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Black River Wet Season Nonpoint Source Total Maximum Daily Load Study

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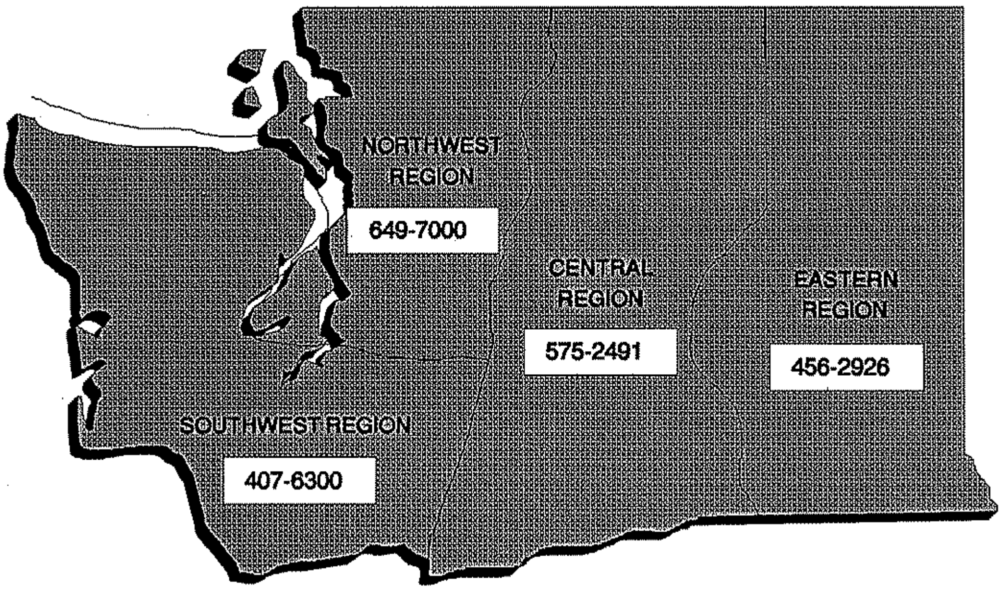

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Black River Wet Season Nonpoint Source Total Maximum Daily Load Study

by
Randy Coots

Environmental Investigations and Laboratory Services Program
Watershed Assessments Section
Olympia, Washington 98504-7710

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Abstract

The Washington State Department of Ecology conducted a two-year wet season fecal coliform study of the Black River in Thurston and Grays Harbor Counties during the winters of 1991-92 and 1992-93. The intent of the study was to establish a nonpoint source loading capacity for fecal coliform bacteria, recommend load allocations for control of sources throughout the basin, and identify specific problem areas for follow-up action or study. Three of the major tributaries (Waddell, Beaver, and Mima Creeks) were sampled to determine inputs from subdrainages. Study findings indicated nine of the 11 mainstem sites violated at least one of the two water quality criteria for fecal coliform. A mass balance model was developed in order to evaluate critical condition loads and estimate pollutant reductions needed to achieve compliance with the fecal coliform standard. Seven of the 10 mainstem Black River segments established in this survey will require load reductions to meet proposed bacteria load allocations. Beaver Creek had the highest fecal coliform counts in the basin, with water quality standards being exceeded throughout both years. Recommendations are included to pursue corrective actions for control of nonpoint source problem areas.

Acknowledgements

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Introduction

The Black River, a Class A waterbody, is contained almost entirely within Thurston County, with less than 5% of the drainage in Grays Harbor County. The Black River drains about 128 square miles of land, and is roughly 24 miles long with over 84 miles of tributaries (Figure 1). The Black River has four major subbasins: Beaver, Mima, Salmon, and Waddell Creeks. Originating in wetlands just south of Black Lake, the Black River flows in a southwesterly direction through Thurston County and enters Grays Harbor County at river mile (RM) 5.7, joining the Chehalis River at RM 47, two miles southeast of Oakville. From the river mouth (RM 0) to about RM 3.5, the Black River winds in and out of the Chehalis Indian Reservation.

The Black River channel has a very low slope, averaging two feet per mile over its course. This accounts for the lake-like character exhibited through the middle portion of the drainage. The Black River features some of the largest natural freshwater wetlands in western Washington. The upper one third of the river has a mixed hydrologic character of wetlands and riffles/runs near the town of Littlerock. The middle one third takes on a ribbon-lake or bayou character, generally without visible flow. Then at about RM 10.0, it assumes a more typical riffle/run/glide character down to the confluence with the Chehalis River.

In August 1989, the Black River gained local attention because of a large fish kill that was first discovered around RM 7.1 at the Moon Road Bridge. The fish kill involved a variety of fish species and total numbers in the thousands. The kill progressed downstream, affecting hundreds of adult Chinook salmon in the Chehalis River near Oakville. It was assumed the origin of the Chehalis fish kill was from the Black River kill. No clear cause was ever identified although toxic substances were suspected (Ecology, 1989).

As a result of the fish kill, Ecology pursued a screening study of the Black River (Dickes, 1990). The study was a cooperative effort between the Chehalis Confederated Tribes and Ecology. Another development was the creation of the Black River Watch Cooperative Monitoring Project. Under the guidance of Thurston County Office of Water Quality (County) the volunteer group made up of shoreline residents, Black River fish farmers, the Black River Canoe Club, and the County, conducted water quality monitoring of the Black River.

In a screening survey of the entire Chehalis River basin by Ecology in 1991 (Dickes, 1992), the Black River basin had one of the most notable fecal coliform problems of any subbasin. These Ecology results were consistent with the results of the

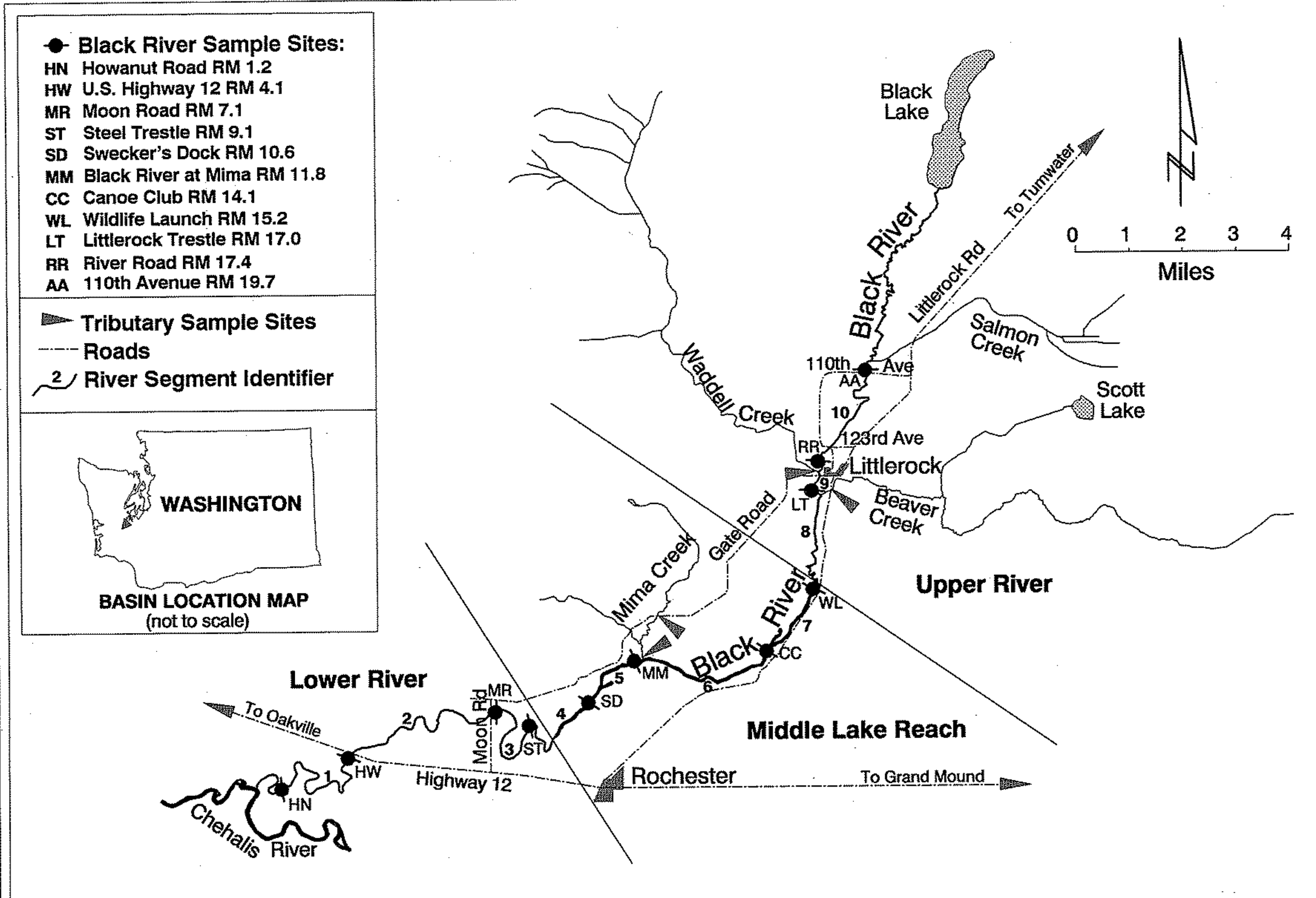

Figure 1. Black River and major tributary TMDL study sites.

cooperative monitoring project conducted under the guidance of the County in 1990-91 (Blocher, 1991). During the course of these investigations, we have also gained better understanding of the nonpoint source (NPS) fecal coliform (FC) problems in the Black River basin.

Fecal coliform bacteria are in the feces of warm blooded animals and are not generally considered pathogens themselves but an "indicator organism" of the potential presence of pathogens. Results of the studies by Thurston County and Ecology require that a total maximum daily load (TMDL) for NPS fecal coliform pollution control in the Black River watershed be developed. A TMDL establishes the maximum pollution loading a river can receive without violating water quality standards through implementation of load allocations. If the loading capacity (LC) is currently exceeded, a pollution control strategy (*i.e.*, TMDL) consisting of wasteload allocations (WLA) for point sources and load allocations (LA) for nonpoint sources must be implemented. This study should provide a framework for future studies in basins impacted largely by NPS bacterial problems.

Since 1972, Section 303(d) of the Federal Clean Water Act has required states to implement water quality-based pollution controls on segments where technology-based controls are inadequate to achieve water quality standards. Until recently the EPA and Ecology had not aggressively implemented all facets of the Act. It has become apparent that whole basin management of water resources is the best approach to watershed protection. To meet the requirements of Section 303(d) on the Black River, a TMDL must be established for pollutants violating water quality standards.

Developing and applying the water quality-based approach to water quality management entails a five step process:

1. identification of water quality-limited segments;
2. priority ranking and targeting;
3. development of TMDLs, WLAs/LAs;
4. implementation of controls; and
5. assessment of control action.

This process cycles with each step leading to the next.

Objectives

The objectives of the Black River Nonpoint TMDL Study are to:

- compare FC bacteria data for the Black River to state water quality standards to determine violations and associate violations with land use;

- develop a process for establishing LC/LAs concerned primarily with NPS pollution; and

- establish a wet season LC for FC bacteria on the Black River, and recommend LAs for control of nonpoint sources.

Methods

Analysis Strategy

This TMDL study was designed with the long-range goal of reducing NPS fecal coliform loading in the Black River basin to a level within the water quality standards. The general approach of the study was to monitor river segments during wet season rain events for two years. Loading to each segment was assessed and ranked, and violations of water quality standards and areas with sensitivity were identified. A FC die-off rate was generated using field data, literature values, and temperature in order to predict changes in FC loads through individual river segments. A simple mass balance model was developed that utilized the FC die-off rate to estimate the contributions from nearshore areas within river segments. From the estimates of segment contributions, the reduction in loading necessary to meet water quality standards was then calculated and segment prioritization proceeded.

Previous investigations on the Black River had determined the wet season to be the most critical time of nonpoint FC loading. Thus, runoff events were used to characterize loading after the wet season began. Although there are many factors that determine surface soil saturation, the start of the wet season was estimated using the following reasoning. Since the basin has extensive wetlands and a low slope it was assumed that considerable groundwater recharge would have to take place following summer low flow before significant runoff would occur. The only concurrent discharge and precipitation data for the Black River was recorded in the late 1940's. A review of these data suggested 10 to 12 inches of rainfall fell during October and November before flows significantly increased relative to the amount of rainfall. Consequently, 10 inches was selected to signal the onset of the wet season.

Sampling Strategy

Samples were collected during the 1991-1992 and the 1992-1993 wet seasons. In both survey years sampling began the first week of December, after 10 or more inches of rain had fallen. The National Weather Service operates a weather station at the Olympia Airport located at the northeast perimeter of the Black River basin. Daily precipitation throughout the study was monitored to initiate sampling runs. In year one, sampling was initiated when 0.5 inch or more of rainfall had fallen within five days. In year two, sampling was initiated when 0.5 inch or more of rainfall had fallen within the previous 48 hours. Because of analytical restrictions at Ecology's Manchester Environmental Laboratory (MEL), sampling days were confined to Monday through Wednesday in year one, and Monday through Thursday in year two. In year one, 10 sampling surveys were completed, and in year two, 11.

FC and *Escherichia coli* (*E. coli*) samples were collected from 11 Black River sites and three major tributaries (*i.e.*, Beaver, Mima, and Waddell Creeks) as shown in Figure 1. The Black River study area sampling locations were selected based on land uses, potential source locations, river morphology, access, and logistics (Figure 1). Samples were collected at segment boundaries. Upstream sampling stations were used to provide a background level of FC entering each segment. The downstream sampling point of one segment was the upstream site for the next. In year two of the study, sampling was extended up the Beaver and Mima Creek subdrainages. Tributary sampling site locations are displayed on Figure A1 in Appendix A. These subdrainages were identified in year one as being potential problem areas. Six sample surveys were completed within the subdrainages for FC and *E. coli* bacteria.

Analytical Methods

Bacteria samples were collected from flowing water, or from the center channel through the lake reach, at 3 to 12 inches depth in 250 mL autoclaved glass bottles. Immediately following collection, samples were placed in the dark, on ice. Analysis commenced within 24 hours of collection at Ecology's MEL. Holding time for bacteria samples were never exceeded throughout the study. Laboratory analyses were performed in accordance with APHA *et al.*, (1989) Method 9222 D (membrane filter {MF} technique) for FC; and EPA (1990) Task Method 1105 for *E. coli*.

Additional field measurements included: temperature (mercury thermometer); conductivity (Beckman meter Model RB-5); and river discharge (Marsh McBirney magnetic velocity meter); using standard protocols (Ecology, 1993). All meters utilized in the survey were calibrated and used in accordance with user manuals. Mercury thermometers were periodically verified by ice bath emersion.

FC data are naturally susceptible to high variation. To improve precision, all samples in year one were collected in replicate. The mean of replicate samples was used to establish data points used in calculations. In year two only five sites were collected in replicate per survey day because year one replicates had adequate precision, which is discussed in the Quality Assurance section below. Additionally, in year two *E. coli* were sampled in replicate at replicate FC sites.

River Discharge

No recent discharge information was available for the Black River or its tributaries. Staff gages were installed at all sample locations except Moon Road where tape down techniques were employed to measure water height. In addition, a continuous stage recorder was installed at the U.S. Highway 12 bridge to log stage height hourly throughout the survey.

Flow rating curves were developed for eight mainstem and three tributary sites in year one. An additional 11 tributary sites were added in year two. Curves were produced each survey year by regression of stage height against five to 10 discharge measurements made from a wide range of flows. Estimated and measured discharges were multiplied by the FC density for each site to obtain FC load estimates.

Land Use and Segment Descriptions

About 80% of the Black River drainage was included in the study area (from 110th Ave. to the confluence with the Chehalis River). Land use, channel type, size, and other characteristics for the 10 mainstem river segments are described in Table 1. Data for dairy herd populations and major land use activities were supplied by Diane Harvester of Ecology's Southwest Regional Office (SWRO), and a United States Geological Survey (USGS) land use inventory (Anderson *et. al.*, 1976), respectively. The entire Black River basin land use data set, delineated by segment, is contained in Appendix B. Percentages of different land uses within the basin (Table 1; Appendix B) were determined using an Arc/Info Geographic Information System (GIS). Although the land use inventory is 17 years old, the data were expected to be of reasonable quality because of the limited amount of new development in the drainage. The Black River basin has remained a rural area of Thurston and Grays Harbor Counties. The state-owned Capitol Forest uplands border the river to the west, extensive wetlands are located along a majority of the river, and over 70% of the surface soils in the drainage have severe on-site septic system limitations (LCCD, 1992).

Quality Assurance

FC bacteria from NPS tend to be more inherently variable than other water quality data. This is because bacterial populations have a patchy distribution in the environment and are intermittently discharged. Standardized field sampling, holding, and shipping procedures were employed to reduce variability. As stated earlier, in year one, all samples were collected in replicate. In year two, five sites were collected in replicate each survey day. To assess the overall variability (*i.e.*, field and analytical) of the bacteria data, the coefficient of variation (CV) was calculated

Table 1. Black River NPS TMDL study segment and surrounding land use characteristics.

Seg. No.	Location (RM)	Drainage Area (sq mi)	Agriculture Types * 1	2	3	4	5	6	7	8	Land Use % A	B	C	D	E	F	G	H	Channel Type	Macrophyte Growth	Tributary
1	1.2–4.1	4.6	2	X	X					400	34	11			54				Riffle/Run	Extensive	
2	4.1–7.1	4.1	1	X	X	X				100	52	6			40		1		Riffle/Run	Moderate	
3	7.1–9.1	1.2	1	X	X	X	X	X	X	50	7				90			4	Riffle/Run	Mode./Exten.	
4	9.1–10.6	4.7		X			3				18	10		12	51	9			Ribbon–lake	Moderate	
5	10.6–11.8	5.4		X		X					25	19		7	41		6		Ribbon–lake	Moderate	
6	11.8–14.0	15.9	1	X						3000	36	46	4		13				Ribbon–lake	Moderate	Mima
7	14.0–15.2	7.4									47	15	4		2	32			Ribbon–lake	Mode./Exten.	
8	15.2–17.0	31.5	1	X						1000	61	9	8		12	6		2	Riffle/Run	Low/Mode.	Beaver
9	17.0–17.4	18.4		X							41	53			3	1		1	Riffle/Run	Low	Waddell
10	17.4–19.7	9.6	2	X						1300	45	19	7	1	24			1	Riffle/Run to Wetland	Low/Mode.	
11	19.7–	25.2		X							44	34	3	2	10	1	3		Wetland	No data	Dempsey/Salmon

Keys:

	Agriculture		Land Use
1	Dairy Farms	A	Mixed Forest
2	Hobby Farms	B	Evergreen Forest
3	Turf and Truck Farms	C	Forested Wetland
4	Poultry Farm	D	Nonforested Wetland
5	Aquaculture	E	Crop and Pasture
6	Blueberry Fields	F	Mixed Rangeland
7	Fruit Packers	G	Residential
8	Estimated Dairy Cow Count	H	Other Agriculture

* Agricultural type numbers reported if known.

for all pairs of replicate samples (Table 2). The CV is calculated by dividing the standard deviation by the mean of the replicates. As shown in Figure 2, when bacteria densities are near the lower detection limit of 1 cfu/100 mL, a higher CV is expected (*e.g.*, the CV for replicate samples with values of 1 and 2 is 47%, whereas the CV for 100 and 101 is 0.7%). The overall mean CV of the FC replicates for the study was 20%. The mean CV of *E. coli* replicates collected in year two was 19%. When the replicate FC results are separated by mean densities of $\geq$100/100 mL and <100/100 mL, the mean CV's are 14% and 21%, respectively. Based on CV values from similar studies, the FC variability was considered acceptable (Determan *et al.*, 1985, Joy *et al.*, 1991; and Patterson and Dickes, 1993).

The lab also used split and blank sample analyses to assess lab variability for quality control. The CV for lab split sample analyses for FC and *E. coli* was 21% and 20%, respectively (Figure 3). All blank samples analyzed for the study were reported as not detected at the method detection limit (*i.e.*, 1cfu/100 mL).

Table 2. Comparison of coefficients of variation calculated for replicate samples.

	Coefficient of Variation Fecal Coliform	*E. coli*
<u>Year 1</u>		
>100/100 mL	12% (n=25)	
<100/100 mL	22% (n=125)	
Total Year 1	21% (n=150)	
<u>Year 2</u>		
>100/100 mL	16% (n=24)	18% (n=22)
<100/100 mL	18% (n=28)	20% (n=29)
Total Year 2	17% (n=52)	19% (n=51)
<u>Year 1 & 2</u>		
>100/100 mL	14% (n=49)	
<100/100 mL	21% (n=153)	
<u>Mean Total Year 1 & 2</u>	20% (n=202)	

The quality of flow data was also assessed by determining the CV of replicate flow measurements. Early in year one, two sets of flow replicates had very low CV's of 0.46% and 1.48% (mean of 0.97%). Because flow measurement on large rivers are very time-intensive, replicate measurements were discontinued in favor of measuring flows at additional sites.

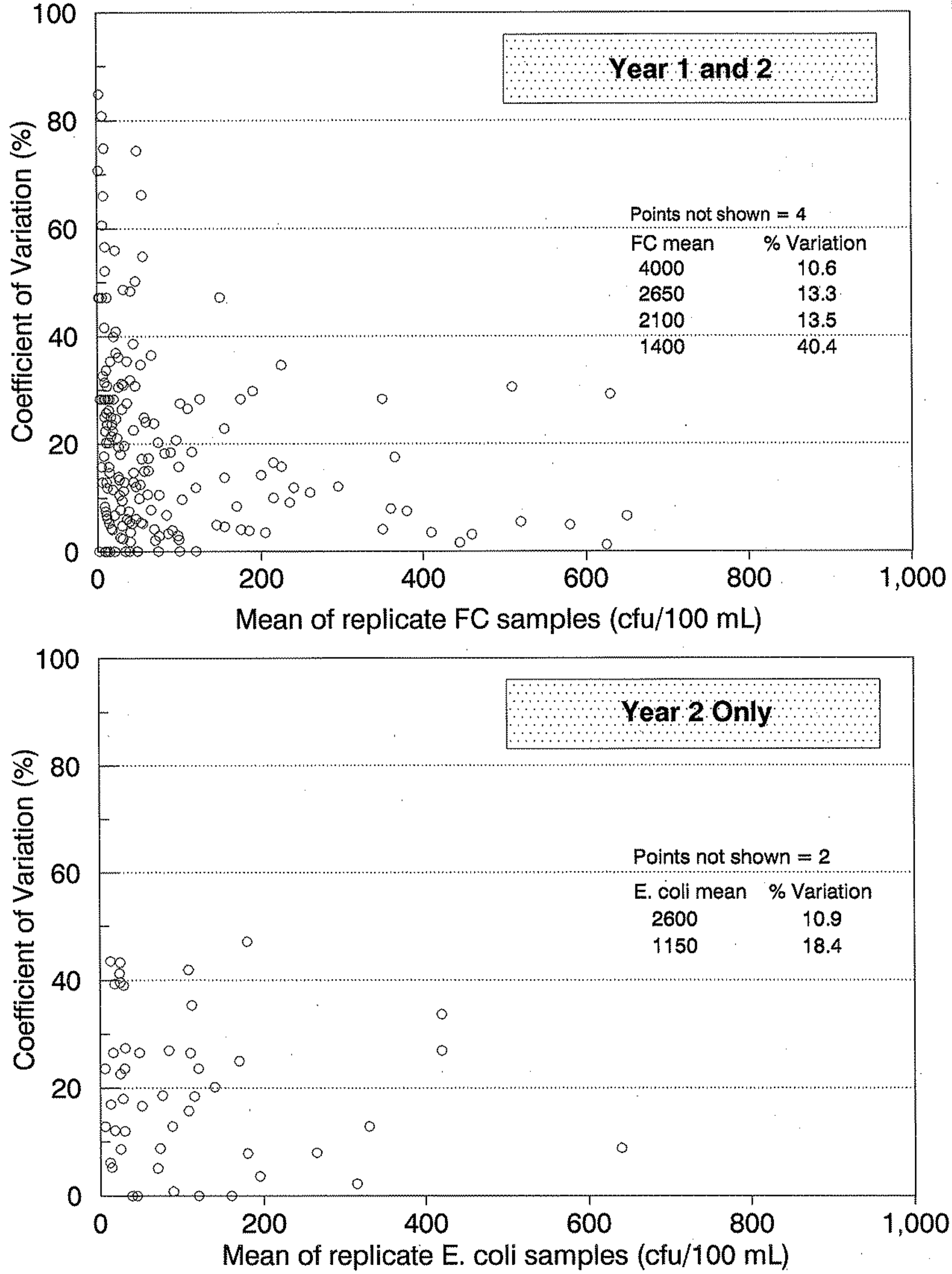

Figure 2. Coefficient of variation for FC and E. coli field replicate samples.

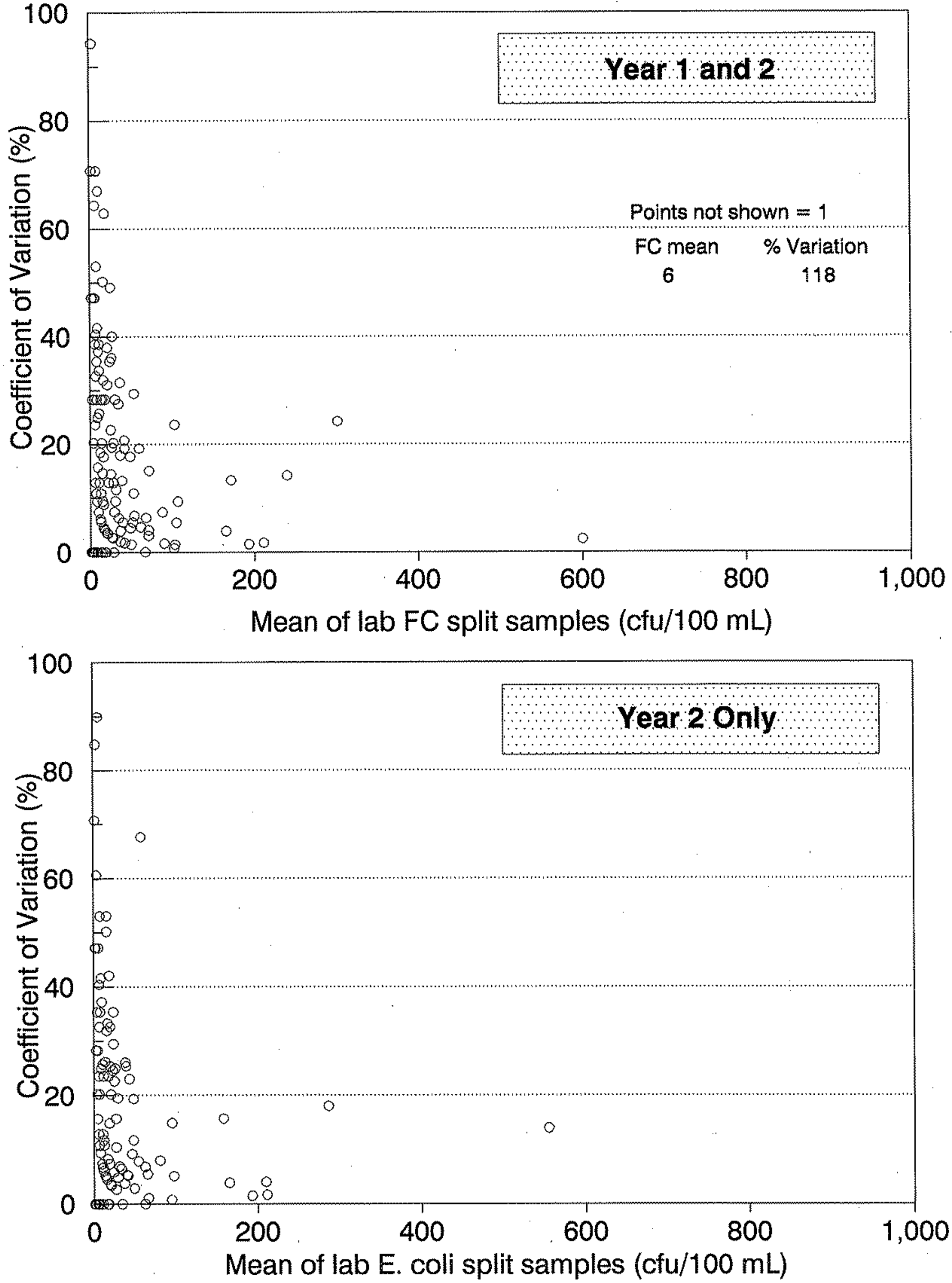

Figure 3. Coefficient of variation for FC and E. coli lab split samples.

Results and Discussion

Water Budget

River discharge was below normal for the December through March study period both years. The only historical data available for flow comparison (Williams and Pearson, 1985) was from a USGS gaging station operated from 1945 to 1950 at 128th Avenue in Littlerock (RM 17.2). For that period of record, the mean December through March discharge was 345 cfs. By contrast, this survey's average discharge at 128th Avenue was 139 cfs in year one and 91.4 cfs in year two (mean flow 115 cfs). The mean flow for actual sample days was 180 cfs in year one and 197 cfs in year two, likely a function of changes in the initiation of sampling from 0.5 inch of rainfall within five days to 0.5 inch within 2 days.

The Black River had a wide range of wet season discharge for both survey years (Figure 4). In general, year one had a higher flow than year two until late in the survey season. Rainfall for the December through March period was below normal during the two survey years (*i.e.*, 8.4 inches below the normal 27.8 inches in year one, and 12.0 inches below the normal in year two). February of year two was the driest on record (0.22 inches). The low rainfall during the two survey years likely reduced groundwater inputs, runoff quantities, and pollutant loading to the river.

River discharge increased down the drainage from 110th Avenue to the Canoe Club. The two largest of the three studied tributaries, Waddell and Beaver Creek, discharge into this portion of the drainage. Waddell Creek's mean discharge for actual survey days was 90.5 cfs, which contributed 21% to 86% of the flow at the Littlerock Trestle site. Beaver Creek's mean discharge for actual survey days was 90.2 cfs, which contributed 20% to 53% of the flow at the Wildlife Launch site.

A slight loss of expected flow (about 10%) from the Littlerock Trestle and Beaver Creek confluence was observed at the Wildlife Launch, although the apparent loss is within the confidence limits of the measurement methods. From the Wildlife Launch to the Canoe Club, there was a significant flow gain (Figure 5).

Below the Canoe Club (RM 14.1), there appeared to be a loss of flow from the main channel, likely to extensive riparian wetlands. In year one, approximately 17% of the river flow was lost to the wetlands as far down as the Steel Trestle (RM 9.1). In year two, the loss was evident as far as the Black River at Mima (RM 11.8), and averaged about 7%. The amount of loss from the main channel was related to the volume of discharge. During lower flows, the loss was little to none, but during higher flows the loss appeared to be substantial.

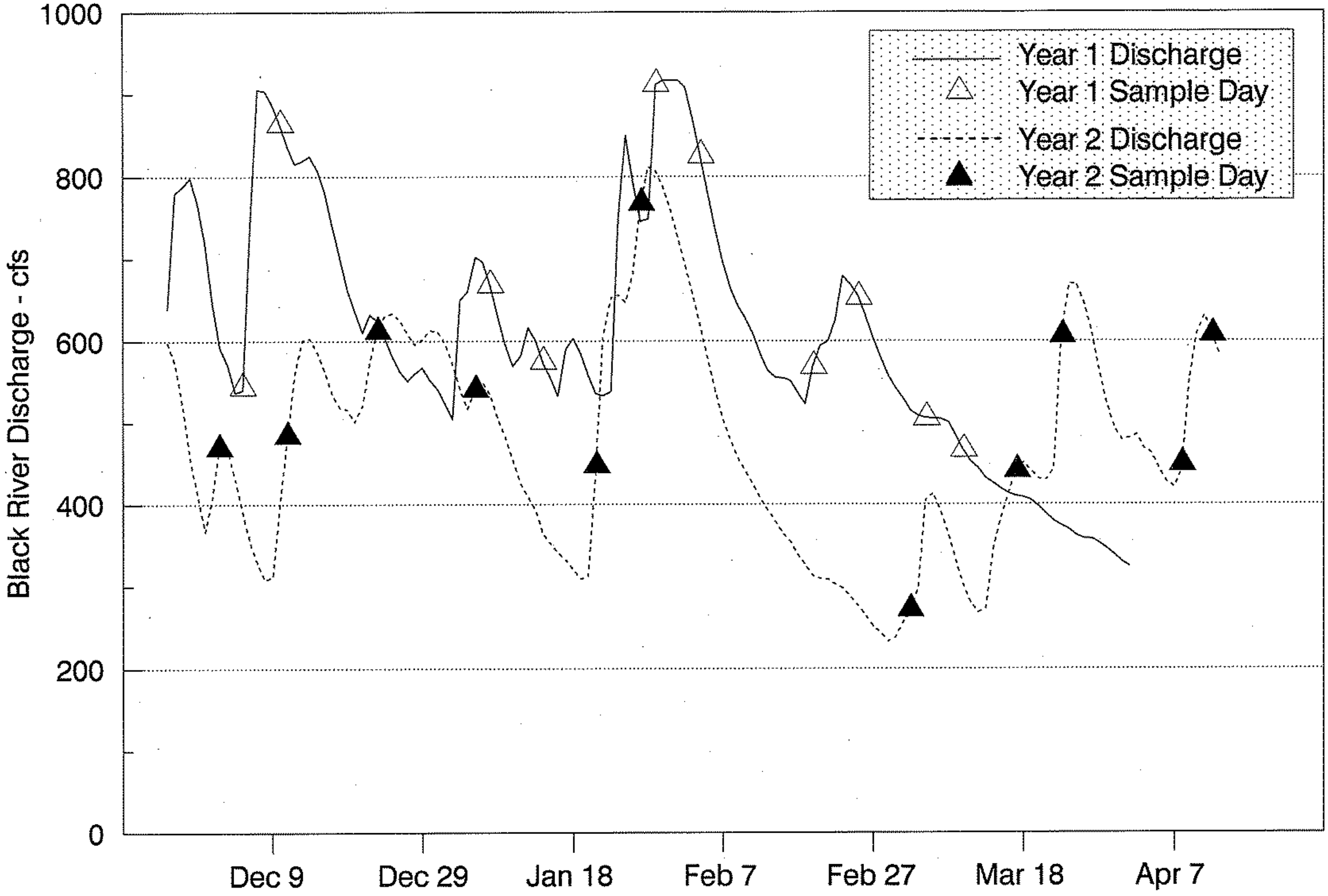

Figure 4. Black River discharge at river mile 1.2, Howanut Road-year 1 and 2.

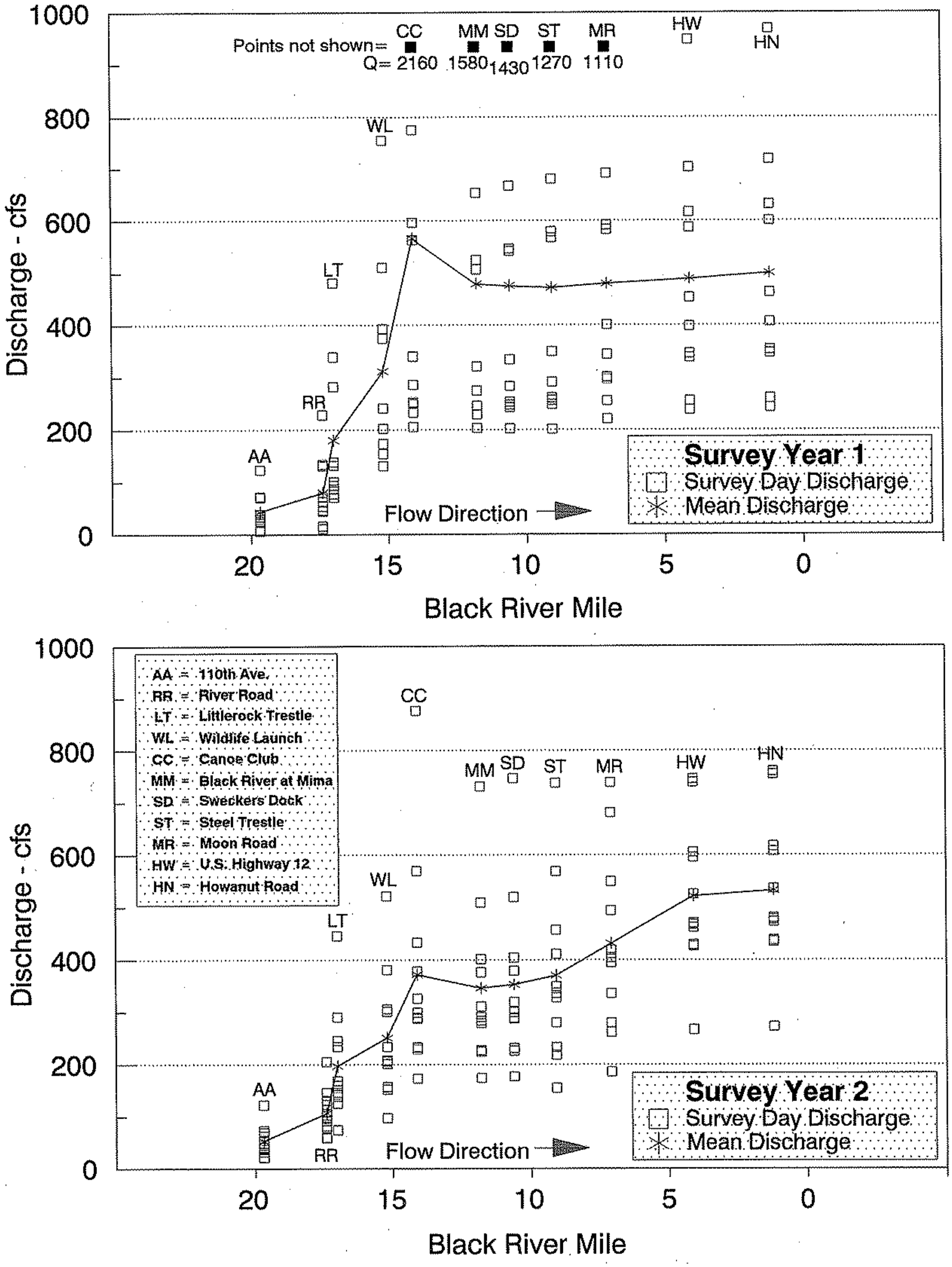

Figure 5. Survey day discharge by station and year.

Just above the Black River at Mima site the smallest of the studied tributaries, Mima Creek, enters. Mima Creek's survey day discharge averaged 50.7 cfs for the two study years, which contributed from 4% to 31% of the discharge at the Black River at Mima station. Flows steadily increased from the Steel Trestle downstream both years.

Fecal Coliform

Year One and Year Two Differences

The initial survey design called for sampling when at least 0.5 inch of rainfall occurred during a five-day period. After the first year of sampling, the antecedent rainfall period was shortened to two days. Year one and two FC data were statistically compared for significance between years at the 95% confidence level. The data could not be transformed to normal distribution so non-parametric analysis of variance (the Kruskal-Wallis test) was used.

Non-parametric analysis tends to be less robust to detect subtle differences than parametric tests, but can be useful when data cannot be normalized for parametric tests. The Kruskal-Wallis test showed a significant difference in FC between the two years ($P< 0.001$). Data from individual sample sites for year one and two were also compared. Log-transformed FC data were compared by analysis of variance (ANOVA). Statistical differences between survey years were found only in the upper basin sites: 110th Ave. ($P=0.02$); River Road ($P=0.02$); Littlerock Trestle ($P=0.002$); and the Wildlife Launch ($P=0.03$). The year-to-year differences may be partly explained by the change in protocol for initiating sampling, as well as the quicker response time of flow to rainfall and lower dilution available in the upper drainage.

A review of sample dates showed that year one surveys were performed on the falling arms of the hydrograph during seven of the 10 survey events (Figure 4). In year two, surveys were performed on rising arms of the hydrograph for all but the last survey. Considering the significantly higher year two FC results and the shorter rainfall period initiating sampling, it appears the magnitude of FC concentrations in the basin is related to sampling time on the hydrograph. Although, exploration of the hydrodynamics of groundwater/surface water interactions and surface soil saturation effects on runoff was beyond the scope of this study, it appears year two results better depict the problems that occur during a winter storm event from NPS runoff in the drainage. In addition, for capturing runoff driven FC loading, particularly in the upper drainage, samples should be collected as close to the rain event as possible on a rising hydrograph.

Water Quality Violations

The Washington State water quality standards for FC are written with two criteria. Both must be met to comply with water quality standards. Chapter 173-201A WAC states, for FC in Class A waters: "organism levels shall both not exceed a geometric mean value of 100 colony forming units (cfu)/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 cfu/100 mL." In the following sections, level one and level two of the standards refer to the 100 cfu/100 mL and the 200 cfu/100 mL criteria, respectively.

The Black River has three distinct hydrographic regions: the upper river, the middle lake reach, and the lower river (Figure 1). The upper river transitions from wetlands to a more typical riffle/run/glide character, similar to the lower river, while the middle river is a distinctly different ribbon-lake. In general, station results for FC densities, water quality violations and loading were similar within each region. The lake reach tends to be more pollution sensitive, which is likely exacerbated by low current velocities. Unfortunately, this portion of the river received the highest FC loading of the drainage.

The following text reports water quality violations and loading for these three regions. Complete FC, *E. coli*, temperature, conductivity, and discharge data sets are contained in Appendix C. Table 3 ranks FC violations while Table 4 ranks loading by site and year. Areas having bank impacts or access by livestock were identified from a U.S. Fish and Wildlife Service study (Wampler *et al.*, 1993) and are summarized in Appendix B. General land use data are also summarized in Appendix B.

Upper River

The upper Black River includes segments 8, 9, 10 (RM 15.2 to 19.7) and stations WL to AA (Figure 1). There are an additional 25 square miles of drainage from the source of the Black River to the uppermost monitoring site at the 110th Avenue bridge (AA). Two of the three Black River tributaries monitored in this study discharge to the upper river.

The upper river mainstem sites at 110th Avenue (AA), River Road (RR), and the Littlerock Trestle (LT) had among the lowest FC counts and loads in the drainage (Tables C1, C2, and 4). Occasional excursions above 100 cfu/100 mL were observed, but geometric mean values for both years were below the 100 cfu/100 mL standard at all three sites (Figure 6). No violations of the second level standard were found in year one. In year two, counts were higher. FC samples collected at the River Road and Littlerock Trestle sites exceeded the second level of the standard on several occasions.

Table 3. Black River Nonpoint TMDL Study ranking of sample stations by fecal coliform water quality standards, year one and two.

1991–92

Station	FC Geometric Mean	Violates WQ Criterion of 100/100 mL	Number of 200/100 mL Excursions	Violates WQ Criterion of Less than 10% >200/100 mL
MM	64	No	3	Yes
SD	55	No	2	Yes
ST	46	No	1	No
WL	40	No	1	No
CC	37	No	1	No
MR	35	No	1	No
HN	32	No	1	No
HW	31	No	0	No
RR	21	No	0	No
AA	16	No	0	No
LT	14	No	0	No
Tributaries:				
BC	160	Yes	3	Yes
MB	23	No	0	No
WC	7	No	0	No

Site Key:	
AA=	110th Ave.
RR=	River Road
LT=	Littlerock Trestle
WL=	Wildlife Launch
CC=	Canoe Club
MM=	Black River at Mima
SD=	Sweckers Dock
ST=	Steel Trestle
MR=	Moon Road
HW=	U.S. Highway 12
HN=	Howanut Road
Tributaries:	
BC=	Beaver Creek
LD=	Littlerock Ditch
MB=	Mima Creek
WC=	Waddell Creek

1992–93

Station	FC Geometric Mean	Violates WQ Criterion of 100/100 mL	Number of 200/100 mL Excursions	Violates WQ Criterion of Less than 10% >200/100 mL
WL	150	Yes	4	Yes
CC	110	Yes	4	Yes
MM	100	No	4	Yes
SD	77	No	2	Yes
RR	76	No	3	Yes
LT	65	No	2	Yes
HN	54	No	2	Yes
ST	51	No	1	No
HW	46	No	2	Yes
MR	45	No	2	Yes
AA	40	No	0	No
Tributaries:				
BC	760	Yes	9	Yes
LD*	100*	No*	1*	Yes*
MB	40	No	2	Yes
WC	10	No	0	No

FC Geometric Mean Ranking Per Year Comparison

	Year 1	Year 2
AA	10	11
RR	9	5
LT	11	6
WL	4	1
CC	5	2
MM	1	3
SD	2	4
ST	3	8
MR	6	10
HW	8	9
HN	7	7
Tributaries:		
BC	1	1
LD		2
MB	2	3
WC	3	4

* LD sampled the last six surveys of year 2 only.

Table 4. Black River fecal coliform loading and rank by station and year.
Units: FC geometric mean = cfu/100 mL; FC mean study load = Trillion cfu/Day.

Station	1991-92 FC Geometric Mean	FC Mean Study Load Trillion cfu/Day	Ranking of Yearly Mean Study Loads	Station	1992-93 FC Geometric Mean	FC Mean Study Load Trillion cfu/Day
MM	64	0.749	1	CC	120	1.08
SD	55	0.639	2	WL	150	0.916
ST	46	0.530	3	MM	100	0.864
CC	37	0.513	4	HN	54	0.702
MR	35	0.410	5	SD	77	0.664
HN	32	0.390	6	HW	46	0.586
HW	31	0.370	7	MR	45	0.475
WL	40	0.304	8	ST	51	0.462
LT	14	0.0616	9	LT	65	0.314
RR	21	0.0411	10	RR	76	0.198
AA	16	0.0169	11	AA	40	0.0521
Tributaries:						
BC	160	0.367	1	BC/LD*	730	1.59
MB	23	0.0262	2	MB	40	0.0533
WC	7	0.0155	3	WC	10	0.0222

Key:
AA 110th Ave.
RR River Road
LT Littlerock Trestle
WL Wildlife Launch
CC Canoe Club
MM Black River at Mima Creek
SD Sweckers Dock
ST Steel Trestle
MR Moon Road
HW U.S. Highway 12
HN Howanut Road
BC/LD Beaver Creek/Littlerock Ditch
MB Mima Creek
WC Waddell Creek

* Beaver Creek and Littlerock Ditch loads were combined year two for reporting.

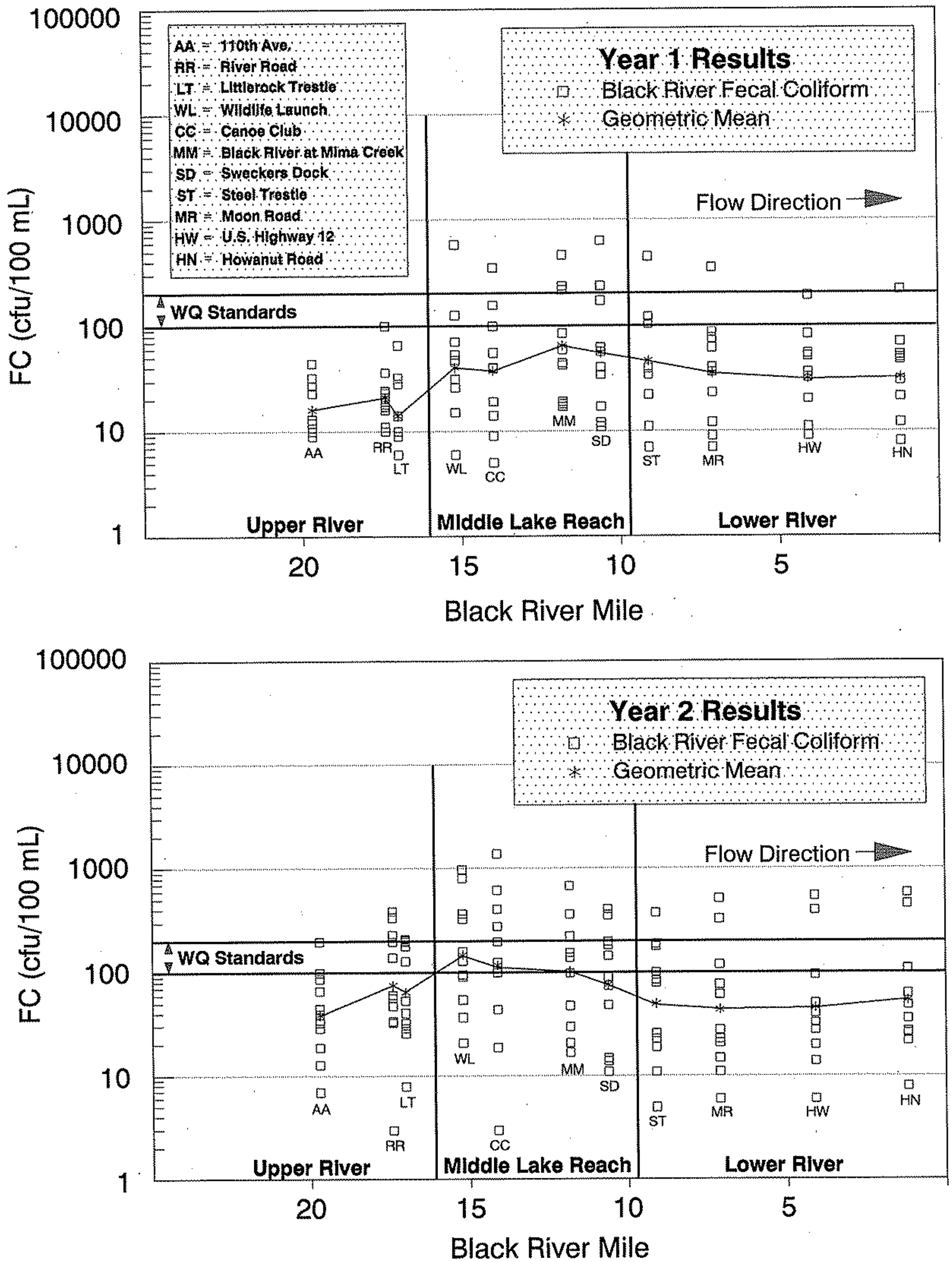

Figure 6. Black River fecal coliform results per site and year.

The upper basin has potential for loading from nonpoint sources, including the two commercial dairy farms (about 1,300 cows total) and scattered hobby farms (Table 1; Appendix B1). Around the 123rd Avenue bridge, manure was observed being sprayed onto fields by gun during both wet seasons. Segment 9 from River Road (RR) to Littlerock Trestle (LT) is the shortest in the basin. It was established to measure the effects of any nonpoint sources in Littlerock, the most populated area along the Black River. Potential sources of FC through this segment are stormwater, on-site septic systems, agriculture, and wildlife. However, results at River Road (RR) indicate that the violations of FC standards at the Littlerock Trestle (LT) station are coming from Segment 10 upstream, not from within Segment 9.

Waddell Creek, the first of the two major tributaries studied in the upper river, joins the Black River within Segment 9 from the west at RM 17.3. Discharge is only a few hundred meters below the River Road station (Figure 1). Waddell Creek (WC) samples had the lowest FC counts of any site in the basin over both survey years (Table 3; Figure 7). The low counts in Waddell Creek over the two years were not surprising given that the majority of the subbasin land area is forested uplands of the Black Hills. Waddell Creek is likely the ideal subbasin to exhibit low NPS impacts since only a small portion is in agricultural lands (Table 1). The large volume of higher quality water from Waddell Creek improved FC counts at the Littlerock Trestle station.

Beaver Creek, the other studied tributary discharging to the upper river, enters from the east at RM 16.8, just south of Littlerock (Figures 1 and A1). Beaver Creek (BC) had the most serious FC pollution problem in the Black River drainage. In year one, Beaver Creek had the highest station FC count for six of the 10 surveys (Table C1) and the highest station geometric mean (Table 3). Beaver Creek violated both levels of the FC standard, and was the only site in year one to violate the first FC criterion level. In year two, Beaver Creek had the highest station FC count for eight of 11 surveys (Table C2), and the highest station geometric mean (Table 3). Beaver Creek violated both levels of the FC standard in year two, with nine of 11 (82%) samples being above 200 cfu/100 mL.

Although flows were similar to Waddell Creek, Beaver Creek's FC loading averaged over 23 times greater in year one and over 71 times greater in year two. In year two, Beaver Creek's mean FC load was almost 50% higher than the mean load of the highest Black River mainstem station (Table 4).

Black River Segment 8, which incorporates Beaver Creek, had the largest drainage area of the study (Appendix B2). The one large commercial dairy and scattered hobby farms (about 1,000 cows combined) may potentially impact Beaver Creek. Roughly 2.8 miles of livestock impacts and 8.9 miles of livestock access to the 21.4 miles of Beaver Creek streambanks were reported in the USFWS degradation survey

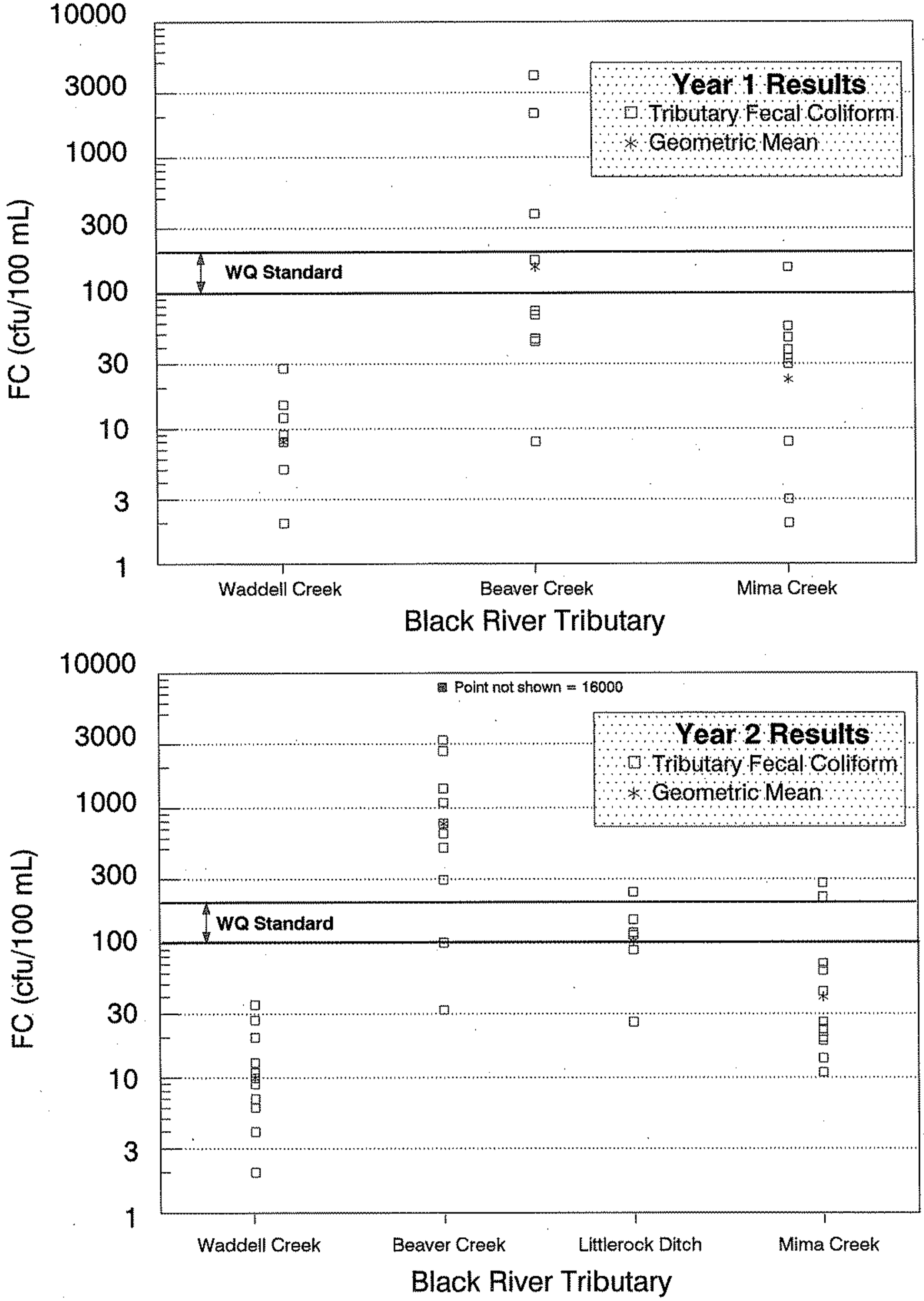

Figure 7. Black River tributary fecal coliform per site and year.

(Appendix B1). A more site specific description of the Beaver Creek subbasin is included in the tributary subsurvey section of this report (Appendix A), which was performed in year two of the study.

The Department of Wildlife boat launch site is the uppermost station in the middle river, but is discussed here as part of the upper river because FC counts measured at the Wildlife Launch (WL) appear to be a result of Beaver Creek FC loads. In year one, there were occasional excursions of the FC water quality standards but no violations (Table 3). In year two, the Wildlife Launch had the highest FC geometric mean for mainstem sites, violating both levels of the FC standard. Loading along Segment 8 between Beaver Creek and the Wildlife Launch was expected to increase from the scattered hobby farms along the river. However, no additional loading beyond that from Beaver Creek could be quantified. Natural treatment from wetlands above the Wildlife Launch are likely masking inputs along the segment.

The mouth of Littlerock Ditch is located at RM 16.8 where Beaver Creek and the Black River meet (Figure A1). This small stream was sampled only on the last six surveys of year two. Mean flow for the six surveys was 4.5 cfs. Originating in wetlands north of Littlerock, the ditch passes through Littlerock and then across pastures to the south of town. The ditch is largely unfenced, generally open to animal access, and without riparian cover. The Littlerock Ditch (LD) samples violated the second level of the FC standard (Table 3). Of the six samples collected, four were excursions over 100 cfu/100 mL and one sample (17%) exceeded 200 cfu/100 mL.

Middle River (Lake Reach)

About 0.7 miles below the Beaver Creek/Littlerock Ditch confluence with the Black River, the channel loses its riffle/run character and breaks into a number of smaller channels which pass through wetlands. Below this area, the middle river or lake reach begins. The Department of Wildlife boat launch site (WL) is located at the upper boundary of the lake reach (Figure 1). The river channel at the Wildlife Launch has visible flow, but just a few hundred meters downstream, the river becomes lake-like in character.

Middle river mainstem sites are the Canoe Club (CC), Black River at Mima (MM), and Swecker's Dock (SD), and this reach includes Segments 4, 5, 6, and 7. FC counts and loads in these segments were the highest in the mainstem. In year one, no violations of the first level of the FC standard occurred at any of the sites (Table 3). However, the Black River at Mima and Swecker's Dock violated the second level of the FC standard on the mainstem in year one. In year two, samples from the Canoe Club (CC) violated both levels of the FC standard, while the Black River at Mima (MM) and Swecker's Dock (SD) samples violated the second FC criterion only.

In year one, the Black River at Mima (MM), Swecker's Dock (SD), and Canoe Club (CC) were among the top four mean FC loads for all mainstem stations (Table 4). In year two, mean FC loads at these same sites were ranked in the top five.

Potential FC loads to the middle river include both known and unidentified sources. In year two, the elevated load measured at the Canoe Club was surprising. Loading was expected to be low to moderate because of the low housing density, lack of dairy farms, and substantial riparian wetlands on both banks to buffer runoff impacts. Year two loads at the Canoe Club were roughly double year one loads. Further investigation will be required to locate the source(s) of FC loading to this segment. Segment 6, from the Canoe Club to the Black River at Mima (MM), includes the largest dairy farm in the basin (about 3,000 cows); it is also the only commercial dairy adjacent to the river within the lake reach. This dairy has a high potential for FC loading because of its high animal density and proximity to the river. Manure was being sprayed on adjacent fields on a number of occasions throughout the two wet seasons, although substantial wetlands along both banks through this reach probably help buffer the river from spray-field runoff. Only limited human activity is evident through the lake reach, and no direct livestock impacts or access areas were seen. This observation was confirmed by the USFWS degradation survey (Appendix B1). With a commercial dairy farm adjacent to the river as the prominent land use in the area, it must be considered a likely source. Previous investigators have identified ditches suspected of discharging to the river from right bank (facing downstream) wetlands (Blocher, 1991; Pickett, 1991). However, further FC source identification may be necessary before specific corrective measures can be prescribed.

Mima Creek is the only major tributary discharging to the lake reach. Mima Creek enters the right bank of the Black River from the north at RM 11.8 (Figure 1). There were two sample stations on Mima Creek. One was placed just above the confluence with the Black River and the other was upstream at the Gate Road bridge. The stations bracketed the large commercial dairy which was under enforcement action by Ecology.

In year one, FC sample results were low at both Mima Creek sites (Table C1). In year two FC sample results were slightly higher (Table C2). At the lower site, two excursions (18% of samples) were measured above 200 cfu/100 mL, which violated the second level of the FC standard. During one of those survey runs, a sample collected at the upper site also had a FC count greater than 200 cfu/100 mL. This infers that some sources may be located upstream of the dairy. At the lower site, FC loads increased from year one to year two by 100%. Geometric mean FC concentrations and loads (Table 4) measured at the lower Mima Creek site (MB) were slightly higher than counts and loads from Waddell Creek (WC), but small compared to those from Beaver Creek (BC). Further sampling results from the Mima Creek basin are included in Appendix A of this report.

Lower River

At about RM 10, the Black River transitions into the lower river. Consisting of more typical riffles, runs, and glides, the lower river is generally shallower and narrower than the lake reach, with a visible current in the channel throughout the year. The lower river consists of Segments 1, 2, and 3, with mainstem sites at Steel Trestle (ST), Moon Road (MR), U.S. Highway 12 (HW), and Howanut Road (HN) (Figure 1). The upper boundary site for the lower river reach is the Steel Trestle at RM 9.1.

In year one, occasional elevated counts were observed, but no violations of standards occurred. In year two, FC counts were generally higher than in year one, and the second level of the FC standard was violated at Moon Road, U.S. Highway 12, and Howanut Road (Table 3). Lower river loads ranked moderate among mainstem sites both years (Table 4).

Very few livestock impacts or access areas were noted in the lower river until Segment 1, from U.S. Highway 12 to Howanut Road (Appendix B). Two commercial dairy farms (about 400 cows combined) are located within this segment, and both are adjacent to the river.

TMDL Modeling

Critical Conditions for FC

Previous TMDLs in Washington have been established to control point source-dominated water quality problems, and NPS has played a minor role. When dealing with point source pollution, the critical time for problems is most often in the low flow period when effluent dilution is at a minimum. Usually the seven-day average low flow with a recurrence of once every 10 years (7Q10) is used for a critical flow statistic (WAC 173-201A-020). The critical time for FC loading to the Black River, and generally for other NPS pollution problems, is usually during high flow in the wet season when surface runoff from the watershed transports pollutants directly to the waterbody. However, state water quality standards and federal guidance documents provide no design statistic for critical high flow events.

A qualitative review of survey precipitation and FC data was used to estimate the critical condition for Black River fecal coliform loading in the wet season. The below-normal precipitation for the two survey years resulted in poor representation of wet season conditions. Extrapolation to a more normal wet season is not possible since FC loading in the Black River is not directly correlated with flow. However, the rising hydrograph appears to be linked with increasing FC counts.

FC survey samples were collected under different conditions in year one and two, thus the two data sets are not totally comparable. FC loading in the Black River basin was greater when at least 0.5 inch of rainfall had fallen within a 48-hour period rather than a 5-day period. Survey data collected on the rising limb of the hydrograph during both survey years generally showed higher FC counts. Four data sets from year one that met criteria established for year two sample collection (*i.e.*, at least 0.5 inch of rainfall in 48 hours) are identified in Table C1. These data were used in conjunction with all year two data in a mass balance model to determine mean segment loading contributions. Table 5 summarizes the critical condition data set synthesized from sampling events on rising hydrograph limbs.

A critical design flow of 577 cfs at Howanut Road (RM 1.2) was established by determining the mean discharge for the synthesized critical condition data set. This mean flow was about 39% below the historical USGS wet weather flow for the same period (December through March), even though it was a mean of storm event flows on rising hydrograph limbs.

FC Mass Balance Model

At the present time there are no accepted models that can, with reliability, predict FC loading and fate from nonpoint sources. The study design called for frequent monitoring at enough sites to detect correlations between FC loading in the Black River and variables that usually drive NPS loading, like precipitation, surface soil saturation, antecedent rainfall, river discharge, land uses, and dairy cow densities. These variables could then be used to develop a predictive FC model for the Black River drainage. However, attempts to correlate FC loading to precipitation, antecedent rainfall, conductivity, and river discharge did not succeed. The exception was that a higher percentage of elevated FC counts were observed on the rising limb of a hydrograph. Accurate livestock numbers were limited only to estimates for the largest dairies in the basin. Therefore, they proved to be of limited value as a predictive tool.

Because FC undergo mortality, regrowth, sedimentation, and resuspension, a bacteria model must generally account for one or more of these complex processes. Instead of estimating the rate of each of these processes for each segment of the river, a cumulative rate was estimated to represent the multiple processes through each segment of the Black River. To estimate the total FC load contributing to individual segments of the drainage, a spreadsheet mass balance model was developed.

The generalized FC decay rates used in the mass balance model were adjusted for segment time of travel and water temperature. The effects of temperature and solar radiation on FC have been evaluated in many studies (Thomann and Mueller, 1987). The temperature formula which was applied to the generalized rates was taken from

Table 5. Black River NPS TMDL Study critical condition fecal coliform results from year one and two data.

Stations (Segment No.)	Critical Condition Geometric Mean (cfu/100 mL)	Critical Condition Geometric Mean Ranking	Number of FC Samples Exceeding 200 cfu/100 mL (15 Total; Year 1=4)
AA – RR (10)	32	10	1
RR – LT (9)	53	7	3
LT – WL (8)	39	9	2
WL – CC (7)	130	1	5
CC – MM (6)	110	3	5
MM – SD (5)	120	2	7
SD – ST (4)	99	4	4
ST – MR (3)	64	5	2
MR – HW (2)	53	7	3
HW – HN (1)	50	8	2
HN	57	6	3
Tributaries:			
WC	9	4	0
BC	600	1	11
LD	100	2	1*
MB	32	3	2

Key:

AA 110th Ave.
RR River Road
LT Littlerock Trestle
WL Wildlife Launch
CC Canoe Club
MM Black River at Mima Creek
SD Sweckers Dock
ST Steel Trestle

MR Moon Road
HW U.S. Highway 12
HN Howanut Road

BC Beaver Creek
LD Littlerock Ditch
MB Mima Creek
WC Waddell Creek

* Littlerock Ditch sampled the last six surveys of year two only.

Mancini (1978). The effect of solar radiation was not addressed in this simplified analysis, but was not expected to be significant in a wet season critical design scenario.

A first order FC decay rate was estimated for the entire river. Since loading within individual segments complicated decay rate estimation, one river segment that showed an upstream to downstream decline in FC throughout the survey was selected as representative of the river. This segment appeared to have minimal internal or riparian area FC loading. The natural logarithms of the FC sample results from within this segment were plotted against the time of travel for each survey (Figure 8). The slope of the average regression (4.19/day) was taken as the raw FC decay rate (K_{FC}). Mancini's (1978) formula was then applied to the K_{FC} value to determine the decay rate as a function of temperature:

$$(K_{FC})_t = (K_{FC})(1.07)^{t-20}$$

where:
K_{FC} = the basic decay rate of FC bacteria;
$(K_{FC})_t$ = the basic decay rate of FC bacteria adjusted for water temperature;
and
t = water temperature.

A new first order FC decay rate of 1.60/day resulted from the temperature correction. The FC load contributed within river segments was then estimated using the temperature adjusted decay rate. FC loading was estimated for each segment by the expression:

Net FC Contribution = Downstream Load/day - ({Upstream Load/day x Decay} - {Trib. Load/day x Decay})
where FC Load/day = cfs x cfu/100 mL x (2.45 x 10^7{constant to adjust for units}).
Decay = $(K_{FC})_t$

An alternative die-off rate was applied to test the sensitivity of this factor alone. Thomann and Mueller (1987) reported a wide range of literature values for bacteria die-off in fresh water (0.05/day to 5.5/day). For the sensitivity test, a literature-average FC die-off rate of 0.8/day was used, which was half the estimated rate. The sensitivity test found that estimated segment FC loads averaged 35% lower, with an individual segment range of 0% to 83% lower. However, Segments 4 and 2 (Table 6) were the only segments to change their rank order of FC load as a result of the decay rate change. Therefore, the generalized rate of 1.6/day was considered acceptable for the purposes of describing FC loading and transport through the Black River.

Model estimated FC loads to each segment under critical high flow conditions are shown in Table 6. This is the net loading within the segment - *i.e.*, the FC load increase which occurred within the segment. Each segment was also assigned a rank,

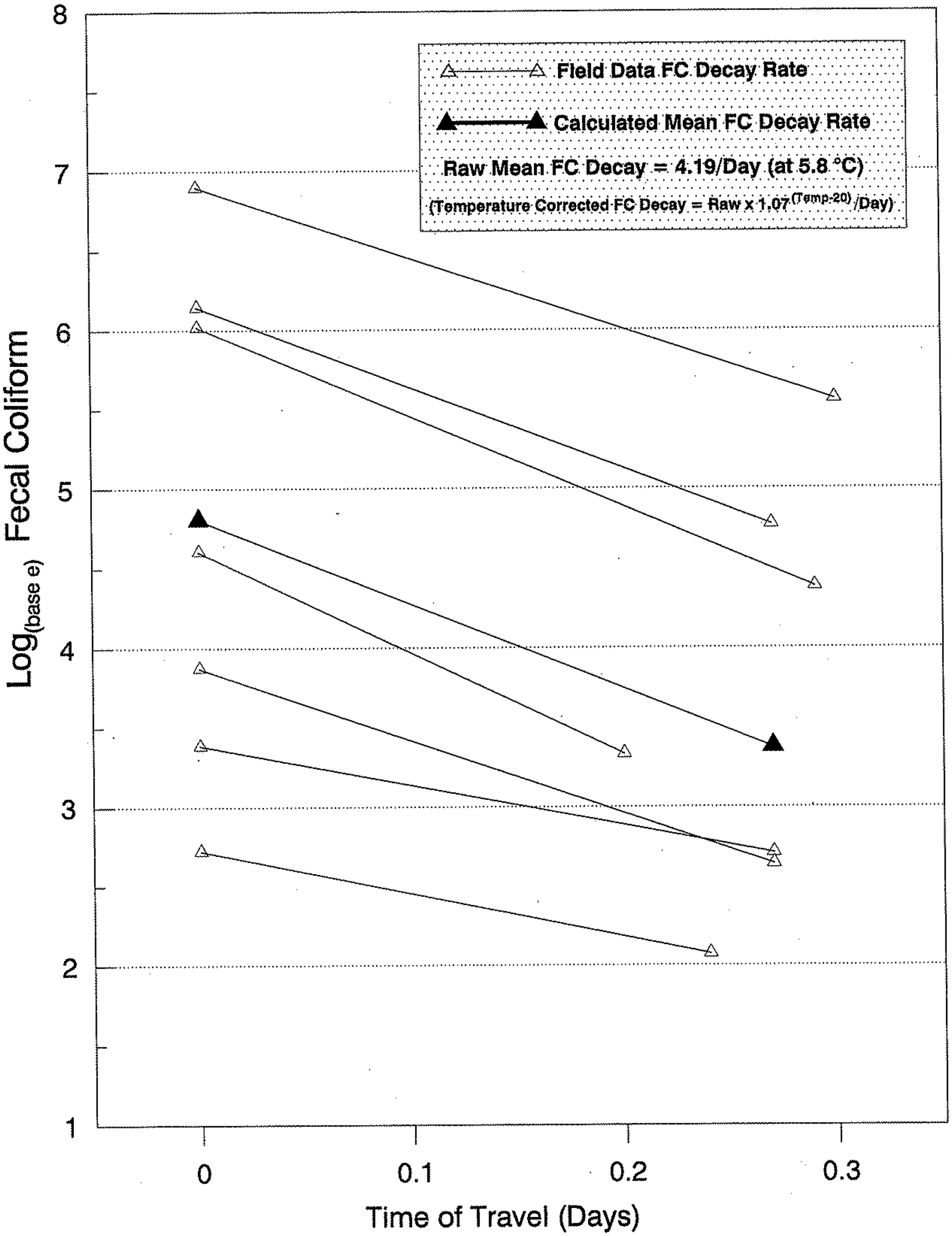

Figure 8. Fecal coliform decay versus time of travel.

Table 6. Black River NPS TMDL Study ranking of segment contributions for fecal coliform loads.

Stations (Segment No.)	Time of Travel (days)	Segment Length (miles)	Start of Segment Geo Mean (cfu/100 mL)	Predicted End of Segment Post Die-Off (cfu/100 mL)	Critical Flow (cfs)	Segment Contribution without Tribs (cfu/day)	Segment Load Ranking	Tributary Contribution to Segment (cfu/day)	Segment Contribution with Tribs (cfu/day)
AA–RR (10)	0.54	2.3	32	4	116	0.144E+12	8		0.144E+12
RR–LT (9)	0.02	0.4	53	47	212	0.0276E+12	9	0.0212E+12	0.0487E+12
LT–WL (8)	0.07	1.8	39	26	311	0.00E+00	10	1.61E+12	1.61E+12
WL–CC (7)	0.33	1.1	130	17	460	1.08E+12	2		1.08E+12
CC–MM (6)	0.57	2.3	110	7	459	1.24E+12	1	0.0462E+12	1.29E+12
MM–SD (5)	0.27	1.2	120	23	474	0.889E+12	3		0.889E+12
SD–ST (4)	0.29	1.5	99	18	463	0.516E+12	5		0.516E+12
ST–MR (3)	0.20	2.0	64	20	509	0.428E+12	7		0.428E+12
MR–HW (2)	0.23	3.0	53	16	563	0.494E+12	6		0.494E+12
HW–HN (1)	0.21	2.9	50	16	577	0.580E+12	4		0.580E+12
Tributaries:									
WC			9	9	96.2		3	0.0212E+12	
BC/LD			600	330	110		1	1.61E+12	
MB			32	30	59.0		2	0.0462E+12	

Key:

AA	110th Ave.
RR	River Road
LT	Littlerock Trestle
WL	Wildlife Launch
CC	Canoe Club
MM	Black River at Mima
SD	Sweckers Dock
ST	Steel Trestle
MR	Moon Road
HW	U.S. Highway 12
HN	Howanut Road
WC	Waddell Creek
BC/LD	Beaver Creek/Littlerock Ditch
MB	Mima Creek

where 1 was the highest FC load and 10 was the lowest. The middle river segments contributed the highest loads to the river, while the upper river segments contributed the lowest loads.

Tributaries can be viewed as point load additions to the river. If critical FC loads from Beaver, Mima, and Waddell Creeks were ranked with the 10 Black River mainstem segment loads, Beaver Creek would be number 1, while Mima and Waddell Creek would be 10th and 12th, respectively.

Model results were in conflict with field data for only one segment. No additional loading was predicted within Segment 8 (Littlerock Trestle to the Wildlife Launch) beyond that from Beaver Creek. After applying the decay rate constant to the sum of the Black River and Beaver Creek FC loads, the predicted load at the Wildlife Launch was higher than observed in the field data. If the predicted FC load is accurate, no additional loading from land adjacent to the river between Beaver Creek and the Wildlife Launch was reaching the river. This is probably not the case, because this area has hobby farms with FC loading potential and was identified in the USFWS degradation survey (Wampler *et al.*, 1993) as having livestock access. One possible explanation for this anomaly is that FC inputs from Beaver Creek and bankside farms in the segment are likely reduced by natural processes in the wetland areas located just upstream of the Wildlife Launch.

LAs for FC

Controlling NPS loading of FC and associated organic materials to the Black River is vitally important to protecting the water quality of this river. FC is an indicator organism. It may not necessarily be a pathogen, but it indicates potential problems from fecal waste inputs.

TMDLs for point source dischargers are established from wasteload allocations (WLAs) as water quality-based permit limits. Because NPS problems are a result of diffuse discharges and are subject to a different set of pollution control mechanisms, load allocations (LAs) for NPS-dominated TMDLs are apportioned differently than WLAs.

The LAs were applied on a segment basis as an approach to reduce current FC loads in order to achieve water quality standards. Those segments which exceeded a target load, conservative enough to protect both levels of the FC criteria, were considered over-allocated. Fecal coliform sources contributing to this excess load will need to collectively reduce their discharge to the target critical condition segment load. NPS reductions may be achieved through development of farm plans, implementation of BMPs, and on-site septic repairs to meet water quality standards.

A large portion of the Black River basin needs corrective measures to bring water quality within FC standards. The present study found that all mainstem sites except 110th Avenue and the Steel Trestle had violations of one of the two FC criteria. A phased TMDL approach is recommended to deal with the NPS pollution problems because of the difficulty in quantifying and modeling FC loads in wash-off (EPA, 1991). The phased TMDL would consist of implementation of corrective measures in critical problem areas based on initial site evaluations. Afterward, post-implementation monitoring would occur to evaluate LAs. Long-term monitoring (ambient, critical condition, and BMP implementation sampling) will also play an important role to assure corrective measures are effective and that the LAs are reasonable and protective of water quality. A phased TMDL would bring the entire drainage into compliance with FC standards by directing corrective actions at the worst problem areas as a priority.

The LC is the total maximum load of a pollutant the waterbody is able to assimilate and still achieve water quality standards and support all characteristic uses. A margin of safety (MOS) can be included as a portion of the TMDL to account for natural background loads, scientific uncertainty associated with model calculations, and any set aside for future growth. Quantitatively the typical TMDL is expressed as: TMDL=WLA+LA+MOS. Because the Black River has no point source dischargers of FC, its TMDL may be expressed as: TMDL=LA+MOS.

With point source-dominated TMDLs, the MOS can be incorporated into conservative assumptions in model development. The Black River is a nonpoint source-dominated TMDL. Because fecal coliform loads have been difficult to quantify, predict, and model (both here and elsewhere), a MOS of 50 cfu/100 mL is recommended.

In an effort to validate the large MOS, the geometric mean of critical condition FC data were compared to the percentage of 200 cfu/100 mL excursions per site. The regression had a high degree of correlation (r^2=0.81). Figure 9 shows these results and the 95% confidence intervals. The data show that sites even with a critical condition geometric mean around 50 cfu/100 mL had violations of the second level of the water quality standards. A large MOS is justified also because sample collection occurred during periods of lower than normal rainfall and river discharge (*e.g.*, critical condition flow was only 61% of mean historical flow), and the inherent high variability of FC data.

To set the LC=TMDL, the Black River wet season NPS TMDL for FC is established at 100 cfu/100 mL, which is the water quality standard. A target LA of 50 cfu/100 mL is recommended for all segments of the river, and the remaining 50 cfu/100 mL allocated to the MOS. Seven mainstem segments and two tributary drainages did not meet the target LA: 110th Avenue to River Road (10); Wildlife Launch to the Canoe Club (7); Canoe Club to the Black River at Mima (6); Black River at Mima to Swecker's Dock (5); Swecker's Dock to the Steel Trestle (4); Steel Trestle to Moon

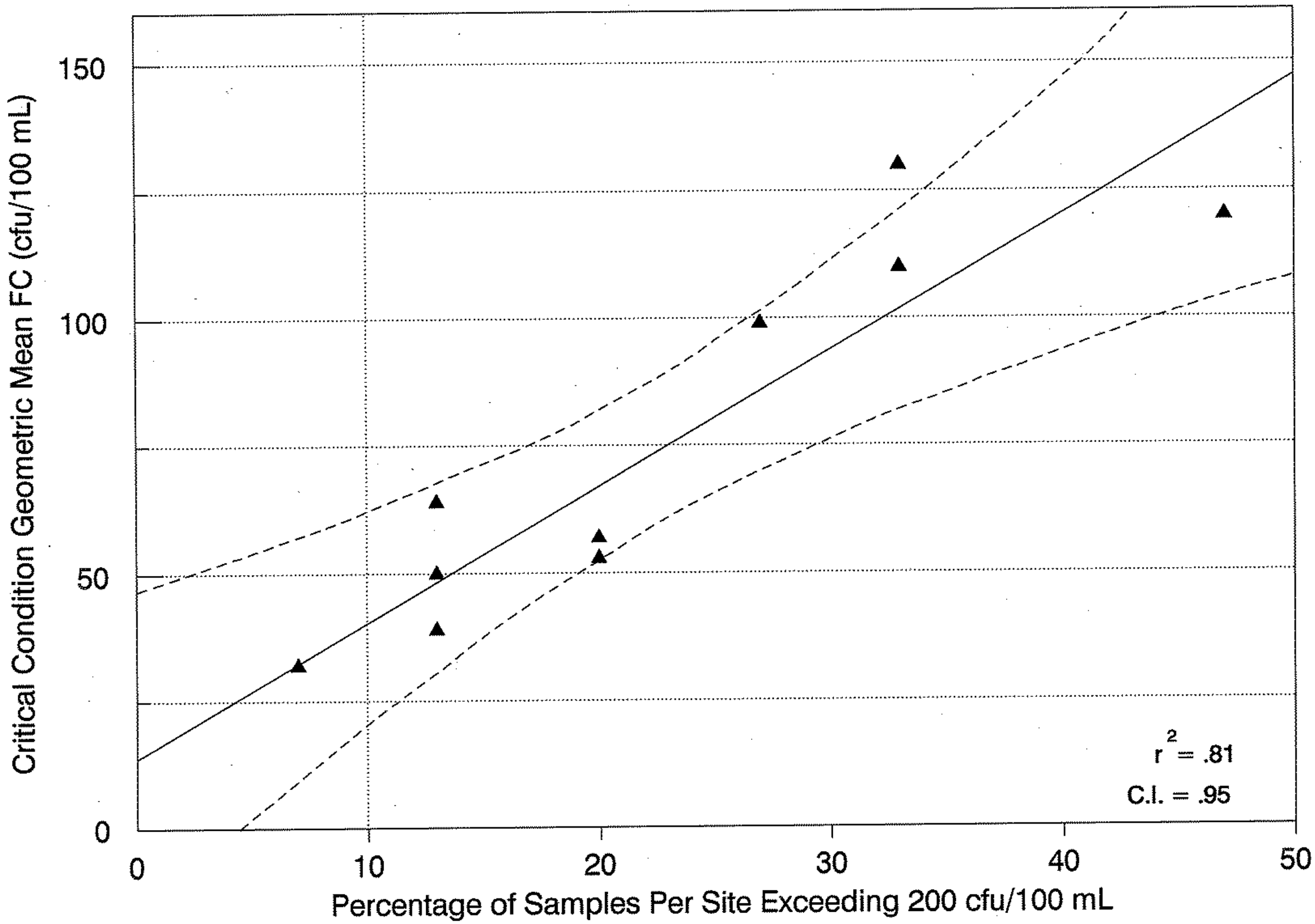

Figure 9. Linear regression of critical condition FC by percentage of 200 cfu/100 mL excursions.

Road (3); U.S. Highway 12 to Howanut Road (1); and the Beaver Creek and Littlerock Ditch subdrainages. Table 7 shows recommended TMDL target load allocations under critical conditions, and the percent reductions required to meet the LAs. Figure 10 displays mean FC counts in the Black River under critical conditions, as well as expected counts under the proposed load allocation strategy. Figure 11 shows critical condition loads and the amount of load reduction necessary to meet the LA by segment, and where within the basin these reductions are needed.

Segment 8, from the Littlerock Trestle to the Wildlife Launch, also violated standards, however the source of the violations appeared to be from Beaver Creek. If control strategies (*i.e.*, BMPs like fencing livestock from stream corridors, establishing vegetative buffer strips, and manure management systems) implemented in the Beaver Creek subdrainage bring FC counts within target loads, counts at the Wildlife Launch should be reduced to less than half the FC standard.

Table 7. Proposed FC load allocations for the Black River wet season NPS TMDL.

Segment (No.)/Subdrainage	Survey Critical Condition FC Load (Trillions/Day)	Target FC Load (Trillions/Day)	Reduction to Meet Target Load (%)
110th Avenue to River Road (10)	0.150	0.142	6
Wildlife Launch to Canoe Club (7)	1.38	0.643	54
Canoe Club to Black R. at Mima (6)	1.40	0.562	60
Black R. at Mima to Swecker's Dock (5)	1.14	0.580	49
Swecker's Dock to Steel Trestle (4)	0.720	0.566	21
Steel Trestle to Moon Road (3)	0.666	0.623	6
U.S. Highway 12 to Howanut Road (1)	0.808	0.706	13
Beaver Creek	1.58	0.131	92
Littlerock Ditch	0.0113	0.00553	51

The LAs are proposed to bring the water quality of the Black River into compliance with FC standards. However, there is uncertainty whether the LAs would be protective enough to meet the second level of the standard during extreme rain events. Use of a phased TMDL approach will allow reconsideration of water quality management goals after evaluating the effectiveness of the LAs.

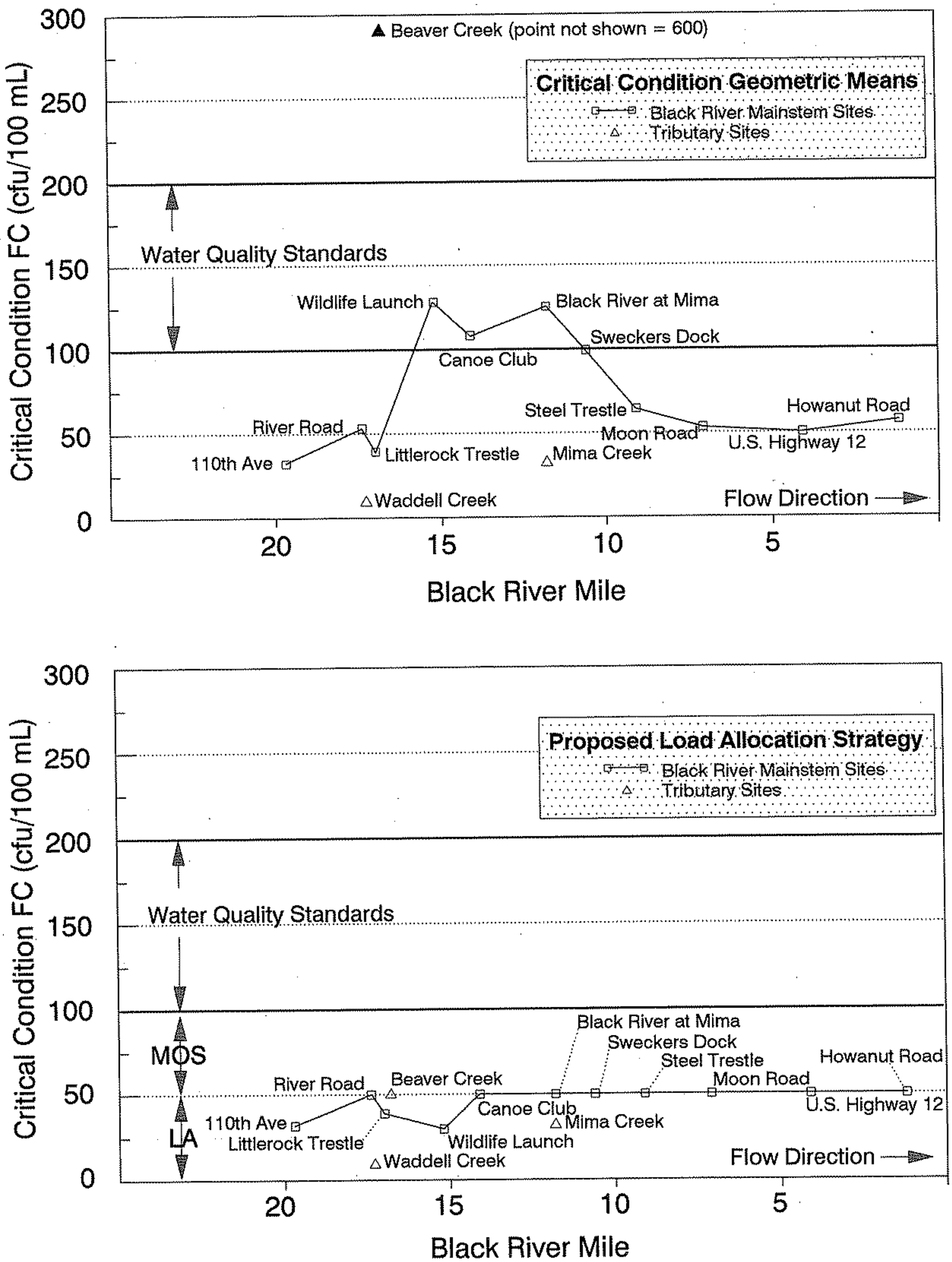

Figure 10. Critical geometric mean FC and proposed LA strategy.

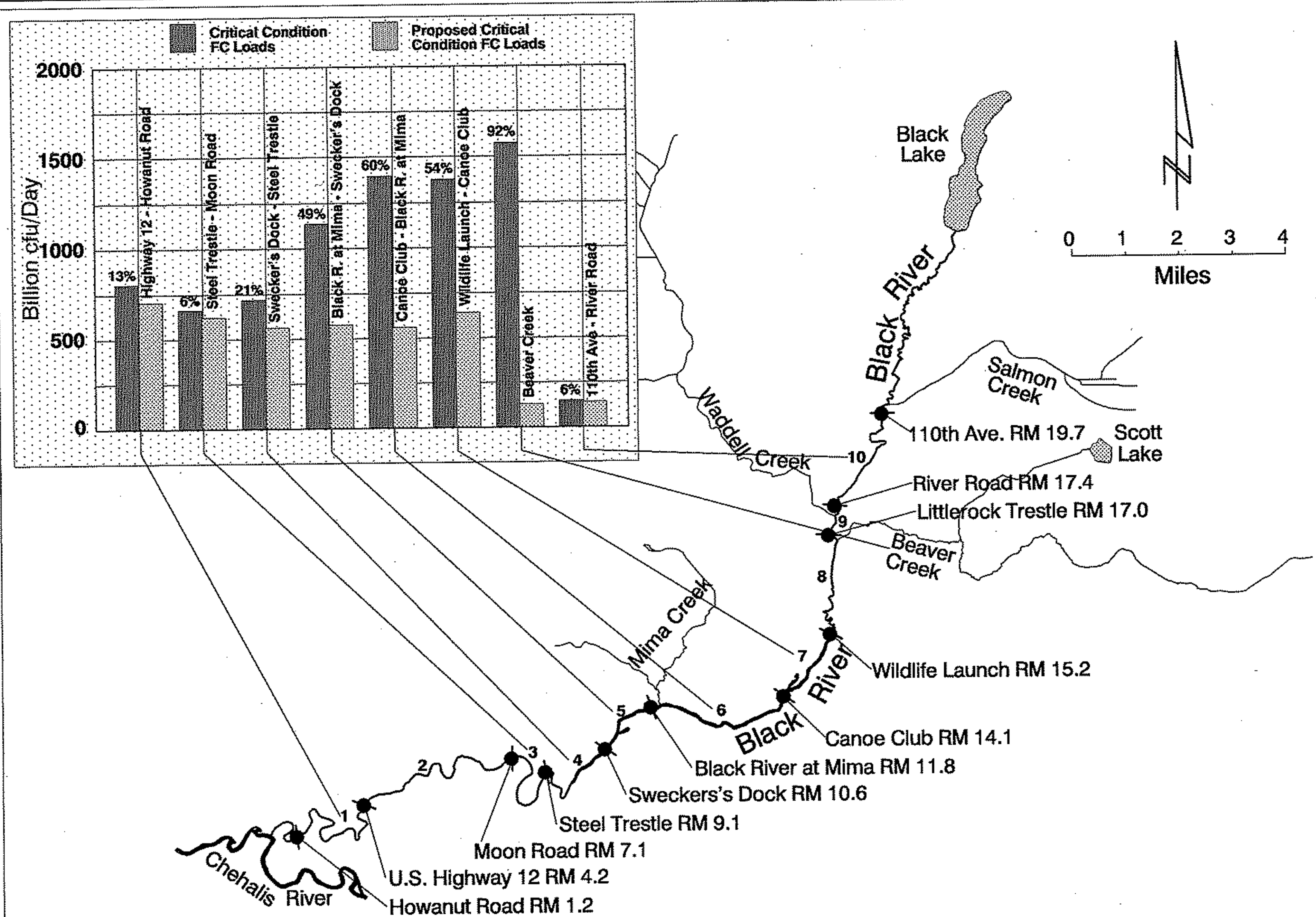

Figure 11. Black River critical condition FC loads and proposed reduction map.

Implementation and Monitoring

One problem with long term resource protection is program consistency. To help ensure consistency in TMDL implementation, Ecology proposes that Thurston County establish a local watershed management committee fashioned after the "nonpoint rule" (Chapter 400-12 WAC), and develop a watershed management plan specific to the Black River basin. The Chehalis River basin currently has an approved watershed management plan which includes the Black River basin. Many of the categorical source control strategies outlined in the Chehalis River Basin Action Plan (LCCD, 1992) directly apply to the specific issues of the Black River. Considering the broad scope of the Chehalis management plan, a Black River subbasin management plan could be more detailed and effective. Creation of a Black River watershed management committee and a watershed management plan may require amendments to the Chehalis River basin plan. The amendments would recommend that subbasin groups develop implementation plans specific to their basin. It is likely the Black River group could build their plan from the foundation already provided in the Chehalis plan.

The watershed management committee would be made up of diverse parties such as municipal and county governments, state and federal agencies (especially the USFWS), the Chehalis Confederated Tribes, special purpose districts like the Thurston County Conservation District, environmental groups, subbasin watershed groups, agricultural interests, the aquaculture industry, and the general public. The TMDL proposed here would assist the committee in establishing a ranking of basin priorities, with the ultimate goal of implementing action plans to prevent NPS pollution. The watershed management committee could apply for grants, loans, and technical assistance through Ecology for action plan implementation. After initial implementation and follow-up monitoring were complete, the committee would meet periodically for the purpose of evaluating and re-ranking priorities. The committee could encourage public participation through public meetings, hearings, workshops, and newsletters.

Local Conservation Districts (CDs) are responsible for evaluation and development of farm plans. Ecology's Agricultural Memorandum of Agreement with Thurston and Grays Harbor Counties calls for water quality problems from agricultural nonpoint sources to be referred to the local CD. On-site septic system failures are referred to the local health department. Ecology (and the watershed management committee, if formed) will need to work together with these agencies to assure that problem assessment, control implementation, and follow-up evaluations are pursued in a timely fashion.

Some areas in the Black River basin are atop the priority list for NPS corrective actions. The Beaver Creek subbasin from Case Road downstream should be pursued as first priority, followed by middle river Segments 6, 7, and 5. Beaver Creek BMPs will be primarily directed at control measures like manure management, confining livestock from stream corridors, and installing buffer strips along streams to filter run-off. For commercial dairies, farm plans will need to be developed and corrective measures implemented. On-site septic management would require identification and evaluation of drainfields and possibly implementation of an operation and maintenance program requiring routine evaluation and pumping in sensitive areas.

In many cases FC sources to the Black River and tributaries were obvious. However, the source of FC loading to Segment 7, between the Canoe Club (RM 14.1) and the Wildlife Launch (RM 15.2), was not apparent. Further investigation will be required to determine where loading originates in this reach.

Effectiveness can vary for different BMPs applied to any given site. Table 8 shows literature values of effectiveness estimates for management practices to control bacterial losses from confined livestock facilities (PSU, 1992). Table 9 reports bacterial responses to four grazing strategies studied in 13 Oregon watersheds in 1984 (EPA, 1993). Both tables show a range of load reductions which might be expected with different BMPs. BMPs also have a variety of technical levels and costs that can range from the simple, like fencing stream corridors from animal access, to the complex, like installing engineered waste retention basins. Local CD offices have the technical knowledge to do site evaluations and recommend implementation of known effective measures to meet LA goals. Considering the FC load reduction required (Table 7), the control measures shown in Tables 8 and 9 should be adequate to meet LAs for the Black River.

Table 8. Relative gross effectiveness of confined livestock control measures (PSU, 1992).

Practice[a]	Fecal Coliform Reduction (%)
Animal Waste System[b]	85
Filter Strips[c]	55
Containment Structures[d]	90

a = Each category includes several specific types of practices.

b = Includes methods for collecting, storing, and disposing of runoff and process-generated wastewater.

c = Includes all practices that reduce contaminant losses using vegetative control measures.

d = Includes such practices as waste storage ponds, waste storage structures, waste treatment lagoons.

Table 9. Bacterial water quality response to four grazing strategies.

	Practice	Geometric Mean Fecal Coliform (cfu/100 mL)
Strategy 1:	Ungrazed.	4
Strategy 2:	Grazing without management for livestock distribution; 20.3 acre/AUM[a].	15
Strategy 3:	Grazing with management for livestock distribution: fencing and water developments; 19.0 acre/AUM.	9
Strategy 4:	Intensive grazing management, including practices to attain uniform livestock distribution and improve forage production with cultural practices such as seeding, fertilizing, and forest thinning; 6.9 acre/AUM.	92

[a] = AUM stands for animal unit month, which is the amount of forage required to maintain a mature 1,000-pound cow or the equivalent for one month.

The *Black River Wet Season Nonpoint Source Total Maximum Daily Load Study* is one of two TMDLs being developed for the Black River. The *Black River Dry Season Total Maximum Daily Load Study* (Pickett, 1994) addresses dissolved oxygen and eutrophication problems during the low flow season. Ecology will need to coordinate both TMDLs in the Black River basin to assure overall priorities are identified and corrective measures implemented for the worst problems first. In any event, it is assumed that BMPs implemented to lower mean FC loading will also likely reduce violations of the second level of the standard during more intense rain events or even more normal wet season conditions. Nonpoint sources in segments which exceeded only the second level of the standard will require site evaluations and plans for correction actions, but the management priority is lower than that required for segments which violated the level one standard.

The phased TMDL approach requires monitoring for re-assessing LAs to ensure attainment of water quality standards. The five-year cycle of Ecology's watershed approach to water quality management lends itself to periodic re-assessment of priorities. Following the allocation of loads (year four) for the current TMDL, year five is for implementation of controls. In the succeeding five year cycle, monitoring will be required on a routine (*e.g.*, ambient monitoring on a once per month basis), critical condition, and site-specific basis.

Monitoring should be used to closely evaluate BMP effectiveness. Assessment of control measures is an important part of a phased TMDL. If grants are secured by local CDs for BMP implementation, post-implementation monitoring should be required by the grant for evaluation of the effectiveness of the control program. The Chehalis Indian Tribe has an interest in follow-up monitoring of the Black River, also citizen monitoring, perhaps by groups like the Black River Watch, may also play a role in post-implementation monitoring. All grant projects and citizen monitoring efforts should be developed with an approved Quality Assurance Project Plan (QAPP) to ensure that the resulting data is of suitable quality to be assimilated into future Ecology watershed scoping and post TMDL evaluation programs. The Beaver Creek site (BC) at Highway 121 should be monitored both routinely and during critical conditions (*i.e.*, from December through March, when at least 0.5 inch of rainfall accumulates during a 48-hour period on the rising limb of the hydrograph). In addition, at least one site in each river region should be monitored. The River Road (RR) site had the most obvious FC problems and thus should be used to monitor the upper river. In the lake reach, the Black River at Mima (MB) site should be a monitoring priority because of elevated counts measured in this study, as well as historical concerns. In the lower river, Howanut Road (HN) is likely the best location for access, and allows for monitoring below the two commercial dairy farms.

In addition to water quality information, long-term data for river discharge are also needed. The USGS maintained a gaging station at 128th Avenue in Littlerock in the 1940s, and they should be encouraged or funded to re-establish a gaging station within the basin. Discharge information is important to water quality managers, and crucial when evaluation of load reductions become necessary.

Conclusions and Recommendations

- **FC geometric mean LAs of 50 cfu/100 mL are recommended for problem Black River segments.** The TMDL of 100 cfu/100 mL would have a 50 cfu/100 mL margin of safety to account for scientific uncertainty, abnormally dry conditions during both survey years, data variability, and future growth. Load reductions are needed under critical run-off conditions for multiple Black River segments, Beaver Creek, and Littlerock Ditch. The reductions needed to meet proposed critical condition load allocations are as follows:

Segment (No.)/Subdrainage	Percent Reduction to Meet Load Allocation
110th Avenue to River Road (10)	6
Wildlife Launch to Canoe Club (7)	54
Canoe Club to Black River at Mima (6)	60
Black River at Mima to Swecker's Dock (5)	49
Swecker's Dock to Steel Trestle (4)	21
Steel Trestle to Moon Road (3)	6
U.S. Highway 12 to Howanut Road (1)	13
Beaver Creek	92
Littlerock Ditch	51

- River discharge and rainfall were lower than normal for the study period. Survey flows measured at 128th Avenue in Littlerock were only about one-third of normal, while cumulative rainfall total was 20 inches below normal for the two study periods.

- The critical condition for FC loading to the Black River basin in the wet season period is on the rising limb of the hydrograph when at least 0.5 inch of rainfall has fallen during a 48-hour period. When sampling for follow-up evaluation of the TMDL, FC samples should be collected as close to this critical condition rain event as possible.

- Samples collected at all but two sites on the mainstem Black River violated one of the two levels of the FC standard. The majority of the violations were based on the second level, which specifies that less than 10% of samples used to calculate the geometric mean shall exceed 200 cfu/100 mL.

- **Beaver Creek had the most serious FC problems in the Black River basin and should be pursued as a first priority for corrective actions.** The load from Beaver Creek dominated the upper basin, making it difficult to quantify contributions to the Black River from nearshore areas below the mouth of the creek. The following actions are recommended to bring Beaver Creek within water quality standards:

  - Site-specific evaluations are needed within the Beaver Creek subbasin to determine appropriate corrective actions. Those subbasin locations requiring corrective measures in order of decreasing priority are:

    1) Beaver Creek at Case Road to the Beaver Creek Ranch;
    2) Beaver Creek Ranch to Beaver Creek at Highway 121;
    3) lower Allen Creek;
    4) the Littlerock Ditch;
    5) the unnamed tributary to Beaver Creek crossing 143rd SW.

  - An evaluation is in order of the waste handling practices at the commercial dairy located on Beaver Creek between CM 2.5 and CM 4.2. The dairy owner/operator should be referred to the local Conservation District via the Agricultural MOA to pursue farm plan development. Ecology should monitor progress of BMP implementation upon acceptance of the farm plan.

  - If corrective measures bring Beaver Creek within its LA, counts at the Wildlife Launch are predicted to be less than half the water quality standard. After corrective measures have been implemented in the Beaver Creek subbasin, the Wildlife Launch and Beaver Creek at Highway 121 should be resampled to verify corrective measures have succeeded in bringing the Black River into compliance.

- **An evaluation is needed within the Mima Creek subbasin to determine corrective actions needed to bring water quality within standards.** The area between Mima Creek at Bordeaux Road (CM 4.4) to the Weyerhaeuser Nursery (CM 1.4) is where efforts should be focused.

- **If grants are secured by CDs for BMP implementation, post-implementation monitoring should be required by the grant for evaluation of the effectiveness of nonpoint source controls.** An approved Quality Assurance Project Plan should be required in conjunction with any post-implementation monitoring.

- **Further investigation in needed to locate the source(s) of FC loading for the Canoe Club to Black River at Mima segment.** Considering the magnitude of loading to the segment, the reduction required to bring FC counts within standards, and the lack of obvious pollutant transport pathways, the source of bacterial loading clearly needs to be identified and corrected.

- **The segment between the Wildlife Launch and the Canoe Club had counts and loads which were higher than expected considering the low number of potential sources through the segment.** Further investigation to locate specific source(s) should be pursued. Ecology should coordinate with Thurston County Environmental Health to conduct dye testing or other appropriate means to evaluate if septic systems within the reach are sources of FC loading.

- **Thurston County should be encouraged to establish a local watershed management committee fashioned after the "nonpoint rule" (WAC 400-12). Amendments to the *Chehalis River Basin Action Plan* (LCCD, 1992) would likely be needed to encourage further development of watershed management plans specific to subbasins like the Black River.** The committee could be made up of the Black River Watch reconvened with additional members made up from other subbasin watershed groups, agricultural interests, the aquaculture industry, and tribal, state, and local resource managers. Much of the work to develop a Black River Basin Management Plan has already been done through the efforts of the Chehalis River Council's *Chehalis River Basin Action Plan*. Perhaps applicable source control strategies taken from the Chehalis Action Plan could be adopted by the Black River Basin Watershed Committee. A watershed management committee would not only develop a plan for restoration but would provide program consistency where none now exists.

- **Ecology should establish the Black River at Moon Road as a core monitoring station and Beaver Creek as a rotating station (sampled one year of every five).** Studies indicate that long-term routine ambient monitoring of the Black River basin is needed above and beyond that which will be required to evaluate BMP implementation.

- **The USGS should be encouraged or funded to re-establish a flow monitoring station within the Black River basin.**

- **Current land use information for the Black River basin needs to be collected.** Land use data for the Black River basin is 17 years old and should be updated. A GIS layer from aerial photography or other appropriate means would likely be most applicable to the needs of local resource managers. Development of this information should be pursued by local and state government for future use in basin management.

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APPENDIX A
Tributary Subsurvey

Tributary Subsurvey

A subsurvey of Beaver and Mima Creek was conducted in year two of the Black River TMDL study. The goals of the subsurvey were to identify FC contributions from areas along the tributaries, and to identify sources for prioritization of corrective measures. Data collected for the subsurvey are independent of data collected for the mainstem TMDL study.

Analytical methods for bacteria and field parameter measurements (*i.e.*, temperature, conductivity, and discharge) followed protocols described in the Methods section of the mainstem TMDL survey. Sample collection was initiated when at least 0.5 inch of rainfall fell within a 48-hour period, usually the day following sampling for the mainstem TMDL survey was completed for that week. Six sets of subsurvey samples were collected.

Beaver Creek

The ten subsurvey sample stations for Beaver Creek are shown in Figure A1. Beaver Creek has one major tributary, Allen Creek (which enters at creek mile (CM) 2.6), and a number of smaller tributaries. Station locations were established based on potential source location, access, and logistics. The Beaver Creek basin separates into two regions: the upper basin above I-5 and the lower basin below I-5 (Figure A1). Results for FC counts and loads are presented in Figure A2 and reported in Tables A1, A2 and A3.

Bacteria counts in the upper Beaver Creek basin were generally low. From Case Road (CM 4.2) to the Beaver Creek Ranch (CM 2.5), counts increased by more than an order of magnitude. FC counts decreased downstream from this reach to the confluence with the Littlerock Ditch and Black River.

The tributary on 143rd SW violated the second level of the FC standards (Table A1). Just upstream of the sample site the creek runs unfenced along the toe of a sloping pasture. The Maytown site (CM 5.6) had the only other count above 100 cfu/100 mL in the upper Beaver Creek basin.

The majority of livestock impact and access to Beaver Creek occurs below CM 4.0 (Appendix B1). FC samples from the Case Road site (CM 4.2) violated the second level of the FC standard (Table A1). At about CM 2.6, Allen Creek merges with Beaver Creek (Figure A1). Two sites were sampled on Allen Creek: a lower site just above the confluence with Beaver Creek, and an upper site at the Case Road crossing. The upper site had low FC counts. The geometric mean of the lower site was

95 cfu/100 mL, although the second level of the FC standard was violated. There is roughly 2.1 miles of creek between the sample sites. The USFWS identified (Appendix B1) almost a mile of livestock access and roughly a half mile of livestock impacts to the banks of Allen Creek within this segment.

The Beaver Creek Ranch (CM 2.5) samples had the highest counts and loads of the tributary, violating both levels of the FC standard (Figure A2). Loading appears to originate between Case Road (CM 4.2) and the Beaver Creek Ranch site (CM 2.5). Within this segment the USFWS survey identified three points of direct livestock waste inputs (Appendix B1).

Highway 121 was the farthest downstream sample site in the subbasin. Counts and loads were lower than the Beaver Creek Ranch samples, but both levels of the FC standard were violated. The pattern of FC loading found in Beaver Creek was also found during the dry season (Pickett, 1994). Violations of the FC criteria were found at Highway 121 in that study, also.

In order to evaluate if the load at Highway 121 was simply a residual from the Beaver Creek Ranch site an analysis of the Beaver Creek Ranch load was performed by applying a temperature-adjusted FC decay rate and estimated time of travel. Two FC decay rates were compared: 0.8/day, an average value taken from literature (Thomann and Mueller, 1987); and 1.6/day, the value generated from mainstem Black River survey data. In all but the last subsurvey sample event, measured counts at CM 0.1 were higher than predicted using either decay rate. This infers there are likely additional sources within the segment. According to the USFWS, one half of the total bank length along this 2.4 mile segment has livestock access, and about a third of a mile has livestock bank impacts (Appendix B1).

Efforts to reduce FC loading to the Beaver Creek drainage should focus on segments with the most serious problems. Prioritization of segments based on the degree of FC standard violation is likely the most defensible approach. Ranking Beaver Creek segments in the order of most to least serious yields:

1) Case Road (CM 4.2) to the Beaver Creek Ranch (CM 2.5);
2) Beaver Creek Ranch to Highway 121 (CM 0.1);
3) lower Allen Creek; and
4) the tributary at 143rd SW.

Efforts are needed to bring Beaver Creek into compliance with FC water quality standards. The estimated success effort needed to meet the proposed LA of 50 cfu/100 mL at the mouth is a 92% reduction of current critical loads. This target reduction would allow for protection at both levels of the FC standard.

Mima Creek

The six subsurvey sampling stations for Mima Creek are also shown in Figure A1. Mima Creek has one major tributary, Mill Creek, entering at CM 4.5 in the upper basin, and a number of smaller tributaries, including two sampled in the lower basin. Station locations were established based primarily on access and logistics. Results for FC counts and loads are presented in Figure A3 and reported in Tables A4, A5, and A6.

The Mima Creek subdrainage generally had low FC counts throughout the subsurvey, with only occasional excursions over 100 cfu/100 mL. The upper basin sites, Mill Creek and Bordeaux Road (CM 4.4), generally had low background counts. The Weyerhaeuser Nursery site (CM 1.4) had low counts for all but one sample event, which resulted in violation of the second level of the FC standard. Between the Bordeaux Road and Weyerhaeuser Nursery sites, Mima Creek has about 1.7 miles of livestock access and a number of points where livestock impacts were observed (Appendix B1).

Mima Creek FC samples collected from the site at Gate Road (CM 0.9) occasionally exceeded 100 cfu/100 mL (Table A4). These samples did not violate standards during the subsurvey, although a violation was noted for the second level of the FC standard in the basin-wide study which was the primary focus of this report. The USFWS reported a substantial amount of livestock access and impacts to the stream banks through the half mile segment between the Weyerhaeuser Nursery and Gate Road sites (Appendix B1).

The 260 cfu/100 mL result in year one was one of the factors which promoted the year two subsurvey and also initiated a field investigation for potential sources. Roughly 0.25 miles upstream of the Gate Road site, a herd of about 40 cattle were observed in the stream and impacting both stream banks. This was one possible cause of the year one count and should be followed up to see if corrective measures are still needed.

Based on these subsurvey results, only the Bordeaux Road (CM 4.4) to the Weyerhaeuser Nursery (CM 1.4) segment appears to need a follow-up evaluation of corrective measures. The site with the lowest FC counts for the Mima Creek basin was from the unnamed tributary merging at CM 1.0, just above Gate Road.

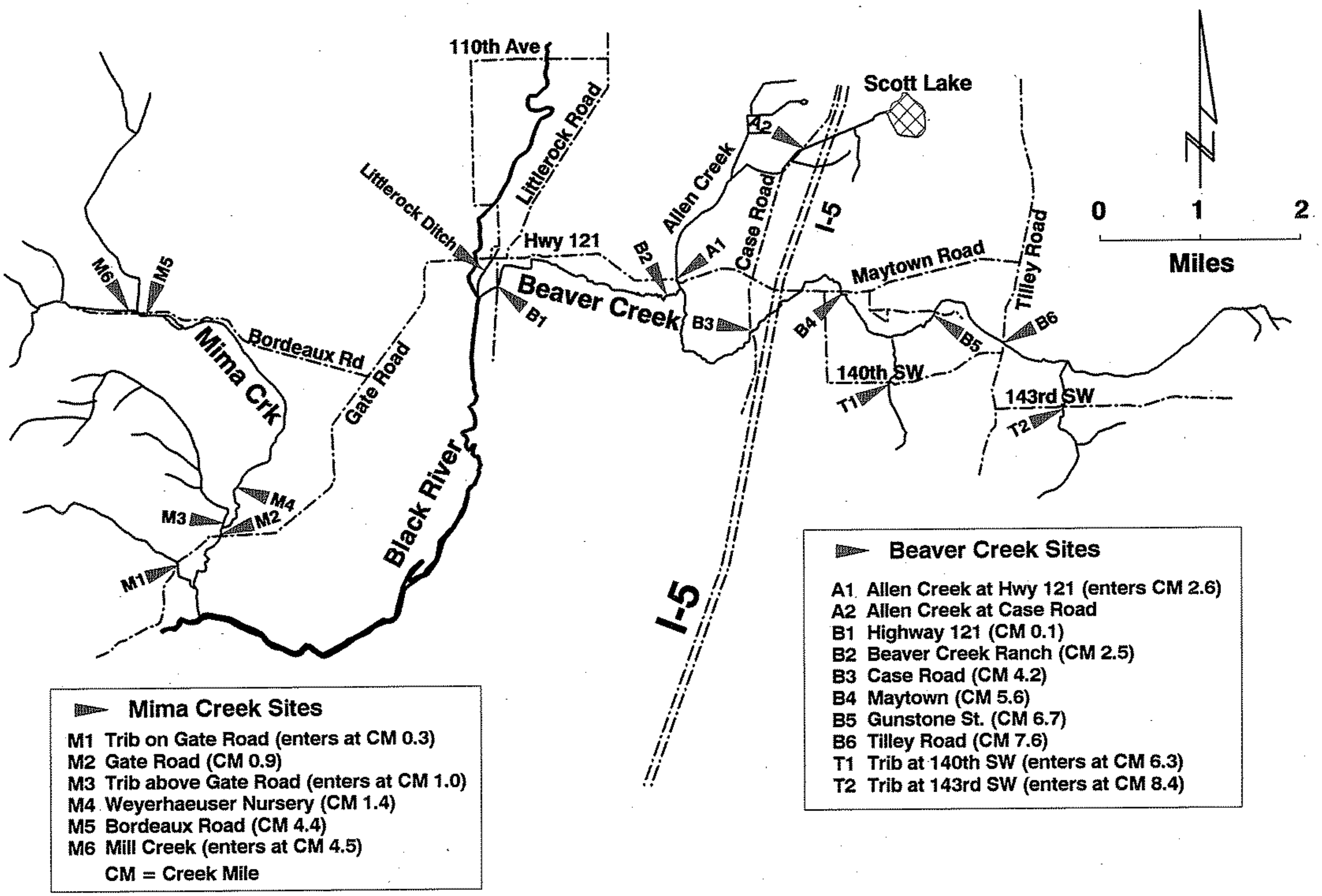

Figure A1. Beaver and Mima Creek subsurvey study sites.

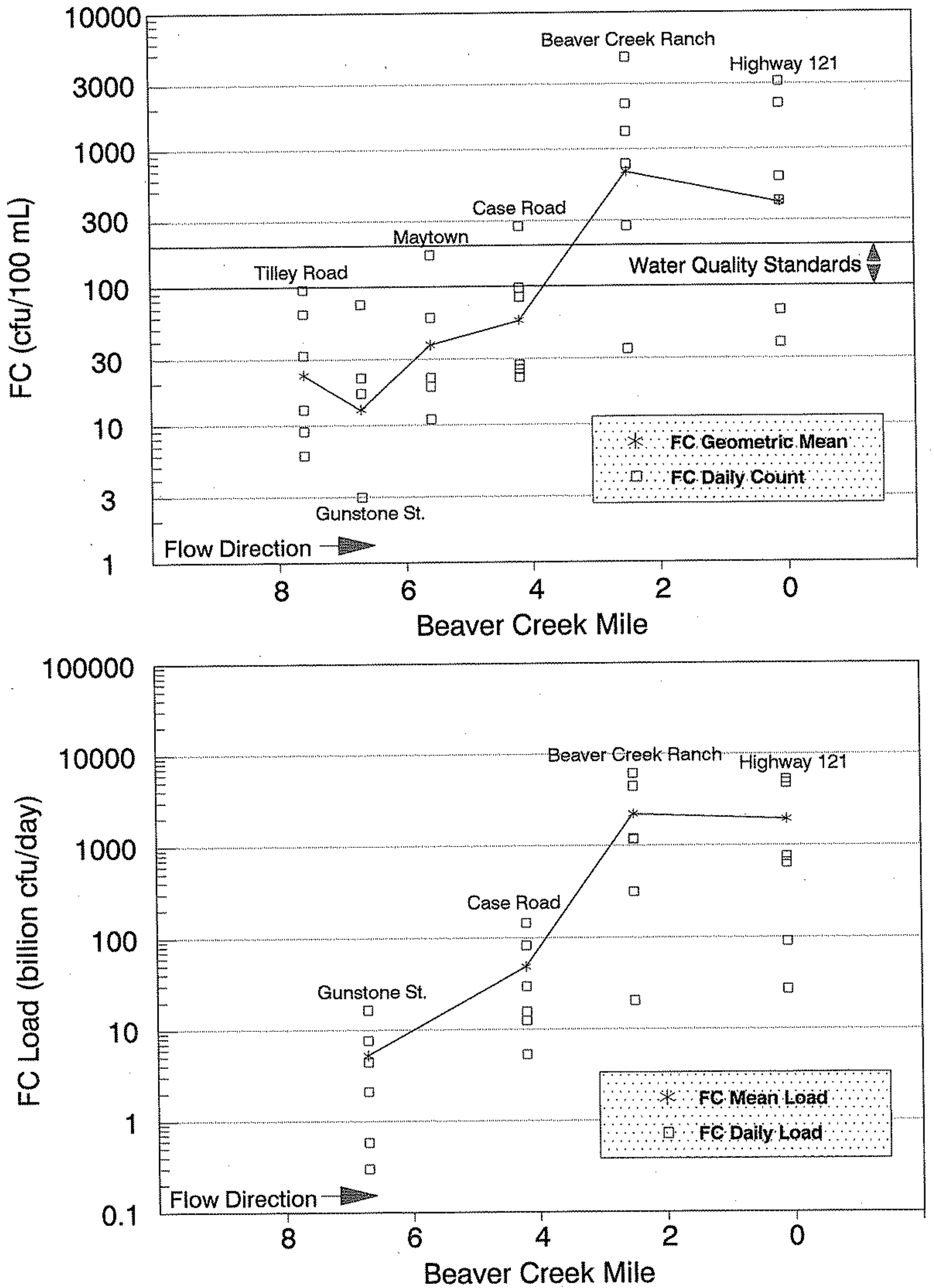

Figure A2. Beaver Creek subsurvey fecal coliform counts and loads.

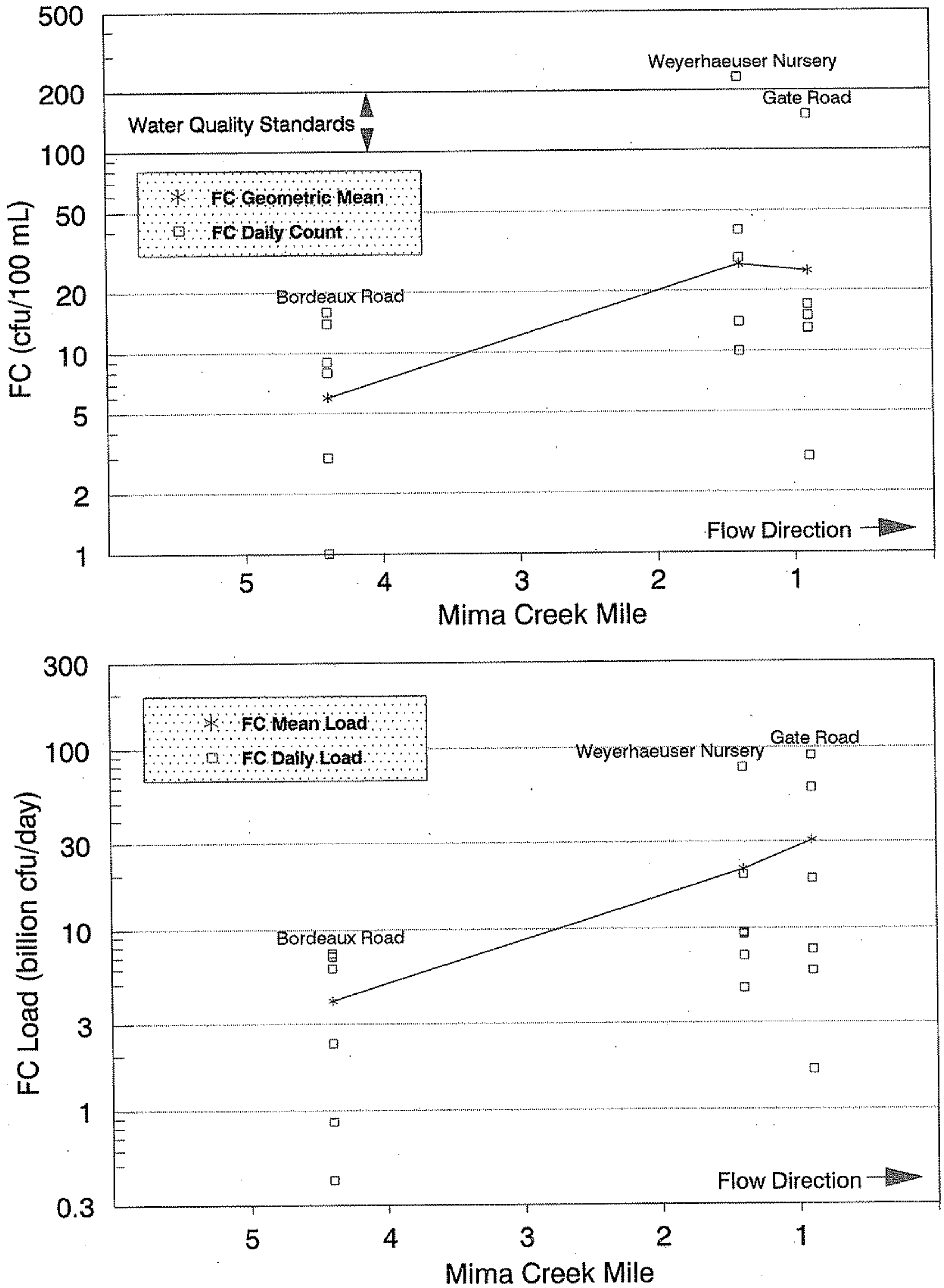

Figure A3. Mima Creek subsurvey fecal coliform counts and loads.

Table A1. Beaver Creek fecal coliform and E. coli results for the year two subsurvey, Dec/92 – Mar/93. Units: cfu/100 mL.

Station (Creek Mile)	12/02/92 FC (E. coli)	12/09/92 FC (E. coli)	12/21/92 FC (E. coli)	01/05/93 FC (E. coli)	03/04/93 FC (E. coli)	03/18/93 FC (E. coli)
Trib at 143rd Ave (enters at CM 8.4)	32	210J	80	21	390	61
Tilley Road (CM 7.6)	96	32	64	9	6	13
Gunstone St. (CM 6.7)	17	75	22	17 (15)	3	3
Trib at 140th Ave (enters at CM 6.3)	16	29	15	5	10	8
Maytown (CM 5.6)	60	170J	60	19	11	22
Case Road (CM 4.2)	84 XS	280 (260)	98 (81)	25 (24)	19 (17)	27 (24)
Allen Creek at Case Rd (enters at CM 2.6)	12 X	69	40	75	35	25
Allen Creek Mouth (enters at CM 2.6)	110	300	140	100S	33 (29)	48
Beaver Creek Ranch (CM 2.5)	1400J (900)	4700J (4400J)	2200 (1800J)	780 (720)	35 (28)	280 (240)
Beaver Creek (CM 0.1)	620 (400)	>3100 (>3100)	2200 (2200J)	420 (380)	39 (28)	67 (51)

J Fecal coliform colonies positively identified; reported value is estimated
X High backgrond count.
S Spreader colony present; number reported is likely underestimated.
> Greater than.

Table A2. Summary of year two Beaver Creek subsurvey study results.
Units: temperature=°C; conductivity=μmhos/cm @ 25°C; bacteria=cfu/100 mL.

Station	Temperature			Conductivity			Fecal Coliform			E. Coli		
(Creek Mile)	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean*	Min	Max	Mean*
Trib at 143rd Ave (enters at CM 8.4)	1.3	6.8	4.6	40	60	50	21	390	80	–	–	–
Tilley Road (CM 7.6)	1.9	6.8	4.6	49	68	60	6	96	23	–	–	–
Gunstone St. (CM 6.7)	2.0	7.2	4.8	64	98	81	3	75	13	15	15	15
Trib at 140th Ave (enters at CM 6.3)	1.8	7.5	4.9	28	41	33	5	29	12	–	–	–
Maytown (CM 5.6)	2.1	7.6	5.0	51	74	63	11	170	38	–	–	–
Case Road (CM 4.2)	2.1	7.6	5.2	45	78	63	22	280	57	17	260	46
Allen Creek at Case Rd (enters at CM 2.6)	2.6	9.6	5.9	73	81	76	12	75	36	–	–	–
Allen Creek Mouth (enters at CM 2.6)	1.9	8.2	5.6	65	86	77	33	300	95	29	29	29
Beaver Creek Ranch (CM 2.5)	2.1	8.2	5.5	62	87	74	35	4700	680	28	1800	380
Beaver Creek (CM 0.1)	2.3	8.2	5.7	64	90	75	39	3100	410	28	2200	220

* Geometric mean.
– No data.

Table A3. Data set from Beaver Creek subsurvey sample stations.

Station No.	Creek Mile	Date	Temp. °C	Conductivity μmhos/cm @ 25 °C	Fecal Coliform cfu/100 mL	E. coli cfu/100 mL
1	8.4	12/02/92	4.5	60	32	–
1	8.4	12/09/92	3.7	55	210	–
1	8.4	12/21/92	4.9	40	80	–
1	8.4	01/05/93	1.3	40	21	–
1	8.4	03/04/93	6.5	52	390	–
1	8.4	03/18/93	6.8	50	61	–
2	7.6	12/02/92	4.5	68	96	–
2	7.6	12/09/92	3.7	66	32	–
2	7.6	12/21/92	4.6	52	64	–
2	7.6	01/05/93	1.9	49	9	–
2	7.6	03/04/93	6.3	67	6	–
2	7.6	03/18/93	6.8	60	13	–
3	6.7	12/02/92	4.5	98	17	–
3	6.7	12/09/92	3.7	91	75	–
3	6.7	12/21/92	4.7	64	22	15
3	6.7	01/05/93	2.0	64	17	–
3	6.7	03/04/93	6.7	92	3	–
3	6.7	03/18/93	7.2	78	3	–
4	6.3	12/02/92	4.7	41	16	–
4	6.3	12/09/92	4.0	35	29	–
4	6.3	12/21/92	4.5	29	15	–
4	6.3	01/05/93	1.8	28	5	–
4	6.3	03/04/93	7.1	34	10	–
4	6.3	03/18/93	7.5	32	8	–
5	5.6	12/02/92	4.6	71	60	–
5	5.6	12/09/92	3.9	69	170	–
5	5.6	12/21/92	4.6	51	60	–
5	5.6	01/05/93	2.1	51	19	–
5	5.6	03/04/93	7.1	74	11	–
5	5.6	03/18/93	7.6	60	22	–
6	4.2	12/02/92	5.0	78	84	–
6	4.2	12/09/92	4.1	69	280	260
6	4.2	12/21/92	4.9	45	98	81
6	4.2	01/05/93	2.1	49	25	24
6	4.2	03/04/93	7.4	78	22	17
6	4.2	03/18/93	7.6	60	27	24

– = No data.

Table A3. Data set from Beaver Creek subsurvey sample stations, continued.

Station No.	Creek Mile	Date	Temp. °C	Conductivity µmhos/cm @ 25 °C	Fecal Coliform cfu/100 mL	E. coli cfu/100 mL
7	2.6	12/02/92	5.7	86	98	–
7	2.6	12/09/92	5.0	81	290	–
7	2.6	12/21/92	5.0	65	120	–
7	2.6	01/05/93	1.9	70	69	–
7	2.6	03/04/93	7.9	79	46	29
7	2.6	03/18/93	8.2	78	39	–
8	2.6	12/02/92	5.9	81	12	–
8	2.6	12/09/92	5.0	78	69	–
8	2.6	12/21/92	5.0	75	40	–
8	2.6	01/05/93	2.6	73	75	–
8	2.6	03/04/93	7.4	75	35	–
8	2.6	03/18/93	9.6	76	25	–
9	2.5	12/02/92	5.5	87	1400	900
9	2.5	12/09/92	4.7	76	4700	–
9	2.5	12/21/92	5.0	62	2200	1800
9	2.5	01/05/93	2.1	64	780	720
9	2.5	03/04/93	7.7	84	35	28
9	2.5	03/18/93	8.2	70	280	240
10	0.1	12/02/92	5.5	90	620	400
10	0.1	12/09/92	5.1	78	3100	-
10	0.1	12/21/92	5.3	66	2200	2200
10	0.1	01/05/93	2.3	64	420	380
10	0.1	03/04/93	7.9	82	39	28
10	0.1	03/18/93	8.2	70	67	51

– = No data.

STATION KEY:

1 Tributary at 143rd Ave
2 Tilley Road
3 Gunstone St.
4 Tributary at 140th Ave
5 Maytown
6 Case Road
7 Allen Creek at Highway 121
8 Allen Creek at Case Road
9 Beaver Creek Ranch
10 Highway 121

Table A4. Mima Creek fecal coliform and E. coli results for the year two subsurvey, Dec/92 – Mar/93. Units: cfu/100 mL.

Station (Creek Mile)	12/02/92 FC (E. coli)	12/09/92 FC (E. coli)	12/21/92 FC (E. coli)	01/05/93 FC (E. coli)	03/04/93 FC (E. coli)	03/18/93 FC (E. coli)
Mill Creek (enters at CM 4.5)	3	4	65	1	15	1
Bordeaux Road (CM 4.4)	14	16	9S	1U	8	3
Weyerhaeuser Nursery (CM 1.4)	40 (38)	14 (14)	10	10	230	29
Trib above Gate Road (enters at CM 1.0)	11	11	4	1	1U	1
Gate Road (CM 0.9)	13 (12)	150J (140J)	17	3	150	14 (10)
Trib at Gate Road (enters at CM 0.3)	13 (12)	–	5 (5)	9 (9)	4 (3)	14 (6)

U Analyte not found at the method detection limit shown.
J Fecal coliform colonies positively identified; reported value is estimated
– No data.

Table A5. Summary of year two Mima Creek subsurvey study results.
Units: temperature=°C; conductivity=μmhos/cm @ 25°C; bacteria=cfu/100 mL.

Station	Temperature			Conductivity			Fecal Coliform			E. Coli		
(Creek Mile)	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean*	Min	Max	Mean*
Mill Creek (enters at CM 4.5)	4.3	7.7	6.4	32	46	38	1	65	5	–	–	–
Bordeaux Road (CM 4.4)	4.0	7.6	6.2	36	44	40	1	16	6	–	–	–
Weyerhaeuser Nursery (CM 1.4)	3.5	8.1	6.1	40	48	44	10	230	27	14	39	23
Trib above Gate Road (enters at CM 1.0)	4.3	7.8	6.3	44	53	49	1	11	3	–	–	–
Gate Road (CM 0.9)	3.7	8.2	6.2	37	49	43	3	150	25	13	140	27
Trib at Gate Road (enters at CM 0.3)	2.1	7.4	4.7	45	78	64	4	14	8	3	9	5

* Geometric mean.
– No data.

Table A6. Data set from Mima Creek subsurvey sample stations.

STATION	CREEK MILE	DATE	TEMP °C	CONDUCTIVITY µmhos/cm @ 25 °C	FECAL COLIFORM cfu/100 mL	E. COLI cfu/100 mL
1	4.5	12/02/92	6.6	46	3	–
1	4.5	12/09/92	5.7	32	4	–
1	4.5	12/21/92	7.2	36	65	–
1	4.5	01/05/93	4.3	35	1	–
1	4.5	03/04/93	7.1	40	15	–
1	4.5	03/18/93	7.7	41	1	–
2	4.4	12/02/92	6.5	44	14	–
2	4.4	12/09/92	5.4	43	16	–
2	4.4	12/21/92	6.7	36	9	–
2	4.4	01/05/93	4.0	36	1	–
2	4.4	03/04/93	7.1	38	8	–
2	4.4	03/18/93	7.6	40	3	–
3	1.4	12/02/92	6.5	48	40	39
3	1.4	12/09/92	5.0	46	14	14
3	1.4	12/21/92	6.4	41	10	–
3	1.4	01/05/93	3.5	40	10	–
3	1.4	03/04/93	7.1	45	230	–
3	1.4	03/18/93	8.1	45	29	–
4	1.0	12/02/92	6.8	52	11	–
4	1.0	12/09/92	5.2	51	11	–
4	1.0	12/21/92	7.1	44	4	–
4	1.0	01/05/93	4.3	45	1	–
4	1.0	03/04/93	6.8	53	1	–
4	1.0	03/18/93	7.8	50	1	–
5	0.9	12/02/92	6.5	49	13	13
5	0.9	12/09/92	5.1	44	150	140
5	0.9	12/21/92	6.5	41	17	–
5	0.9	01/05/93	3.7	40	3	–
5	0.9	03/04/93	7.1	48	150	–
5	0.9	03/18/93	8.2	37	15	10
6	0.3	12/02/92	5.0	78	13	–
6	0.3	12/09/92	4.1	69	5	5
6	0.3	12/21/92	4.9	45	9	9
6	0.3	01/05/93	2.1	49	4	3
6	0.3	03/04/93	7.4	78	14	–

– = No data.

STATION KEY:
1 Mill Creek
2 Bordeaux Road
3 Weyerhaeuser Nursery
4 Trib above Gate Road
5 Gate Road
6 Trib on Gate Road

APPENDIX B

USFWS Degradation Survey Data (Wampler *et al.*, 1993)
USGS Land Use Data (Anderson *et al.*, 1976)

Table B1. Black River and tributary bank impacts and access by livestock as reported by the USFWS, (Wampler, et.al., 1993).

Water Body	Segment	River Mile (RM)	Bank (Left/Right)	Livestock Bank Impact (Lineal Feet)	Livestock Bank Access (Lineal Feet)	Livestock Waste Input (Lineal Feet)
Black River	Above AA	21.1	Left		403	
	AA–RR	19.6–18.9	Right		3758	
	AA–RR	19.5–18.9	Left		3447	
	AA–RR	19.4–19.3	Left	490		
	AA–RR	19.3–19.1	Left	931		
	AA–RR	19.3–19.1	Right	931		
	AA–RR	19.0–18.9	NR	4 – 20 *		
	AA–RR	17.4–16.6	Left		4299	
	AA–RR	17.4–17.0	Left	2039		
	AA–RR	17.4	NR		20 *	
	AA–RR	16.9	NR		20 *	
	MR–HW	5.8	NR		20 *	
	HW–HN	3.9	Right	93		
	HW–HN	3.9	Right		93	
	HW–HN	3.5	NR	20 *		
	HW–HN	3.1–3.0	Right	169		
	HW–HN	2.8	Left	182		
	HW–HN	2.7–2.4	Left	1633		
	HW–HN	2.6	NR	20 *		
	HW–HN	1.2–1.3	NR	2 – 20 *		

NR = Not reported.
* = Indicates a point location, defined as 20 lineal feet or less. A preceding number indicates the number of point occurrences.

Segment key:
AA = 110th Ave.
RR = River Road
MR = Moon Road
HW = U.S. Highway 12
HN = Howanut Road

Table B1. Continued.

Water Body	Segment (Refer to Figure A1)	Creek Mile (CM)	Bank (Left/Right)	Livestock Bank Impact (Lineal Feet)	Livestock Bank Access (Lineal Feet)	Livestock Waste Input (Lineal Feet)
Beaver Creek	Above B6	10.7–7.5	Right		16975	
RM 16.8	Above B6	10.3–7.5	Left		14770	
	Above B6	10.3–9.4	Left	4466		
	Above B6	10.3–9.4	Right	4466		
	B4–B5	6.7–6.5	Left		955	
	B4–B5	6.7–6.5	Right		955	
	B2–B3	4.0–3.6	Left	2010		
	B2–B3	4.0–3.6	Right	2010		
	B2–B3	3.6	NR			20 *
	B2–B3	3.1	NR			20 *
	B2–B3	3.0	NR			20 *
	B2–B3	2.9	NR	20 *		
	B2–B3	2.6	NR		20 *	
	B2–B3	2.5	NR	20 *		
	B1–B2	1.6–2.5	Left		4685	
	B1–B2	1.3–2.5	Right		6266	
	B1–B2	2.3	NR	3 – 20 *		
	B1–B2	2.2	NR	20 *		
	B1–B2	2.0–2.1	Left	135		
	B1–B2	2.1	NR	20 *		
	B1–B2	2.0	NR	2 – 20 *		
	B1–B2	1.9	NR	20 *		
	B1–B2	1.8–1.9	Right	707		
	B1–B2	1.8–1.9	Left	878		
	B1–B2	1.6	NR	20 *		
	B1–B2	0.6–0.7	Right		360	
	B1–B2	0.0–0.2	Left		911	
	B1–B2	0.0–0.2	Right		911	
	B1–B2	0.2	NR	20 *		
	B1–B2	0.1	NR	20 *		

NR = Not reported.
* = Indicates a point location, defined as 20 lineal feet or less. A preceding number indicates the number of point occurrences.

Table B1. Continued.

Water Body	Segment (Refer to Figure A1)	Creek Mile (CM)	Bank (Left/Right)	Livestock Bank Impact (Lineal Feet)	Livestock Bank Access (Lineal Feet)	Livestock Waste Input (Lineal Feet)
Allen Creek (Tributary to Beaver Creek Right bank at CM 2.6)	Above A2	3.2	NR	20 *		
	Above A2	3.1	NR	20 *		
	Above A2	3.0–3.2	Right		1030	
	Above A2	2.8–3.0	Left	809		
	Above A2	2.8–3.2	Left		2114	
	Above A2	2.2–2.4	Left	865		
	Above A2	2.2–2.4	Right	865		
	Above A2	2.2–2.4	Left		940	
	Above A2	2.2–2.4	Right		942	
	A1–A2	2.0	NR	20 *		
	A1–A2	1.7–1.9	Right	1262		
	A1–A2	1.6–1.7	Left	100		
	A1–A2	1.4–1.7	Left		1735	
	A1–A2	1.4–1.6	Left	1364		
	A1–A2	1.2–1.9	Right		3542	
Mima Creek RM 11.8	M4–M5	2.9–3.3	Left		2000	
	M4–M5	3.2	NR	20 *		
	M4–M5	3.0–3.2	Right		847	
	M4–M5	3.0	NR	2 – 20 *		
	M4–M5	2.8–2.9	Left		98	
	M4–M5	2.1–2.7	Left		2885	
	M4–M5	2.2–2.7	Right		2367	
	M4–M5	2.3–2.7	NR	6 – 20 *		
	M3–M4	1.2–1.5	Left		1319	
	M3–M4	1.2–1.5	Right		1319	
	M3–M4	1.2–1.5	NR	4 – 20 *		
	M3–M4	1.4	Left	100		
	M1–M4	0.5–1.1	Right		3191	
	M1–M4	0.6–1.1	Left		3046	
	M1–M2	0.6–1.0	NR	9 – 20 *		
Waddell Creek RM 17.3		8.7	NR		20	
		1.9–2.0	Left	335		
		1.9–2.0	Right	335		
Unnamed Trib. to Waddell Creek Right bank at CM 8.6		0.1	NR	20 *		
		0.0–0.1	Left	434		
		0.0–0.1	Right	434		

NR = Not reported.
* = Indicates a point location, defined as 20 lineal feet or less. A preceding number indicates the number of point occurrences.

Table B2. USGS land use classifications for designated segments of the Black River basin.

LAND CLASSIFICATION	USGS CODE	SEGMENT/ SIZE RANK	SEG. #	SQ FT PER USE TYPE	% USE PER SEG.	SQ MILES
Transitional Areas	76		8	3179068	0.36	31.47
Gravel Pits/Quarries	75	Wildlife Launch	8	1481125	0.17	
Forested Wetland	61	(RM 15.2)	8	71685349	8.17	
Reservoirs	53	to	8	1011372	0.12	
Lakes	52	Littlerock Trestle	8	6027423	0.69	
Mix Forest	43	(RM 17.0)	8	531576923	60.60	
Evergreen Forest	42		8	75577441	8.62	
Mixed Rangeland	33	1	8	49285255	5.62	
Schrub/Brush Rangeland	32		8	1388418	0.16	
Herbaceous Rangeland	31		8	5289400	0.60	
Crop and Pasture	21		8	107065062	12.21	
Transport/Commun/Util	14		8	7225223	0.82	
Industrial	13		8	2137204	0.24	
Commercial/Services	12		8	147892	0.02	
Residential	11		8	14124225	1.61	
Mix Forest	43		9	212642725	41.40	18.42
Evergreen Forest	42	Littlerock Trestle	9	271781870	52.91	
Mixed Rangeland	33	(RM 17.0)	9	38230	0.01	
Schrub/Brush Rangeland	32	to	9	5601806	1.09	
Other AG	24	River Road	9	298514	0.06	
Crop and Pasture	21	(RM 17.4)	9	13619961	2.65	
Industrial	13		9	1419515	0.28	
Commercial/Services	12	2	9	757984	0.15	
Residential	11		9	5120917	1.00	
ND	0		9	2362149	0.46	
Nonforest Wetland	62	Black River	6	2073365	0.47	15.86
Forested Wetland	61	at Mima	6	18396000	4.16	
Mix Forest	43	(RM 11.8)	6	161242510	36.47	
Evergreen Forest	42	to	6	202380117	45.78	
Mixed Rangeland	33	Canoe Club	6	863510	0.20	
Other AG	24	(RM 14.1)	6	520265	0.12	
Crop and Pasture	21	3	6	55726020	12.61	
Mix Urban/Builtup Land	16		6	877347	0.20	
Nonforest Wetland	62		10	2859448	1.07	9.60
Forested Wetland	61	River Road	10	20032454	7.49	
Lakes	52	(RM 17.4)	10	1370088	0.51	
Mix Forest	43	to	10	115233696	43.06	
Evergreen Forest	42	110th Ave.	10	51691873	19.32	
Deciduous Forest	41	(RM 19.7)	10	5855771	2.19	
Schrub/Brush Rangeland	32		10	666243	0.25	
Other AG	24	4	10	1495559	0.56	
Crop and Pasture	21		10	64788388	24.21	
Transport/Commun/Util	14		10	744108	0.28	
Residential	11		10	2862820	1.07	

Table B2. Continued.

LAND CLASSIFICATION	USGS CODE	SEGMENT/ SIZE RANK	SEG. #	SQ FT PER USE TYPE	% USE PER SEG.	SQ MILES
Forested Wetland	61	Canoe Club	7	9211729	4.47	7.40
Mix Forest	43	(RM 14.1)	7	96514861	46.82	
Evergreen Forest	42	to	7	30334262	14.71	
Mixed Rangeland	33	Wildlife Launch	7	65955270	31.99	
Other AG	24	(RM 15.2)	7	505143	0.25	
Crop and Pasture	21	5	7	3639739	1.77	
Nonforest Wetland	62	Sweckers Dock	5	10791770	7.17	5.40
Mix Forest	43	(RM 10.6)	5	37945863	25.23	
Evergreen Forest	42	to	5	28697383	19.08	
Confined Feeding	23	Black River	5	396414	0.26	
Crop and Pasture	21	at Mima	5	61567130	40.93	
Mix Urban/Builtup Land	16	(RM 11.8)	5	1644492	1.09	
Commercial/Services	12	6	5	399121	0.27	
Residential	11		5	8984636	5.97	
Nonforest Wetland	62	Steel Trestle	4	15241750	11.72	4.67
Mix Forest	43	(RM 9.1)	4	23225736	17.85	
Evergreen Forest	42	to	4	12509662	9.62	
Other AG	24	Sweckers Dock	4	563950	0.43	
Crop and Pasture	21	(RM 10.6)	4	66762652	51.32	
Mix Urban/Builtup Land	16		4	1396065	1.07	
Commercial/Services	12	7	4	232320	0.18	
Residential	11		4	10154631	7.81	
Mix Forest	43	Howanut Road	1	44036127	34.03	4.64
Evergreen Forest	42	(RM 1.2)	1	14040319	10.85	
Other AG	24	to	1	1287302	0.99	
Crop and Pasture	21	U.S. Highway 12	1	69434010	53.65	
Residential	11	(RM 4.1) / 8	1	614437	0.47	
Mix Forest	43	U.S. Highway 12	2	58550551	51.75	4.06
Evergreen Forest	42	(RM 4.1)	2	7297743	6.45	
Other AG	24	to	2	24357	0.02	
Confined Feeding	23	Moon Road	2	473954	0.42	
Crop and Pasture	21	(RM 7.1)	2	45330666	40.07	
Residential	11	9	2	1456896	1.29	
Mix Forest	43	Moon Road	3	2231181	6.58	1.22
Other AG	24	(RM 7.1) to	3	507752	1.50	
Confined Feeding	23	Steel Trestle	3	778807	2.30	
Crop and Pasture	21	(RM 9.1) / 10	3	30413060	89.63	

Table B2. Continued.

LAND CLASSIFICATION	USGS CODE	SEGMENT	SQ FT PER USE TYPE	% USE PER SEG.	SQ MILES
Transitional Areas	76		2884016	0.41	25.17
Gravel Pits/Quarries	75	Black River Headwaters	1478404	0.21	
Nonforest Wetland	62	to	12848497	1.83	
Forested Wetland	61	110th Ave.	19127277	2.73	
Reservoirs	53	(RM 19.7)	499294	0.07	
Mix Forest	43		310984106	44.33	
Evergreen Forest	42		240638977	34.30	
Mixed Rangeland	33		8521813	1.21	
Other AG	24		694411	0.10	
Orcds/Grov/Vinyd/Nursry	22		2326343	0.33	
Crop and Pasture	21		72242439	10.30	
Other Urban/Builtup Land	17		4132719	0.59	
Mix Urban/Builtup Land	16		822469	0.12	
Transport/Commun/Util	14		3618365	0.52	
Industrial	13		691553	0.10	
Residential	11		19902869	2.84	
ND	0		176243	0.03	
Mix Forest	43	Black/Chehalis River	345	0.002	0.54
Evergreen Forest	42	Confluence to	2709393	18.03	
Crop and Pasture	21	Howanut Road (RM 1.2)	12313670	81.96	
Basin Total Sq. Feet / %			3209679388	100 %	
Basin Total Sq. Miles					128.43

APPENDIX C

Tables

Fecal coliform, discharge, *E. coli*, temperature, conductivity, and data summary

Table C1. Year one Black River Nonpoint TMDL Study results for fecal coliform bacteria, Winter 91–92.
Results given are means of sample replicates expressed as cfu/100 mL.

Station/Code (river mile)	12/04/91	12/09/91	01/06/92	01/13/92	01/28/92	02/03/92	02/18/92	02/24/92	03/04/92	03/09/92
110th Ave./AA (19.7)	23	27 S	13 S	10	44	9	10	32	12	10
River Road/RR (17.4)	21	99	24	18	36	11	16	23	17	10
Littlerock Trestle/LT (17.0)	32	65 S	14	14	28	6	6	9	10	14
Wildlife Launch/WL (15.2)	70	47 S	26	15	580 J	53	15	120	31	6
Canoe Club/CC (14.1)	55	40 S	39	14	350 S	98	9	160	19	5
Black River at Mima/MM (11.8)	59	42 S	17	18	460 J,S	84	240	220	44	19
Sweckers Dock/SD (10.8)	62	40 S	17	12	630 J	56 S	170	240 J	34	11
Steel Trestle/ST (9.1)	120	34 S	22	7	440 J,S	39	120	100	34	11
Moon Road/MR (7.1)	86	36	12 S	9	350 J,S	40	75	61	23	7
U.S. Highway 12/HW (4.1)	82	32	9	11	190 S	36	51	54 S	20	9
Howanut Road/HN (1.2)	47 J	52	12	12	220 S	49	30	69	21	8
Tributaries:										
Waddell Creek/WC (at 17.3)	9	9	5	8	28 S	2	15 S	2 U	12	12
Beaver Creek/BC (at 16.8)	4000 J	180	46	44	2100	180	69	380	74	8
Mima Creek Upstream/MC	6	30	3	100	74	3	66	10	260	53
Mima Creek/MB (at 11.8)	30	38	2	47	57	3	57	8	160	33 S

S Spreader colony present; number reported is likely underestimated.
J Fecal coliform colonies positively identified; the reported value is estimated.
U Analyte not found at the method detection limit shown.
☐ Indicates year one data used in TMDL analysis.

Table C2. Year two Black River Nonpoint TMDL Study results for fecal coliform bacteria, Winter 92–93. All units are cfu/100 mL.

Station/Code (river mile)	12/01/92	12/10/92	12/22/92	01/04/93	01/20/93	01/26/93	03/03/93	03/17/93	03/23/93	04/08/93	04/12/93
110th Ave./AA (19.7)	13	67	29	19	88	33	7	40	100	200	45
River Road/RR (17.4)	33	340	34	48	390	57	200	230 S	140	3	61
Littlerock Trestle/LT (17.0)	41	210	26	33	210	54	180	130 S	200	8	29
Wildlife Launch/WL (15.2)	160	96	55	330	990 J	370	37	92	810	21	130
Canoe Club/CC (14.1)	410 J,S	120	100 J	620 J	100	280	19	44	1400 J	3	200
Black River at Mima/MM (11.8)	48	690	99	30	140	360	21	220 S	160 S	17	220 S
Sweckers Dock/SD (10.6)	14	410 J	140	15	75	360 S	11	180 S	91 S	49	200 S
Steel Trestle/ST (9.1)	26	80	100	23	19	380	11	180 S	86 S	5	190 S
Moon Road/MR (7.1)	15	62	28	21	23	520 J	6	120 S	77	11 S	330
U.S. Highway 12/HW (4.1)	28	51	28	20	33	550	6	41	96 S	14	400
Howanut Road/HN (1.2)	22	49	26	27	110	590	8	36	63	27 S	460 J
Tributaries:											
Waddell Creek/WC (at 17.3)	9	27	11	20	35	7	2	4	13 S	10	6
Beaver Creek/BC (at 16.8)	1100 J,S	3200 J	770	510 J	16000 J	1400 J	100	300 S	2600 J	32	650 J,S
Littlerock Ditch/LD (at 16.8)	ND	ND	ND	ND	ND	240 S	26	120	120	88	150
Mima Creek Upstream/MC	20	450 J	16	56	100	20	28	28	96	84	43
Mima Creek/MB (at 11.8)	19	280	26	44	220	14	20	11	71	63	23

J Fecal coliform colonies positively identified; the reported value is estimated.
S Spreader colony present; number reported is likely underestimated.
ND No data.

Table C3. Year one Black River and tributary survey day flows, in cubic feet per second (cfs).

Station	12/04/91	12/09/91	01/06/92	01/13/92	01/28/92	02/03/92	02/18/92	02/24/92	03/04/92	03/09/92
110th Ave.	25.0	70.3	38.8	29.2	123	72.1	24.0	33.7	5.9	8.6
River Road	46.4	131	72.1	54.3	228	134	44.6	62.7	11.0	16.0
Littlerock Trestle	86.6	339	139	99.8	480	282	93.6	132	77.3	70.5
Wildlife Launch	154	374	173	131	510	754	241	393	202	173
Canoe Club	233	563	252	205	774	2163	340	596	286	249
Black River at Mima	229	506	245	203	653	1584	320	524	274	245
Sweckers Dock	243	542	253	202	667	1428	334	546	283	247
Steel Trestle	256	579	261	201	680	1273	349	568	291	248
Moon Road	255	583	300	220	691	1110	400	592	344	296
U.S. Highway 12	255	587	338	238	702	947	452	617	397	345
Howanut Road	260	600	346	243	718	969	462	631	406	353
Tributaries:										
Waddell Creek	40.2	112	67.3	45.5	251	148	49.1	69.0	66.3	54.5
Beaver Creek	40.0	74.9	43.2	44.0	270	193	79.8	112	57.6	52.8
Mima Creek	22.4	56.7	30.1	18.8	126	65.9	42.4	52.3	28.4	22.4

Table C4. Year two Black River and tributary survey day flows, in cubic feet per second (cfs).

Station	12/01/92	12/10/92	12/22/92	01/04/93	01/20/93	01/26/93	03/03/93	03/17/93	03/23/93	04/08/93	04/12/93
110th Ave.	40.6	41.0	62.4	45.7	41.9	122	20.9	37.2	68.9	32.0	72.7
River Road	92.9	82.0	123	103	60.0	205	58.8	91.7	131	79.5	146
Littlerock Trestle	142	146	234	160	168	445	74.2	139	291	125	245
Wildlife Launch	208	201	306	234	206	521	97.1	157	301	152	381
Canoe Club	299	288	433	326	290	876	173	233	378	229	569
Black River at Mima	291	279	401	311	284	731	174	227	376	224	509
Sweckers Dock	300	290	404	319	288	746	177	231	379	226	519
Steel Trestle	337	328	457	349	280	738	155	233	411	218	568
Moon Road	404	394	549	418	336	739	186	280	493	262	681
U.S. Highway 12	462	470	595	525	429	739	267	426	605	468	745
Howanut Road	472	480	607	536	438	754	272	435	617	477	760
Tributaries:											
Waddell Creek	49.5	63.6	112	56.5	108	240	15.3	47.5	160	45.5	99.7
Beaver Creek	50.1	66.2	89.5	76.2	96.7	165	25.1	58.8	123	53.4	122
Littlerock Ditch	–	–	–	–	–	9.2	1.0	2.5	6.2	2.2	6.0
Mima Creek	32.4	37.7	60.9	29.4	55.9	146	13.2	18.8	115	21.3	68.5

– = No data.

Table C5. Year two Black River Nonpoint TMDL Study results for E. coli bacteria, Winter 92–93.
Results given are means of replicate samples. Units: cfu/100 mL.

Station (river mile)	12/01/92	12/10/92	12/22/92	01/04/93	01/20/93	01/26/93	03/03/93	03/17/93	03/23/93	04/08/93	04/12/93
110th Ave. (19.7)	–	–	–	–	–	–	–	–	–	–	–
River Road (17.4)	–	–	–	–	–	–	–	–	–	–	–
Littlerock Trestle (17.0)	–	200	–	–	–	–	–	–	–	–	–
Wildlife Launch (15.2)	–	–	48	–	–	–	–	–	–	–	–
Canoe Club (14.1)	–	110	–	560 J	–	–	–	–	–	–	–
Black River at Mima (11.8)	–	–	88	25	–	330	16	180	120	13	170
Sweckers Dock (10.6)	13	330	110	–	70	320	6	140	89	–	160
Steel Trestle (9.1)	25	–	–	–	12	–	6	–	–	–	–
Moon Road (7.1)	14	51	–	–	–	420	–	–	–	–	–
U.S. Highway 12 (4.1)	28	–	25	18	30	–	–	30	84	–	–
Howanut Road (1.2)	–	45	25	18	110 J	–	–	–	–	–	–
Tributaries:											
Waddell Creek (17.3)	–	–	–	–	–	–	–	–	–	–	–
Beaver Creek (16.8)	–	–	–	420	>8000	1200	73	260	2600	29	640 J
Littlerock Ditch (16.8)	–	–	–	–	–	180	73	120	120	76	110
Mima Creek Upstream	–	–	–	–	–	–	–	–	–	–	–
Mima Creek (11.8)	39	–	–	31	–	–	–	–	–	–	–

– = No data.
J = E. coli colonies positively identified; the reported value is estimated.
> = Greater than the value reported.

Table C6. Year one Black River NPS TMDL Study results for temperature (°C, by mercury thermometer), Winter 91–92.

Station (river mile)	12/04/91	12/09/91	01/06/92	01/13/92	01/28/92	02/03/92	02/18/92	02/24/92	03/04/92	03/09/92
110th Ave. (19.7)	7.9	8.1	3.3	4.4	8.1	7.3	6.0	7.9	9.3	6.9
River Road (17.4)	7.4	8.0	4.3	4.6	7.4	7.6	6.7	8.0	9.8	7.9
Littlerock Trestle (17.0)	7.9	8.3	4.6	5.2	8.3	7.5	5.8	8.1	9.5	7.8
Wildlife Launch (15.2)	8.1	8.4	4.8	5.5	8.1	7.8	6.0	8.2	9.5	7.5
Canoe Club (14.1)	8.7	8.4	4.8	5.8	8.5	7.7	6.8	8.3	9.6	8.4
Black River at Mima (11.8)	8.1	8.5	5.5	5.9	8.5	8.0	6.8	8.4	9.8	8.9
Sweckers Dock (10.6)	8.3	8.5	5.4	6.1	8.3	8.1	6.2	8.5	9.7	9.5
Steel Trestle (9.1)	7.8	8.5	5.6	6.5	8.0	8.2	6.4	8.3	9.6	9.6
Moon Road (7.1)	8.0	8.5	5.8	6.5	8.0	8.5	6.5	8.4	9.8	11.6
U.S. Highway 12 (4.1)	8.0	8.5	6.0	6.2	8.0	8.5	6.7	8.6	10.2	10.8
Howanut Road (1.2)	8.1	8.4	5.7	6.6	7.9	8.4	7.0	8.5	10.3	10.6
Tributaries:										
Waddell Creek (17.3)	8.3	8.6	4.9	6.0	8.4	7.5	7.0	8.1	8.7	6.7
Beaver Creek (16.8)	8.0	8.2	4.3	5.5	8.5	7.5	6.2	8.4	9.7	7.5
Mima Creek at Gate	8.4	8.9	4.9	5.9	8.6	7.5	6.2	8.4	8.7	6.5
Mima Creek (11.8)	8.5	8.9	4.8	6.0	8.7	7.7	6.1	8.8	9.1	7.5

Table C7. Year one Black River NPS TMDL Study results for conductivity (μmhos/cm @ 25°C), Winter 91–92.

Station (river mile)	12/04/91	12/09/91	01/06/92	01/13/92	01/28/92	02/03/92	02/18/92	02/24/92	03/04/92	03/09/92
110th Ave. (19.7)	49	45	58	64	42	45	60	53	68	56
River Road (17.4)	67	52	59	64	50	45	61	52	65	66
Littlerock Trestle (17.0)	59	46	52	56	38	41	53	48	58	59
Wildlife Launch (15.2)	70	54	60	63	43	48	61	55	65	66
Canoe Club (14.1)	70	54	60	70	42	48	63	54	65	67
Black River at Mima (11.8)	70	52	60	68	45	46	65	55	70	70
Sweckers Dock (10.6)	73	53	62	68	47	48	67	54	70	61
Steel Trestle (9.1)	75	53	63	79	53	47	69	56	70	68
Moon Road (7.1)	79	57	67	74	52	48	71	58	73	72
U.S. Highway 12 (4.1)	80	57	70	76	56	51	74	60	75	78
Howanut Road (1.2)	84	58	71	79	57	55	76	62	78	79
Tributaries:										
Waddell Creek (17.3)	45	39	40	44	34	37	40	41	43	43
Beaver Creek (16.8)	87	68	74	78	54	60	72	65	75	72
Mima Creek at Gate	56	45	49	52	38	40	46	45	48	49
Mima Creek (11.8)	55	45	49	53	40	41	46	45	48	49

Table C8. Year two Black River NPS TMDL Study results for temperature (°C, by mercury thermometer), Winter 92–93.

Station (river mile)	12/01/92	12/10/92	12/22/92	1/04/93	1/20/93	1/26/93	3/03/93	3/17/93	3/23/93	4/08/93	4/12/93
110th Ave. (19.7)	4.3	3.1	5.1	1.2	2.0	5.7	5.8	6.5	9.1	9.3	8.4
River Road (17.4)	5.3	3.7	5.0	1.6	2.4	6.1	5.6	6.9	10.0	9.6	9.5
Littlerock Trestle (17.0)	5.5	4.0	5.7	2.3	3.6	6.6	5.9	7.0	8.7	9.2	8.9
Wildlife Launch (15.2)	5.6	4.0	5.7	2.7	4.0	6.9	6.4	7.2	9.3	10.1	9.5
Canoe Club (14.1)	5.7	4.4	5.8	2.7	4.3	6.9	6.9	7.3	9.0	10.1	9.1
Black River at Mima (11.8)	6.3	4.6	6.0	3.4	4.1	6.7	6.6	7.5	9.2	9.8	9.4
Sweckers Dock (10.6)	6.2	4.7	6.1	3.2	4.1	6.6	6.6	8.2	9.7	10.1	10.4
Steel Trestle (9.1)	6.2	5.5	6.3	4.4	5.1	6.8	6.4	8.3	9.7	10.6	9.8
Moon Road (7.1)	6.4	4.8	5.8	3.7	4.3	6.7	7.2	8.7	10.5	10.4	9.7
U.S. Highway 12 (4.1)	6.4	4.7	5.9	3.8	4.6	6.7	7.1	8.7	10.7	10.0	9.6
Howanut Road (1.2)	6.1	4.7	5.8	3.7	4.9	6.5	7.5	8.8	10.3	10.4	9.4
Tributaries:											
Waddell Creek (17.3)	6.0	4.5	6.7	3.5	4.3	6.9	6.3	6.8	7.9	8.5	7.3
Beaver Creek (16.8)	5.2	3.5	5.0	2.6	3.2	6.6	6.7	7.3	9.3	10.2	9.2
Littlerock Ditch (16.8)	–	–	–	–	–	5.9	6.4	7.3	9.0	10.3	9.0
Mima Creek at Gate	5.9	4.6	6.8	3.6	4.2	7.2	6.0	6.8	8.3	8.7	7.5
Mima Creek (11.8)	5.9	4.6	6.8	3.7	4.5	7.7	6.4	7.2	8.3	9.9	8.7

– = No Data.

Table C9. Year two Black River NPS TMDL Study results for conductivity (μmhos/cm @ 25 °C), Winter 92–93.

Station (river mile)	12/01/92	12/10/92	12/22/92	1/04/93	1/20/93	1/26/93	3/03/93	3/17/93	3/23/93	4/08/93	4/12/93
110th Ave. (19.7)	55	–	41	36	46	27	60	55	40	56	40
River Road (17.4)	58	–	50	53	65	40	68	62	52	61	48
Littlerock Trestle (17.0)	52	–	43	45	48	33	57	48	38	50	40
Wildlife Launch (15.2)	61	–	49	52	60	40	72	51	45	60	48
Canoe Club (14.1)	62	–	–	56	60	38	67	60	45	61	46
Black River at Mima (11.8)	65	–	–	57	53	38	78	142	50	64	46
Sweckers Dock (10.6)	66	–	–	55	63	37	79	76	54	66	45
Steel Trestle (9.1)	68	–	65	74	84	40	79	80	56	84	51
Moon Road (7.1)	70	–	53	63	70	40	82	73	58	68	48
U.S. Highway 12 (4.1)	73	–	57	65	78	44	84	78	62	70	48
Howanut Road (1.2)	75	–	60	68	79	47	85	76	67	73	50
Tributaries:											
Waddell Creek (17.3)	38	–	36	34	34	29	49	34	31	35	35
Beaver Creek (16.8)	73	–	65	65	85	52	85	72	54	74	54
Littlerock Ditch (16.8)	–	–	–	–	–	99	88	80	68	86	108
Mima Creek at Gate	45	–	40	40	42	34	49	46	38	45	36
Mima Creek (11.8)	42	–	–	40	40	34	50	47	37	44	38

– = No Data.

Table C10. Summary of year one Black River NPS TMDL Study results.

1991–92	Fecal Coliform (cfu/100 mL)			Temperature (°C)			Conductivity (µmhos/cm @25°C)		
Station	Min	Max	Mean*	Min	Max	Mean	Min	Max	Mean
110th Ave. (RM 19.7)	9	44	16	3.3	9.3	6.9	42	68	54
River Road (RM 17.4)	10	99	21	4.3	9.8	7.2	45	67	58
Littlerock Trestle (RM 17.0)	6	65	14	4.6	9.5	7.3	38	59	51
Wildlife Launch (RM 15.2)	6	580	40	4.8	9.5	7.4	43	70	59
Canoe Club (RM 14.1)	5	350	37	4.8	9.6	7.7	42	70	59
Black River at Mima (RM 11.8)	17	460	64	5.5	9.8	7.8	45	70	60
Sweckers Dock (RM 10.6)	11	630	55	5.4	9.7	7.9	47	73	60
Steel Trestle (RM 9.1)	7	440	46	5.6	9.6	7.9	47	79	63
Moon Road (RM 7.1)	7	350	35	6.5	11.6	8.4	48	79	65
U.S. Highway 12 (RM 4.1)	9	190	31	6.0	10.8	8.2	51	80	68
Howanut Road (RM 1.2)	8	220	32	5.7	10.6	8.2	55	84	70
Tributaries:									
Waddell Creek (RM 17.3)	2	28	7	4.9	8.7	7.4	34	45	41
Beaver Creek (RM 16.8)	8	4000	160	4.3	9.7	7.4	54	87	71
Mima Creek at Gate	3	260	25	4.9	8.9	7.4	38	56	47
Mima Creek (RM 11.8)	2	160	23	4.8	9.1	7.6	40	55	47

* Geometric mean.

Table C11. Summary of year two Black River NPS TMDL Study results.

1992–93 Station	Fecal Coliform (cfu/100 mL) Min	Max	Mean*	Temperature (°C) Min	Max	Mean	Conductivity (μmhos/cm @25°C) Min	Max	Mean
110th Ave. (RM 19.7)	7	200	40	1.2	9.3	5.5	27	60	46
River Road (RM 17.4)	3	390	76	1.6	10.0	6.0	40	68	56
Littlerock Trestle (RM 17.0)	8	210	65	2.3	9.2	6.1	33	57	45
Wildlife Launch (RM 15.2)	21	990	150	2.7	10.1	6.5	40	72	54
Canoe Club (RM 14.1)	3	1400	120	2.7	10.1	6.6	38	67	50
Black River at Mima (RM 11.8)	17	690	100	3.4	9.8	6.7	38	142	59
Sweckers Dock (RM 10.6)	11	410	77	3.2	10.4	6.9	37	79	54
Steel Trestle (RM 9.1)	5	380	51	4.4	10.6	7.2	40	84	68
Moon Road (RM 7.1)	6	520	45	3.7	10.5	7.1	40	82	63
U.S. Highway 12 (RM 4.1)	6	550	46	3.8	10.7	7.1	44	84	66
Howanut Road (RM 1.2)	8	590	54	3.7	10.4	7.1	47	85	68
Tributaries:									
Waddell Creek (RM 17.3)	2	35	10	3.5	8.5	6.2	29	49	36
Beaver Creek (RM 16.8)	32	16000	760	2.6	10.2	6.3	52	85	68
Littlerock Ditch (RM 16.8)	24	240	100	5.9	10.3	8.0	68	108	88
Mima Creek at Gate	16	450	48	3.6	8.7	6.3	34	49	42
Mima Creek (RM 11.8)	11	280	40	3.7	9.9	6.7	34	50	41

* Geometric mean.