

# Bacterial Source Tracking Analyses to Support Virginia's TMDLs

## *Non-Shellfish Stations*

Prepared by

**MapTech, Inc.**

in cooperation with

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## **1. INTRODUCTION**

EPA's document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (USEPA, 1999) states:

*According to section 303(d) of the Clean Water Act and EPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The water bodies are considered water quality-limited and require TMDLs.*

*. . . A TMDL, or total maximum daily load, is a tool for implementing State water quality standards and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a water body and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a water body to meet water quality standards.*

The purpose of this project is to use bacterial source tracking (BST) to identify sources of *E. coli* to support the development of *E. coli* TMDLs for impaired segments in Virginia. In fulfilling the state requirement for the development of a TMDL, a systematic process will be utilized to establish the maximum allowable *E. coli* loading for each waterbody to meet the applicable standard, allocate that load among pollutant contributors, and provide a basis for taking actions needed to restore water quality. This report focused on water quality sampling conducted in non-shellfish waters. A companion document will be published later this year to report the results of water quality sampling in shellfish waters. Together, these reports reflect the third year of BST sampling conducted by VADEQ (2004-2005).

Bacterial Source Tracking (BST) methods can be subdivided into three basic groups: Molecular, Biochemical, and Chemical. Molecular (genotype) are typically referred to as "DNA fingerprinting" and are based on the unique genetic makeup of different strains, or

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subspecies, of fecal bacteria. Biochemical (phenotype) methods are based on an effect of an organism's genes that actively produce a biochemical substance. The type and quantity of these substances produced is what is actually measured. Chemical methods are based on finding chemical compounds that are associated with human wastewaters, and generally are restricted to determining if sources of pollution are human or not.

Hagedorn's (Hagedorn et al., 1999) Antibiotic Resistance Analysis (ARA) technique was used for this project because it has been demonstrated to be a reliable procedure for confirming the presence of human, livestock, wildlife and pet sources. Compared to DNA fingerprinting, biochemical profiling is much quicker, typically allows for many more isolates to be analyzed (*e.g.*, hundreds per week vs. a few dozen per week for DNA analysis), is more economical, has survived limited court testing, and has undergone rigorous peer review from the scientific community. Additionally, observation of an increased number of isolates allows for an estimate of the relative proportions of the fecal indicator (*e.g.*, *E. coli*) originating from different sources.

## **2. OBJECTIVES**

BST was used to identify sources of *E. coli* as well as the relative percentage contribution from four source groups (*i.e.*, livestock, wildlife, human and pets) to support the development of *E. coli* TMDLs for impairments located throughout Virginia. BST results will be used to improve public awareness of the problem, improve model calibration/validation of *E. coli* densities, and provide a more equitable allocation of loads to source classes.

The specific objectives of the project were to:

1. collect fecal samples from known sources in 22 areas, based on Hydrologic Unit Codes (HUCs),
2. use collected samples to develop a known-source library for each impairment area, and
3. perform bacterial enumerations and BST analyses on whole water samples from impaired segments, using the libraries developed for objective 2.



### **3. METHODS**

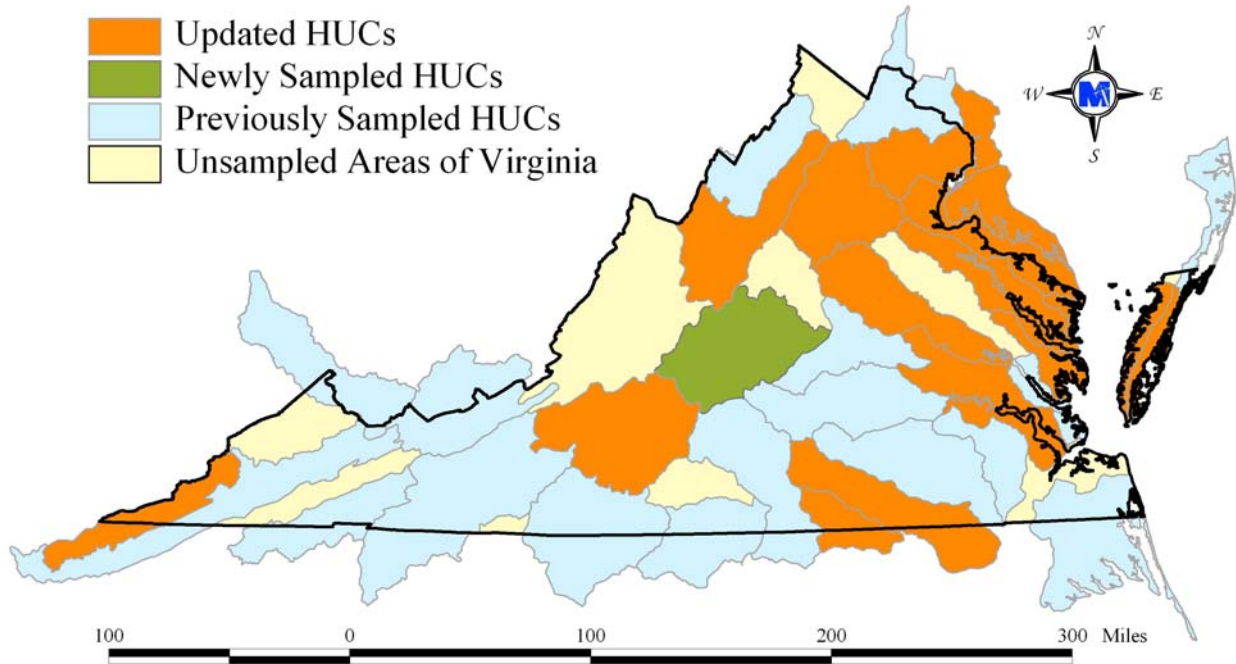
Hagedorn's ARA method has been extensively and successfully used by MapTech, and separates fecal sources based on patterns of antibiotic resistance in the *enterococci* or *E. coli*. For this study, *E. coli* was the indicator organism analyzed. The premise of ARA is that fecal bacteria from each source (*e.g.*, human, livestock, wildlife, and pets) will have different resistance patterns to the battery of antibiotics and concentrations used in the analysis. Hagedorn's method for *E. coli* tests each isolate on 28 different combinations of antibiotic type and concentration. Confidence in BST techniques is measured by the level of separation of isolates from known sources, represented as the percentage of isolates that are accurately separated into respective source types (*e.g.*, Average Rate of Correct Classification – ARCC). Additional analyses can be applied to test the specificity of the library. These analyses are discussed further in Section 4 of this document. The ARA method, like other methods (*e.g.*, molecular), requires the collection of source samples from feces of known sources to build a source library. In support of this study, known source samples from the four source classes were collected, analyzed, and entered into known-source libraries.

#### **3.1 Collection of Known Sources**

Known source samples were collected in twenty-two HUCs associated with fecal-bacteria impaired waters throughout Virginia (Figure 3.1). In HUCs where known-source samples had not previously been collected to support VADEQ's BST program (newly sampled HUCs), a total of 60 samples were collected in each HUC. In HUCs where known-source samples were previously collected (updated HUCs), a total of 20 samples were collected to update existing libraries. Each set of source samples was distributed evenly between human, livestock, wildlife, and pets (Table 3.1). Specific species within each source category (*e.g.*, deer, raccoon, poultry, beef, etc.) that were selected to represent the sources in each region were identified through field observation, discussion with local stakeholders, and review of available data (*e.g.*, Virginia Agricultural Statistics). From each sample, 8 isolates were analyzed using BST to create a known-source library of 480 isolates for each newly sampled HUC, and to increase known-source libraries by 160 isolates in updated HUCs. To date, approximately 2,844 fecal samples have been collected to support VADEQ's BST program, resulting in over 23,105 isolates

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analyzed. In total, 730 fecal samples were collected for this study, resulting in 5,864 isolates analyzed.



**Figure 3.1** Locations of known-source sampling conducted to support this year's and previous years' BST analyses.

**Table 3.1 Source samples collected for BST library development.**

Source	Source Species	Number of Samples Collected in Newly Sampled HUCs	Additional Samples Collected in Updated HUCs
Human	Septic Systems, Portable Toilets, ...	15	5
Livestock	Dairy, Beef, Horse, Sheep, Broilers, Turkeys, Swine, Waste Storage Pits, ...	15	5
Wildlife	Deer, Raccoon, Muskrat, Duck, Goose, ...	15	5
Pets	Dogs & Cats	15	5
Total		60	20

**3.2 Development of Known-Source Libraries**

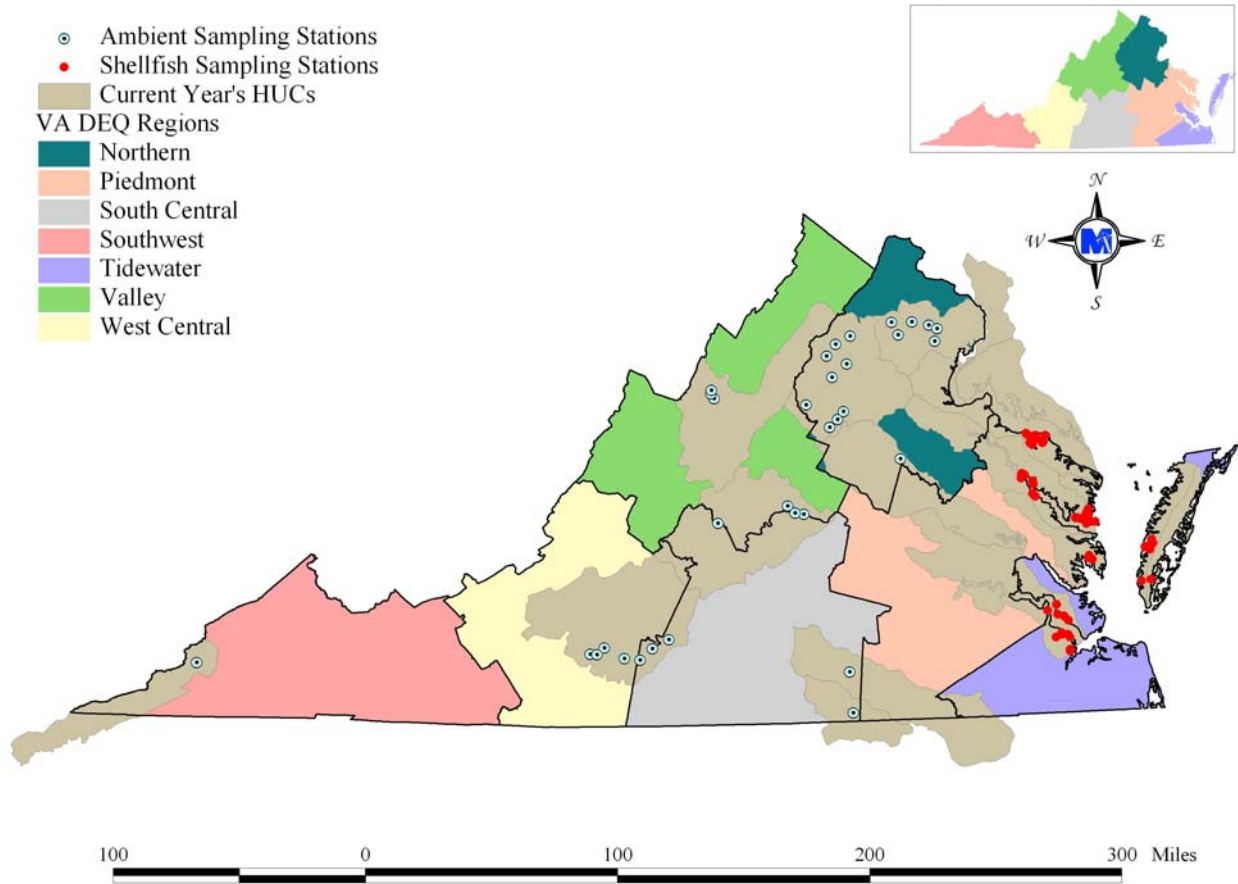
An appropriate known-source library was selected for each of the impairments to complete objective 2. A predictive model was developed from each library using logistic regression. A known-source library must be large enough to prevent an over-specified fit to the library. However, known-source responses to ARA analyses have been observed to vary geographically. The characteristics of this variance have not been well defined, so the regional libraries developed for this study were combined in a stepwise procedure and analyzed to measure the resulting specificity and the predictive accuracy of the combined libraries, as detailed in Section 4 of this document.

**3.3 Bacterial Enumerations and BST Analyses**

For objective 3, water quality monitoring sites were identified and sampled by the granting agency (Figure 3.2 and Table 3.2). For many sites, the contract began in July 2004. At the conclusion of the study, all sites will have been sampled monthly for one year. Samples were received as whole-water samples (*i.e.*, ambient sampling as presented in Table 3.2). All water samples were analyzed for *E. coli* and fecal coliform. BST was run on bacteria isolated from the whole-water samples. Bacteria were analyzed using Hagedorn's ARA methodology, yielding the percentage of isolates classified as human, livestock, wildlife, and pets. Up to 24 bacterial

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isolates were analyzed per sample, limited only by the number of isolates available from the enumeration process.



**Figure 3.2 Spatial distribution of impaired segments identified by region.**

**Table 3.2 Distribution of ambient sampling stations addressed in this study.**

<b>Waterbody</b>	<b>Hydrologic Unit</b>	<b>BST Stations</b>
Broad Run	A19	1
Bull Run	A23	1
Little Bull Run	A21	1
Occoquan River	A20	1
Popes Head Creek	A23	1
South Run	A19	1
Beaver Creek	B18	2
Union Spring Run	B18	1
Hardware River	H19	1
Little Georgia Creek	H17	1
Piney River	H10	1
Totier Creek	H17	1
Blue Run	E13	1
Hazel River	E04	1
Hughes River	E03	1
Rapidan River	E13	1
Rapidan River	E11	1
Robinson River	E15	1
Rappahannock River	E01	1
Rush River	E05	1
Thornton River	E05	1
Great Creek	L80	1
Old Woman's Creek	L13	1
Pigg River	L18	1
Pigg River	L16	1
Pigg River	L14	2
Story Creek	L14	1
Snow Creek	L17	1
Flat Rock Creek	K03	1
Northeast Creek	F09	1
Chestnut Creek	N06	2



#### 4. KNOWN-SOURCE LIBRARY DEVELOPMENT

As discussed in Section 3, a predictive model was developed from each library (HUC) using logistic regression. Where a previously developed library existed (*i.e.*, updated HUCs), this year's data was combined with the existing data and the updated library was used for further assessment. These regional libraries were combined in a stepwise procedure and analyzed to measure the resulting specificity and the predictive accuracy of the combined libraries. The specificity and predictive accuracy were assessed through three analyses. First, the ARCC was calculated for the library. Second, a randomization test was performed by randomly assigning source categories to samples and assessing the ARCC for the randomized library. Ten randomizations were performed and the results averaged. The expected result of randomization of four source categories is an ARCC of 25%, indicating a completely random result. Greater values for the randomized ARCC indicate a more specified model. Third, a jackknifing routine was conducted, where data from each whole fecal sample were individually withheld during development of the statistical model. The model was then tested for predictive accuracy on the withheld sample. In combining regional libraries, a balance was sought between minimizing the randomized ARCC and maximizing the jackknifed ARCC. Table 4.1 shows the resulting analyses on the finalized libraries, and Table 4.2 shows how the libraries were applied to the analysis of whole-water samples by the HUC in which they were sampled.

**Table 4.1 Results of known-source library development.**

<b>Known-Source Library</b>	<b>Regional Libraries Included (by HUC)</b>	<b>ARCC (%)</b>	<b>Randomized ARCC (%)</b>	<b>Jackknifed ARCC (%)</b>
2005-01	2070010 + 2070005 + 207008	82	42	73
2005-02	2080103 + 207005 + 2080207	80	37	74
2005-03	3010101 + 2080207	85	40	77
2005-04	2080203 + 2080207	80	38	74
2005-05	2080106 + 2080207	82	39	74
2005-06	3010204 + 3010103 + 2080207	85	38	80
2005-07	3010106 + 2080207	73	37	67
2005-08	2070005 + 6010205	89	41	78

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**Table 4.2** Known-source libraries associated with HUCs included in this study.

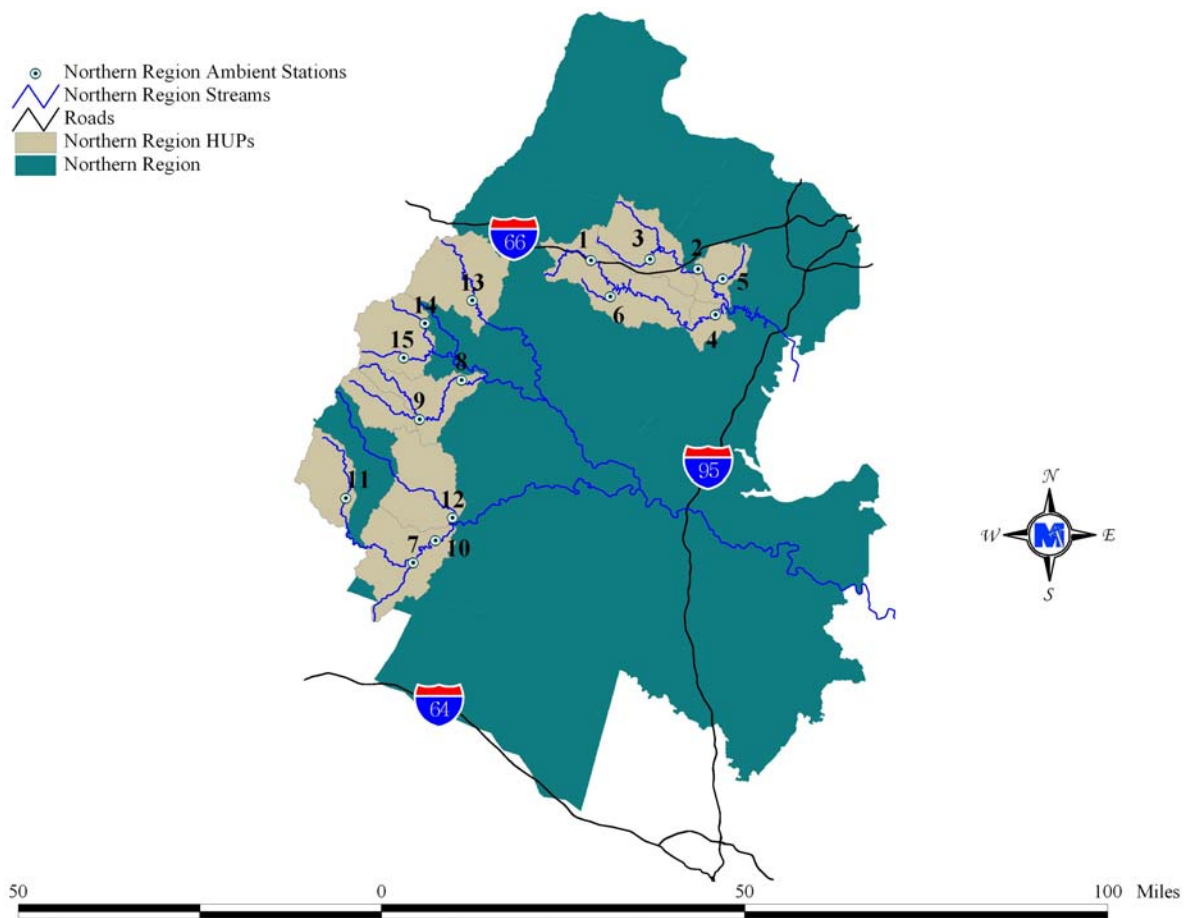
<b>HUC</b>	<b>Known-Source Library</b>
HUC 2070005	2005-08
HUC 2070010	2005-01
HUC 2080103	2005-02
HUC 2080106	2005-05
HUC 2080203	2005-04
HUC 3010101	2005-03
HUC 3010106	2005-07
HUC 3010204	2005-06

## **5. RESULTS**

The results of the water quality analyses for VADEQ's 2004-2005 BST sampling in non-shellfish waters are reported in this section. Fecal coliform enumerations, *E. coli* enumerations, and the results of the BST analyses are reported. The *E. coli* enumerations are reported with the BST results to give an indication of the bacteria concentration at the time of sampling. The proportions reported are formatted to indicate statistical significance (*i.e.*, **BOLD** numbers indicate a statistically significant result). The statistical significance was determined through two tests. The first was based on the sample size. A z-test was used to determine if the proportion was significantly different from zero ( $\alpha = 0.10$ ). During the second test, the rate of false positives was calculated for each source category in each library, and a proportion was not considered significantly different from zero unless it was greater than the false-positive rate plus three standard deviations.

**5.5 Results for Northern Region**

The results of the water quality analyses for VADEQ's Northern Region (Figure 5.5) are reported in the following tables. Table 5.39 indicates the number of samples analyzed in the 2004-2005 sampling phase. Fecal coliform and *E. coli* enumerations are reported in Tables 5.40 through 5.54. The results of the BST analysis are reported in Tables 5.55 through 5.69.



**Figure 5.5 Bacterial sampling stations in VADEQ's Northern Region.**

Table 5.39 Summary of bacterial sampling in VADEQ's Northern Region.

Station Number	Station ID	HUP	County / City	Stream Name	# of Samples Received	% Violations for <i>E. Coli</i>	% Violations for Fecal Coliform
1	1ABRU026.40	A19	Fauquier	Broad Run	12	25	25
2	1ABUL010.28	A23	Prince William	Bull Run	12	8	0
3	1ALII003.97	A21	Prince William	Little Bull Run	12	17	0
4	1AOCC021.35	A20	Prince William	Occoquan River	12	17	8
5	1APOE002.00	A23	Fairfax	Popes Head Creek	12	0	0
6	1ASOT001.65	A19	Fauquier	South Run	12	8	9
7	3BLU000.80	E13	Orange	Blue Run	12	17	0
8	3HAZ018.29	E04	Culpeper	Hazel River	12	25	0
9	3HUE000.20	E03	Rappahannock	Hughes River	12	33	8
10	3RAP045.08	E13	Orange	Rapidan River	12	25	0
11	3RAP077.28	E11	Madison	Rapidan River	12	0	8
12	3ROB001.90	E15	Madison	Robinson River	12	42	8
13	3RPP175.51	E01	Rappahannock	Rappahannock River	12	17	8
14	3RUS005.66	E05	Rappahannock	Rush River	12	25	42
15	3THO021.19	E05	Rappahannock	Thornton River	12	8	17

**Table 5.40 Bacterial Enumeration for Broad Run at Station 1ABRU026.40.**

Enumerations											
Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	<i>E. coli</i> cfu/100ml	Quality	Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
1ABRU026.40	7/22/2004	10:20	D3556	7/23/2004	640		670			8/31/2004	DM
1ABRU026.40	8/12/2004	10:33	D3612	8/13/2004	800		750			8/31/2004	DM
1ABRU026.40	9/8/2004	12:42	D3702	9/9/2004	2,700		600			9/20/2004	DM
1ABRU026.40	10/27/2004	11:05	D3858	10/28/2004	98		120			11/3/2004	DM
1ABRU026.40	12/14/2004	12:30	D3997	12/15/2004	74		1	U		12/17/2004	DM
1ABRU026.40	1/26/2005	10:05	D4099	1/27/2005	72		90			2/4/2005	DM
1ABRU026.40	2/10/2005	9:38	D4156	2/11/2005	118		180			2/16/2005	DM
1ABRU026.40	3/16/2005	10:33	D4212	3/17/2005	40		70			3/22/2005	DM
1ABRU026.40	4/27/2005	12:15	D4340	4/28/2005	36	B	40	B		4/29/2005	DM
1ABRU026.40	5/26/2005	10:44	D4433	5/27/2005	218	A	310			5/31/2005	DM
1ABRU026.40	6/29/2005	11:20	D4497	6/30/2005	181	A	140	B		7/5/2005	DM
1ABRU026.40	07/27/2005	9:55	D4606	7/28/2005	84		130	B		8/1/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.41 Bacterial Enumeration for Bull Run at Station 1ABUL010.28.**

Enumerations											
Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	<i>E. coli</i> cfu/100ml	Quality	Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
1ABUL010.28	7/22/2004	11:11	D3557	7/23/2004	10		150			8/31/2004	DM
1ABUL010.28	8/12/2004	11:05	D3611	8/13/2004	700		140			8/31/2004	DM
1ABUL010.28	9/8/2004	11:18	D3703	9/9/2004	20		80			9/20/2004	DM
1ABUL010.28	10/27/2004	11:50	D3859	10/28/2004	98		120			11/3/2004	DM
1ABUL010.28	12/14/2004	13:45	D3998	12/15/2004	38		1	U		12/17/2004	DM
1ABUL010.28	1/26/2005	10:44	D4100	1/27/2005	22		50			2/4/2005	DM
1ABUL010.28	2/10/2005	10:22	D4157	2/11/2005	40		90			2/16/2005	DM
1ABUL010.28	3/16/2005	11:11	D4213	3/17/2005	28		20			3/22/2005	DM
1ABUL010.28	4/27/2005	12:45	D4341	4/28/2005	32	B	50	B		4/29/2005	DM
1ABUL010.28	5/26/2005	11:15	D4435	5/27/2005	219	A	80	B		5/31/2005	DM
1ABUL010.28	6/29/2005	12:40	D4499	6/30/2005	52		200			7/5/2005	DM
1ABUL010.28	7/27/2005	11:00	D4607	7/28/2005	42		80	B		8/1/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.42 Bacterial Enumeration for Little Bull Run at Station 1ALII003.97.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
1ALII003.97	7/22/2004	9:44	D3555	7/23/2004	120		120			8/31/2004	DM
1ALII003.97	8/12/2004	10:00	D3608	8/13/2004	6,000		60			8/31/2004	DM
1ALII003.97	9/8/2004	10:05	D3701	9/9/2004	160		100			9/20/2004	DM
1ALII003.97	10/27/2004	10:30	D3857	10/28/2004	30		80			11/3/2004	DM
1ALII003.97	12/14/2004	13:15	D3995	12/15/2004	46		10			12/17/2004	DM
1ALII003.97	1/26/2005	9:22	D4098	1/27/2005	82		80			2/4/2005	DM
1ALII003.97	2/10/2005	9:05	D4155	2/11/2005	261		340			2/16/2005	DM
1ALII003.97	3/16/2005	9:50	D4211	3/17/2005	18		30			3/22/2005	DM
1ALII003.97	4/27/2005	11:30	D4338	4/28/2005	28	B	40	B		4/29/2005	DM
1ALII003.97	5/26/2005	10:10	D4431	5/27/2005	216	A	300			5/31/2005	DM
1ALII003.97	6/29/2005	12:05	D4498	6/30/2005	28	B	50	B		7/5/2005	DM
1ALII003.97	7/27/2005	10:30	D4604	7/28/2005	38	B	80	B		8/1/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.43 Bacterial Enumeration for Occoquan River at Station 1AOCC021.35.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
1AOCC021.35	7/22/2004	12:15	D3559	7/23/2004	20		50			8/31/2004	DM
1AOCC021.35	8/12/2004	11:55	D3609	8/13/2004	1	U	70			8/31/2004	DM
1AOCC021.35	9/8/2004	12:30	D3705	9/9/2004	580		50			2/2/2005	DM
1AOCC021.35	10/27/2004	13:00	D3861	10/28/2004	50		60			11/3/2004	DM
1AOCC021.35	12/14/2004	11:15	D3994	12/15/2004	205		1	U		12/17/2004	DM
1AOCC021.35	2/10/2005	11:10	D4159	2/11/2005	110		100			2/16/2005	DM
1AOCC021.35	3/16/2005	12:15	D4215	3/17/2005	10		20			3/22/2005	DM
1AOCC021.35	4/27/2005	14:15	D4337	4/28/2005	46		70	B		4/29/2005	DM
1AOCC021.35	5/26/2005	12:22	D4430	5/27/2005	330	A	1,545	A		5/31/2005	DM
1AOCC021.35	6/29/2005	13:25	D4501	6/30/2005	2	B	1	U		7/5/2005	DM
1AOCC021.35	7/27/2005	8:45	D4603	07/28/2005	20	B	90	B		8/1/2005	DMT
1AOCC021.35	8/17/2005	16:15	D4661	8/18/2005	42		170			8/23/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.44 Bacterial Enumeration for Popes Head Creek at Station 1APOE002.00.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
1APOE002.00	7/22/2004	11:35	D3558	7/23/2004	60		200			8/31/2004	DM
1APOE002.00	8/12/2004	11:36	D3610	8/13/2004	130		60			8/31/2004	DM
1APOE002.00	9/8/2004	11:44	D3704	9/9/2004	60		370			9/20/2004	DM
1APOE002.00	10/27/2004	12:22	D3860	10/28/2004	12		220			11/3/2004	DM
1APOE002.00	12/14/2004	14:00	D3999	12/15/2004	40		20			12/17/2004	DM
1APOE002.00	1/26/2005	11:06	D4101	1/27/2005	24		40			2/4/2005	DM
1APOE002.00	2/10/2005	10:45	D4158	2/11/2005	46		50			2/16/2005	DM
1APOE002.00	3/16/2005	11:35	D4214	3/17/2005	10		40			3/22/2005	DM
1APOE002.00	4/27/2005	13:15	D4342	4/28/2005	28	B	40	B		4/29/2005	DM
1APOE002.00	5/26/2005	11:35	D4434	5/27/2005	68		90	B		5/31/2005	DM
1APOE002.00	6/29/2005	13:00	D4500	6/30/2005	68		80	B		7/5/2005	DM
1APOE002.00	7/27/2005	11:15	D4608	7/28/2005	70		230			8/1/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.45 Bacterial Enumeration for South Run at Station 1ASOT001.65.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
1ASOT001.65	7/22/2004	9:15	D3554	7/23/2004	180		430			8/31/2004	DM
1ASOT001.65	8/12/2004	9:25	D3607	8/13/2004	30		40			8/31/2004	DM
1ASOT001.65	9/8/2004	9:30	D3700	9/9/2004	290		300			9/20/2004	DM
1ASOT001.65	10/27/2004	10:00	D3856	10/28/2004	48		170			11/3/2004	DM
1ASOT001.65	12/14/2004	12:00	D3996	12/15/2004	50		1	U		12/17/2004	DM
1ASOT001.65	1/26/2005	8:45	D4097	1/27/2005	50		80			2/4/2005	DM
1ASOT001.65	2/10/2005	8:33	D4154	2/11/2005	10		250			2/16/2005	DM
1ASOT001.65	3/16/2005	9:15	D4210	3/17/2005	14		10	U		3/22/2005	DM
1ASOT001.65	4/27/2005	11:00	D4339	4/28/2005	8	B	30	B		4/29/2005	DM
1ASOT001.65	5/26/2005	9:25	D4432	5/27/2005	80		130	B		5/31/2005	DM
1ASOT001.65	6/29/2005	10:50	D4496	6/30/2005	46		50	B		7/5/2005	DM
1ASOT001.65	7/27/2005	9:30	D4605	7/28/2005	156	A	240			8/1/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.46 Bacterial Enumeration for Blue Run at Station 3BLU000.80.**

Enumerations											
Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	<i>E. coli</i> cfu/100ml	Quality	Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
3BLU000.80	7/15/2004	10:05	D3505	7/16/2004	190		280			7/27/2004	DM
3BLU000.80	8/17/2004	10:30	D3641	8/18/2004	100		120			8/31/2004	DM
3BLU000.80	9/21/2004	9:55	D3756	9/22/2004	130		190			9/29/2004	DM
3BLU000.80	10/19/2004	9:45	D3827	10/20/2004	36		20			10/26/2004	DM
3BLU000.80	11/2/2004	9:50	D3882	11/3/2004	197		220			11/5/2004	DM
3BLU000.80	12/8/2004	10:10	D3971	12/9/2004	179		10			12/10/2004	DM
3BLU000.80	1/19/2005	9:22	D4078	1/20/2005	202		210			1/24/2005	DM
3BLU000.80	2/3/2005	9:50	D4115	2/4/2005	130		200			2/7/2005	DM
3BLU000.80	3/2/2005	9:30	D4193	3/3/2005	238		170			3/7/2005	DM
3BLU000.80	4/6/2005	9:55	D4281	4/7/2005	303		110	B		4/11/2005	DM
3BLU000.80	5/3/2005	10:00	D4351	5/4/2005	173	A	90	B		5/10/2005	DM
3BLU000.80	6/8/2005	10:16	D4455	6/9/2005	195	A	190	B		6/11/2005	DM

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.47 Bacterial Enumeration for Hazel River at Station 3HAZ018.29.**

Enumerations											
Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	<i>E. coli</i> cfu/100ml	Quality	Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
3HAZ018.29	7/28/2004	8:20	D3575	7/29/2004	120		170			8/31/2004	DM
3HAZ018.29	8/30/2004	9:20	D3672	8/31/2004	30		20			9/7/2004	DM
3HAZ018.29	9/28/2004	9:00	D3786	9/29/2004	380		240			10/7/2004	DM
3HAZ018.29	10/21/2004	9:00	D3829	10/22/2004	70		120			10/26/2004	DM
3HAZ018.29	11/30/2004	8:30	D3953	12/1/2004	236		290			12/7/2004	DM
3HAZ018.29	12/16/2004	12:40	D4015	12/17/2004	20		50			1/7/2005	DM
3HAZ018.29	2/8/2005	8:30	D4133	2/9/2005	12		10			2/11/2005	DM
3HAZ018.29	3/8/2005	8:40	D4197	3/9/2005	46		20			3/16/2005	DM
3HAZ018.29	4/13/2005	8:45	D4286	4/14/2005	58		70	B		4/21/2005	DM
3HAZ018.29	5/25/2005	8:40	D4424	5/26/2005	318	A	390			5/31/2005	DM
3HAZ018.29	6/28/2005	10:45	D4491	6/29/2005	20	B	10	B		7/5/2005	DM
3HAZ018.29	7/26/2005	10:05	D4596	7/27/2005	78		100	B		7/29/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.48 Bacterial Enumeration for Hughes River at Station 3HUE000.20.**

Enumerations											
Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	<i>E. coli</i> cfu/100ml	Quality	Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
3HUE000.20	7/28/2004	9:25	D3576	7/29/2004	330		250			8/31/2004	DM
3HUE000.20	8/30/2004	10:25	D3673	8/31/2004	80		50			9/7/2004	DM
3HUE000.20	9/28/2004	9:45	D3787	9/29/2004	550		2,600			10/7/2004	DM
3HUE000.20	10/21/2004	9:52	D3830	10/22/2004	120		130			10/26/2004	DM
3HUE000.20	11/30/2004	9:50	D3954	12/1/2004	100		220			12/7/2004	DM
3HUE000.20	12/16/2004	11:35	D4014	12/17/2004	16		20			1/7/2005	DM
3HUE000.20	2/8/2005	9:27	D4134	2/9/2005	169		80			2/11/2005	DM
3HUE000.20	3/8/2005	9:45	D4198	3/9/2005	140		140			3/16/2005	DM
3HUE000.20	4/13/2005	9:50	D4287	4/14/2005	261		120	B		4/21/2005	DM
3HUE000.20	5/25/2005	9:33	D4425	5/26/2005	334	A	370			5/31/2005	DM
3HUE000.20	6/28/2005	11:30	D4492	6/29/2005	221	A	120	B		7/5/2005	DM
3HUE000.20	7/26/2005	10:45	D4597	7/27/2005	217	A	390			7/29/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.49 Bacterial Enumeration for Rapidan River at Station 3RAP045.08.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations			Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality	Fecal Coliform cfu/100ml			
3RAP045.08	7/15/2004	9:10	D3503	7/16/2004	120		210		7/27/2004	DM
3RAP045.08	8/17/2004	9:55	D3640	8/18/2004	50		80		8/31/2004	DM
3RAP045.08	9/21/2004	8:50	D3754	9/22/2004	300		310		9/29/2004	DM
3RAP045.08	10/19/2004	8:48	D3825	10/20/2004	74		120		10/26/2004	DM
3RAP045.08	11/2/2004	8:55	D3880	11/3/2004	54		110		11/5/2004	DM
3RAP045.08	12/8/2004	9:20	D3969	12/9/2004	403		80		12/10/2004	DM
3RAP045.08	1/19/2005	8:38	D4076	1/20/2005	199		260		1/24/2005	DM
3RAP045.08	2/3/2005	9:00	D4113	2/4/2005	94		110		2/7/2005	DM
3RAP045.08	3/2/2005	8:40	D4191	3/3/2005	88		50		3/7/2005	DM
3RAP045.08	4/6/2005	9:00	D4280	4/7/2005	241		180	B	4/11/2005	DM
3RAP045.08	5/3/2005	9:05	D4350	5/4/2005	78		80	B	5/10/2005	DM
3RAP045.08	6/8/2005	9:50	D4454	6/9/2005	98		110	B	6/11/2005	DM

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.50 Bacterial Enumeration for Rapidan River at Station 3RAP077.28.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
3RAP077.28	9/21/2004	11:15	D3757	9/22/2004	50		120			9/29/2004	DM
3RAP077.28	10/19/2004	11:10	D3828	10/20/2004	20		100			10/26/2004	DM
3RAP077.28	11/2/2004		D3883	11/3/2004	20		40			11/5/2004	DM
3RAP077.28	12/8/2004	11:22	D3972	12/9/2004	12		1	U		12/10/2004	DM
3RAP077.28	1/19/2005	10:30	D4079	1/20/2005	14		10			1/24/2005	DM
3RAP077.28	2/3/2005	11:11	D4116	2/4/2005	24		40			2/7/2005	DM
3RAP077.28	3/2/2005	10:45	D4194	3/3/2005	2		10			3/7/2005	DM
3RAP077.28	4/6/2005	11:15	D4282	4/7/2005	12	B	20	B		4/11/2005	DM
3RAP077.28	5/3/2005	11:25	D4352	5/4/2005	6	B	20	B		5/10/2005	DM
3RAP077.28	6/8/2005	11:35	D4456	6/9/2005	36		30	B		6/11/2005	DM
3RAP077.28	7/26/2005	11:45	D4601	7/27/2005	18	B	80	B		7/29/2005	DMT
3RAP077.28	8/17/2005		D4658	8/18/2005	56		1,335	A		8/23/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.51 Bacterial Enumeration for Robinson River at Station 3ROB001.90.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
3ROB001.90	7/15/2004	9:30	D3504	7/16/2004	650		710			7/27/2004	DM
3ROB001.90	8/17/2004	9:40	D3639	8/18/2004	290		50			8/31/2004	DM
3ROB001.90	9/21/2004	9:13	D3755	9/22/2004	460		350			9/29/2004	DM
3ROB001.90	10/19/2004	9:10	D3826	10/20/2004	80		260			10/26/2004	DM
3ROB001.90	11/2/2004	9:20	D3881	11/3/2004	92		190			11/5/2004	DM
3ROB001.90	12/8/2004	9:35	D3970	12/9/2004	286		180			12/10/2004	DM
3ROB001.90	1/19/2005	8:51	D4077	1/20/2005	233		110			1/24/2005	DM
3ROB001.90	2/3/2005	9:21	D4114	2/4/2005	100		60			2/7/2005	DM
3ROB001.90	3/2/2005	8:58	D4192	3/3/2005	78		70			3/7/2005	DM
3ROB001.90	4/6/2005	9:25	D4283	4/7/2005	391		320			4/11/2005	DM
3ROB001.90	5/3/2005	9:25	D4353	5/4/2005	175	A	130	B		5/10/2005	DM
3ROB001.90	6/8/2005	9:25	D4457	6/9/2005	80		190	B		6/11/2005	DM

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.52 Bacterial Enumeration for Rappahannock River at Station 3RPP175.51.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
3RPP175.51	7/28/2004	11:22	D3579	7/29/2004	140		260			8/31/2004	DM
3RPP175.51	8/30/2004	11:53	D3676	8/31/2004	120		60			9/7/2004	DM
3RPP175.51	9/28/2004	11:00	D3790	9/29/2004	3,600		3,700			10/7/2004	DM
3RPP175.51	10/21/2004	11:55	D3833	10/22/2004	120		180			10/26/2004	DM
3RPP175.51	11/30/2004	11:25	D3957	12/1/2004	198		280			12/7/2004	DM
3RPP175.51	12/16/2004	9:45	D4011	12/17/2004	68		150			1/7/2005	DM
3RPP175.51	2/8/2005	11:11	D4137	2/9/2005	22		22			2/11/2005	DM
3RPP175.51	3/8/2005	12:15	D4201	3/9/2005	260		70			3/16/2005	DM
3RPP175.51	4/13/2005	11:38	D4290	4/14/2005	48		90	B		4/21/2005	DM
3RPP175.51	5/25/2005	11:22	D4428	5/26/2005	155	A	80	B		5/31/2005	DM
3RPP175.51	6/28/2005	12:35	D4494	6/29/2005	68		150	B		7/5/2005	DM
3RPP175.51	7/26/2005	14:20	D4600	7/27/2005	72		320			7/29/2005	DMt

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.53 Bacterial Enumeration for Rush River at Station 3RUS005.66.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
3RUS005.66	7/28/2004	10:15	D3578	7/29/2004	400		410			8/31/2004	DM
3RUS005.66	8/30/2004	11:15	D3675	8/31/2004	70		50			9/7/2004	DM
3RUS005.66	9/28/2004	10:30	D3789	9/29/2004	6,000		4,500			10/7/2004	DM
3RUS005.66	10/21/2004	10:50	D3832	10/22/2004	142		480			10/26/2004	DM
3RUS005.66	11/30/2004	10:44	D3956	12/1/2004	164		240			12/7/2004	DM
3RUS005.66	12/16/2004	10:40	D4012	12/17/2004	90		170			1/7/2005	DM
3RUS005.66	2/8/2005	10:22	D4136	2/9/2005	32		60			2/11/2005	DM
3RUS005.66	3/8/2005	11:00	D4200	3/9/2005	790		780			3/16/2005	DM
3RUS005.66	4/13/2005	10:40	D4289	4/14/2005	171		170	B		4/21/2005	DM
3RUS005.66	5/25/2005	10:20	D4427	5/26/2005	90		60	B		5/31/2005	DM
3RUS005.66	6/28/2005	13:30	D4495	6/29/2005	122		80	B		7/5/2005	DM
3RUS005.66	7/26/2005	13:50	D4599	7/27/2005	150	A	460			7/29/2005	DMt

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

**Table 5.54 Bacterial Enumeration for Thornton River at Station 3THO021.19.**

Station ID	Date of Sample	Time of Sample	Lab ID	Lab-In Date	Enumerations		Fecal Coliform cfu/100ml	Quality	Comments	Lab-Out Date	Lab Personnel
					<i>E. coli</i> cfu/100ml	Quality					
3THO021.19	7/28/2004	9:55	D3577	7/29/2004	110		300			8/31/2004	DM
3THO021.19	8/30/2004	10:55	D3674	8/31/2004	100		70			9/7/2004	DM
3THO021.19	9/28/2004	10:13	D3788	9/29/2004	550		1,400			10/7/2004	DM
3THO021.19	10/21/2004	10:20	D3831	10/22/2004	140		230			10/26/2004	DM
3THO021.19	11/30/2004	10:22	D3955	12/1/2004	74		90			12/7/2004	DM
3THO021.19	12/16/2004	11:00	D4013	12/17/2004	16		50			1/7/2005	DM
3THO021.19	2/8/2005	9:58	D4135	2/9/2005	18		80			2/11/2005	DM
3THO021.19	3/8/2005	10:25	D4199	3/9/2005	100		130			3/16/2005	DM
3THO021.19	4/13/2005	10:15	D4288	4/14/2005	20	B	70	B		4/21/2005	DM
3THO021.19	5/25/2005	10:00	D4426	5/26/2005	96		160	B		5/31/2005	DM
3THO021.19	6/28/2005	12:00	D4493	6/29/2005	155	A	570			7/5/2005	DM
3THO021.19	7/26/2005	12:40	D4598	7/27/2005	80		170	B		7/29/2005	DMT

A: Value reported is the mean of two or more determinations.

B: Results based upon colony counts outside the acceptable range.

U: Material was analyzed for, but not detected. Value stored is the limit of detection for the process in use.

Table 5.55 Bacterial Source Tracking for Broad Run at Station 1ABRU026.40.

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
1ABRU026.40	7/22/2004	D3556	A19	24	640	<b>67%</b>	0%	<b>12%</b>	<b>21%</b>
1ABRU026.40	8/12/2004	D3612	A19	24	800	<b>25%</b>	<b>12%</b>	<b>51%</b>	<b>12%</b>
1ABRU026.40	9/8/2004	D3702	A19	24	2,700	<b>54%</b>	0%	8%	<b>38%</b>
1ABRU026.40	10/27/2004	D3858	A19	24	98	<b>38%</b>	<b>29%</b>	<b>29%</b>	4%
1ABRU026.40	12/14/2004	D3997	A19	24	74	<b>33%</b>	<b>25%</b>	<b>25%</b>	<b>17%</b>
1ABRU026.40	1/26/2005	D4099	A19	24	72	8%	8%	<b>33%</b>	<b>51%</b>
1ABRU026.40	2/10/2005	D4156	A19	24	118	4%	<b>38%</b>	<b>12%</b>	<b>46%</b>
1ABRU026.40	3/16/2005	D4212	A19	22	40	<b>14%</b>	<b>58%</b>	<b>14%</b>	<b>14%</b>
1ABRU026.40	4/27/2005	D4340	A19	16	36	<b>25%</b>	12%	<b>57%</b>	6%
1ABRU026.40	5/26/2005	D4433	A19	24	218	<b>71%</b>	0%	8%	<b>21%</b>
1ABRU026.40	6/29/2005	D4497	A19	24	181	<b>67%</b>	4%	<b>25%</b>	4%
1ABRU026.40	7/27/2005	D4606	A19	24	84	<b>84%</b>	0%	<b>12%</b>	4%

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

Table 5.56 Bacterial Source Tracking for Bull Run at Station 1ABUL010.28.

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
1ABUL010.28	7/22/2004	D3557	A23	2	10	50%	50%	0%	0%
1ABUL010.28	8/12/2004	D3611	A23	24	700	<b>75%</b>	0%	<b>21%</b>	4%
1ABUL010.28	9/8/2004	D3703	A23	4	20	100%	0%	0%	0%
1ABUL010.28	10/27/2004	D3859	A23	6	98	50%	50%	0%	0%
1ABUL010.28	12/14/2004	D3998	A23	24	38	<b>62%</b>	<b>21%</b>	0%	<b>17%</b>
1ABUL010.28	1/26/2005	D4100	A23	13	22	8%	8%	<b>31%</b>	<b>53%</b>
1ABUL010.28	2/10/2005	D4157	A23	22	40	<b>36%</b>	<b>18%</b>	5%	<b>41%</b>
1ABUL010.28	3/16/2005	D4213	A23	15	28	<b>20%</b>	<b>53%</b>	<b>20%</b>	7%
1ABUL010.28	4/27/2005	D4341	A23	23	32	<b>61%</b>	4%	<b>22%</b>	<b>13%</b>
1ABUL010.28	5/26/2005	D4435	A23	24	219	<b>71%</b>	8%	<b>21%</b>	0%
1ABUL010.28	6/29/2005	D4499	A23	24	52	<b>100%</b>	0%	0%	0%
1ABUL010.28	7/27/2005	D4607	A23	24	42	<b>88%</b>	0%	8%	4%

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.57 Bacterial Source Tracking for Little Bull Run at Station 1ALII003.97.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
1ALII003.97	7/22/2004	D3555	A21	11	120	<b>82%</b>	0%	0%	18%
1ALII003.97	8/12/2004	D3608	A21	24	6,000	<b>62%</b>	0%	<b>38%</b>	0%
1ALII003.97	9/8/2004	D3701	A21	16	160	<b>63%</b>	6%	<b>19%</b>	12%
1ALII003.97	10/27/2004	D3857	A21	24	30	<b>63%</b>	<b>12%</b>	<b>17%</b>	8%
1ALII003.97	12/14/2004	D3995	A21	24	46	<b>55%</b>	<b>12%</b>	<b>29%</b>	4%
1ALII003.97	1/26/2005	D4098	A21	24	82	4%	4%	<b>42%</b>	<b>50%</b>
1ALII003.97	2/10/2005	D4155	A21	24	261	8%	<b>25%</b>	<b>38%</b>	<b>29%</b>
1ALII003.97	3/16/2005	D4211	A21	10	18	10%	<b>50%</b>	0%	<b>40%</b>
1ALII003.97	4/27/2005	D4338	A21	22	28	<b>27%</b>	5%	<b>27%</b>	<b>41%</b>
1ALII003.97	5/26/2005	D4431	A21	24	216	<b>62%</b>	0%	<b>17%</b>	<b>21%</b>
1ALII003.97	6/29/2005	D4498	A21	18	28	<b>94%</b>	0%	6%	0%
1ALII003.97	7/27/2005	D4604	A21	24	38	<b>46%</b>	0%	8%	<b>46%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.58 Bacterial Source Tracking for Occoquan River at Station 1AOCC21.35.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
1AOCC021.35	7/22/2004	D3559	A20	3	20	0%	0%	0%	100%
1AOCC021.35	8/12/2004	D3609	A20	8	1	38%	0%	38%	24%
1AOCC021.35	9/8/2004	D3705	A20	24	580	<b>21%</b>	<b>75%</b>	4%	0%
1AOCC021.35	10/27/2004	D3861	A20	24	50	<b>12%</b>	<b>25%</b>	<b>17%</b>	<b>46%</b>
1AOCC021.35	12/14/2004	D3994	A20	24	205	<b>33%</b>	<b>55%</b>	<b>12%</b>	0%
1AOCC021.35	2/10/2005	D4159	A20	2	110	0%	50%	0%	50%
1AOCC021.35	3/16/2005	D4215	A20	24	10	<b>12%</b>	4%	0%	<b>84%</b>
1AOCC021.35	4/27/2005	D4337	A20	24	46	<b>67%</b>	0%	0%	<b>33%</b>
1AOCC021.35	5/26/2005	D4430	A20	1	330	100%	0%	0%	0%
1AOCC021.35	6/29/2005	D4501	A20	11	2	<b>55%</b>	0%	0%	<b>45%</b>
1AOCC021.35	7/27/2005	D4603	A20	24	20	0%	0%	<b>100%</b>	0%
1AOCC021.35	8/17/2205	D4661	A20	3	42	0%	0%	0%	100%

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.59 Bacterial Source Tracking for Popes Head Creek at Station 1APOE002.00.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
1APOE002.00	7/22/2004	D3558	A23	8	60	12%	0%	25%	63%
1APOE002.00	8/12/2004	D3610	A23	16	130	<b>69%</b>	0%	<b>31%</b>	0%
1APOE002.00	9/8/2004	D3704	A23	24	60	<b>46%</b>	4%	<b>17%</b>	<b>33%</b>
1APOE002.00	10/27/2004	D3860	A23	24	12	<b>50%</b>	<b>38%</b>	4%	8%
1APOE002.00	12/14/2004	D3999	A23	24	40	<b>33%</b>	<b>21%</b>	<b>21%</b>	<b>25%</b>
1APOE002.00	1/26/2005	D4101	A23	16	24	<b>63%</b>	6%	12%	<b>19%</b>
1APOE002.00	2/10/2005	D4158	A23	24	46	<b>22%</b>	<b>33%</b>	<b>12%</b>	<b>33%</b>
1APOE002.00	3/16/2005	D4214	A23	11	10	18%	<b>27%</b>	<b>37%</b>	18%
1APOE002.00	4/27/2005	D4342	A23	14	28	<b>58%</b>	0%	<b>21%</b>	<b>21%</b>
1APOE002.00	5/26/2005	D4434	A23	24	68	<b>79%</b>	0%	0%	<b>21%</b>
1APOE002.00	6/29/2005	D4500	A23	24	68	<b>84%</b>	8%	8%	0%
1APOE002.00	7/27/2005	D4608	A23	24	70	<b>71%</b>	0%	<b>25%</b>	4%

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.60 Bacterial Source Tracking for South Run at Station 1ASTO001.65.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
1ASOT001.65	7/22/2004	D3554	A19	19	180	11%	<b>47%</b>	5%	<b>37%</b>
1ASOT001.65	8/12/2004	D3607	A19	3	30	33%	67%	0%	0%
1ASOT001.65	9/8/2004	D3700	A19	24	290	<b>67%</b>	0%	<b>12%</b>	<b>21%</b>
1ASOT001.65	10/27/2004	D3856	A19	24	48	<b>54%</b>	4%	<b>38%</b>	4%
1ASOT001.65	12/14/2004	D3996	A19	24	50	<b>46%</b>	<b>12%</b>	<b>25%</b>	<b>17%</b>
1ASOT001.65	1/26/2005	D4097	A19	24	50	8%	<b>25%</b>	<b>17%</b>	<b>50%</b>
1ASOT001.65	2/10/2005	D4154	A19	7	10	13%	29%	29%	29%
1ASOT001.65	3/16/2005	D4210	A19	7	14	29%	43%	14%	14%
1ASOT001.65	4/27/2005	D4339	A19	8	8	50%	12%	38%	0%
1ASOT001.65	5/26/2005	D4432	A19	24	80	<b>64%</b>	<b>12%</b>	<b>12%</b>	<b>12%</b>
1ASOT001.65	6/29/2005	D4496	A19	24	46	<b>84%</b>	0%	<b>12%</b>	4%
1ASOT001.65	7/27/2005	D4605	A19	24	156	<b>88%</b>	0%	8%	4%

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.61 Bacterial Source Tracking for Blue Run at Station 3BLU000.80.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3BLU000.80	7/15/2004	D3505	E13	19	190	<b>16%</b>	11%	<b>62%</b>	11%
3BLU000.80	8/17/2004	D3641	E13	11	100	<b>45%</b>	0%	0%	<b>55%</b>
3BLU000.80	9/21/2004	D3756	E13	14	130	7%	0%	<b>93%</b>	0%
3BLU000.80	10/19/2004	D3827	E13	24	36	4%	0%	<b>67%</b>	<b>29%</b>
3BLU000.80	11/2/2004	D3882	E13	24	197	<b>33%</b>	<b>12%</b>	<b>17%</b>	<b>38%</b>
3BLU000.80	12/8/2004	D3971	E13	24	179	<b>45%</b>	<b>21%</b>	<b>17%</b>	<b>17%</b>
3BLU000.80	1/19/2005	D4078	E13	24	202	<b>50%</b>	0%	<b>21%</b>	<b>29%</b>
3BLU000.80	2/3/2005	D4115	E13	24	130	<b>63%</b>	<b>12%</b>	<b>17%</b>	8%
3BLU000.80	3/2/2005	D4193	E13	24	238	8%	<b>12%</b>	<b>55%</b>	<b>25%</b>
3BLU000.80	4/6/2005	D4281	E13	24	303	<b>12%</b>	<b>46%</b>	<b>42%</b>	0%
3BLU000.80	5/3/2005	D4351	E13	24	173	<b>12%</b>	<b>50%</b>	<b>38%</b>	0%
3BLU000.80	6/8/2005	D4455	E13	24	195	<b>42%</b>	4%	<b>42%</b>	<b>12%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.62 Bacterial Source Tracking for Hazel River at Station 3HAZ018.29.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3HAZ018.29	7/28/2004	D3575	E04	12	120	<b>100%</b>	0%	0%	0%
3HAZ018.29	8/30/2004	D3672	E04	3	30	0%	100%	0%	0%
3HAZ018.29	9/28/2004	D3786	E04	24	380	<b>42%</b>	8%	<b>33%</b>	<b>17%</b>
3HAZ018.29	10/21/2004	D3829	E04	24	70	<b>12%</b>	4%	<b>59%</b>	<b>25%</b>
3HAZ018.29	11/30/2004	D3953	E04	24	236	<b>33%</b>	0%	<b>42%</b>	<b>25%</b>
3HAZ018.29	12/16/2004	D4015	E04	7	20	29%	0%	57%	14%
3HAZ018.29	2/8/2005	D4133	E04	9	12	11%	22%	<b>45%</b>	22%
3HAZ018.29	3/8/2005	D4197	E04	24	46	<b>38%</b>	8%	<b>25%</b>	<b>29%</b>
3HAZ018.29	4/13/2005	D4286	E04	24	58	<b>38%</b>	<b>21%</b>	<b>12%</b>	<b>29%</b>
3HAZ018.29	5/25/2005	D4424	E04	24	318	<b>68%</b>	8%	<b>12%</b>	<b>12%</b>
3HAZ018.29	6/28/2005	D4491	E04	18	20	<b>50%</b>	0%	<b>22%</b>	<b>28%</b>
3HAZ018.29	7/26/2005	D4596	E04	24	78	<b>59%</b>	8%	<b>12%</b>	<b>21%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.63 Bacterial Source Tracking for Hughes River at Station 3HUE000.20**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3HUE000.20	7/28/2004	D3576	E03	24	330	<b>38%</b>	0%	<b>62%</b>	0%
3HUE000.20	8/30/2004	D3673	E03	8	80	50%	0%	25%	25%
3HUE000.20	9/28/2004	D3787	E03	24	550	<b>38%</b>	8%	<b>33%</b>	<b>21%</b>
3HUE000.20	10/21/2004	D3830	E03	24	120	8%	0%	<b>80%</b>	<b>12%</b>
3HUE000.20	11/30/2004	D3954	E03	24	100	<b>33%</b>	0%	<b>55%</b>	<b>12%</b>
3HUE000.20	12/16/2004	D4014	E03	11	16	0%	<b>64%</b>	9%	<b>27%</b>
3HUE000.20	2/8/2005	D4134	E03	24	169	<b>38%</b>	<b>12%</b>	<b>33%</b>	<b>17%</b>
3HUE000.20	3/8/2005	D4198	E03	24	140	4%	0%	<b>92%</b>	4%
3HUE000.20	4/13/2005	D4287	E03	24	261	<b>25%</b>	<b>38%</b>	<b>12%</b>	<b>25%</b>
3HUE000.20	5/25/2005	D4425	E03	24	334	<b>21%</b>	<b>21%</b>	<b>33%</b>	<b>25%</b>
3HUE000.20	6/28/2005	D4492	E03	24	221	<b>50%</b>	0%	<b>12%</b>	<b>38%</b>
3HUE000.20	7/26/2005	D4597	E03	24	217	<b>42%</b>	0%	<b>16%</b>	<b>42%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.64 Bacterial Source Tracking for Rapidan River at Station 3RAP045.08.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3RAP045.08	7/15/2004	D3503	E13	16	120	<b>19%</b>	<b>25%</b>	<b>50%</b>	6%
3RAP045.08	8/17/2004	D3640	E13	6	50	33%	0%	17%	50%
3RAP045.08	9/21/2004	D3754	E13	24	300	<b>17%</b>	0%	<b>45%</b>	<b>38%</b>
3RAP045.08	10/19/2004	D3825	E13	24	74	0%	0%	<b>100%</b>	0%
3RAP045.08	11/2/2004	D3880	E13	24	54	<b>55%</b>	4%	<b>33%</b>	8%
3RAP045.08	12/8/2004	D3969	E13	24	403	<b>46%</b>	<b>25%</b>	<b>21%</b>	8%
3RAP045.08	1/19/2005	D4076	E13	24	199	<b>34%</b>	<b>12%</b>	<b>25%</b>	<b>29%</b>
3RAP045.08	2/3/2005	D4113	E13	24	94	<b>17%</b>	<b>25%</b>	<b>29%</b>	<b>29%</b>
3RAP045.08	3/2/2005	D4191	E13	24	88	<b>12%</b>	<b>25%</b>	<b>51%</b>	<b>12%</b>
3RAP045.08	4/6/2005	D4280	E13	24	241	4%	<b>50%</b>	<b>46%</b>	0%
3RAP045.08	5/3/2005	D4350	E13	24	78	<b>12%</b>	<b>38%</b>	<b>33%</b>	<b>17%</b>
3RAP045.08	6/8/2005	D4454	E13	24	98	<b>42%</b>	<b>25%</b>	<b>12%</b>	<b>21%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.65 Bacterial Source Tracking for Rapidan River at Station 3RAP077.28.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3RAP077.28	9/21/2004	D3757	E11	5	50	0%	0%	0%	100%
3RAP077.28	10/19/2004	D3828	E11	24	20	8%	0%	<b>38%</b>	<b>54%</b>
3RAP077.28	11/2/2004	D3883	E11	16	20	<b>63%</b>	<b>19%</b>	12%	6%
3RAP077.28	12/8/2004	D3972	E11	7	12	29%	42%	0%	29%
3RAP077.28	1/19/2005	D4079	E11	7	14	71%	0%	29%	0%
3RAP077.28	2/3/2005	D4116	E11	16	24	12%	<b>45%</b>	<b>31%</b>	12%
3RAP077.28	3/2/2005	D4194	E11	2	2	0%	100%	0%	0%
3RAP077.28	4/6/2005	D4282	E11	9	12	22%	<b>45%</b>	0%	<b>33%</b>
3RAP077.28	5/3/2005	D4352	E11	3	6	0%	0%	100%	0%
3RAP077.28	6/8/2005	D4456	E11	24	36	<b>67%</b>	4%	<b>12%</b>	<b>17%</b>
3RAP077.28	7/26/2005	D4601	E11	10	18	<b>60%</b>	0%	20%	20%
3RAP077.28	8/17/2005	D4658	E11	24	56	<b>42%</b>	4%	<b>54%</b>	0%

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.66 Bacterial Source Tracking for Robinson river at Station 3ROB001.90.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3ROB001.90	7/15/2004	D3504	E15	24	650	<b>21%</b>	<b>29%</b>	<b>12%</b>	<b>38%</b>
3ROB001.90	8/17/2004	D3639	E15	24	290	<b>29%</b>	<b>12%</b>	<b>12%</b>	<b>47%</b>
3ROB001.90	9/21/2004	D3755	E15	24	460	0%	0%	<b>100%</b>	0%
3ROB001.90	10/19/2004	D3826	E15	24	80	<b>17%</b>	0%	<b>83%</b>	0%
3ROB001.90	11/2/2004	D3881	E15	24	92	<b>42%</b>	0%	<b>25%</b>	<b>33%</b>
3ROB001.90	12/8/2004	D3970	E15	24	286	<b>29%</b>	<b>21%</b>	<b>38%</b>	<b>12%</b>
3ROB001.90	1/19/2005	D4077	E15	24	233	<b>33%</b>	8%	<b>33%</b>	<b>26%</b>
3ROB001.90	2/3/2005	D4114	E15	24	100	<b>38%</b>	<b>12%</b>	<b>29%</b>	<b>21%</b>
3ROB001.90	3/2/2005	D4192	E15	24	78	4%	<b>21%</b>	<b>50%</b>	<b>25%</b>
3ROB001.90	4/6/2005	D4283	E15	24	391	<b>34%</b>	<b>25%</b>	<b>29%</b>	<b>12%</b>
3ROB001.90	5/3/2005	D4353	E15	24	175	<b>21%</b>	<b>58%</b>	<b>17%</b>	4%
3ROB001.90	6/8/2005	D4457	E15	24	80	<b>21%</b>	<b>21%</b>	<b>29%</b>	<b>29%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.67 Bacterial Source Tracking for Rappahannock River at Station 3RPP175.51.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3RPP175.51	7/28/2004	D3579	E01	14	140	<b>93%</b>	0%	7%	0%
3RPP175.51	8/30/2004	D3676	E01	15	120	<b>80%</b>	0%	7%	13%
3RPP175.51	9/28/2004	D3790	E01	24	3,600	8%	0%	<b>80%</b>	<b>12%</b>
3RPP175.51	10/21/2004	D3833	E01	24	120	0%	0%	<b>58%</b>	<b>42%</b>
3RPP175.51	11/30/2004	D3957	E01	24	198	<b>17%</b>	<b>21%</b>	0%	<b>62%</b>
3RPP175.51	12/16/2004	D4011	E01	24	68	<b>41%</b>	<b>21%</b>	<b>17%</b>	<b>21%</b>
3RPP175.51	2/8/2005	D4137	E01	14	22	14%	<b>65%</b>	<b>21%</b>	0%
3RPP175.51	3/8/2005	D4201	E01	24	260	<b>12%</b>	<b>21%</b>	<b>38%</b>	<b>29%</b>
3RPP175.51	4/13/2005	D4290	E01	24	48	<b>29%</b>	<b>21%</b>	<b>12%</b>	<b>38%</b>
3RPP175.51	5/25/2005	D4428	E01	24	155	<b>25%</b>	0%	<b>42%</b>	<b>33%</b>
3RPP175.51	6/28/2005	D4494	E01	24	68	<b>79%</b>	0%	<b>21%</b>	0%
3RPP175.51	7/26/2005	D4600	E01	24	72	<b>55%</b>	0%	<b>12%</b>	<b>33%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.68 Bacterial Source Tracking for Rush River at Station 3RUS005.66.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3RUS005.66	7/28/2004	D3578	E05	24	400	8%	4%	<b>21%</b>	<b>67%</b>
3RUS005.66	8/30/2004	D3675	E05	9	70	0%	0%	<b>33%</b>	<b>67%</b>
3RUS005.66	9/28/2004	D3789	E05	24	6,000	<b>17%</b>	<b>12%</b>	<b>63%</b>	8%
3RUS005.66	10/21/2004	D3832	E05	24	142	0%	<b>17%</b>	<b>71%</b>	<b>12%</b>
3RUS005.66	11/30/2004	D3956	E05	24	164	<b>50%</b>	<b>29%</b>	<b>21%</b>	0%
3RUS005.66	12/16/2004	D4012	E05	24	90	8%	<b>46%</b>	8%	<b>38%</b>
3RUS005.66	2/8/2005	D4136	E05	18	32	<b>33%</b>	<b>33%</b>	<b>17%</b>	<b>17%</b>
3RUS005.66	3/8/2005	D4200	E05	24	790	<b>17%</b>	4%	<b>62%</b>	<b>17%</b>
3RUS005.66	4/13/2005	D4289	E05	24	171	<b>54%</b>	<b>17%</b>	4%	<b>25%</b>
3RUS005.66	5/25/2005	D4427	E05	24	90	<b>46%</b>	8%	<b>21%</b>	<b>25%</b>
3RUS005.66	6/28/2005	D4495	E05	24	122	<b>75%</b>	0%	<b>21%</b>	4%
3RUS005.66	7/26/2005	D4599	E05	24	150	<b>29%</b>	4%	<b>21%</b>	<b>46%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

**Table 5.69 Bacterial Source Tracking for Thornton River at Station 3THO021.19.**

VADEQ ID	Date of Sample	Lab ID	HUP ID	Number of Isolates	<i>E. coli</i> (cfu/100 ml)	Wildlife	Human	Livestock	Pet
3THO021.19	7/28/2004	D3577	E05	12	110	<b>67%</b>	8%	17%	8%
3THO021.19	8/30/2004	D3674	E05	12	100	<b>25%</b>	0%	<b>42%</b>	<b>33%</b>
3THO021.19	9/28/2004	D3788	E05	24	550	<b>55%</b>	4%	<b>29%</b>	<b>12%</b>
3THO021.19	10/21/2004	D3831	E05	24	140	4%	4%	<b>88%</b>	4%
3THO021.19	11/30/2004	D3955	E05	24	74	<b>46%</b>	<b>21%</b>	<b>29%</b>	4%
3THO021.19	12/16/2004	D4013	E05	6	16	0%	50%	17%	33%
3THO021.19	2/8/2005	D4135	E05	11	18	<b>45%</b>	<b>45%</b>	10%	0%
3THO021.19	3/8/2005	D4199	E05	24	100	<b>21%</b>	<b>25%</b>	<b>50%</b>	4%
3THO021.19	4/13/2005	D4288	E05	20	20	<b>20%</b>	<b>35%</b>	<b>15%</b>	<b>30%</b>
3THO021.19	5/25/2005	D4426	E05	24	96	<b>12%</b>	<b>29%</b>	4%	<b>55%</b>
3THO021.19	6/28/2005	D4493	E05	24	155	<b>33%</b>	0%	8%	<b>59%</b>
3THO021.19	7/26/2005	D4598	E05	24	80	<b>33%</b>	0%	<b>17%</b>	<b>50%</b>

**BOLD** type indicates a statistically significant value.

\*NVI - No Viable isolates

## **6. DISCUSSION**

Results of the 2004-2005 VADEQ BST program have been presented in this report. The ARCCs achieved during the library development stage are acceptable and there does not appear to be a high level of over-fitting. Based on the sample size targeted in each sample (*i.e.*, 24 isolates), there is 90% confidence that the proportions measured in each sample are within 15% of the actual proportions in the sampled population (*i.e.*, all bacteria in the stream at the time of sampling). Because a fixed-frequency sampling scheme was used, samples are not biased toward a particular flow regime and can therefore be combined to estimate the actual proportions contributed by the different sources over the entire year with greater precision (*i.e.*, 90% confidence that the estimate is within 5% of the actual proportions). Additionally, the statistical analyses applied to determine a significant difference from zero give a good indication of presence and absence of each source in each sample. All of these data are valuable for use in improving public awareness of the problem, improving model calibration/validation, and providing a more equitable allocation of loads to source classes.

In spite of the high quality of the data collected, care should be taken in using these data. These data represent, at most, 14 instantaneous observations at each station and may not be representative of long-term conditions. The hydrologic conditions during this period may not reflect either average or critical conditions. Additionally, the dynamics of the bacterial community are not well understood, so care should be taken in extrapolating from the in-stream condition to activities in the watershed. As with any other monitoring program, the data should not be viewed in a vacuum. Local knowledge of the sources involved, historical water quality records, and the hydrologic conditions during sampling should all be considered in any interpretation of this data.



## REFERENCES

## REFERENCES

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**APPENDIX A**

Bacterial Source Tracking Analyses Supplemental Report

*Bacterial Source Tracking Analyses to Support Virginia's TMDLs*

**Table A.1 False-positive and correct classification rates for eight BST libraries developed in support of VADEQ's Phase-III BST Program.**

Library	False-Positive Rates				Rate of Correct Classification			
	Wildlife	Human	Livestock	Pet	Wildlife	Human	Livestock	Pet
<b>2005-01</b>	7.1	3.6	7.6	3.7	82.42	92.14	77.50	76.89
<b>2005-02</b>	8.7	3.3	6.2	5.8	76.98	86.93	82.12	81.64
<b>2005-03</b>	5.6	1.6	8.2	5.4	71.94	96.67	83.42	85.56
<b>2005-04</b>	7.2	3.8	10.0	5.5	73.44	83.33	81.36	82.50
<b>2005-05</b>	6.4	4.5	7.5	5.2	74.26	81.25	85.10	88.21
<b>2005-06</b>	6.8	1.7	7.7	3.2	76.46	93.75	86.04	85.42
<b>2005-07</b>	8.2	6.5	11.8	9.2	65.57	75.20	72.20	79.74
<b>2005-08</b>	5.3	2.2	4.7	2.0	92.80	90.62	87.18	87.14

**Table A.2 Species sampled for 8 libraries developed in support of VADEQ's Phase-III BST Program.**

Source Category	Species	2005 Library Number							
		01	02	03	04	05	06	07	08
Human	Human	x	x	x	x	x	x	x	x
Livestock	Beef	x	x	x	x	x	x	x	x
	Dairy	x	x	x	x	x	x	x	x
	Donkey	x	x						x
	Goat	x	x				x		
	Horse	x	x	x	x	x	x	x	x
	Llama								x
	Poultry	x	x	x	x	x	x	x	x
	Sheep	x	x				x		x
	Swine	x	x	x	x	x	x	x	
Pet	Cat	x	x	x	x	x	x	x	x
	Dog	x	x	x	x	x	x	x	x
	Rabbit - Domestic	x						x	
Wildlife	Bear	x	x	x	x	x	x	x	x
	Coyote	x	x				x		x
	Deer	x	x	x	x	x	x	x	x
	Duck	x	x				x		x
	Fox	x	x	x	x	x	x	x	x
	Goose	x	x	x	x	x	x	x	x
	Muskrat		x	x	x		x	x	
	Opossum								x
	Otter		x	x	x	x	x	x	
	Pigeon								x
	Rabbit						x		
	Raccoon	x	x	x	x	x	x	x	x
	Skunk		x	x	x	x	x	x	
	Squirrel		x	x	x	x	x	x	
	Wild Turkey							x	
	Wildlife - Avian							x	
	Wildlife - Unknown					x		x	