish harvesting and recreational use impairments, the appropriate water quality standard was determined based on the designated use and the corresponding water quality standards. Calibrated model simulation results were used to establish the current loads in the system. The loads that are necessary to meet water quality standards were established for the TMDLs. The difference between the TMDL and the current loading (annually based loading) represents the necessary level of reduction. Because loading of enterococci and *E. coli* from upstream tributaries will influence the downstream bacterial concentrations in the Back River for which the fecal coliform criteria apply, all TMDLs were written as fecal coliform. In order to take into account the future growth, one percent (1%) of the TMDL load is allocated to future growth (FA). There are nine stormwater permits in the watershed: York County (VAR040028), City of Hampton (VA0088641), City of Poquoson (VAR040024), City of Newport News (VA0088633), NASA Langley Research Center (VAR040079), Langley Air Force Base (DOD properties), DOE Thomas Jefferson Accelerator Facility (VAR040079), Thomas Nelson Community College (VAR040087), and VDOT (VAR040115).) Wastewater quantities are allocated to these MS4s based on the percentage of urban land use within the MS4s' regulated area. The maximum reduction required to meet the fecal coliform water quality standard is approximately 37.3% for the Back River watershed. The fecal coliform TMDLs (counts per day) are summarized below:

Impairment	WLA	LA	MOS	TMDL
Back River	**2.38E+12**	**2.98E+12**	implicit	**5.35E+12**
MS4 Newport News (VA0088633)	*2.31E+11*			
VDOT (VAR040115)				
DOE-TJ Accelerator Facility				

(VAR040079)	
MS4 Hampton (VA0088641)	*1.83E+12*
VDOT (VAR040115)	
TNCC (VAR040087)	
Langley Air Force Base	
MS4 Poquoson (VAR040024)	*8.20E+10*
MS4 York (VAR040028)	*1.65E+11*
VDOT (VAR040115)	
MS4 NASA Langley Research *Center (VAR040079)*	*1.21E+10*
Future Load	*5.35E+10*

*Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load and other Phase II MS4 permit holders where noted, due to the continuity of the system.

Where:

TMDL =Total Maximum Daily Load
LA = Load Allocation (nonpoint source)
WLA =Wasteload Allocation (MS4)
FA =Future Allocation, which is 1% of allowable load
MOS =Margin of Safety

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

Impairment	WLA	LA	MOS	TMDL
Back River	**3.87E+14**	**4.85E+14**	implicit	**8.73E+14**
MS4 Newport News (VA0088633)	*3.78E+13*			
VDOT (VAR040115)				
DOE-TJ Accelerator Facility (VAR040079)				
MS4 Hampton (VA0088641)	*2.99E+14*			
VDOT (VAR040115)				
TNCC (VAR040087)				
Langley Air Force Base				
MS4 Poquoson (VAR040024)	*1.33E+13*			
MS4 York (VAR040028)	*2.70E+13*			
VDOT (VAR040115)				
MS4 NASA Langley Research *Center (VAR040079)*	*1.98E+12*			
Future Load	*8.73E+12*			

*Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load and other Phase II MS4 permit holders where noted, due to the continuity of the system.

The fecal coliform existing and allowable loads for York County, and the Cities of Hampton, Poquoson, and Newport News, and federal land are summarized below:

Jurisdiction	Existing Load (Counts/Day)	Allowable Load (Counts/Day)	Reduction (%)
City of Newport News	4.34E+11	3.58E+11	17.5
City of Hampton	6.62E+12	3.98E+12	40.0
City of Poquoson	9.66E+11	6.04E+11	37.5
York County	4.76E+11	3.72E+11	21.8
NASA	4.34E+10	4.34E+10	0.0
Total	8.54E+12	5.35E+12	37.3

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

Jurisdiction	Existing Load (Counts/Year)	Allowable Load (Counts/ Year)	Reduction (%)
City of Newport News	7.08E+13	5.84232E+13	17.5
City of Hampton	1.08E+15	6.48353E+14	40.0
City of Poquoson	1.57E+14	9.83012E+13	37.5
York County	7.76E+13	6.06757E+13	21.8
NASA	7.09E+12	7.08877E+12	0.0
Total	1.39E+15	8.72842E+14	37.3

Based on model simulation results of the current condition and data analysis, load reduction is not required for federal facilities including NASA Langley Research Center, Langley Air Force Base (DOD properties), and the DOE Thomas Jefferson Accelerator Facility, as the dominant pollutant sources is wildlife and the discharge from these facilities do not cause downstream impairments. The subwatersheds that drain to the Big Bethel Reservoir do not require load reduction because of large water volume of the reservoir and decay of the bacteria, which include portions of the York County watersheds, the Newport News watershed, and the Thomas Jefferson Accelerator Facility.

Finally, the load allocation that would meet water quality standards according to sources was determined using the results of the fecal coliform loading for each source category, which were estimated by the watershed approach and model simulations with respect to the reduction of bacterial sources. A reduction of SSO is considered in the TMDL allocation, although it does not occur daily. An allocation to boating activities (marinas) is also considered in the load allocation. A scenario for the complete reduction of human impacts (livestock, septic, SSOs, and marinas) and a portion of pets are applied to the load allocation 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. Load allocation is summarized below:

Waterbody Name	Category	Current Load (Counts/Day)	Load Allocation (Counts/Day)	Reduction Needed (%)
Back River	**Livestock**	7.69E+11	0.00E+00	100%
	Wildlife	5.30E+12	5.30E+12	1%
	Human (Septic, SSO, Marina)	5.13E+11	0.00E+00	100%
	Pets	1.96E+12	5.69E+10	99%
	Total	8.54E+12	5.35E+12	100%

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 in this study by using long-term water quality data that cover different flow regimes and temperatures, and a long-term simulation to estimate the current bacteria loads and load reduction targets. An implicit margin of safety (MOS) was incorporated in this TMDL establishing allocations that would meet both the geometric mean and the 90th percentile water quality standards and to meet the enterococci standards for a monthly *geometric mean of 35 cfu/100ml and a sample maximum below 104 cfu/100ml*.

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 TMDLs developed for the Back River watershed impairments is for providing an allocation scenario that will be a starting point for developing 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 Back 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 Back River drains northeast to the mainstem of the Bay, which then drains directly southeast to the Atlantic Ocean. Big Bethel Reservoir is located at the upstream of Brick Kiln Creek, which discharges to the Back River. The Reservoir drains a portion of the York County watershed and a subwatershed of the City of Newport News. A subwatershed of the City of Newport News drains into Newmarket Creek, which passes through the City of Hampton and drains into the Back River. Poquoson County, located on the northeastern part of the Back River, drains into the Northwest Branch of the Back River. There are two federal facilities, NASA Langley Research Center and Langley Air Force Base, located in the City of Hampton that drain into Back River, and a portion of the DOE Thomas Jefferson Accelerator Facility, located in the City of Newport News, that drain into the Big Bethel Reservoir. A total of 19 segments of Back River 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 standard for fecal coliform and enterococcus (see table in Executive 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 impaired segments.

A TMDL of the Back 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 from each jurisdiction for MS4 permits. York County and the Cities of Poquoson and Hampton have expended millions of dollars in recent years providing public sewer and taking septic systems offline. Starting in 2007, these local jurisdictions 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. The bacterial concentration is much lower than the period from 2000-2008. In order to fulfill TMDL requirements, TMDL development using a watershed-based approach based on observation data since 2008 was needed for this watershed. This document, upon approval of EPA, establishes fecal coliform TMDLs for these 19 impaired segments.

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.

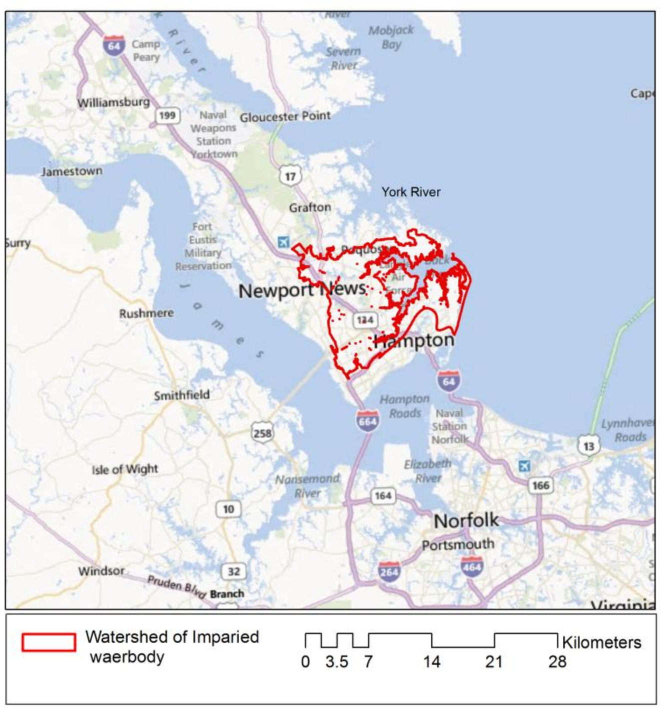


Figure 1.1: Location Map of the Back River

1.3 Watershed Location and Description

The Back 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 the Back River is 159.9 km^2 (39,520.8 acres) in size. The Back River watershed is mainly urban (45.3%), wetlands (23.2%), and open space (18.5%). These three land uses account for approximately 87% of the watershed area.

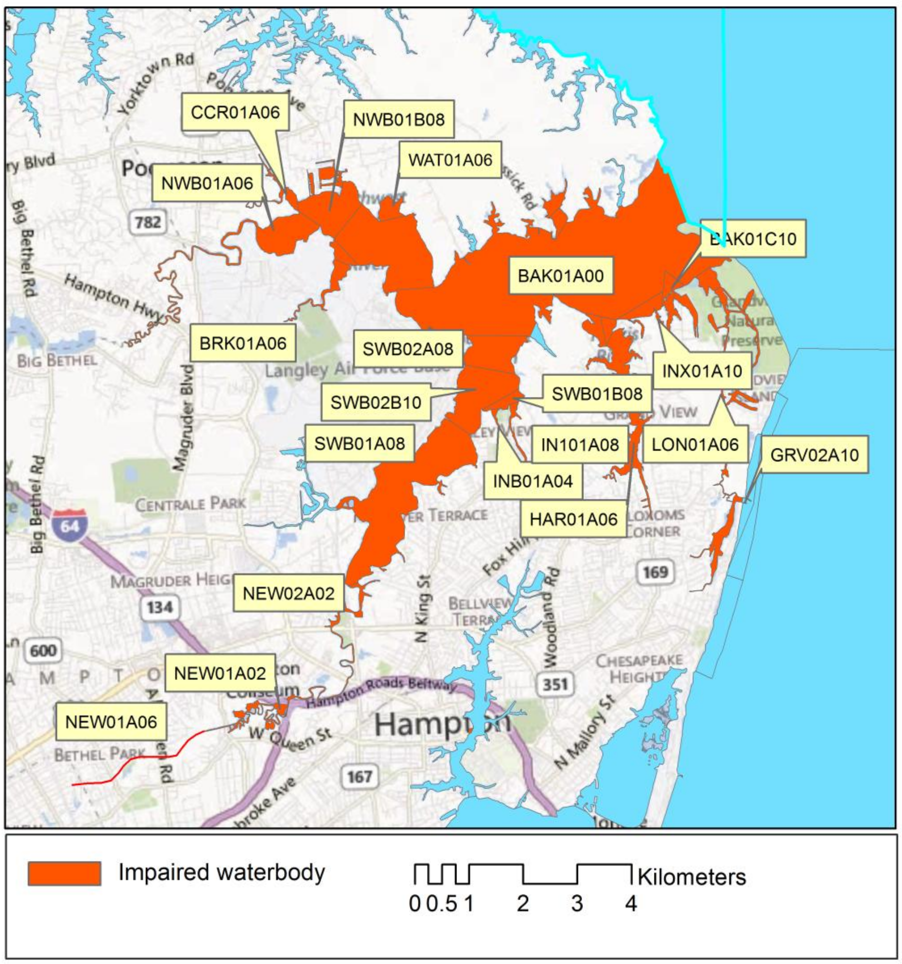


Figure 1.2: Delineation of the Back River Impaired Segments

1.4 Designated Uses and Applicable Water Quality Standards

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 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. Back River is considered as a Class II water, "Estuarine Water (Tidal Water-Coastal Zone to Fall Line)" (9VAC25-260-50).

1.4.2 Bacteria Standards

Effective February 1, 2010, VA-DEQ 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."

E.coli bacteria shall not exceed a monthly geometric mean of 126 CFU/100 ml in freshwater. If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E.coli 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 90^{th} 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 in the Back River. These data were used for assessing impairment and for supporting the model.

1.5.1 VDH-DSS monitoring data

The VDH-DSS state agency has occupied 44 fecal coliform measurement stations in the Back River 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 Back River 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 90^{th} percentile are tabulated in Table 1.1 for all 44 VDH-DSS stations. The designated uses, impairments, and criteria for Back River segments are summarized in Table 1.2.

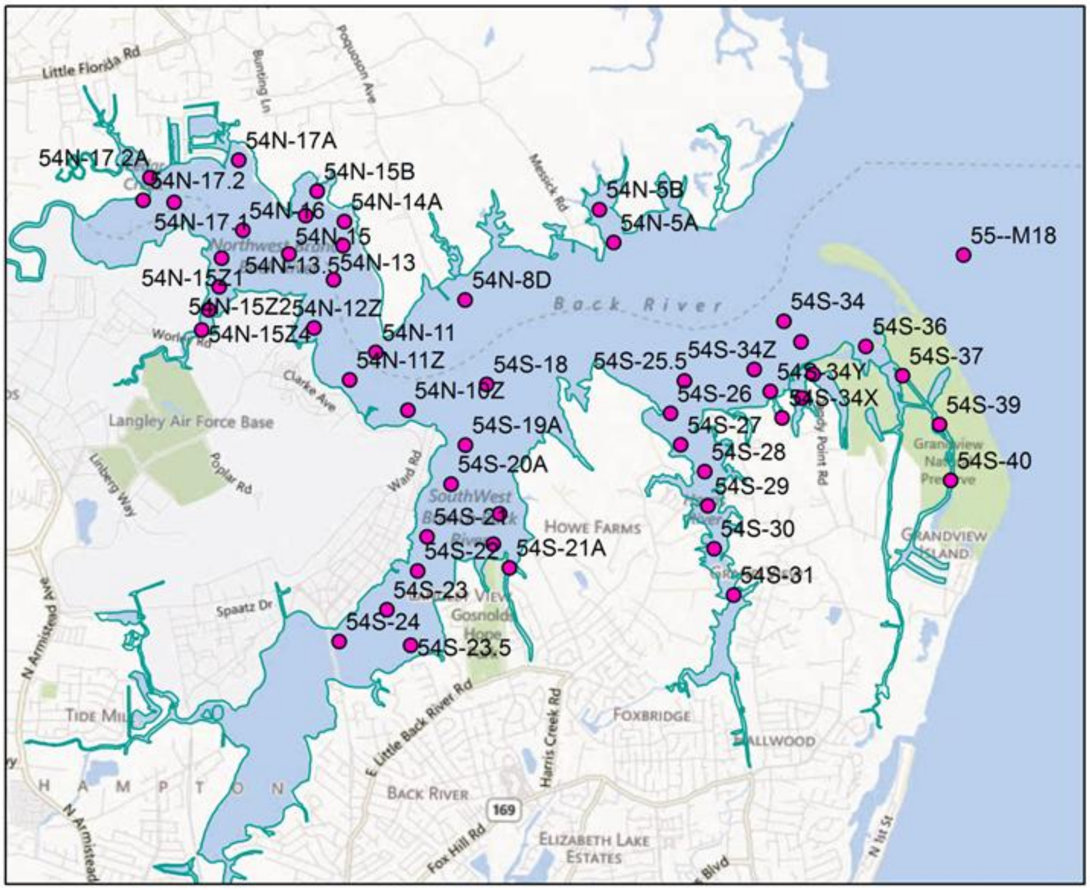


Figure 1.3: Locations of VDH-DSS Stations in the Back River

Table 1.1: Exceedances of the Fecal Coliform Criteria (1990-2012) of Back 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
Back R.	54N-5A	253	14	0.0%	49	7.4%
Back R.	54N-5B	253	14	8.6%	49	48.4%
Back R.	54N-8D	254	14	0.0%	49	0.0%
Back R.	54N-10Z	252	14	0.0%	49	3.1%
NW Bran.	54N-11	252	14	0.0%	49	0.0%
NW Bran.	54N-11Z	252	14	0.0%	49	5.1%
NW Bran.	54N-12Z	253	14	0.0%	49	3.5%
NW Bran.	54N-13	255	14	0.0%	49	12.5%
NW Bran.	54N-14A	250	14	0.0%	49	10.9%
NW Bran.	54N-15	253	14	0.0%	49	7.4%
NW Bran.	54N-15A	131	14	0.0%	49	12.5%
NW Bran.	54N-15B	208	14	5.5%	49	29.3%
NW Bran.	54N-15Z1	246	14	0.0%	49	32.4%

Stream Name	Station ID	Number of Samples	Geomean Criterion MPN/100 ml	Geomean Exceedance Percentage	90th Percentile Criterion MPN/100 ml	90th Percentile Exceedance
NW Bran.	54N-15Z2	213	14	13.3%	49	57.4%
NW Bran.	54N-16	252	14	0.0%	49	18.8%
NW Bran.	54N-17A	242	14	20.3%	49	78,1%
NW Bran.	54N-17.1	233	14	9.0%	49	59.4%
NW Bran.	54N-17.2	225	14	41.4%	49	80.9%
NW Bran.	54N-17.2A	203	14	34.8%	49	73.0%
SW Bran.	54S-18	254	14	0.0%	49	5.1%
SW Bran.	54S-19A	253	14	0.0%	49	30.9%
SW Bran.	54S-20A	254	14	6.3%	49	53.9%
SW Bran.	54S-20Z	252	14	6.3%	49	53.9%
SW Bran.	54S-21	254	14	14.1%	49	56.3%
SW Bran.	54S-21A	163	14	33.6%	49	62.5%
SW Bran.	54S-21Y	252	14	6.3%	49	40.6%
SW Bran.	54S-22	251	14	27.0%	49	59.0%
SW Bran.	54S-23	251	14	44.9%	49	67.2%
SW Bran.	54S-23.5	87	14	5.1%	49	27.3%
SW Bran.	54S-24	250	14	56.3%	49	73.8%
Harris Cr.	54S-25.5	71	14	0.0%	49	0.0%
Harris Cr.	54S-28	252	14	12.1%	49	55.1%
Harris Cr.	54S-29	252	14	19.5%	49	69.1%
Harris Cr.	54S-30	252	14	64.1%	49	84.4%
Back R.	54S-33V	254	14	17.6%	49	48.8%
Back R.	54S-33W	252	14	14.5%	49	59.8%
Back R.	54S-33Z	72	14	0.0%	49	0.0%
Back R.	54S-34	254	14	0.0%	49	0.4%
DSS Inlet	54S-34X	247	14	7.0%	49	53.9%
Back R.	54S-34Y	72	14	0.0%	49	0.0%
Back R.	54S-34Z	72	14	0.0%	49	0.0%
Long Cr.	54S-36	69	14	0.0%	49	4.7%
Long Cr.	54S-37	251	14	21.1%	49	59.0%
Long Cr.	54S-39	251	14	50.8%	49	87.1%

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

Stream Name	Water Type	Designated Use	Impairment	Criteria (MPN/100ml)	List Year
Long & Grunland Creeks	Tidal	Shellfish harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	1998
Harris River-upper	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	1998
DSS Inlet #1	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	2008
Cedar & Topping Creeks	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	1998
Northwest Branch	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	1998
Newmarket Creek-upper	Tidal	Recreation & Shellfish	Enterococci Fecal coliform	Geomean < 14 90th Percentile <49	1998
Newmarket Creek-lower	Tidal	Recreation & Shellfish	Enterococci Fecal coliform	Geomean < 14 90th Percentile <49	1998
Southwest Branch	Tidal	Recreation & Shellfish	Enterococci Fecal coliform	Geomean < 14 90th Percentile <49	1998
Watts Creek	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	1998
Mainstem-Back River	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	1998
Southwest Branch	Tidal	Recreation & Shellfish	Enterococci Fecal coliform	Geomean < 14 90th Percentile <49	1998
Back River-S Shore at Wallace	Tidal	Shellfish	Fecal coliform	Geomean < 14 90th Percentile <49	2010
Northwest Branch	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	1998
Inlet near Wallace Creek	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	2010
Southwest Branch	Tidal	Recreation	Enterococci	Geomean < 35	2002
Southwest Branch	Tidal	Recreation & Shellfish	Enterococci Fecal coliform	Geomean < 14 90th Percentile <49	1998
Brick Kiln Creek	Tidal	Recreation & Shellfish	Enterococci	Geomean < 35	1998
DSS Inlet # 2	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	2004
Grandview Pier & Salt Ponds Beach	Tidal	Shellfish Harvesting	Fecal coliform	Geomean < 14 90th Percentile <49	2010
New Market Lower-Riverine	Non-tidal	Recreation	E. coli	Geomean < 126	2002

1.5.2 VA-DEQ monitoring data

In the Back River, the VA-DEQ state agency has occupied approximately 12 stations for the measurement of fecal coliform and 12 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 cfu/100 ml.

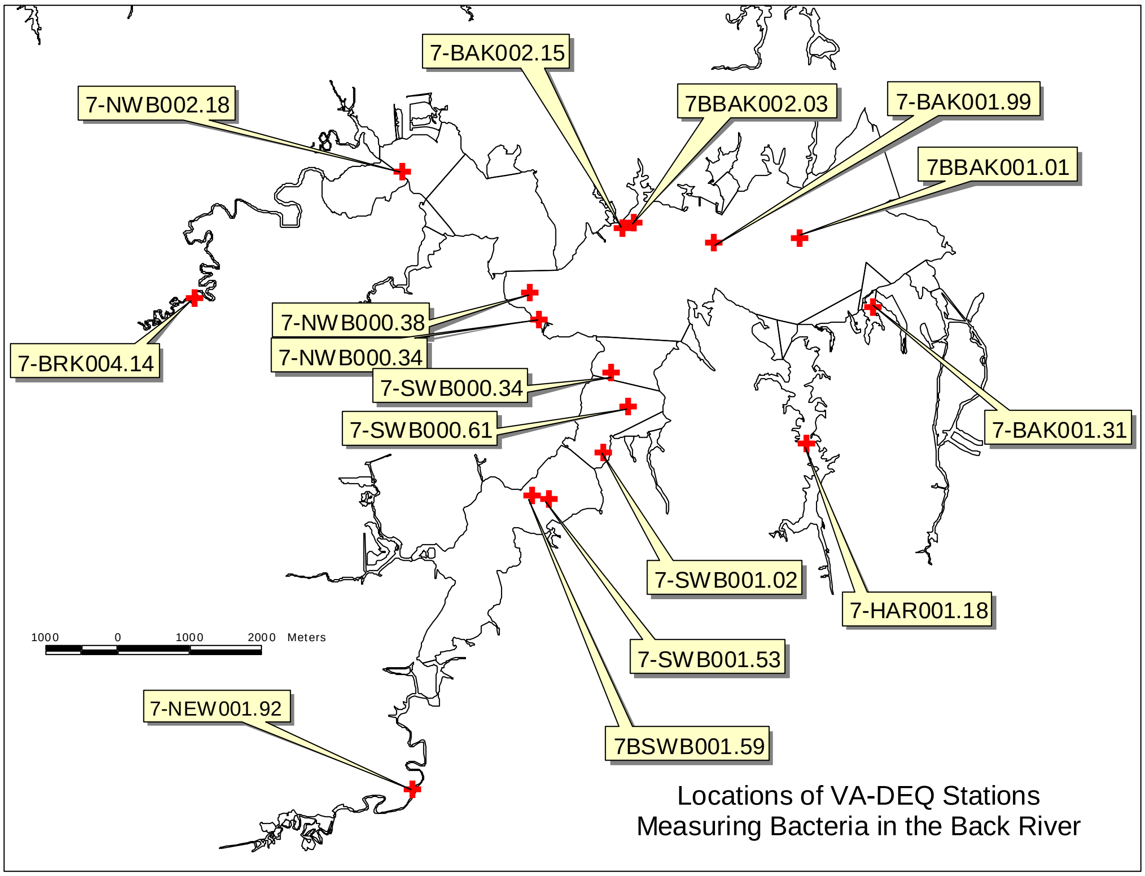


Figure 1.4: Locations of VA-DEQ Stations in the Back River

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

Station	Number of Observations	Fecal Coliform Average (MPN/100 ML)
7-BAK002.15	1	25
7-BRK004.14	111	565
7-NEW001.92	111	555
7-NEW005.44	32	1215
7-NWB000.38	1	25
7-NWB002.18	1	25
7-SWB000.34	1	25
7-SWB001.02	1	25
7-SWB001.53	1	25
7BBAK001.01	1	25
7BBAK002.03	1	25
7BSWB001.59	1	25

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

Station	Number of Observations	Enterococci Average (cfu/100 ML)	Percentage in Violation*
7-BAK001.31	13	77	8%
7-BAK002.15	1	10	0%
7-BRK004.14	61	478	74%
7-NEW001.92	58	327	47%
7-NWB000.38	1	10	0%
7-NWB002.18	1	10	0%
7-SWB000.34	1	10	0%
7-SWB001.02	1	10	0%
7-SWB001.53	1	20	0%
7BBAK001.01	1	10	0%
7BBAK002.03	1	10	0%
7BSWB001.59	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 Back 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://soils.usda.gov/survey/*). As part of the Tidewater Climate Region, the Back 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.

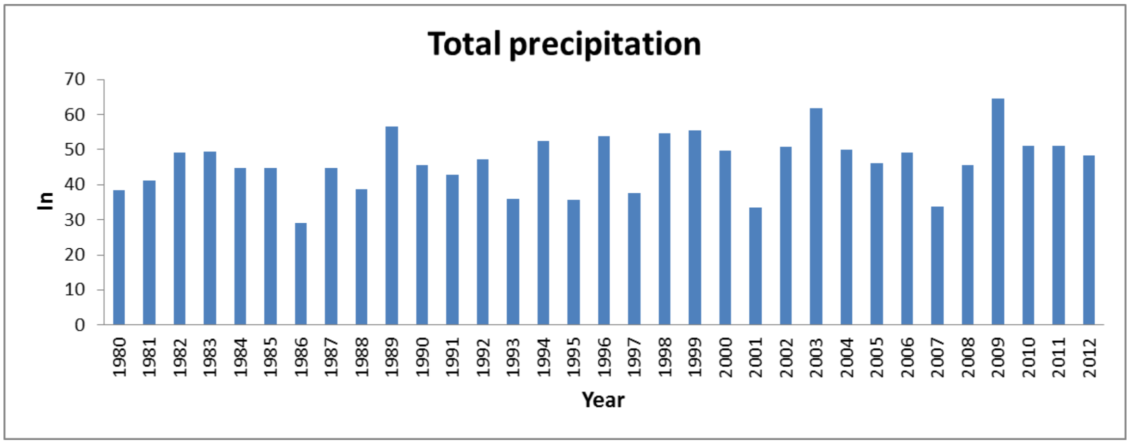


Figure 2.1: Total Annual Precipitation in the Poquoson River Watershed (Norfolk Airport)

2.2 Landuse

The land use characterization for the entire Back River watershed was based on land cover data from the NOAA Coastal Change Analysis Program (C-CAP) (www.csc.noaa.gov/lancover). 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 in the watershed are presented in Table 2.1. Landuse areas and percentages for each city or county are presented in Table 2.2 and for NASA Langley in Table 2.3. Dominant land uses in the watershed were found to be urban (45.3%), wetlands (23.2%), and open space (18.5%), which account for 87% of the total area in the watershed. Figure 2.3 shows the percentage land uses within the entire watershed for Back River and each local jurisdiction.

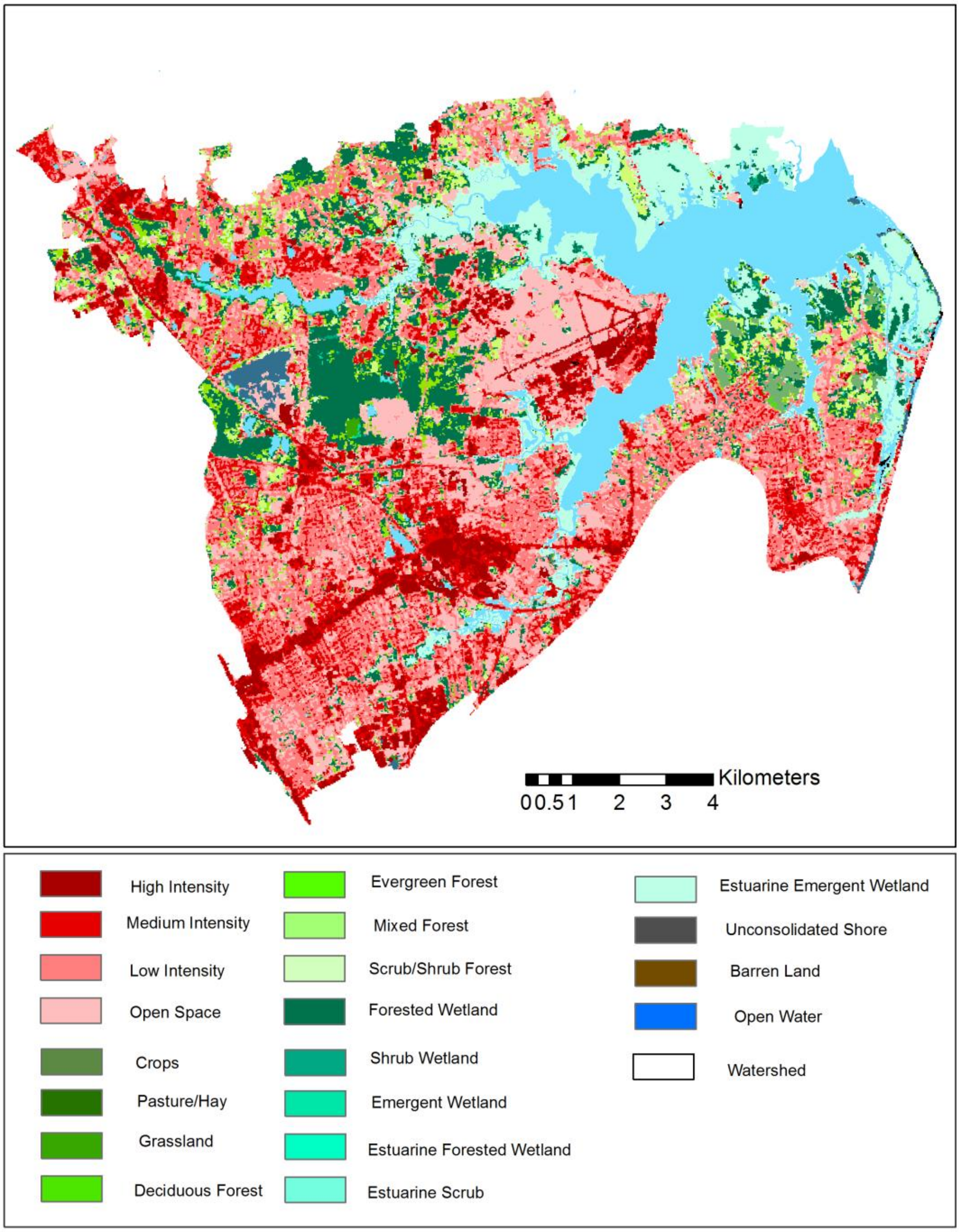


Figure 2.2: Land Use of the Back River Watershed

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, Area (ac), and Percentages of the Back River Watershed

Name	City of Hampton	%	City of Poquoson	%	York County	%	City of Newport News	%	Total	%
High Intensity	1785.6	6.9	32.2	0.8	120.8	3.3	407.8	11.8	2346.4	6.4
Medium Intensity	3678.7	14.3	84.1	2.1	474.3	13.0	715.8	20.7	4952.9	13.4
Low Intensity	6204.8	24.0	422.2	10.6	1106.4	30.3	1125.0	32.5	8858.5	24.0
Open Space	5492.2	21.3	383.5	9.6	471.6	12.9	612.3	17.7	6959.6	18.9
Crops	294.3	1.1	17.9	0.4	5.1	0.1	0.0	0.0	317.3	0.9
Pasture	15.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	15.5	0.0
Grassland	56.3	0.2	3.3	0.1	9.3	0.3	2.0	0.1	70.9	0.2
Deciduous Forest	927.8	3.6	145.3	3.6	313.3	8.6	146.0	4.2	1532.5	4.2
Evergreen Forest	385.1	1.5	216.2	5.4	113.5	3.1	37.8	1.1	752.7	2.0
Mixed Forest	191.6	0.7	27.2	0.7	88.5	2.4	48.1	1.4	355.3	1.0
Scrub/Shrub Forest	381.7	1.5	120.3	3.0	101.1	2.8	57.2	1.7	660.2	1.8
Forested Wetland	3213.0	12.5	482.6	12.1	587.5	16.1	227.0	6.6	4510.0	12.2
Shrub Wetland	152.3	0.6	30.0	0.8	18.6	0.5	2.7	0.1	203.6	0.6
Emergent Wetland	89.4	0.3	13.9	0.3	14.4	0.4	11.7	0.3	129.4	0.4
Estuarine Forested Wetland	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.7	0.0
Shrub Wetland	57.2	0.2	34.9	0.9	2.0	0.1	0.0	0.0	94.1	0.3
Estuarine Emergent	1978.3	7.7	1911.6	47.9	98.3	2.7	2.4	0.1	3990.6	10.8
Unconsolida ted Shore	36.9	0.1	2.6	0.1	1.3	0.0	0.5	0.0	41.3	0.1
Barren Land	321.2	1.2	0.9	0.0	6.4	0.2	0.5	0.0	329.0	0.9
Open Water	537.8	2.1	60.5	1.5	117.3	3.2	66.0	1.9	781.6	2.1
Estuarine Aquatic Bed	1.3	0.0	0.2	0.0	0.0	0.0	0.9	0.0	2.4	0.0
Total	25800.9	100.0	3989.7	100.0	3650.2	100.0	3464.0	100.0	36904.8	100.0

Table 2.3: Landuse Descriptions, Area, and Percentages of NASA Langley

Name	Area (ac)	%
High Intensity	74.0	10.2%
Medium Intensity	67.3	9.2%
Low Intensity	63.1	8.6%
Open Space	218.6	30.0%
Crops	1.6	0.2%
Pasture	0.0	0.0%
Grassland	1.1	0.2%
Deciduous Forest	15.5	2.1%
Evergreen Forest	14.1	1.9%
Mixed Forest	2.0	0.3%
Scrub/	7.1	1.0%
Forested Wetland	121.4	16.6%
Shrub Wetland	2.7	0.4%
Emergent Wetland	2.2	0.3%
Estuarine Forested Wetland	0.0	0.0%
Shrub Wetland	0.5	0.1%
Estuarine Emergent	132.5	18.2%
Unconsolidated Shore	0.0	0.0%
Barren Land	1.1	0.2%
Open Water	4.2	0.6%
Estuarine Aquatic Bed	0.0	0.0%

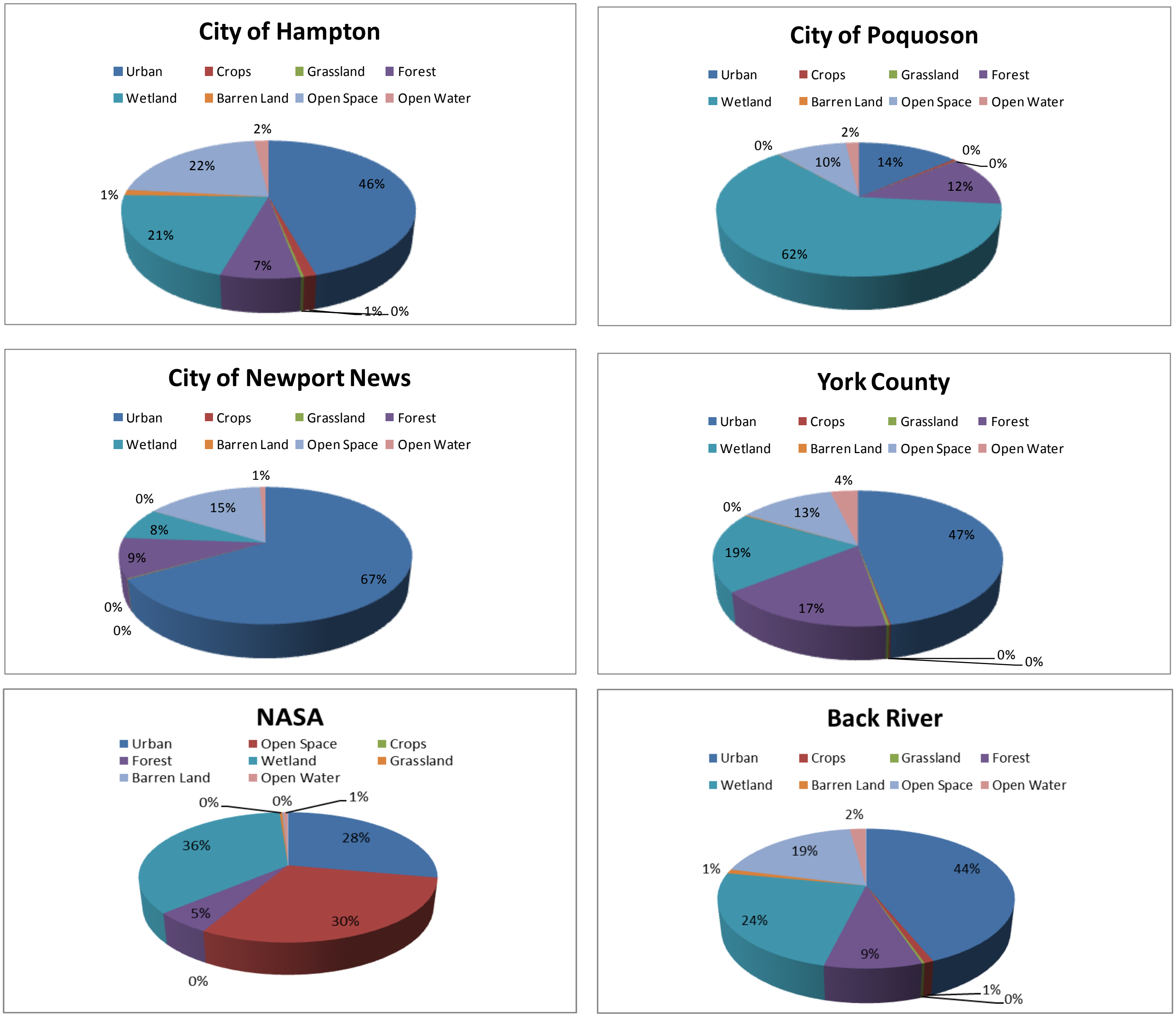


Figure 2.3: Percentage Landuses of the Back River Watershed and Each Local Jurisdiction

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 Back River (Figure 2.1). 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 44 fecal coliform measurement stations in the Back River during the period 1990-2012. The routine measurements are conducted monthly. Figure 2.3 shows the annual mean fecal coliform concentrations from 1990 to 2012. It can be seen that fecal coliform concentrations vary from year to year with high concentrations occurring in wet hydrological years of 1998, 2003, 2004, and 2006, but not always following the precipitation variation. Mean daily high concentration occurs in July and later from fall to winter (October –December). Large variations also occur in July and December (Figure 2.5).

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 Cities of Poquoson and Hampton 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 starting in 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 for the 2000-2007 period. There are large gaps between bacterial concentration intervals that have a tendency to yield a high 90th percentile. The large uncertainty associated with measurements is reduced using new method. 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 and maximum 90th percentile from 2000-2007. It can be seen that concentration decrease significantly. The average maximum 90th percentile decrease about 54%. Twenty-four stations have maximum 90th percentile values that exceed the water quality standard. The mean 90th percentile value that exceeded the water quality standards was 60% during the 2008-2012 period. Watts Creek - NW Br. Back River (VAT-C07E_WAT01A06) and Unnamed Inlet - Back R South Shore near Wallace Cr (VAT-C07E_INX01A10) show no violations. Although Back River-S Shore at the Mouth of Wallace Cr. (VAT-C07E_BAK01C10) does not show a violation, its upstream embayments (Stations 33V and 33W) show violations. The downstream of Back River (BAK01A00) does not show any violation.

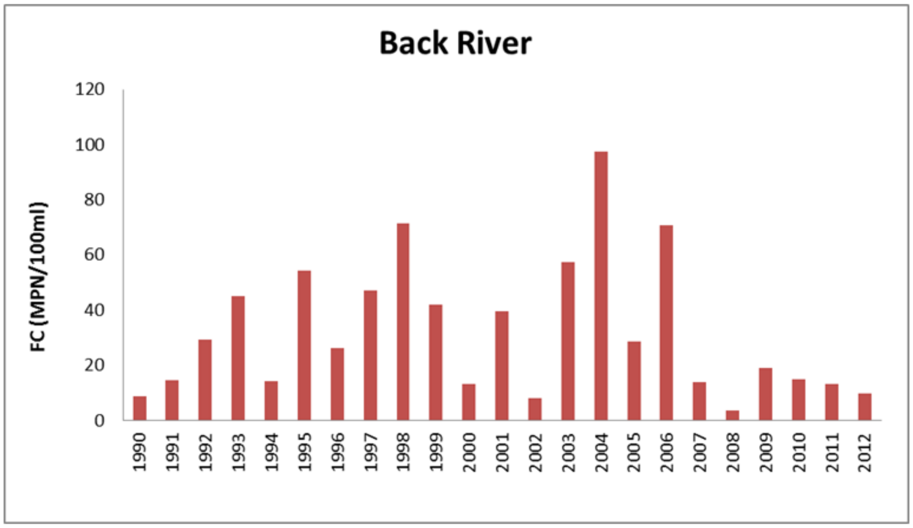


Figure 2.4: Annual Distribution of Mean Fecal Coliform Concentration

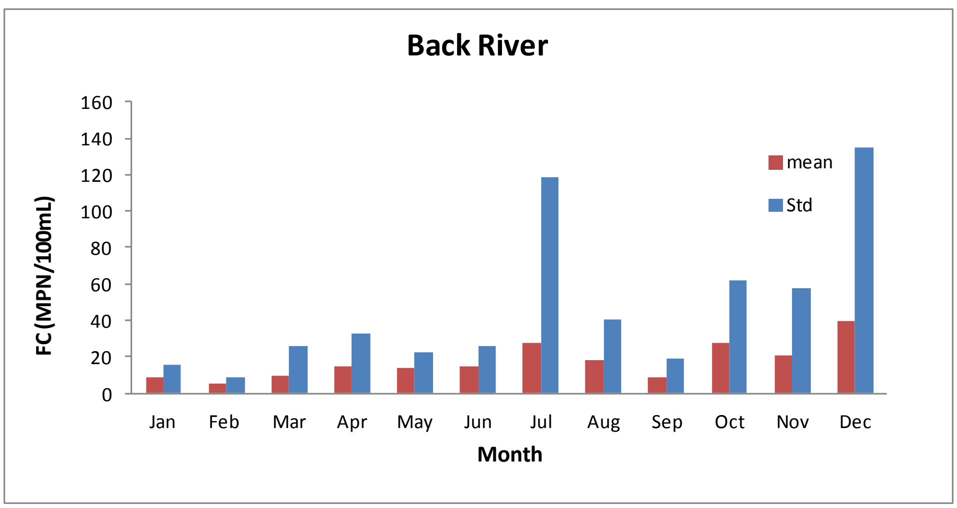


Figure 2.5: Monthly Mean and Standard Deviation of Fecal Coliform Concentration

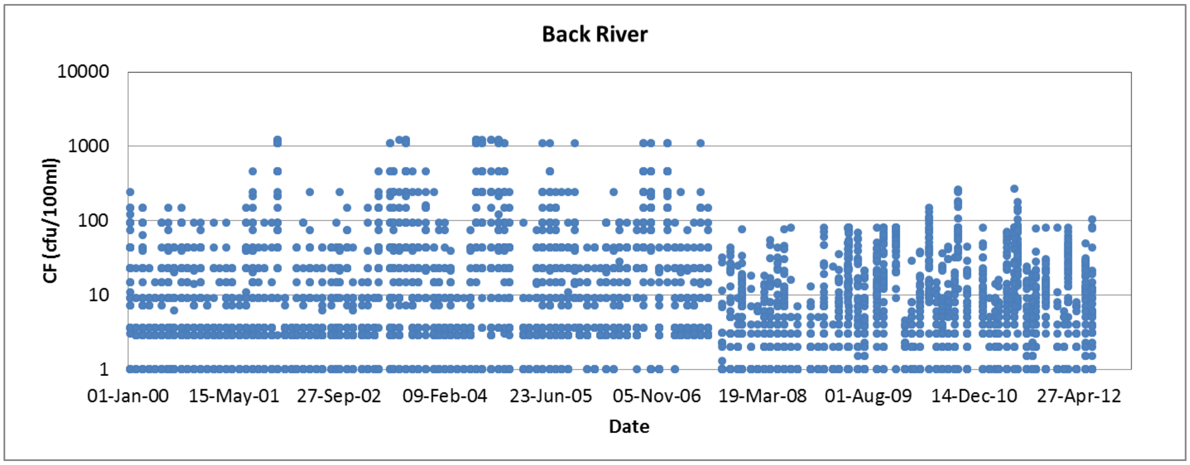


Figure 2.6: Observations of Fecal Coliform Concentration

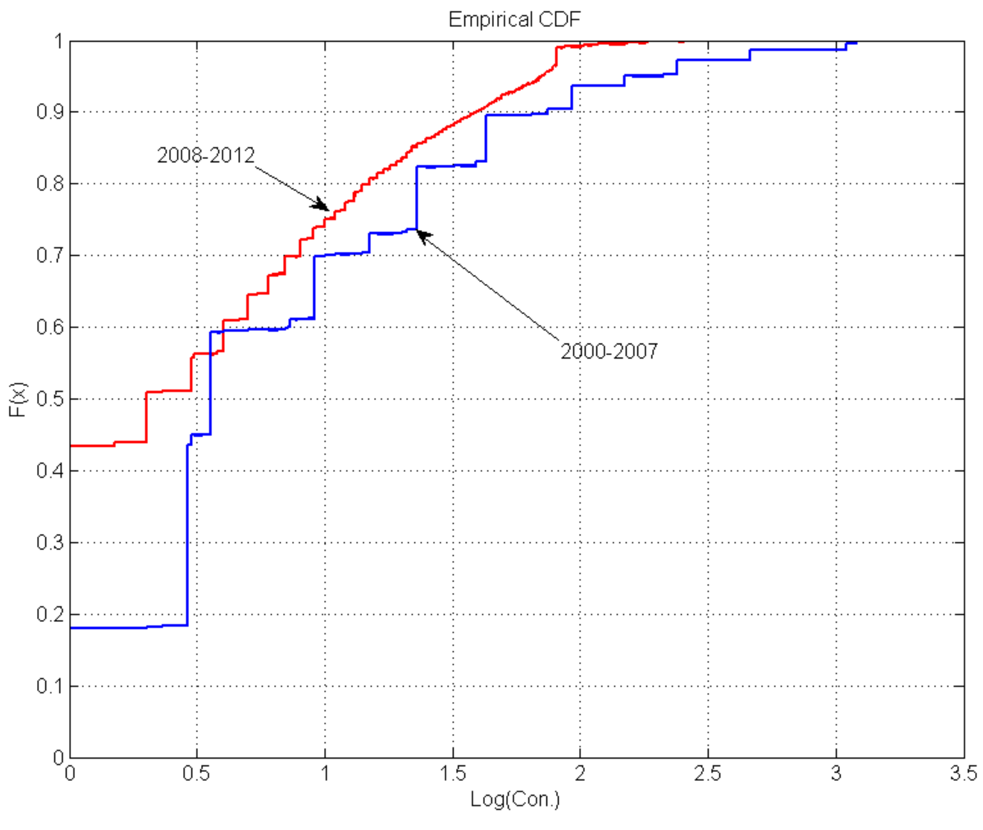


Figure 2.7: Observations of Fecal Coliform Concentration Distribution since 1990

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

Station	Mean 90th	Max. 90th	Max. 90th (2000-2007)	% exceeding standard (2008-2012)	Associated Impaired Site	Station	Mean 90th	Max. 90th	Max. 90th (2000-2007)	% exceeding standard (2008-2012)	Associated Impaired Site
5A	21.5	27.0	47.9	0%	FRT02A08	21	32.3	39.1	112.7	0%	SWB01A08
5B	38.8	50.0	103.0	3.4%	FRT02A08	21A	83.1	97.6	1275.5	100%	SWB01A08
8D	3.6	4.1	28.1	0%	ZZZ01A00	21Y	18.5	23.8	163.3	0%	SWB01A08
10Z	12.8	16.2	46.1	0%	***BAK01A00***	22	32.4	40.5	117.6	0%	SWB01A08
11	13.8	16.9	36.4	0%	***BAK01A00***	23	43.3	52.5	251.2	24.1%	SWB01A08
11Z	12.6	16.1	49.5	0%	***BAK01A00***	23_5	53.3	62.2	340.3	65.5%	SWB01A08
12Z	12.1	15.4	54.6	0%	***WAT01A06***	24	48.9	60.2	321.2	62.1%	SWB01A08
13	21.9	29.3	44.4	0%	NWB02A06	25_5	17.0	21.3	31.5	0%	***BAK01A00***
13_5	19.6	28.5	20.1	0%	NWB02A06	26	15.6	19.5	96.7	0%	HAR02A10
14A	26.0	34.2	94.4	0%	WAT01A06	27	1.7	3.8	1.0	0%	BAK01A00
15	16.3	21.1	51.2	0%	NWB02A06	28	31.0	37.8	228.5	0%	HAR02B10
15A	27.0	34.2	109.6	0%	***WAT01A06***	29	53.6	67.0	246.7	75.9%	HAR02B10
15B	27.9	36.8	143.4	0%	WAT01A06	30	70.5	87.2	787.5	100%	SWB01B08
15Z1	15.7	21.4	82.2	0%	NWB02A06	33V	46.0	54.5	195.9	41.4%	WAL01A06
15Z2	19.5	27.9	227.6	0%	BRK01A06	33W	43.8	56.3	218.4	31.0%	WAL02A06
16	28.7	36.9	69.3	0%	***WAT01A06***	33Z	11.6	14.7	43.6	0%	***BAK01C10***
17A	65.3	88.2	383.0	82.8%	CCR01A06	34	11.0	12.8	53.8	0%	***BAK01A00***
17_1	91.6	116.0	132.3	100.0%	NWB01B08	34X	13.6	19.5	138.5	0%	***INX01A10***
17_2	114.4	130.5	466.3	100.0%	NWB01A08	34Y	11.5	21.0	33.0	0%	INX01A10
17-2A	54.8	69.5	564.8	79.3%	CCR01A06	34Z	8.4	9.9	32.9	0%	INX01A10
18	11.0	12.9	34.3	0%	***BAK01A00***	36	51.6	63.5	28.5	58.6%	GLD01A10
19A	16.3	19.6	65.4	0%	SWB02A08	37	50.8	61.9	135.6	69.0%	GLD01A10
20A	21.4	26.1	106.6	0%	SWB02B10	39	58.8	70.5	164.1	93.1%	LON01A06
20Z	19.7	27.5	105.5	0%	SWB02B10	40	77.5	91.1	262.6	100%	LON01A06
BRK004.14*			72%		NEW001.92*			28%			
*Instantaneous Enterococcus >104 cfu/100ml											

3.0 SOURCE ASSESSMENT

3.1 General

A primary component of bacteria TMDL development for Back 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. The Cities of Hampton and Poquoson along with York County provided GIS data, including septic information and impervious landuse, which 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 permitted facilities in the Poquoson and Back River watersheds. However, there is no known point source that discharges fecal coliform within the Back River watershed.

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 Back River watershed. Overall, there are nine MS4 permits held in the Back River TMDL watershed: two Phase I MS4 permits and seven Phase II MS4 permits. 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 the NOAA C-CAP 2006 landuse data. As VDOT is located inside of each jurisdiction, the regulated acreage associated with VDOT is not listed explicitly. The TAC recommended that the WLAs for VDOT, TNCC, and DOE-Jefferson Accelerator Facility be aggregated with those of the respective municipalities. Table 3.1 lists the MS4 permit holders located within the Back River TMDL watershed.

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

MS4 Permit Holder	Phase	Permit Number	Jurisdiction	Acreage	Urban(ac)
City of Newport News	I	VA0088633	Newport News	3,398	2,248
City of Hampton	I	VA0088641	City of Hampton	21,535	10,477
York County	II	VAR040028	York County	3,167	1,423

City of Poquoson	II	VAR040024	City of Poquoson	3929	539
Thomas Nelson Community College	II	VAR040087	City of Hampton	91.3	32
NASA Langley Research Center	II	VAR040079	City of Hampton*	724	204
VDOT	II	VAR040115			
DOE Thomas Jefferson Accelerator Facility	II	VAR040079	Newport News*	116	47
Langley Air Force Base, DOD properties	II		City of Hampton*	2,897	890

*location of federal land

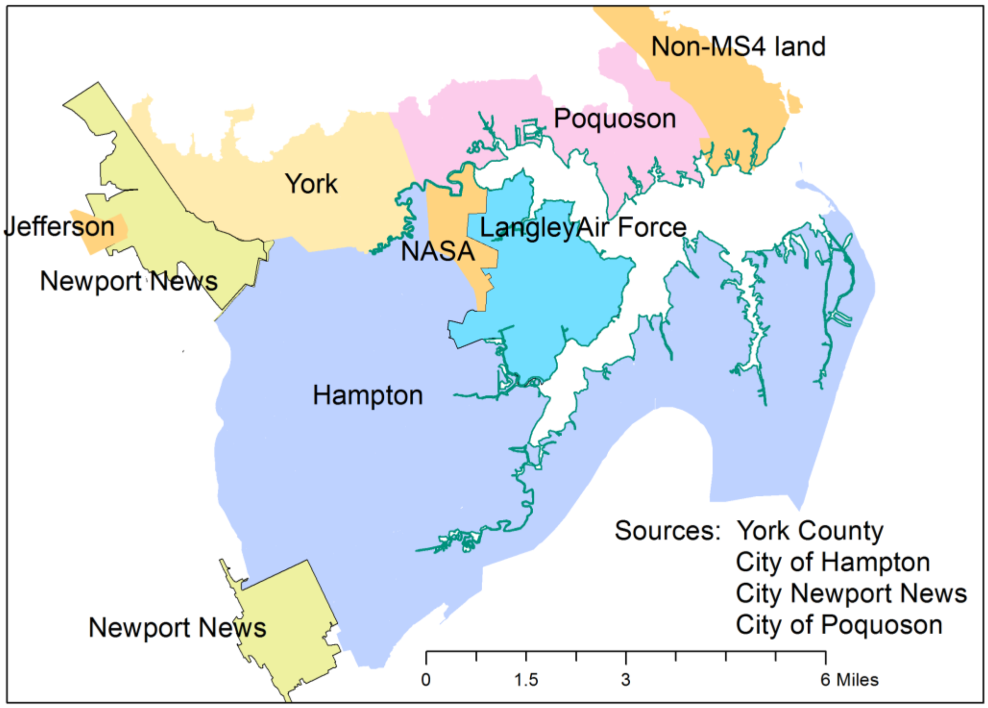


Figure 3.1: MS4 Phase I and Phase II for the Cities of Hampton, Poquoson, and Newport News, and for York County, in the Back River Watershed

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-derived sources (failures of septic systems, SSOs), 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 (US Census Bureau, 2011). For example, as only a portion of York County and City of Newport News are within the watershed, the human population of York County and Newport News within the watershed is estimated based on percent of residential area within the Back River watershed with respect to the County or City residential area. 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 higher than the number of licenses registered in the cities contacted. The current number of licenses for the Cities of Poquoson, Hampton and Newport News were obtained. The number was divided by urban landuse acreage to obtain the number of dogs per acre of urban landuse area. A different rate was applied to each jurisdictional area in the Back River watershed. 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. Note that the federal areas are excluded from this table as wildlife is the dominant bacterial source.

Table 3.2: Human Population, Households, and Pets in the Back River Watershed

	City of Poquoson	York County	City of Hampton*	City of Newport News	Total
Population (2011)	4,766	9,451	136,836	22,234	188,898
Households	1,862	3,906	60,118	8,235	81,829
Dogs	588	1,872	6,972	1,299	10,731

* A small portion of the population living in the watershed does not drain to the Back River

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 Cities of Hampton and Poquoson are currently on public sewer systems. Some areas of York County are still using septic systems – there are 613 septic tanks in the watershed. Septic system locations are shown in Figure 3.2 for the Back River watershed. 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). After a major campaign to reduce the number of septic systems in the watershed, the water quality condition was improved significantly. The loading estimated here is based on average loading and could under-estimate the influence of septic systems.

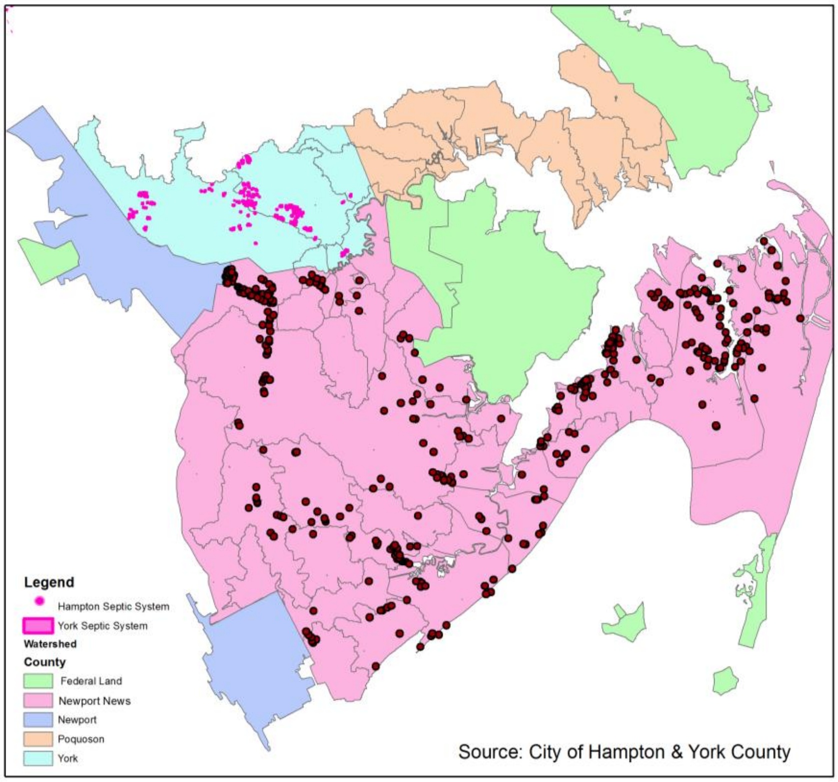


Figure 3.2: Septic System Locations in the Back River Watershed

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 (VADEQ, 2010). SSOs are often caused by blockages and/or breaks in the sewer lines (EPA, 2009).

SSOs were recorded from 2008-2012. According to observations, SSOs that occurred in the watershed are shown in Figure 3.3. An accumulative spillage distribution is shown in Figure 3.4. The loading corresponding to a 95th percentile 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. In general, SSO spills occurred less than 5% each year for each region with high spatial and temporal variations, 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.

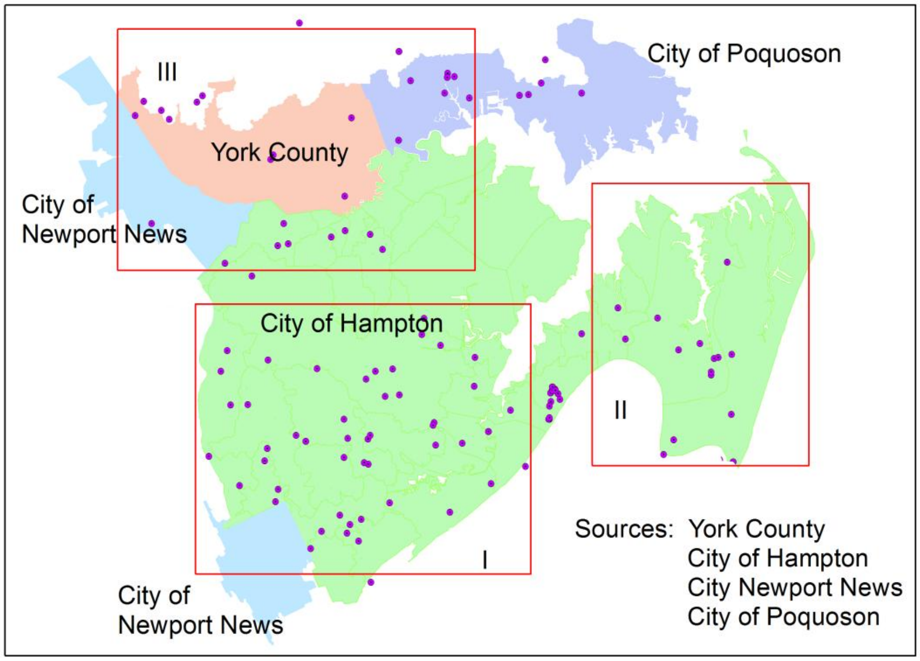
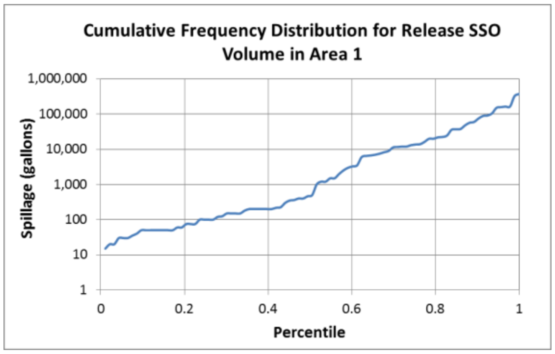
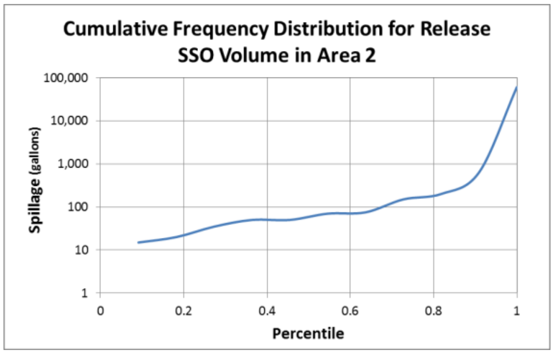


Figure 3.3: Distribution of SSO Locations in the Back River Watershed





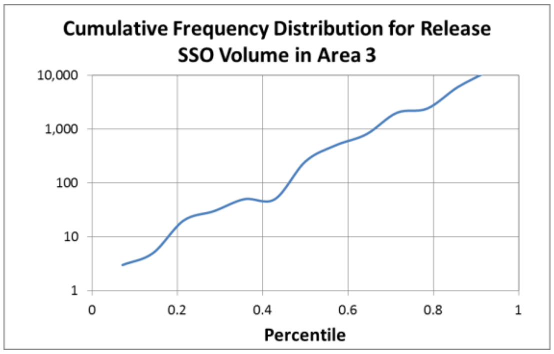


Figure 3.4: Cumulative Frequency Distributions of SSOs in the Back River Watershed

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

Area	Number of spills	95% Volume (Gallons)	Raw Sewage (MNP/100mL)	Non-raw Sewage* (MPN/100mL)	m^3	Fecal Coliform (Counts/Day)
1	93	154,362	2,700,000	500,000	584.32	6.135×10^{12}
2	11	30,315	2,700,000	500,000	114.75	1.21×10^{12}
3	14	17,390	2,700,000	500,000	65.83	6.91×10^{11}
*The concentration is based on published value						

Wildlife

The wildlife inventory for the Back River 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 wildlife in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. 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 field survey and the UVA population model, the deer population is much higher in Poquoson and York watersheds than its averaged density in this region. Therefore, high acreage densities of 0.094 animals per acre were used to estimate the deer population in the City of Poquoson and York County and a lower density of 0.047 animals per acre was used for the Cities of Hampton and Newport News.

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 can be expected to be higher in the adjacent 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 contribution, a tidal prism model was used to inversely estimate the fecal coliform loading from the Plum Tree Island National Wildlife Refuge based on observations. 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:

$$Q_{in}C_{in}-Q_{out}C+L_0-k_cV=0$$

where Q_{in} and Q_{out} are water fluxes (m^3 per tidal cycle) in and out of the model segment. 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 values of the decay rate vary 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, 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 per day (USEPA, 2001a), an estimated mean density of about 0.77 birds per acre was determined. 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, wetlands, and urban land. The value was further verified by the watershed model simulations, which yield good agreement between model predictions and observations (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	0.047-0.094 animals/acre	Entire watershed, except open water and urban development (the high value of 0.094 was used in York County and City of Poquoson)
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
Ducks/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 entire remainder of the watershed.		

Livestock

The shoreline survey data of the Shellfish Sanitation Division of the Virginia Dept. of Health, together with National Agriculture Statistics Survey data, were used to estimate the livestock values. VDH-DSS 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 Back River Watershed

Animal Name	Number	Direct Access
Horses	182	Yes/No
Cattle	80	Yes/No
Cows	3	No
Kenneled dogs	60	No
Pastured goats	6	No
Donkeys	9	No
Sheep	8	No
Pigs	2	No
Bobcats	2	No
Deer	1	No
Rabbits	8	No
Raccoons	3	No
Caged chickens	535	No
Geese	65	No
Caged ducks	45	No
Pigeons	30	No
Owls	6	No
Hawks	2	No
Turkey Vulture	1	No
Rooster	1	No

Marinas

Marina 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 for each slip is assumed and only 10% of the slips in the water contribute to the loading.

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

Location	Slips/Moorings	Existing
Langley Air Force Base Marina	100 - dry storage	
Marina Cove Basin 600 Harris Creek Rd, Hampton	87	Wet: 9 < 26 ft, 33 > 26 ft
Dandy Haven Marina,	75	Wet: 23<26 ft,

374 Dandy Haven Rd, Hampton		17>26 ft
Wallace's Marina 373 Dandy Haven Rd, Hampton	11	Wet: 2 < 26ft, 4 > 26ft
Belle Isle Marina 2 Bell's Island Road, Hampton	65	Wet: 4 < 26ft, 20 > 26ft
Bill Forrest Seafood 287 Messick Rd., Poquoson	8	Wet: 2 < 26ft, 1 > 26ft
Messick Point Boat Landing End of Messick Rd., Poquoson	20	Wet: 9 < 26ft, 2 > 26ft
Poquoson Yacht Club POB 2044, Poquoson	10	Wet: 1 < 26ft
Public Boat Dockage 435 Messick Rd., Poquoson	30	Wet: 3 < 26ft, 3 > 26ft
Tennis Boat Yard Cove Road, Poquoson	6	Wet: 1 < 26ft
Roy Davis Seafood	4	Wet: 5 < 26ft

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 loading is estimated based on the average of 95th-percentile loading at each different region. As spillage occurred less than 5% per year in each region, it does not contribute significantly daily. Overall, wildlife and pets contribute 85% of the total loading. A source distribution for the watershed is summarized in Table 3.8.

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

Name	Number	Loading (Counts/Day)	Percent
Deer	3,788	1.89E+12	4.9%
Dog	10,731	1.51E+13	26.1%
Ducks/Birds	31,031	1.89E+13	48.9%
Muskrats	1,013	2.53E+11	0.7%
Nutria	2,321	5.80E+11	1.5%
Raccoons	1,123	1.40E+11	0.4%
Human-SSO*		2.68E+12	6.9%
Human-Septic	613	5.27E+09	0.0%
Marina (slips)	306	1.84E+11	0.5%
Livestock		3.92E+12	10.1%
Totals		**4.36E+13**	**100.0**

*SSO is estimated based on the mean 95th-percentile loading of different area.

Table 3.8: Loadings from Source Categories as Percentages of Total

Name	Loading (Counts/Day)	Percent
Livestock	3.92E+12	9%
Wildlife	2.76E+13	62%
Human (Septics, SSOs, Marinas)	2.87E+12	6%
Pet	1.03E+13	23%
Total	4.47E+13	100%

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, 2006b). 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:

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

This section documents the detailed fecal coliform TMDLs and LA development for the Back 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 of the impaired segments are within shellfish growing areas delineated by the VDH-DSS. According to WQS 9VAC25-260-50, the numerical criteria for fecal coliform for the shellfish harvesting use of Back River is a *Geometric Mean* of 14 MPN/100mL and a *90th Percentile* of 49 MPN/100ml. For the riverine segment, two *E. coli* criteria were used: 1) a monthly geometric mean of 126 cfu/100ml and 2) no more than 10% of the total samples in the assessment period shall exceed 235 *E.coli* cfu/100 ml. Because a *90th Percentile value* of 49 MPN/100ml is more stringent, it was used as the endpoint for fecal coliform to determine the TMDL. Following VDH-DSS assessment protocol, a 30-month period is used as the assessment period. For tributaries impaired with enterococci, 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.

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:

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

To compute *E. coli*, the following translator equation (VA-DEQ 2003, 2008) was used to convert fecal coliform concentrations to *E. coli* concentrations:

$$\log_2(E.coli) = -0.0172 + 0.91905 \times \log_2(Fecal\ Coliform)$$

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.

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 Back 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 ecoregion. 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 the Back River area for urban landuse. A comparison of model results against the EPA watershed model at a selected subwatershed in Back River and Beaverdam Swamp against the USGS station of flow is shown in Figure 4.1. Detailed modeling processes and calibration procedures are presented in Appendix A.

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 the 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.

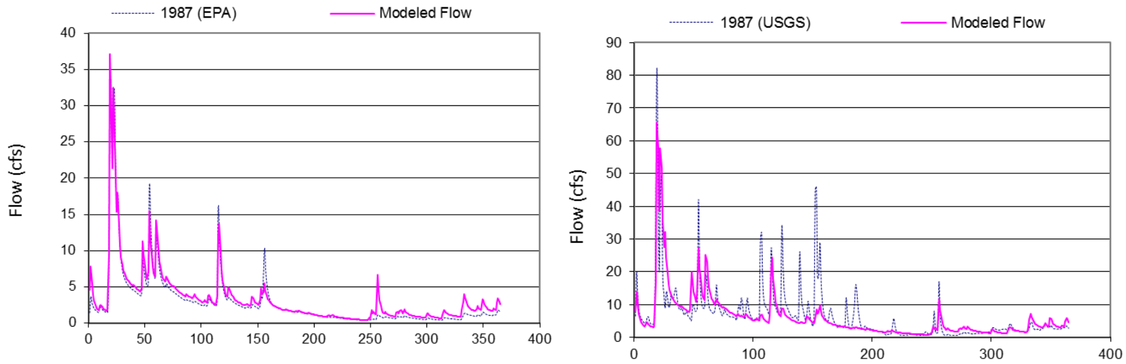
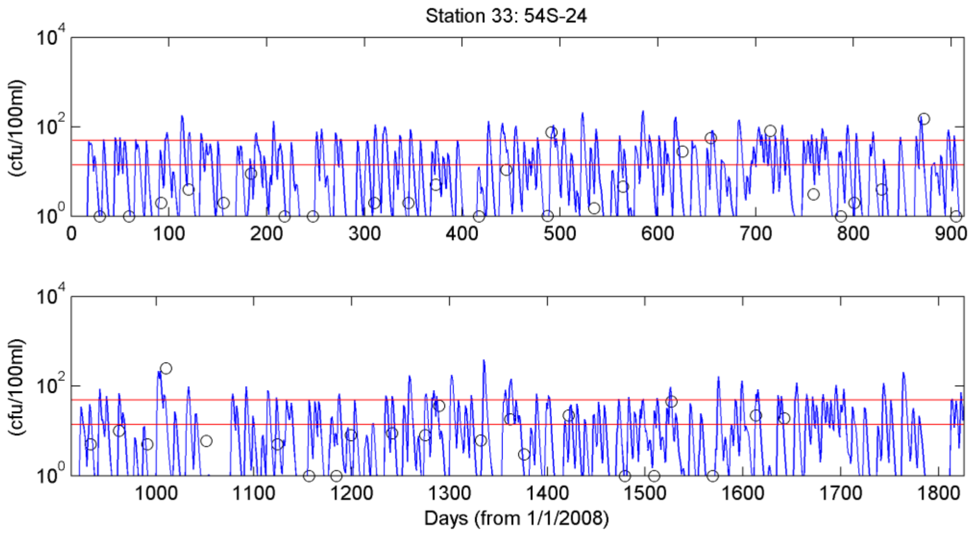
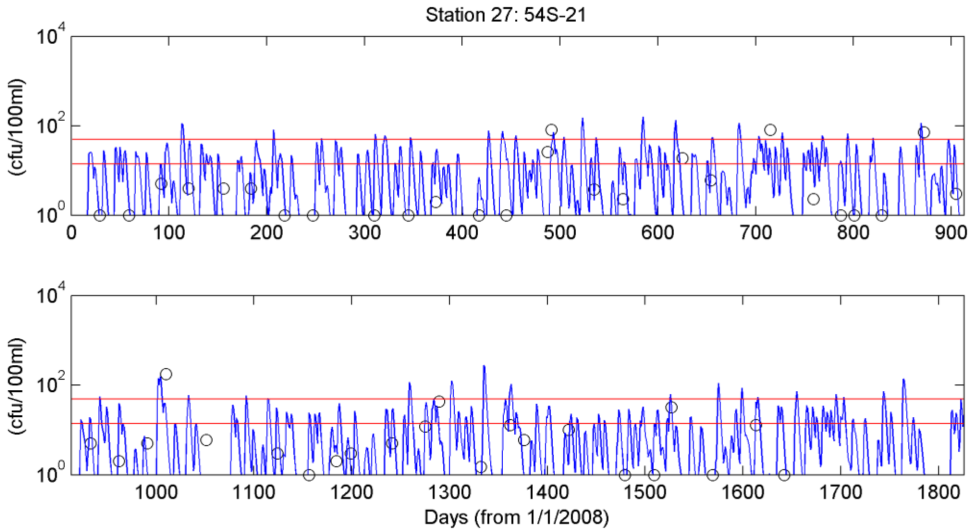


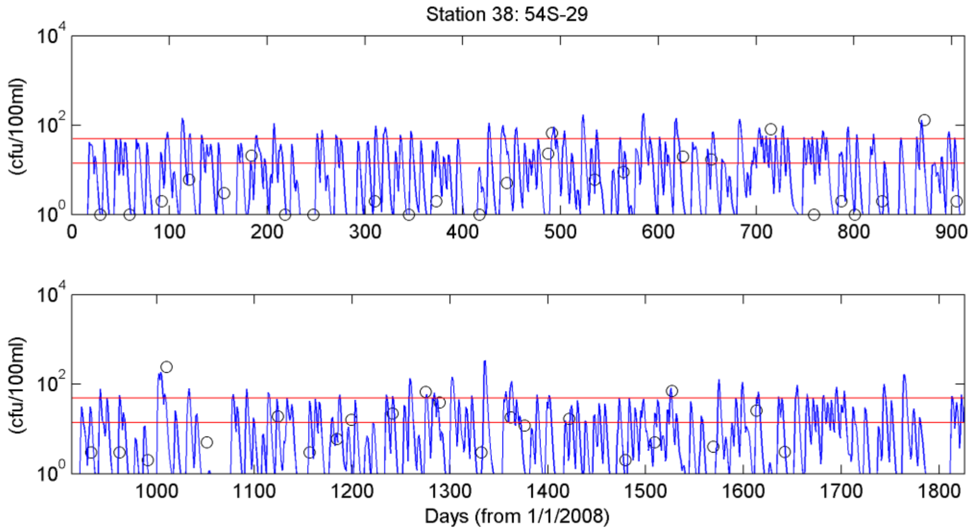
Figure 4.1: Time Series Comparison of Daily Stream Flow between Model Simulation and EPA Watershed Model (Left Panel) and Observations from USGS Stream Gage 01670000 in 1987 (Right Panel)

A portion of the watersheds of York County and Newport News flows into the Big Bethel Reservoir before flowing downstream into Brick Kiln Creek. The flow that discharges to the Brick Kiln is controlled by spillway. The Big Bethel Reservoir was modeled by the EFDC model and flow control through the spillway was implemented using the built-in function of the model. Because of the large volume of the reservoir, the bacterial concentration is lower. Therefore, loading output from the reservoir does not contribute to the impairment of Brick Kiln Creek downstream, which is mainly caused by adjacent watersheds, because the creek is very narrow with a low capacity to accept large loadings.

Model results at 6 selected stations, including one DEQ station located in the tributary (BRK0014.14), are shown in Figures 4.2. Because of many random events that are unknown, the model calibration focuses on the general seasonal variation rather than attempting to match individual events, which may result in over-prediction. 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 4.3 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 Back 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 33: 54S-24
(cfu/100ml)
Days (from 1/1/2008)


Station 27: 54S-21
(cfu/100ml)
Days (from 1/1/2008)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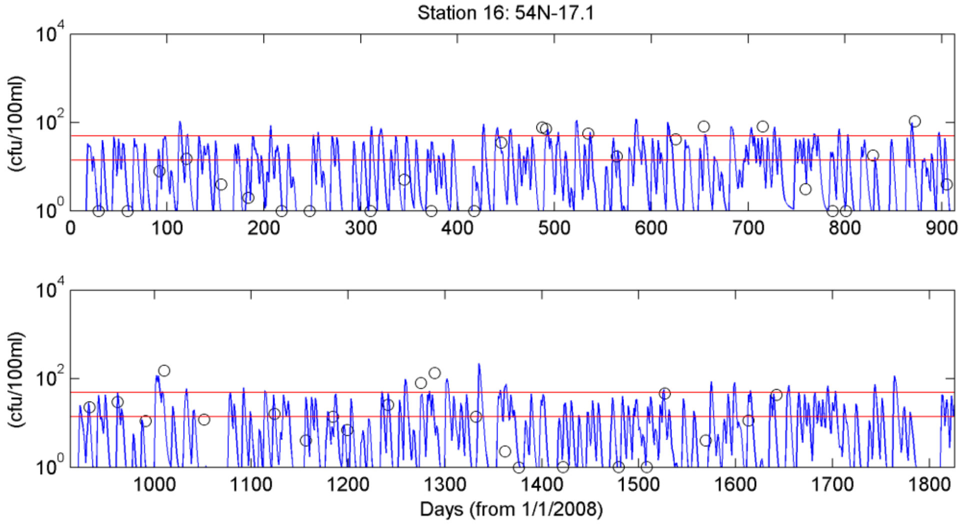
(cfu/100ml)
Days (from 1/1/2008)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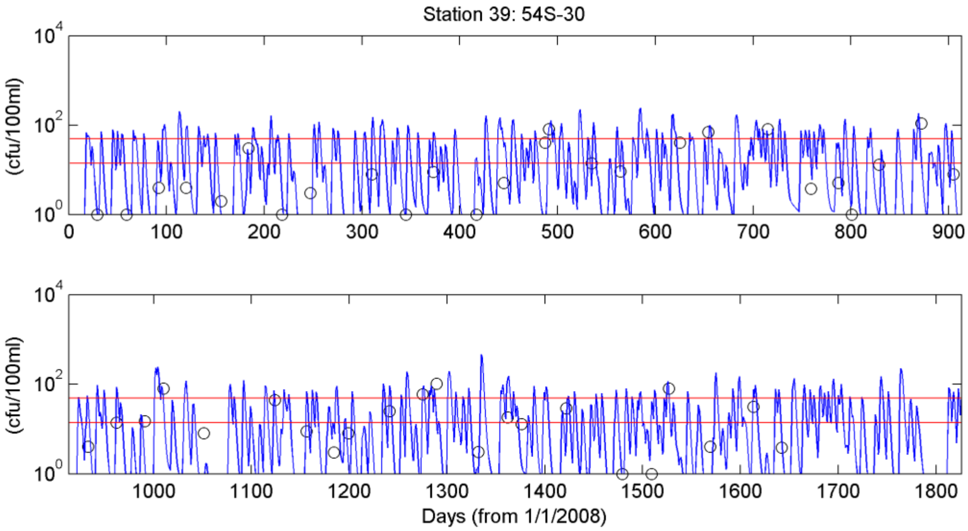
(cfu/100ml)
Days (from 1/1/2008)


Station 39: 54S-30
(cfu/100ml)
Days (from 1/1/2008)

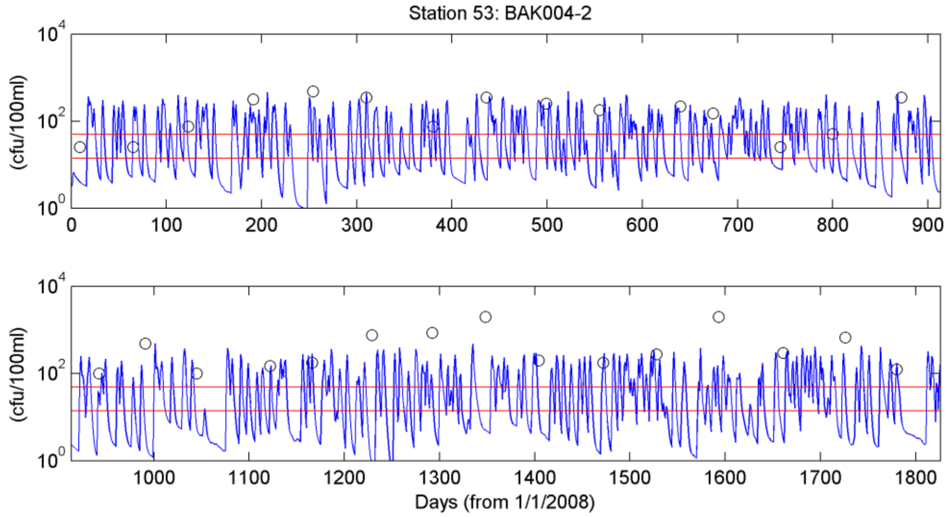


Figure 4.2: Time Series Comparison of Fecal Coliform Concentration between Model Simulation (Blue Lines) and Observations (Circles) from 2008 to 2012. The Red Lines Denote the Geometric Mean and 90th Percentile Criteria.

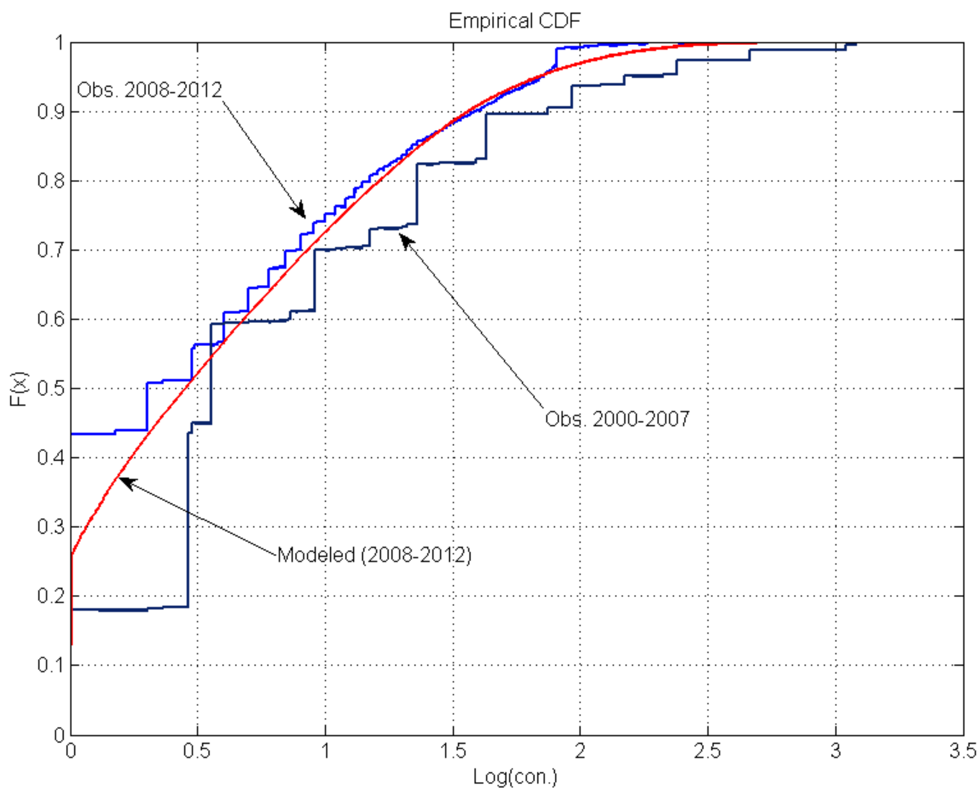


Figure 4.3: Comparison of Cumulative Distribution of Modeled and Observed Fecal Coliform at All Stations against 2008-2012 Observations and 2000-2007 Observations, respectively.

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 2008-2012 record of water quality monitoring (observation) data and the model simulation of 2000-2007. 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 2008-2012 calibration period 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 an 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 Back River, long-term model simulations were conducted to account for a large range of variations. Therefore, the MOS was implicitly incorporated in this TMDL that allocation scenarios were designed to meet the fecal coliform standards for a *geometric mean* of 14 MPN/100 mL, a *90^{th} percentile* of 49 MPN/100mL, and for instantaneous values of enterococci not to exceed 10% during the access period of 104 cfu/100ml and the monthly geometric mean not to exceed 43 cfu/100 ml.

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 was computed based on model simulation results of long-term annual mean loading with the consideration of the probability of being exceeded on a daily basis. The EPA-recommended method to convert long-term annual mean loading to daily maximum loading was 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 loading from the watershed 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 90^{th} 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 the Back River are listed in Table 4.1. The annual load was computed as multiple mean annual loads, or mean daily load times 365.25 day. The results and reduction expressed as annual loads are listed in Tables 4.2.

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

Pollutant	Criterion (cfu/100ml)	Current Load (Counts/Day)	Allowable Load (Counts/Day)	Required Reduction (%)
Fecal Coliform	Geomean: 14 90^{th} Percentile: 49 Enterococci: 104 Geomean: 35	8.54E+12	5.35E+12	37.3%

Table 4.2: Estimated Annual Loads and Load Reductions for Fecal Coliform

Pollutant	Criterion (cfu/100ml)	Current Load (Counts/Year)	Allowable Load (Counts/Year)	Required Reduction (%)
Fecal Coliform	Geomean: 14 90^{th} Percentile: 49 Enterococci: 104 Geomean: 35	1.39E+15	8.73E+14	37.3%

The fecal coliform existing and allowable loads for York County, and the Cities of Hampton, Poquoson, and Newport News, and federal land are summarized in Table 4.3. It should be noted that the storm water regulated areas within the county and cities were included in the county and cities, except for NASA. Jefferson Lab and Langley Air Force are aggregated in the Cities of Newport News and Hampton, respectively. The annual loading is listed in Table 4.4. According to the model simulation, no reduction is required for NASA, Jefferson Lab, and Langley Air Force, as the major source in these areas is wildlife, which does not cause any impairment of downstream segments. The watershed of the City of Newport News, which discharges into the Big Bethel Reservoir, does not require reduction, nor does the subwatershed of York County that discharges to the Reservoir. The reduction from the City of Newport News is the watershed discharge into the riverine portion of the upstream portion of Newmarket Creek. The reductions from watersheds of York County are mainly discharges into Brick Kiln Creek and the Northwest Branch of Back River. The reductions from watersheds of the City of Poquoson are mainly discharges into Cedar Creek and the Northwest Branch of Back River.

Table 4.3: Estimated Daily Loads and Load Reductions Fecal Coliform for Each Jurisdiction

Jurisdiction	Existing Load (Counts/Day)	Allowable Load (Counts/Day)	Reduction (%)
City of Newport News	4.34E+11	3.58E+11	17.5
City of Hampton	6.62E+12	3.98E+12	40.0
City of Poquoson	9.66E+11	6.04E+11	37.5
York County	4.76E+11	3.72E+11	21.8
NASA	4.34E+10	4.34E+10	0.0
Total	8.54E+12	5.35E+12	37.3

Table 4.4: Estimated Annual Loads and Load Reductions Fecal Coliform for Each Jurisdiction

Jurisdiction	Existing Load (Counts/Year)	Allowable Load (Counts/Year)	Reduction (%)
City of Newport News	7.08E+13	5.84232E+13	17.5
City of Hampton	1.08E+15	6.48353E+14	40.0
City of Poquoson	1.57E+14	9.83012E+13	37.5
York County	7.76E+13	6.06757E+13	21.8
NASA	7.09E+12	7.08877E+12	0.0
Total	1.39E+15	8.72842E+14	37.3

4.7 Summary of TMDL and Load Allocation

There are no permitted industrial or wastewater treatment facilities in the watershed of the Back River that discharge fecal coliform. There are nine regulated storm water permits in the watershed, and wastewater quantities are allocated to each MS4 regulated area based on the amount of urban land within the MS4's regulated area. The TMDLs are summarized in Table 4.5. The annual TMDL is shown in Table 4.6.

Table 4.5: Bacterial TMDL for Back River (Counts/Day)

Impairment	WLA	LA	MOS	TMDL
Back River	**2.38E+12**	**2.98E+12**	implicit	**5.35E+12**
MS4 Newport News (VA0088633)	*2.31E+11*			
VDOT (VAR040115)				
DOE-TJ Accelerator Facility (VAR040079)				
MS4 Hampton (VA0088641)	*1.83E+12*			
VDOT (VAR040115)				
TNCC (VAR040087)				
Langley Air Force Base				
MS4 Poquoson (VAR040024)	*8.20E+10*			
MS4 York (VAR040028)	*1.65E+11*			
VDOT (VAR040115)				
MS4 NASA Langley Research *Center (VAR040079)*	*1.21E+10*			
Future Load	*5.33E+10*			

*Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load and other Phase II MS4 permit holders where noted, 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
Future Load =Future growth

Table 4.6: Bacterial Annual Maximum Load for Back River (Counts/Year)

Impairment	WLA	LA	MOS	TMDL
Back River	**3.87E+14**	**4.82E+14**	implicit	**8.73E+14**
MS4 Newport News (VA0088633)	*3.781E+13*			
VDOT (VAR040115)				
DOE-TJ Accelerator Facility (VAR040079)				
MS4 Hampton (VA0088641)	*2.99E+14*			
VDOT (VAR040115)				
TNCC (VAR040087)				
Langley Air Force Base				
MS4 Poquoson (VAR040024)	*1.33E+13*			
MS4 York (VAR040028)	*2.70E+13*			
VDOT (VAR040115)				
***MS4 NASA Langley Research** Center (VAR040079)*	*1.98E+12*			
Future Load	*8.73E+12*			

*Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load and other Phase II MS4 permit holders where noted, due to the continuity of the system.

Future Growth Considerations

A future growth component was developed and modeled as part of the overall WLA (WLA-FG). A bacteria load value for future growth was determined as 1% of the total TMDL and allocated as future load. This was incorporated into the WLA for use as current dischargers expand and for future permits that may discharge bacteria.

This future growth is NOT allocated to the individual permittees; rather the future growth is allocated to the entire watershed, as defined by the TMDL polygon boundary. This future growth is available to a new or expanding permittee in the watershed on a first-come first-served basis. The Future Growth portion of the WLA has been verified in a model run scenario to document that a new or expanding individual VPDES permit will not cause or contribute to a violation of water quality standards under an alternate TMDL scenario.

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 scenario seeks to eliminate 100% of the human-derived fecal component, regardless of the allowable load determined through the allocation process. Human-derived fecal coliform is a serious concern in the estuarine environment and both state and federal law preclude 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. Although SSO incidence does not occur daily, it can contribute to a 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 as the worst-case scenario. The allocations presented a scenario as to 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: Load Allocation and Required Reduction for Fecal Coliform for Each Source Category

Waterbody Name	Category	Current Load (Counts/Day)	Percentage	Load Allocation (Counts/Day)	Reduction Needed (%)
Back River	Livestock	7.69E+11	9	0.00E+00	100%
	Wildlife	5.30E+12	62	5.30E+12	1%
	Human (SSO, Septic, Marina)	5.13E+11	6	0.00E+00	100%
	Pets	1.96E+12	23	5.69E+10	99%
	Total	8.54E+12	100	5.35E+12	37%

- Note that the loads listed in the table include both WLAs and LAs

Table 4.8: Nonpoint Source Load Allocation and Required Reduction for Fecal Coliform for Each Source Category

Waterbody Name	Category	Current Load (LA) (Counts/Day)	Percentage	Load Allocation (LA) (Counts/Day)	Reduction Needed (%)
Back River	Livestock	7.69E+11	20	0.00E+00	100%
	Wildlife	2.98E+12	79	2.98E+12	0%
	Human (Marina)	3.51E+10	1	0.00E+00	100%
	Pets	0.00E+00	0	0.00E+00	0%
	Total	3.75E+12	100	2.98E+12	21%

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 Back River 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 process. 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.

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Appendix A: Model Development

A.1 Model Development

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

A.1.1 Model Description

A.1.1.1 Watershed Model

The LSPC model is a stand-alone, personal computer-based watershed modeling program developed in Microsoft C^{++} (Shen *et al*., 2005). It includes selected Hydrologic Simulation Program FORTRAN (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land, as well as a simplified stream transport model (USEPA, 2004; Shen *et al.*, 2002a, b; USEPA, 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 Back River watershed to simulate this watershed of 65 hydrologically connected subwatersheds (Figure A.1). The subwatersheds were used as modeling units for the simulation of flow and bacteria deposition on the watershed. LSPC was used to simulate the freshwater flow and its associated nonpoint source pollutants. The simulated freshwater flow and bacteria loadings for each subwatershed were fed into the adjacent water quality model segments. In simulating nonpoint source pollutants from the watershed, LSPC uses a traditional buildup and washoff approach. Pollutants from various sources (manure, wildlife, septic systems, etc.) accumulate on the land surface and are subject to runoff during rain events. Different land uses are associated with various anthropogenic and natural processes that determine the potential pollutant load. The pollutants contributed by interflow and groundwater are also modeled in LSPC for each land use category. Pollutant loadings from surface runoff, interflow, and groundwater outflow are combined to form the final loading output from LSPC. In summary, nonpoint sources from the watershed are represented in the model as landuse-based runoff from the landuse categories to account for their contribution (USEPA, 2001a).

For this study, the watershed processes were simulated based on buildup and washoff processes. The final loads were converted to model accumulation rates (ACQOP, units of counts/acre/day for bacteria). 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 count per day and were applied to forest and wetland. For urban landuse, contributions from wildlife (birds/duck), pets, and failures of septic systems are summed together and applied to the urban landuse. As wildlife and pets are dominant bacterial sources, urban landuse contributes the highest bacterial loading. The contribution from livestock was applied only to the subwatershed where these sources are located. For the current model simulation, SSOs were not simulated by the watershed model as incidences occurred less than 5% of the time within a given year. Loading estimation was conducted for each subwatershed and each landuse so that spatial loading variations could be simulated. These loading parameters were adjusted accordingly for individual sub-watersheds where source estimation is not accurate (i.e., livestock contribution) during model calibration. 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 lb/acre/day for nutrients or counts/acre/day) and the washoff rate (WSQOP, unit 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.

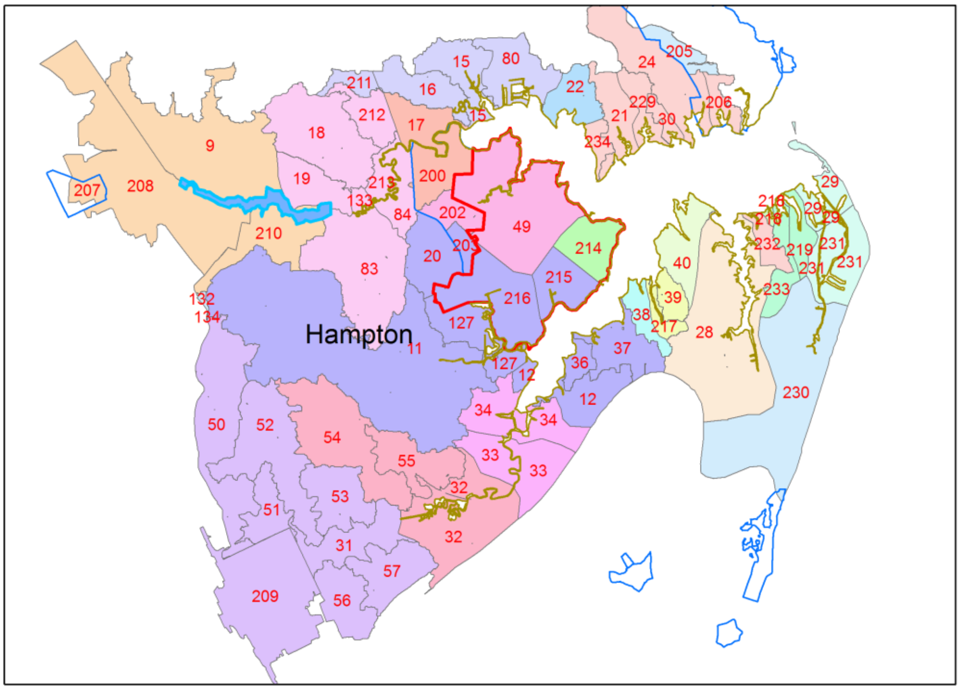


Figure A.1: Subwatersheds Model Segmentation

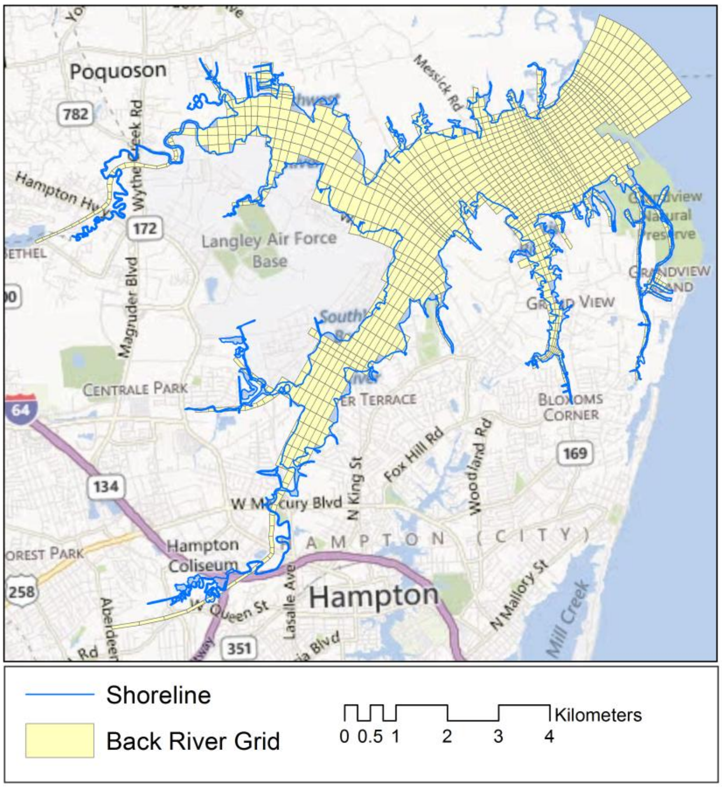


Figure A.2: EFDC Model Grid

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 Back 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 Back River include:

- Bathymetry
- Freshwater inputs (lateral and up-stream) 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 Back River was developed based on the high-resolution shoreline digital files from USEPA and USGS topographic maps. The bathymetry used NOAA bathymetry data (NOAA http://www.ngdc.noaa.gov/mgg/bathymetry/).The grid covered 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 increased the model accuracy by reducing the influence of the boundary condition. There are a total of 1264 cells in the horizontal surface grid.

The Big Bethel Reservoir was also modeled by the EFDC model. The outflow from the Reservoir was based on the spillway control, which is a built-in function of the model. The water will maintain in the Reservoir unless the stage of the reservoir overflows the spillway. Under normal conditions, flow does not discharge to the downstream Brick Kiln Creek.

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 was achieved. Since there is no USGS gage or any other continuous flow data available in the Back 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 Back River watershed, was used to calibrate the model parameters for hydrology simulation. This is the only gage station in this region. The observation was from 1980-1989. The landuses of forest and wetland and soil types are similar to those of the Back River watershed, but it has less urban land. The USGS flow was used mainly for calibration non-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 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 subwatershed in the Back 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.

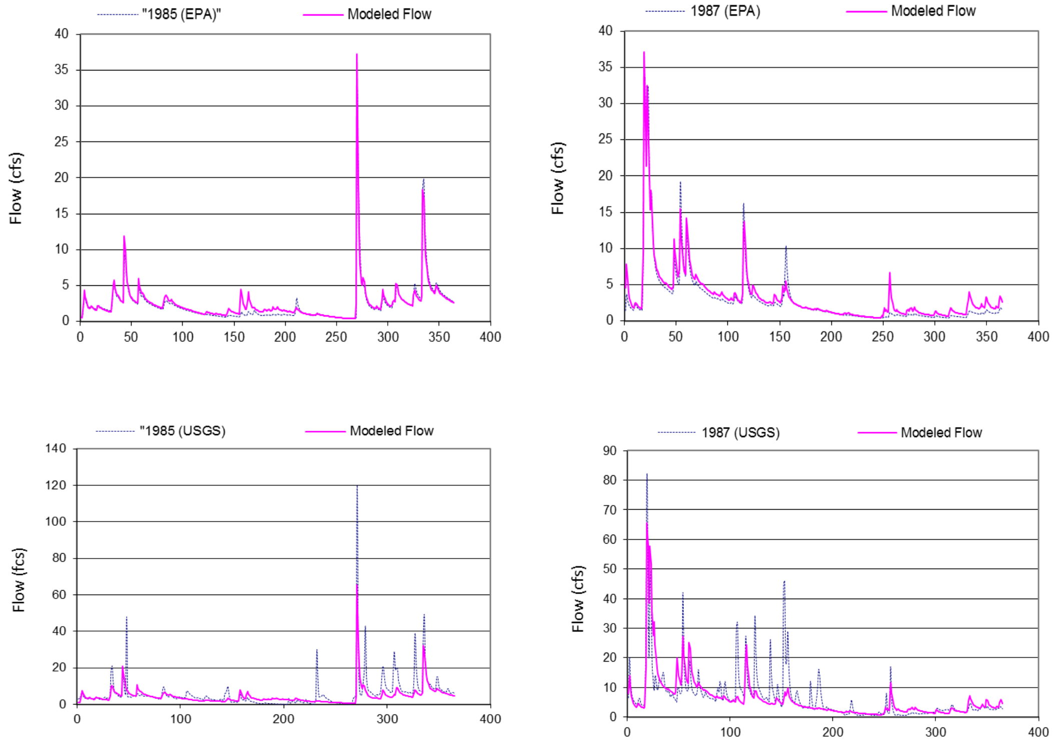


Figure A.3: Time Series Comparison of the Daily Stream Flow of Model Simulation vs. Observed Data from USGS Stream Gage 01670000 in 1985 & 1987

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 the comparison, it can be seen that LSPC has reasonably reproduced the observations.

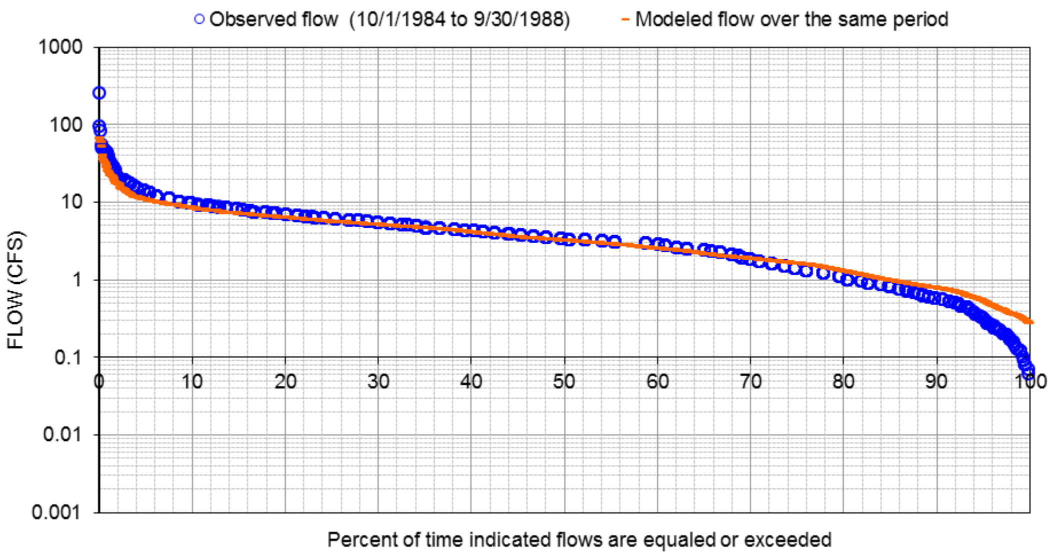
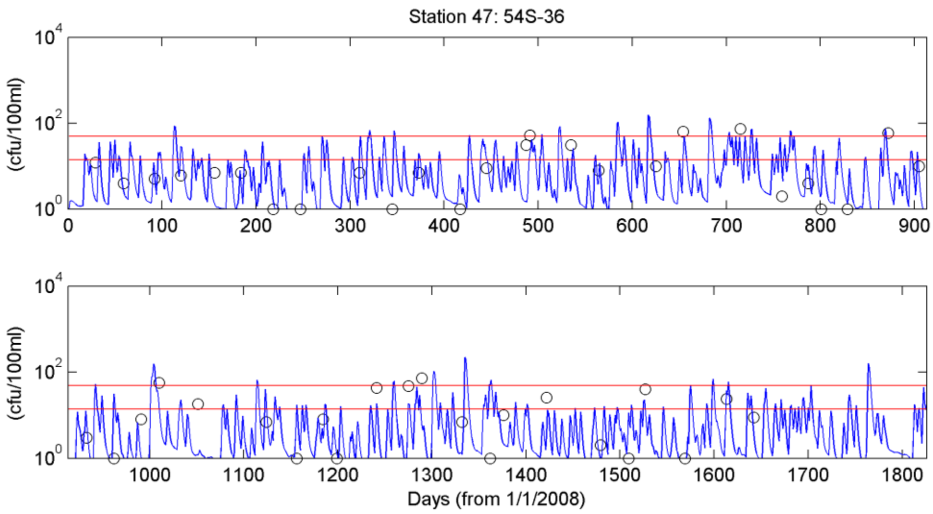
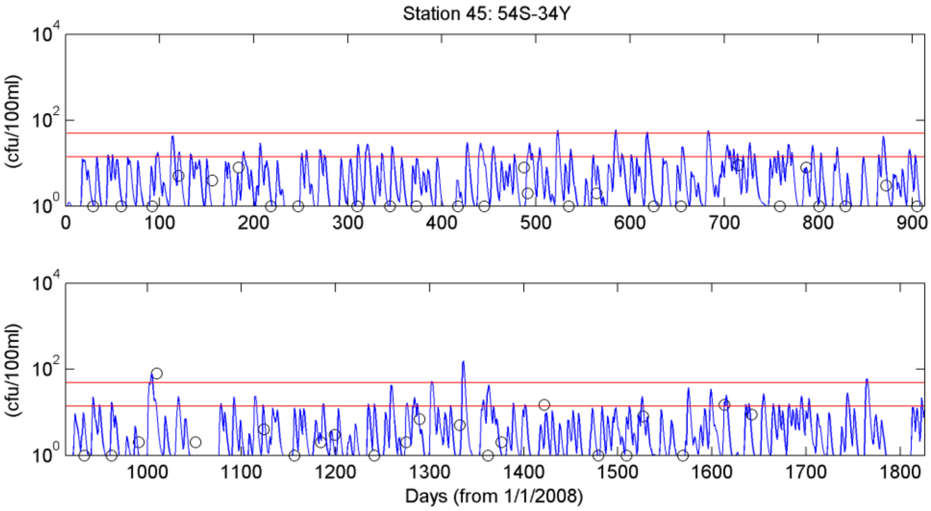


Figure A.4: Long-term Accumulated Daily Stream Flow Comparison between Model Simulation and the Reference Flow Station USGS 01670000

Calibration of the bacteria transport model is typically performed using water quality measurements from the watershed. Absent the necessary data from the Back River watershed, the calibration was performed on the observation data in the Back 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 using USEPA recommended loading production rates (USEPA, "FecalTool.xls" program, 1998). The model was calibrated from 2008-2012. The loading distribution estimated in Section 3 only provides a background average value and this loading distribution is not uniform over the entire watershed. Some 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 selection of the model calibration period is to obtain a better estimation of the current condition. 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 17 selected stations of impaired segments. It can be seen that the model prediction matches the observed data quite well. As bacterial concentrations in the River are highly driven by events, 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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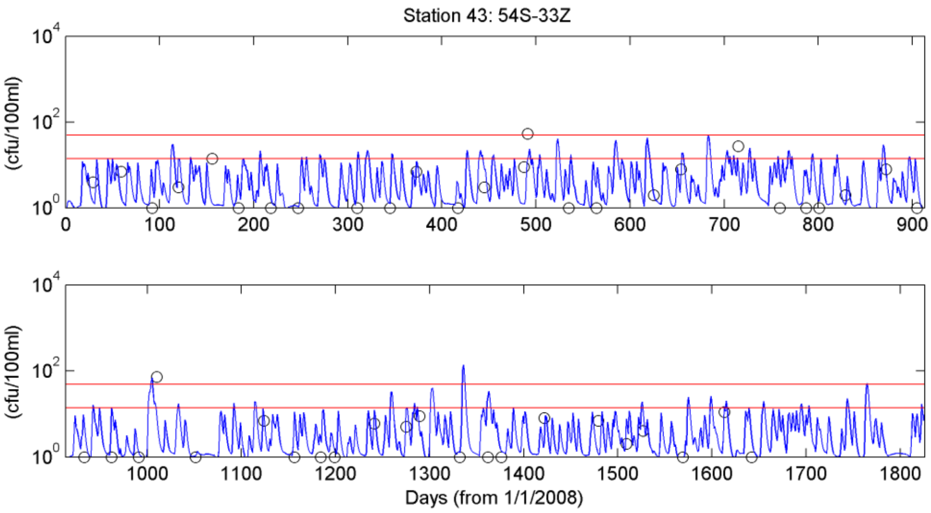

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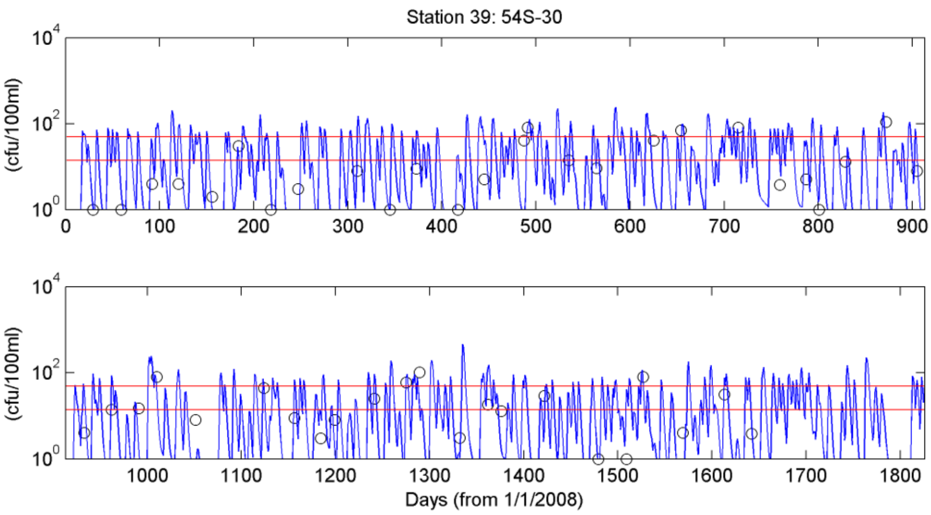

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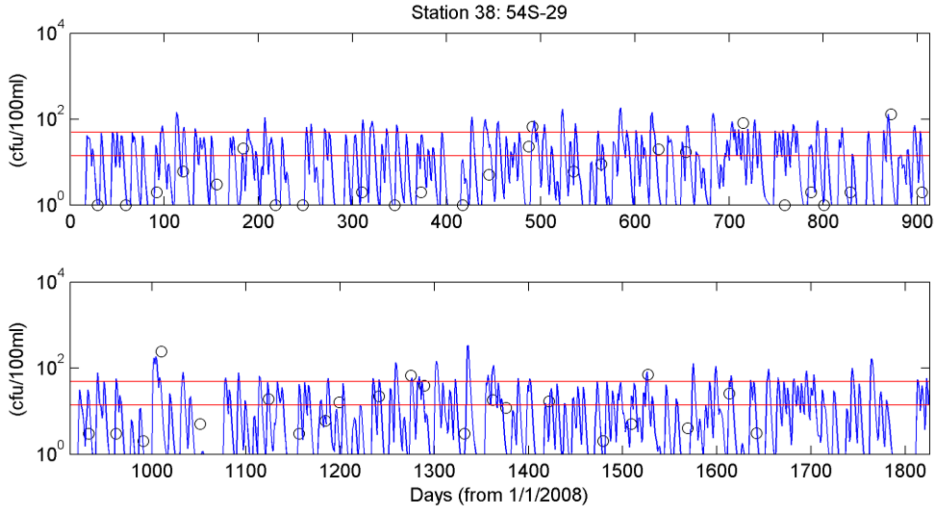

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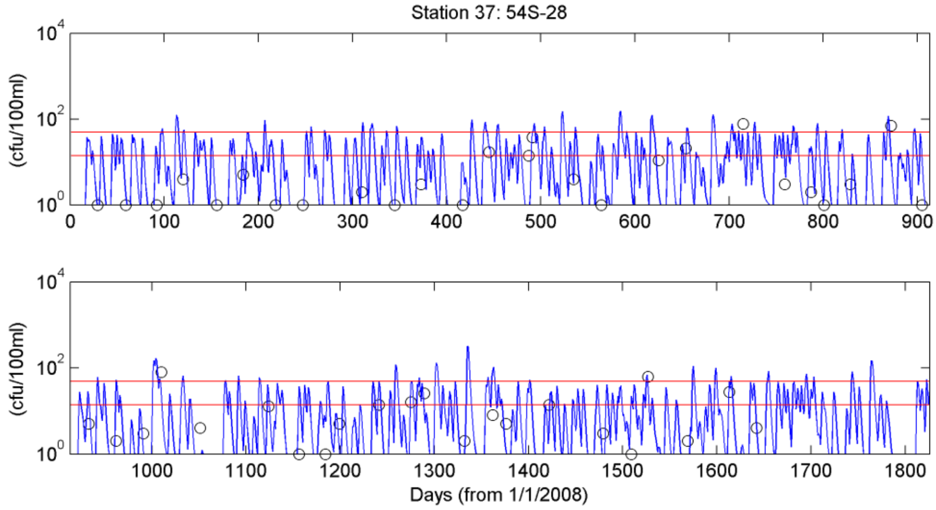

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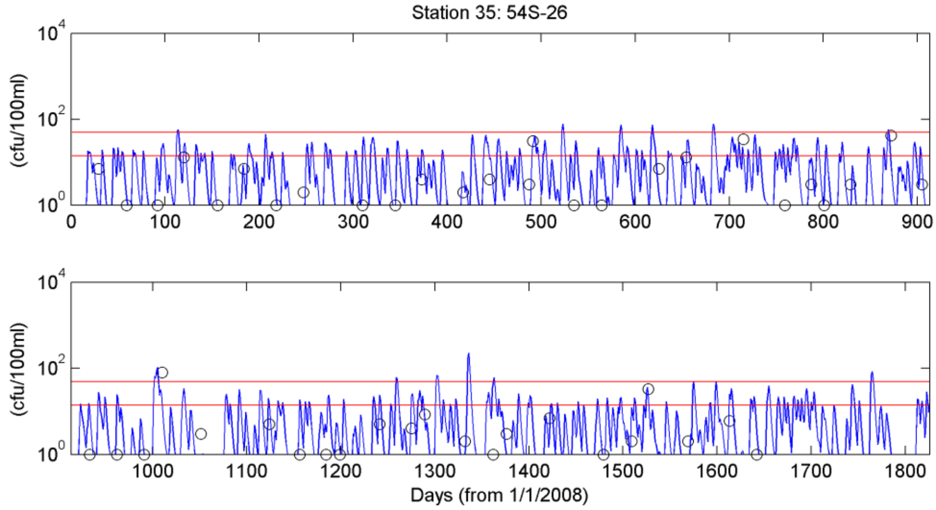

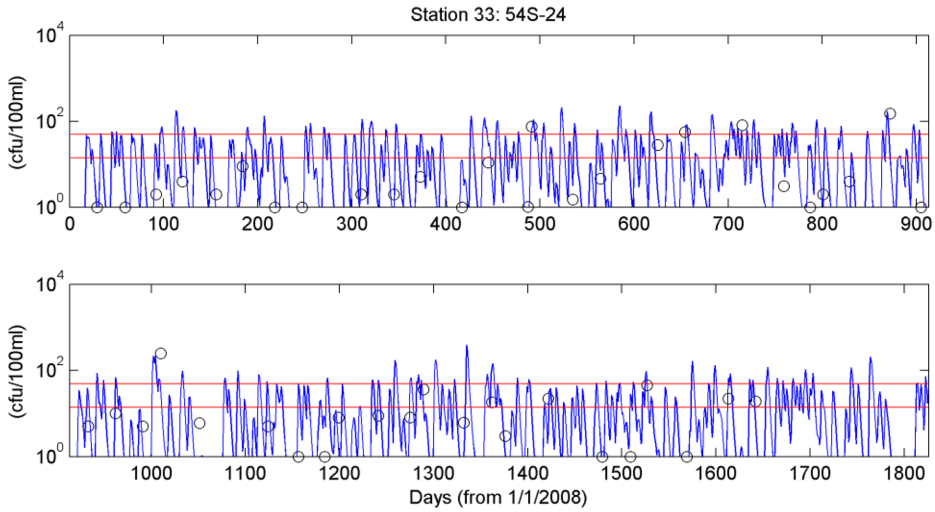
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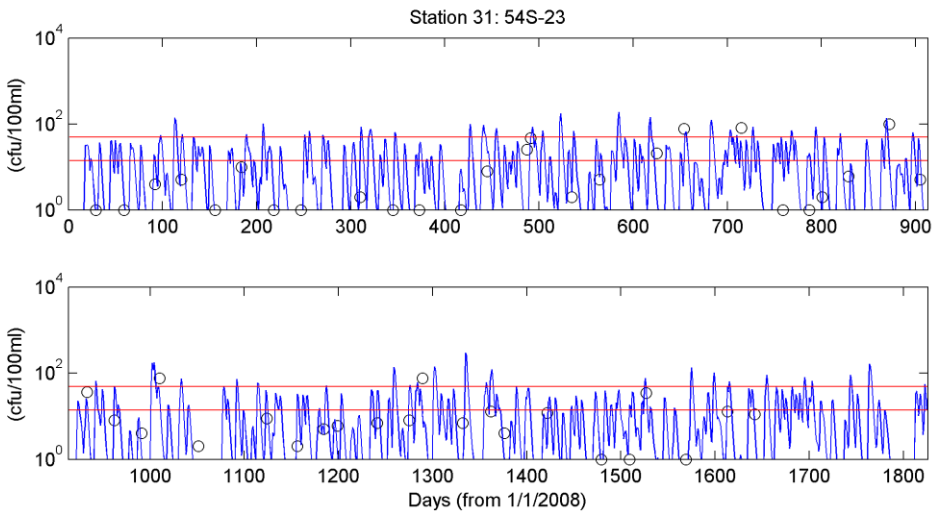
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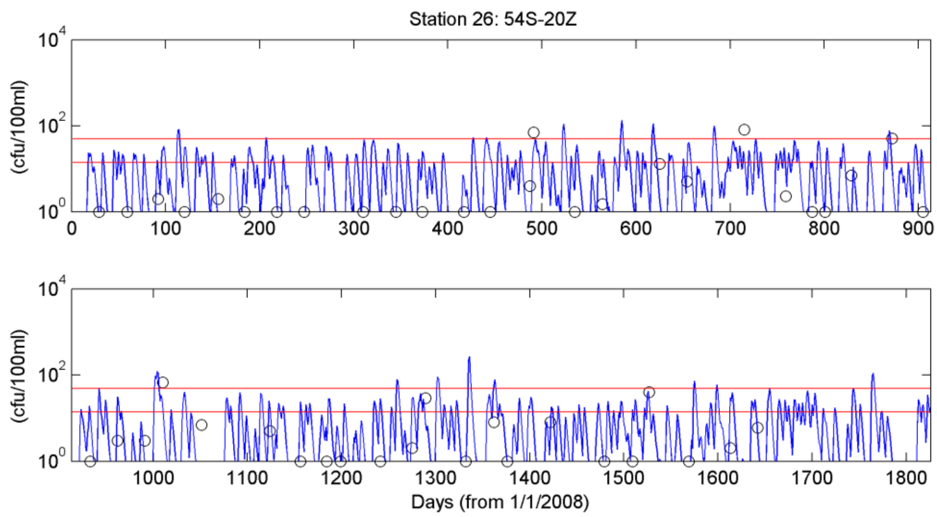
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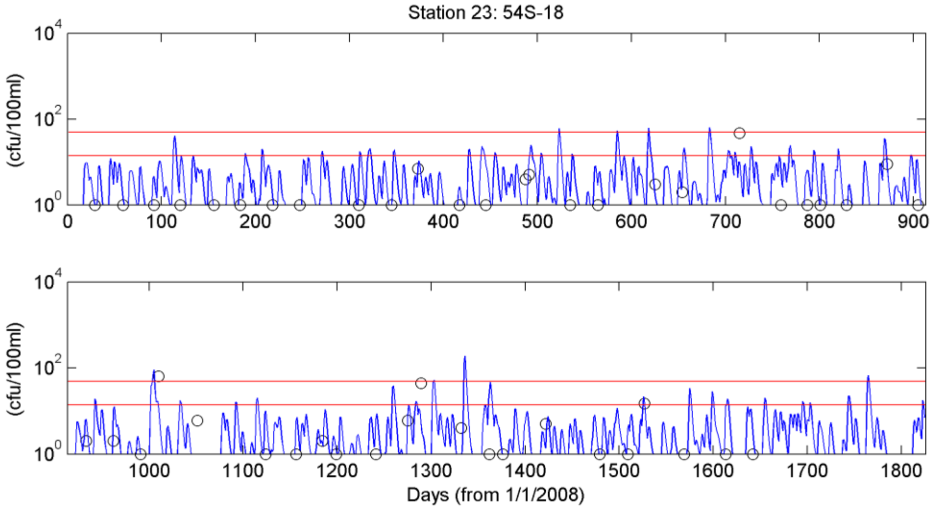
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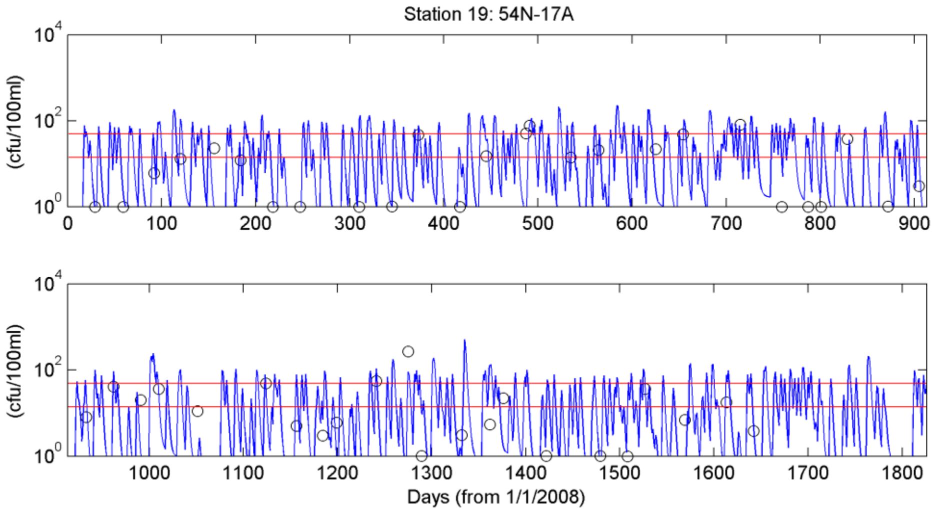
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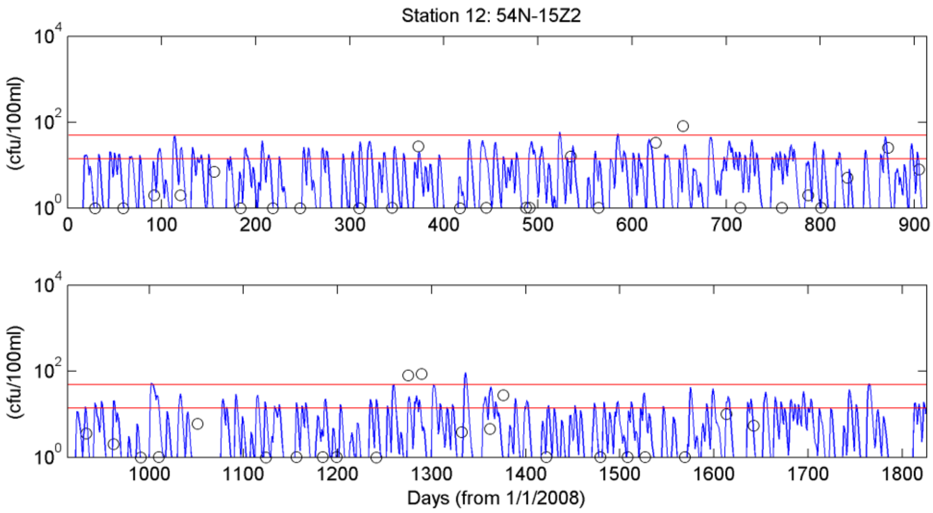
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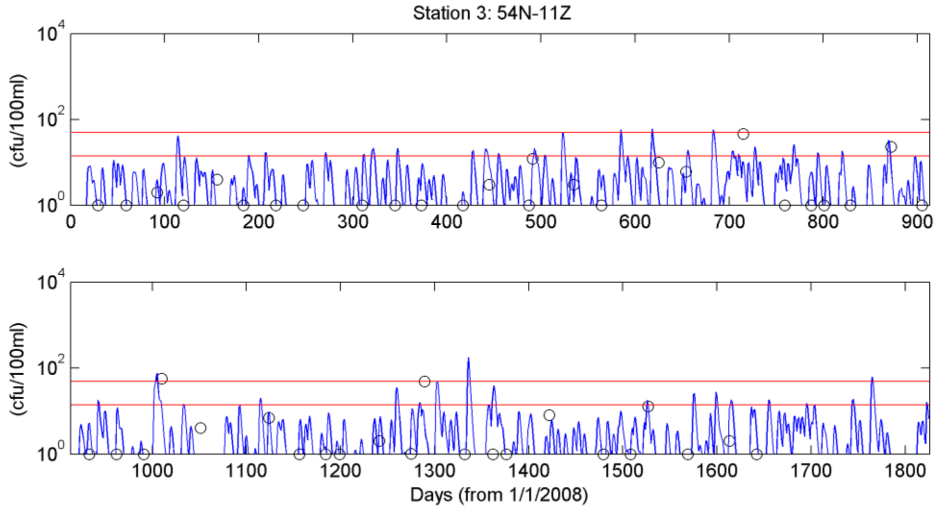
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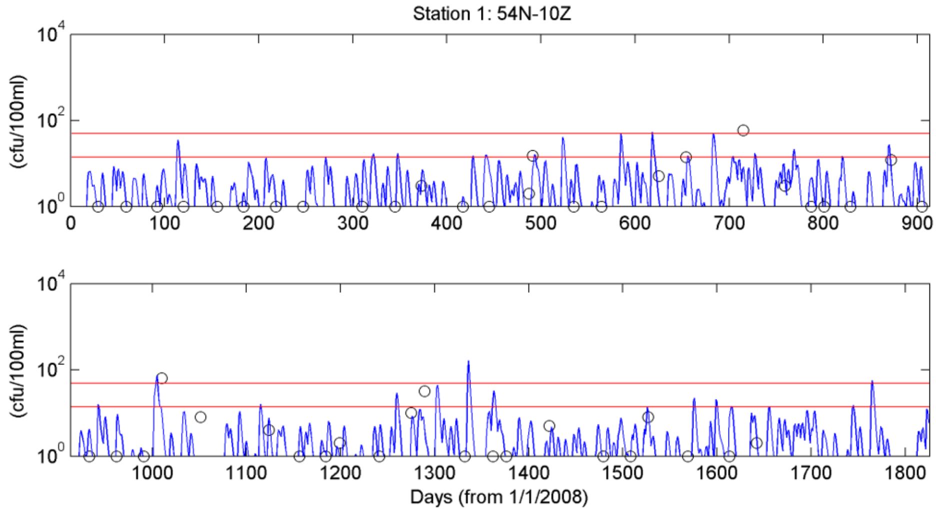
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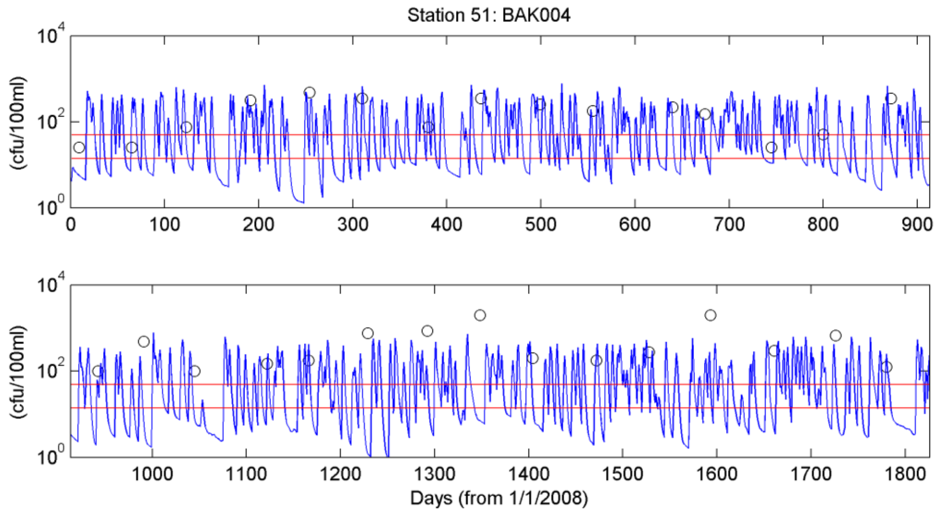
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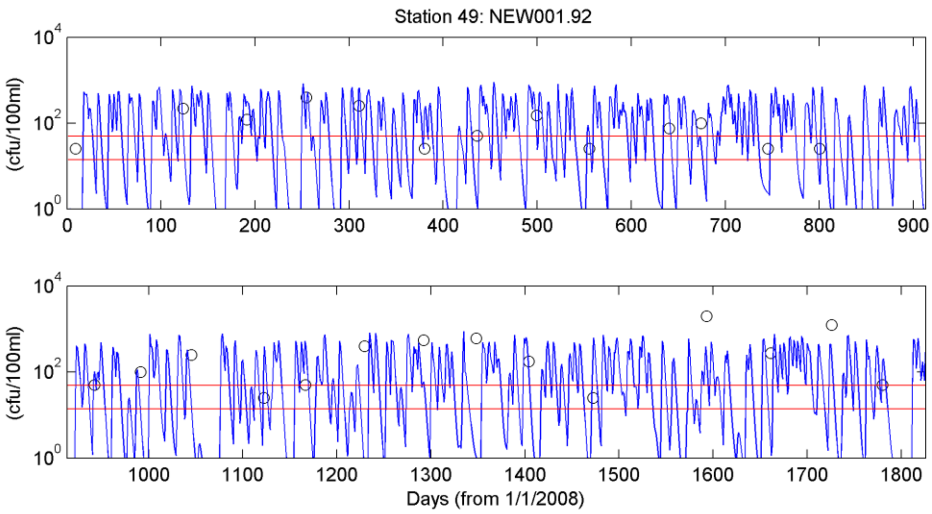


Figure A.6: Model Calibration Results

A.2 TMDL Development

A.2.1 Allowable Load

The TMDL was computed for an eight-year period from 2000-2007. The calibrated model used the current data run for this period to generate the existing condition. 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. Each subwatershed is associated with corresponding impaired segment (Figure A.7). The Big Bethel Lake (BAKlake) is grouped together with Brick Kiln Creek to compute the loading, but there is no reduction of loading for subwatersheds that discharge to the Lake. The impaired segment, VAT-C07E_SWB01B08, is located in the middle of the Back River, but the influence on this segment depends on both upstream and downstream segments. As it should be noted, some segments are not only influenced by adjacent subwatersheds, but also are influenced by upstream and downstream segments, and therefore the improvement of the water quality cannot solely depend on the reduction of adjacent watersheds. With about 16-53% 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 for shellfish-impaired segments.

Fecal coliform concentrations at each observation stations were assessed to ensure that water quality standards were met. There are three segments (Upper Newmarket Creek, Lower Newmarket Creek, and Brick Kiln Creek) that violate primary contact criteria. The enterococci endpoints (an instantaneous criterion of 104 cfu/100 ml and the monthly geometric mean of 35 cfu/100 ml) are used to determine the load reduction. The *E. coli* endpoints (an instantaneous criterion of 235 cfu/100 ml and the monthly geometric mean of 126 cfu/100 ml) are used to determine the load reduction in the riverine section.

There are two segments, VAT-C07E_WAT01A06 and VAT-C07E_INX01A10, that show no violation and the existing loadings are used as TMDLs. The downstream segment of Back River (BAK01A00) also shows no violation. Therefore, the existing loading associated with BAK01A00 is used as the TMDL.

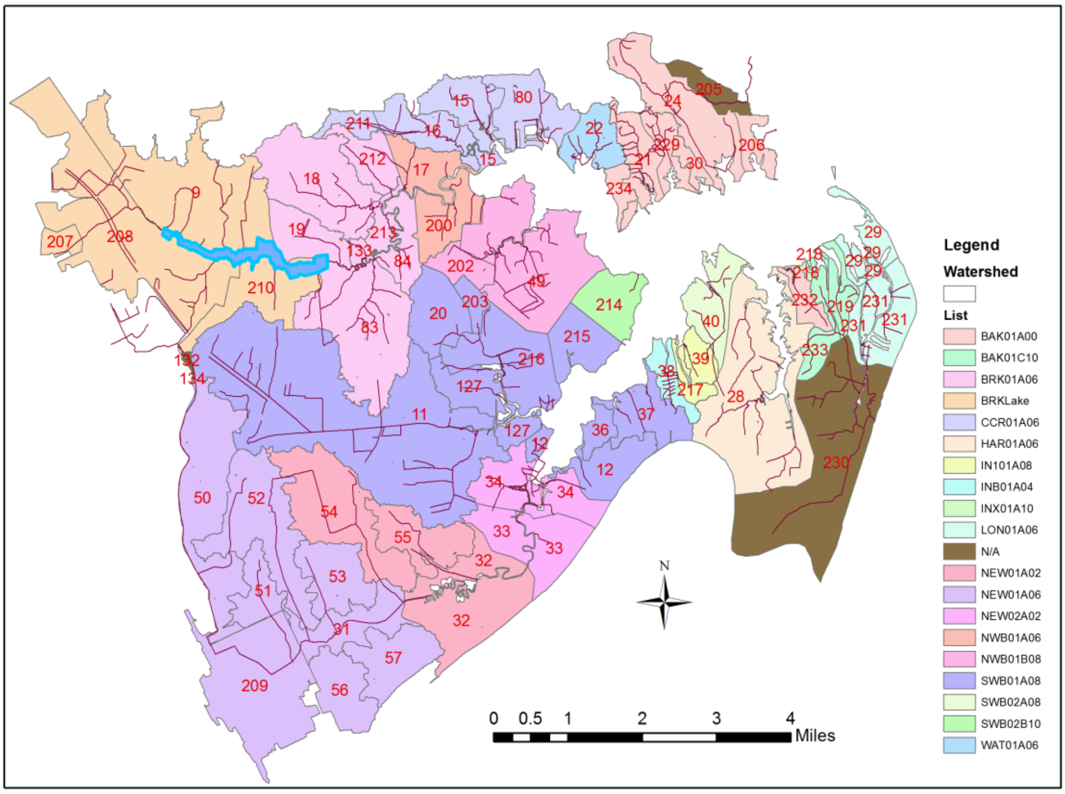


Figure A.7: Drainage Basins for Impaired Segments

A.2.2 Total Maximum Daily Load

The TMDL scenario presented here 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 a scenario as to 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 95^{th} 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 90^{th} 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 Back 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 p^{th} percentage point of the standard normal distribution. For the 95^{th} 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 the coefficient of variation of the untransformed data, which equals to the standard deviation divided by the mean.

Using the method described above, *LTA* is the mean daily loading from 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 Tables 4.1 for Back River. The loading distribution between York County, the Cities of Hampton, Poquoson, and Newport News, and federal facilities is listed in Table A.2 and the loading distributions by impaired segments are listed in Table A.3. Subwatersheds that require load reduction are shown in Figure A.8. Because of the nature of the stream and estuary, upstream loading will transport to the downstream. In order to meet downstream water quality criteria, upstream loading reduction is needed. The loading and loading reduction for the downstream segment should include the loading and loading reduction upstream. For management purposes, only loading reduction of adjacent to the listed segments (Figure A.7) is listed in Table A.3.

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

Pollutant	Criterion	Current Load (Counts/Day)	Allowable Load (Counts/Day)	Required Reduction (%)
Fecal Coliform	Fecal coliform 90^{th} Percentile: 49 (MPN/100ml) Enterococci: (43 cfu/100ml)	8.54×10^{12}	5.35×10^{12}	37.3%

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

Jurisdiction	Existing Load (Counts/Day)	Allowable Load (Counts/Day)	Reduction (%)
Newport News	4.34E+11	3.58E+11	17.5
Hampton	6.62E+12	3.98E+12	40.0
Poquoson	9.66E+11	6.04E+11	37.5
York County	4.76E+11	3.72E+11	21.8
NASA	4.34E+10	4.34E+10	0.00
Total	8.54E+12	5.35E+12	37.3

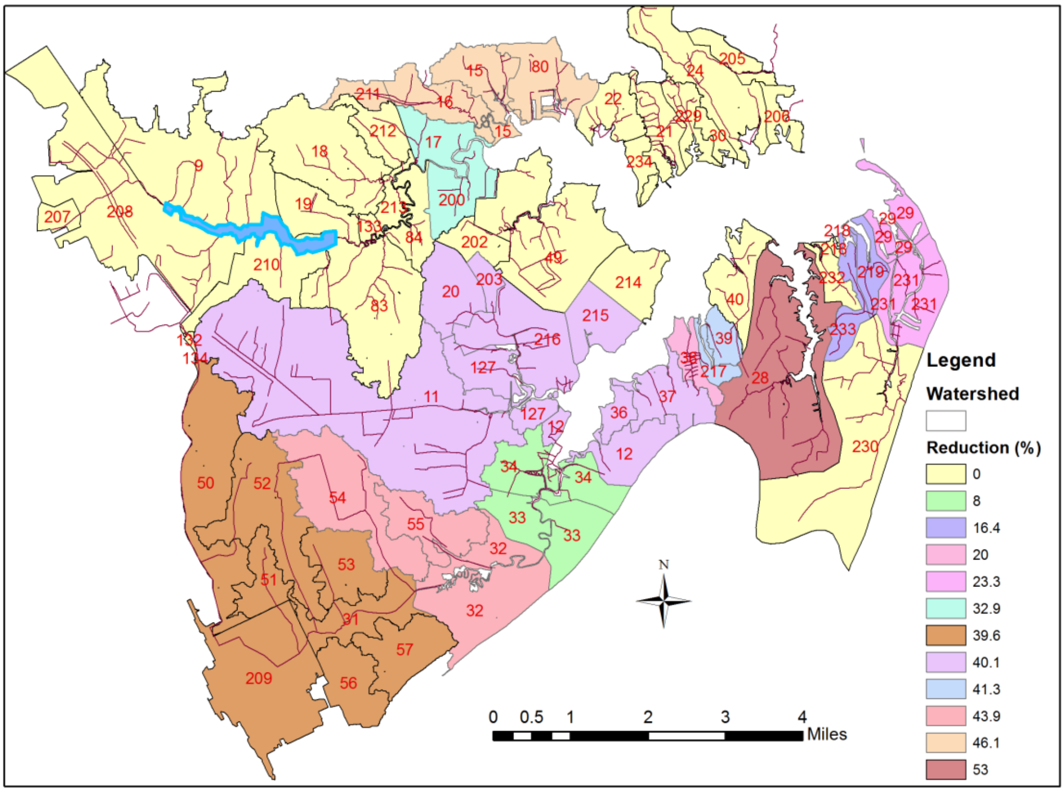


Figure A.7: Distribution of Loading Reduction for Each Subwatershed.

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 (%)	Jurisdictions needing load reduction
VAT-C07E_LON01A06	Long & Grunland Creeks	5.15E+11	3.95E+11	23.3%	Hampton
VAT-C07E_HAR01A06	Harris River – Upper	1.93E+12	9.09E+11	53.0%	Hampton
VAT-C07E_WAT01A06	Watts Creek - (NW Br. Back River)	3.74E+10	3.74E+10	0.0%	
VAT-C07E_BAK01C10	Back River-S	1.11E+11	9.28E+10	16.4%	

	Shore at Mouth Wallace Cr.				
VAT-C07E_INX01A10	Unnamed Inlet - Back R South Shore near Wallace Cr	3.47E+09	3.47E+09	0.0%	
VAT-C07E_BRK01A06	Brick Kiln Creek	1.07E+12	8.31E+11	22.3%	York Hampton (Downstream of Big Bethel Reservoir)
VAT-C07E_NWB01A06	Northwest Br. Back River - Upper	1.30E+11	8.73E+10	32.9%	Downstream Brick Kiln
VAT-C07E_CCR01A06	Cedar & Topping Creeks	6.97E+11	3.75E+11	46.1%	Poquoson
VAT-C07E_NWB01B08*	Northwest Br. Back River - Upper	9.21E+11	5.56E+11	39.6%	Poquoson (including Cedar)
VAT-C07R_NEW01A06	Newmarket Creek –Lower Riverine	8.30E+11	5.01E+11	39.6%	Newport News Hampton
VAT-C07E_NEW01A02	Newmarket Creek - Upper	3.79E+11	2.13E+11	43.9%	Hampton
VAT-C07E_NEW02A02	Newmarket Creek – Lower	2.36E+11	2.18E+11	7.7%	Hampton
VAT-C07E_SWB01A08	SW Br Back River - Incl Tides Mill Cr	2.12E+12	1.27E+12	40.1%	Hampton
VAT-C07E_IN101A08	DSS Inlet #1 - Unnamed Inlet at Mouth of SW Branch	9.86E+10	5.79E+10	41.3%	Hampton
VAT-C07E_INB01A04	DSS Inlet #2 - Unnamed Inlet S. Shore of SW Br. Back River	1.08E+11	8.66E+10	20.0%	Hampton
VAT-C07E_SWB01B08*	SW Br Back River - Outside DSS Inlet #1 & #2	2.07E+11	1.45E+11	30.1%	Hampton

VAT-C07E_SWB02B10*	SW Br Back R	2.37E+11	1.75E+11	26.3%	Hampton
VAT-C07E_SWB02A08*	Southwest Br. Back River - Mouth	2.49E+11	1.86E+11	25.1%	Hampton
VAT-C07E_BAK01A00	Mainstem Back River	1.40E+11	1.40E+11	0.0%	
Total		8.54E+12	5.35E+12	37.3%	

*****Loading reduction including adjacent segments and corresponding subwatersheds.

The bacterial TMDL for each listed segments is shown in Table A.4 to provide information for each listed segment. Note that, because upstream bacterial loading affects the downstream bacterial concentration, the loading of the listed waterbody includes all the loadings from its upstream drainage basin plus the loading from the adjacent watersheds. Therefore, the impact of the upstream on the downstream should be taken into consideration. Wastewater quantities are allocated to these MS4 regulated areas based on the percentage of urban land use within the MS4s' regulated area. The fecal coliform TMDLs (counts per day) for impaired waterbodies are listed in Table A.4:

Table A.4: Bacterial TMDL for each listed impairment (Counts/Day)

List ID	TMDL	LA	WLA	MOS
VAT-C07E_LON01A06	3.95E+11	3.74E+11	2.15E+10	Implicit
VAT-C07E_HAR01A06	9.09E+11	4.91E+11	4.18E+11	Implicit
VAT-C07E_WAT01A06	3.74E+10	3.23E+10	5.13E+09	Implicit
VAT-C07E_BAK01C10	9.28E+10	7.17E+10	2.11E+10	Implicit
VAT-C07E_INX01A10	3.47E+09	2.74E+09	7.33E+08	Implicit
VAT-C07E_BRK01A06	8.31E+11	4.43E+11	3.88E+11	Implicit
VAT-C07E_NWB01A06	8.73E+10	7.64E+10	1.09E+10	Implicit
VAT-C07E_CCR01A06	3.75E+11	2.68E+11	1.08E+11	Implicit
VAT-C07E_NWB01B08*	5.56E+11	4.44E+11	1.13E+11	Implicit
VAT-C07R_NEW01A06	5.01E+11	1.55E+11	3.47E+11	Implicit
VAT-C07E_NEW01A02	2.13E+11	7.11E+10	1.42E+11	Implicit
VAT-C07E_NEW02A02	2.18E+11	8.07E+10	1.37E+11	Implicit
VAT-C07E_SWB01A08	1.27E+12	7.11E+11	5.59E+11	Implicit
VAT-C07E_IN101A08	5.79E+10	3.29E+10	2.50E+10	Implicit
VAT-C07E_INB01A04	8.66E+10	5.93E+10	2.73E+10	Implicit
VAT-C07E_SWB01B08*	1.45E+11	8.91E+10	5.54E+10	Implicit
VAT-C07E_SWB02B10*	1.75E+11	9.26E+10	8.24E+10	Implicit
VAT-C07E_SWB02A08*	1.86E+11	1.25E+11	6.17E+10	Implicit
VAT-C07E_BAK01A00	1.40E+11	1.34E+11	6.73E+09	Implicit

*Loading including adjacent segments.

A.3 Source Distribution and Load Allocation

Finally, the load allocation that would meet water quality standards according to sources was determined using the results of the fecal coliform loading for each source category, which were estimated by the watershed approach and model simulations with respect to the reduction of bacterial sources. Although a 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. The allocation is summarized below:

Waterbody Name	**Category**	**Current Load (Counts/Day)**	**Load Allocation (Counts/Day)**	**Reduction Needed** (%)
Back River	**Livestock**	7.69E+11	0.00E+00	100%
	Wildlife	5.30E+12	5.30E+12	1%
	Human (SSO, septic, marina)	5.13E+11	0.00E+00	100%
	Pets	1.96E+12	5.69E+10	99%
	Total	8.54E+12	5.35E+12	100%

The distributions of source contribution, current load, and reduction required for each listed area are summarized in Table A.5. For these segments showing violation, the existing loadings are often higher than the background loadings estimated in Section 3 because of the nonhomogeneous loading distribution, underestimated livestock, and impact of septic system, as well as unknown sources. These loadings are determined based on data analysis and model calibration against 2008-2012 observations. The results presented here provide a starting point for designing an implementation plan. More source analysis is needed to identify the problem. These sources cannot be addressed without public understanding of, and support for, the implementation process. 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 assessment of SSOs was based on 95th percentile flow of incidences 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 impaired area.

Table A.5: Load Allocation and Required Source Reduction for Fecal Coliform

List ID	Area	Source	Percent	Current Load (Counts/Day)	Allocable Load (Counts/Day)	Reduction
VAT-C07E_BAK01A00	Mainstem Back River	Human	0.1%	1.87E+08	1.87E+08	0%
		Livestock	0.0%	0.00E+00	0.00E+00	0%
		Pet	5.6%	7.90E+09	7.90E+09	0%
		Wildlife	94.2%	1.32E+11	1.32E+11	0%
		Total	100	1.40E+11	1.40E+11	0%
VAT-C07E_BRK01A06	Brick Kiln Creek	Human	13.5%	1.45E+11	0.00E+00	100%
		Livestock	5.1%	5.42E+10	0.00E+00	100%
		Pet	26.2%	2.80E+11	2.41E+11	14%
		Wildlife	55.2%	5.90E+11	5.90E+11	0%
		Total	100	1.07E+12	8.31E+11	22%
VAT-C07E_CCR01A06	Cedar & Topping Creeks	Human	1.5%	1.04E+10	0.00E+00	100%
		Livestock	0.0%	0.00E+00	0.00E+00	0%
		Pet	33.6%	2.34E+11	0.00E+00	100%
		Wildlife	64.9%	4.52E+11	3.75E+11	17%
		Total	100	6.97E+11	3.75E+11	46%
VAT-C07E_HAR01A06	Harris River	Human	28.1%	5.44E+11	0.00E+00	100%
		Livestock	20.0%	3.87E+11	0.00E+00	100%
		Pet	16.3%	3.14E+11	2.20E+11	30%
		Wildlife	35.6%	6.89E+11	6.89E+11	0%
		Total	100	1.93E+12	9.09E+11	53%
VAT-C07E_IN101A08	DSS Inlet #1 - Unnamed Inle	Human	0.0%	0.00E+00	0.00E+00	0%
		Livestock	92.6%	9.13E+10	9.13E+10	0%
		Pet	2.2%	2.14E+09	2.14E+09	0%
		Wildlife	5.3%	5.19E+09	5.19E+09	0%
		Total	100	9.86E+10	5.79E+10	41%
VAT-C07E_INB01A04	DSS Inlet #2	Human	1.3%	1.40E+09	0.00E+00	100%
		Livestock	0.0%	0.00E+00	0.00E+00	0%
		Pet	36.2%	3.92E+10	1.90E+10	52%
		Wildlife	62.5%	6.76E+10	6.76E+10	0%
		Total	100	1.08E+11	8.66E+10	20%
VAT-C07E_LON01A06	Long & Grunland Creeks	Human	54.7%	2.82E+11	1.78E+11	37%
		Livestock	3.2%	1.67E+10	0.00E+00	100%
		Pet	2.9%	1.47E+10	1.47E+10	0%
		Wildlife	39.2%	2.02E+11	2.02E+11	0%
		Total	100	5.15E+11	3.95E+11	23%
VAT-C07E_NEW01A02	Newmarket Creek - Upper	Human	46.8%	1.77E+11	1.57E+10	91%
		Livestock	1.3%	4.95E+09	0.00E+00	100%
		Pet	21.1%	7.99E+10	7.99E+10	0%

		Wildlife	30.9%	1.17E+11	1.17E+11	0%
		Total	100	3.79E+11	2.13E+11	44%
VAT-C07E_ NEW02A02	Newmarket Creek – Lower	Human	66.1%	1.56E+11	1.38E+11	12%
		Livestock	0.1%	2.11E+08	0.00E+00	100%
		Pet	13.3%	3.14E+10	3.14E+10	0%
		Wildlife	20.5%	4.83E+10	4.83E+10	0%
		Total	100	2.36E+11	2.18E+11	8%
VAT-C07E_ NWB01A06	Northwest	Human	0.0%	0.00E+00	0.00E+00	0%
		Livestock	0.0%	0.00E+00	0.00E+00	0%
		Pet	10.1%	8.35E+10	0.00E+00	100%
		Wildlife	89.9%	7.46E+11	5.01E+11	33%
		Total	100	8.30E+11	5.01E+11	40%
VAT-C07E_ NWB01B08	Northwest Br. Back River - Upper	Human	0.0%	0.00E+00	0.00E+00	0%
		Livestock	0.0%	0.00E+00	0.00E+00	0%
		Pet	0.0%	0.00E+00	0.00E+00	0%
		Wildlife	100.0%	8.30E+11	5.56E+11	33%
		Total	100	9.21E+11	5.56E+11	40%
VAT-C07E_ SWB01A08	SW Br Back River - Incl Tides Mill Cr	Human	67.1%	1.42E+12	0.00E+00	100%
		Livestock	0.3%	7.25E+09	0.00E+00	100%
		Pet	3.3%	6.90E+10	6.90E+10	0%
		Wildlife	29.3%	6.20E+11	6.20E+11	0%
		Total	100	2.12E+12	1.27E+12	40%
VAT-C07E_ SWB02A08	Southwest Br. Back River - Mouth	Human	Reference allocation of IN101A08, IN101A08 and INB01A04, SWB01A08			
		Livestock				
		Pet				
		Wildlife				
		Total				
VAT-C07E_ SWB02B10	SW Br Back R - DSS OPEN	Human	Reference allocation of IN101A08, IN101A08, and INB01A04, SWB01A08			
		Livestock				
		Pet				
		Wildlife				
		Total				
VAT-C07E_ WAT01A06	Watts Creek	Human	0.0%	0.00E+00	0.00E+00	0%
		Livestock	0.0%	0.00E+00	0.00E+00	0%
		Pet	20.6%	7.72E+09	7.72E+09	0%
		Wildlife	79.4%	2.97E+10	2.97E+10	0%
		Total	100	3.74E+10	3.74E+10	0%
VAT-C07E_ SWB01B08	SW Br Back River - Outside DSS Inlet #1 & #2	Human	Reference allocation of IN101A08 and IN101A08 and INB01A04			
		Livestock				
		Pet				
		Wildlife				
		Total				
VAT-C07E_	Unnamed	Human	56.7	1.97E+11	0.00E+00	100%

INX01A10	Inlet - Back R South Shore near Wallace Cr	Livestock	0.0	0.00E+00	0.00E+00	0%
		Pet	0.0	0.00E+00	0.00E+00	0%
		Wildlife	43.3	1.50E+11	3.47E+09	98%
		Total	100.0	3.47E+09	3.47E+09	0%
VAT-C07R_NEW 01A06	Newmarket Upper Riverine	Human	27.8%	2.31E+11	0.00E+00	100%
		Livestock	0.8%	6.45E+09	0.00E+00	100%
		Pet	29.2%	2.43E+11	1.52E+11	37%
		Wildlife	42.2%	3.50E+11	3.50E+11	0%
		Total	100	8.30E+11	5.01E+11	40%
VAT-C07E_ BAK01C10	Back River-S Shore at Mouth Wallace Cr.	Human	53.8%	5.97E+10	5.93E+10	1%
		Lifestock	4.8%	5.30E+09	0.00E+00	100%
		Pet	8.2%	9.15E+09	9.15E+09	0%
		Wildlife	22.0%	2.44E+10	2.44E+10	0%
		Total	100.0%	1.11E+11	9.28E+10	16%

Appendix B: Fecal coliform data collected by the Virginia Department of Shellfish Sanitation (VA-DSS) In the Back River

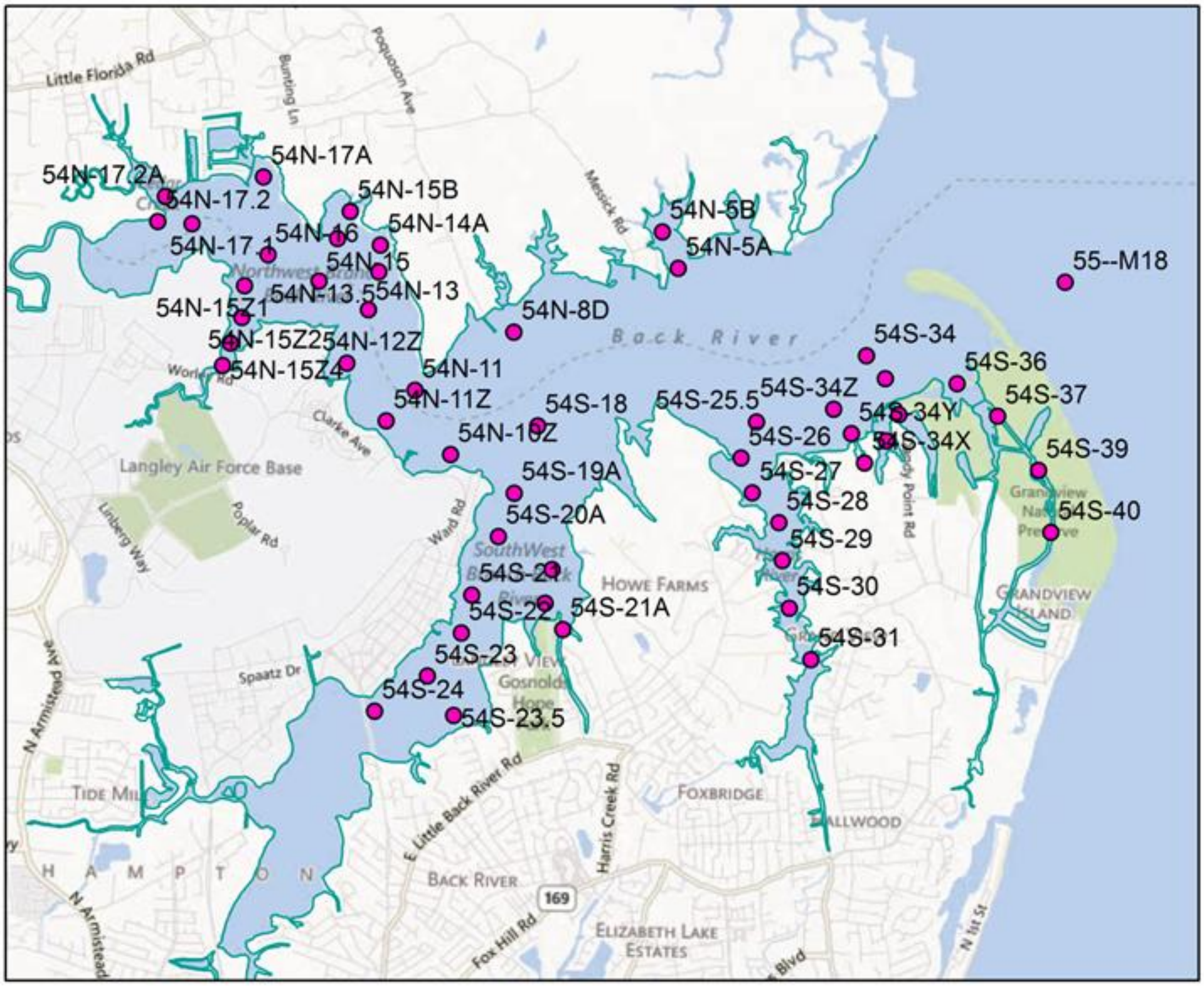
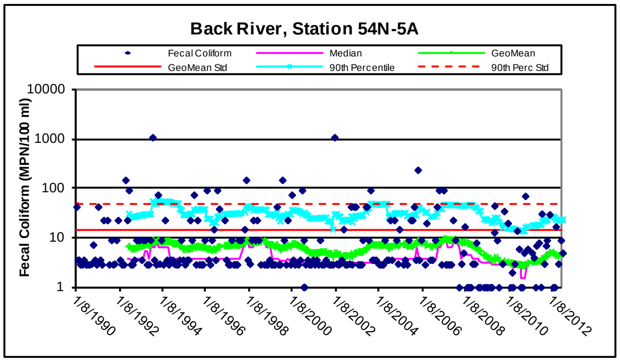


Figure B.1: Locations of DSS Stations Monitored in the Back River (1990-2012).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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
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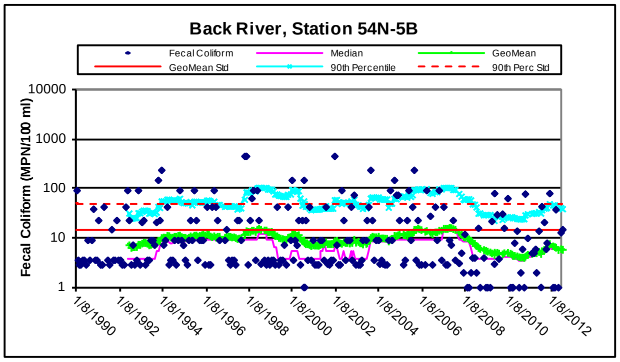
1/8/2010
1/8/2012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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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100
10
1
1/8/1990
1/8/1992
1/8/1994
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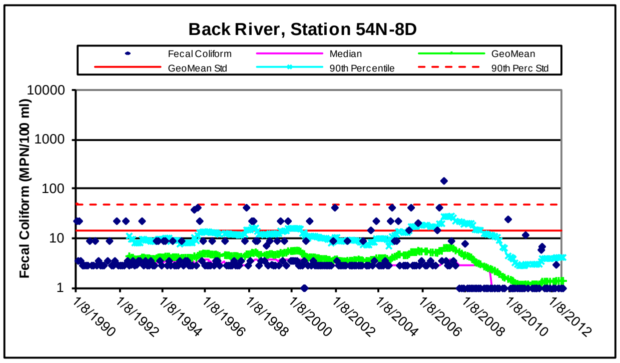
1/8/2010
1/8/2012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Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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100
10
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1/8/1990
1/8/1992
1/8/1994
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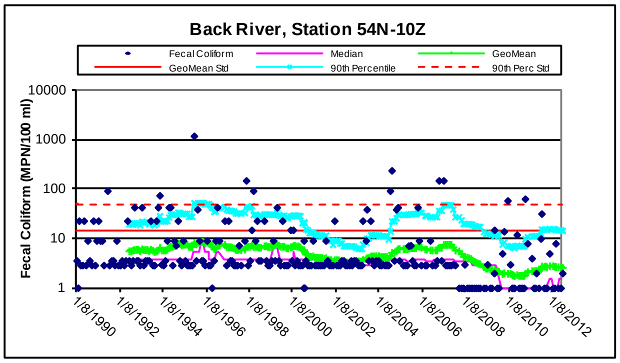
1/8/2010
1/8/2012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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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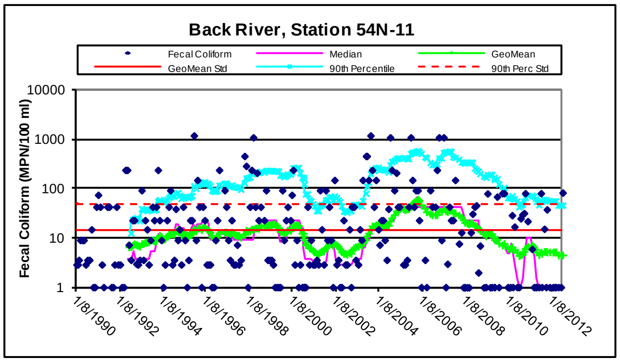
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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100
10
1
1/8/1990
1/8/1992
1/8/1994
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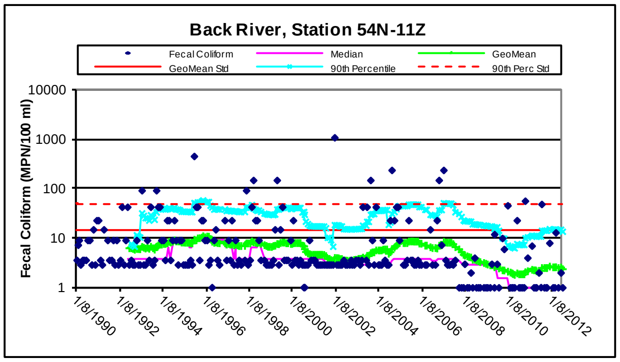
1/8/2010
1/8/2012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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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1000
100
10
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1/8/1990
1/8/1992
1/8/1994
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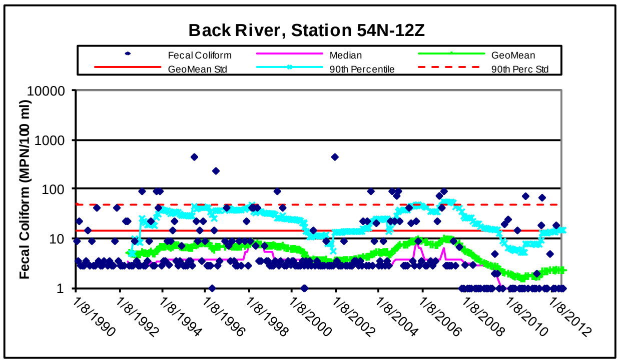
1/8/2010
1/8/2012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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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1000
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10
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1/8/1990
1/8/1992
1/8/1994
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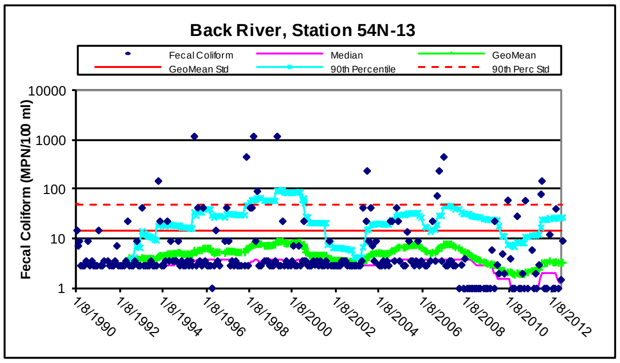
1/8/2010
1/8/2012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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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1/8/1990
1/8/1992
1/8/1994
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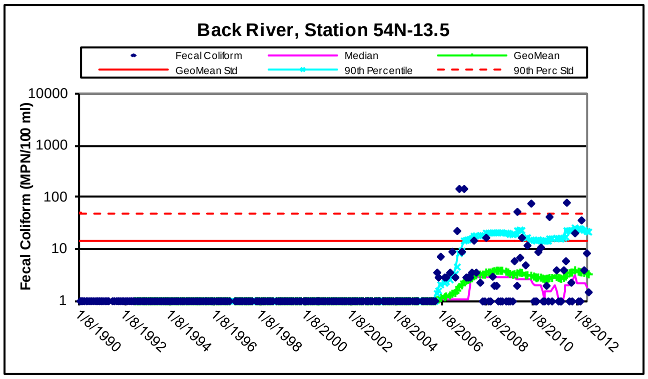
1/8/2010
1/8/2012


Back River, Station 54N-13.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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1000
100
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1/8/1990
1/8/1992
1/8/1994
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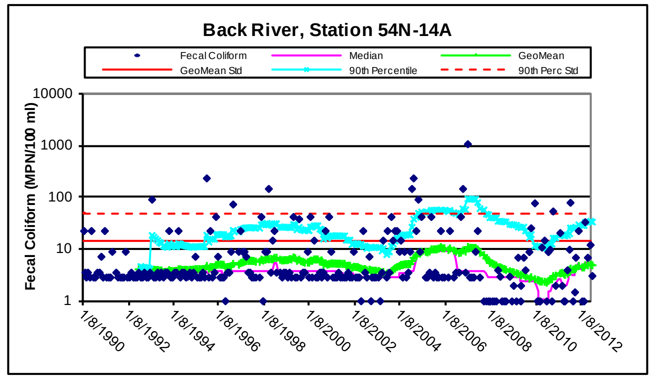
1/8/2010
1/8/2012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Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
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100
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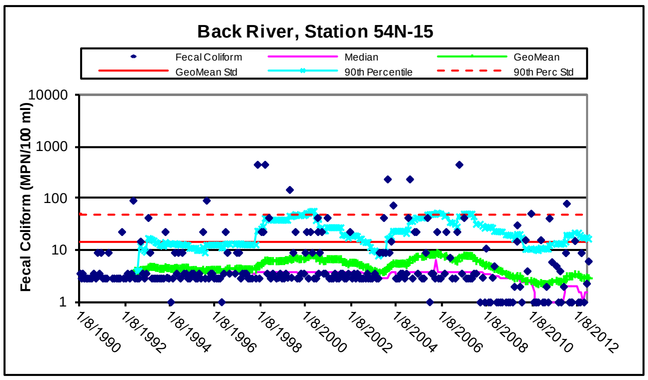
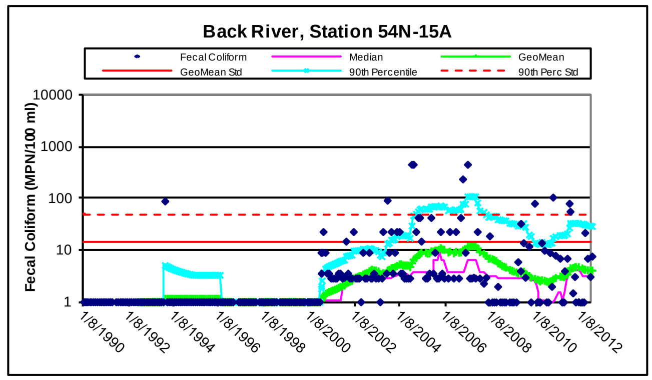
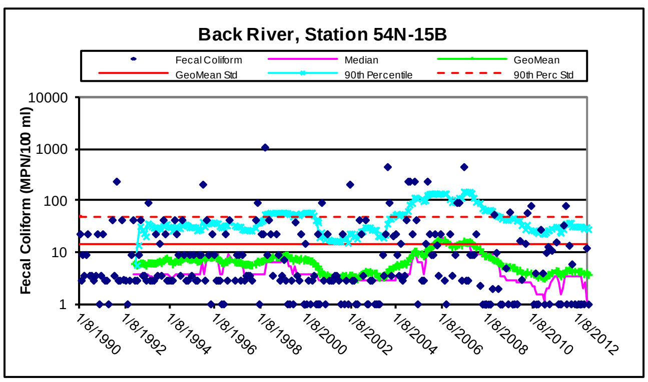
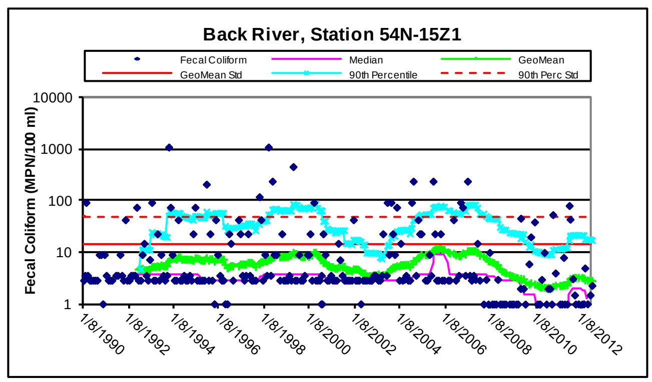
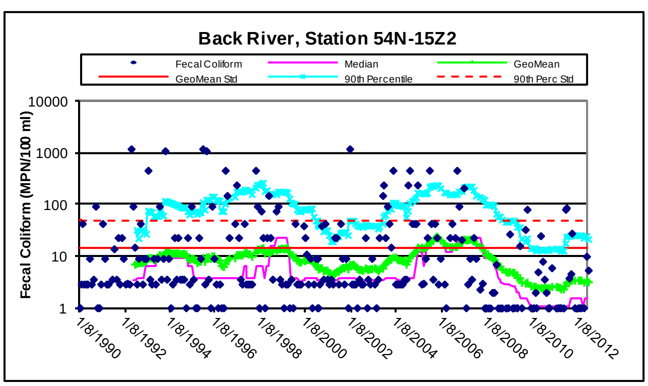
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

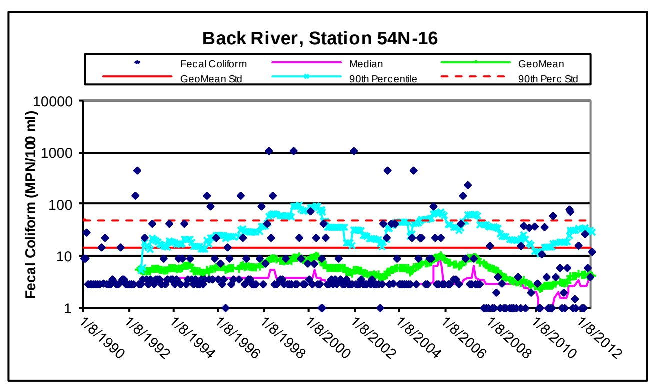

Back River, Station 54N-15
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

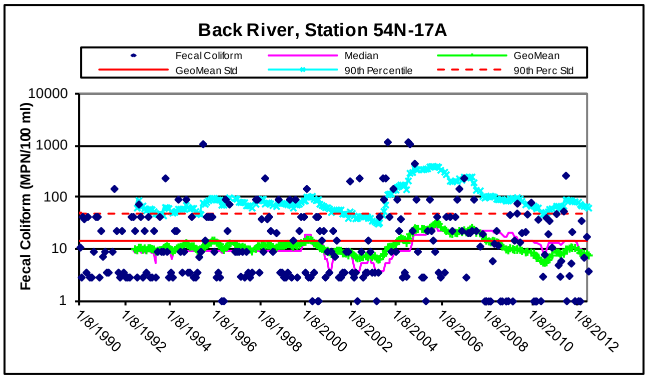

Back River, Station 54N-15A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

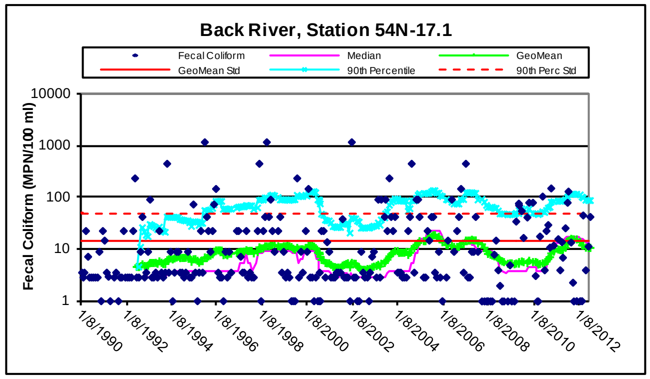

Back River, Station 54N-15B
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

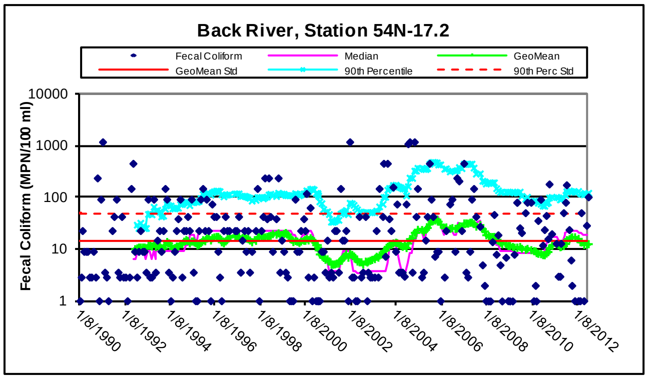

Back River, Station 54N-15Z1
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

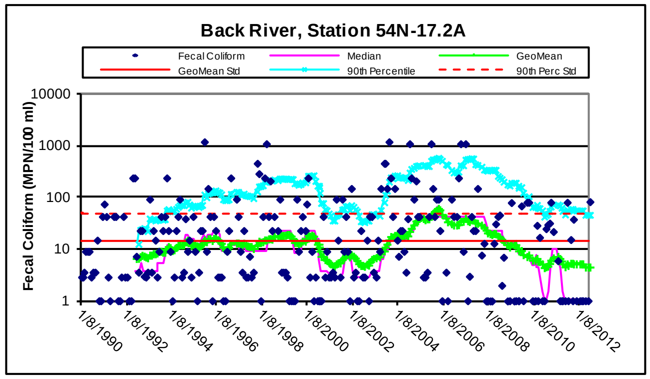

Back River, Station 54N-15Z2
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

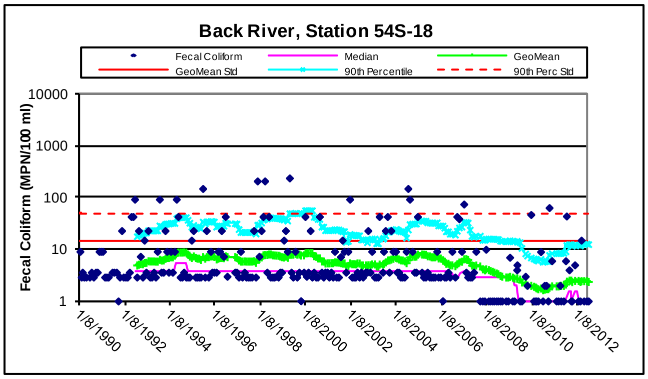

Back River, Station 54N-16
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

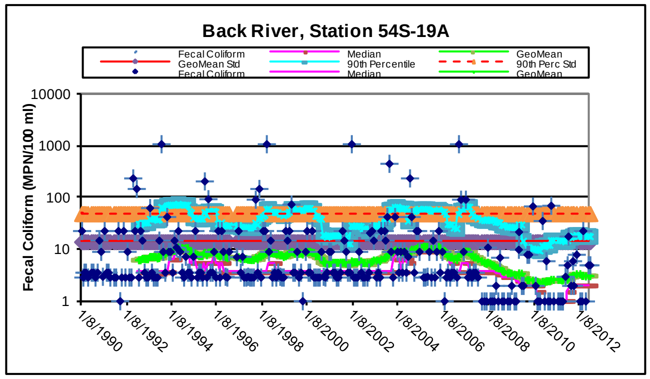

Back River, Station 54N-17A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

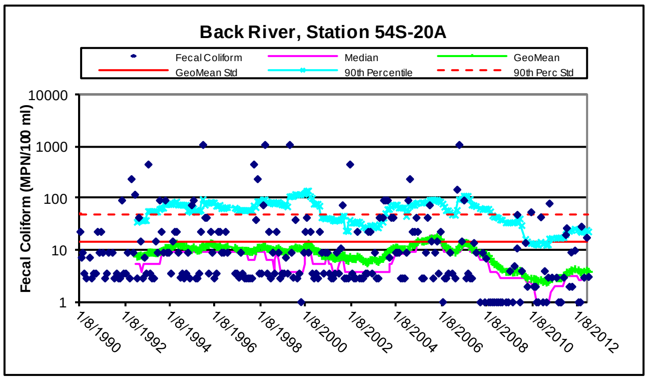

Back River, Station 54N-17.1
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

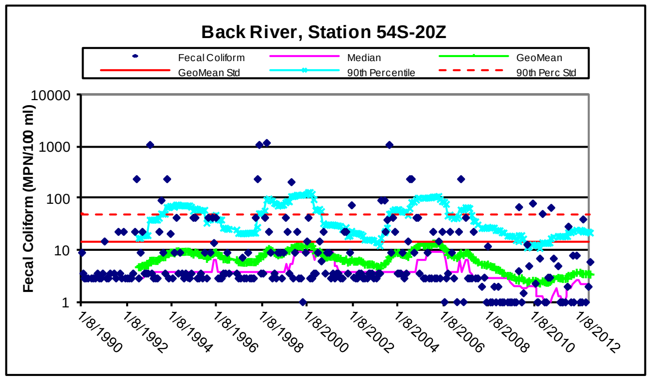

Back River, Station 54N-17.2
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

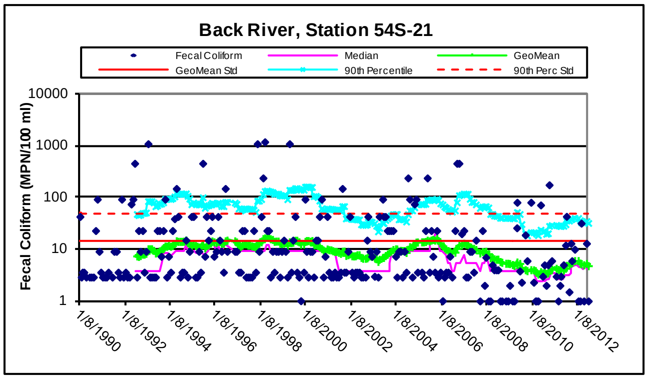

Back River, Station 54N-17.2A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

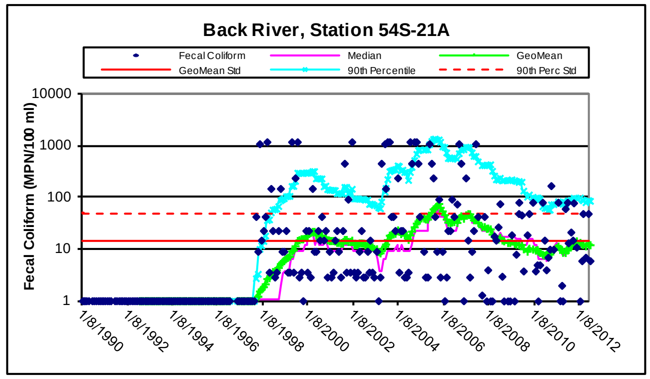

Back River, Station 54S-18
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

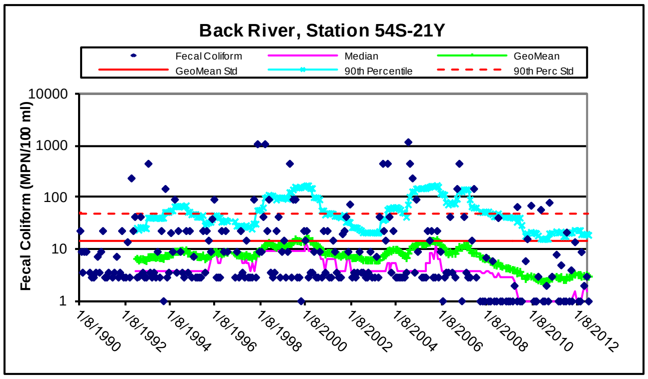

Back River, Station 54S-19A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

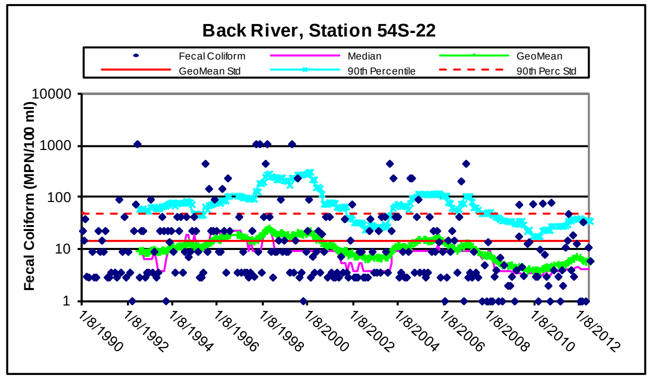

Back River, Station 54S-20A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

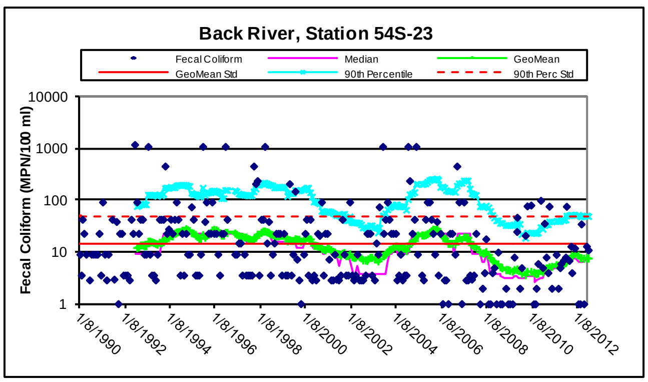

Back River, Station 54S-20Z
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)

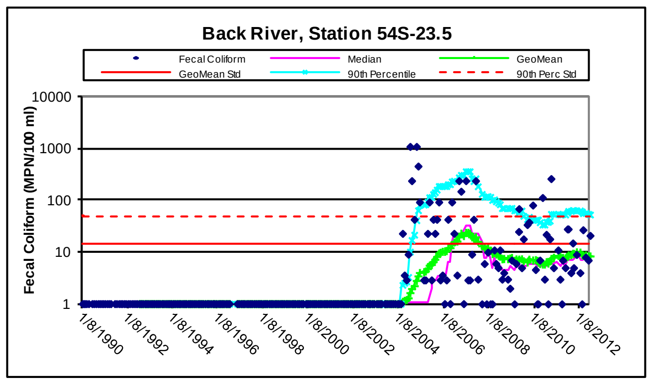

Back River, Station 54S-21
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

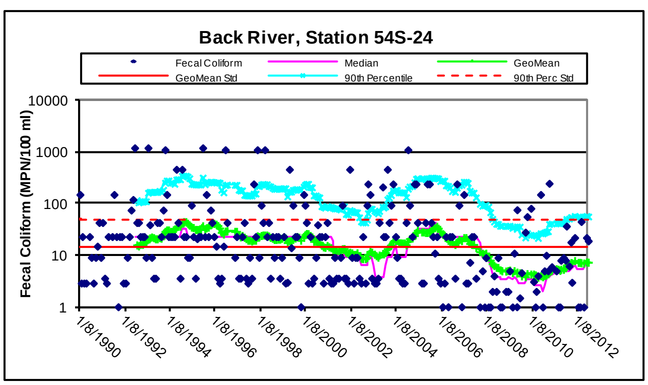

Back River, Station 54S-21A
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

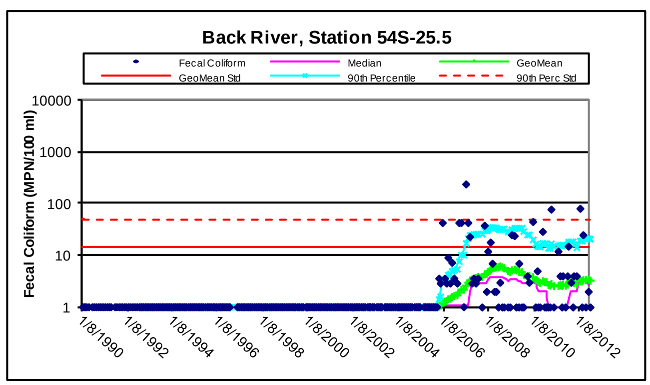

Back River, Station 54S-21Y
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

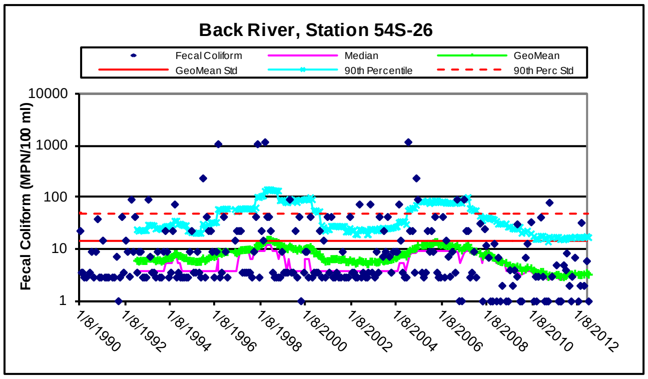

Back River, Station 54S-22
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

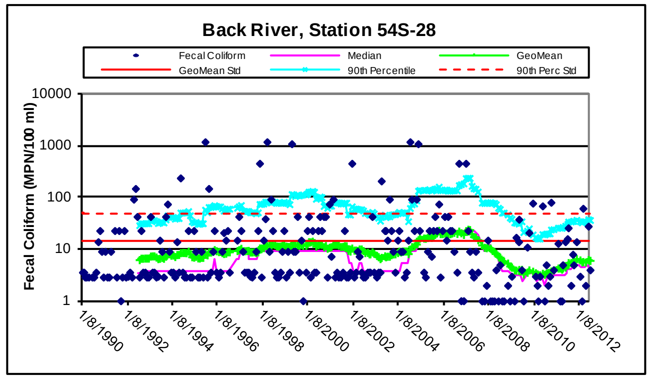

Back River, Station 54S-23
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

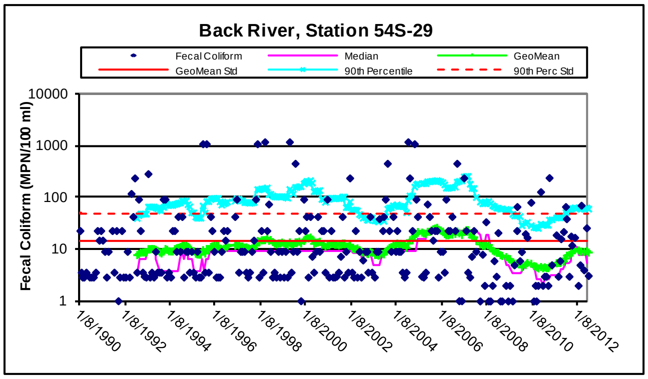

Back River, Station 54S-23.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

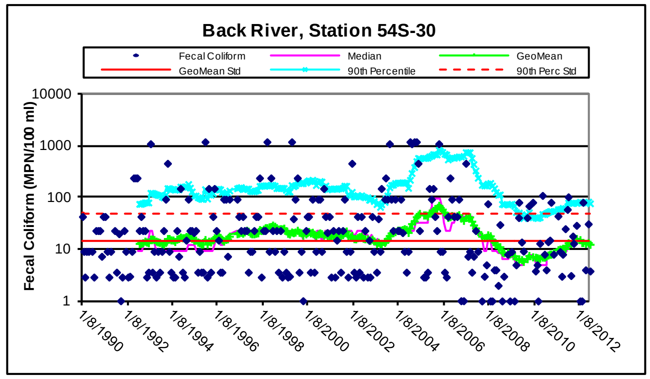

Back River, Station 54S-24
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

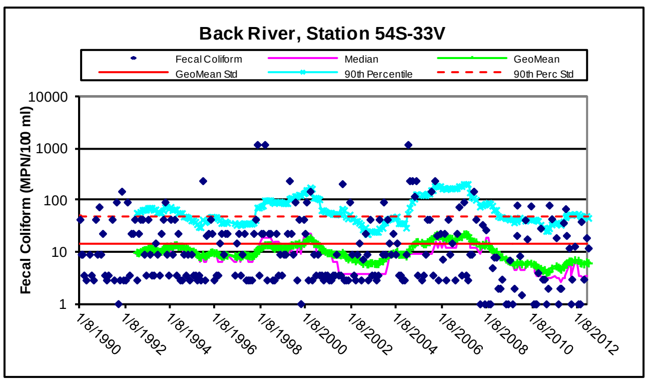

Back River, Station 54S-25.5
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

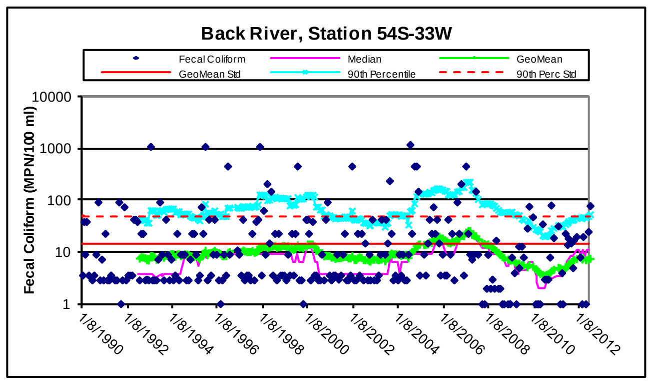

Back River, Station 54S-26
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

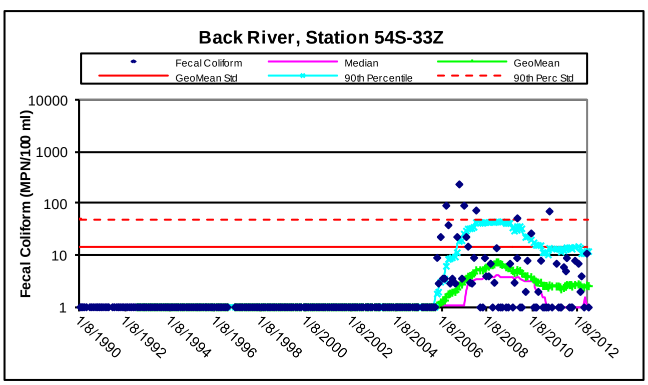

Back River, Station 54S-28
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

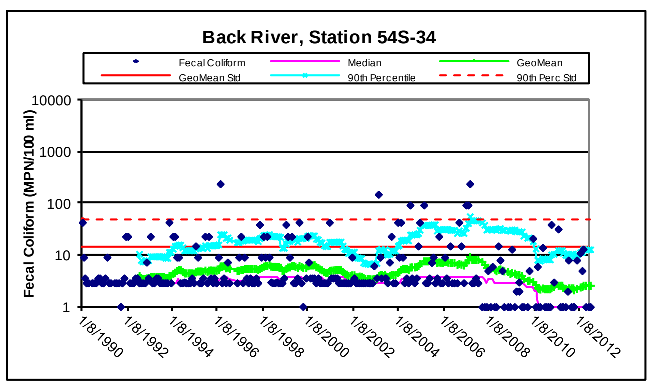

Back River, Station 54S-29
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

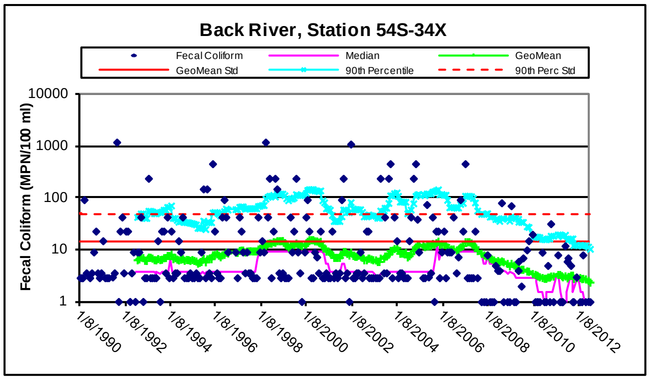

Back River, Station 54S-30
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

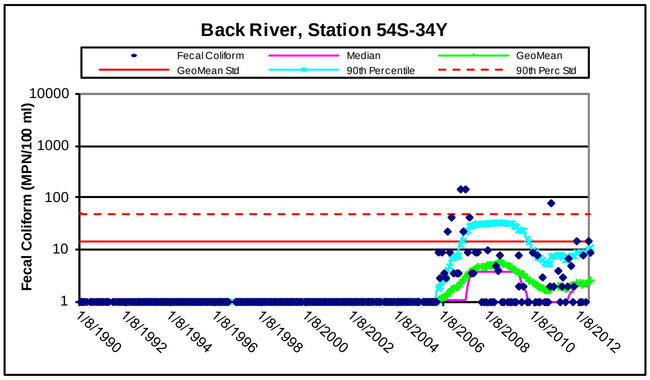

Back River, Station 54S-33V
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

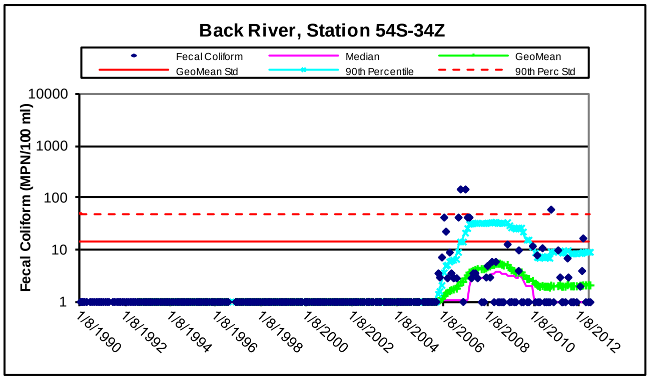

Back River, Station 54S-33W
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

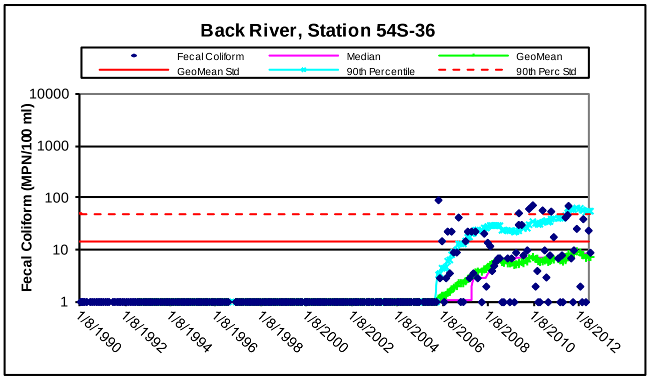

Back River, Station 54S-33Z
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

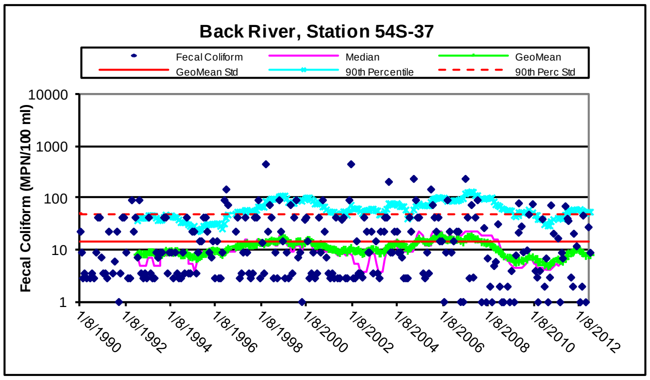

Back River, Station 54S-34
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012

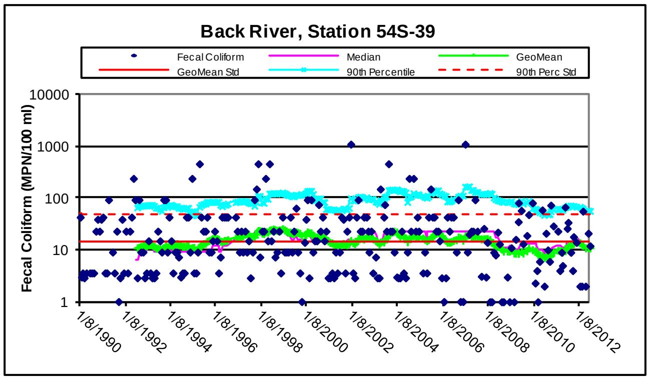

Back River, Station 54S-34X
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012


Back River, Station 54S-34Y
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012


Back River, Station 54S-34Z
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012


Back River, Station 54S-36
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012


Back River, Station 54S-37
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012


Back River, Station 54S-39
Fecal Coliform
Median
GeoMean
GeoMean Std
90th Percentile
90th Perc Std
Fecal Coliform (MPN/100 ml)
10000
1000
100
10
1
1/8/1990
1/8/1992
1/8/1994
1/8/1996
1/8/1998
1/8/2000
1/8/2002
1/8/2004
1/8/2006
1/8/2008
1/8/2010
1/8/2012