Fecal Coliform Total Maximum Daily Load South Fork South Branch Potomac River, 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 South Fork South Branch Potomac River, 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 watersbodies that are not or not expected to meet designated uses under technology-based controls or waterbodies that are considered threatened. The TMDLs 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.

The South Fork South Branch Potomac River ("South Fork") has been placed on the State of West Virginia's Section 303(d) list of waters for fecal coliform bacteria problems. The South Fork watershed lies in the Potomac Headwaters primarily in the state of West Virginia. A Total Maximum Daily Load (TMDL) analysis was developed for fecal coliform bacteria for 73.99 miles of the South Fork.

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 South Fork 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 the South Fork and its tributaries, the watershed was divided into 15 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. 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 quality 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 15 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 (1) Best Management Practices (BMPs) are implemented in the agricultural areas to reduce fecal coliform bacteria runoff by 41.5% and (2) the point source loading of fecal coliform from the Wampler-Longacre Chicken, Inc. Parking lot were reduced 100%. The point and 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%

Fecal Coliform Bacteria Point Source Allocations for South Fork Watershed

Point Source	Existing			Allocation			Percent Reduction
	Loading (cfu)	Flow Rate (cfs)	Effluent Conc. (Cfu/100mL)	Loading (cfu	Flow Rate (cfs)	Effluent Conc. (Cfu/100mL)	
Wampler-Longacre-Pipe	2.6052×10^{11}	2.072	14.08	2.6052×10^{11}	2.072	14.08	0.0%
Wampler-Longacre-Lot	2.8518×10^{11}	0.088	3629.0	0.0	0.0	0.0	100.0%
Dept. Of Navy Radio Station	1.3025×10^{11}	0.078	187.0	1.3025×10^{11}	0.078	187.0	0.0%
Moorefield Filtration Plant	1.7860×10^{9}	0.020	10.0	1.7860×10^{9}	0.020	10.0	0.0%
Hester Industries-Moorefield	4.7218×10^{10}	0.750	7.05	4.7218×10^{10}	0.750	7.05	0.0%
Brandywine Laundromat	NA	NA	NA	NA	NA	NA	NA
Pendleton County PSD	NA	NA	NA	NA	NA	NA	NA

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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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).

The South Fork South Branch Potomac River ("South Fork") watershed lies in the Potomac Headwaters primarily in the state of West Virginia (Figure 1.1). The watershed traverses two West Virginia counties, Pendleton and Hardy, and a small upstream portion of the basin lies in the state of Virginia. The land area of the watershed is approximately 179,000 acres. Runoff from the South Fork 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 at the mouth of the South Fork. 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 the South Fork. The West Virginia Division of Environmental Protection (DEP) has identified the South Fork as being impacted by fecal coliform bacteria for a length of 73.99 miles, as reported in the 1996 303(d) list of water quality limited waters (West Virginia, 1996). The South Fork is ranked number 39 on the list and carries an agency code of PSB-21. 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 four stations along the South Fork main stem. The results of this sampling indicated that one of the stations along the South Fork had significant fecal coliform levels; more than 36% of the samples at the station had fecal coliform counts above 200 cfu/100 mL. Based on these data and the state's water quality standard for fecal coliform bacteria, the South Fork 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 South Fork 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 the South Fork 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 South Fork 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.

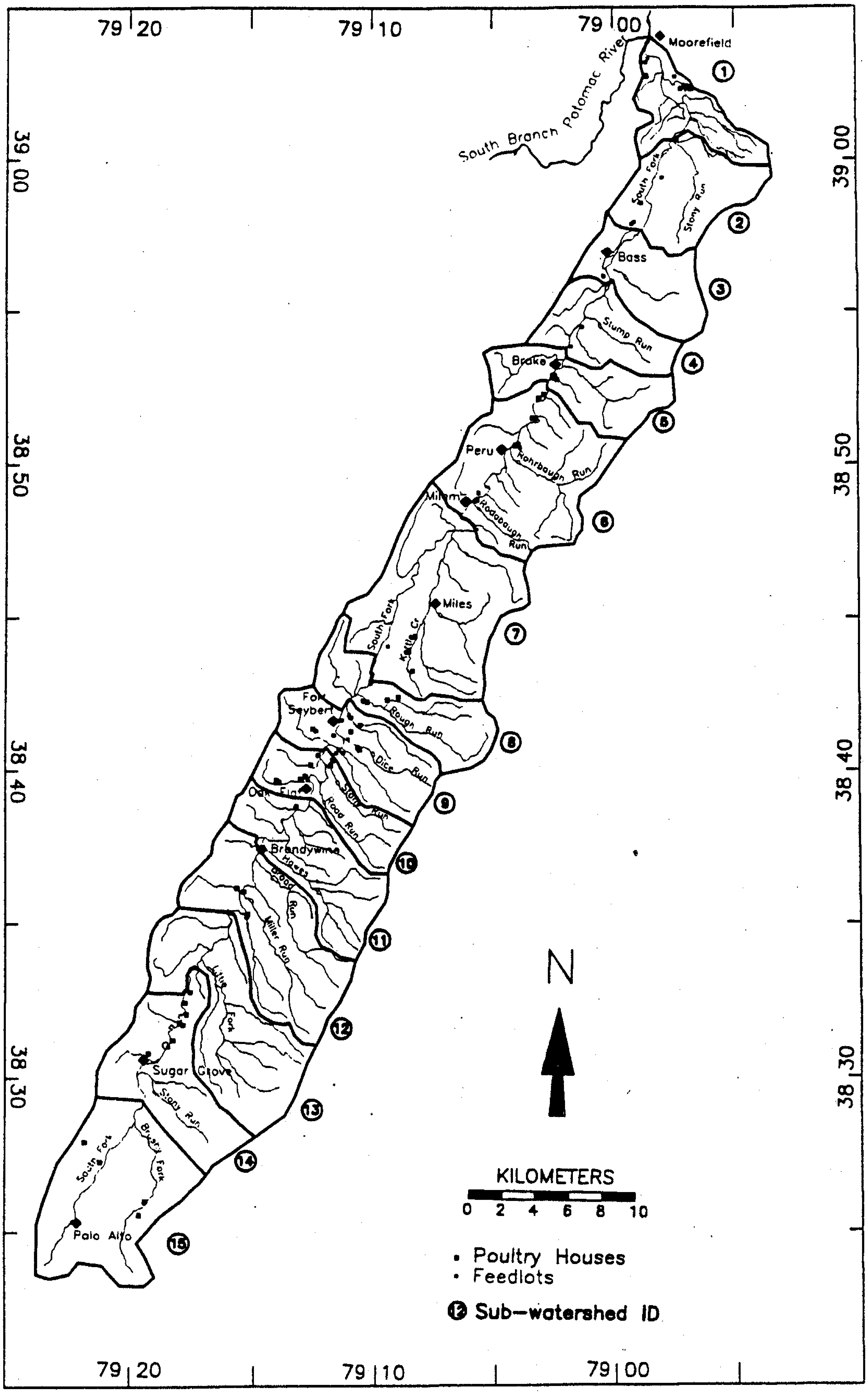

Figure 1.1 Study area: South Fork South Branch Potomac River watershed, West Virginia.

2.0 SOURCE ASSESSMENT

This section presents an overview of the instream water quality monitoring data available for the South Fork 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 on the South Fork and its tributaries 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 four sites labeled USGS#9 through USGS#12 were 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). These four USGS stations were sampled approximately once per month throughout the study period. Time-series plots of the fecal coliform data for each of these sites are shown in Figures 2.2 - 2.5. From these figures 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.

Historically, the most frequently sampled station in the South Fork watershed has been Station 080201, which is located on Hawes Run downstream of Brandywine Lake in the Brandywine Recreation Area. The lake contains a swimming area which is open from Memorial Day to Labor Day each year. Fecal coliform bacteria has been sampled at a frequency of once or twice per week from Memorial Day to Labor Day each year since 1979. The data are available from EPA STORET and are presented in Figure 2.6. Individual data points have never been recorded above the 400 cfu/100 mL standard and the 30-day geometric mean has never been greater than the 200 cfu/100 mL standard.

In support of this fecal coliform bacteria TMDL development, the West Virginia Division of Environmental Protection (DEP) has begun an intensive monitoring program in the South Fork watershed in which 8 sites on the main stem and 10 tributary sites are sampled during a single field excursion. As of the date of this report, three intensive sampling runs have been completed on the South Fork: August 13, 1996, August 19, 1996, and July 15, 1997. The locations of the stations and the sampling results for these three monitoring events are shown in Figures 2.7, 2.8, and 2.9, respectively. Both the August 13 and 19, 1996 sampling dates coincided with the receding tail of small storm hydrographs. The July 15, 1997, sampling event was during a low-flow period and three of the tributary sites were dry. High fecal coliform bacteria is indicated at the sampling site T05 on the unnamed tributary near the town of Oak Flat for both the August 19, 1996 (2200 cfu/100 mL) and the July 15, 1997 (32200 cfu/100 mL) sampling dates. Since the fecal coliform concentration was higher during the low-flow period (July 15, 1997), this may be an indication of direct discharge/inflow to the stream. Such discharge could be the result of failing septic systems, animal waste discharge, direct access of animals to the stream, illicit discharge, or some other unknown source.

It is also interesting to note that on June 3-4, 1997, DEP conducted intensive sampling runs on five nearby watersheds (Anderson Run, Lunice Creek, Mill Creek, North Fork, and South Branch). The sampling team arrived during the rising portion of a storm hydrograph and the sampling results indicated very high fecal coliform bacteria levels in excess of 6000 cfu/100 mL at 24 of 38 sampling sites. Unfortunately, the South Fork was not visited during this sampling run. However, using the nearby watersheds as a representative indicator, it is likely that similar results would also occur in the South Fork during the rising limb of a storm hydrograph. These high values are normally observed during storm events but have short duration (i.e., they typically last for only several hours).

The 1994-95 USGS reconnaissance survey provided the best long-term multi-year data set of fecal coliform bacteria in the South Fork. 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 four stations on the South Fork is given in Table 2.1. Station USGS#9 indicates 5 of 16 samples (31.2%) are above the 200 cfu/100 mL level which is the reason the South Fork was placed on the 303(d) list.

Table 2.1 Summary of Fecal Indicator Bacteria from 1994-95 USGS Study of South Fork.

		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#9	16	2	110	1200	31.2	18.8	980	0.2
USGS#10	12	1	49	290	16.7	0.0	140	0.2
USGS#11	10	20	73	530	20.0	10.0	730	0.3
USGS#12	18	2	83	590	16.7	5.6	680	0.2

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 four USGS stations in the South Fork all had FC/FS ratios of 0.3 or less (see Table 2.1) 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.

Two chicken-processing plants, the Moorefield Filtration Plant, the Brandywine Laundromat, a Naval Radio Station, and the Pendleton County PSD discharge to the receiving waters of the South Fork. The PCS Database contained permitted as well as average flows and permitted as well as average fecal

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

coliform concentrations for the major contributors. In general, all facilities are required to abide by the 200 cfu/100 mL average monthly limit and the 400 cfu/100 mL maximum daily limit. Average values for flow and fecal coliform concentrations for years in which data are available were calculated for the major contributors. Flow and fecal coliform concentration values for minor contributors were assumed based on SIC codes. Table 2.2 provides permitted flow and average fecal coliform concentration values for major facilities and assumed flow and concentration values for minor facilities. Facility locations are displayed in Figure 2.10. The Wampler-Longacre Lot discharge is sampled on a quarterly basis and the values listed in the Table 2.2 are averages from the monitoring period December 1993 to June 1997. Runoff from this site is due to discharge from trucks containing frozen poultry which leaves the parking lot and enters nearby surface waters and is not necessarily storm event related.

Table 2.2 Municipal and Industrial Dischargers in the South Fork Watershed

NPDES No.	Facility Name	SIC codes	Permitted Flow (gpd)	Fecal Coliform cfu/100 mL
WV0020117	Dept. Of Navy - Naval Radio Station	4952, 9711	50,000	187
WV0037371	Moorefield Filtration Plant	4941	50,000	10
WV0047236	Hester Industries, Moorefield	2013, 2015	1,000,000	7
WV0005495	Wampler-Longacre Chicken, Inc. - Pipe	2015, 2016	2,160,000	14
	Wampler-Longacre Chicken, Inc. - Lot		57,000*	3629*
WV0070742	Brandywine Laundromat	7215	20,000	10
WV0077291	Pendleton County PSD	4941	50,000	10

* average based on quarterly sampling from Dec 1993 to Jun 1997

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.

More than 60 tributaries enter the South Fork along its 67 mile length from Moorefield to its headwaters near Palo Alto. However, inadequate monitoring data were available to characterize the flow and bacterial loading from each of these peripheral tributaries. Instead, the watershed was divided into

15 sub-watersheds based on 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 South Fork Watershed (see figure in Appendix A). The land uses in the South Fork watershed consist primarily of forested (86%), agricultural, and urban areas. The various land uses for each of the 15 sub-watersheds are listed in Table 2.3. The Potomac Interagency Water Quality Office maintains a partially-completed geographic information system (GIS) with the locations of poultry houses, feedlots, and other agricultural-related information obtained through "windshield surveys" of the area. The delineations of the 15 sub-watersheds for the South Fork was provided to this office and they in turn estimated the number of poultry houses and animal feedlots within each of the sub-watersheds. The total head of cattle in each sub-watershed were also estimated by this office. This information is given in Table 2.4.

Table 2.3 Land Use Distributions and Septic Population for the 15 South Fork Subwatersheds

Subwatershed Number	Total Area (acres)	Urban (Acres)	Agricultural (acres)	Forest (acres)	Septic Population
1	6,428	277	2,222	3,929	
2	8,750	0	1,022	7,728	
3	7,219	0	722	6,497	
4	7,286	0	630	6,656	
5	7,457	25	776	6,658	
6	17,510	0	1,753	15,757	
7	21,688	0	2,659	19,029	
8	9,939	40	727	9,172	
9	9,775	0	2,357	7,418	
10	7,354	15	1,332	6,007	
11	11,289	266	934	10,089	
12	15,140	49	1,769	13,322	
13	16,631	32	2,157	14,442	
14	13,274	24	3,167	10,085	
15	19,188	19	3,574	15,595	
Total	178,928	743	25,801	152,384	

Table 2.4 Inventory of Poultry Houses and Cattle Feedlots in South Fork Watershed.

Subbasin Number	Stream Name Location	Area (acres)	Poultry Houses Broiler	Poultry Houses Breeder	Poultry Houses Turkey	Litter Storage Areas	Number Cattle Feedlots	Head Cattle
1	Moorefield	6,606	8	0	0	2	3	330
2	Stony Run	9,852	0	0	0	NA	5	300
3	Bass	7,954	0	0	0	NA	1	100
4	Stump Run	7,489	0	0	0	NA	3	100
5	Brake	8,563	3	0	0	1	1	50
6	Rohrbaugh Run	17,525	11	0	1	2	5	260
7	Kettle Creek	21,005	0	0	8	2	1	50
8	Rough Run	9,251	4	0	3	1	2	150
9	Dice Run	9,885	4	3	7	3	8	500
10	Road Run	7,395	0	0	4	NA	3	100
11	Hawes Run	11,141	0	0	1	NA	0	0
12	Miller Run	15,384	8	0	2	NA	1	50
13	Little Fork	16,043	2	0	2	NA	0	0
14	Stony Run	12,147	10	0	4	NA	1	50
15	Brushy Fork	17,147	6	0	2	NA	0	0
	Totals	177,388	56	3	34	11	34	2040

The West Virginia Division of Natural Resources (DNR) provided estimates of the numbers of geese and ducks within the South Fork watershed 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 180 for the migratory goose population and 100 for the migratory duck population in the South Fork 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 South Fork watershed are given in Table 2.5.

Table 2.5 Population Estimates of Farm and Wild Animals in South Fork Watershed.

Subbasin Number	Stream Name Location	Number Broilers	Number Breeders	Number Turkeys	Number Ducks	Number Geese	Number Deer
1	Moorefield	224,000	0	0	4	6	356
2	Stony Run	0	0	0	5	9	485
3	Bass	0	0	0	4	7	400
4	Stump Run	0	0	0	4	7	404
5	Brake	84,000	0	0	4	8	413
6	Rohrbaugh Run	308,000	0	15,000	10	18	971
7	Kettle Creek	0	0	120,000	12	22	1,202
8	Rough Run	112,000	0	45,000	6	10	551
9	Dice Run	112,000	27,000	105,000	5	10	542
10	Road Run	0	0	60,000	4	7	408
11	Hawes Run	0	0	15,000	6	11	626
12	Miller Run	224,000	0	30,000	8	15	839
13	Little Fork	56,000	0	30,000	9	17	922
14	Stony Run	280,000	0	60,000	7	13	736
15	Brushy Fork	168,000	0	30,000	11	19	1,064
	Totals	1,568,000	27,000	510,000	100	180	9,918

Onsite septic systems are the predominant form of domestic waste water treatment in the South Fork watershed. No information was readily available on the specific locations of septic systems, septic tank densities, or failure rates. However, WVDEP 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. A septic system failure rate of about 2.5% was estimated for Hardy County (NSFC 1993) and it was assumed this rate was applicable throughout the South Fork watershed. It was further assumed that 100% of the fecal coliform load from the failed systems reached the receiving waters at a concentration of $1x10^4$ cfu/100 mL (Metcalf & Eddy 1991). The assumed septic system waste flow rate was based on a typical value of 70 gallons per capita per day (Horsely & Whitten 1996).

As previously mentioned in section 2.1, the USGS 1994-95 monitoring data suggest that the source of bacterial contamination in the South Fork is from animal sources based on the fecal coliform to fecal streptococci ratio of 0.2 to 0.3. 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 shipped to other sub-watersheds or may be moved completely out of the South Fork watershed, however, 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 South Fork 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 TMDL analysis.

Table 2.6 Land Application Sites in South Fork Watershed.

Generator	Type	Farm	Acres	Drainage Area/Location
Hester Ind.	Ind.	Island	25	South Branch/South Fork confluence
WLC	Ind.	Bill Keplinger*		Dumpling Run
WLC	Ind.	Charlie Williams*		Dumpling Run
U.S. Navy	Sludge	Naval Reservation	30	Unnamed Tributary-South Fork (Sugar Grove, Pendleton Co.)
U.S. Navy	Sludge	Canterbury Farm	25	Little Stoney Run above dam

* These farms have not been used since 1994

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 species used for the total load calculation are given in Table 2.7. 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. 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 within the watershed (with the exception of the septic load which is the estimated load reaching the stream). Various processes and agricultural management practices will reduce these loads before they reach surface waters.

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	best professional judgement estimate

Table 2.8 Potential Nonpoint Source Fecal Coliform Production in South Fork Watershed.

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	Moorefield	5.608E+13	5.376E+13	1.782E+12	3.952E+10	3.169E+11	1.782E+11	2.610E+08
2	Stony Run	2.348E+12	0.000E+00	1.620E+12	5.379E+10	4.313E+11	2.425E+11	1.133E+08
3	Bass	1.140E+12	0.000E+00	5.400E+11	4.438E+10	3.559E+11	2.001E+11	3.179E+07
4	Stump Run	1.146E+12	0.000E+00	5.400E+11	4.479E+10	3.592E+11	2.019E+11	3.842E+07
5	Brake	2.105E+13	2.016E+13	2.700E+11	4.584E+10	3.676E+11	2.067E+11	3.179E+07
6	Rohrbaugh Run	7.873E+13	7.587E+13	1.404E+12	1.076E+11	8.631E+11	4.853E+11	6.822E+07
7	Kettle Creek	1.767E+13	1.560E+13	2.700E+11	1.333E+11	1.069E+12	6.011E+11	9.472E+07
8	Rough Run	3.437E+13	3.273E+13	8.100E+11	6.110E+10	4.899E+11	2.755E+11	5.961E+07
9	Dice Run	5.052E+13	4.701E+13	2.700E+12	6.009E+10	4.818E+11	2.709E+11	1.921E+08
10	Road Run	8.952E+12	7.800E+12	5.400E+11	4.521E+10	3.625E+11	2.038E+11	9.472E+07
11	Hawes Run	2.889E+12	1.950E+12	0.000E+00	6.940E+10	5.565E+11	3.129E+11	2.153E+08
12	Miller Run	5.919E+13	5.766E+13	2.700E+11	9.308E+10	7.463E+11	4.196E+11	2.292E+08
13	Little Fork	1.872E+13	1.734E+13	0.000E+00	1.022E+11	8.198E+11	4.609E+11	2.563E+08
14	Stony Run	7.637E+13	7.500E+13	2.700E+11	8.160E+10	6.543E+11	3.679E+11	2.146E+08
15	Brushy Fork	4.582E+13	4.422E+13	0.000E+00	1.180E+11	9.458E+11	5.318E+11	9.936E+07
	Total	4.750E+14	4.491E+14	1.102E+13	1.100E+12	8.820E+12	4.959E+12	2.000E+09
	Percent	100.00%	94.55%	2.32%	0.23%	1.86%	1.04%	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. In addition, there was at least one "hot spot" which was evident during low-flow conditions at station T05 on the tributary near Oak Flat. 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.

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 South Fork watershed from within the screening period. Additionally, model results for flow compared well with USGS flow data for the 1991 water year (see Figure 2.11).

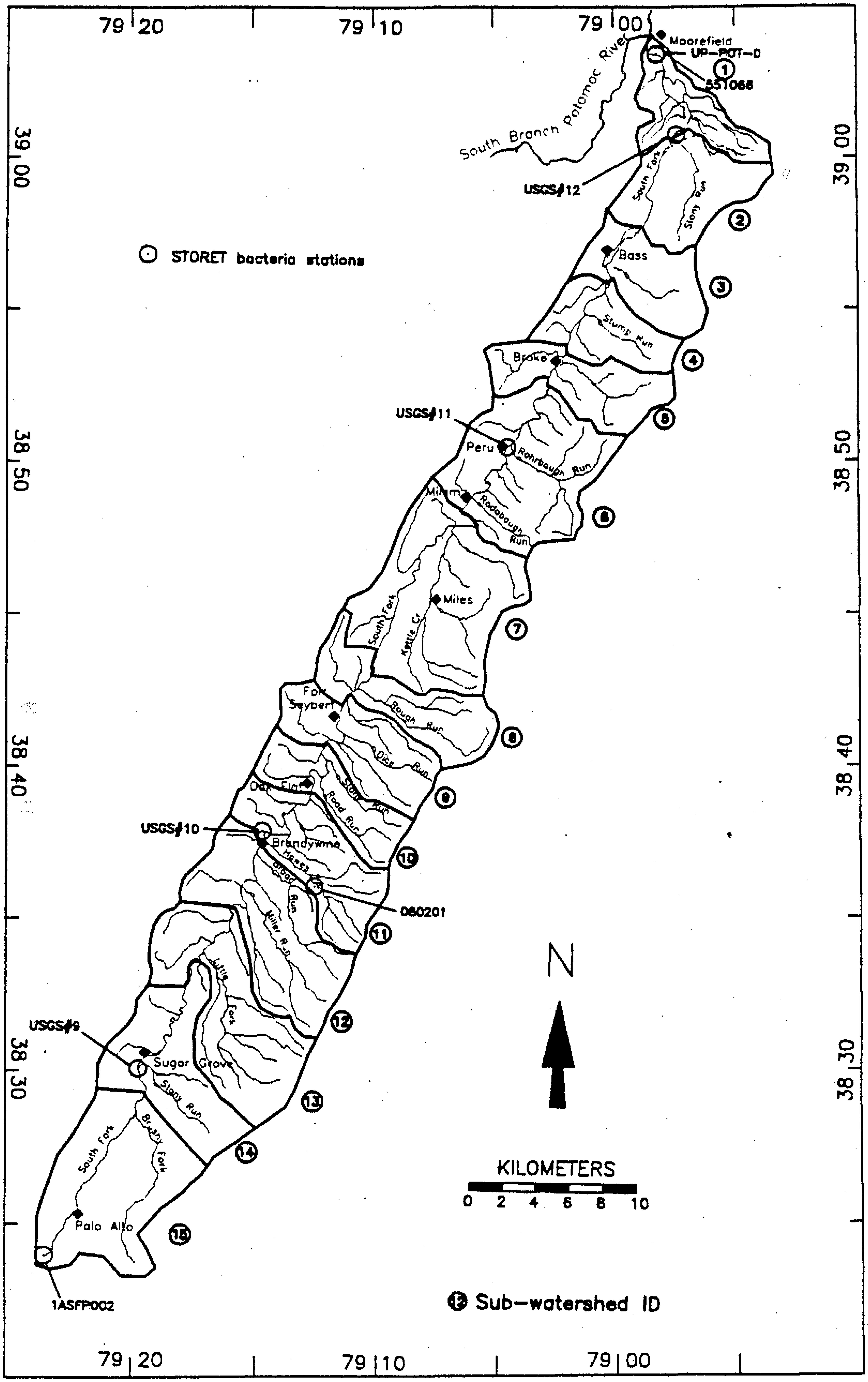

Figure 2.1 STORET bacteria monitoring stations.

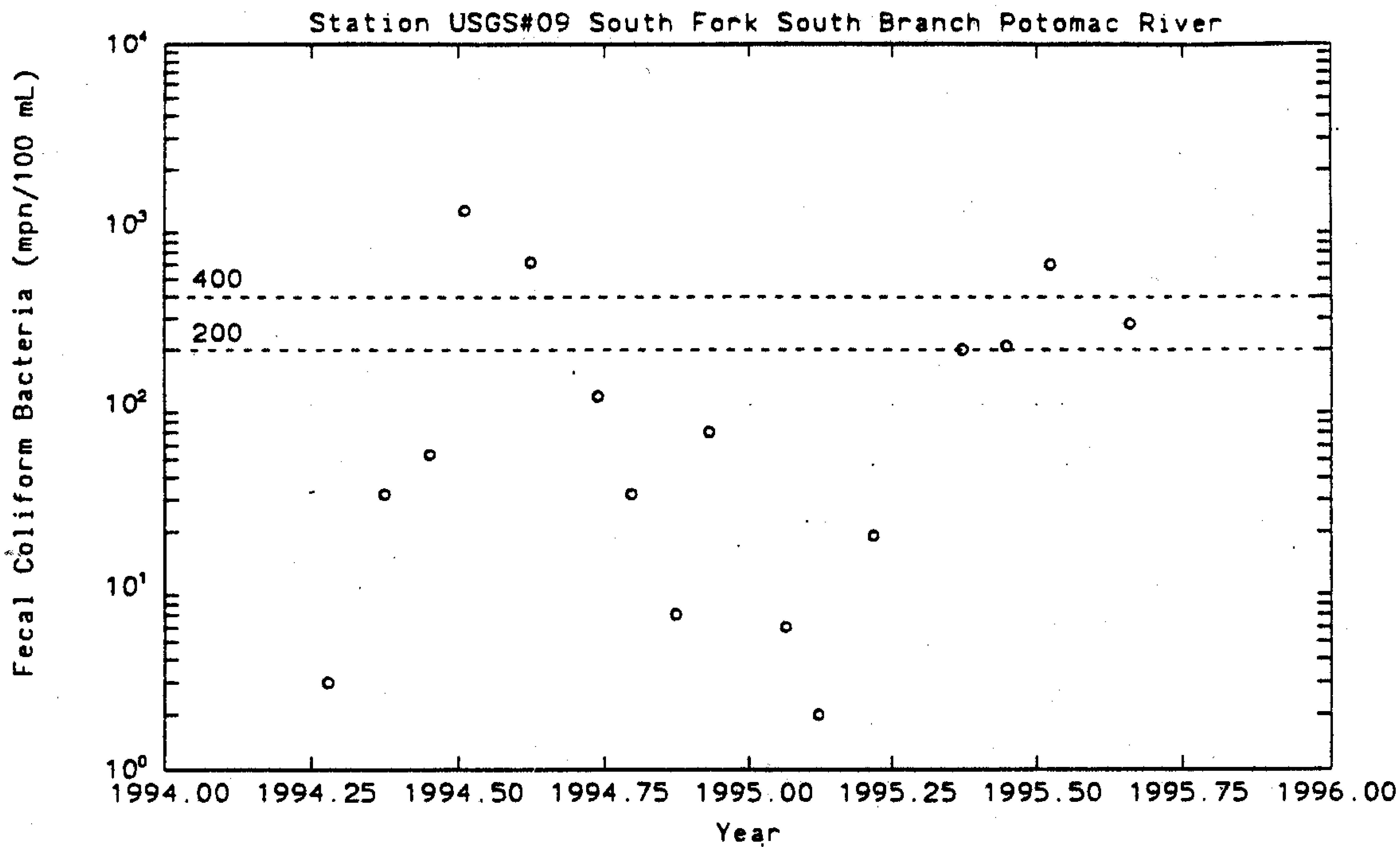

Figure 2.2 Time-series fecal coliform bacteria data for USGS Station #9.

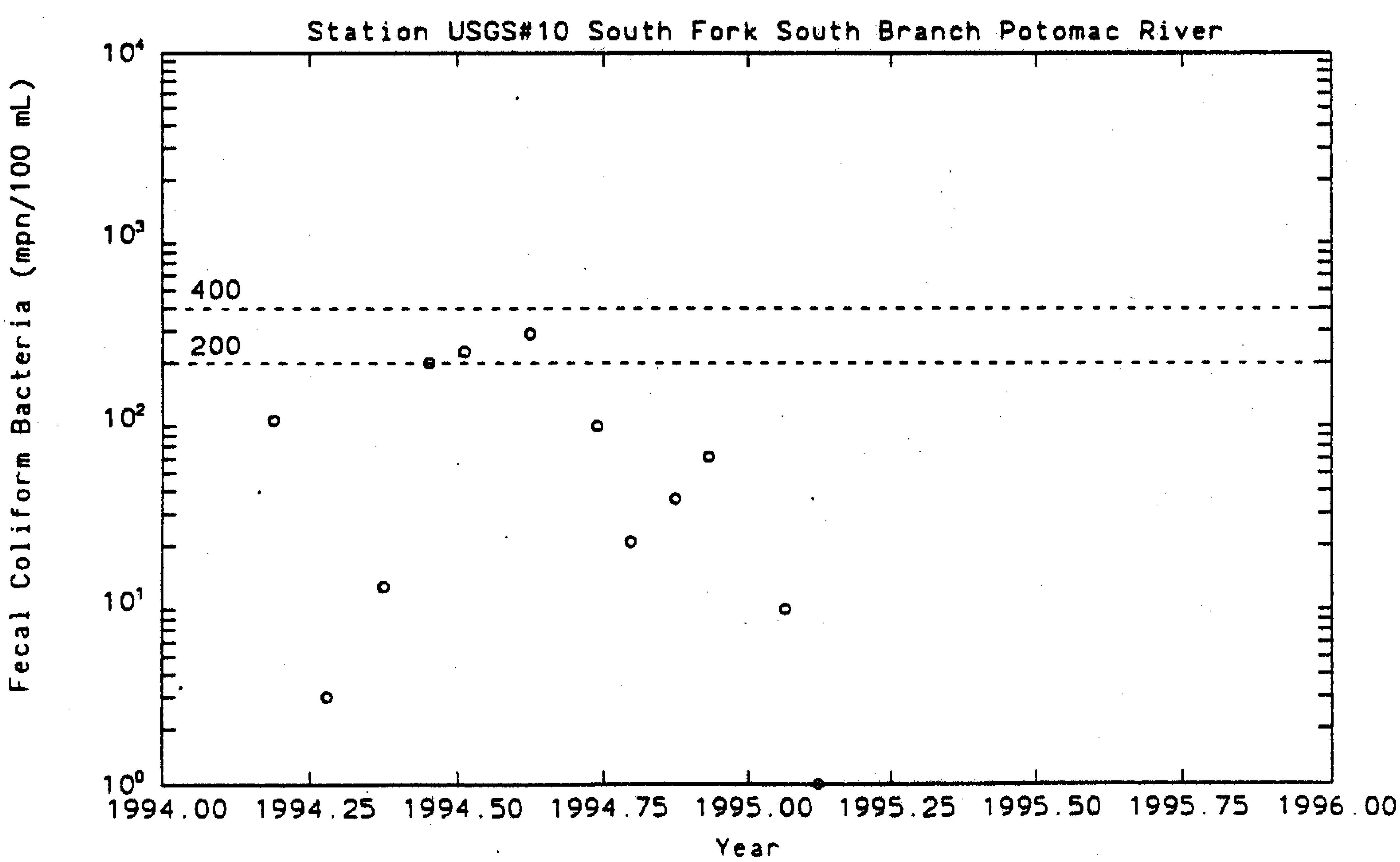

Figure 2.3 Time-series fecal coliform bacteria data for USGS Station #10.

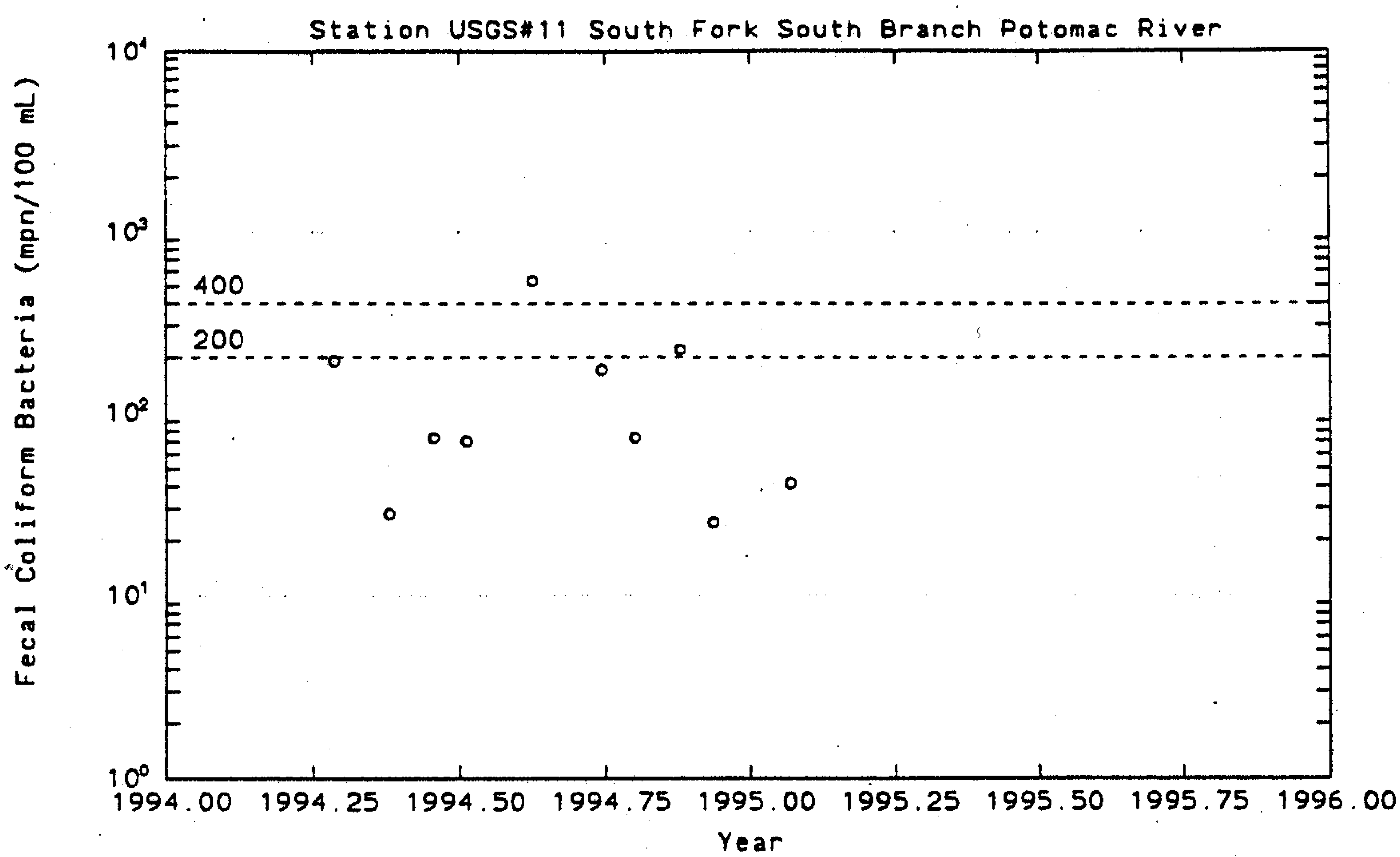

Figure 2.4 Time-series fecal coliform bacteria data for USGS Station #11.

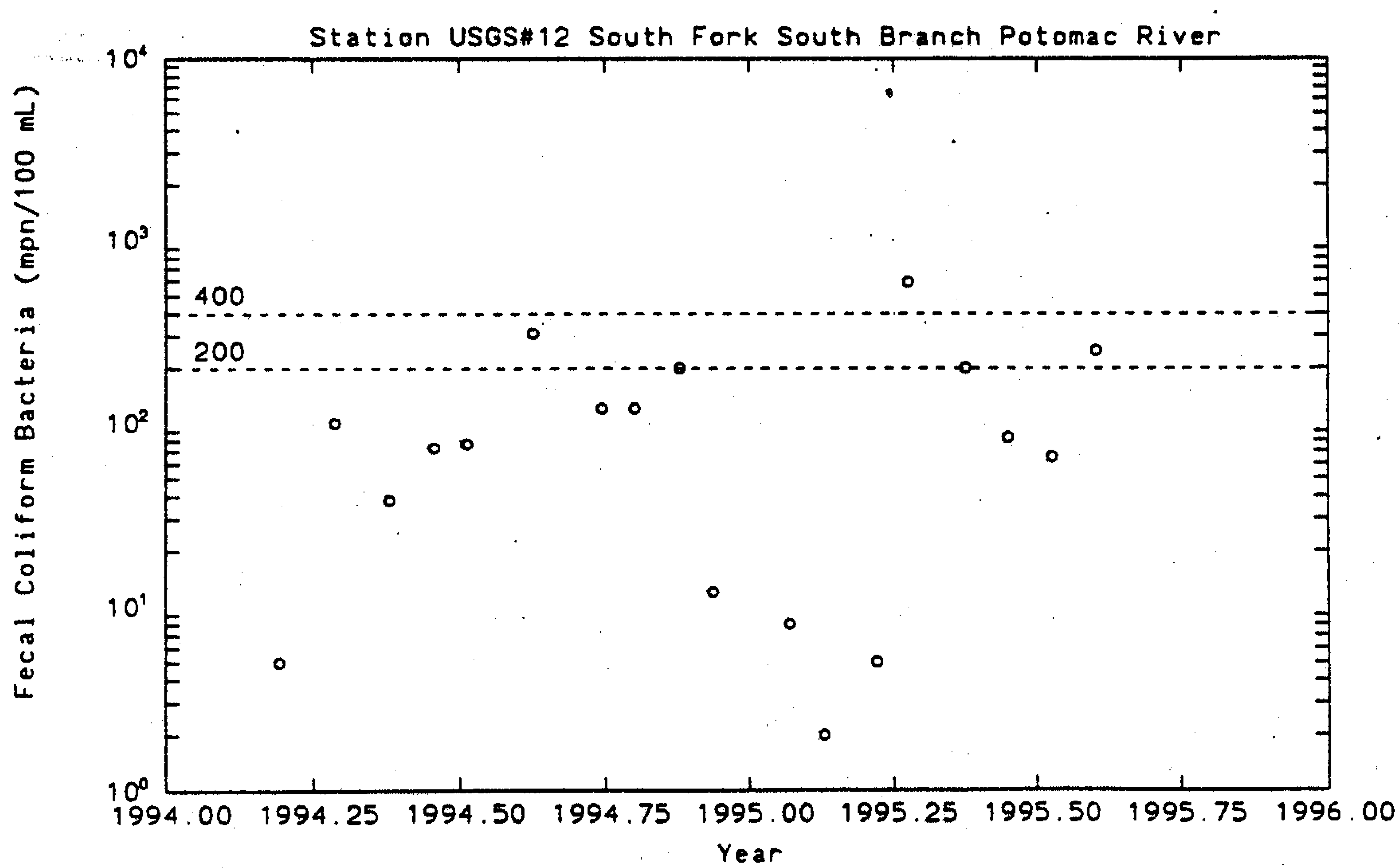

Figure 2.5 Time-series fecal coliform bacteria data for USGS Station #12.

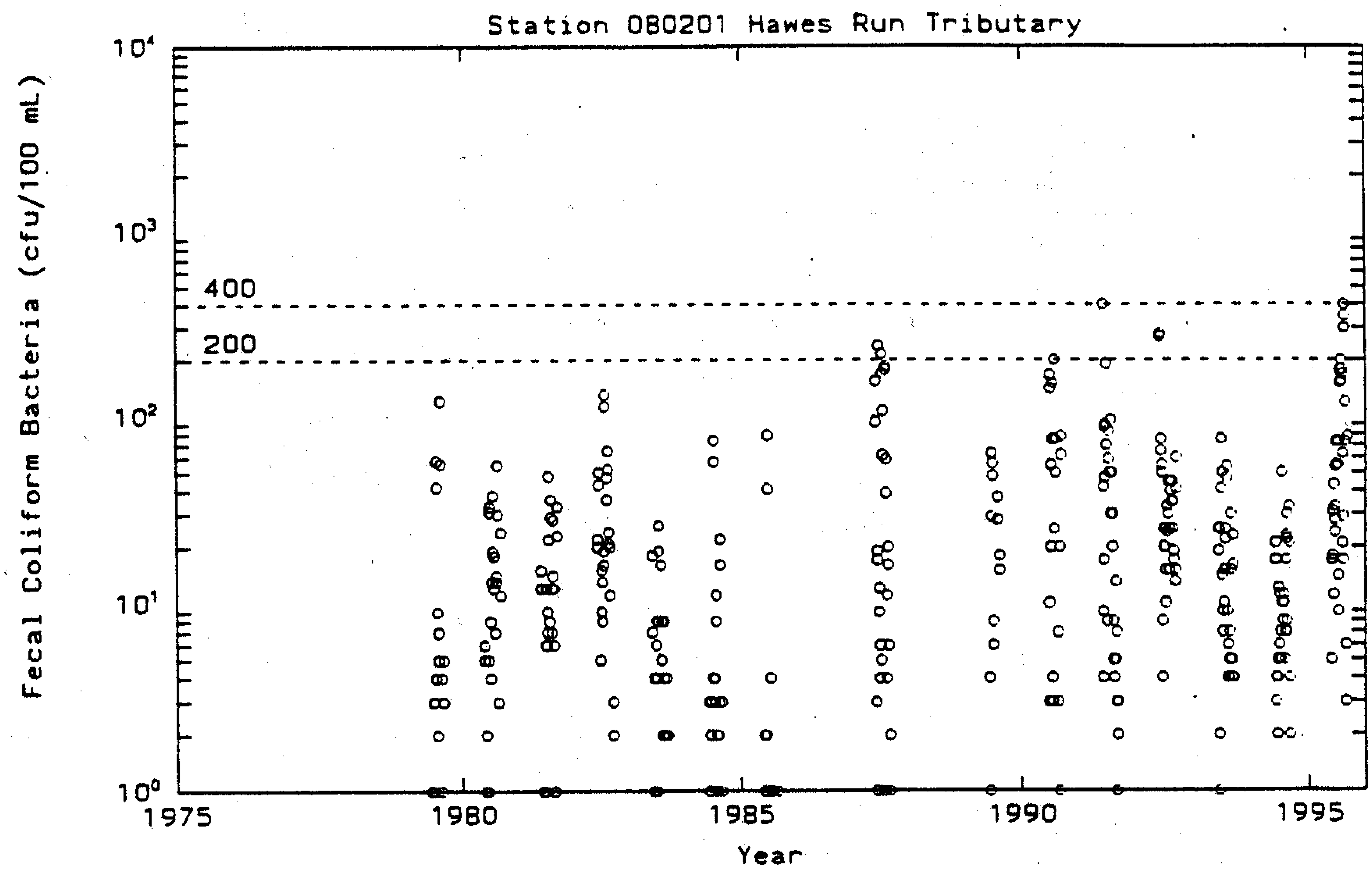

Figure 2.6 Time-series fecal coliform bacteria data for station 080201 (Hawes Run).

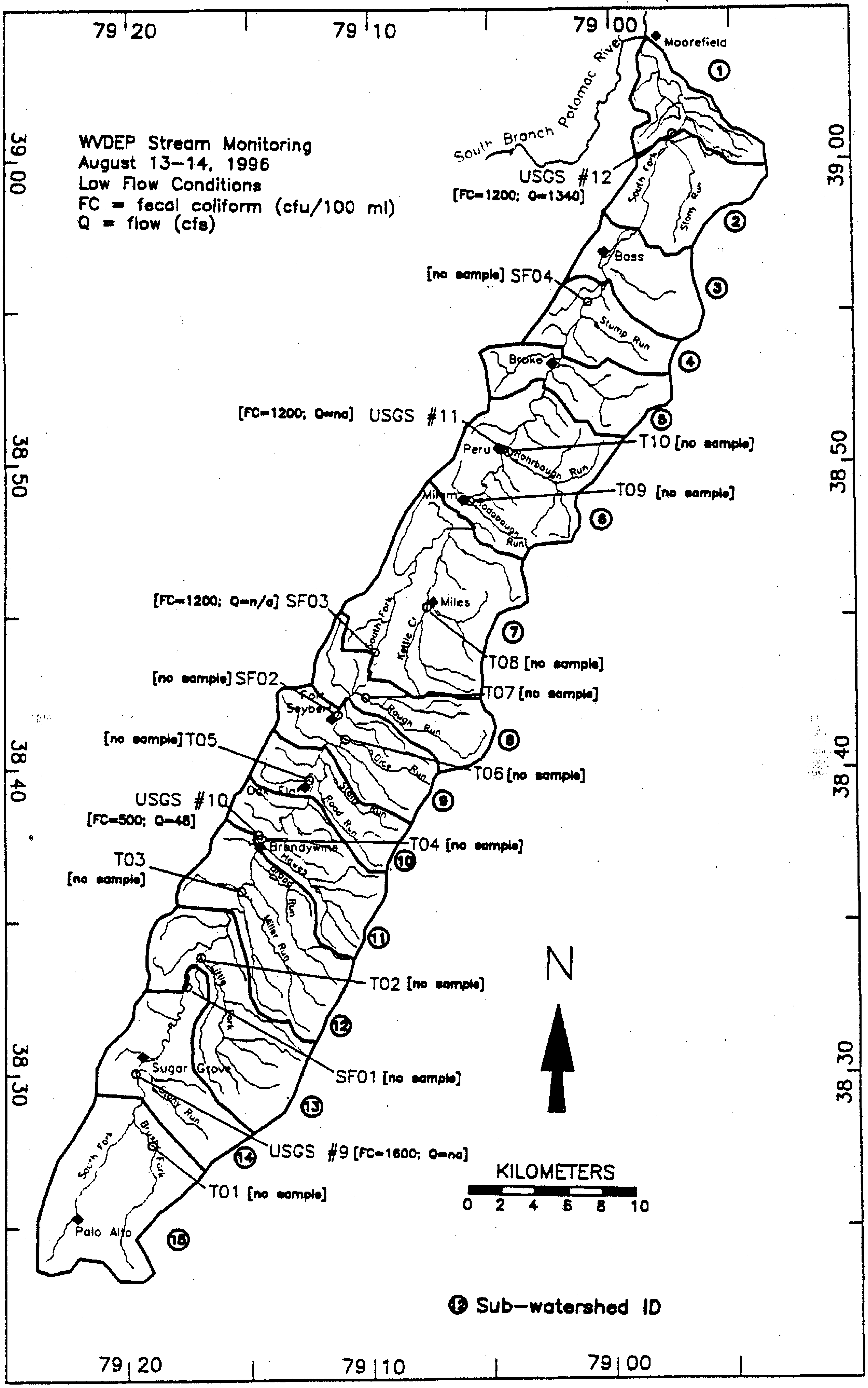

Figure 2.7 Sampling results for fecal coliform monitoring on August 13-14, 1996

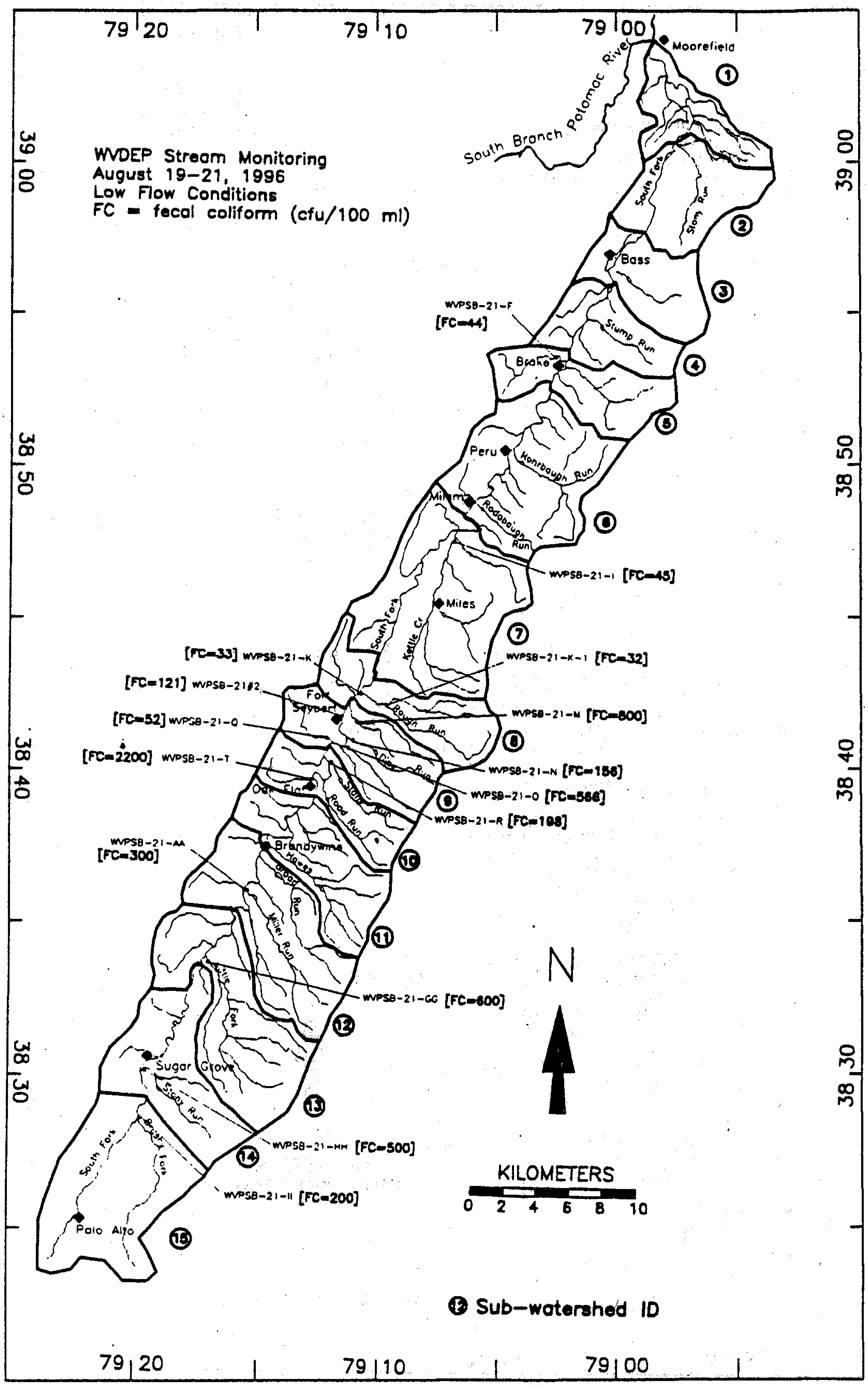

Figure 2.8 Sampling results for fecal coliform monitoring on August 19-21, 1996

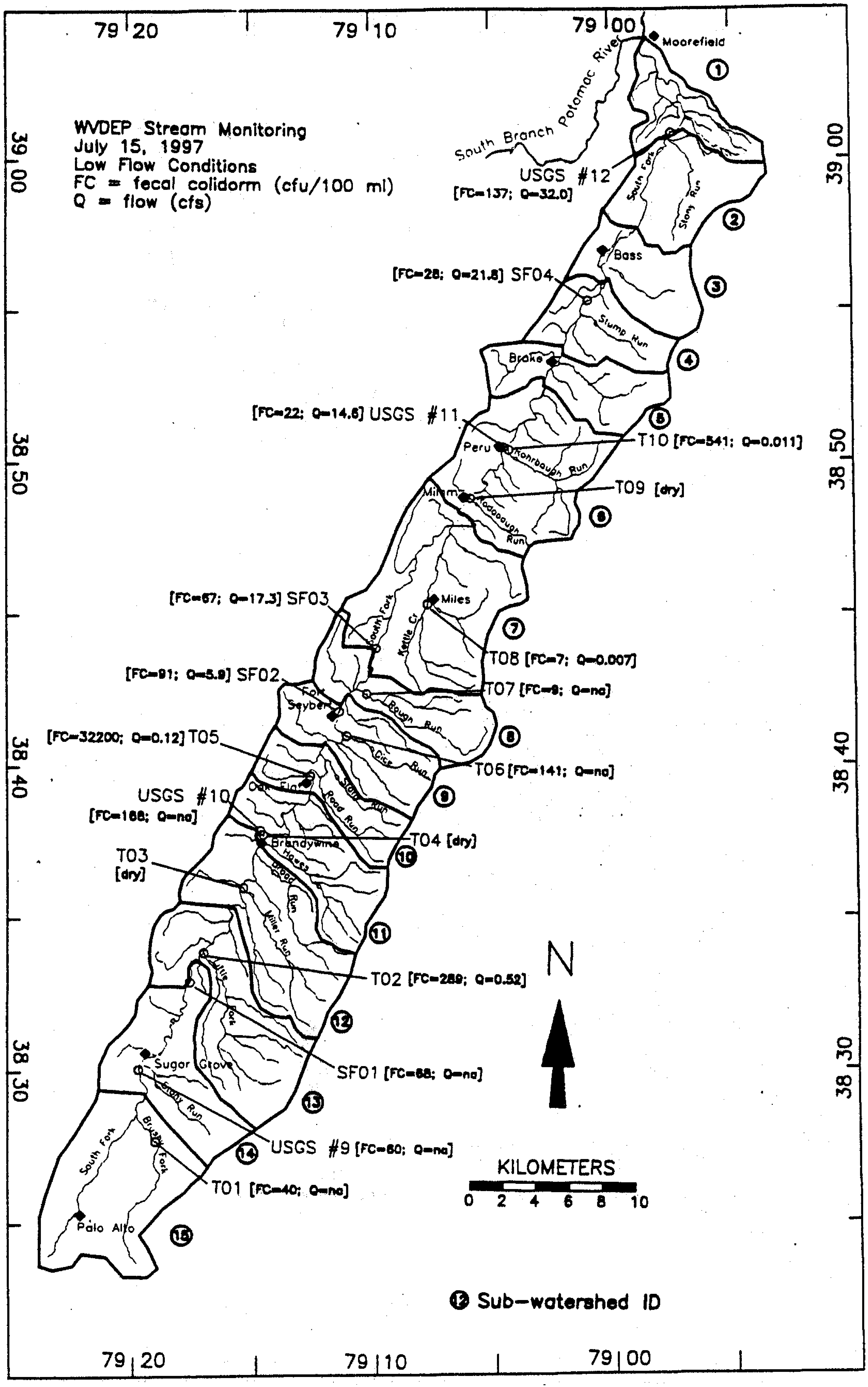

Figure 2.9 Sampling results for fecal coliform monitoring on July 15, 1997

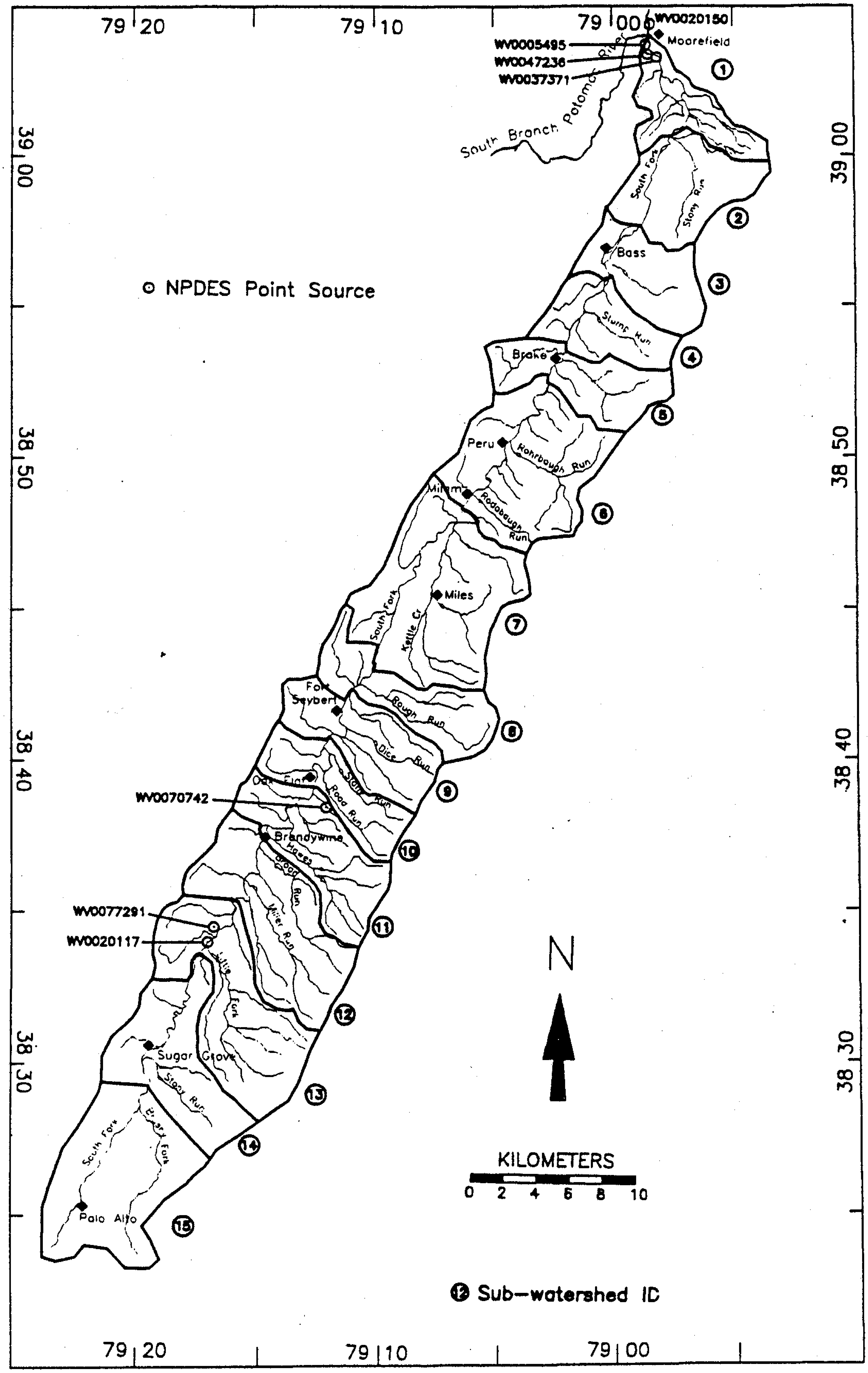

Figure 2.10 Locations of point source dischargers in South Fork watershed.

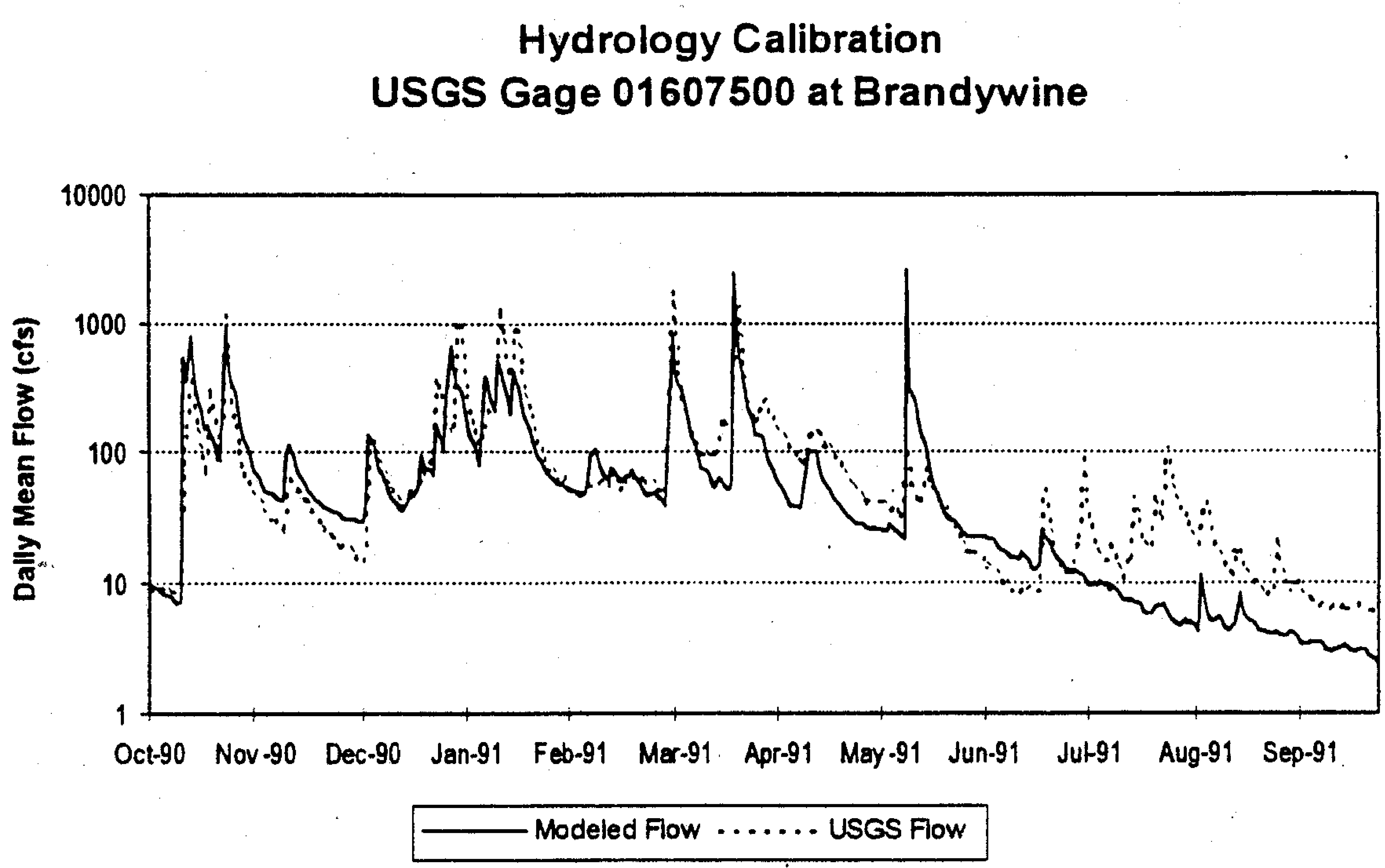

Figure 2.11 Comparison of observed and modeled flow at USGS gage #01607500.

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 model 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 South Fork, the watershed was subdivided into 15 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, land use coverage, and soil characteristics obtained from SCS soil surveys for Hardy and Pendleton Counties (USDA 1989 and USDA 1992).

3.3 Source Representation

Both point and nonpoint sources were represented in the model. The point sources that were used are shown in Table 3.0. Flow rates and fecal coliform concentrations were obtained from the EPA PCS database for major facilities. In the absence of flow rates and fecal coliform concentrations for minor sources, either typical values for facilities with similar SIC codes were used or facilities were excluded from the modeling. In the model, flow rates were based on average flow rates from facilities rather than permitted flows. 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 septic systems. A variety of parameters needed for predicting runoff and fecal coliform loadings were then estimated for each of the land uses within these 15 sub-watersheds.

Table 3.1 Characteristics of Municipal and Industrial Dischargers in the South Fork Watershed

NPDES No.	Facility Name	SIC codes	Flow (gpd)	cfu/100 mL
WV0020117	Dept. Of Navy - Naval Radio Station	4952, 9711	50,000	187
WV0037371	Moorefield Filtration Plant	4941	13,000	10
WV0047236	Hester Industries, Moorefield	2013, 2015	483,000	7
WV0005495	Wampler-Longacre Chicken, Inc. - Pipe	2015, 2016	1,336,000	14
	Wampler-Longacre Chicken, Inc. - Lot		57,000	3629
WV0070742	Brandywine Laundromat	7215	NA	NA
WV0077291	Pendleton County PSD	4941	NA	NA

Septic system discharges were quantified based on the following information: the population distribution within each of the 14 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), and a 2.5% failure rate (NSFC 1993). The entire population outside the Town of Moorefield (which is served by a wastewater treatment plant) was assumed to use septic systems. The septic system contribution in the model inherently contains a margin of safety based on the assumption that all the fecal coliform bacteria discharged from failing septic systems reaches the stream. In reality, it is likely that only a 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 may 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 (divided into Hardy and Pendleton counties) were readily available as were deer population densities. Because the most detailed information on these wildlife populations was by county, two separate loading rates were calculated: one for each county's forested land uses. Subwatersheds 1 through 6 fall into Hardy county and subwatersheds 7 through 15 fall into Pendleton county. The fecal coliform loading rates per acre were based on those described earlier for various animal species (Metcalf and Eddy 1995).

A similar analysis was performed to estimate fecal coliform loading rates for agriculture landuses in each of the 15 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. The subwatersheds were then grouped into nine separate categories based on these relative densities. The categories and respective subwatersheds are displayed in Table 3.2. Each agricultural land use in the 15 subwatersheds was then assigned a fecal coliform loading rate based on this categorization. Subwatersheds 7, 10, 11, 13, and 15, for example, had relatively low poultry and cattle densities and therefore had a low fecal coliform loading rate. Subwatershed 8, on the other hand, had high poultry and cattle densities and subsequently a higher loading rate. The specific loading rates for each category were calculated based on an average cattle and poultry density for each of the nine categories and typical fecal coliform loading rates for the cattle and poultry species (Metcalf and Eddy 1995). The specific values that were used for each of the landuses in each of the 15 subwatersheds are shown in Appendix A.

Table 3.2 Grouping of Subwatersheds Based on Cattle and Poultry Densities

Cattle Density	**Poultry Density**	**Subwatersheds**
Low	Low	7, 10, 11, 13, 15
Low	Medium	5, 12, 14
Low	High	-
Medium	Low	3, 4
Medium	Medium	1
Medium	High	6
High	Low	2
High	Medium	9
High	High	8

3.4 Stream Characteristics

The channel geometry for South Fork sub-watershed #1 was well-defined from a Corps of Engineers HEC-2 flood model which contained a number of cross-section surveys from the confluence of the South Fork with the South Branch to the USGS gage #01608000 upstream of Moorefield. Channel geometry for the remaining 14 sub-watersheds were derived from the other USGS gaging stations (Peru, Brandywine, and Sugar Grove). Topographic maps (1:24,000 scale) were used to determine channel slopes for each reach.

3.5 Selection of Representative Modeling Period

The hydrologic conditions in the South Fork watershed consist of relatively random successions of dry, average, and wet rainfall years. Since it was determined that bacteria contamination in the South Fork 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. Additionally, the modeled flow best-matched the USGS flow data for this year, once hydrologic calibration was performed.

3.6 Model Calibration Process

To develop a representative linkage between the sources and the instream water quality response in the 15 reaches of the South Fork, model parameters were adjusted to the extent possible for both hydrology and bacteria loading. Hydrologic calibration required a comparison of the modeled overall water balance and stream flows for the portion of the watershed upstream from USGS gage #01607500 (at Brandywine) to the actual water balance and flows for 10/1/1990 - 9/30/1991. A variety of parameters relating to surface water runoff, water balance, and groundwater flows were adjusted within their reasonable range of values until the predicted flows adequately matched observed values. Some of these parameters represented groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow inflow, and length of assumed overland flow. Once the model had been calibrated for the subwatersheds contributing to stream flow at gage station #01607500, the results were validated using flow data at gage station #01608000 (above Moorefield), which is located downstream and encompasses a larger drainage area. Based on this validation and a verification that the parameter values were reasonable, it was determined that the model was adequately representing the hydrology of the South Fork.

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 uses were adjusted based on the data for the Hawes Run drainage area (which consists of primarily undisturbed forest land); these values were then applied to the other forested land in the remaining subwatersheds. The loading parameters for urban runoff were primarily based on literature values and the background concentration values were adjusted to match the available background (i.e., low flow) data from the 1996 and 1997 DEP monitoring data. Background concentration parameters for the nine different categories of agricultural lands 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 changed within a range of acceptable values, in a manner which retained consistency between relative contributions from the nine different agricultural groupings (see Table 3.2).

3.7 Existing Loadings

The model was run for the representative hydrologic period (October 1990 through September 1991). The modeling run represents the existing condition of bacteria concentrations and loadings at various reaches of the South Fork. For the existing conditions, the overall fecal coliform bacteria loadings by land-use category for the South Fork watershed are given in Table 3.3. A summary of the existing point source loading estimates is given in Table 3.4.

Table 3.3 Annual Nonpoint Source Fecal Coliform Bacteria Loading Factors.

Land Use Category	Annual Fecal Coliform Loading
Agriculture and Pasture	2.7975×10^{15} cfu
Forest Land	1.0990×10^{14} cfu
Urban	1.6974×10^{13} cfu

Table 3.4 Existing Annual Fecal Coliform Bacteria Point Source Loads for South Fork Watershed.

Point Source Facility Name	Annual Fecal Coliform Loading (cfu)	Flow Rate (cfs)	Effluent Concentration cfu/100 mL
Wampler-Longacre Chicken Inc. - Pipe	2.6052×10^{11}	2.072	14
Wampler-Longacre Chicken Inc. - Lot	2.8518×10^{11}	0.088	3629
Dept. of Navy-Naval Radio Station	1.3025×10^{11}	0.078	187
Moorefield Filtration Plant	1.7860×10^{9}	0.020	10
Hester Industries, Moorefield	4.7218×10^{10}	0.750	7
Brandywine Laundromat	NA	NA	NA
Pendleton County PSD	NA	NA	NA

A summary of West Virginia water quality standard violations for the selected representative hydrologic period is given in Table 3.5. All 15 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 3.5 that reaches in subwatersheds 1-9 are in violation of the 200 cfu/100 mL standard.

Table 3.5 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	15	2	17	4.66%
2	1	8	8	8	2.19%
3	1	8	8	8	2.19%
4	1	8	8	8	2.19%
5	1	8	8	8	2.19%
6	1	8	8	8	2.19%
7	2	2	2	4	1.10%
8	2	2	1	3	0.82%
9	2	2	1	3	0.82%
10	0	0	0	0	0.00%
11	0	0	0	0	0.00%
12	0	0	0	0	0.00%
13	0	0	0	0	0.00%
14	0	0	0	0	0.00%
15	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:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS$$

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 used for this TMDL analysis include the following:

- The discharge rates from the two chicken processing point sources in sub-watershed #1 were assumed to flow at a constant rate throughout the year. If this flow rate varies based on plant operations, the fecal coliform load may be substantially different from those used in the model.

- 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 future TMDL analyses to reflect the effectiveness of these BMPs.

4.2 Assessing Alternatives

For the allocation runs, the model was run for the same representative hydrologic 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 South Fork watershed are given in Table 4.1. An allocation reduction of 43.5% was applied to all agriculture and pasture lands in the 15 sub-watersheds for this TMDL. No reductions were applied to the urban and forest lands. These nonpoint source load allocations in conjunction with the point source waste load allocations given in Table 4.2 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. For the allocation run, the Wampler-Longacre Chicken, Inc. - parking lot discharge was reduced to zero flow and zero fecal coliform bacteria concentration. Although it did not contribute to exceedances of the 30-day geometric mean standard of 200 cfu/100 mL during the relatively high-flow periods, it elevated in-stream fecal coliform levels tremendously during low-flow periods. Under many circumstances these elevated concentrations may result in exceedances of the 200 cfu/100 mL 30-day geometric mean standard. The impact of these load reductions on the 30-day geometric mean of fecal coliform bacteria can be seen in the time-series plots presented in Appendix A for each of the 15 sub-watersheds.

Table 4.1 Fecal Coliform Bacteria Nonpoint Source Allocations for South Fork Watershed for representative hydrologic year (10/01/90 to 09/30/91).

Land Use	Loading for Existing Run	Loading for Allocation Run	Percent Reduction
Agriculture and Pasture	2.7975×10^{15} cfu/yr	1.5812×10^{15} cfu/yr	43.5%
Urban	1.6974×10^{13} cfu/yr	1.6974×10^{13} cfu/yr	0.0%
Forest	1.0990×10^{14} cfu/yr	1.0990×10^{14} cfu/yr	0.0%

Table 4.2 Fecal Coliform Bacteria Point Source Allocations for South Fork Watershed.

Point Source Facility Name	Existing			Allocation			Percent Reduction
	Loading (cfu/yr)	Flow Rate (cfs)	Effluent Conc. (cfu/100ml)	Loading (cfu/yr)	Flow Rate (cfs)	Effluent Conc. (cfu/100ml)	
Wampler-Longacre - Pipe	2.6052×10^{11}	2.072	14.08	2.6052×10^{11}	2.072	14.08	0.0%
Wampler-Longacre - Lot	2.8518×10^{11}	0.088	3629.0	0.0	0.0	0.0	100.0%
Dept. of Navy - Radio Station	1.3025×10^{11}	0.078	187.0	1.3025×10^{11}	0.078	187.0	0.0%
Moorefield Filtration Plant	1.7860×10^{9}	0.020	10.0	1.7860×10^{9}	0.020	10.0	0.0%
Hester Industries, Moorefield	4.7218×10^{10}	0.750	7.05	4.7218×10^{10}	0.750	7.05	0.0%
Brandywine Laundromat	NA	NA	NA	NA	NA	NA	NA
Pendleton County PSD	NA	NA	NA	NA	NA	NA	NA

5.0 SUMMARY

The South Fork South Branch Potomac River 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 South Fork watershed was divided into 15 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 half 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 15 sub-watersheds were in compliance with the fecal coliform bacteria standard of 200 cfu/100 ml geometric mean. The model analysis indicates that water quality standards will be achieved if (1) the point source loading of fecal coliform bacteria from the Wampler-Longacre Chicken, Inc. - parking lot discharge is reduced 100% and (2) if BMPs are implemented in the agriculture areas to reduce fecal coliform runoff by 43.5%. Time-series graphs of model results for each of the 15 subwatersheds are presented 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 two long-term stream USGS gages available in the South Fork watershed (#01607500 at Brandywine and #0160800 above Moorefield). Daily flow values from these gages were used to calibrate the hydrologic flow in the NPSM model thereby improving confidence in the computed stream flows in the model.

5.2.2 Fecal Coliform Monitoring

In general, fecal coliform data in the receiving waters in the South Fork 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 South Fork 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 assume[illegible]ailure rate of 2.5% for septic systems as well as the assumption of a fecal coliform concentration of 10[illegible] 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 Potomac Interagency Water Quality Office and were very useful for developing these TMDLs for fecal coliform bacteria. However, no information was available for the subwatersheds located in Pendleton County. This information should be assembled and incorporated into the watershed models for future TMDL analyses. Also, the upper-most portion of the South Fork watershed lies in Virginia and no agriculture information was incorporated into the NPSM model for this area. 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 this TMDL 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 for the entire South Fork basin. The upper reaches of the watershed are located over 40 miles from this rain gage and may experience different precipitation events than occur at Moorefield. Another rain gage, perhaps the one at Franklin, may be appropriate to use for precipitation affecting the upper reaches of the South Fork watershed.

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 South Fork 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 the Potomac Interagency Water Quality Office for this study for this study (i.e., estimates for the 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

Table A-1. NPSM Parameters for Fecal Coliform Bacteria Loading - Agriculture

Watershed	County	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
1	Hardy	5.67×10^{9}	5.67×10^{9}	5.11×10^{10}	3.8	28328	28328
2	Hardy	2.12×10^{9}	2.12×10^{9}	1.90×10^{10}	3.8	28328	28328
3	Hardy	2.00×10^{9}	2.00×10^{9}	1.80×10^{10}	3.8	28328	28328
4	Hardy	2.00×10^{9}	2.00×10^{9}	1.80×10^{10}	3.8	28328	28328
5	Hardy	5.57×10^{9}	5.57×10^{9}	5.01×10^{10}	3.8	28328	28328
6	Hardy	9.35×10^{9}	9.35×10^{9}	8.42×10^{10}	3.8	28328	28328
7	Pendleton	1.89×10^{9}	1.89×10^{9}	1.70×10^{10}	3.8	28328	28328
8	Pendleton	9.46×10^{9}	9.46×10^{9}	8.51×10^{10}	3.8	28328	28328
9	Pendleton	5.78×10^{9}	5.78×10^{9}	5.20×10^{10}	3.8	28328	28328
10	Pendleton	1.89×10^{9}	1.89×10^{9}	1.70×10^{10}	3.8	28328	28328
11	Pendleton	1.89×10^{9}	1.89×10^{9}	1.70×10^{10}	3.8	28328	28328
12	Pendleton	5.57×10^{9}	5.57×10^{9}	5.01×10^{10}	3.8	28328	28328
13	Pendleton	1.89×10^{9}	1.89×10^{9}	1.70×10^{10}	3.8	28328	28328
14	Pendleton	5.57×10^{9}	5.57×10^{9}	5.01×10^{10}	3.8	28328	28328
15	Pendleton	1.89×10^{9}	1.89×10^{9}	1.70×10^{10}	3.8	28328	28328

Table A-2. NPSM Parameters for Fecal Coliform Bacteria Loading - Forest

Watershed	County	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
1 - 6	Hardy	3.26×10^{7}	3.26×10^{7}	2.93×10^{8}	3.2	7832	7832
7 - 15	Pendleton	6.87×10^{7}	6.87×10^{7}	6.18×10^{8}	3.2	7832	7832

Table A-3. NPSM Parameters for Fecal Coliform Bacteria Loading - Urban (pervious)

Watershed	County	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
1 - 6	Hardy	5.01×10^{8}	5.01×10^{8}	4.51×10^{9}	4.2	28328	28328
7 - 15	Pendleton	5.01×10^{9}	5.01×10^{8}	4.51×10^{9}	4.2	28328	28328

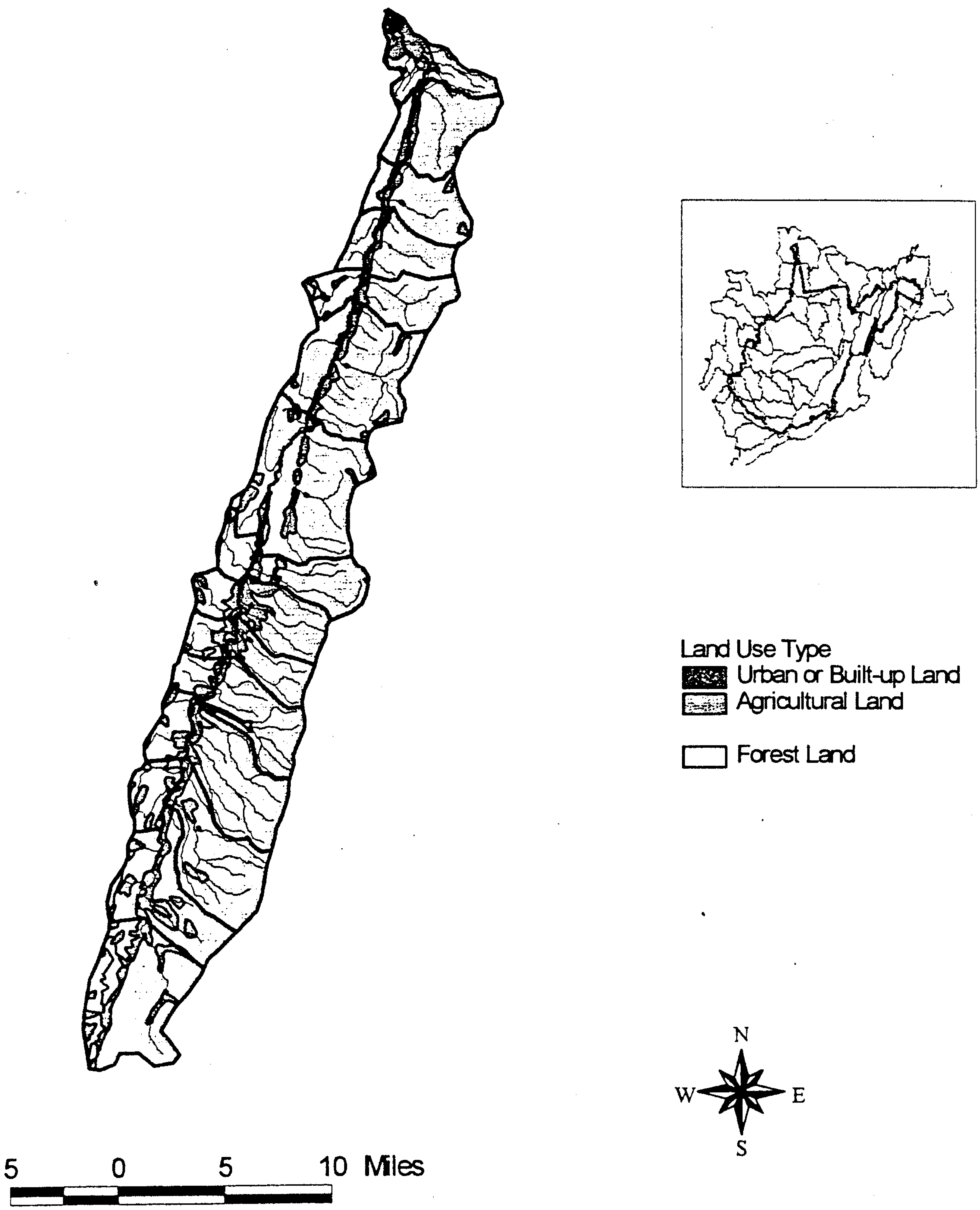
Table A-4. NPSM Parameters for Fecal Coliform Bacteria Loading - Urban (impervious)

Watershed	County	SQO	ACQOP	SQOLIM	WSQOP
1 - 6	Hardy	5.01×10^{8}	5.01×10^{8}	4.51×10^{9}	5.2
7 - 15	Pendleton	5.01×10^{8}	5.01×10^{8}	4.51×10^{9}	5.2

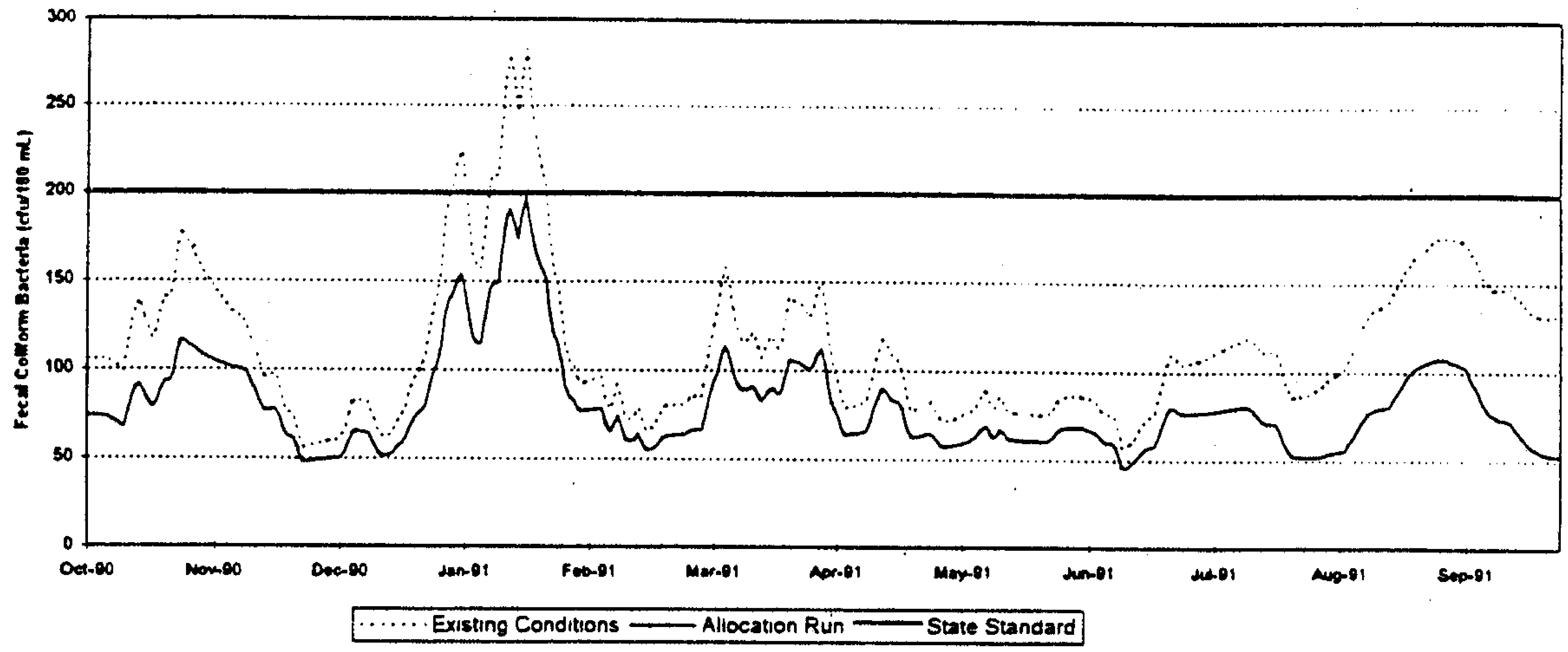
Table A-5. NPSM Fecal Coliform Bacteria Loading Parameter Definitions

Parameter	Definition	Units
SQO	Initial storage of fecal coliform bacteria on land surface	cfu / acre
ACQOP	Rate of fecal coliform bacteria accumulation on land surface	cfu / acre-day
SQOLIM	Maximum storage of fecal coliform bacteria on land surface	cfu / acre
WSQOP	Rate of surface runoff which removes 90% of stored fecal coliform bacteria	inches / hour
IOQC	Concentration of fecal coliform bacteria in interflow outflow	cfu / ft^3
AOQC	Concentration of fecal coliform bacteria in active groundwater outflow	cfu / ft^3

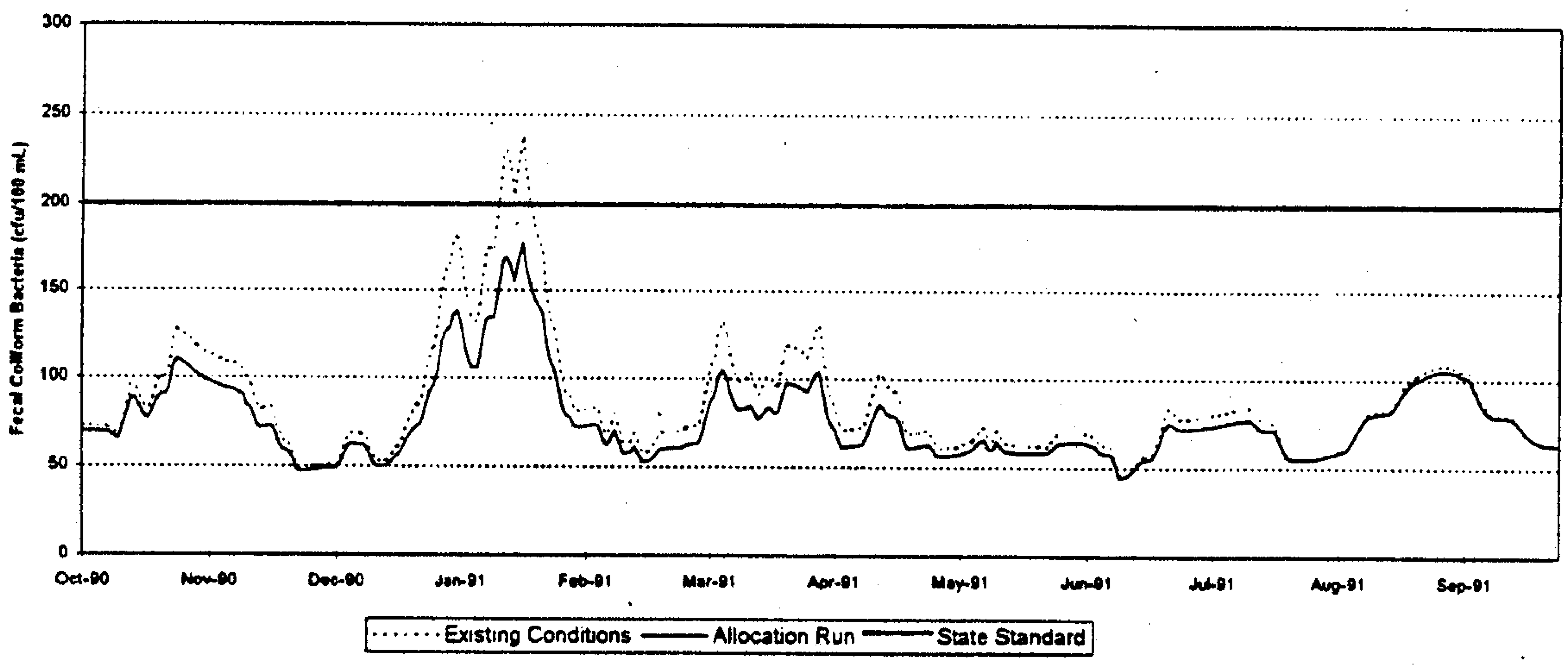
Land Use Types: South Fork South Branch Potomac River, West Virginia



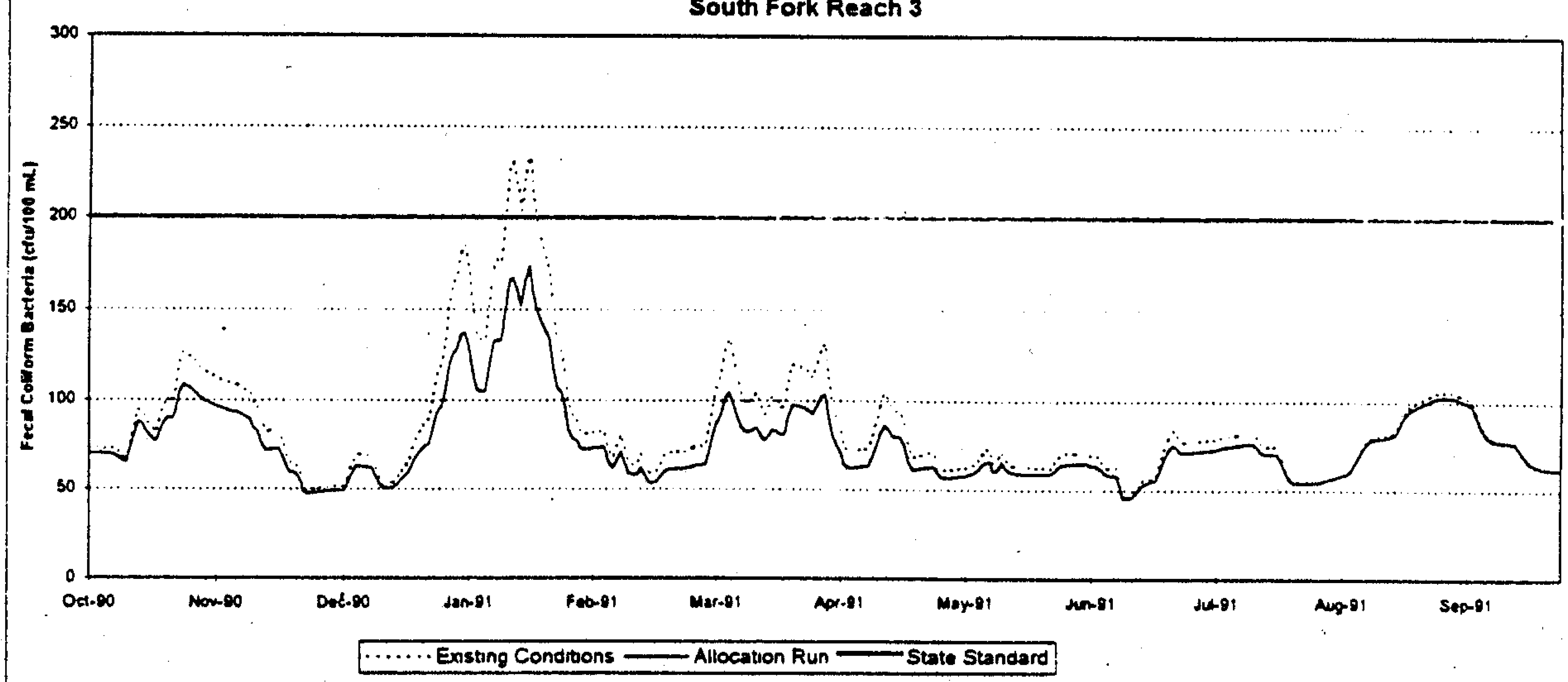
30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 1



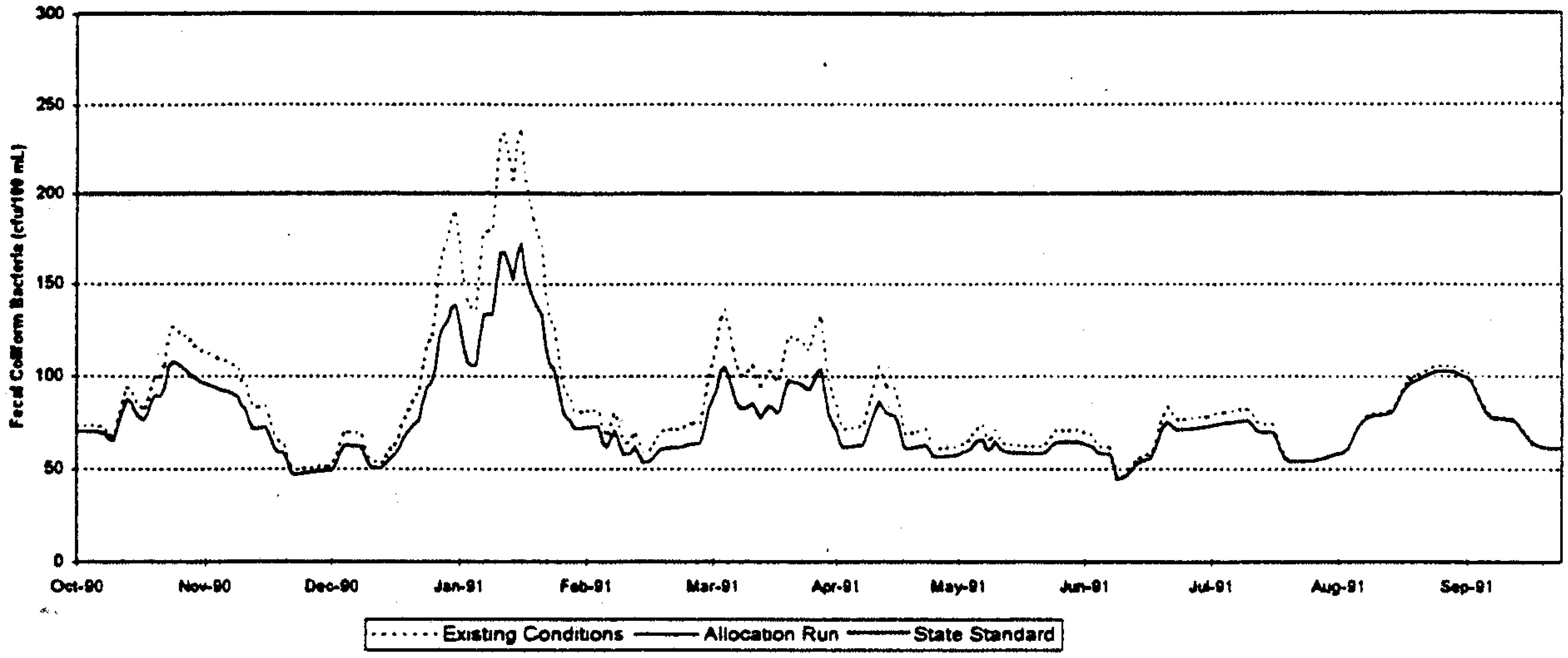
30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 2



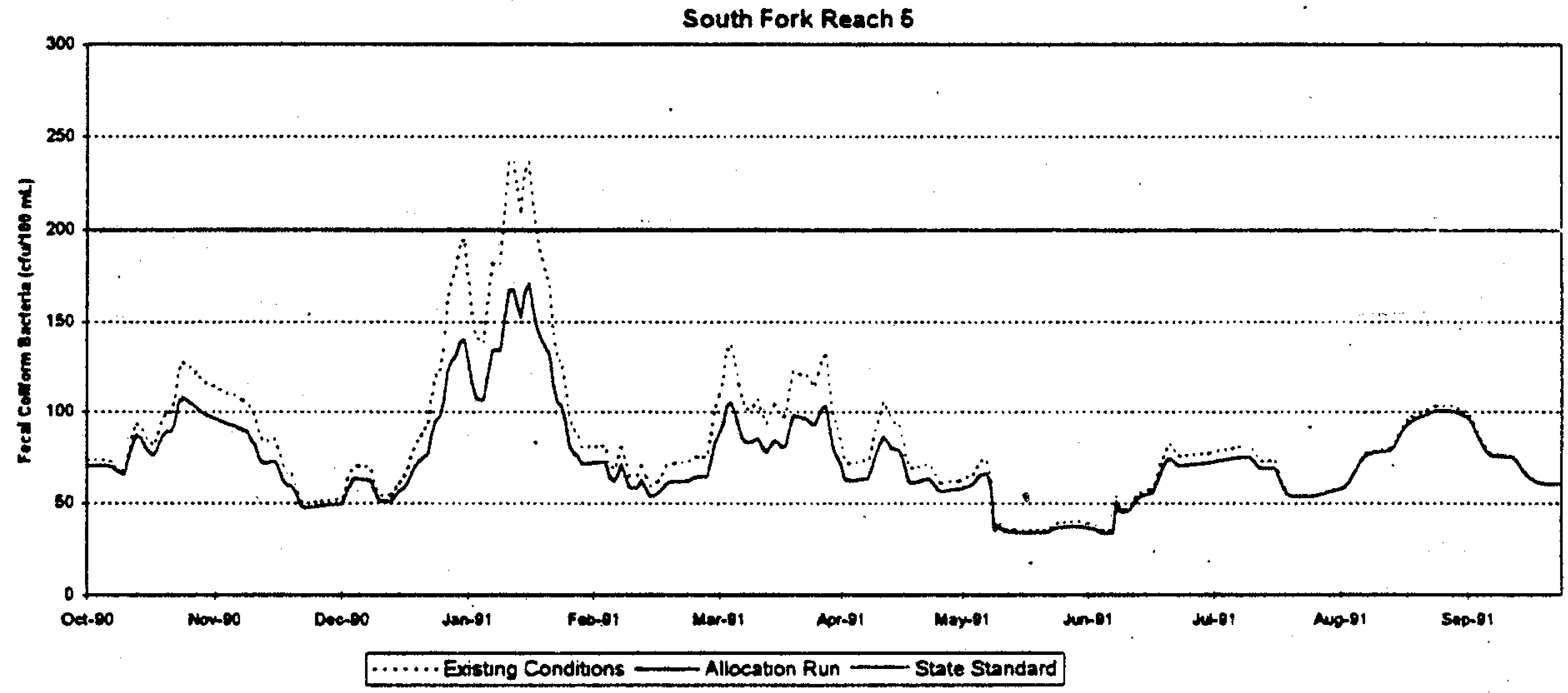
30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 3



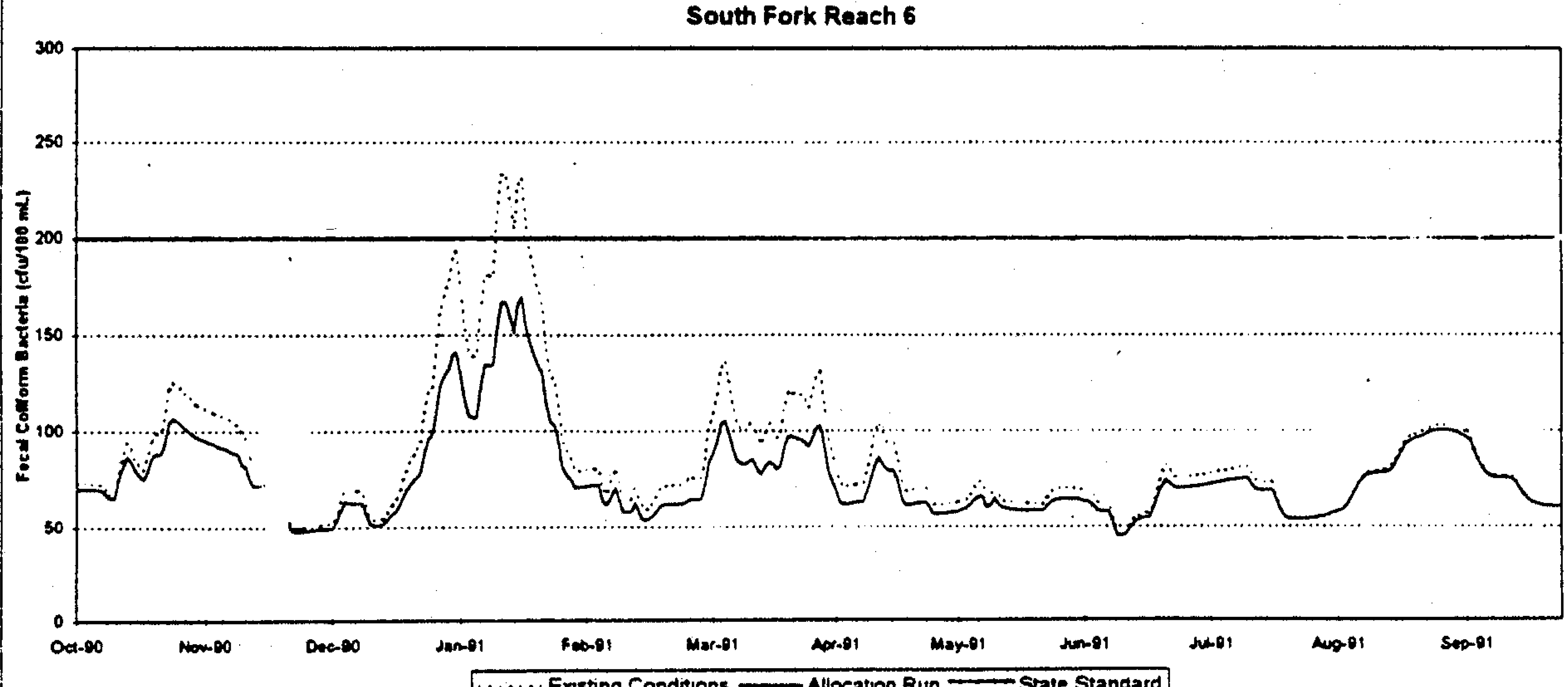
30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 4

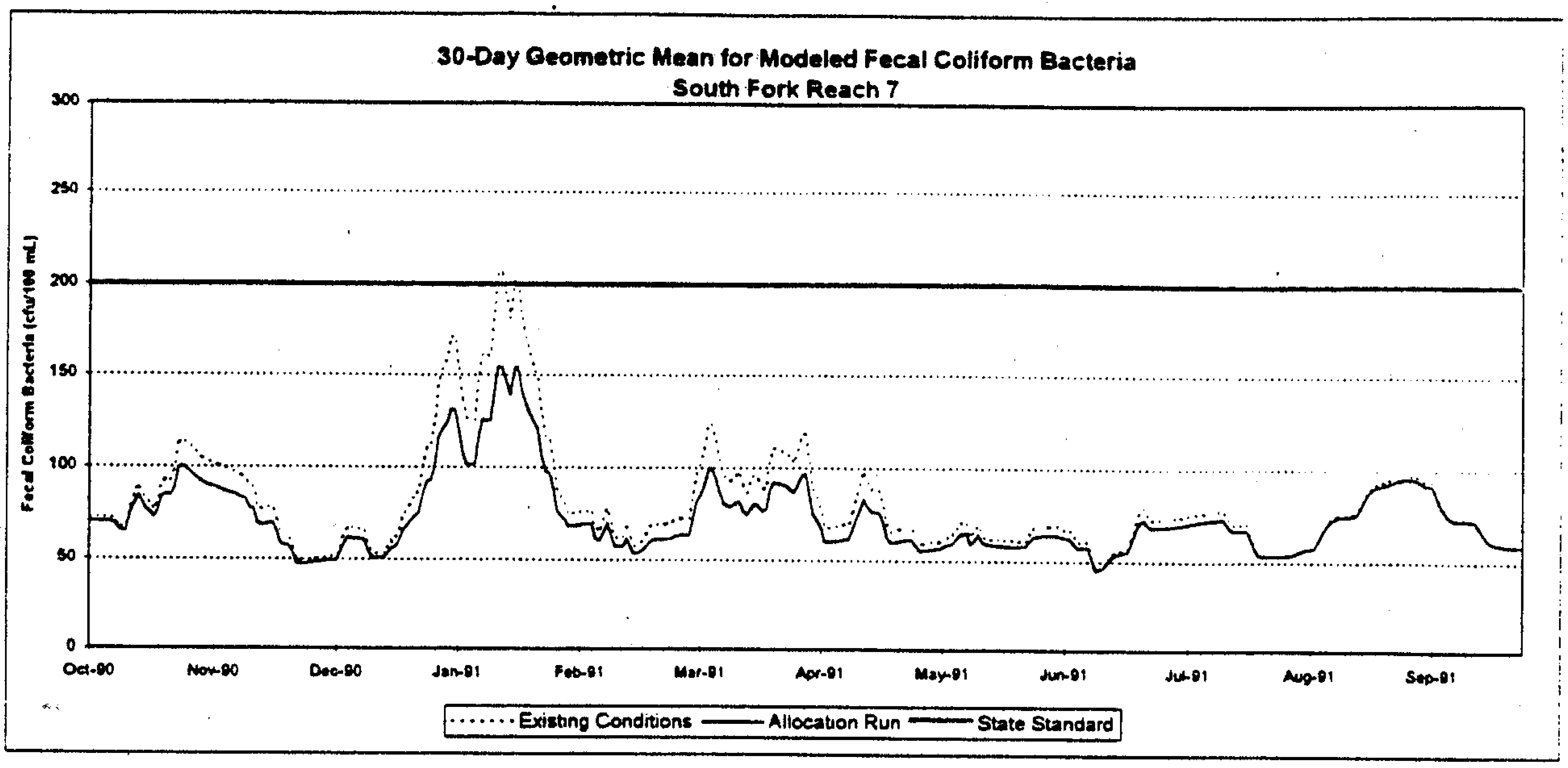


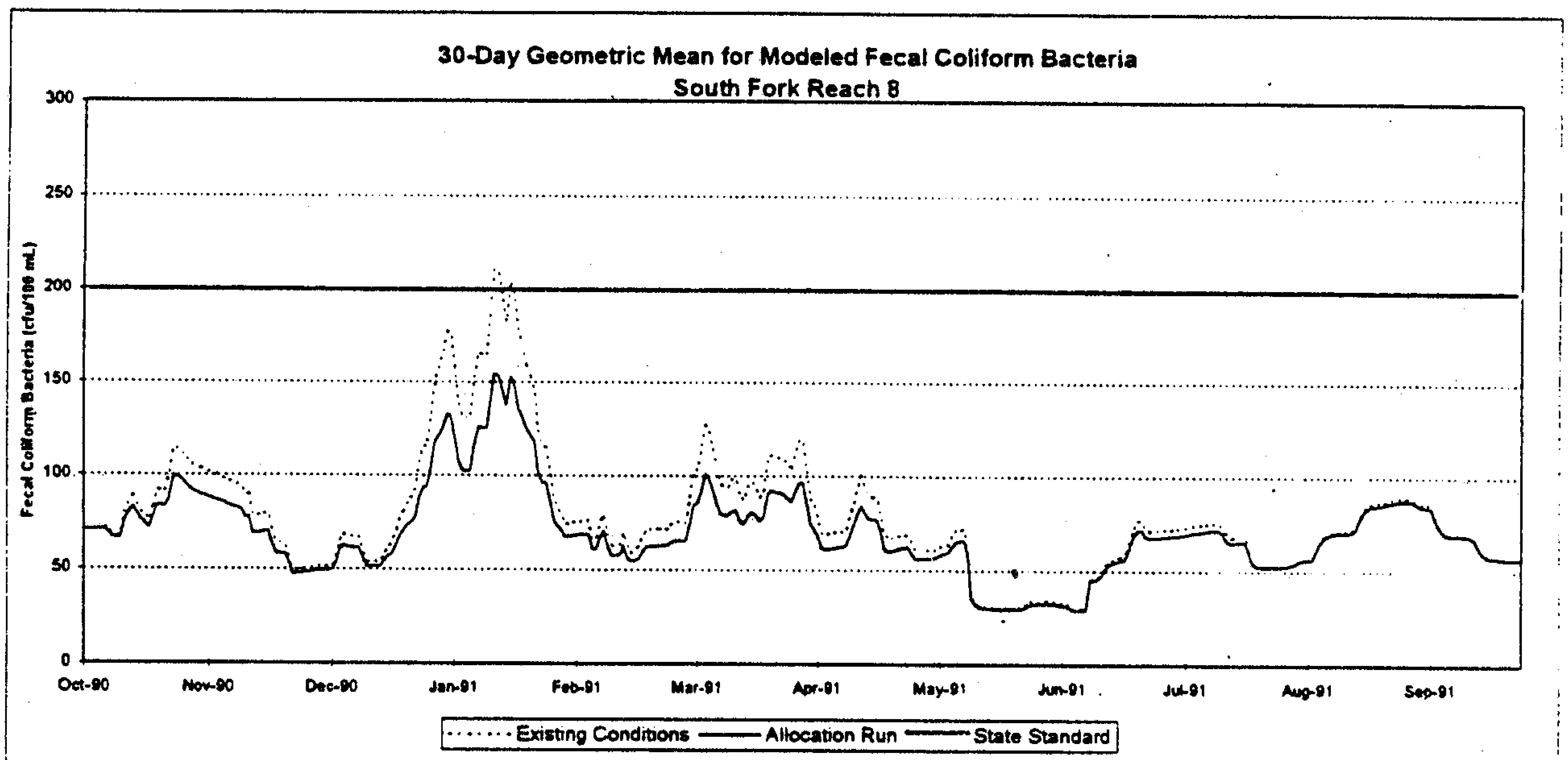
30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 5

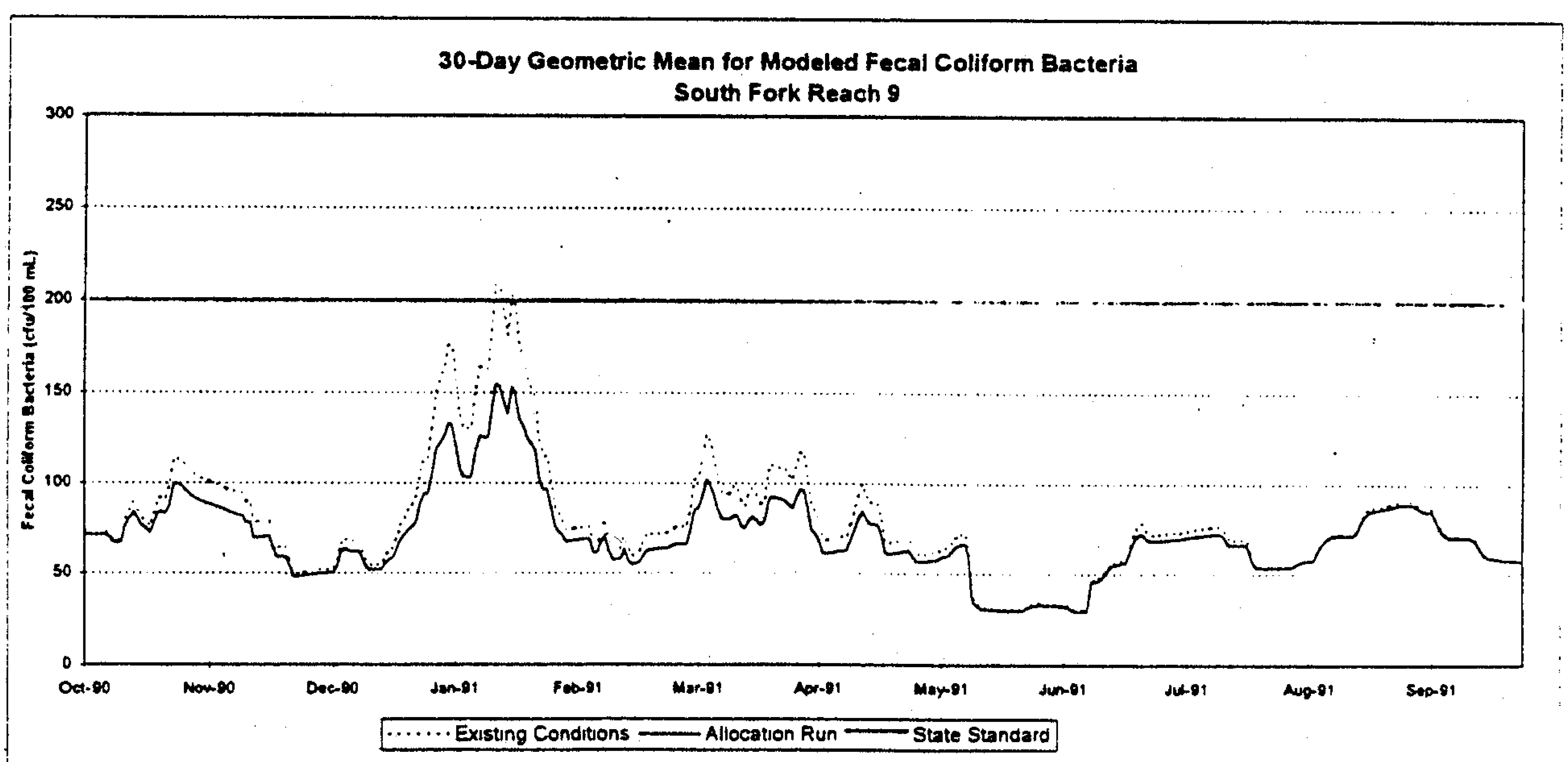


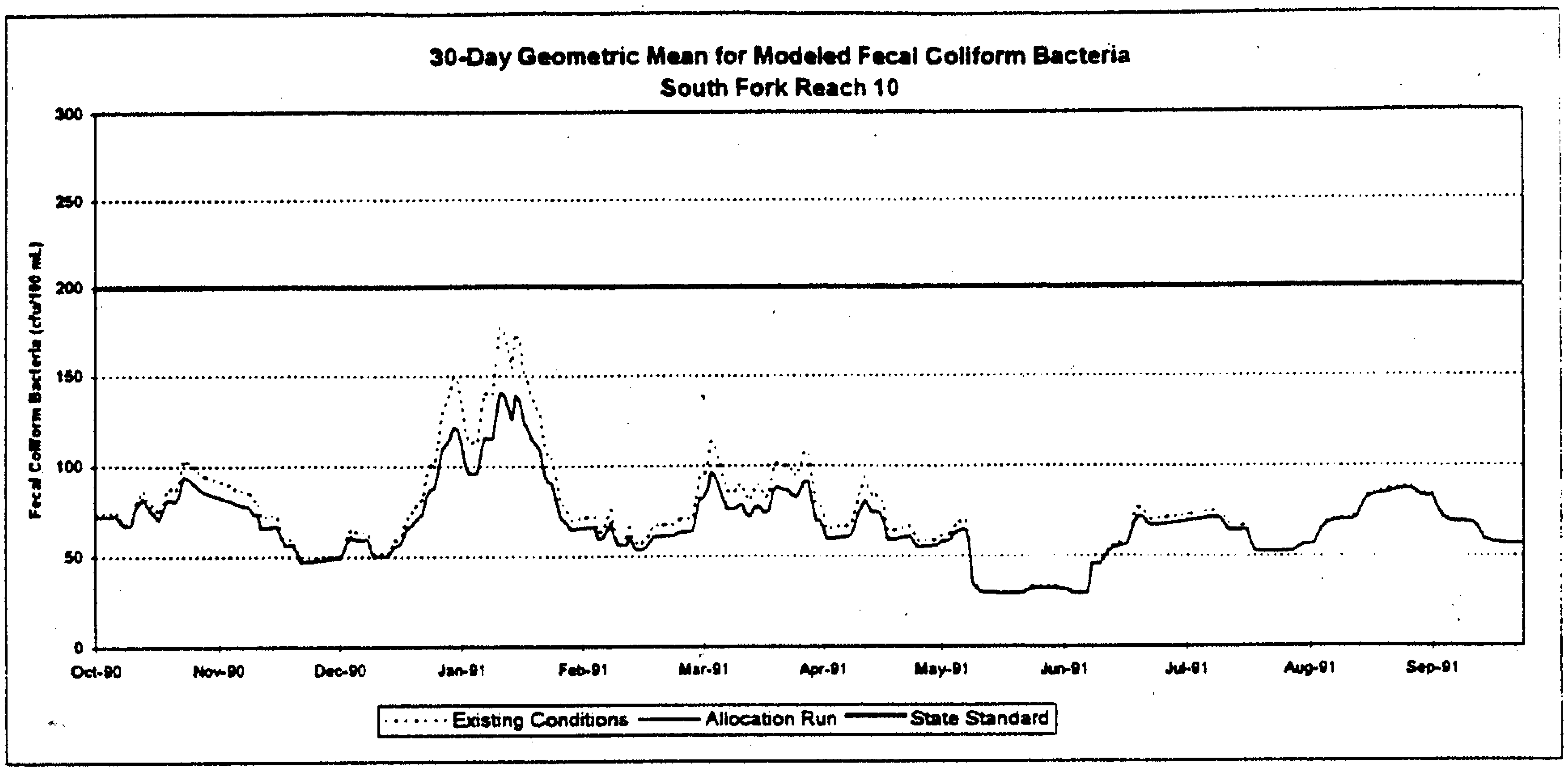
30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 6

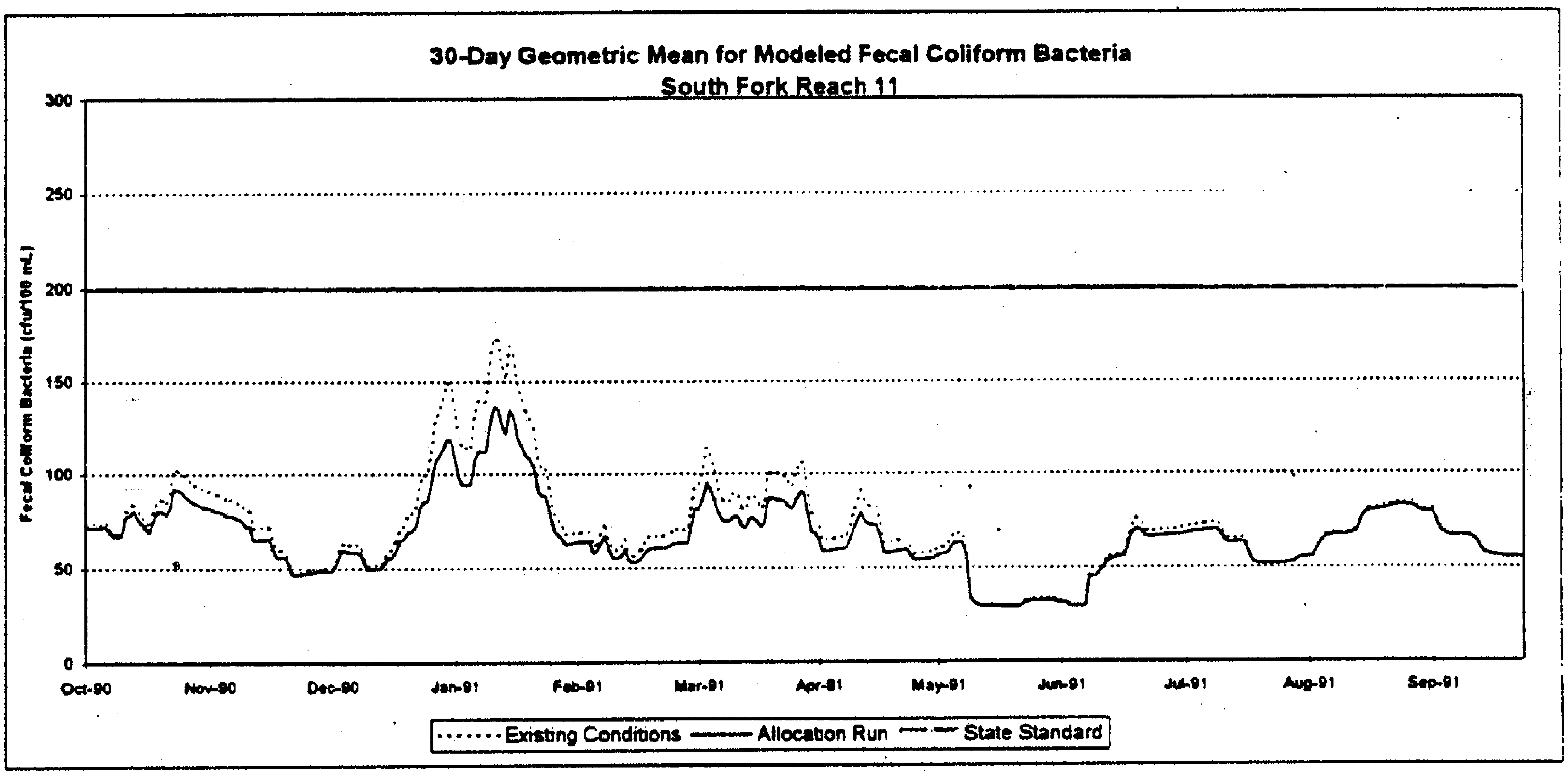


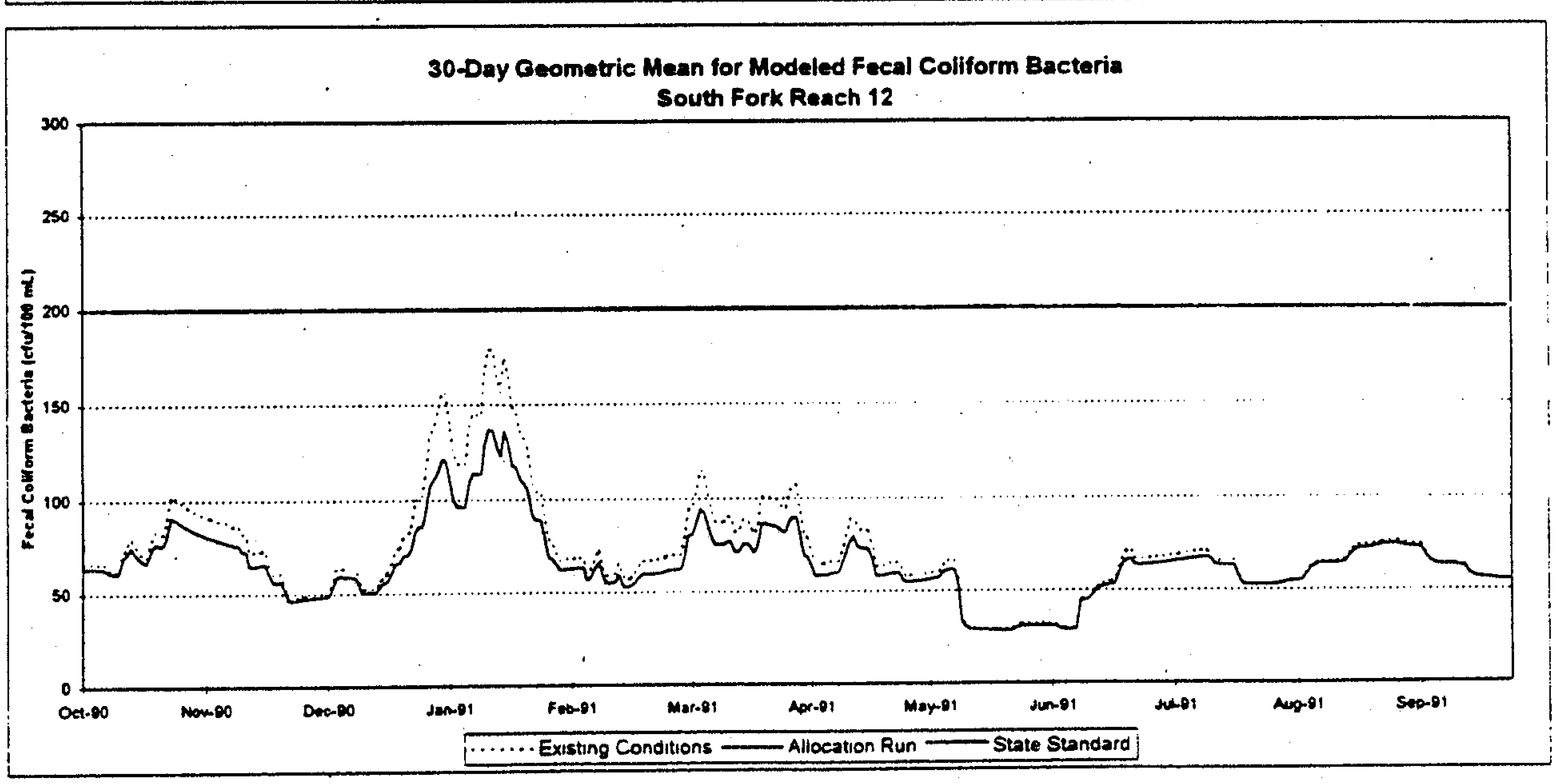

30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 7
Fecal Coliform Bacteria (cfu/100 mL)
0
50
100
150
200
250
300
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 8
Fecal Coliform Bacteria (cfu/100 mL)
0
50
100
150
200
250
300
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard

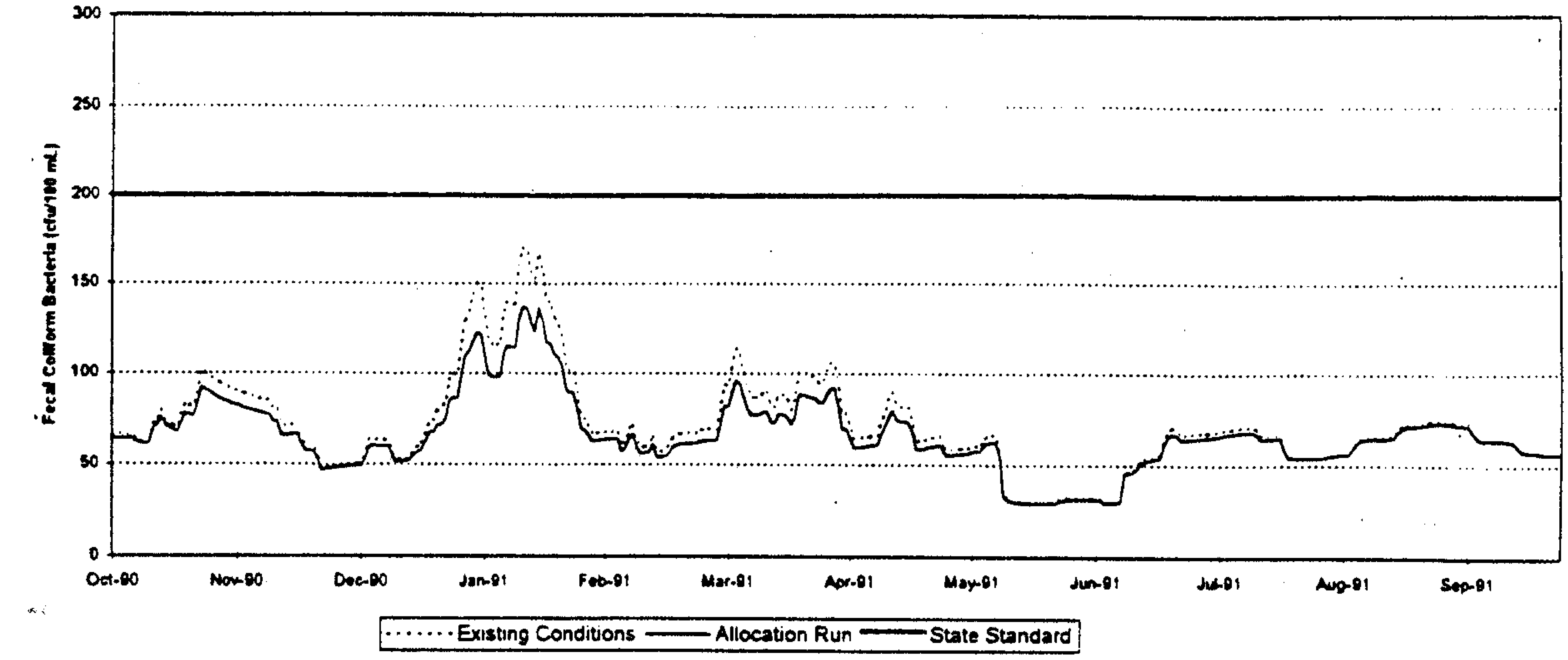

30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 9
Fecal Coliform Bacteria (cfu/100 mL)
0
50
100
150
200
250
300
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 10
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard

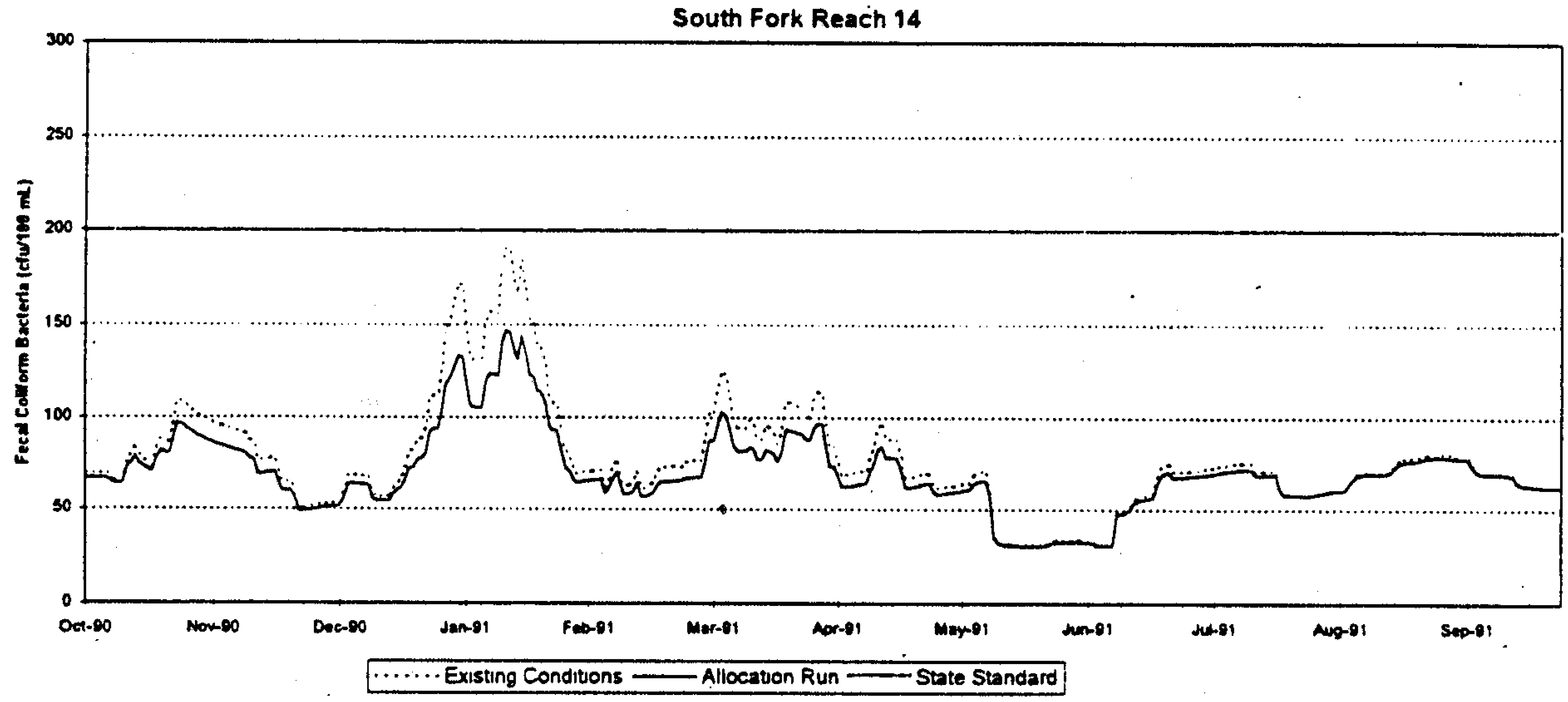

30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 11
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 12
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard

30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 13



30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 14



30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
South Fork Reach 15