Fecal Coliform TMDL Development for Lost River, Hardy County, West Virginia

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EXECUTIVE SUMMARY

The Lost River has been placed on the state of West Virginia's 303(d) list of water quality impaired waterbodies for fecal coliform bacteria. The applicable state standard specifies that the maximum allowable level of fecal coliform for primary contact recreation may not exceed 200 cfu/100 mL as a monthly geometric mean (based on not less than five samples per month). The fecal coliform content also may not exceed 400 cfu/100 mL (individual observation on a day) in more than 10 percent of all samples taken during any one month. A review of available monitoring data for the study area indicates that fecal coliform bacteria are occasionally elevated above the 200cfu/100 mL and 400-cfu/100 mL levels. In cases where a direct comparison with the standard of a geometric mean of 200cfu/100 mL of at least five samples in a 30-day period can be made, the geometric mean is in exceedance. With the majority of the observed data available, direct comparison cannot be made to the standard and, therefore, the elevated fecal coliform levels observed in the monitoring data might or might not indicate a water quality violation. For this study, the Lost River watershed was divided into 11 subwatersheds and the BASINS Nonpoint Source Model (NPSM) was selected as the modeling framework for performing the TMDL allocations.

Daily flow values from the USGS gage at McCauley (#01610200) were used to calibrate the hydrologic flow for the Lost River watershed in the NPSM model, thereby improving confidence in the computed stream flows in the model. The representative hydrologic year used for this TMDL was the 1990-91 water year.

A USGS monitoring study conducted in 1994-95 collected data once per month at 4 locations in the watershed over a 7-month period. The Cacapon Institute provided frequent sampling data with multiple samples in a month at many stations and some storm event sampling. Flow rates and fecal coliform bacteria concentrations from point source discharges in the study area are not generally well documented and reported in EPA's Permit Compliance System (PCS) database. The flow rates and fecal coliform concentrations were determined from available facility permits and monitoring reports, and the point sources were assumed to discharge at a constant flow rate throughout the year. The available water quality data were compared to the water quality output to calibrate the model.

Estimated number of failing septic systems in the watershed; numbers of geese, wild turkey, and deer; and numbers of cattle, feedlots, and poultry houses and information on manure management practices for the Lost River watershed were used to calculate fecal coliform loading from nonpoint sources in the watershed. The fecal coliform contribution from septic systems was estimated on the assumption of a 2.5% failure rate and a concentration of 10^4 cfu/100 mL in the septic overcharge. Wildlife contributions were based on best professional judgment and literature values on typical daily fecal coliform production based on animal species. Agricultural contributions considered manure practices (land application, litter transport out of the watershed). The estimated fecal coliform production and accumulation rates due to nonpoint sources were calculated for the watershed and incorporated into the model.

Output from NPSM indicated comparable violations of the 200 cfu/100 mL geometric mean standard in the majority of the watershed for the existing conditions using the representative time period (October 1990 through September 1991). After applying the load allocations, NPSM indicated that all 11 subwatersheds would be 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 fecal coliform loads from pastureland are reduced by 38.34%, loads from forestland are reduced by 12.8%, and loads from cropland are reduced by 37.75%. Time-series graphs of model results for each of the 11 subwatersheds are presented in Appendix C.

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 instream 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 1991).

The Lost River watershed lies in the Potomac headwaters in Hardy County, West Virginia. (Figure 1-1.) The Lost River flows northeast to the Cacapon River and then by way of the Potomac River to the Chesapeake Bay. The land area of the watershed is approximately 116,600 acres with forest and agriculture as the primary land uses. The Lost River is designated for the propagation and maintenance of fish and other aquatic life (Category B) and water contact recreation (Category C) and as a trout water (Category B-2) (WVEQB 1996).

1.2 Purpose of the Study

The objective of this study was to identify the background information and framework and develop a fecal coliform TMDL for the Lost River. The West Virginia Division of Environmental Protection (DEP) has identified the Lost River as being impacted by fecal coliform bacteria for a length of 26.03 miles, as reported on the 1998 303(d) list of water quality-limited waters (WVDEP 1998c). The Lost River is prioritized as "high" on the list and carries an agency code of PC-24.

The West Virginia state standard specifies that the maximum allowable level of fecal coliform for water contact recreation may not exceed 200 cfu/100 mL as a monthly geometric mean (based on not less than five samples per month) nor shall it exceed 400 cfu/100 mL in more than 10 percent of all samples taken during any one month (WVEQB, 1996). 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 in the Lost River watershed, indicated that one of the stations along Upper Cove Run, a tributary to the Lost River, had significant fecal coliform levels; more than 85% of the samples at the station had fecal coliform counts above 200 cfu/100 mL (PHIWQO 1996). The remaining three stations also had high percentages of samples above 200 cfu/100mL—28.6%, 28.6%, and 57.1% (Table 1.1 and Figure 1.2). The data collected during the 1994-95 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. When fewer than five samples are collected per month, the applicable standard becomes 400 cfu/100 mL.

All of the samples collected during the USGS study (7 samples at each of 4 sites) were not available in STORET. Of the data available in STORET, Table 1.2 displays the data available in STORET and compares it to the applicable water quality standard of "not to exceed 400 cfu/100 mL in more than 10% of the samples taken in any one month.

Table 1.1. Summary of fecal coliform levels from USGS 1994-1995 Lost River monitoring stations (as presented in PHIWQO, 1996).

Station ID	No. of Samples	Minimum	Median	Maximum	Percent >200
01610200	7	48	300	650	57.1
385048078522001	7	26	73	1,000	28.6
385230078514401	7	150	1,100	2,600	85.7
385800078495701	7	16	75	480	28.6

Source: PHIWQO, 1996.

Table 1.2. Summary of fecal coliform levels from the USGS monitoring stations, as available in STORET.

Station ID	No. of Samples	Minimum	Median	Maximum	Percent >400
01610200	5	48	300	4600	40
385048078522001	4	26	109	310	0
385230078514401	4	150	820	2,600	50
385800078495701	4	16	48	480	25

1.3 Selection of a TMDL Endpoint

One of the major components of a TMDL is the establishment of instream numeric endpoints, which 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 Lost River TMDL, the applicable endpoints and associated target values can be determined directly from the West Virginia standard for waters designated for water contact recreation. The West Virginia state standard specifies that the maximum allowable level of fecal coliform for primary contact recreation may not exceed 200 cfu/100 mL as a monthly geometric mean (based on not less than five samples per month). The fecal coliform content also may not exceed 400 cfu/100 mL (individual observation on a day) in more than 10 percent of all samples taken during any one month.

The dynamic modeling performed for the TMDL produces output continuously. This continuous output is a substantially larger amount of information than the limited number of samples normally taken in a month. Model results were compared to the 200 cfu/100 mL as a monthly geometric mean standard, which is more representative of the overall condition of the stream. That is, the allocation of loads will be distributed such that the fecal coliform levels in the Lost River will not exceed 200 cfu/100 mL as a monthly geometric mean based on not less than five samples per month or exceed 400 cfu/100 mL in more than 10 percent of all samples taken during any one month (WVEQB, 1996).

Figure 1.1. Study area: Lost River watershed, West Virginia.

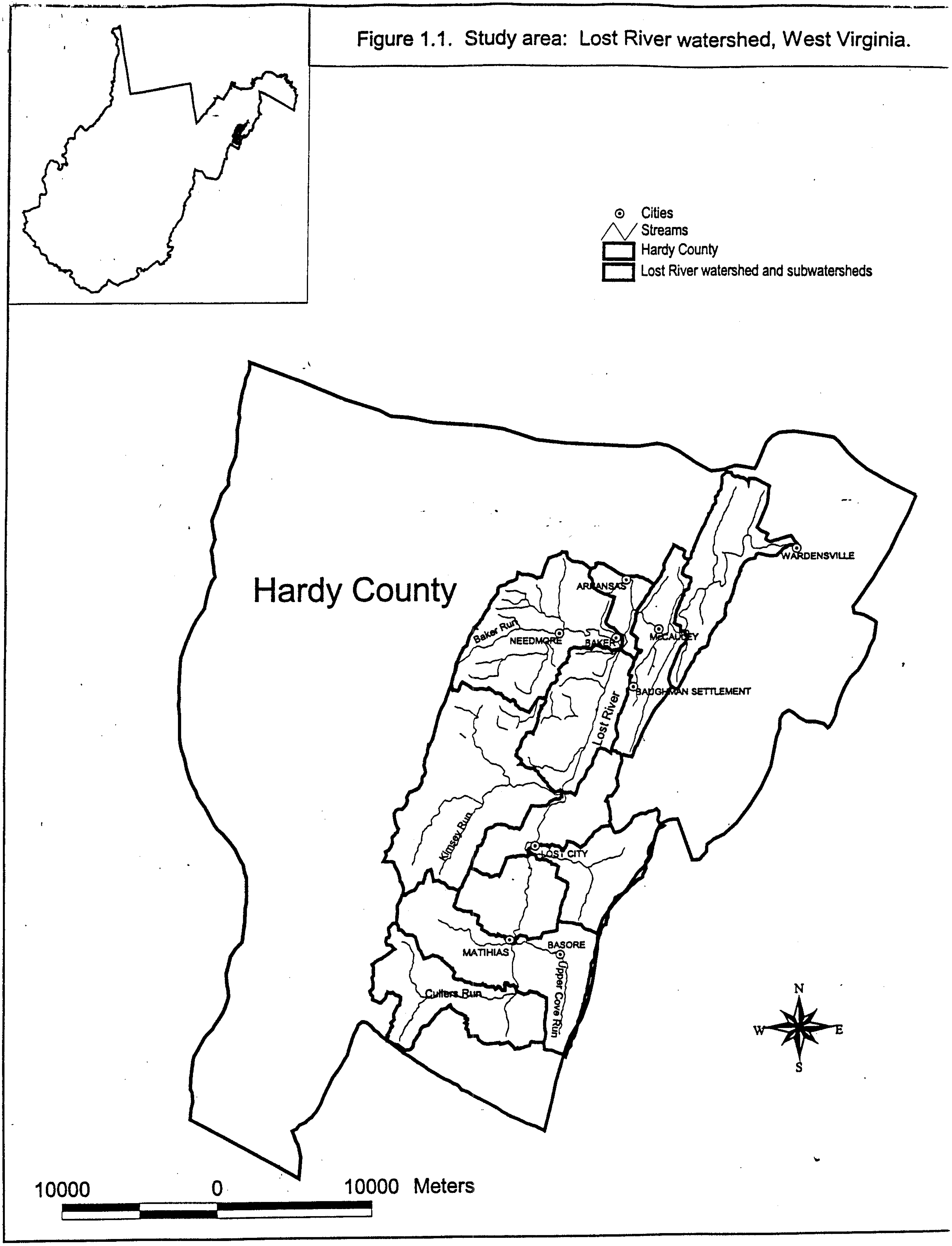
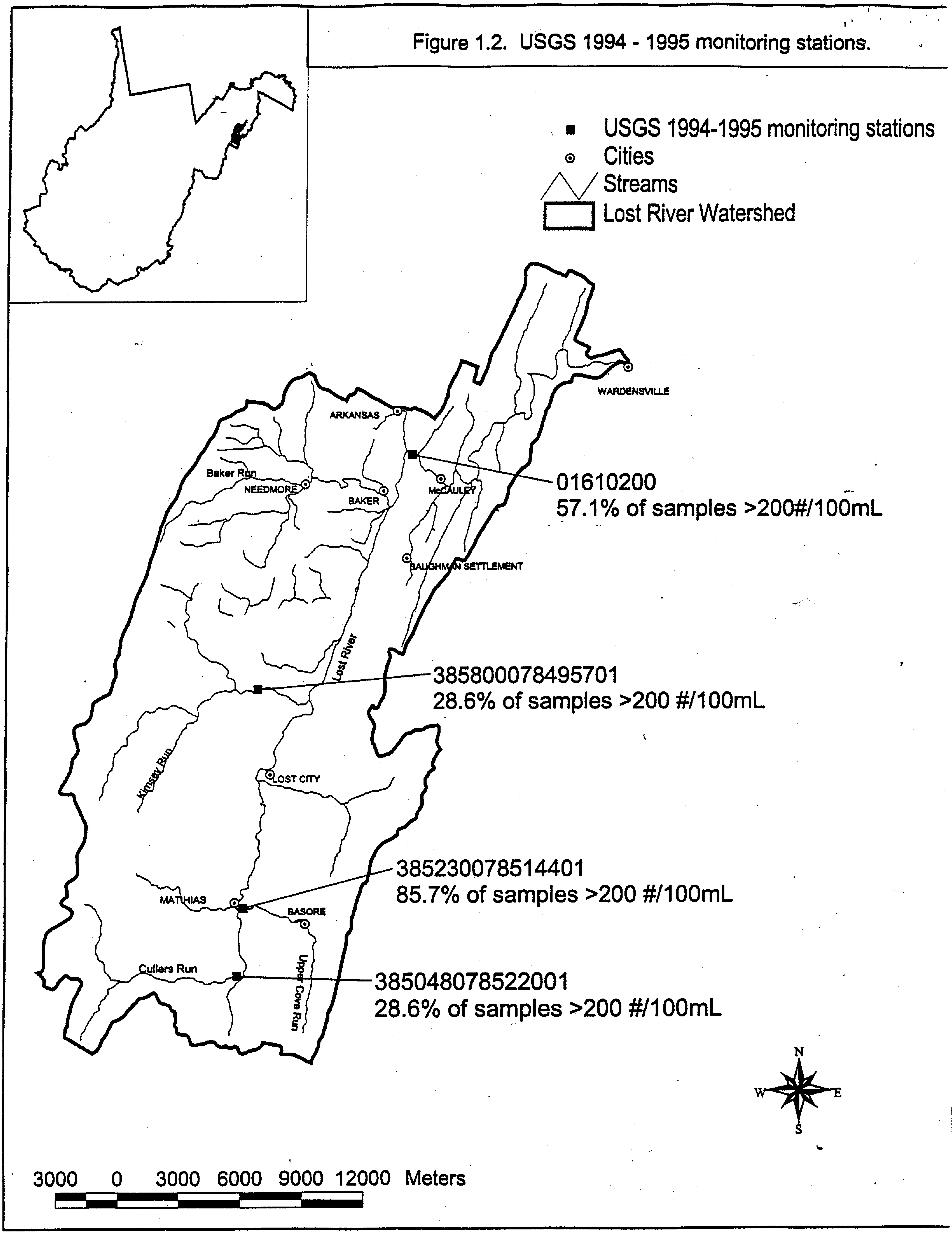


Figure 1.2. USGS 1994 - 1995 monitoring stations.



2.0 SOURCE ASSESSMENT

This section presents an overview of the instream water quality monitoring data available for the Lost River 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 sewage, urban storm water runoff, sanitary sewer overflows, combined sewer overflows (CSOs), and untreated domestic sewage. Potential nonpoint sources include manure disposal and runoff of animal waste from feedlots, disposal and handling of poultry litter, failing or ill-sited septic systems, runoff from pasturelands, application of manure or municipal sludge on cropland and other agricultural areas, and loadings from various wildlife species.

2.1 Instream Water Quality Monitoring Data

Periodic monitoring for fecal coliform bacteria at a number of locations in the Lost River watershed has been conducted over the years. Six historic monitoring sites in the watershed (with at least one fecal coliform bacteria data value) were found in STORET—five maintained by USGS and one by the West Virginia Division of Natural Resources (DNR). In addition to the stations listed in STORET, there are 11 monitoring stations within the Lost River watershed that are maintained by the Cacapon Institute as part of the Lost River Water Quality Study. A summary of the available monitoring data is listed in Table 2.1, with number of samples collected and minimum, median and maximum concentration values; station locations are shown in Figure 2.1. Time series plots of the fecal coliform data for eight of the Cacapon Institute stations (those with at least six samples) are shown in Figures 2.2 to 2.9 at the end of this section. From these figures it is apparent that individual sample points are occasionally and, at some stations, frequently in exceedance of the state water quality standard. At some Cacapon Institute stations there are sufficient samples to allow direct comparison to the water quality standards. The geometric means of five samples collected within 30 days are listed in Table 2.2, and all exceed the state standard. The flows measured with these samples were varied and somewhat higher than other reported values. The sampling conditions were varied, with samples collected during and following a large storm, a small storm and days with no rain. At most stations, it is not possible to compare sample concentrations to the state standard of 200 cfu/100mL as a geometric mean of at least five samples in a 30-day period. When fewer than five samples are collected per month, the applicable standard becomes 400 cfu/100 mL in no more than 10% of the samples.

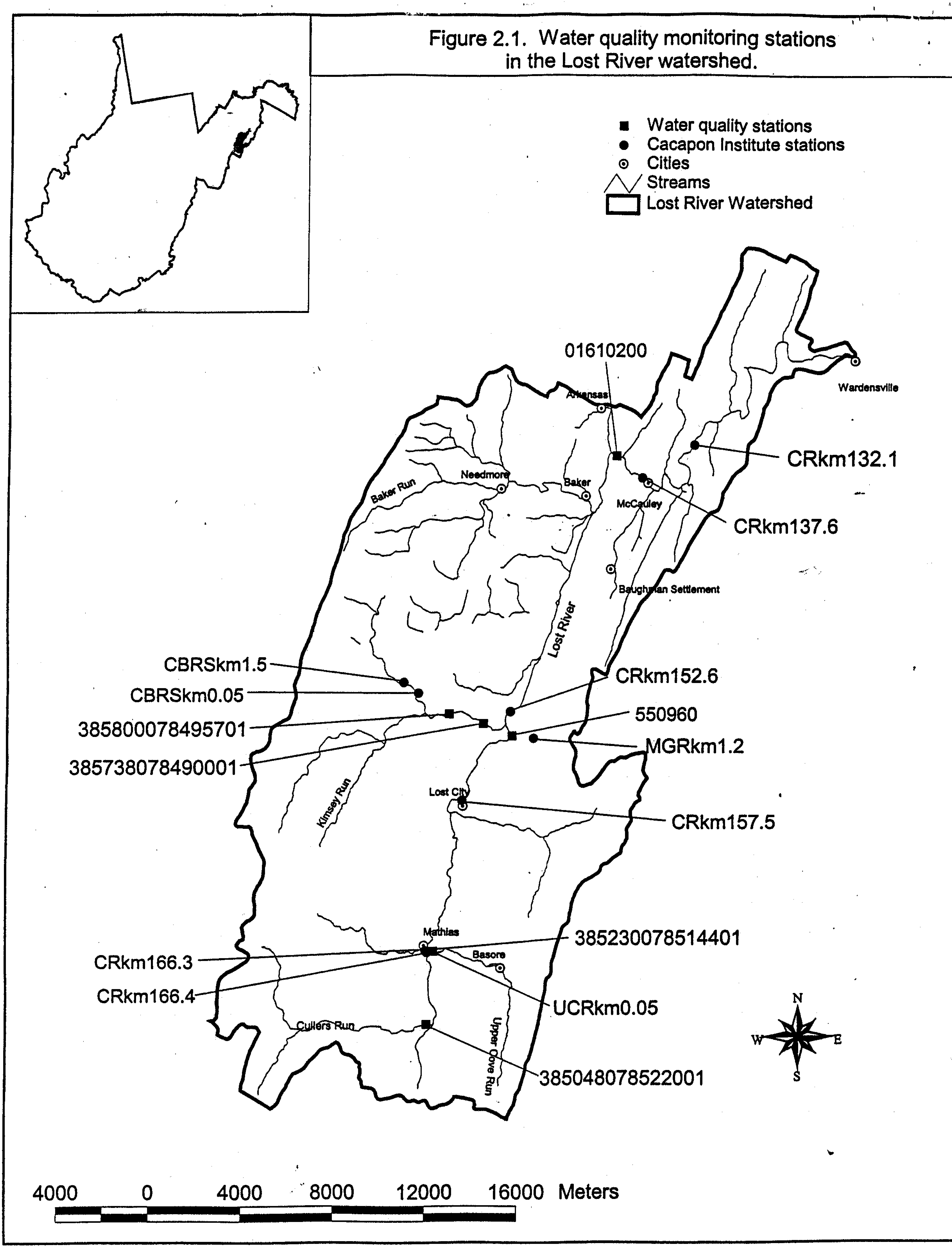
Table 2.1. Summary of fecal coliform levels from Lost River monitoring stations.

Station ID	Period of record	n	Min	Median	Max	Percent >400 cfu/100mL
01610200	10/2/74 - 8/30/95	30	18	225	1,400	30
385048078522001	3/23/95 - 8/30/95	4	26	109	310	0
385230078514401	3/23/95 - 8/30/95	4	150	820	2,600	50
385738078490001	10/26/88 - 9/5/89	10	1	12	1,400	10
385800078495701	3/23/95 - 8/30/95	4	16	47.5	480	25
550960	8/28/47 - 10/20/49	3	510	1,100	3,900	100
CBRSkm0.05	10/27/97 - 11/7/97	3	227	1,667	2,700	100
CBRSkm1.5	11/1/97	1	1,433	1,433	1,433	100
CRkm132.1	7/16/96 - 3/2/98	20	3	49.5	1,600	20
CRkm137.6	9/29/97 - 3/23/98	22	17	466	52,000	50
CRkm152.6	9/29/97 - 3/23/98	19	13	200	39,000	31.6
CRkm157.5	7/16/96 - 3/23/98	34	17	205	27,800	29.4
CRkm166.3	9/29/97	1	7,500	7,500	7,500	100
CRkm166.4	10/20/97 - 3/23/98	20	66.5	908.5	21,000	60
CuRkm0.4	1/19/98 - 3/23/98	6	28	63.5	103	0
MGRkm1.2	10/27/97 - 3/23/98	7	7	53	1,000	14.3
UCRkm0.05	10/27/97 - 3/23/98	9	23	310	2,500	33.3

Table 2.2. Geometric means of five samples collected within 30 days at selected Cacapon Institute monitoring sites.

Site	Sample collection dates	Geometric mean (cfu/100mL)
CRkm137.6	11/1/97 - 11/24/97	786.78
CRkm137.6	1/6/98 - 1/26/98	599.76
CRkm152.6	11/1/97 - 11/24/97	221.45
CRkm157.5	11/1/97 - 11/24/97	338.93
CRkm166.4	11/1/97 - 11/24/97	948.64
CRkm166.4	3/2/98 - 3/23/98	2,020.22
UCRkm0.05	2/25/98 - 3/23/98	344.49

Figure 2.1. Water quality monitoring stations in the Lost River watershed.



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, although usually not discharged intentionally, can reach waterbodies through leaks in sanitary sewer systems, overflows from surcharged sanitary sewers (noncombined sewers), illicit connections of sanitary sewers to storm sewer collection systems, or unidentified broken sanitary sewer lines.

Two schools and a continuous care center discharge to the receiving waters of Lost River. Table 2.3 lists the point source dischargers and permit information and Figure 2.10 shows their discharge locations. Names and locations of EPA Permit Compliance System (PCS) dischargers in the watershed were obtained from the PCS database. Although PCS contained no permit or effluent monitoring information, facility permits and monitoring reports for the facilities provided information on permits and facilities operation (WVDEP 1998a, 1998b). The permit for the Hardy County Board of Education includes package plants for two schools—East Hardy High School and East Hardy Early/Middle School. The E.A. Hawse Continuous Care Center (AMFM of Hardy County, Inc.), a nursing home with 50 retirement units, discharges to the Lost River at mile 7.8 (WVDEP 1998a). The facility has a 1.25-acre stabilization pond and uses ultraviolet (UV) disinfection to treat the wastewater effluent. Only two Discharge Monitoring Reports (DMR) for the facility were obtained—one for the fourth quarter of 1995 and one for the first quarter of 1996. The December 1995 DMR indicated a grab sample fecal coliform level of 660 counts/100 mL, violating the instantaneous maximum limit of 500 counts/100 mL. The March 1996 DMR reported a fecal coliform level of only 25 counts/100 mL.

The sewage collection and treatment system at East Hardy High School is a 5,000-gallon per day (GPD) system consisting of a 5,000-gallon aeration tank, an 835-gallon clarifier, and tablet-type chlorine disinfection with a 308-gallon contact tank. The treated wastewater is discharged to Baker Run at mile 1.4 from its confluence with the Lost River. The sewage collection and treatment system for East Hardy Early/Middle School is a 6,000-GPD system consisting of approximately 320 linear feet of 4-inch PVC sewer line, 600 linear feet of 6-inch PVC sewer line, one manhole, six cleanouts, a 2,000-gallon flow equalization tank, a 6,000-GPD extended aeration "package" plant with a 6,000-gallon aeration tank and a 1,000-gallon clarifier, and tablet-type chlorine disinfection with a 188-gallon contact tank. The system discharges the treated wastewater to Baker Run, 2 miles from its confluence with the Lost River. A DMR for the fourth quarter of 1997 was available for each of these facilities under the Hardy County Board of Education permit. Both reported fecal coliform levels below 200 counts/100 mL.

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

Figure 2.10. Point source dischargers in the Lost River watershed.

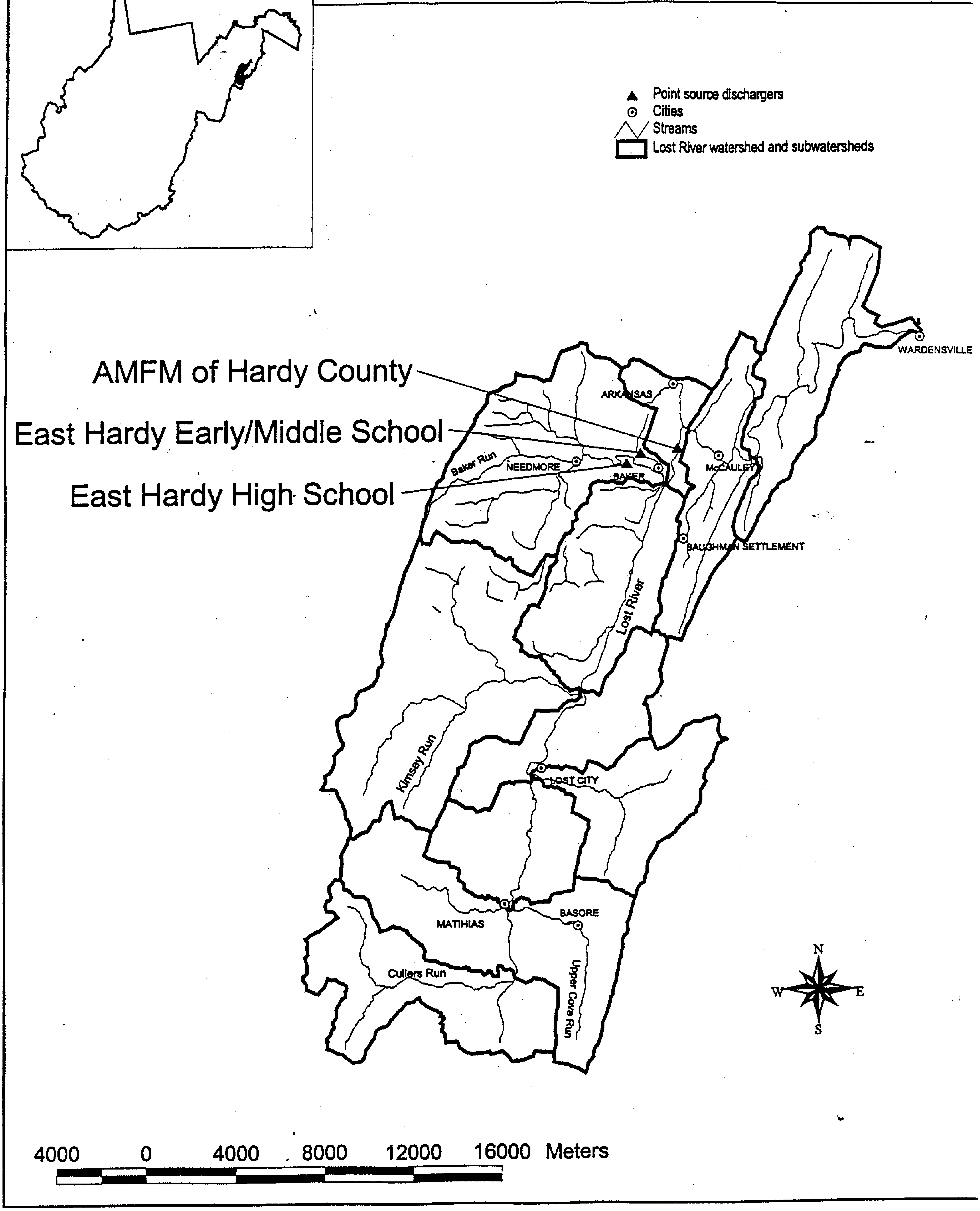


Table 2.3 Municipal and industrial dischargers in the Lost River watershed.

NPDES No.	Facility Name	Permitted Flow (gpd)	Fecal Coliform Permit Limit (cfu/100 mL)		
			Average Monthly	Daily Maximum	Instantaneous Maximum
WV0100960	East Hardy High School	5,000	200	400	N/A
WV0100960	East Hardy Early/Middle School	6,000	200	400	N/A
WVG550120[a]	AMFM of Hardy County (E.A. Hawse Continuous Care Center)	20,500	200	400	500

[a]Registration number under the General WV/NPDES permit no. WV0103110

2.3 Assessment of Nonpoint Sources

Nonpoint sources of fecal coliform bacteria are typically separated into urban and rural components. In urban or residential 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.

To spatially analyze the bacteria loading, the Lost River watershed was divided into 11 subwatersheds (Figure 2.11). The land uses in each of those subwatersheds were determined using data from the USGS Land Cover Characterization Program (USGS 1997). As part of the Land Cover Characterization Program, a National Land Cover Dataset is being developed. The Federal Region III Land Cover Dataset (USGS 1998), which uses Multiresolution Landscape Characterization (MRLC) data, was used to determine land use coverage in the Lost River. The more specific MRLC land use categories were then grouped into broader categories for modeling purposes. The grouped land uses are listed in Table 2.4 for each subwatershed. See Appendix A for specific MRLC land use areas by subwatershed.

Onsite septic systems are the predominant form of domestic wastewater treatment in Hardy County and in the Lost River watershed. In addition to failing septic systems, straight pipe discharges contribute fecal coliform loads to receiving waterbodies. There is no apparent threat posed by straight pipe discharges in the Lost River watershed, where the majority of the houses are built away from the river (WVDEP 1998d). No information was available on the specific locations of septic systems, septic tank densities, or failure rates (WVDEP 1998d). However, according to the 1990 US Census data, 3,431 housing units in Hardy County use septic systems for sewage disposal. A septic system failure rate of 2.5% was estimated for Hardy County. The 2.5% failure rate represents the 2.0% failure rate calculated for Hardy county in NSFC (1993) plus an additional 0.5% corresponding to a 25% margin of safety, accounting for older and unpermitted tanks. The failure rate was used to estimate the number of failing septic systems in the Lost River watershed. Using county-level and subwatershed-level land use data, the

Figure 2.11. Subwatersheds of the Lost River watershed.

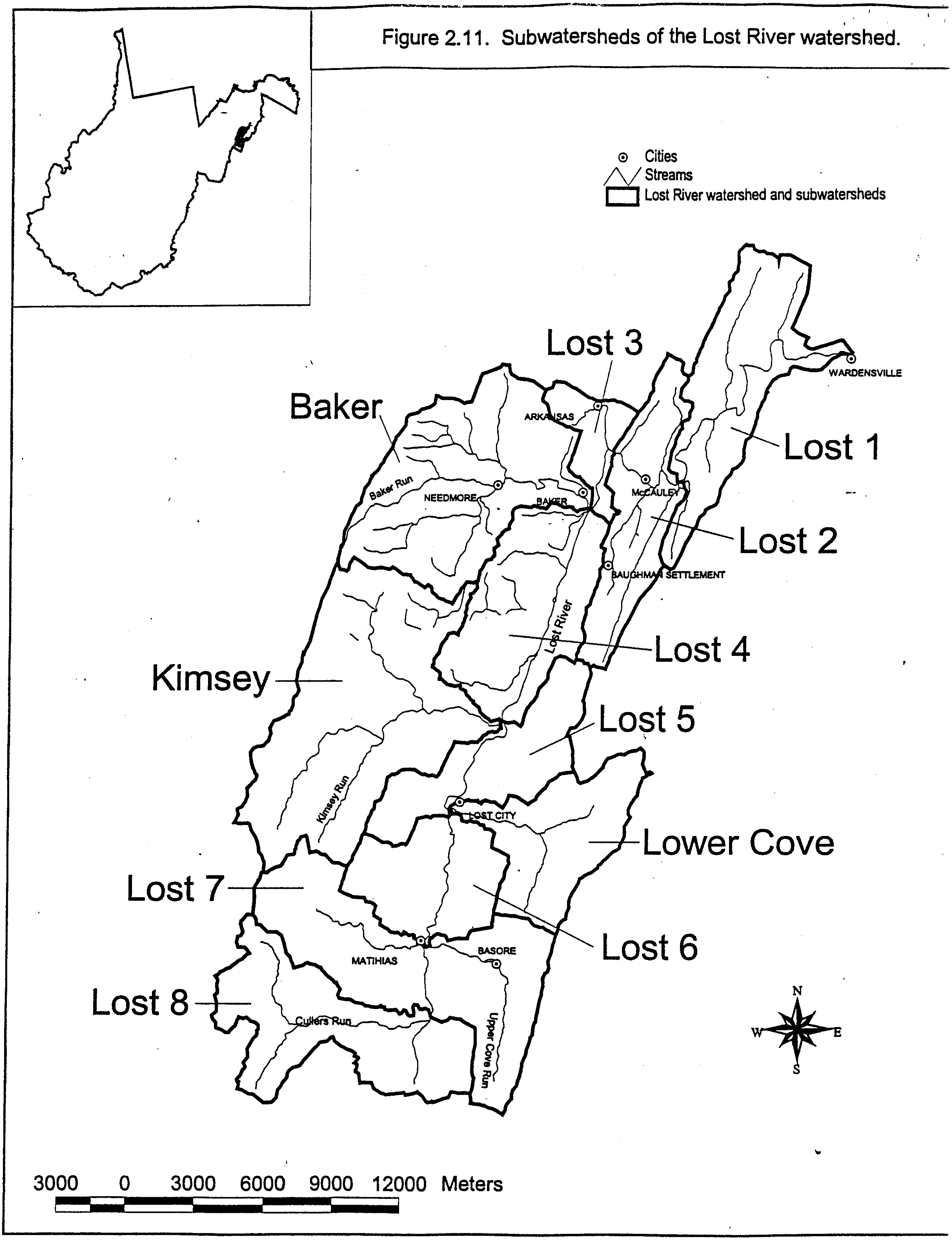


Table 2.4. MRLC land use distributions for the 11 Lost River subwatersheds.

Subwatershed ID	Residential (acres)	Barren (acres)	Forest (acres)	Pasture (acres)	Cropland (acres)	Other Rural (acres)	TOTAL (acres)
Lost 1	4.00	4.67	9,890.12	281.33	52.49	3.11	10,235.72
Lost 2	0.89	3.11	7,041.69	412.99	15.35	1.78	7,475.80
Lost 3	4.45	10.9	2,223.06	442.79	50.48	10.01	2,741.68
Baker	19.35	79.62	12,986.75	2,374.51	156.12	1.11	15,617.46
Lost 4	9.34	35.58	8,714.54	1,741.8	394.97	15.35	10,911.58
Kimsey	11.12	213.05	18,423.41	1,879.68	157.68	1.11	20,686.06
Lost 5	19.57	245.52	6,108.52	769.04	212.61	4.23	7,359.49
Lower Cove	7.78	1.33	7,104.18	832.65	22.91	0.44	7,969.30
Lost 6	25.35	12.01	5,760.03	1,208.49	167.91	9.12	7,182.91
Lost 7	39.81	9.34	12,880.22	1,982.87	177.25	1.56	15,091.05
Lost 8	10.23	121.65	9,741.34	1,254.75	119.87	2.00	11,249.84
TOTAL	151.9	736.79	100,873.85	13,180.90	1527.63	49.82	116,520.89

number of failing septic systems in each subwatershed was then estimated proportionally based on residential land area (Table 2.5). In representing the fecal coliform contribution from failing septic systems, it was also assumed that 100% of the fecal coliform load reached the receiving waters at a concentration of 10^4 cfu/mL (Metcalf & Eddy 1991). The 10^4 cfu/mL (10^6 cfu/100 mL) concentration is the low end of a range of typical values of fecal coliform concentration for raw sewage (Metcalf & Eddy 1991) and was chosen to account for die-off of bacteria during transport to receiving water. The assumed septic system waste flow was based on a typical value of 70 gallons per capita per day (Horsley & Whitten 1996), and an average of 2.5 persons per household served was estimated based on 1990 Census data.

West Virginia DNR provided estimates of the number of geese in the Lost River watershed. DNR estimated a range of 60 to 70 geese in the watershed, noting that winter populations could be substantially lower, maybe even zero. To provide a margin of safety and to conservatively account for migratory patterns, it was assumed that the geese population is 70 year-round. It was assumed that all fecal coliform from geese were deposited on the land surface and delivered to the stream via overland flow. Considering that most fecal contributions from geese would be directly in the waterbody or in close proximity to it, this assumption could offset an overestimation of the goose population. The numbers of deer and wild turkey in the Lost River watershed were estimated using the *Big Game Bulletin* for 1997 (WVDNR 1997). WVDNR estimates the deer population for Hardy County as 10 times the number of bucks killed in the county during the buck gun-hunting season (Personal communication, Stephen Stutler, WV DEP, June 24, 1998). The county estimate was then used to determine the number of deer in each subwatershed based on the number of deer per acre of forestland. From a statewide

Table 2.5. Inventory of wild animals and failing septic systems in Lost River watershed.

Subwatershed	Area (acres)	Deer	Geese	Wild Turkey	Failing Septic Systems
Lost 1	10,235.72	1162	7	107	0
Lost 2	7,475.80	827	5	76	0
Lost 3	2,741.68	261	2	24	1
Baker	15,617.46	1526	9	140	2
Lost 4	10,911.58	1024	6	94	1
Kimsey	20,686.06	2165	13	199	1
Lost 5	7,359.49	718	4	66	2
Lower Cove	7,969.30	835	5	77	1
Lost 6	7,182.91	677	4	62	3
Lost 7	15,091.05	1514	9	139	4
Lost 8	11,249.84	1145	7	105	1
TOTAL	116,520.89	11854	71	1089	14

population estimate of 140,000 wild turkeys (WVDNR 1997) and statewide land use information, subwatershed numbers of wild turkey were estimated based on density of animals per acre of forest. Bear estimates indicated approximately nine in the watershed, and they were therefore not explicitly included in the analysis. Wildlife counts for each subwatershed are listed in Table 2.5. The wildlife population estimates were used to calculate the available fecal coliform from wildlife.

The numbers of cattle and broilers, breeders, and turkeys in the subwatersheds were used to estimate the amount of waste and, in turn, the amount of fecal coliform available on agricultural lands in each watershed. The Natural Resource Conservation Service (NRCS) provided estimates of feedlots and poultry houses based on preliminary subwatersheds (NRCS 1998). Those subwatersheds were further divided, and the numbers of feedlots and poultry houses were distributed among them proportionally using relative densities of houses and feedlots in the appropriate areas, based on a map of locations of poultry houses and feedlots in the Lost River watershed in a Potomac Valley Soil Conservation District report (PVSCD 1995). Table 2.6 contains the distribution of poultry houses and feedlots throughout the Lost River watershed.

To estimate the amount of waste produced, the number of cattle in each subwatershed was estimated. The West Virginia Soil Conservation Agency (WVSCA) estimated the number of cattle in the Lost River watershed at between 6,000 and 8,000 from the 1995 agricultural census (WVSCA 1998). It was assumed that there were 8,000 cattle in the watershed and that those cattle were distributed among the feedlots and the pastureland. To estimate the number of cattle per subwatershed, a density of one cow per 4 acres of pastureland was assumed. After distribution of cattle throughout the pastureland, the

Table 2.6. Inventory of poultry houses and cattle feedlots in Lost River watershed.

Subwatershed	Area (acres)	Poultry houses			Cattle Feedlots
		Broiler	Breeder	Turkey	
Lost 1	10,235.72	1	1	0	1
Lost 2	7,475.80	1	1	0	1
Lost 3	2,741.68	4	0	0	1
Baker	15,617.46	27	8	0	4
Lost 4	10,911.58	17	5	7	6
Kimsey	20,686.06	12	8	0	1
Lost 5	7,359.49	2	6	11	6
Lower Cove	7,969.30	1	2	3	2
Lost 6	7,182.91	2	1	2	1
Lost 7	15,091.05	21	6	11	7
Lost 8	11,249.84	16	4	8	5
TOTAL	116,520.89	104	42	42	35

remaining cattle and the total number of feedlots in the watershed were used to determine the average number of cattle per feedlot. That density was then used to determine the total number of cattle in feedlots in each subwatershed. The distribution of cattle between pastures and feedlots and the total number of cattle per subwatershed are listed in Table 2.7. NRCS provided estimated averages of litter production (tons/year) for each type of poultry house—165 tons/year/broiler house, 100 tons/year/breeder house, 120 tons/year/ turkey house (NRCS 1998). Using these estimates and the number of poultry houses to calculate the total litter produced in each subwatershed, it was unnecessary to determine the actual number of birds per subwatershed.

Using available information on poultry, cattle, wildlife, and failing septic systems, daily fecal coliform loads were computed for each subwatershed. The average fecal coliform loading rates for the various animals used for the total load calculation are given in Table 2.8. The fecal coliform production rate for deer was assumed to be greater than that of a turkey but less than that of a beef cow, both rates which were available from the Metcalf & Eddy (1995) reference. The rate for deer was then determined by linear interpolation using the typical animal weights and their fecal coliform production rates. A beef cow was assumed to weigh 1400 lb, a turkey 25 lb, and a deer 125 lb. The "known" fecal coliform production rates for the beef cow and turkey were 5.4×10^9 and 0.13×10^9 cfu/day, respectively. The interpolation method gives a rate of 0.5×10^9 cfu/day for deer.

The total potential fecal coliform production per subwatershed for each of the animal categories is given in Table 2.9. It is important to understand that the values in Table 2.9 are the "potential" fecal coliform loads from various nonpoint sources and not necessarily the loads that reach the receiving waters within the watershed (with the exception of the septic load, which is assumed to be the load reaching the stream). Various processes and agricultural management practices will reduce these loads before they reach surface waters. These factors are accounted for and represented in the model setup and source representation, as discussed in Section 4.0.

Table 2.7. Inventory of cattle in Lost River watershed.

Subwatershed	Total Area (acres)	Pastureland (acres)	Number of Feedlots	Cattle in Pastures	Cattle in Feedlots	Total Cattle
Lost 1	10,235.72	281.33	1	70	134	204
Lost 2	7,475.80	412.99	1	103	134	237
Lost 3	2,741.68	442.79	1	111	134	245
Baker	15,617.46	2,374.51	4	594	538	1132
Lost 4	10,911.58	1,741.8	6	435	807	1242
Kimsey	20,686.06	1,879.68	1	470	134	604
Lost 5	7,359.49	769.04	6	192	807	999
Lower Cove	7,969.30	832.65	2	208	269	477
Lost 6	7,182.91	1,208.49	1	302	134	436
Lost 7	15,091.05	1,982.87	7	496	941	1437
Lost 8	11,249.84	1,254.75	5	314	673	987
TOTAL	116,520.89	13,180.90	35	3,295	4,705	8,000

Table 2.8. Estimated fecal coliform production rates.

Animal	Fecal Coliform Production Rate	Fecal Coliform Content of Feces	Reference
Cow	5.4×10^9 cfu/day	0.23×10^6 cfu/g	Metcalf & Eddy, 1991
Chicken	0.24×10^9 cfu/day	1.3×10^6 cfu/g	Metcalf & Eddy, 1991
Turkey	0.13×10^9 cfu/day	0.29×10^6 cfu/g	Metcalf & Eddy, 1991
Goose	49.0×10^9 cfu/day	N/A	LIRPB, 1982
Deer	0.50×10^9 cfu/day	N/A	Best professional judgment

Table 2.9. Potential nonpoint source fecal coliform production in Lost River watershed.

Subwatershed	Cow (#/day)	Poultry (#/day)	Geese (#/day)	Deer (#/day)	Wild Turkey (#/day)	Septics (#/day)	Total (#/day)
Lost 1	1.10E+12	7.69E+11	1.96E+11	5.81E+11	1.39E+10	0.00E+00	2.66E+12
Lost 2	1.28E+12	7.69E+11	1.47E+11	4.14E+11	9.88E+09	0.00E+00	2.62E+12
Lost 3	1.33E+12	1.78E+12	4.90E+10	1.31E+11	3.12E+09	1.32E+08	3.29E+12
Baker	6.11E+12	1.46E+13	2.45E+11	7.63E+11	1.82E+10	2.64E+08	2.18E+13
Lost 4	6.70E+12	9.52E+12	1.96E+11	5.12E+11	1.22E+10	1.32E+08	1.69E+13
Kimsey	3.26E+12	7.93E+12	3.43E+11	1.08E+12	2.59E+10	1.32E+08	1.26E+13
Lost 5	5.39E+12	3.35E+12	9.80E+10	3.59E+11	8.58E+09	2.64E+08	9.21E+12
Lower Cove	2.58E+12	1.23E+12	1.47E+11	4.18E+11	1.00E+10	1.32E+08	4.38E+12
Lost 6	2.36E+12	1.31E+12	9.80E+10	3.39E+11	8.06E+09	3.96E+08	4.11E+12
Lost 7	7.76E+12	1.18E+13	2.45E+11	7.57E+11	1.81E+10	5.28E+08	2.06E+13
Lost 8	5.33E+12	8.80E+12	1.96E+11	5.73E+11	1.37E+10	1.32E+08	1.49E+13
Total	4.32E+13	6.19E+13	1.96E+12	5.93E+12	1.42E+11	2.11E+09	1.13E+14

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. Graphs of corresponding flow and fecal coliform levels for 5 stations within the watershed are in Appendix B. Thus, it is the high-flow, storm event conditions that 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 causes large concentrations of fecal coliform bacteria to occur in the receiving waters. During dry periods, little or no land-based runoff occurs, 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 1991 water year, from October 1990 through September 1991, was selected as the most representative of an average meteorologic year for the Lost River watershed.

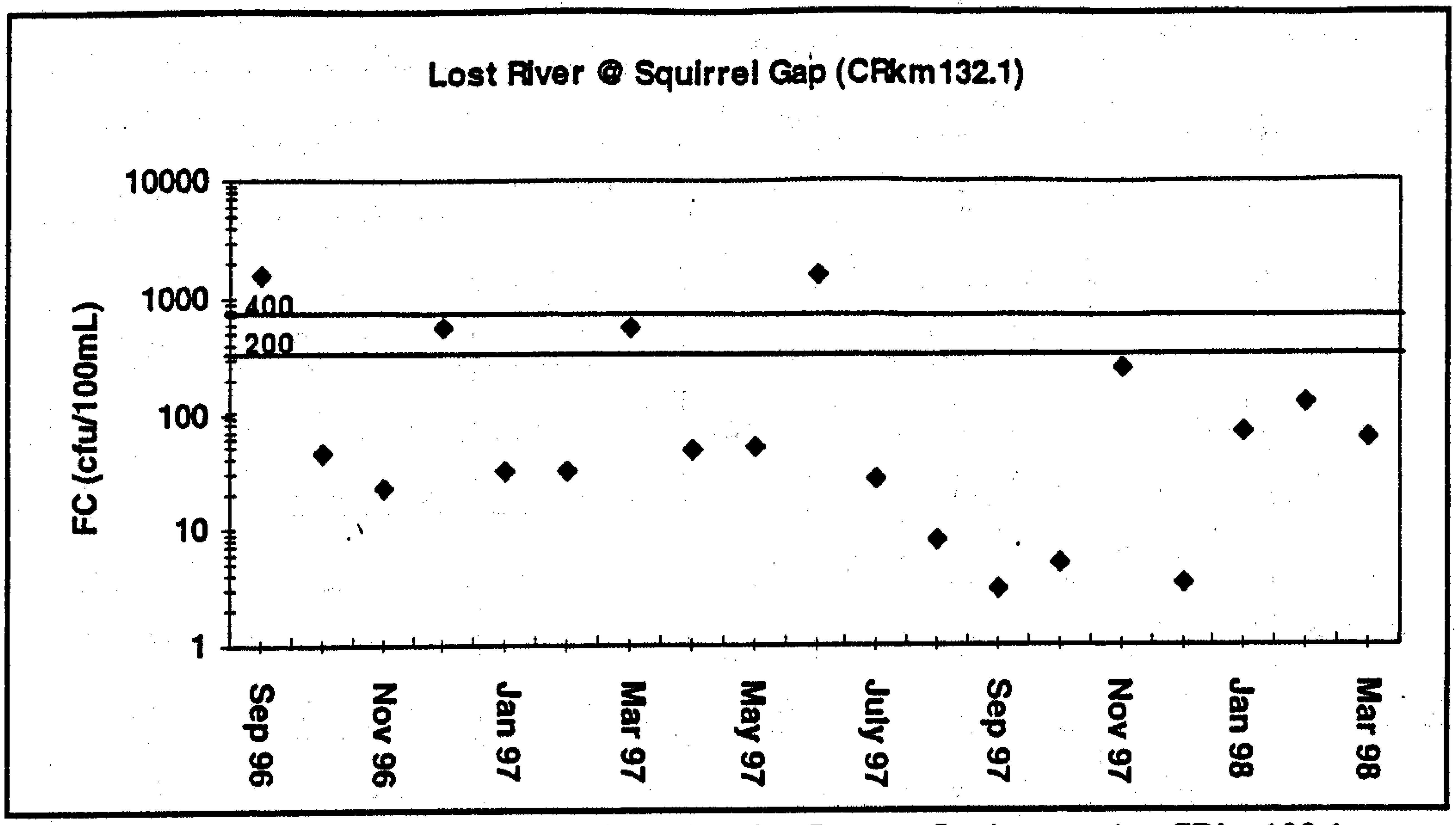


Figure 2.2. Time-series fecal coliform data for Cacapon Institute station CRkm132.1.

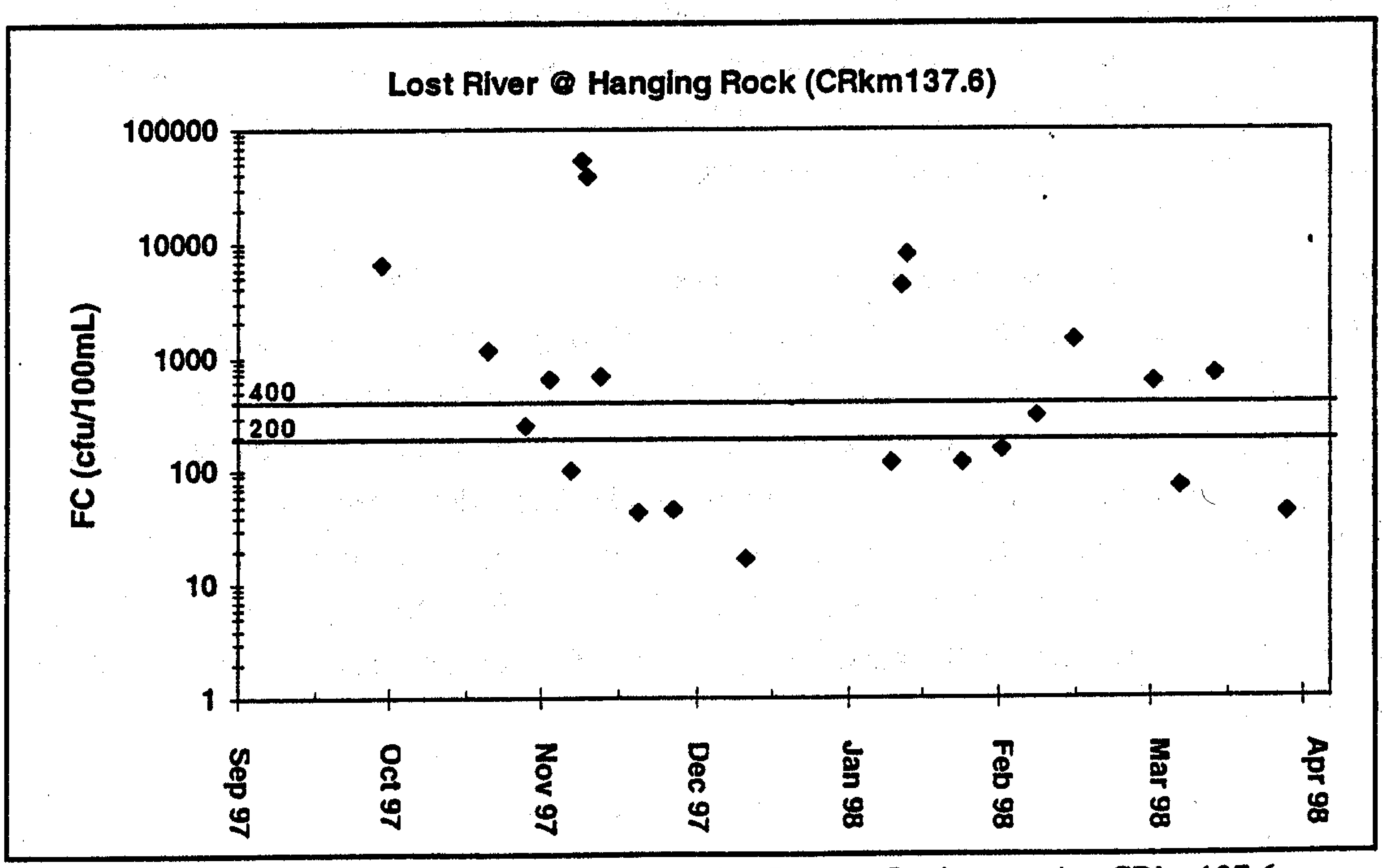


Figure 2.3. Time-series fecal coliform data for Cacapon Institute station CRkm137.6.

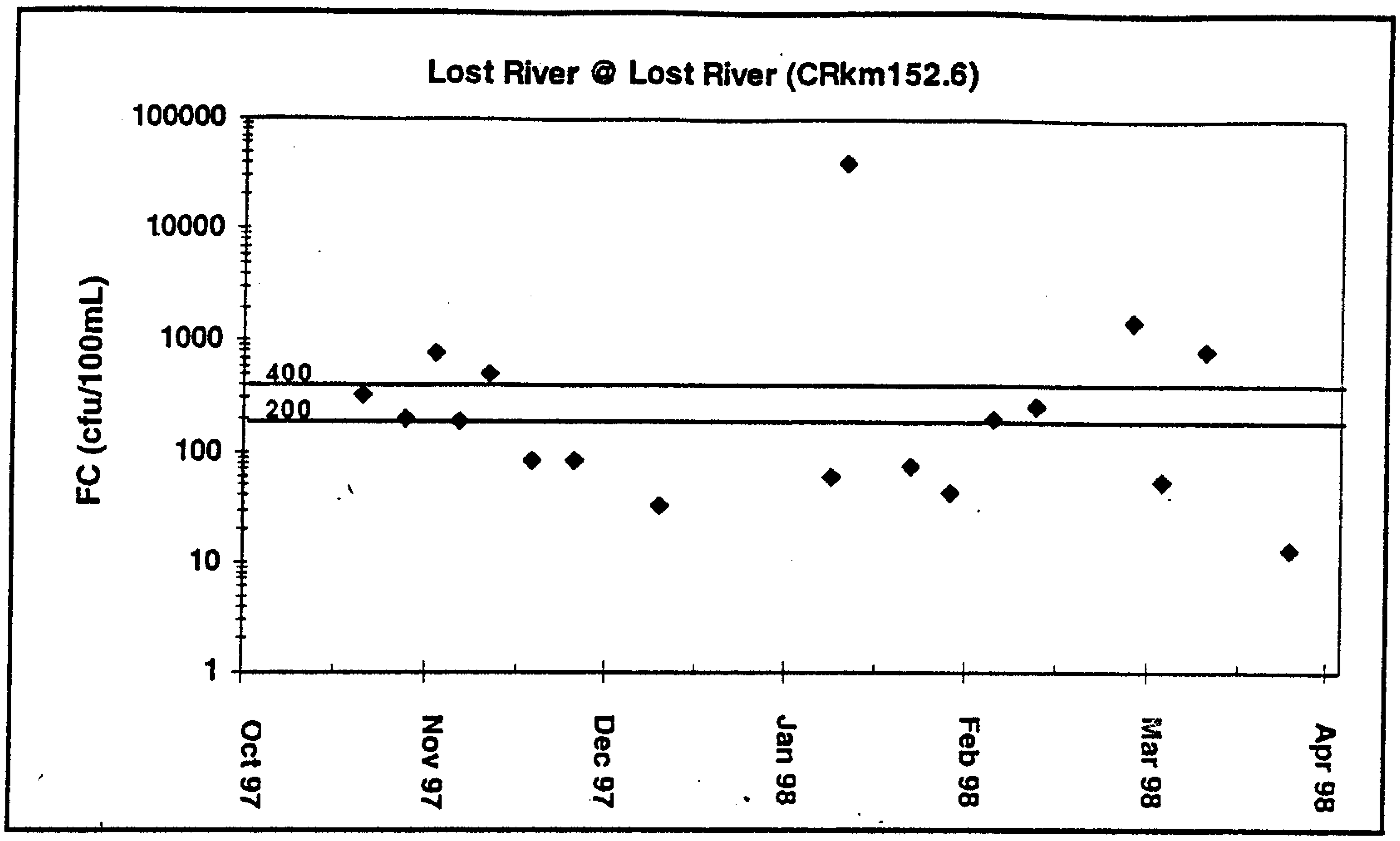


Figure 2.4. Time-series fecal coliform data for Cacapon Institute station CRkm152.6.

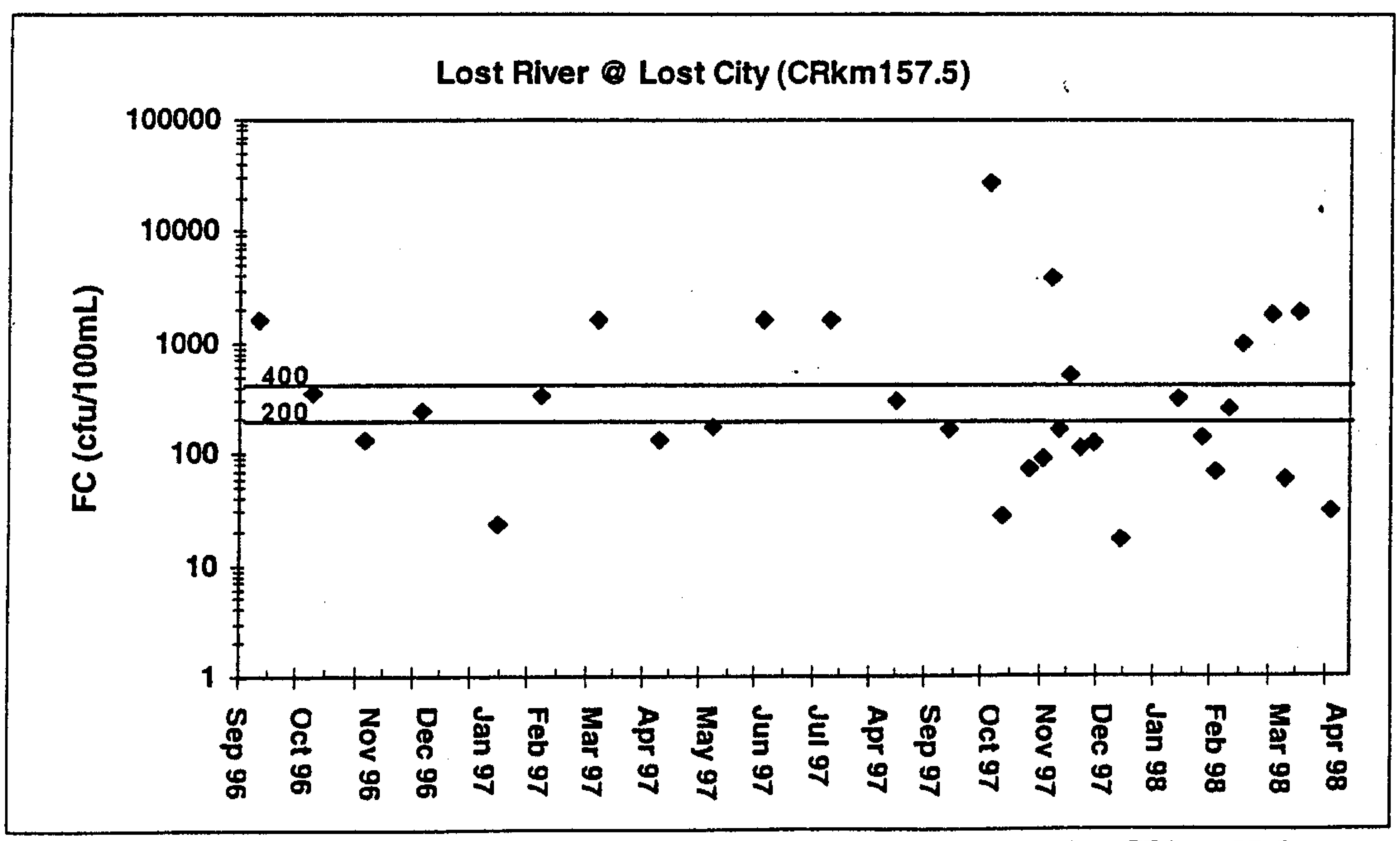


Figure 2.5. Time-series fecal coliform data for Cacapon Institute station CRkm157.5.

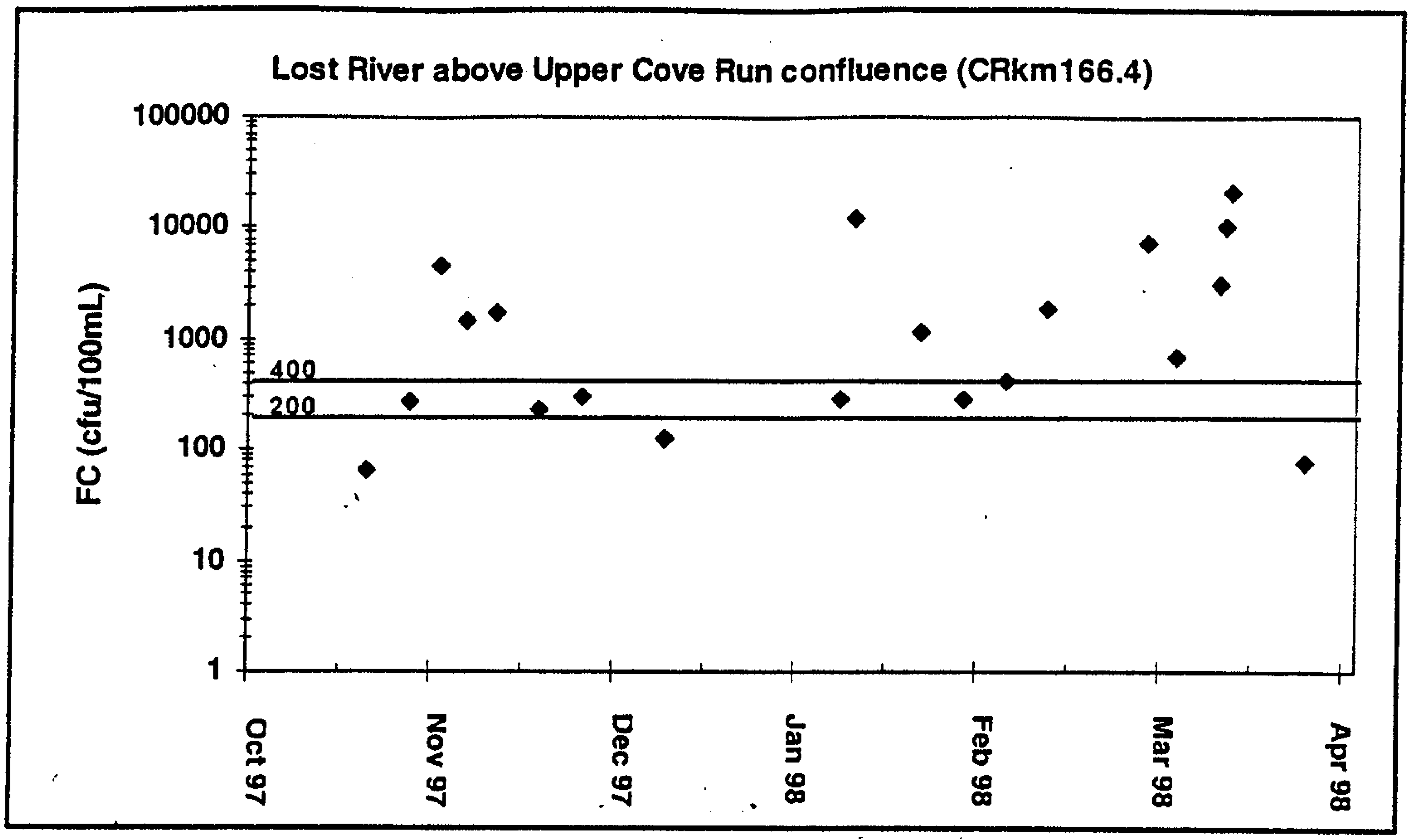


Figure 2.6. Time-series fecal coliform data for Cacapon Institute station CRkm166.4.

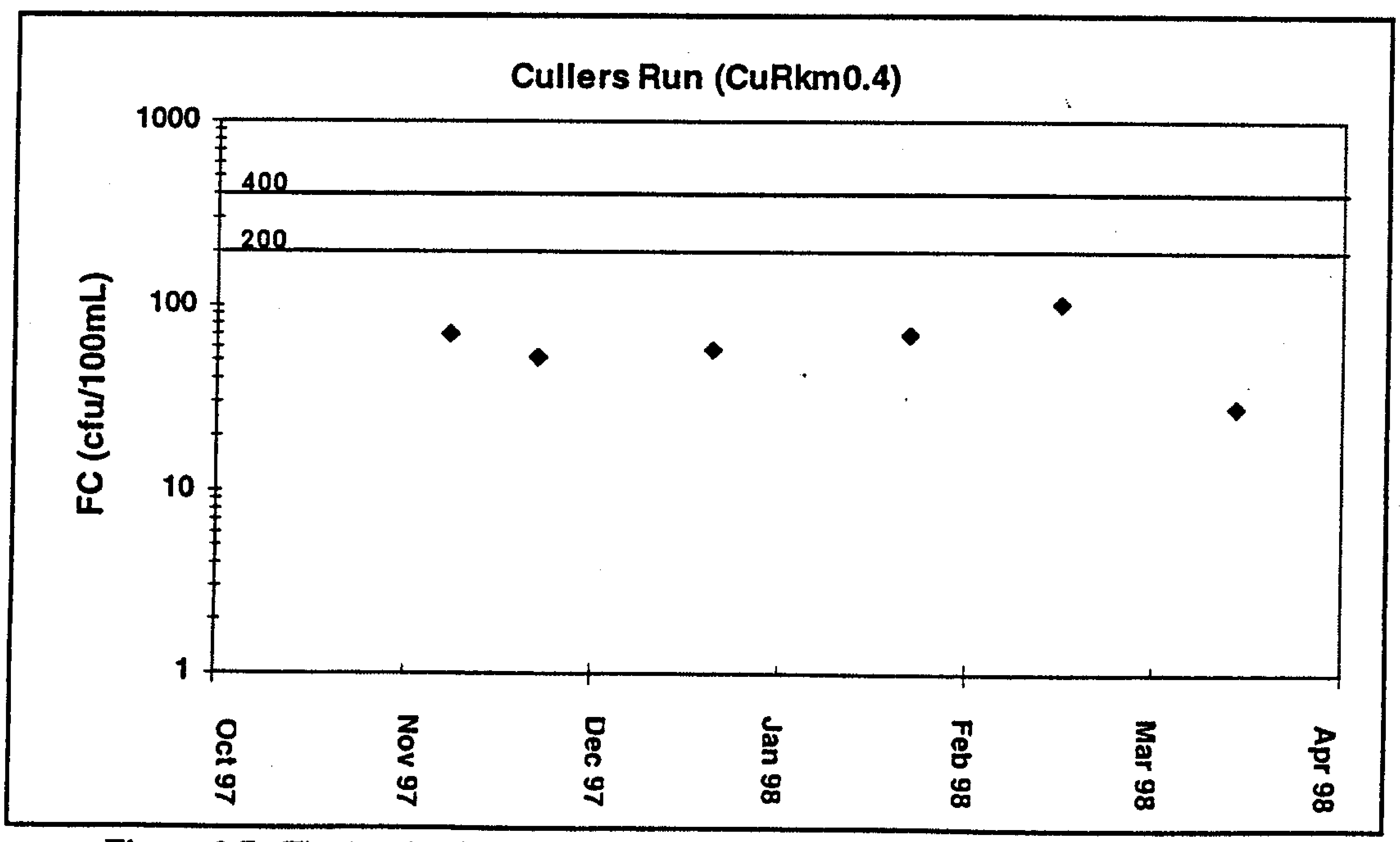


Figure 2.7. Time-series fecal coliform data for Cacapon Institute station CuRkm0.4.

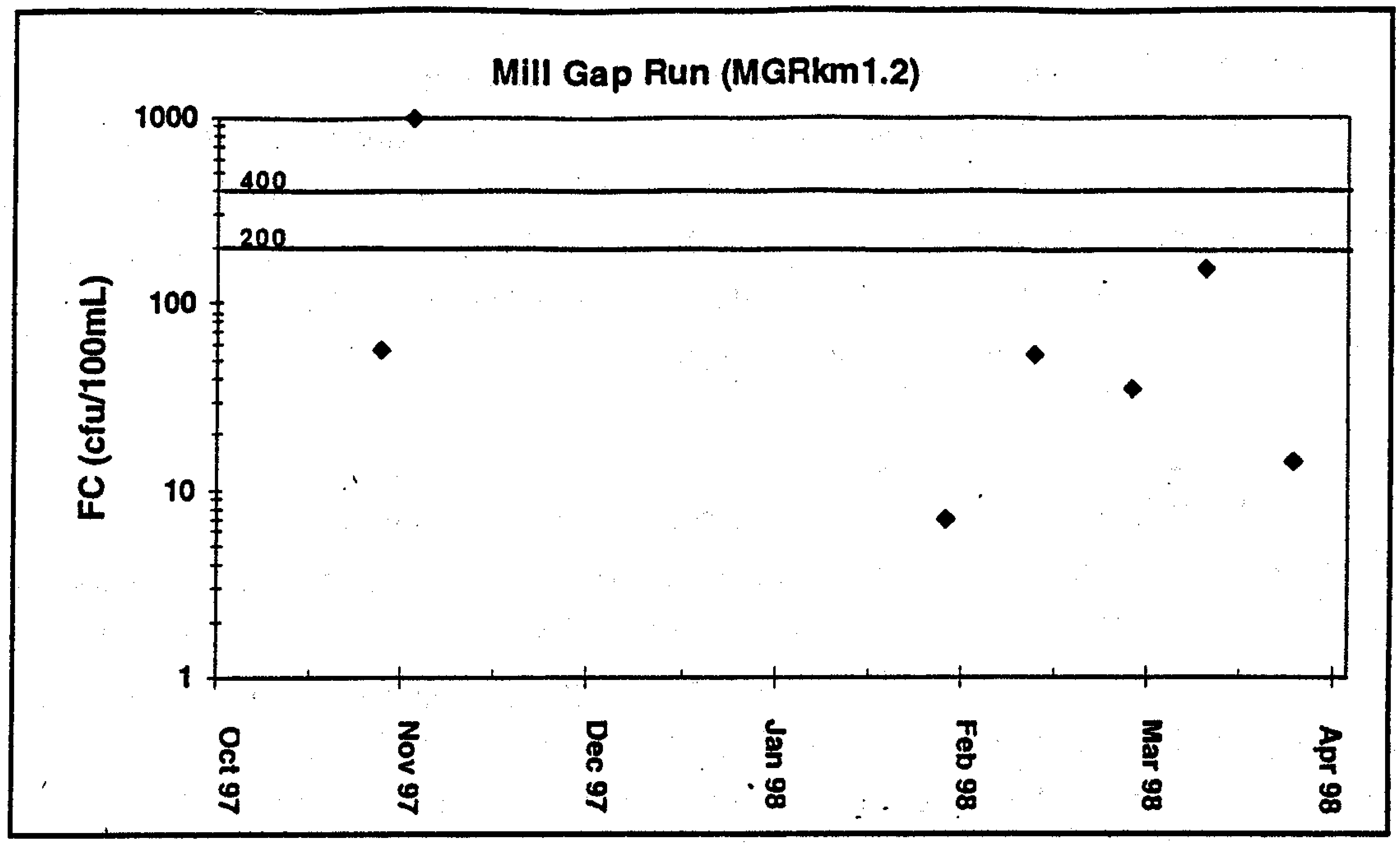


Figure 2.8. Time-series fecal coliform data for Cacapon Institute station MGRkm1.2.

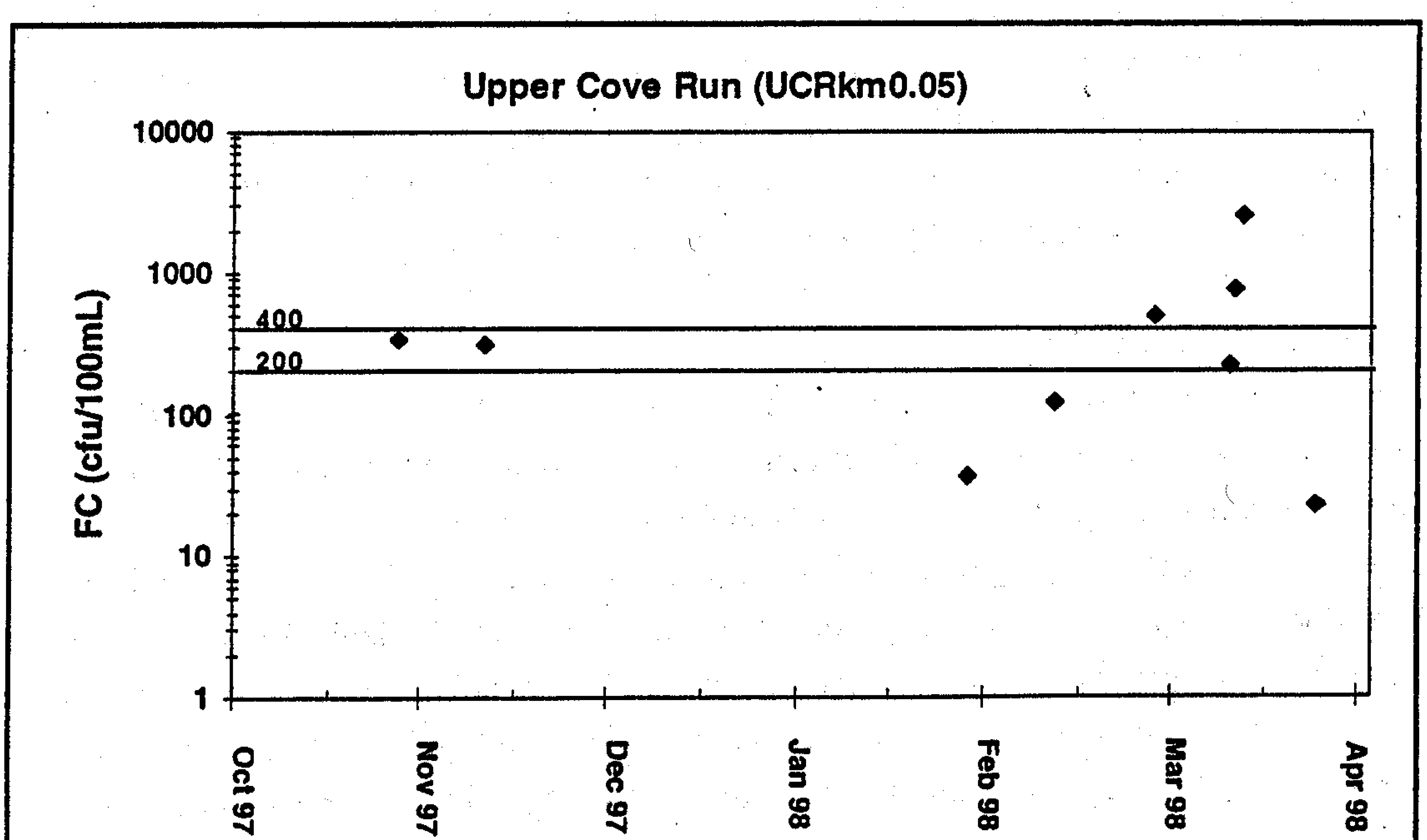


Figure 2.9. Time-series fecal coliform data for Cacapon Institute station UCRkm0.05.

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 Version 2.0 (USEPA 1998) and the Nonpoint Source Model (NPSM) were used to predict the significance of fecal coliform sources and fecal coliform levels in the Lost River 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 reason 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 Setup

To obtain a spatial variation of the concentration of bacteria along the Lost River, the watershed was subdivided into 11 subwatersheds. This allowed analysts to address the relative contribution of sources within each subwatershed 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 land use coverage.

3.3 Source Representation

Both point and nonpoint sources were represented in the model. The point sources used are shown in Table 3.1. Because flow rates and fecal coliform concentrations were unavailable from the U.S. Environmental Protection Agency's PCS database for facilities, they were estimated based on inspection reports and best professional judgment. AMFM is the only facility with available flow data. Using flow conditions documented on inspection reports, an average flow was calculated for AMFM. However, there was not sufficient information to determine average flows for East Hardy High School or East Hardy Early/Middle School or to determine fecal coliform concentration for any of the point sources. In the absence of sufficient flow rates and fecal coliform concentrations, East Hardy High School and Early/Middle school flow rates were set equal to their design flow, and the fecal coliform loads from each point source were determined assuming an effluent concentration equivalent to the average monthly limit of 200 cfu/100 mL.

Table 3.1. Municipal and industrial dischargers in the Lost River watershed.

NPDES No.	Facility Name	Permitted flow (gpd)	Fecal Coliform Permit Limit (cfu/100 mL)		
			Average Monthly	Daily Maximum	Instantaneous Maximum
WV0100960	East Hardy High School	5,000	200	400	N/A
WV0100960	East Hardy Early/Middle School	6,000	200	400	N/A
WVG550120[a]	AMFM of Hardy County (E.A. Hawse Continuous Care Center)	20,500	200	400	500

[a] Registration number under the General WV/NPDES permit no. WV0103110.

The three major nonpoint source categories addressed in this study were forestland, pastureland, and cropland. Accounting for the distribution of feedlots, poultry houses, wildlife, and failing septic systems, a variety of parameters needed for predicting runoff and fecal coliform loadings were then estimated for each of the land uses within the 11 subwatersheds.

Septic system discharges were quantified based on the following information: the number of households with septic systems in Hardy County, the average number of people per household, the area of residential land in Hardy County and the Lost River watershed, a 2.5% failure rate (NSFC 1993), an assumed average daily discharge of 70 gallons per person per day (Horsley & Whitten 1996), and an assumed septic effluent concentration of 10^4 cfu/100 mL of effluent (Metcalf & Eddy 1991). 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 reach the stream after being filtered through the soil. Additionally, these septic system discharges are assumed to be constant throughout the year, whereas in reality septic system failures might occur less frequently. To offset these assumptions somewhat and to account for die-off of bacteria during transport, the low value of a range of typical fecal coliform concentrations in raw sewage was used.

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 Section 2.3, geese populations for the watershed were provided by WVDNR and numbers of deer and wild turkey were estimated based on information in the *Big Game Bulletin* (WVDNR 1997). The fecal coliform loading rates per acre were based on those described earlier for various animal species (Metcalf & Eddy 1991).

A similar analysis was performed to estimate fecal coliform loading rates for agricultural land uses in each of the 11 subwatersheds. As discussed earlier, information was available on the number and types of poultry houses and feedlots and the total number of cattle in the watershed (WVSCA 1998; WVDNR 1998; PHIWQO 1996). The amount of fecal coliform produced in each subwatershed for each land use was calculated using animal counts, information on manure production, and typical fecal coliform production rates for the animal types (Metcalf & Eddy 1991). Accumulation rates of fecal coliform by acre were calculated based on amounts of fecal coliform produced and on certain assumptions about the distribution of animals and agricultural practices.

Estimates of poultry litter production per house per year were provided by the NRCS (NRCS 1998). Those estimates were used to calculate the total load of poultry litter produced by subwatershed based on the number of houses in that subwatershed. That load represented the potential load of litter available for land application. For this study it was assumed that the manure produced in a subwatershed was applied to the agricultural land in that same subwatershed (i.e., in the subwatershed where the poultry house is located). However, in practice, poultry litter is bought, sold, and moved between farms, and in and out of its watershed of origin (NRCS 1998). Based on current practices, the WVSCA expects that an estimated 5,000 tons (or more) of poultry litter will be transported out of the Lost River watershed to private facilities each year when the poultry sales operation is in full swing (WVSCA 1998). This expectation was represented when calculating fecal coliform loading from poultry litter. It was assumed that 14 tons of litter is sold to the private sector and transported out of the watershed each day. From estimates of current litter sales by poultry type (WVSCA 1998), it was assumed that 55% of the litter (7.7 tons/day) shipped out is broiler litter and 45% is turkey litter (6.3 tons/day). Those amounts were proportionally applied to the subwatersheds based on what fraction of the total watershed litter load was produced in that subwatershed. That is to say, each subwatershed had an amount of litter (both broiler and turkey) that was assumed to be shipped out and was therefore subtracted from its litter load available for land application. After accounting for the litter being shipped out of the watershed, the remaining amount of litter is that load available for land application. It was estimated that litter is applied to 100% of the cropland and 75% of the pastureland, providing litter application rates and fecal coliform accumulation rates by subwatershed by land use.

The estimated 8,000 cows in the Lost River watershed were distributed among the pastureland and feedlots, as discussed in Section 2.3. The fecal coliform loading from the cows in the pasture was represented as a direct application to the pastureland, and was distributed evenly across the pasture acreage to determine fecal coliform accumulation per acre per day. The manure produced from the cows in the feedlot was assumed to be applied in that subwatershed to the same estimated percentages of cropland and pastureland as for litter application—100% of cropland and 75% of pastureland (WVSCA 1998). These loads and acreages were then used to calculate the accumulation of fecal coliform per acre per day for cropland and pasture from application of cow manure.

The total fecal coliform accumulation rates for pastureland and cropland were then calculated as the sum of the individual accumulation rates from application of broiler, breeder, and turkey litter, cows in feedlots, and cows in pastures. The specific values, along with other model paramters, that were used for each land use in each of the 11 subwatersheds are shown in Appendix C.

3.4 Stream Characteristics

The channel geometry for Lost River subwatersheds was estimated as having an average 25-foot width and an average 0.8-foot depth. Channel geometry was based on review of available information on rivers of the same order within the same region. Segment lengths and Digital Elevation Model (DEM) data were used to determine channel slopes for each reach.

3.5 Selection of Representative Modeling Period

The hydrologic conditions in the Lost River watershed consist of relatively random successions of dry, average, and wet rainfall years. Since it was determined that bacteria contamination in the Lost River 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 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 11 reaches of the Lost River, model parameters were adjusted to the extent possible for both hydrology and bacteria loading. Hydrologic calibration required a comparison of the modeled stream flows for the portion of the watershed upstream from USGS gage 01610200 (at McCauley near Baker) to the observed flows for October 1, 1971, to January 31, 1980. Figure 3.1 shows the observed and modeled flows for the water year from October 1, 1978, to September 30, 1979. Figure 3.2 shows the monthly average flows for October 1, 1978, to September 30, 1979. Figure 3.3 shows the annual flows over the entire period of record from the USGS gage (October 1, 1971, to January 31, 1980). 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. Based on this examination and a verification that the parameter values were reasonable, it was determined that the model was adequately representing the hydrology of the Lost River.

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, primarily focusing on forest, pasture, and cropland parameters. This process was limited because most of the observed data are available for 1998 and precipitation data are available only through 1997. Data available from the Cacapon Institute from September through December of 1997 were provided with sampling days as well as hours. The model was run to yield hourly water quality results, allowing for comparison to the appropriate Cacapon Institute data. The loading parameters for urban runoff were primarily based on literature values. Loading parameters for the forest and 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 that retained consistency between relative contributions from the different land uses.

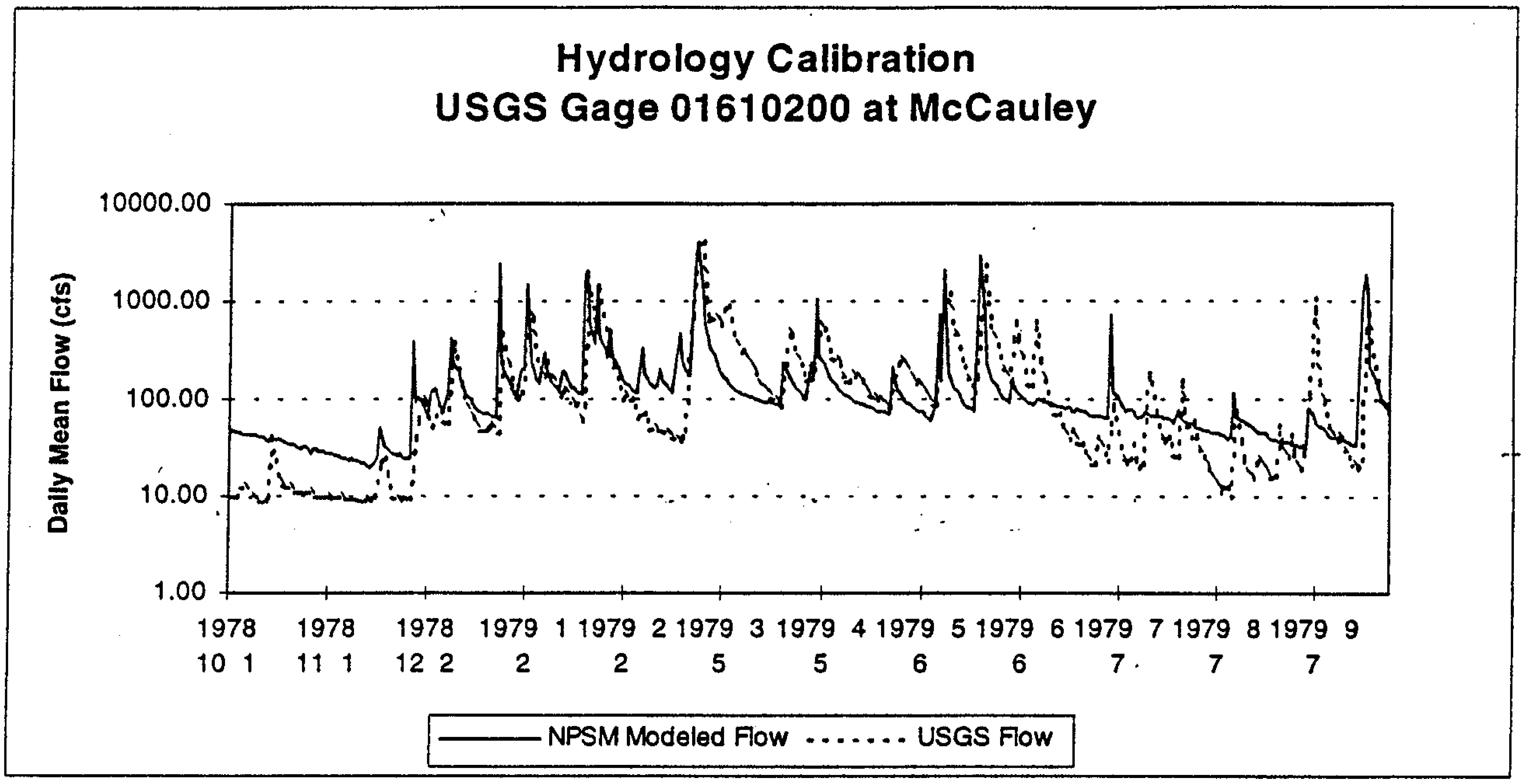


Figure 3.1. Comparison of observed and modeled flow at USGS gage 01610200.

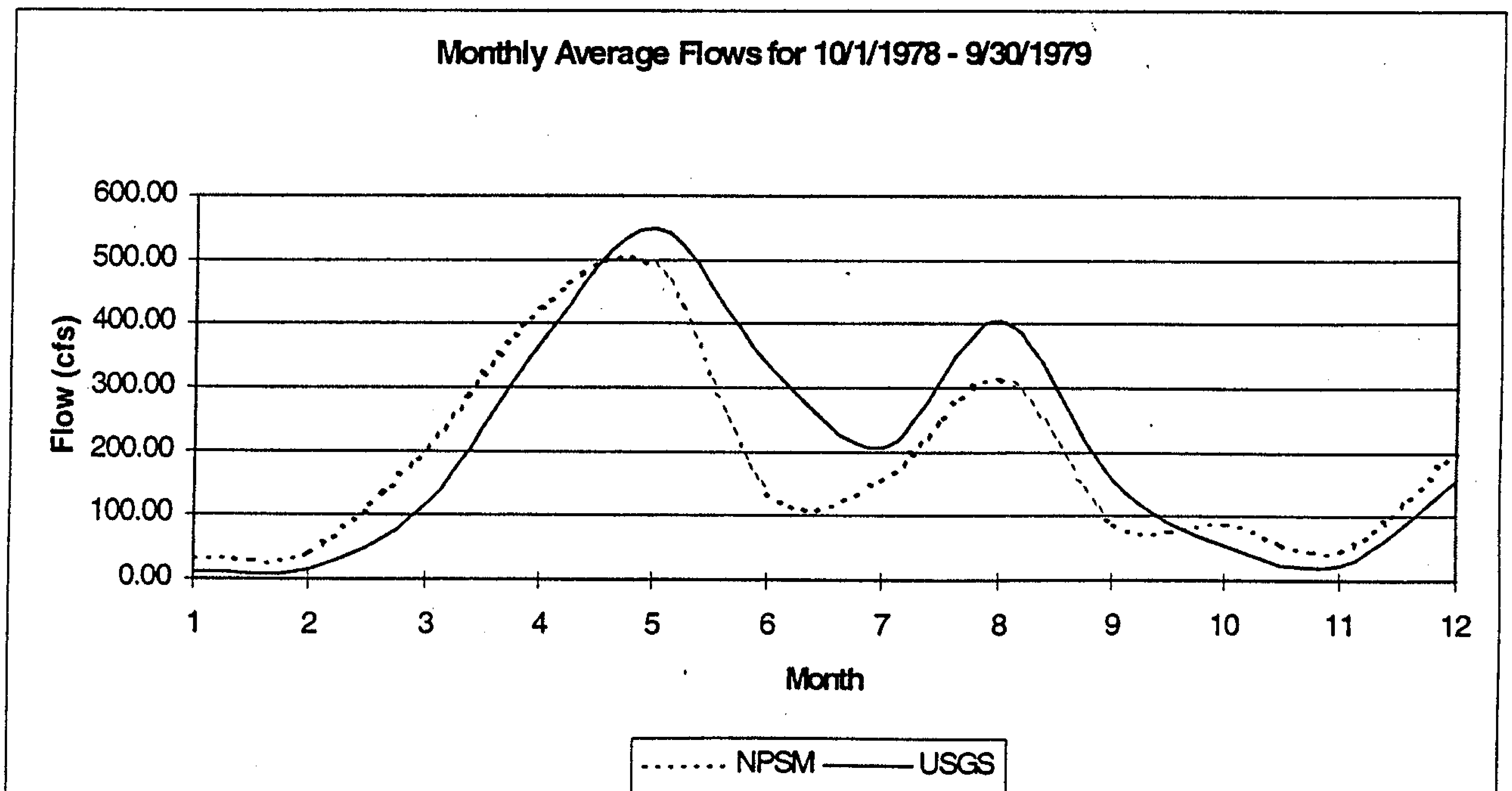


Figure 3.2 Comparison of observed and modeled monthly average flows at USGS gage 01610200.

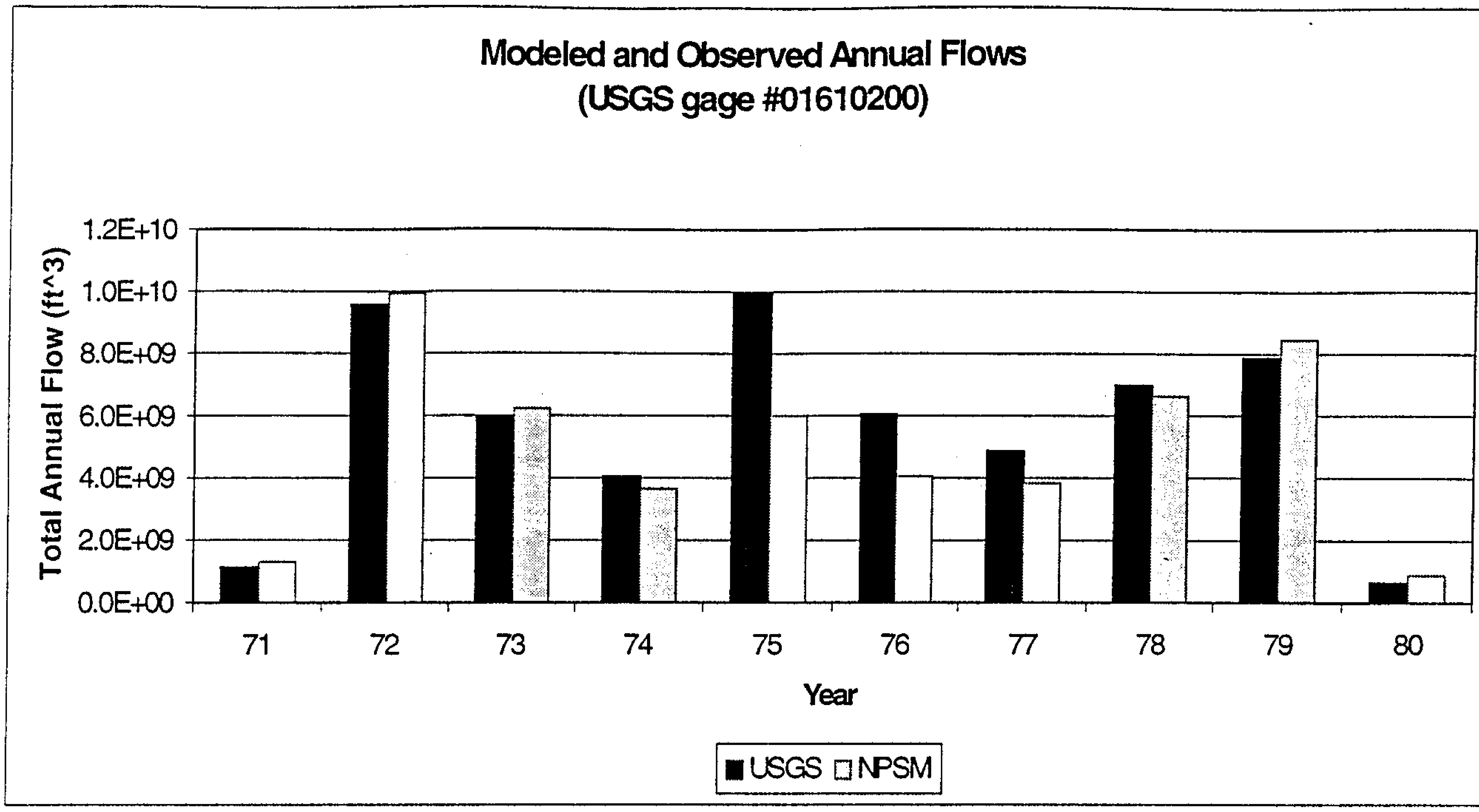


Figure 3.3 Comparison of observed and modeled annual flows at USGS gage 01610200.

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 Lost River. For the existing conditions, the overall fecal coliform bacteria loadings by land use category for the Lost River watershed are given in Table 3.2. The 30-day or running "monthly" geometric mean of fecal coliform concentration was calculated based on daily model output. A summary of West Virginia water quality standard violations for the selected representative hydrologic period is given in Table 3.3. All 11 reaches (represented as the subwatershed name) and information relating to violation of the 200 cfu/100 mL geometric mean standard are presented. It is apparent from Table 3.3 that violations occur throughout the watershed with relative magnitude.

Table 3.2. Model results of simulated existing conditions—
Annual nonpoint source fecal coliform bacteria loading factors.

Land Use Category	Annual Fecal Coliform Loading
Barren	1.73×10^{12} cfu/yr
Cropland	9.48×10^{14} cfu/yr
Forest	2.64×10^{14} cfu/yr
Other rural	6.2×10^{10} cfu/yr
Pasture	7.73×10^{15} cfu/yr
Residential - pervious[a]	5.06×10^{10} cfu/yr
Residential - impervious[a]	8.61×10^{10} cfu/yr

[a] For modeling purposes, residential area was assumed to be 50% pervious and 50% impervious.

Table 3.3. Existing conditions—summary of violations of the 200 cfu/100 mL geometric mean 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
Lost 1	2	6	3	9	2.68%
Lost 2	2	6	3	9	2.68%
Lost 3	2	6	3	9	2.68%
Baker	1	1	1	1	0.30%
Lost 4	2	9	3	12	3.57%
Kimsey	2	6	3	9	2.68%
Lost 5	2	6	3	9	2.68%
Lower Cove	0	0	0	0	0%
Lost 6	2	6	3	9	2.68%
Lost 7	2	10	3	13	3.87%
Lost 8	2	6	3	9	2.68%

4.0 ALLOCATION

Total maximum daily loads (TMDLs) are composed 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 waterbody. 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 MOS is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA 1991):

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

For the Lost River TMDL, 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:

In estimating cattle and geese counts for the watershed, the high values of the ranges provided were used, incorporating a margin of safety. In estimating the amount of litter transported out of the watershed, the lower end of a range of values was used, resulting in a larger amount of litter for land application and a margin of safety concerning the litter accumulation rates.

The 1993 *Summary of Onsite Systems in the United States* (NSFC 1993) indicates 60 failures for 3,000 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.

4.2 Assessing Alternatives

For the allocation runs, the model was run for the same representative hydrologic period (October 1990 through September 1991) as that used for the existing conditions calibration run. The overall nonpoint source fecal coliform bacteria loadings by land use category for the Lost River watershed are given in

Table 4.1. No load reductions were allocated to any permitted point sources in the watershed. An allocation reduction of 37.75% was applied to all cropland, 12.80% to all forestland, and 38.34% to all pasturelands in the 11 subwatersheds for this TMDL. No reductions were applied to the urban, barren, and other rural lands. These nonpoint source load allocations, given in Table 4.1, 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 scenario, it was assumed that loads from failing septic systems will be reduced 50%. 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 C for each of the 11 subwatersheds.

Table 4.1. Fecal coliform bacteria nonpoint source allocations for Lost River watershed for representative hydrologic year (October 1, 1990, to September 30, 1991).

Land Use Category	Loading for Existing Run	Loading for Allocation Run	Percent Reduction
Barren	1.73×10^{12} cfu/yr	1.73×10^{12} cfu/yr	0%
Cropland	9.48×10^{14} cfu/yr	5.91×10^{14} cfu/yr	37.7%
Forest	2.64×10^{14} cfu/yr	2.30×10^{14} cfu/yr	12.8%
Other rural	6.2×10^{10} cfu/yr	6.2×10^{10} cfu/yr	0%
Pasture	7.73×10^{15} cfu/yr	4.76×10^{15} cfu/yr	38.4%
Residential - pervious	5.06×10^{10} cfu/yr	5.06×10^{10} cfu/yr	0%
Residential - impervious	8.61×10^{10} cfu/yr	8.61×10^{10} cfu/yr	0%

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APPENDIX A

Table A.1. Lost River land use by subwatershed

Land use category	MRLC categories included	Subwatershed acreages											
		Lost 1	Lost 2	Lost 3	Baker	Lost 4	Kimsey	Lost 5	Lower Cove	Lost 6	Lost 7	Lost 8	Total
Residential	Low-density developed	4.00	0.89	3.11	14.68	7.12	7.12	19.57	7.78	24.91	36.92	10.23	136.33
	High-density commercial/residential	0.00	0.00	1.33	4.67	2.22	4.00	0.00	0.00	0.44	2.89	0.00	15.57
	Total	**4.00**	**0.89**	**4.45**	**19.35**	**9.34**	**11.12**	**19.57**	**7.78**	**25.35**	**39.81**	**10.23**	**151.90**
Barren	Transitional barren	4.67	3.11	10.90	79.62	35.58	213.05	245.52	1.33	12.01	9.34	121.65	736.79
	Total	**4.67**	**3.11**	**10.90**	**79.62**	**35.58**	**213.05**	**245.52**	**1.33**	**12.01**	**9.34**	**121.65**	**736.79**
Forest	Deciduous forest	8619.80	6129.42	1971.75	12074.93	7430.43	16987.41	5469.13	6474.80	5029.01	11543.18	8351.59	90081.48
	Evergreen forest	261.54	167.91	51.37	94.52	209.94	169.02	102.30	65.16	118.09	216.39	283.78	1740.02
	Mixed forest	1008.78	744.36	199.93	817.30	1074.17	1266.98	537.08	564.22	612.92	1120.65	1105.97	9052.36
	Total	**9890.12**	**7041.69**	**2223.06**	**12986.75**	**8714.54**	**18423.41**	**6108.52**	**7104.18**	**5760.03**	**12880.22**	**9741.34**	**100873.85**
Pasture	Hay/pasture	281.33	412.99	442.79	2374.51	1741.80	1879.68	769.04	832.65	1208.49	1982.87	1254.75	13180.90
	Total	**281.33**	**412.99**	**442.79**	**2374.51**	**1741.80**	**1879.68**	**769.04**	**832.65**	**1208.49**	**1982.87**	**1254.75**	**13180.90**
Cropland	Row Crops	52.49	15.35	50.48	156.12	394.97	157.68	212.61	22.91	167.91	177.25	119.87	1527.63
	Total	**52.49**	**15.35**	**50.48**	**156.12**	**394.97**	**157.68**	**212.61**	**22.91**	**167.91**	**177.25**	**119.87**	**1527.63**
Other rural	Woody wetlands	3.11	0.00	1.56	0.22	0.00	0.00	0.00	0.00	1.33	0.00	1.78	8.01
	Emergent herbaceous wetland	0.00	1.78	8.45	0.89	15.35	1.11	4.23	0.44	7.78	1.56	0.22	41.81
	Total	**3.11**	**1.78**	**10.01**	**1.11**	**15.35**	**1.11**	**4.23**	**0.44**	**9.12**	**1.56**	**2.00**	**49.82**
TOTAL		**10235.72**	**7475.80**	**2741.68**	**15617.46**	**10911.58**	**20686.06**	**7359.49**	**7969.30**	**7182.91**	**15091.05**	**11249.84**	**116520.89**

APPENDIX B

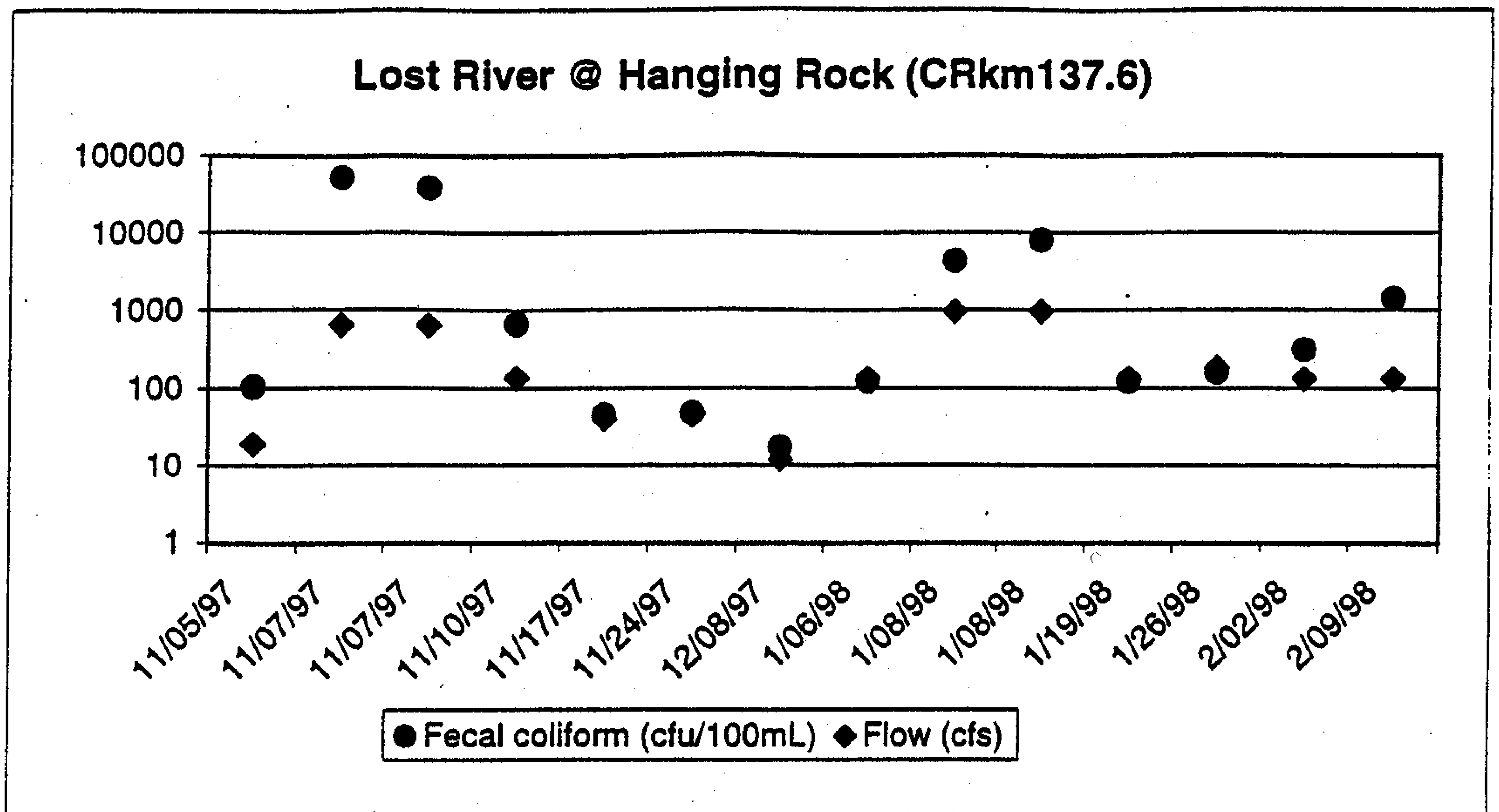

Figure B.1. Flow and Fecal coliform concentrations at CRkm137.6.

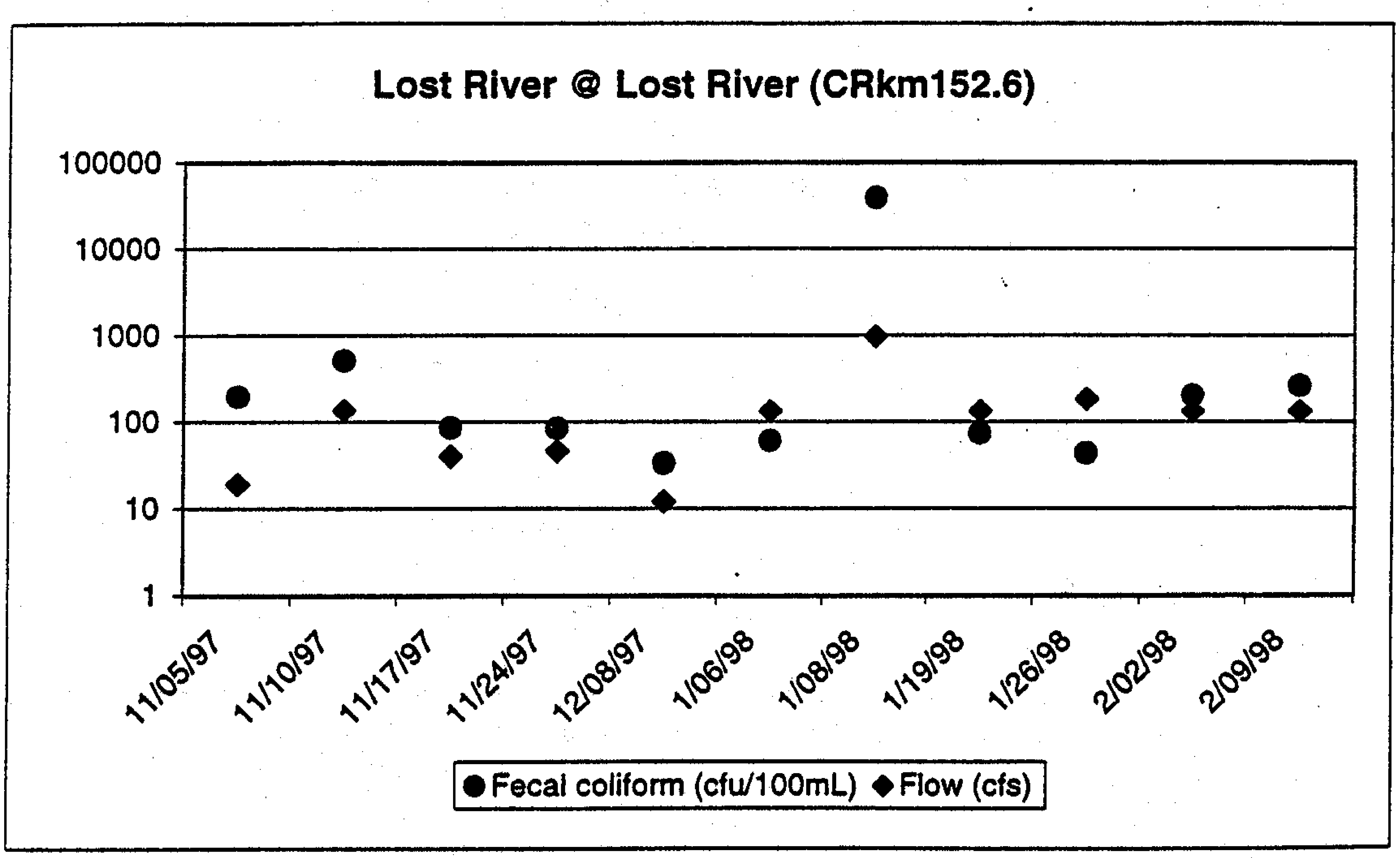

Figure B.2. Flow and Fecal coliform concentrations at CRkm152.6.

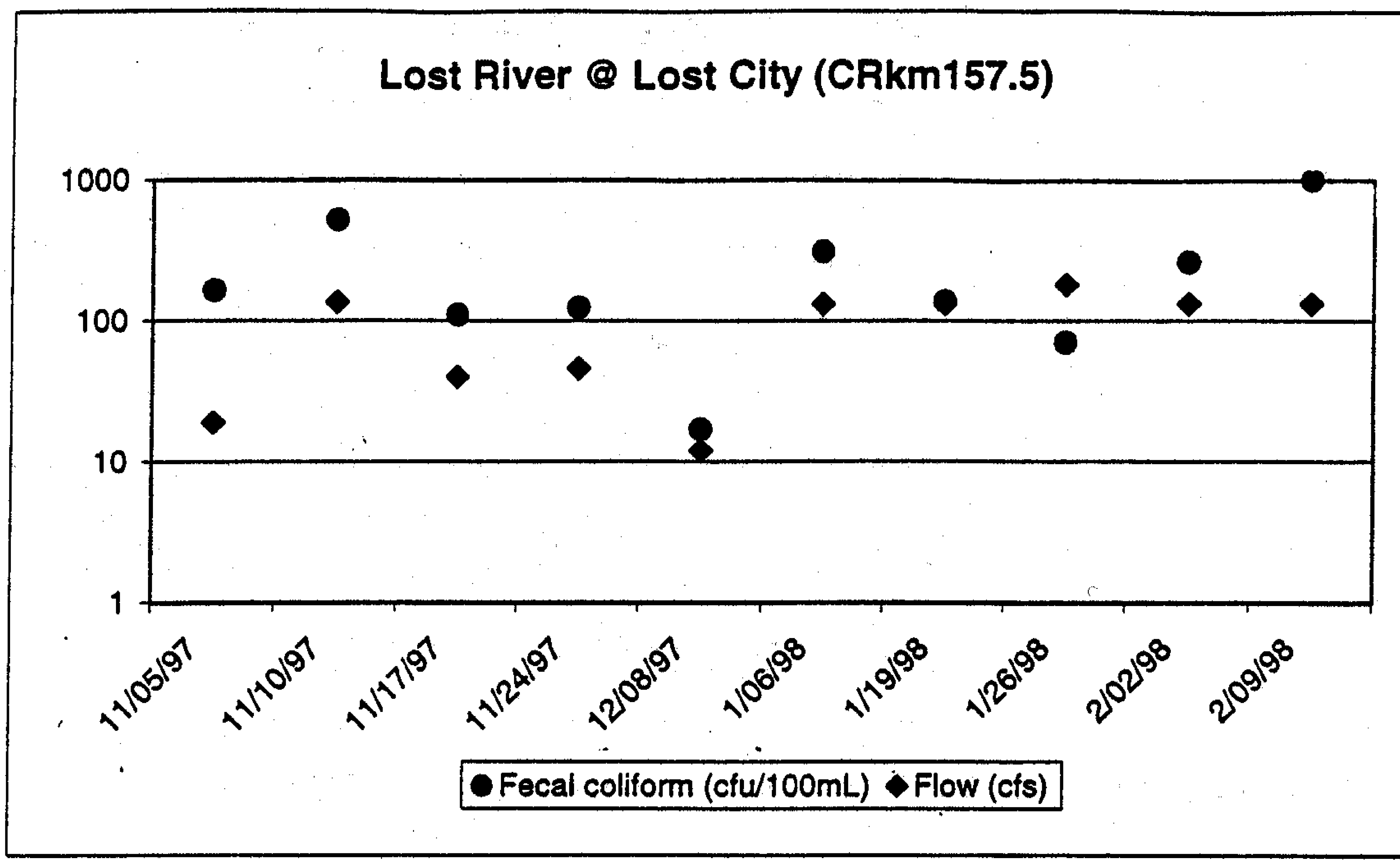

Figure B.3. Flow and Fecal coliform concentrations at CRkm157.5.

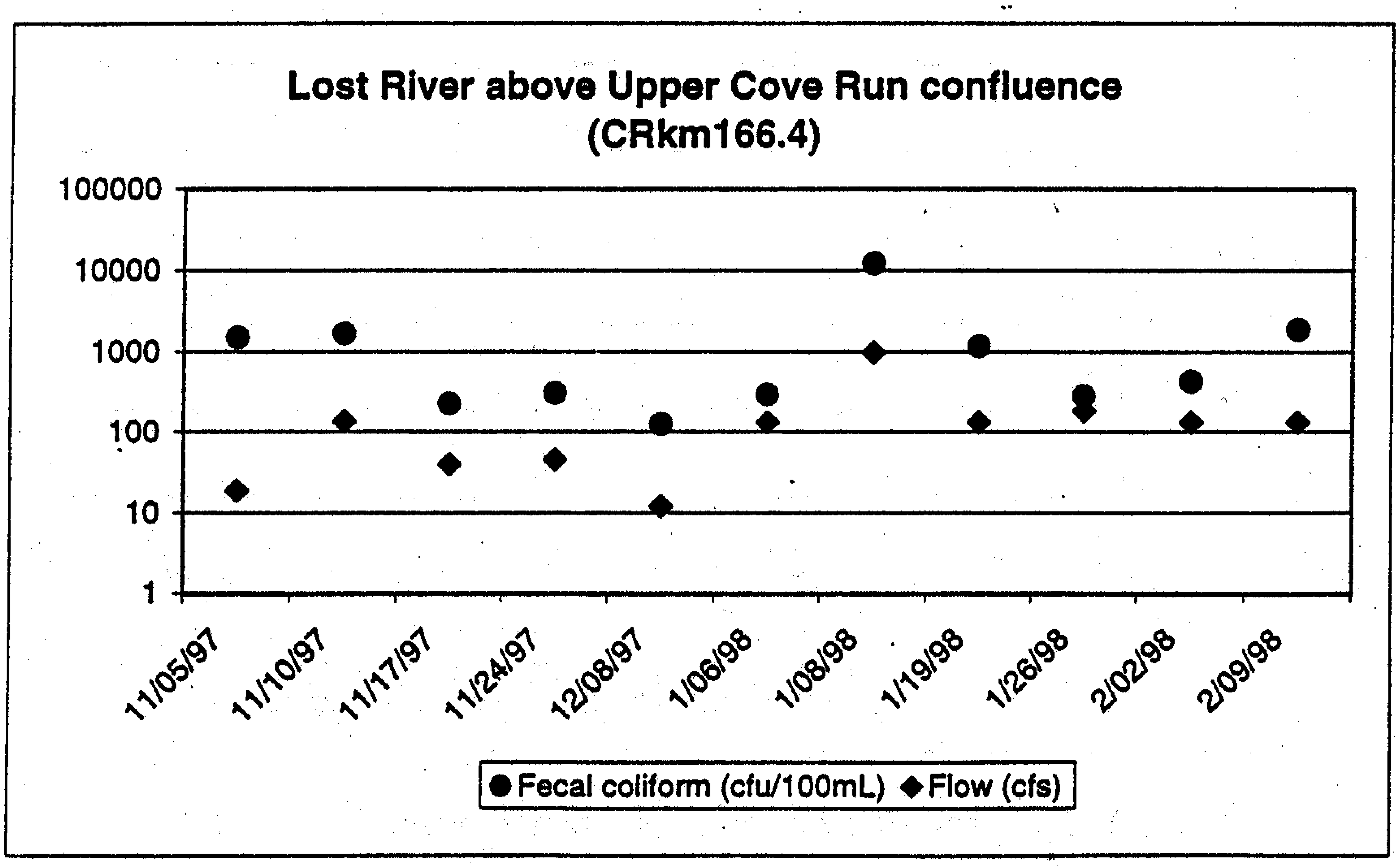

Figure B.4. Flow and Fecal coliform concentrations at CRkm166.4.

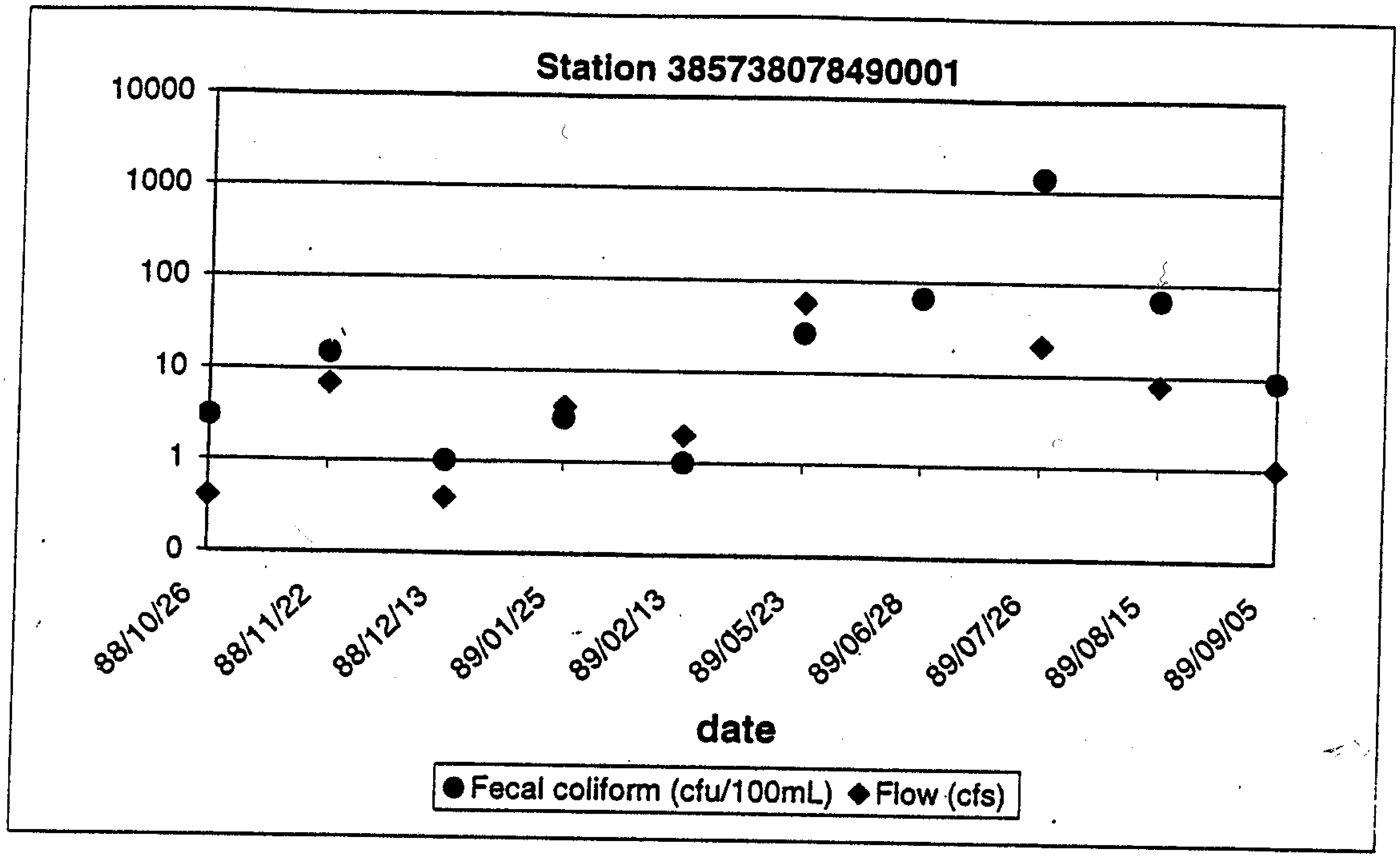

Figure B.5. Flow and Fecal coliform concentrations at Station 385738078490001.

APPENDIX C

Table C.1. NPSM parameters for fecal coliform bacteria loading for existing conditions (residential, barren, and other rural)[a]

Land use	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Residential	1.70E+07	8.40E+07	1.50E+08	4.20E+00	1.40E+04	7.10E+03
Barren	8.40E+06	8.40E+07	7.50E+08	4.20E+00	1.40E+04	7.10E+03
Other rural	4.40E+06	4.40E+07	4.00E+08	3.20E+00	1.10E+04	5.70E+03

[a] Parameters for Residential, Barren and Other Rural land uses did not change by subwatershed.

Table C.2. NPSM parameters for fecal coliform bacteria loading for existing conditions (forest)

Subwatershed	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Lost 1	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 2	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 3	4.40E+06	5.20E+08	9.40E+08	3.20E+00	1.10E+04	5.70E+03
Baker	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 4	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Kimsey	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 5	4.40E+06	4.60E+08	8.30E+08	3.20E+00	1.10E+04	5.70E+03
Lower Cove	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 6	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 7	4.40E+06	4.70E+08	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 8	4.40E+06	4.80E+08	8.60E+08	3.20E+00	1.10E+04	5.70E+03

Table C.3. NPSM parameters for fecal coliform bacteria loading for existing conditions (pasture)

Subwatershed	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Lost 1	1.80E+07	2.50E+11	1.70E+11	3.80E+00	2.30E+04	1.10E+04
Lost 2	1.80E+07	2.00E+11	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 3	1.80E+07	1.70E+11	1.20E+11	3.80E+00	2.30E+04	1.10E+04
Baker	1.80E+07	1.40E+11	9.50E+10	3.80E+00	2.30E+04	1.10E+04
Lost 4	1.80E+07	2.30E+11	1.60E+11	3.80E+00	2.30E+04	1.10E+04
Kimsey	1.80E+07	4.20E+11	2.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 5	1.80E+07	5.00E+11	3.50E+11	3.80E+00	2.30E+04	1.10E+04
Lower Cove	1.80E+07	2.00E+11	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 6	1.80E+07	6.10E+10	4.30E+10	3.80E+00	2.30E+04	1.10E+04
Lost 7	1.80E+07	2.80E+11	1.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 8	1.80E+07	3.10E+11	2.20E+11	3.80E+00	2.30E+04	1.10E+04

Table C.4. NPSM parameters for fecal coliform bacteria loading for existing conditions (cropland)

Subwatershed	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Lost 1	1.80E+07	1.20E+11	1.70E+11	3.80E+00	2.30E+04	1.10E+04
Lost 2	1.80E+07	1.00E+11	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 3	1.80E+07	8.60E+10	1.20E+11	3.80E+00	2.30E+04	1.10E+04
Baker	1.80E+07	6.80E+10	9.50E+10	3.80E+00	2.30E+04	1.10E+04
Lost 4	1.80E+07	1.20E+11	1.60E+11	3.80E+00	2.30E+04	1.10E+04
Kimsey	1.80E+07	2.10E+11	2.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 5	1.80E+07	2.50E+11	3.50E+11	3.80E+00	2.30E+04	1.10E+04
Lower Cove	1.80E+07	1.00E+11	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 6	1.80E+07	3.10E+10	4.30E+10	3.80E+00	2.30E+04	1.10E+04
Lost 7	1.80E+07	1.40E+11	1.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 8	1.80E+07	1.50E+11	2.20E+11	3.80E+00	2.30E+04	1.10E+04

Table C.5. NPSM parameters for fecal coliform bacteria loading for allocation conditions (residential, barren, and other rural)[a]

Land use	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Residential	1.70E+07	8.40E+07	1.50E+08	4.20E+00	1.40E+04	7.10E+03
Barren	8.40E+06	8.40E+07	7.50E+08	4.20E+00	1.40E+04	7.10E+03
Other rural	4.40E+06	4.40E+07	4.00E+08	3.20E+00	1.10E+04	5.70E+03

[a] Parameters for Residential, Barren and Other Rural land uses did not change by subwatershed.

Table C.6. NPSM parameters for fecal coliform bacteria loading for allocation conditions (forest)

Subwatershed	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Lost 1	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 2	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 3	4.40E+06	4.20E+07	9.40E+08	3.20E+00	1.10E+04	5.70E+03
Baker	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 4	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Kimsey	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 5	4.40E+06	3.60E+07	8.30E+08	3.20E+00	1.10E+04	5.70E+03
Lower Cove	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 6	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 7	4.40E+06	3.70E+07	8.50E+08	3.20E+00	1.10E+04	5.70E+03
Lost 8	4.40E+06	3.80E+07	8.60E+08	3.20E+00	1.10E+04	5.70E+03

Table C.7. NPSM parameters for fecal coliform bacteria loading for allocation conditions (pasture)

Subwatershed	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Lost 1	1.80E+07	2.50E+09	1.70E+11	3.80E+00	2.30E+04	1.10E+04
Lost 2	1.80E+07	2.00E+09	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 3	1.80E+07	1.70E+09	1.20E+11	3.80E+00	2.30E+04	1.10E+04
Baker	1.80E+07	1.40E+09	9.50E+10	3.80E+00	2.30E+04	1.10E+04
Lost 4	1.80E+07	2.30E+09	1.60E+11	3.80E+00	2.30E+04	1.10E+04
Kimsey	1.80E+07	4.20E+09	2.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 5	1.80E+07	5.00E+09	3.50E+11	3.80E+00	2.30E+04	1.10E+04
Lower Cove	1.80E+07	2.00E+09	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 6	1.80E+07	6.10E+09	4.30E+10	3.80E+00	2.30E+04	1.10E+04
Lost 7	1.80E+07	2.80E+09	1.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 8	1.80E+07	3.10E+09	2.20E+11	3.80E+00	2.30E+04	1.10E+04

Table C.8. NPSM parameters for fecal coliform bacteria loading for allocation conditions (cropland)

Subwatershed	SQO	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Lost 1	1.80E+07	2.50E+09	1.70E+11	3.80E+00	2.30E+04	1.10E+04
Lost 2	1.80E+07	2.00E+09	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 3	1.80E+07	1.70E+09	1.20E+11	3.80E+00	2.30E+04	1.10E+04
Baker	1.80E+07	1.40E+09	9.50E+10	3.80E+00	2.30E+04	1.10E+04
Lost 4	1.80E+07	2.30E+09	1.60E+11	3.80E+00	2.30E+04	1.10E+04
Kimsey	1.80E+07	4.20E+09	2.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 5	1.80E+07	5.00E+09	3.50E+11	3.80E+00	2.30E+04	1.10E+04
Lower Cove	1.80E+07	2.00E+09	1.40E+11	3.80E+00	2.30E+04	1.10E+04
Lost 6	1.80E+07	6.10E+08	4.30E+10	3.80E+00	2.30E+04	1.10E+04
Lost 7	1.80E+07	2.80E+09	1.90E+11	3.80E+00	2.30E+04	1.10E+04
Lost 8	1.80E+07	3.10E+09	2.20E+11	3.80E+00	2.30E+04	1.10E+04

Table C.9. 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 the land surface	cfu/acre-day
SQOLIM	Maximum storage of fecal coliform bacteria on the land surface	cfu/acre
WSQOP	Rate of surface runoff which removes 90% of stored fecal coliform bacteria	in/hour
IOQC	Concentration of fecal coliform bacteria in interflow outflow	cfu/ft^3
AOQC	Concentration of fecal coliform bacteria in active groundwater flow	cfu/ft^3

Figure C.1. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 1

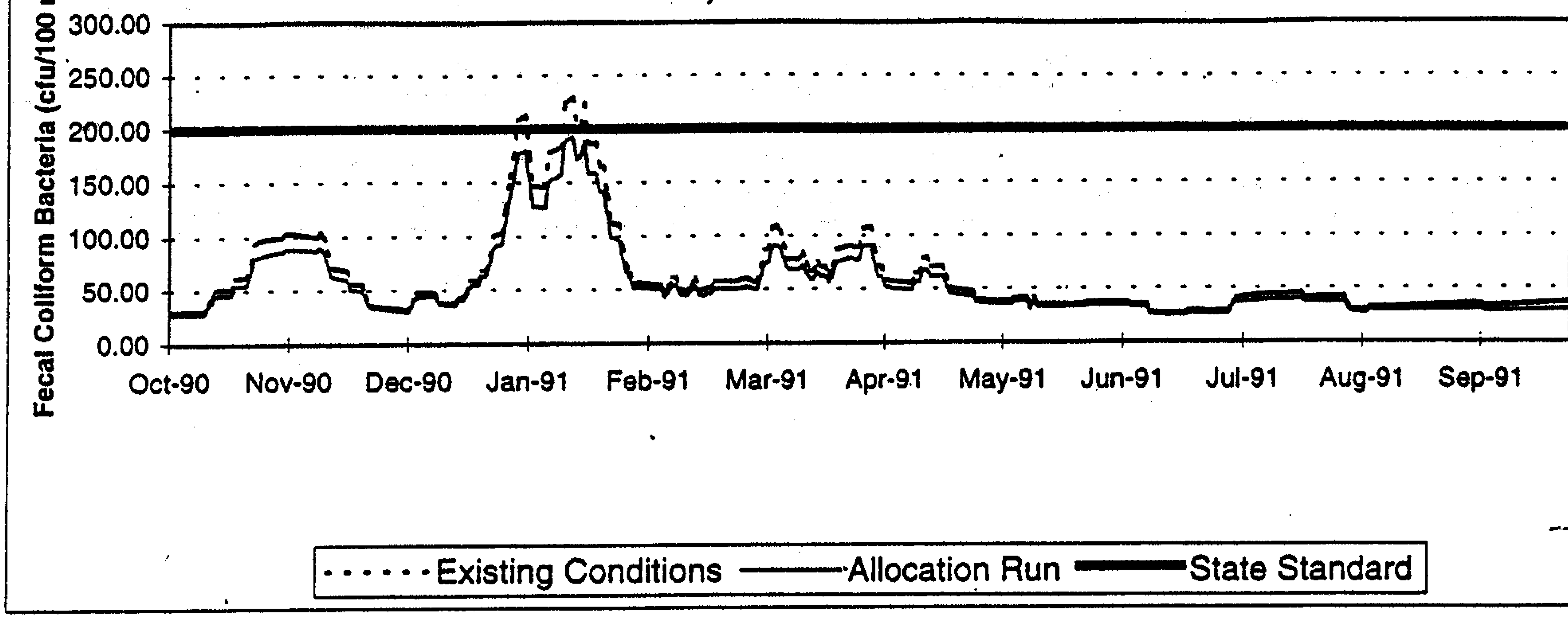

Figure C.2. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 2

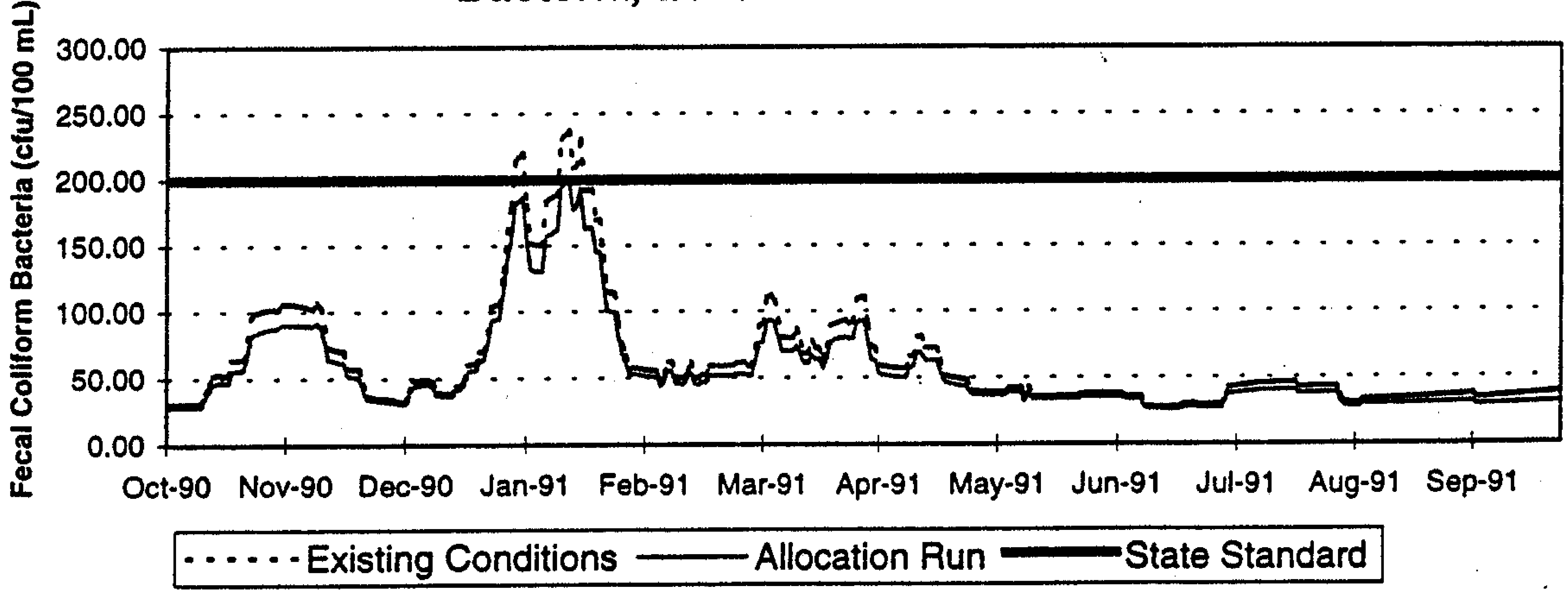

Figure C.3. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 3

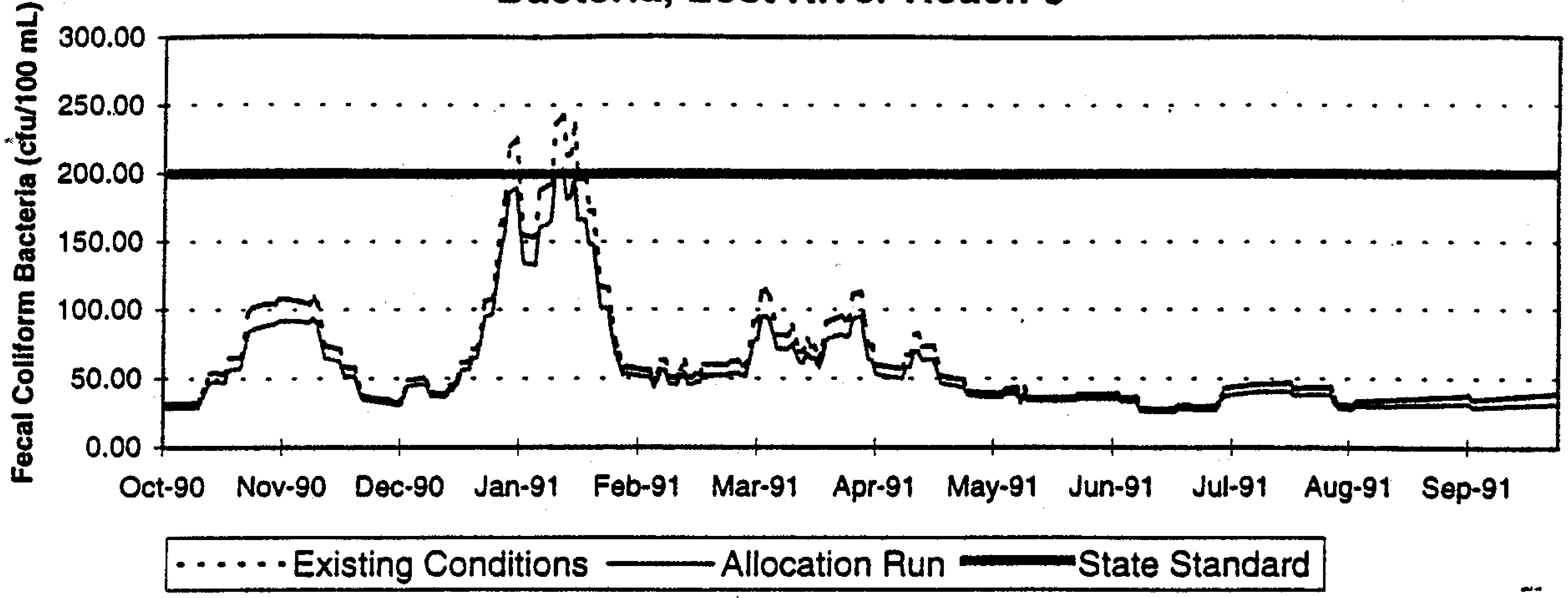

Figure C.4. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Baker Reach 1

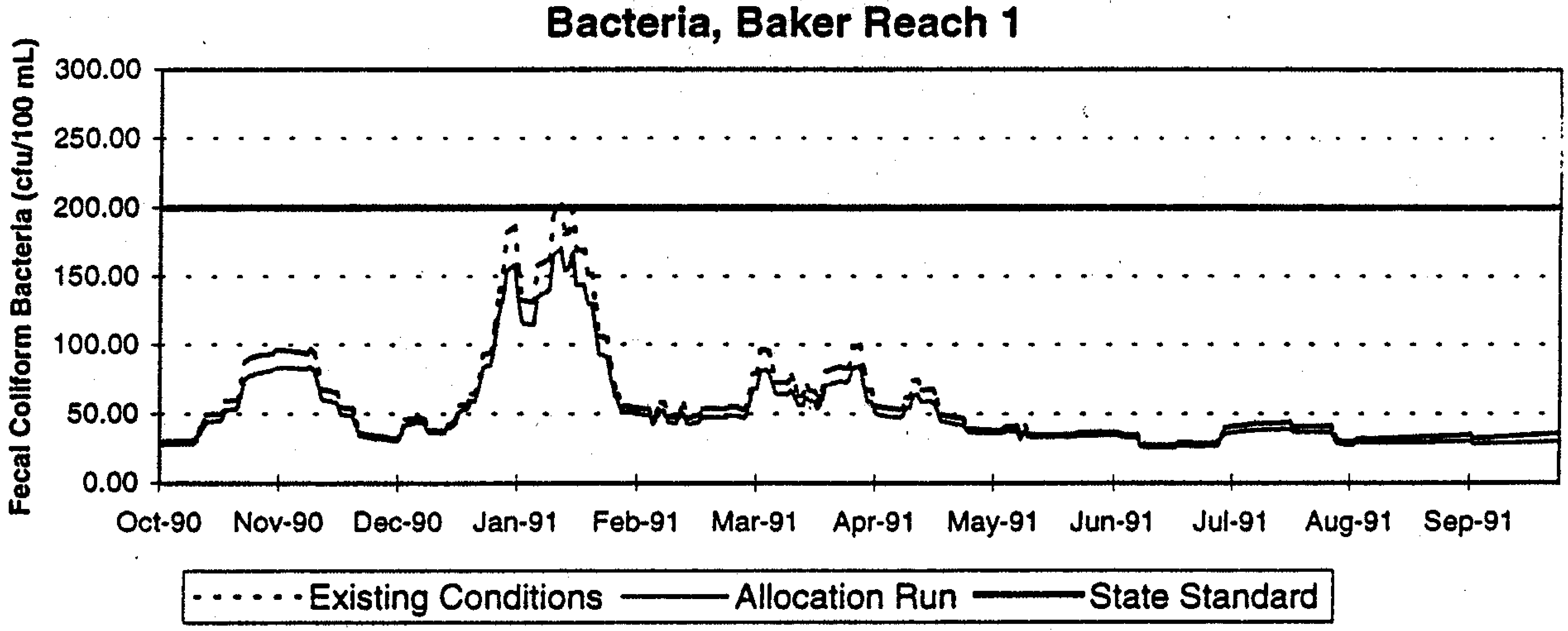

Figure C.5. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 4

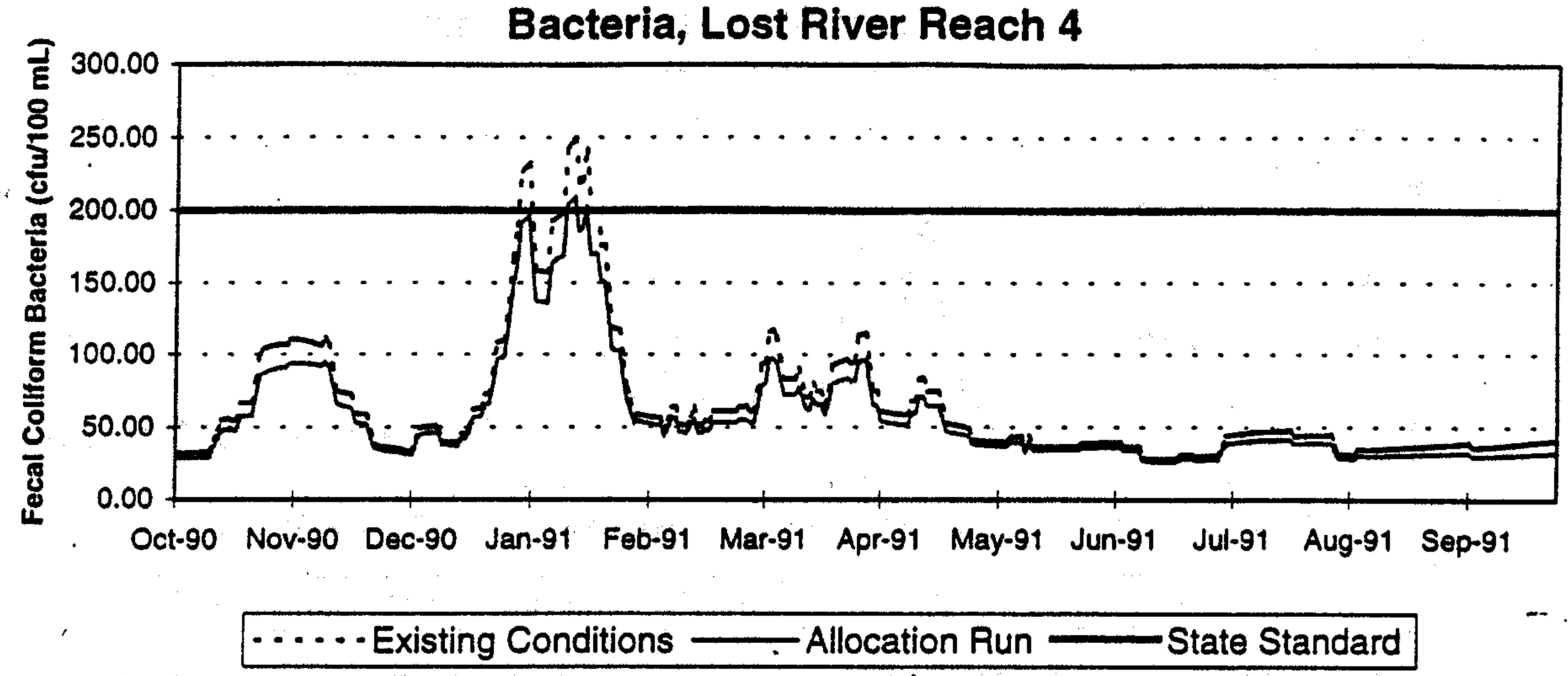

Figure C.6. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Kimsey Reach 1

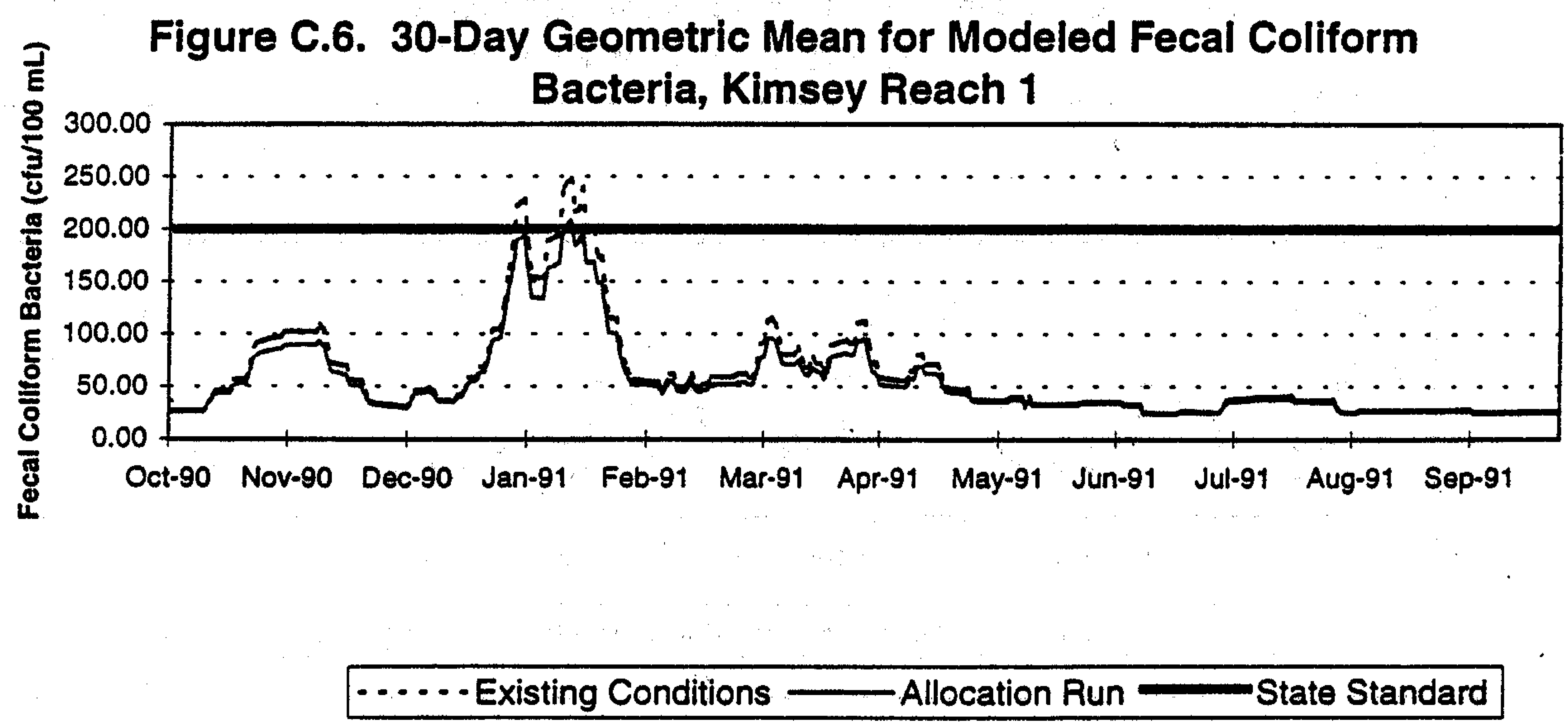

Figure C.7. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 5

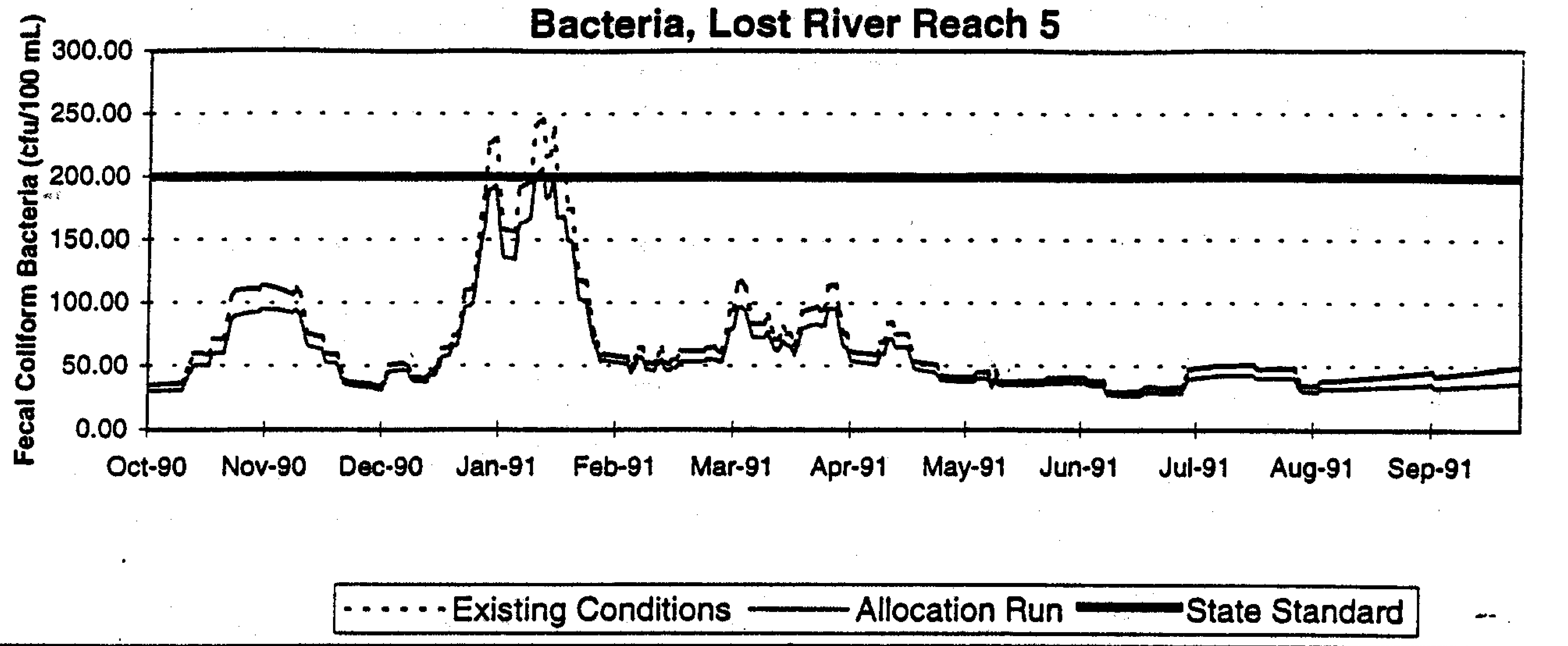

Figure C.8. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lower Cove Reach 1

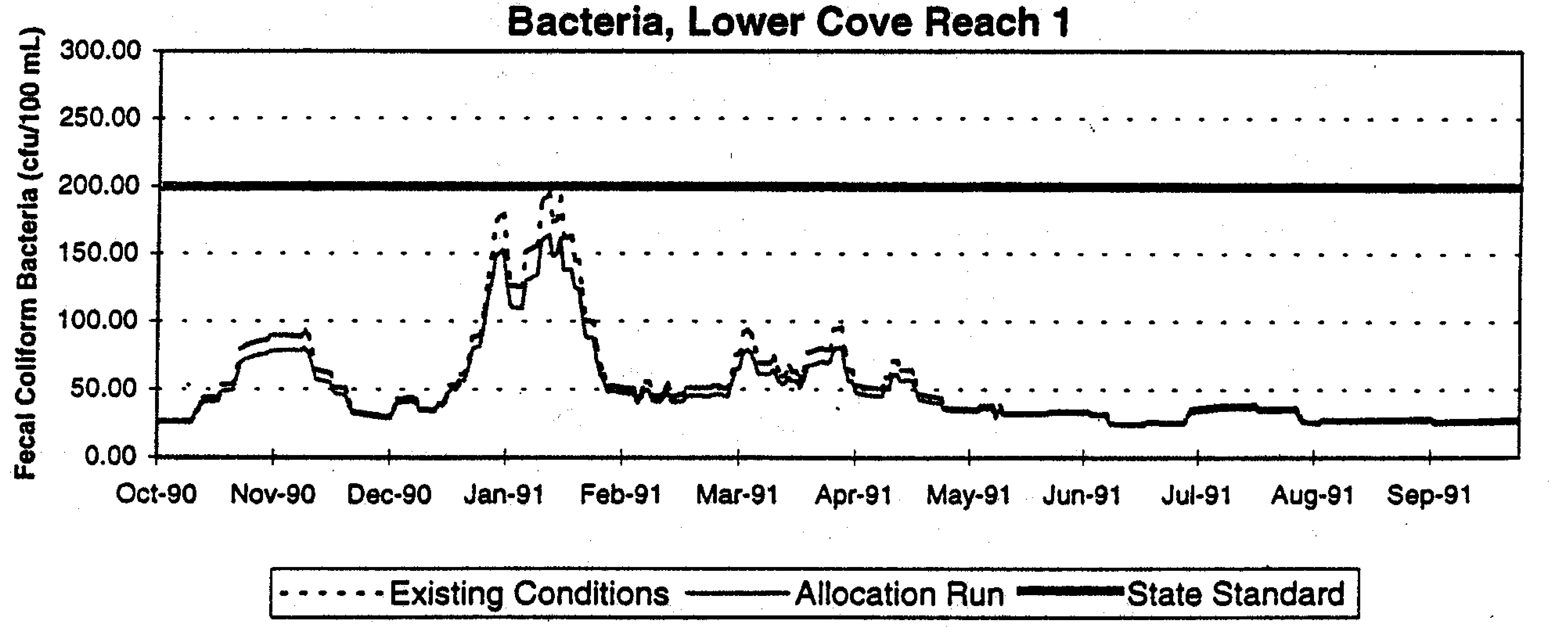

Figure C.9. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 6

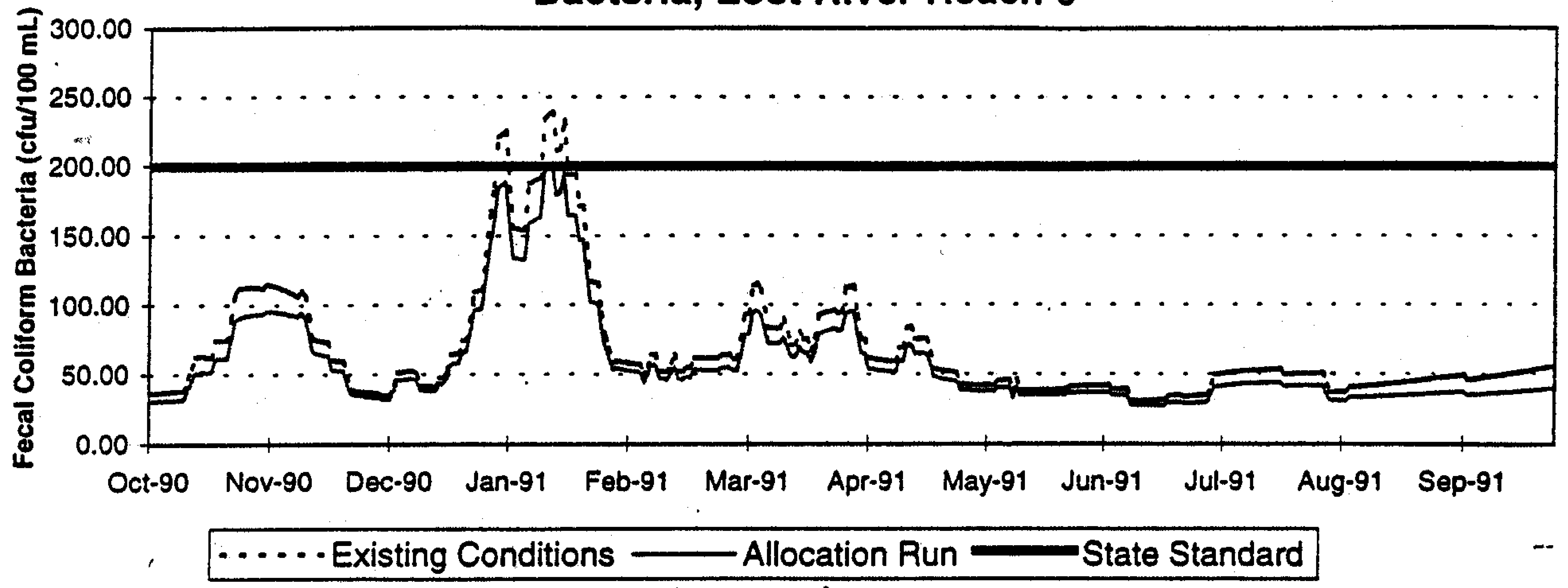

Figure C.10. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 7

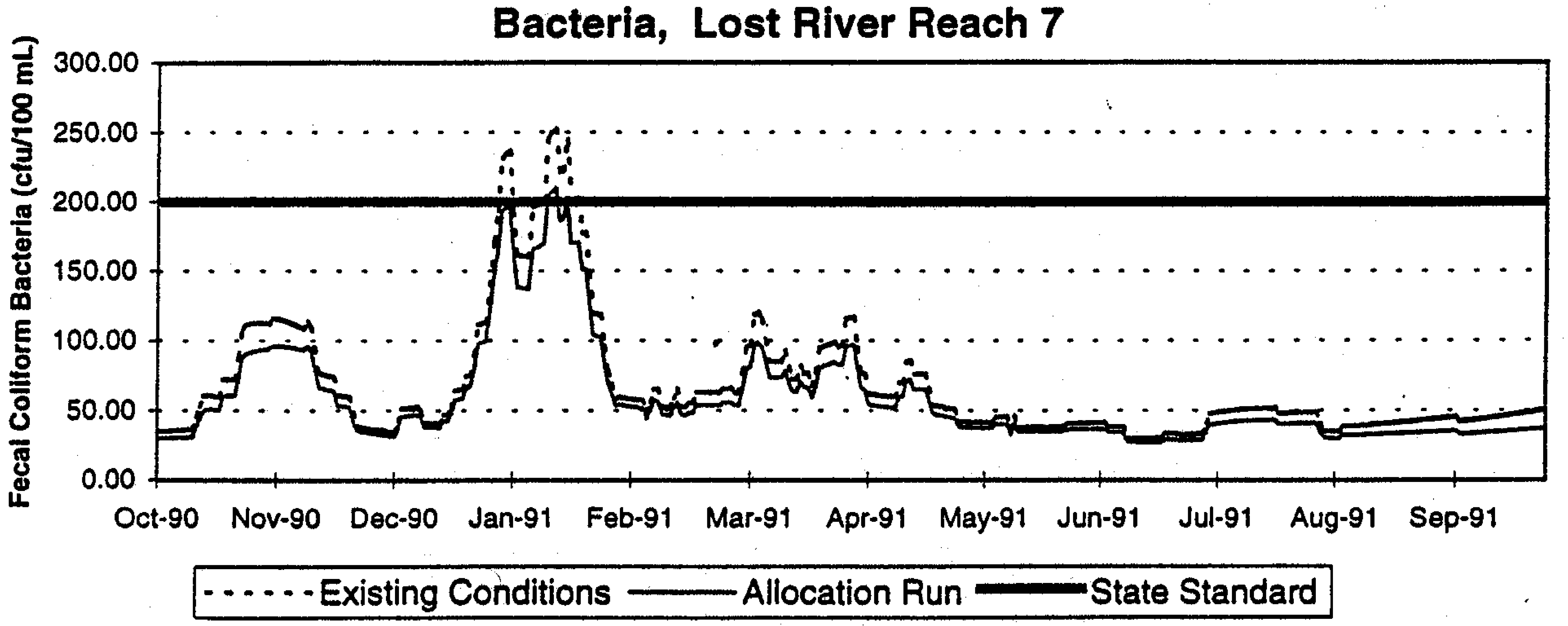

Figure C.11. 30-Day Geometric Mean for Modeled Fecal Coliform Bacteria, Lost River Reach 8