Fecal Coliform Total Maximum Daily Load Anserson Run, West Virginia

Established by the U.S. Environmental Protection Agency Region III

Developed in cooperation with the West Virginia Division of Environmental Protection

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Executive Summary: Fecal Coliform TMDL for Anderson Run, West Virginia

The Clean Water Act at Section 303(d) and its implementing regulations at 40CFR Part 130 require the states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not or not expected to meet designated uses under technology-based controls or waterbodies that are considered threatened. TheTMDLs documented in this report were developed by Tetra Tech, Inc under close oversight from EPA. The funding for this study was provided through EPA contract # 68-C3-0303, work assignment #4-116.

Anderson Run has been placed on the State of West Virginia's Section 303(d) list of waters for fecal coliform bacteria problems. Anderson Run is a tributary of the South Branch Potomac River and lies in the Potomac Headwaters in Hardy County, West Virginia. A Total Maximum Daily Load (TMDL) analysis was developed for fecal coliform bacteria for 4.94 miles of Anderson Run.

The U.S. EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system (US EPA, 1996) and the Nonpoint Source Model (NPSM) were used to predict the significance of fecal coliform bacteria sources and fecal coliform bacteria levels in the Anderson Run watershed. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies. The NPSM simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of pollutants through stream reaches. To obtain a spatial variation of the concentrations of fecal coliform bacteria along Anderson Run and its tributaries, the watershed was divided into 6 sub-watersheds. This allowed analysts to address the relative contribution of sources within each sub-watershed to different segments of the river. Both point and nonpoint sources were represented in the model. Although no point source dischargers are located in the watershed, septic system discharges for the watershed were included in the model as point sources. The three major nonpoint source categories that were addressed in this study were: forest land, agricultural land, and urban areas.

Output from the NPSM indicated a number of violations of West Virginia's water quallity standard of 200 cfu/100 ml geometric mean in the lower portion of the watershed for the existing conditions using a representative time period (October 1990 through September 1991). After applying the load allocations, the NPSM indicated that all 6 sub-watersheds did not exceed the fecal coliform bacteria standard of 200 cfu/100 ml geometric mean. The relative contribution of wildlife and septic systems did not appear in the model to be as significant of a source of fecal coliform during the critical condition of high flow in the watershed. The model analysis shows that water quality standards will be achieved if Best Management Practices (BMPs) are implemented in the agricultural areas to reduce fecal coliform bacteria runoff by 41.5%. The nonpoint source load allocation, shown in the table reduces the instream concentrations of fecal coliform bacteria sufficiently for the representative year so that no violations of the water quality standard occurs.

Fecal Coliform Bacteria Nonpoint Source Allocation for Anderson Run Watershed

Land Use	Loading for Existing Run	Load for Allocation Run	Percent Reduction
Agricultural and Pasture	1.0758×10^{15} cfu	6.2974×10^{14} cfu	41.5%
Urban	2.1030×10^{11} cfu	2.1030×10^{11} cfu	0.0%
Forest	1.6715×10^{13} cfu	1.6715×10^{13} cfu	0.0%

A long-term study recommendation of sampling for fecal coliform, fecal streptococci, and enterococci bacteria at demonstration sites both with and without BMPs or before and after BMPs has been implemented.

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ACKNOWLEDGMENTS

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1.0 INTRODUCTION

1.1 Background

Levels of fecal coliform bacteria can become elevated in waterbodies as a result of both point and nonpoint sources of pollution. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water-quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA 1991b).

Anderson Run is a tributary of the South Branch Potomac River. The Anderson Run watershed lies in the Potomac Headwaters in Hardy County, West Virginia (Figure 1.1). The land area of the watershed is approximately 26,000 acres. Runoff from the Anderson Run watershed flows into the South Branch and then by way of the Potomac River to the Chesapeake Bay. The primary industry in the watershed is agriculture with poultry and beef cattle leading the gross revenues. Most of the poultry produced in the watershed and adjacent areas is processed in Moorefield, West Virginia, which is located about 3 miles upstream of the confluence of Anderson Run and South Branch. The primary land uses in the watershed are forest, agricultural land, and small areas of urban development.

1.2 Purpose of the Study

The objective of this study was to identify the background information and framework needed for developing a TMDL for Anderson Run. The West Virginia Division of Environmental Protection (WVDEP) has identified the Anderson Run as being impacted by fecal coliform bacteria for a length of 4.94 miles, as reported in the 1996 303(d) list of water quality limited waters (West Virginia, 1996). Anderson Run is ranked number 20 on the list and carries an agency code of PSB-18. The determination for impairment and inclusion on the West Virginia 303(d) list was based on a water quality survey performed by the U.S. Geological Survey (USGS) in 1994-95 in which samples were collected at a monthly frequency at a station on Anderson Run at Old Fields. The results of this sampling indicated that this monitoring station had significant fecal coliform levels: more than 73% of the samples at the station had fecal coliform concentrations above 200 cfu/100 mL. According to the USGS (Mathes 1996), cattle were observed in Anderson Run less than 100 ft upstream from the monitoring station during the collection of several of the samples. Based on these data and the state's water quality standard for fecal coliform bacteria, Anderson Run was placed on the 1996 303(d) list. The West Virginia state standard specifies that the maximum allowable level of fecal coliform for primary contact recreation shall not exceed 200 cfu/100 mL as a monthly geometric mean (based on not less than 5 samples per month. The fecal coliform content also shall not exceed 400 cfu/100 mL in more than 10 percent of all samples taken during any one month (PVSCD, 1995). The data collected during the 1994-1995 USGS study do not allow a direct comparison to the state standard of 200 cfu/100 mL as a monthly geometric mean because there is an insufficient quantity of samples. However, when fewer than five samples are collected per month, the applicable standard becomes 400 cfu/100 mL.

1.3 Selection of a TMDL Endpoint

One of the major components of a TMDL is the establishment of instream numeric endpoints that are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints therefore represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. The endpoints allow for a comparison between predicted instream conditions and conditions that are expected to restore beneficial uses; the endpoints are usually based on either the narrative or numeric criteria available in state water quality standards. For the Anderson Run TMDL, the applicable endpoints and associated target values can be determined directly from the West Virginia standard for waters designated as primary contact recreation. That is, the allocation of loads will be distributed such that the fecal coliform levels in Anderson Run will not exceed 200 cfu/100 mL as a monthly geometric mean. The fecal coliform content also shall not exceed 400 cfu/100 mL in more than 10 percent of all samples taken during any one month (PVSCD 1995).

1.4 Phased TMDL Approach

Under a phased TMDL approach, load allocations are calculated with margins of safety to meet water quality standards because of uncertainty in the available data or due to lack of certain key information. This study is the first part of a phased TMDL for the Anderson Run watershed. The allocations derived herein are based on estimates which use available data and information, however, monitoring for additional new data is required to ensure that any implemented nonpoint source controls are achieving their expected load reductions. The TMDL analysis in this study is based on the 1990-91 hydrologic year but also uses fecal coliform bacteria monitoring data from the 1994-97 period for "calibrating" the nonpoint source runoff model. It is important to understand that any BMPs implemented since 1991 are not explicitly accounted for in the model since their impact on loading rates is not known due to lack of "before and after" monitoring. Since the model does not reflect certain BMPs which may be reducing nonpoint source loads, the overall load allocation reductions computed in this analysis may be overestimated and can be considered as part of the margin of safety for this phased TMDL.

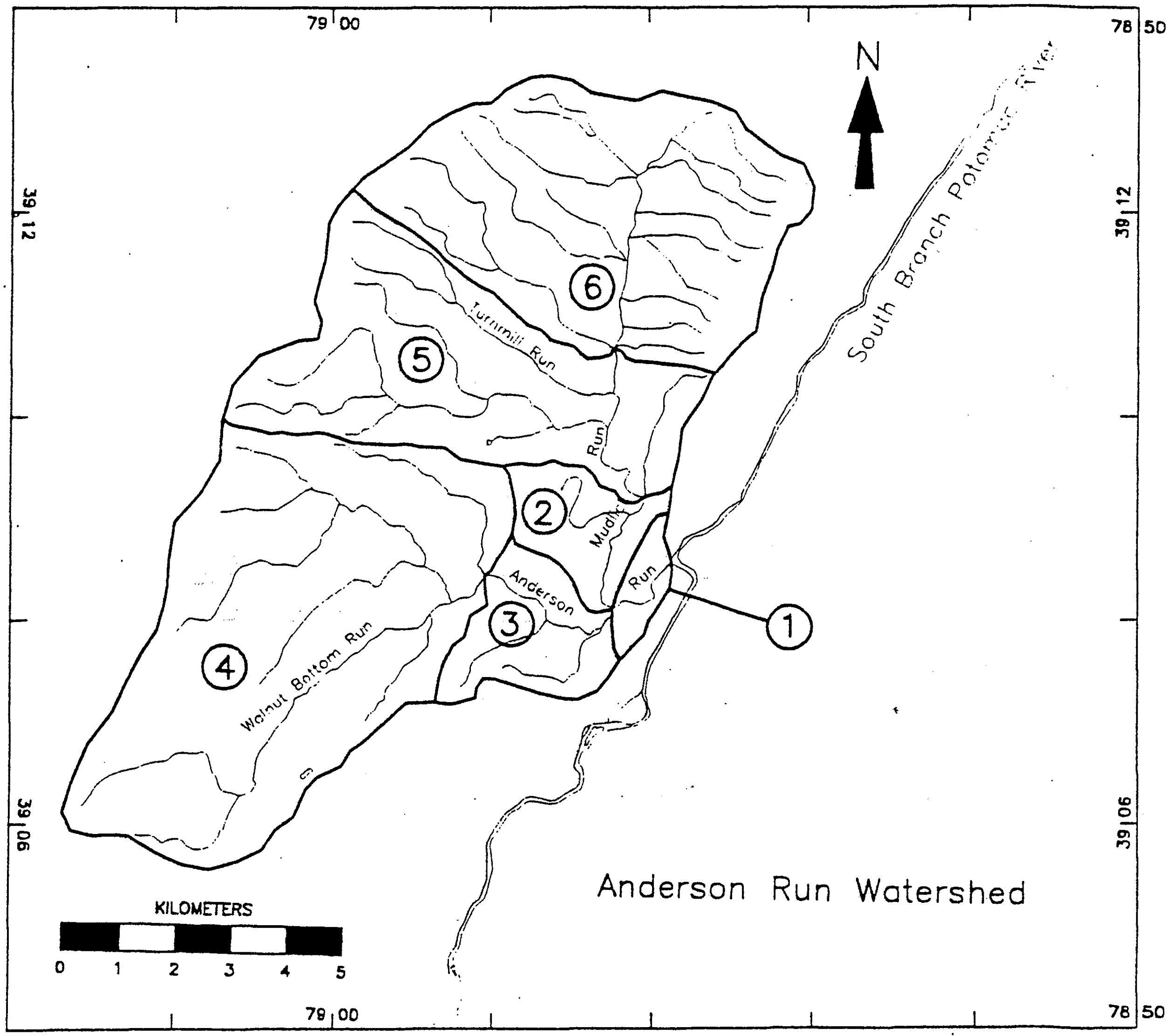

Figure 1.1 Study area: Anderson Run watershed, West Virginia.

2.0 SOURCE ASSESSMENT

This section presents an overview of the instream water quality monitoring data available for Anderson Run and then discusses the type, magnitude, and location of potential point and nonpoint sources of fecal coliform loading. In general, potential sources of fecal coliform bacteria are numerous, and often occur in combination. Potential point sources include poorly treated municipal sewages, urban storm water runoff, sanitary sewer overflows, combined sewer overflows (CSOs), and untreated domestic sewage. Potential nonpoint sources include poor management and handling of animal waste from feedlots, poor management and handling of poultry litter, failing or ill-sited septic systems, poor management of pasture lands, excess application of manure or municipal sludge in cropland and other agricultural areas, and natural background loadings from wildlife.

2.1 Instream Water Quality Monitoring Data

Periodic monitoring for fecal coliform bacteria at a number of locations in the Anderson Run watershed has been conducted over the years. Locations of the historic monitoring sites found in STORET containing at least one fecal coliform bacteria data value are shown in Figure 2.1. The site labeled USGS#13 was part of a special study conducted by the U.S. Geological Survey from March 1994 to August 1995 for the Potomac Headwaters study (PHIWQO 1996). This USGS station was sampled approximately once per month throughout the study period. Time-series plots of the fecal coliform data for station USGS#13 is shown in Figure 2.2. From this figure it is apparent that individual sample points are occasionally higher than the state water quality standards of 200 and 400 cfu/100 mL. However, because only one data value was collected per month, it was not possible to make a direct comparison to the 200 cfu/100 mL state standard (which requires a geometric mean of at least 5 samples per month). When fewer than 5 samples are collected per month, the applicable standard becomes 400 cfu/100 mL.

In support of this fecal coliform bacteria TMDL development, the West Virginia Division of Environmental Protection (DEP) has begun a monitoring program in the Anderson Run watershed in which 4 sites are sampled during a single field excursion. As of the date of this report, three intensive sampling runs have been completed on the Anderson Run: August 26-28, 1996, June 3, 1997, and August 25, 1997. The locations of the monitoring stations are shown in Figure 2.1 and the fecal coliform sampling results for these three monitoring events are given in Table 2.1. The June 3, 1997 sampling date coincided with a high runoff event whereas the August 26-28, 1996 and August 25, 1997 sampling dates occurred during low-flow periods.

Table 2.1 Recent Bacteria Sampling in Anderson Run.

STORET Station Name	Alternative Station Names	Sample Date	Fecal Coliform (cfu/100 mL)	Flow (cfs)
PSB-18-{02.0}	AR03	08/13/96	5800	NA
PSB-18-A-{6.7}		08/26/96	623	NA
PSB-18-A-1		08/26/96	630	NA
PSB-18-A-0.5		08/26/96	32	NA
PSB-18		08/26/96	318	NA
PSB-18-A-{1.0}	AR05	08/26/96	253	NA
PSB-18-B	AR04	08/28/96	8	NA
PSB-18-{00.9}	AR01; USGS#13	06/03/97	2300	31.4
PSB-18-{02.0}	AR03	06/03/97	>6000	19.7
PSB-18-B-{02.2}	AR04	06/03/97	2800	9.4
PSB-18-A-{00.4}	AR05	06/03/97	>6000	11.7
PSB-18-{00.9}	AR01; USGS#13	08/25/97	1800	NA
PSB-18-{02.0}	AR03	08/25/97	20	2.0
PSB-18-B-{02.2}	AR04	08/25/97	270	0.5
PSB-18-A-{00.4}	AR05	08/25/97	>6000	1.3

The 1994-95 USGS reconnaissance survey provided the best long-term multi-year data set of fecal coliform bacteria for Anderson Run. West Virginia DEP used the results of the USGS survey to determine whether a stream segment should be added to the 303(d) list of water quality limited streams. Since the sample frequency was less than 5 per month, it was not possible to determine whether a stream segment was in compliance with the 200 cfu/100 mL State standard for fecal coliform bacteria. Instead, if more than 25% of the samples were greater than 200 cfu/100 mL, the stream segment was considered threatened and placed on the 303(d) list as needing a TMDL for fecal coliform bacteria. A summary of the USGS bacteria data for the monitoring station on Anderson Run is given in Table 2.2. Station USGS#13 indicates 14 of 19 samples (73.7%) are above the 200 cfu/100 mL level which is the reason Anderson Run was placed on the 303(d) list.

Table 2.2 Summary of Fecal Indicator Bacteria from 1994-95 USGS Study.

		Fecal Coliform Bacteria (cfu/100 mL)					Fecal Streptococci	
Station	n	Min	Median	Max	percent greater than 200	percent greater than 400	Median (cfu/100 mL)	FC/FS median ratio
USGS#13	19	18	570	220,000	73.7	18.8	940	0.9

Both fecal coliform (FC) and fecal streptococci (FS) were measured during the 1994-95 USGS survey. The ratio of fecal coliform to fecal streptococci can indicate possible sources of bacterial contamination. Each warm-blooded species has a unique bacteria ratio of fecal coliform to fecal streptococci in the intestinal tract. In humans, this ratio is generally greater than 4.0 whereas in animals the ratio is usually less than 0.7. Therefore, ratios greater than 4.0 in stream-water samples indicate that the source of bacterial contamination is likely human waste. Conversely, ratios of less than 0.7 indicate a bacterial source which is non-human. Intermediate ratios indicate mixed or undetermined sources of bacterial contamination (PHIWQO 1996). The USGS station on Anderson Run had an FC/FS ratio of 0.9 (see Table 2.2) indicating the likely source of bacterial contamination is from animal waste (APHA, 1985).

2.2 Assessment of Point Sources

The greatest potential source of human fecal coliform from point sources is raw sewage. Raw sewage typically has a total coliform count of 10^7 to 10^9 mpn[1]/100 mL (Novotny and Olem, 1994), along with significant concentrations of fecal coliform bacteria, viruses, protozoans, and other parasites. Typical treatment in a municipal plant reduces the total coliform count in effluent by about 3 orders of magnitude, to the range of 10^4 to 10^6 mpn/100 mL. Raw sewage, while usually not discharged intentionally, may reach waterbodies through leaks in sanitary sewer systems, overflows from surcharged sanitary sewers (non-combined sewers), illicit connections of sanitary sewers to storm sewer collection systems, or unidentified broken sanitary sewer lines.

There are no point sources permitted for fecal coliform bacteria in the Anderson Run watershed.

2.3 Assessment of Nonpoint Sources

Nonpoint sources of fecal coliform bacteria are typically separated into urban and rural components. In urban or suburban settings with high amounts of paved impervious area, important sources of loading are surface storm flow, failing septic tanks, and leakage of sanitary sewer systems. In rural settings, the amount of impervious area is usually much lower, and sources of fecal coliform may include runoff of animal wastes associated with the erosion of sediments, runoff from concentrated animal operations, contributions from wildlife, and failing septic tanks.

The primary tributaries in Anderson Run watershed are Walnut Bottom Run, Mudlick Run, and Turnmill Run. However, inadequate long-term monitoring data were available to characterize the flow and bacterial loading from each of these peripheral tributaries. Instead, the watershed was divided into 6 sub-

1. MPN stands for Most Probable Number (of colony forming units).

watersheds based on tributary location, land use, poultry house and feedlot density, and location of water quality and flow monitoring stations.

The U.S. GeoData 1:250,000 scale land use and land cover data (U.S. GeoData 1986) were used to determine land uses in the Anderson Run. The land uses in the Anderson Run watershed consist primarily of forested, agricultural, and urban areas. The various land uses for each of the 6 sub-watersheds are listed in Table 2.3. The West Virginia Soil Conservation Agency (WVSCA) maintains a geographic information system (GIS) with the locations of poultry houses, feedlots, and other agricultural-related information. The delineations of the 6 sub-watersheds for Anderson Run were provided to WVSCA and they in turn estimated the number of poultry houses and animal feedlots within each of the sub-watersheds. Estimates of total head of cattle in each sub-watershed were also provided by WVSCA (see Table 2.4).

The West Virginia Division of Natural Resources (DNR) provided estimates of the numbers of geese and ducks within the South Branch region for July 1. The numbers of birds may vary with season because of migratory patterns as well as birds moving in and out of the watershed. The DNR estimated an upper bound of 40 for the migratory goose population and 20 for the migratory duck population in the Anderson Run watershed. In addition, deer population was estimated from the Big Game Bulletin (DNR 1996). The total deer population can be estimated as about 10 times the number of buck killed during hunting season. Animal population estimates for the Anderson Run watershed are given in Table 2.5.

Table 2.3 Land Use Distributions in Each of the 6 Anderson Run Sub-watersheds

Subbasin Number	Stream Name	Total Area (acres)	Urban (acres)	Agricultural (acres)	Forest (acres)	Septic Population
1	Lower Anderson Run	357	0	272	75	10
2	Lower Mudlick Run	1,201	3	433	669	96
3	Anderson Run	1,538	7	1,117	370	44
4	Walnut Bottom Run	9,515	0	2,719	6,706	90
5	Turnmill Run	5,840	0	2,538	3,108	194
6	Mudlick Run	7,457	0	3,055	4,013	389
	Totals	25,908	10	10,134	14,941	823

Table 2.4 Inventory of Poultry Houses and Cattle Feedlots in Anderson Run Watershed.

Subbasin	Stream Name	Poultry Houses Broiler	Poultry Houses Breeder	Poultry Houses Turkey	Cattle Feedlots	Head Cattle	Poultry Litter Storage
1	Lower Anderson Run	1	0	0	2	50	0
2	Lower Mudlick Run	2	0	0	3	50	1
3	Anderson Run	2	0	0	3	50	0
4	Walnut Bottom Run	0	1	0	0	100	0
5	Turnmill Run	8	3	0	1	200	1
6	Mudlick Run	8	18	0	3	200	2
	Totals	21	22	0	12	650	4

Table 2.5 Population Estimates of Farm and Wild Animals in Anderson Run Watershed.

Subbasin Number	Stream Name	Number Chickens Broilers	Number Chickens Breeders	Number Turkeys	Head Cattle	Number Migratory Ducks	Number Migratory Geese	Number Deer
1	Lower Anderson Run	28,000	0	0	50	0	0	6
2	Lower Mudlick Run	56,000	0	0	50	1	2	54
3	Anderson Run	56,000	0	0	50	1	2	30
4	Walnut Bottom Run	0	9,000	0	100	8	15	546
5	Turnmill Run	224,000	27,000	0	200	5	9	253
6	Mudlick Run	224,000	162,000	0	200	6	11	327
	Totals	588,000	198,000	0	650	20	40	1,216

Onsite septic systems are the predominant form of waste water treatment in the Anderson Run watershed. No information was readily available on the specific locations of septic systems, septic tank densities, or failure rates. However, DEP provided estimates of the percent of the population for each county which used septic systems. For Hardy County, it was estimated that 80% of the population of 11,000 residents used septic systems. In Pendleton County, about 90% of the 8,000 residents are on septic systems. In addition, a septic system failure rate of about 2.5% was estimated for Hardy County (NSFC 1993) and it was assumed this rate was also applicable to the Anderson Run watershed. It was further assumed that 100% of the fecal coliform load from the failed systems reached the receiving waters at a concentration of 1×10^4 cfu/100 mL for raw sewage (Metcalf & Eddy 1991). The assumed septic system waste flow rate was computed based on a typical value of 70 gallons per capita per day.

As previously mentioned in section 2.1, the USGS 1994-95 monitoring data suggest that the source of bacterial contamination in Anderson Run is from animal sources based on the fecal coliform to fecal streptococci ratio of 0.9. For this study, it was assumed that manure from poultry operations was applied to agricultural land within the sub-watershed in which the poultry house was situated. In practice, poultry manure may be transported to or imported from other sub-watersheds; or it may be moved completely out of the Anderson Run watershed. No information was available as to the specific manure management practices. A list of sites for the land application of municipal and industrial sludge in the Anderson Run watershed was provided by WVDEP (Aug 5, 1997) and is given in Table 2.6. Since the amount of sludge applied to the land areas is not known at this time, no attempt was made to incorporate these sites as a possible source of fecal coliform bacteria into this phase of the TMDL analysis.

Table 2.6 Land Application Sites in Anderson Run Watershed

Generator	Type	Farm	Acres	Drainage Area/Location
Helman Septic	Septage	Gerald Helman	12	Mudlick Run west of Rt. 220 at Hampshire Co. line
Wampler-Longacre	Ind.	Renick Williams	105	Walnut Bottom Run
Wampler-Longacre	Ind.	R. Williams	170	Walnut Bottom Run
Wampler-Longacre	Ind.	R. Williams	145	Walnut Bottom Run
Wampler-Longacre	Ind.	R. Williams	385	Walnut Bottom Run/South Br.
Moorefield	Sludge	R. Williams	385	Walnut Bottom Run/South Br.

Ind. = sludge from industrial facility (chicken processing)

Using the available information for poultry houses, head of cattle, and wildlife estimates, the daily fecal coliform loads were computed for each sub-watershed. The average fecal coliform loading rates for the various animal species used for the total potential load calculation are given in Table 2.7.

Table 2.7 Estimated Fecal Coliform Production Rates.

Animal	Fecal Coliform Production Rate	Reference
beef cow	5.40×10^9 cfu/day	Metcalf & Eddy, 1991
chicken	0.24×10^9 cfu/day	Metcalf & Eddy, 1991
turkey	0.13×10^9 cfu/day	Metcalf & Eddy, 1991
duck	11.0×10^9 cfu/day	Metcalf & Eddy, 1991
goose	49.0×10^9 cfu/day	LIRPB, 1982
deer	0.50×10^9 cfu/day	BPJ estimate

The average number of birds for each type of poultry house was based on information obtained from WVDEP (1997) as follows: 15,000 Turkeys; 9,000 Breeders; and 28,000 Broilers. The total potential fecal coliform production per subwatershed for each of the animal categories is given in Table 2.8. Poultry makes up 97% of the potential nonpoint source fecal coliform load in the watershed. It is important to understand that the values in Table 2.8 are the "potential" fecal coliform loads from various nonpoint sources and not necessarily the loads which reach the receiving waters in the watershed (with the exception of the septic load which is the estimated load reaching the stream). Various attenuation processes and agricultural management practices will reduce these loads before they reach the stream.

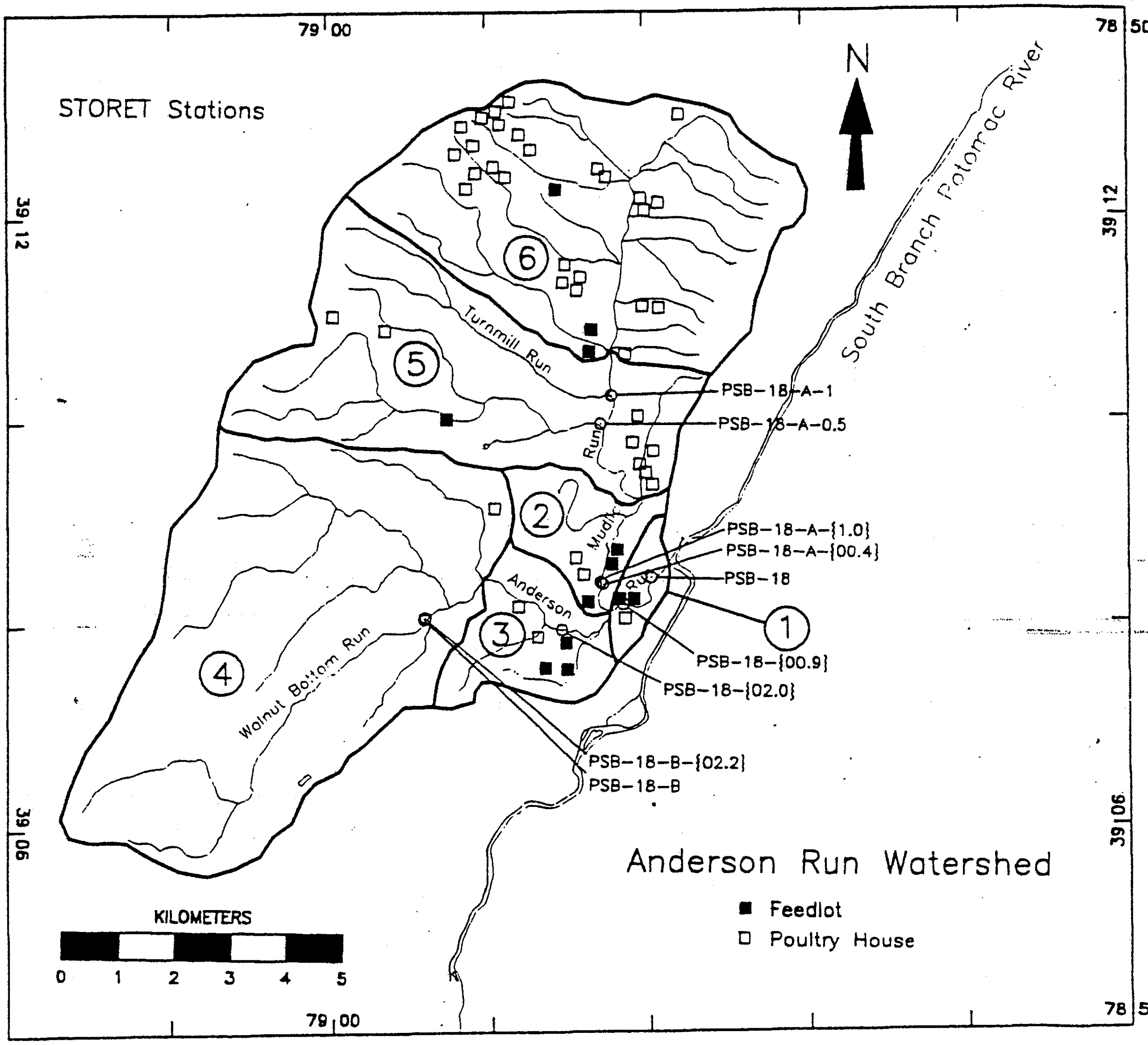

Figure 2.1 STORET bacteria monitoring stations.

Table 2.8 Potential Nonpoint Source Fecal Coliform Production in Anderson Run.

Subbasin Number	Stream Name Location	Total Load (cfu/day)	Poultry (cfu/day)	Cattle (cfu/day)	Ducks (cfu/day)	Geese (cfu/day)	Deer (cfu/day)	Septic (cfu/day)
1	Lower Anderson Run	7.011E+12	6.720E+12	2.700E+11	1.780E+09	1.586E+10	3.053E+09	6.624E+06
2	Lower Mudlick Run	1.383E+13	1.344E+13	2.700E+11	9.767E+09	8.701E+10	2.723E+10	6.359E+07
3	Anderson Run	1.385E+13	1.344E+13	2.700E+11	1.289E+10	1.148E+11	1.506E+10	2.914E+07
4	Walnut Bottom Run	3.810E+12	2.160E+12	5.400E+11	8.449E+10	7.527E+11	2.730E+11	5.961E+07
5	Turnmill Run	6.194E+13	6.024E+13	1.080E+12	4.971E+10	4.428E+11	1.265E+11	1.285E+08
6	Mudlick Run	9.449E+13	9.264E+13	1.080E+12	6.137E+10	5.468E+11	1.633E+11	2.577E+08
	Totals	1.949E+14	1.886E+14	3.510E+12	2.200E+11	1.960E+12	6.081E+11	5.451E+08
	Percent	100%	96.77%	1.80%	0.11%	1.01%	0.31%	0.00%

2.4 Critical Conditions

Based on the available data described in section 2.1, it was apparent that the highest concentrations of fecal coliform bacteria measured in the stream occurred during high-flow periods. Sampling in other nearby watersheds also indicated higher fecal coliform bacteria levels during high-flow, storm event conditions. Thus, it is the high-flow, storm event conditions which are most likely to induce violations of the State water quality standards for fecal coliform bacteria due to nonpoint source runoff. However, free-roaming cattle are also a likely to cause violations which can occur during low-flow periods as well. The USGS study (PHIWQO 1996) also noted that cows were in Anderson Run approximately 100 feet upstream of the USGS#13 monitoring station on several occasions when samples were being collected.

To develop a TMDL, it is necessary to consider a range of flow conditions to represent the bacterial loading phenomenon occurring within the watershed. During storm events, runoff from urban and agricultural land uses will cause large concentrations of fecal coliform bacteria to occur in the receiving waters. During dry periods, little or no land-based runoff will occur, and elevated bacteria levels in the stream may be due to point sources. A continuous simulation model is necessary to capture the buildup and washoff of pollutants due to nonpoint sources. For this study, an average hydrologic year was selected for the continuous simulation period. The period 1984 to 1992 was used as the initial screening period. The 1991 water year, from October 1990 through September 1991 was selected as the most representative of an average meteorologic year for the Anderson Run watershed from within the screening period. There were no long-term flow gaging stations in the watershed which could be used to calibrate the hydrologic flows computed by the nonpoint source runoff model. The time-series of computed flows at the downstream-most reach of the model is shown in Figure 2.3.

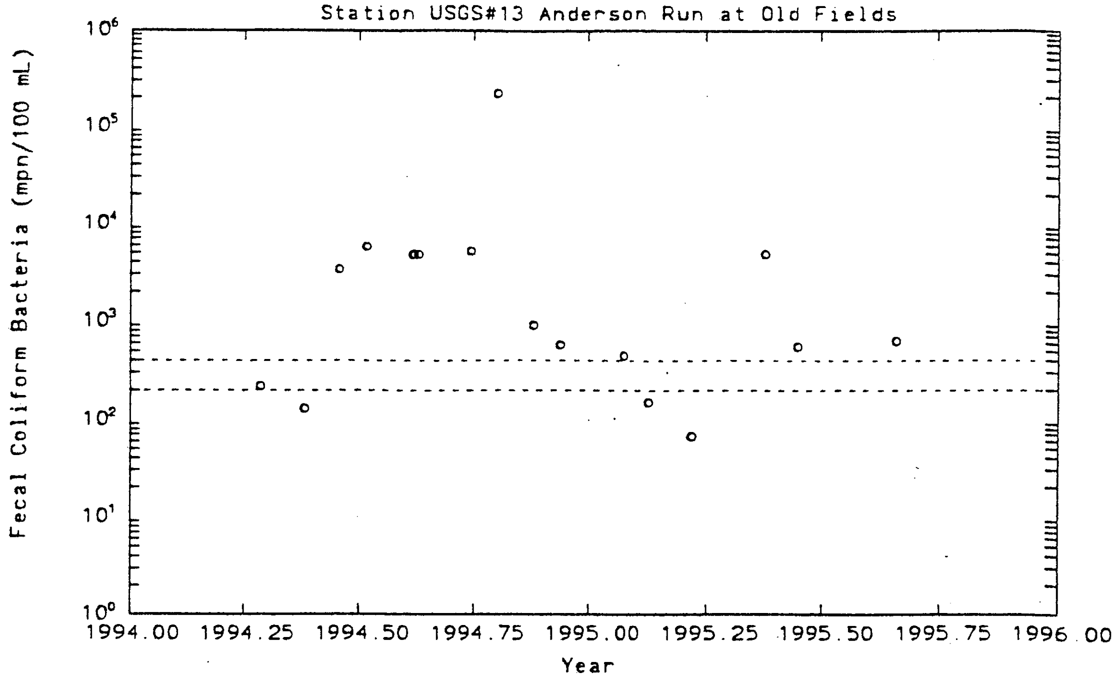

Figure 2.2 Time-series fecal coliform bacteria data for USGS Station #13.

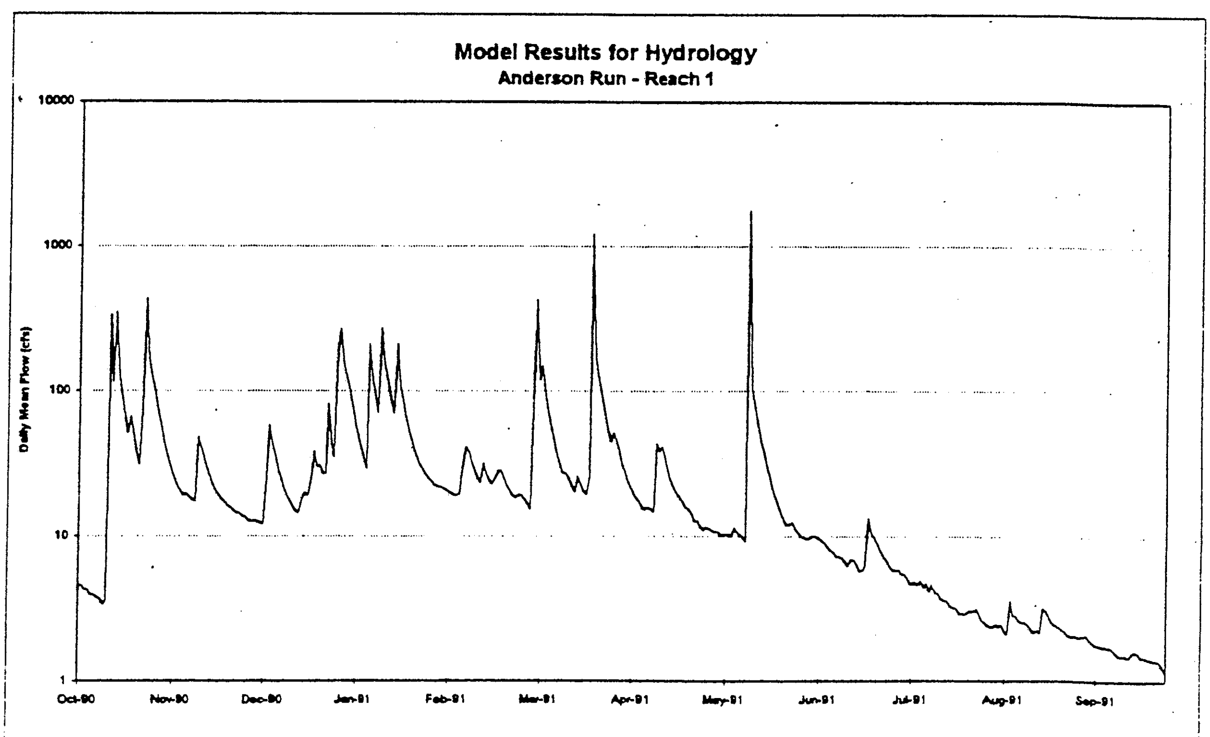

Figure 2.3 Model flow time series for 1990-1991 representative hydrologic year.

3.0 MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the instream water quality target and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions.

3.1 Modeling Framework Selection

The U.S. EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system (USEPA 1996) and the Nonpoint Source Model (NPSM) were used to predict the significance of fecal coliform sources and fecal coliform levels in the South Fork watershed. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies. A geographic information system (GIS) provides the integrating framework for BASINS and allows for the display and analysis of a wide variety of landscape information (e.g., land uses, monitoring stations, point source dischargers). The NPSM simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of the pollutants through stream reaches. A key criteria for using BASINS as the modeling framework is its ability to integrate both point and nonpoint source simulation, as well as its ability to assess instream water quality response.

3.2 Model Set-Up

To obtain a spatial variation of the concentration of bacteria along the Anderson Run and its major tributaries, the watershed was subdivided into 6 sub-watersheds. This allowed analysts to address the relative contribution of sources within each sub-watershed to the different segments of the river. The watershed subdivision was based on a number of factors, including the locations of flow monitoring stations, the locations of stream sampling stations, the locations of feedlots and poultry houses, and the land use coverage.

3.3 Source Representation

Both point and nonpoint sources were represented in the model. Although no point source dischargers are located within the watershed, septic system discharges for the watershed were included as point sources in the model. The three major nonpoint source categories that were addressed in this study were: forest land, agricultural land, and urban areas. To better represent these three categories, they were further divided into more refined land use types. This breakdown was based on additional information regarding the distribution of feedlots, poultry houses, and wildlife. A variety of parameters needed for predicting runoff and fecal coliform loadings were then estimated for each of the land uses within these 6 sub-watersheds.

Septic system discharges were quantified based on the following information: the population distribution within each of the 6 sub-watersheds based on 1990 Census Data (WVDEP 1996), an assumed average daily discharge of 70 gallons per person per day (Horsley & Whitten 1996), an assumed septic effluent concentration of 10^4 cfu/100 mL of effluent (Horsley & Whitten 1996; Metcalf and Eddy 1991), and a 2.5% failure rate (NSFC 1993). The septic system contribution in the model inherently contains a margin of safety, based on the assumption that all of the fecal coliform bacteria discharged from the septic system reaches the stream. In reality, it is likely that only a small portion of the bacteria will reach the stream after being filtered through the soil. Additionally, these septic system discharges are assumed to be constant throughout the year, while in reality septic system failures are likely to occur less frequently.

The initial default values for the fecal coliform loading parameters needed for each land use were based on either general literature values or a variety of available site-specific information. Loading parameters for urban land uses were based on literature values (USEPA 1988).

Fecal coliform loading parameters for forest land uses were based on the wildlife population within the study area. As described in earlier sections, duck and geese populations for the watershed were readily available as were deer population densities (in Hardy County). Separate loading rates were calculated for each of the 6 subwatersheds. These rates were based on those described earlier for various animal species (Metcalf and Eddy 1991).

A similar analysis was performed to estimate fecal coliform loading rates for agriculture landuses in each of the 6 subwatersheds. Information was available on the number and type of poultry houses and cattle in each subwatershed (WVSCA 1997 and PHIWQO 1986). Cattle densities and poultry densities (based on the type of poultry house) were determined for each subwatershed. Each agricultural land use in the 6 subwatersheds was assigned a different fecal coliform loading rate based on these densities and typical fecal coliform loading rates for the cattle and poultry species (Metcalf and Eddy 1991).

BMPs were not represented explicitly in the model. However, BMPs already in place during the representative period 10/1/1990 - 9/30/1991 are implicitly represented in the model. That is, calibration of the model for the representative period inherently requires consideration of everything present in the watershed (BMPs included).

3.4 Stream Characteristics

The channel geometries for Anderson Run were determined from cross-section surveys performed by WVDEP during stream flow monitoring activities in June 1997 at several sampling locations.

3.5 Selection of Representative Modeling Period

The hydrologic conditions in the Anderson Run watershed consist of relatively random successions of dry, average, and wet rainfall years. Since it was determined that bacteria contamination in Anderson Run is critical during high flow conditions, the selection of a hydrologically representative time period was necessary. In addition, the amount of bacteria loading is most likely to increase in response to both the magnitude and intensity of storm events, which can occur in both dry and wet years. It should also be noted that frequent small storms or individual large storms can lead to excessive fecal coliform loading. To represent the hydrological regime, an average rainfall year was selected based on a review of annual rainfall. The period 1984 to 1992 was used as the initial screening period and the 1991 water year (October 1990 through September 1991) was selected as the most representative meteorologic year.

3.6 Model Calibration Process

To develop a representative linkage between the sources and the instream water quality response in the 6 reaches of Anderson Run, model parameters were adjusted to the extent possible for both hydrology and fecal coliform bacteria loading. Hydrologic parameters used in calibration, validation, and verification of NPSM for the nearby South Fork watershed were applied to the Anderson Run watershed, due to its proximity and hydrologic similarities. Observed daily mean flow values in Anderson Run were not available for the period 10/1/1990 - 9/30/1991. Hydrologic parameters which were set for the model relate to surface water runoff, water balance, and groundwater flows. Some of these parameters represent groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow inflow, and length of assumed overland flow.

Parameters related to fecal coliform surface loading as well as background concentrations in the reaches were adjusted by comparing the modeled in-stream concentrations to available observed data. This process was limited by the absence of data for high flow and storm flow conditions. The loading rate and background concentration parameters for the forested land were set to values similar to those in the nearby South Fork watershed. For the South Fork watershed study, these values were adjusted based on data for the Hawes Run drainage area (which consists of primarily undisturbed forest land). The loading parameters for urban runoff were primarily based on literature values, however, the background concentration values were adjusted to match the available background (i.e., low flow) data from the 1994-95 USGS data and the recent 1996-97 WVDEP monitoring data. Background concentration parameters for the six different agricultural landuses were also adjusted to match available low flow data. Loading parameters for the agricultural land uses were adjusted until modeled water quality most closely matched the observed data. Parameter values were varied within a range of acceptable values, in a manner which retained consistency between relative contributions from the six different agricultural landuse categories.

3.7 Existing Loadings

The model was run for the hydrologically representative period (October 1990 through September 1991). The modeling run represents the existing condition of bacteria concentrations and loadings at various reaches of Anderson Run. For the existing conditions, the fecal coliform bacteria loading from the septic systems was 1.990×10^{11} cfu. The overall fecal coliform bacteria loadings by land-use category for Anderson Run watershed are given in Table 3.1.

Table 3.1 Annual Nonpoint Source Fecal Coliform Bacteria Loading Factors.

Land Use Category	Annual Fecal Coliform Loading
Agriculture and Pasture	1.0758×10^{15} cfu
Forest Land	1.6715×10^{13} cfu
Urban	2.1030×10^{11} cfu

A summary of West Virginia water quality standard violations for the selected hydrologically representative period is given in Table 3.2. All 6 reaches (consisting of the same numerical representation as the subwatersheds) and information relating to violation of the 200 cfu/100 mL geometric mean standard are presented. It is apparent from Table 3.2 that reaches in subwatersheds 1 and 4 are in violation of the 200 cfu/100 mL standard.

Table 3.2 Existing Conditions - Summary of Violations of 200 cfu/100 mL Standard.

Reach No. (Subwatershed)	No. of Exceedances	Max No. of Days in an Exceedance	Min No. of Days in an Exceedance	Total No. of Exceedance Days	Exceedance Percentage
1	2	11	5	16	4.38%
2	2	3	1	4	1.10%
3	0	0	0	0	0.00%
4	0	0	0	0	0.00%
5	0	0	0	0	0.00%
6	0	0	0	0	0.00%

4.0 ALLOCATION

Total maximum daily loads (TMDLs) are comprised of the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards.

For some pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For bacteria, however, TMDLs can be expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR 130.2(I).

4.1 Incorporating a Margin of Safety

The margin of safety (MOS) is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA 1991b):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations, or
- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The MOS is incorporated implicitly into the modeling process by running a dynamic simulation to calculate the daily instream fecal coliform values. Other margins of safety for this TMDL analysis include the following:

- The 1993 Summary of Onsite Systems in the United States report (NSFC 1993) indicates 60 failures for 3000 septic systems in Hardy County, or a 2.0% failure rate. For this study a 2.5% failure rate was assumed which corresponds to a 25% margin of safety.

- The baseline year for calibrating the NPSM model for this TMDL analysis was 1990-91. Any BMPs which have been implemented in the watershed since 1991 are not explicitly included in the model and the resulting allocation reductions should be adjusted in the next phase of this TMDL to reflect the effectiveness of these BMPs.

4.2 Assessing Alternatives

For the allocation runs, the model was run for the same hydrologically representative period (October 1990 through September 1991) as used for the existing conditions calibration run. The overall nonpoint source fecal coliform bacteria loadings by landuse category for the Anderson Run watershed are given in Table 4.1. These nonpoint source load allocations reduce the instream concentrations of fecal coliform bacteria sufficiently for the representative year so that no violations of the 200 cfu/100 mL state water quality standards occur.

Table 4.1 Fecal Coliform Bacteria Nonpoint Source Allocations for Anderson Run Watershed.

Land Use	Annual Loading for Existing Run	Annual Loading for Allocation Run	Percent Reduction
Agriculture and Pasture	1.0758×10^{15} cfu	6.2974×10^{14} cfu	41.5%
Urban	2.1030×10^{11} cfu	2.1030×10^{11} cfu	0.0%
Forest	1.6715×10^{13} cfu	1.6715×10^{13} cfu	0.0%

5.0 SUMMARY

Anderson Run has been placed on the State of West Virginia's 303(d) list of water quality impaired waterbodies for fecal coliform bacteria. A review of available monitoring data for the study area indicates that fecal coliform bacteria are occasionally elevated above the 200 cfu/100 mL and 400 cfu/100 mL levels. However, due to the small number of samples, a direct comparison with the 200 cfu/100 mL standard, which requires at least 5 samples in a 30-day period, cannot be made and, therefore, the elevated fecal coliform levels observed in the monitoring data may or may not indicate a water quality violation. The Anderson Run watershed was divided into 6 subwatersheds and the BASINS Nonpoint Source Model (NPSM) was selected as the modeling framework for performing the TMDL allocations.

For this TMDL analysis, load allocations are calculated with margins of safety to meet water quality standards because of uncertainty in the available data or due to lack of key information. The uncertainty in the data used for this study is discussed later in this section with recommendations for improving future TMDL analyses.

5.1 Findings

Output from NPSM indicated a number of violations of the 200 cfu/100 mL geometric mean standard in the lower portion of the watershed for the existing conditions using the representative time period (October 1990 through September 1991). After applying the load allocations, the NPSM model indicated that all 6 sub-watersheds were in compliance with the fecal coliform bacteria standard of 200 cfu/100 ml geometric mean. The nonpoint source allocations in this TMDL were allocated such that an overall 41.5% reduction in fecal coliform load in the Anderson Run watershed will result in compliance with the 200 cfu/100 mL standard (see the time-series graphs of model results for each of the 6 sub-watersheds in Appendix A).

5.2 Recommendations

This TMDL analysis was performed with very limited fecal coliform bacteria data for characterizing point and nonpoint sources as well as for characterizing instream water quality conditions. Because of the lack of high-frequency, long-term fecal coliform data sets, the water quality calibration of the NPSM watershed model should be considered to be a "qualitative" calibration only. As additional data become available, they can be incorporated into the model and/or used to determine whether implemented controls are having the intended effect on improving water quality. The remainder of this section is a discussion which includes the key areas of data uncertainty as well as recommendations for filling the data gaps for future TMDL analyses.

5.2.1 Hydrologic Flow Data

There were no long-term stream gages available in Anderson Run which contributes to uncertainty to flow estimates for this watershed. The implementation of a long-term (i.e., multi-season) gaging station in Anderson Run will improve the certainty of the model results. Once data are obtained from the new gaging station, a correlation factor can be established with other nearby long-term gages to assist with flow estimates for future TMDL analyses.

5.2.2 Fecal Coliform Monitoring

In general, fecal coliform data in the receiving waters in the Anderson Run are monitored infrequently. The only long-term monitoring study in the watershed was conducted by the USGS in 1994-95 which collected data once per month at one location over an 18-month period. Since fecal coliform problems in the study area tend to coincide with storm runoff events, sampling at intervals of less than once per day will almost certainly miss the highest concentrations since storms tend to be short-term events. The ideal fecal coliform data set would consist of weekly samples collected during dry-weather periods, and daily samples (or more frequent) during storm events. The cost of such an ambitious monitoring program may be prohibitive. In 1996, West Virginia DEP began a sampling program for fecal coliform bacteria in the Anderson Run watershed to support this TMDL development effort. It is recommended that sampling program be continued on at least a monthly basis during the spring-to-autumn seasons to develop a long-term data base which will be necessary to (1) provide additional data for future modeling efforts and (2) determine the "before-and-after" impacts of BMPs which are implemented in the study watershed.

5.2.3 Point Sources

Flow rates and fecal coliform bacteria concentrations from point source discharges in the study area are generally well-documented and reported in EPA's PCS data system or are on file at WVDEP offices. In the model application, it was assumed that point source effluent discharged at a constant flow rate throughout the year. In practice, some industrial flows may be highly variable or intermittent which could impact fecal coliform levels estimated by the model during low-flow periods.

5.2.4 Septic System Information

The assumed failure rate of 2.5% for septic systems as well as the assumption of a fecal coliform concentration of 10^4 cfu/100 mL in the septic overcharge used in this TMDL analysis is a source of some uncertainty. A septic survey should be conducted in the study area to determine whether the assumed failure rate is valid. Failing septic systems which are in close proximity to surface waters have the potential to cause elevated fecal coliform levels especially during low-flow periods.

5.2.5 Agricultural Data

The estimated numbers of feedlots, poultry houses, and poultry litter storage units per subwatershed for Hardy County and Grant County were provided by the West Virginia Soil Conservation Agency and were very useful for developing these TMDLs for fecal coliform bacteria. Additional discussion on agriculture-related issues is given in section 5.2.8.

5.2.6 Wildlife Information

Estimates of duck, geese, and deer populations were provided by West Virginia DNR. An attempt was made to estimate the potential fecal coliform contribution from these wildlife species by using literature values of typical daily fecal coliform production based on animal species. No information in the literature was found for daily fecal coliform production by whitetail deer. A value of 0.5×10^9 cfu/day was assumed which is subject to uncertainty. Future TMDL analyses should attempt to refine this loading rate. In addition, it was assumed that all fecal matter produced by deer was deposited in the forested land areas only. In reality, deer are likely to also use agricultural areas for these purposes. Future TMDL analyses should consider performing model sensitivity analyses to determine the impacts of different scenarios of wildlife activity on water quality.

5.2.7 Rainfall Data and Representative Hydrologic Year

The representative hydrologic year used for these initial TMDLs was the 1990-91 water year. The hourly rainfall database available in BASINS for the this project covered the period 1973-1993. The next release of BASINS will include more recent rainfall data through at least 1996. Future modeling should use more recent rainfall records corresponding to a representative hydrologic year which includes the best available concurrent fecal coliform water quality data set (i.e., 1994-97). This will help to improve certainty in the model water quality calibration. A rain gage situated at Moorefield was used for the watershed runoff modeling.

5.2.8 General Discussion on Data Needs

This section discusses the types of data that would be useful to support more accurate characterization of source loading for agricultural areas for refinement of the pathogen (bacteria) TMDLs for the Anderson Run watershed. The desired data is organized in two levels to represent the range from simplified (Level I) to more detailed (Level II) TMDL analyses.

Level I data allows for estimates of local and animal concentration but management options cannot be examined in detail. Level II data would provide information needed to evaluate the land area available for disposal of manure, the practices used, the resulting loads, and possible management options. Some of the Level I data were provided by WVSCA for this study for this study (i.e., number of feedlots and poultry houses, head of cattle, litter storage facilities, and county soil survey reports).

Level I Data:

- Location and types of animal facilities (chicken, turkey, cattle feed lots, hogs, etc.)
- Proximity of facilities to stream (i.e., within 1000 ft)
- Number of livestock units (e.g., head of cattle, number of chickens per poultry house, etc.)
- Use of waste storage facilities
- Presence of other waste-management BMPs (such as flow diversions, buffer strips)
- Number of clean-outs per year
- Soil characteristics (hydrologic soil group)
- Long-term daily stream flow measurements at least one location within the watershed for the purpose of calibrating the model hydrologic flows.

Level II Data:

- More detailed information in GIS format on land use, land cover, soils, and topography (land use coverage with crop type/rotation and soil type or hydrologic soil group and land slopes)
- Identification of land areas used for manure disposal
- Practices used in spreading manure and schedules
- Land areas with and without nutrient management programs
- Supplemental information on manure characteristics (bacteria counts)
- Mortality rate and disposal techniques for dead birds

A long-term study recommendation would be for sampling of fecal coliform, fecal streptococci, and enterococci bacteria at demonstration sites both with and without BMPs or before and after BMPs have been implemented. This is necessary to determine the effectiveness of BMPs implemented under the TMDL for pathogen control. Sampling should be performed during low-flow as well as storm periods.

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Appendix A