Publication No. 93-e46

SNOQUALMIE RIVER BACTERIA STUDY

by
Barbara R. Patterson and Betsy Dickes
April 1993

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Watershed Assessments Section
Olympia, Washington 98504-7710

Waterbody Nos. WA-07-1060, WA-07-1100
(Segment No. 03-07-13)

ABSTRACT

Five swimming areas along the Snoqualmie River were monitored during summer 1992 to evaluate bacterial contamination. The results are compared to the state Class A criterion for fecal coliform (FC) and to the federal criteria for enterococci and *Escherichia coli* (*E. coli*). Three swimming areas had bacterial concentrations that exceeded one or both of the criteria. These areas are located at river mile (RM) 9.8 at Duvall, RM 24.9 near Carnation, and RM 39.6 near Fall City. The area at Duvall had significantly higher FC and *E. coli* concentrations than all other areas except for Carnation. Further investigation of bacterial sources and implementation of source controls is recommended at these three swimming areas.

INTRODUCTION

The Snoqualmie River basin is located in King and Snohomish Counties, Washington. The forks of the river originate in the Cascade mountains and flow west to form the mainstem near North Bend. The study area includes the portion of the Snoqualmie River from Duvall at RM 9.8, to approximately one mile downstream of the Snoqualmie Wastewater Treatment Plant (WWTP) at RM 39.6 (Figure 1). The Department of Ecology has classified the mainstem of the Snoqualmie River as Class A (WAC 173-201-045).

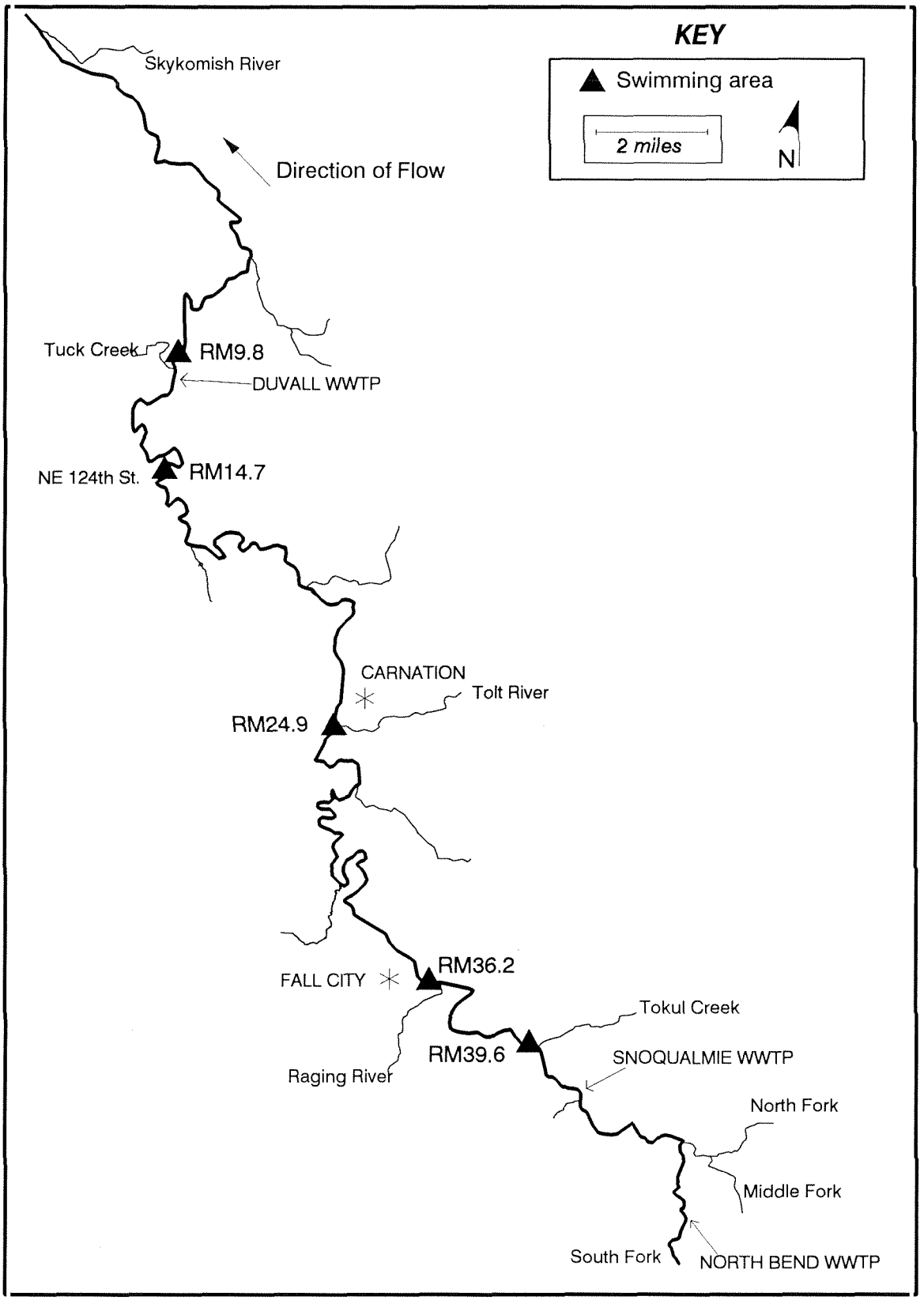

Figure 1. Swimming areas for the Snoqualmie River bacteria study, July 20 - August 25, 1992.

Joy *et al.* (1991) determined that sections of the mainstem Snoqualmie River and many of its tributaries were not meeting the Class A fecal coliform (FC) criterion. The causes of high FC were suspected to be wastewater treatment plants and nonpoint sources. Possible nonpoint sources include livestock in the river, bank-side manure storage piles, improper placement of manure guns, and septic tank leachate.

Due to concern of possible public health risks from bacterial loading, the Watershed Assessments Section of Ecology performed water quality monitoring at five swimming areas along the mainstem Snoqualmie River. The study objectives were to: 1) evaluate FC, enterococci, and *Escherichia coli* (*E. coli*) contamination at each swimming area; and 2) compare FC results to the state Class A criterion, and enterococci and *E. coli* results to federal criteria. The Class A criterion for FC is used to determine the presence of bacterial pathogens. Enterococci and *E. coli* freshwater bathing criteria established by the United States Environmental Protection Agency (USEPA) have not yet been adopted by Washington. Epidemiological studies have shown that these bacteria are better indicators of human health risks than FC (USEPA, 1986).

This report summarizes data collected at five swimming beaches on the Snoqualmie River during summer 1992. FC, enterococcus, and *E. coli* bacteria results are summarized and compared to state and federal criteria.

METHODS

Five swimming areas, based on recommendations from Joy (1992), were sampled along the Snoqualmie River (Figure 1) once weekly for six weeks, July 20 through August 25, 1992. An A and B site were established at each swimming area to assess spacial variability. Samples were taken in the morning, 9:00 a.m. to 12:00 p.m., and afternoon, 1:00 p.m. to 4:00 p.m., at each site to assess temporal variability.

Site descriptions, sampling methods, and QA/QC are summarized in Appendix A.

RESULTS AND DISCUSSION

All data are provided in Appendix B.

Site Comparison

Notched box plots in Figure 2 illustrate the differences in bacterial concentrations among the sites. As illustrated in the example, the notches on each box represent the 95% confidence interval about the median. If the notches on different boxes do not overlap, the median site values for the given parameter are deemed significantly different.

Within each swimming area there was no significant difference between the A and B sites, indicating little, if any, spatial variability.

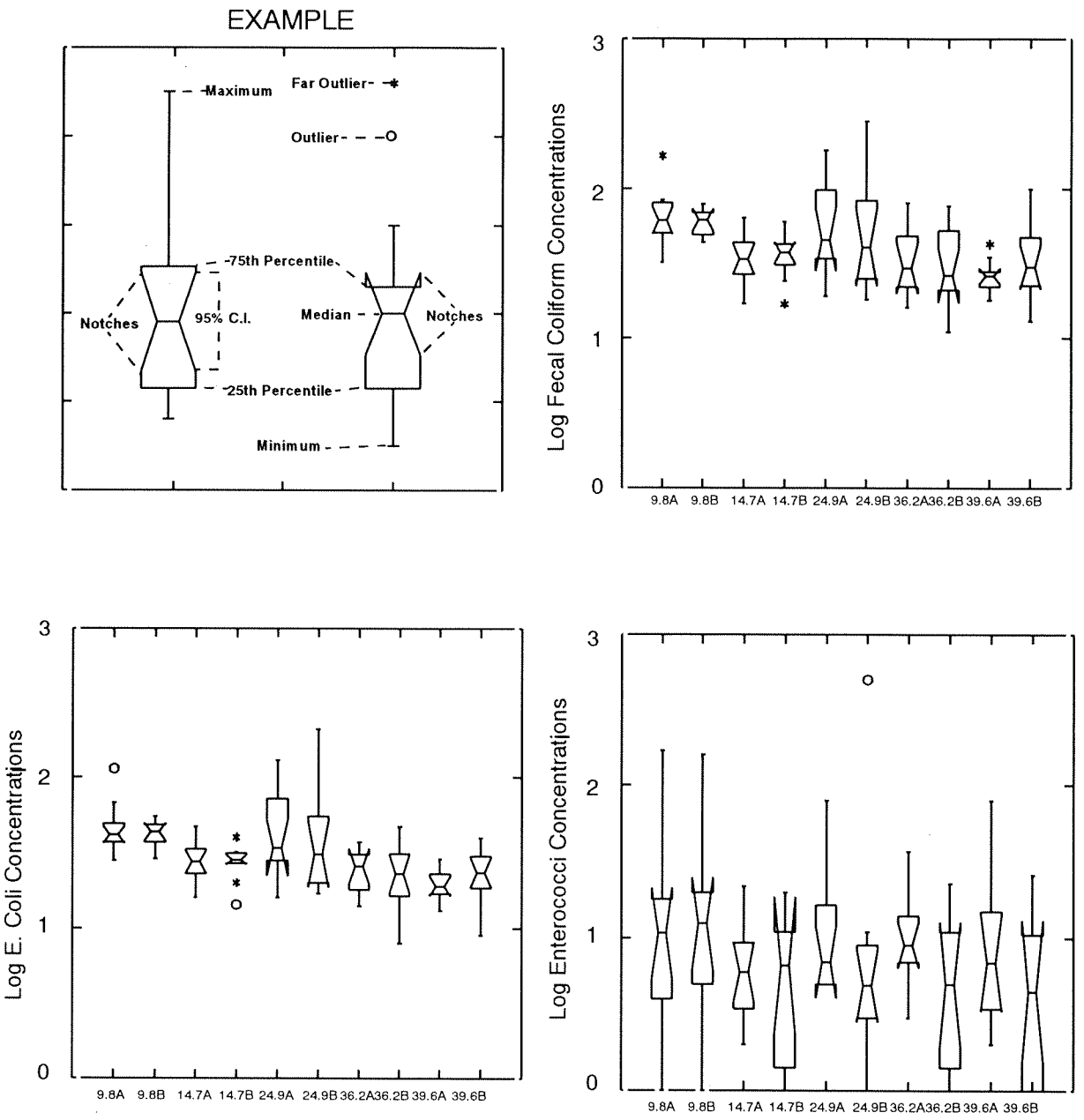

Figure 2. Snoqualmie River site comparisons for log concentrations (cfu/100 mL) of fecal coliform, E. coli, and enterococci.

Both sites at RM 9.8 (at Duvall) had significantly higher concentrations of FC and *E. coli* than all other sites, except RM 24.9 sites (above Carnation). RM 24.9B had the highest single sample concentration for each bacteria type, and RM 36.2B (at Fall City) had the lowest single sample concentration for each bacteria type (Table 1).

Enterococci concentrations did not differ significantly among the sites.

Morning versus Afternoon Comparison

In general, morning bacteria concentrations were higher than afternoon bacteria concentrations at each swimming area. Significantly higher morning bacterial concentrations were measured at RM 14.7 (NE 124th St.) and RM 39.6 (below Snoqualmie WWTP), as illustrated in Figure 3. At RM 14.7, FC and enterococci concentrations were significantly higher in the morning. At RM 39.6, FC and *E. coli* concentrations were significantly higher in the morning. These morning concentrations, although significantly higher than afternoon concentrations, did not lead to any violations of state or federal criteria. Light and temperature are important factors attributing to increases in coliform decay rates (Bowie *et al.*, 1985). This may explain lower afternoon FC and *E. coli* concentrations at the swimming areas. Point and nonpoint sources may also be contributing to this trend.

Study Period Variability

Data for each site were examined for general trends in bacterial level changes over the six-week period. There were no similar trends among the sites, nor were there trends of increase or decrease in bacteria at any one site over the study period.

Comparison to State and Federal Criteria

State Criterion for Fecal Coliform

The Class A criterion for FC consists of the following two parts: 1) the geometric mean shall not exceed 100 coliform forming units (cfu) per 100 mL; and 2) not more than 10% of the samples shall exceed 200 cfu per 100 mL. All sites met the first part of the criterion (Table 1). FC concentrations of 220 cfu/100 mL and 280 cfu/100 mL at RM 24.9B (above Carnation) led to 20% of the samples exceeding 200 cfu/100 mL, an excursion of the second part of the criterion (Figure 4). Nonpoint sources are likely the cause of these high levels. Contamination from known point sources would have been apparent at upstream sites.

Federal Criteria for Enterococci and *E. Coli*

The federal criteria for enterococci and *E. coli* consist of two parts (USEPA, 1986). The first part requires that the geometric mean not exceed either 33 cfu per 100 mL for enterococci or 126 cfu per 100 mL for *E. coli*. This is based on an acceptable swimming associated

Table 1. The geometric mean (GM) and range for each site sampled on the Snoqualmie River, July 20 – August 25, 1992. All values are expressed in cfu/100 mL.

		FECAL COLIFORM		ENTEROCOCCI		E. COLI	
SITE	n =	GM	RANGE	GM	RANGE	GM	RANGE
9.8A	12	64	32 – 160	10	1 – 170	45	28 – 110
9.8B	10	60	44 – 79	10	1 – 160	41	29 – 55
14.7A	12	35	17 – 64	6	1 – 22	28	16 – 47
14.7B	10	35	17 – 60	5	< 1 – 20	27	14 – 40
24.9A	12	54	19 – 180	10	5 – 80	42	16 – 130
24.9B	10	53	18 – 280	7	< 1 – 500	41	17 – 210
36.2A	10	33	16 – 80	9	3 – 37	24	14 – 37
36.2B	12	31	11 – 77	4	< 1 – 23	20	8 – 47
39.6A	12	26	18 – 100	8	2 – 79	20	13 – 40
39.6B	10	33	13 – 53	4	1 – 18	20	9 – 31
CRITERIA		100		33		126	

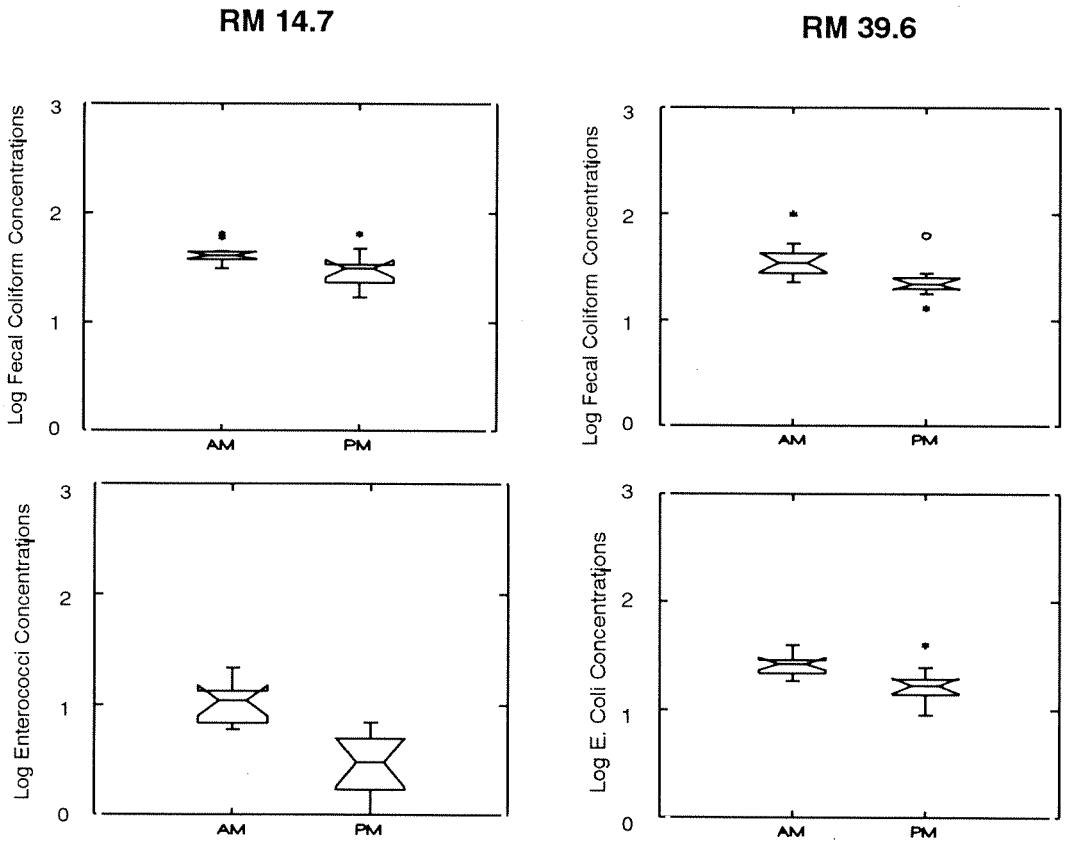

Figure 3. Comparison of morning and afternoon bacteria log concentrations (cfu/100 mL) at RM 14.7 and RM 39.6 on the Snoqualmie River.

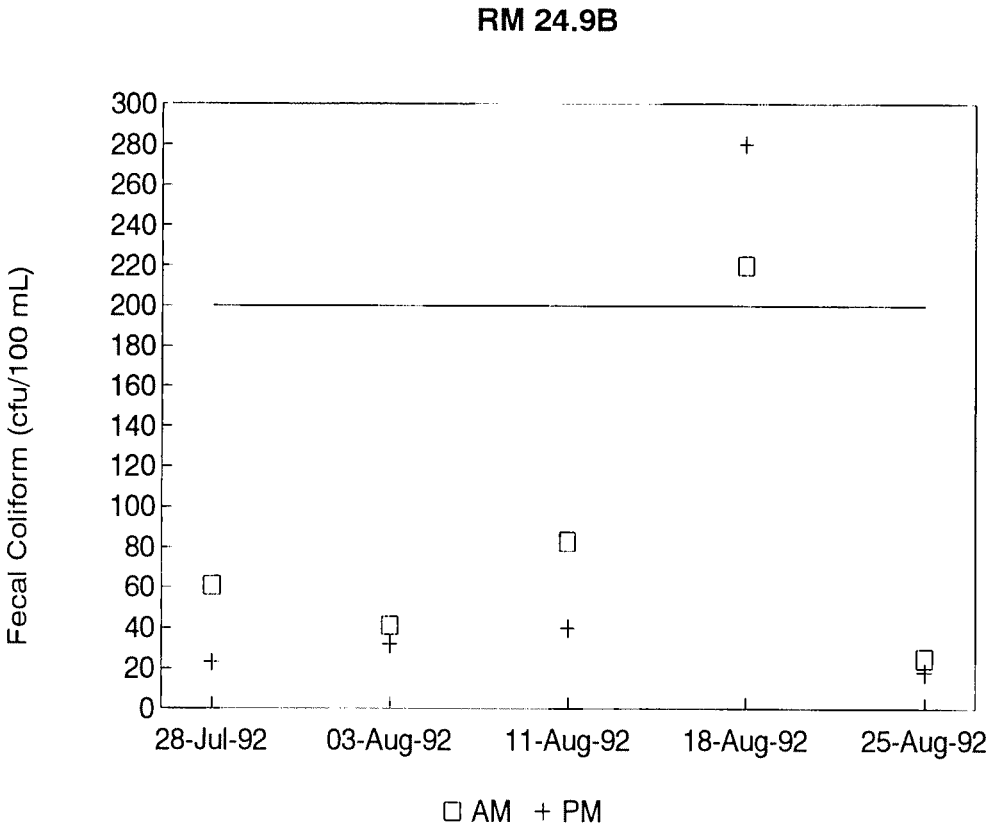

Figure 4. Fecal coliform concentrations at RM 24.9B on the Snoqualmie River. If more than 10% of the samples exceed the line at 200 cfu/100 mL, there is an excursion of the second part of the Class A criterion.

gastroenteritis rate of 8 per 1,000 swimmers. The geometric mean values for all sites met the first part of the federal criteria (Table 1).

The second part of the criteria requires that no sample exceed a one-sided confidence limit (C.L.) for enterococci or *E. coli* based on the following guidance:

75% C.L. for a designated bathing beach[1]
82% C.L. for moderate bathing use
90% C.L. for light bathing use
95% C.L. for infrequent bathing use

Each confidence limit is calculated using the geometric mean from the first part of the criteria and the log standard deviation of each site (Appendix C). The 75% C.L. is the lowest calculated value. This limit is applied to designated bathing beaches because it provides the greatest protection of public health. The 95% C.L. is the highest calculated value and allows higher single sample concentrations at infrequently used swimming areas. It was not possible to determine a use level for each swimming area based on only six mid-week visits.

Appendix D lists the confidence limits for each site. All sample results were either below the 75% C.L. or above the 95% C.L. Three swimming areas had one or more samples that exceeded all four confidence limits for enterococci or *E. coli* (Figure 5). Confidence limits for enterococci were exceeded at RM 9.8 sites (at Duvall) on August 3 and August 25, at RM 24.9 sites (above Carnation) on August 18, and at RM 39.6A (below Snoqualmie WWTP) on August 11. Confidence limits for *E. coli* were exceeded at RM 24.9B on August 18. Due to high enterococci and *E. coli* concentrations at these three swimming areas, a gastroenteritis rate greater than 8 per 1,000 swimmers could be expected (USEPA, 1986).

Nonpoint sources are likely contributing to elevated bacterial concentrations at RM 9.8, RM 24.9, and RM 39.6. Chlorine residual values in discharge monitoring reports from Duvall WWTP, Snoqualmie WWTP, and North Bend WWTP indicated that these point sources were not contributing to elevated bacterial concentrations at these swimming areas.

CONCLUSIONS AND RECOMMENDATIONS

- Two of the swimming areas, RM 14.7 at the NE 124th Street Bridge, and RM 36.2 at Fall City, did not exceed state or federal bacteria criteria. The data from this study suggest that these areas pose a low health risk for swimming related illness.

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[1] Designated bathing beach is defined by the EPA as a swimming area that is frequently lifeguard protected, has provided parking and other public access, and is heavily used by the public (USEPA, 1986).

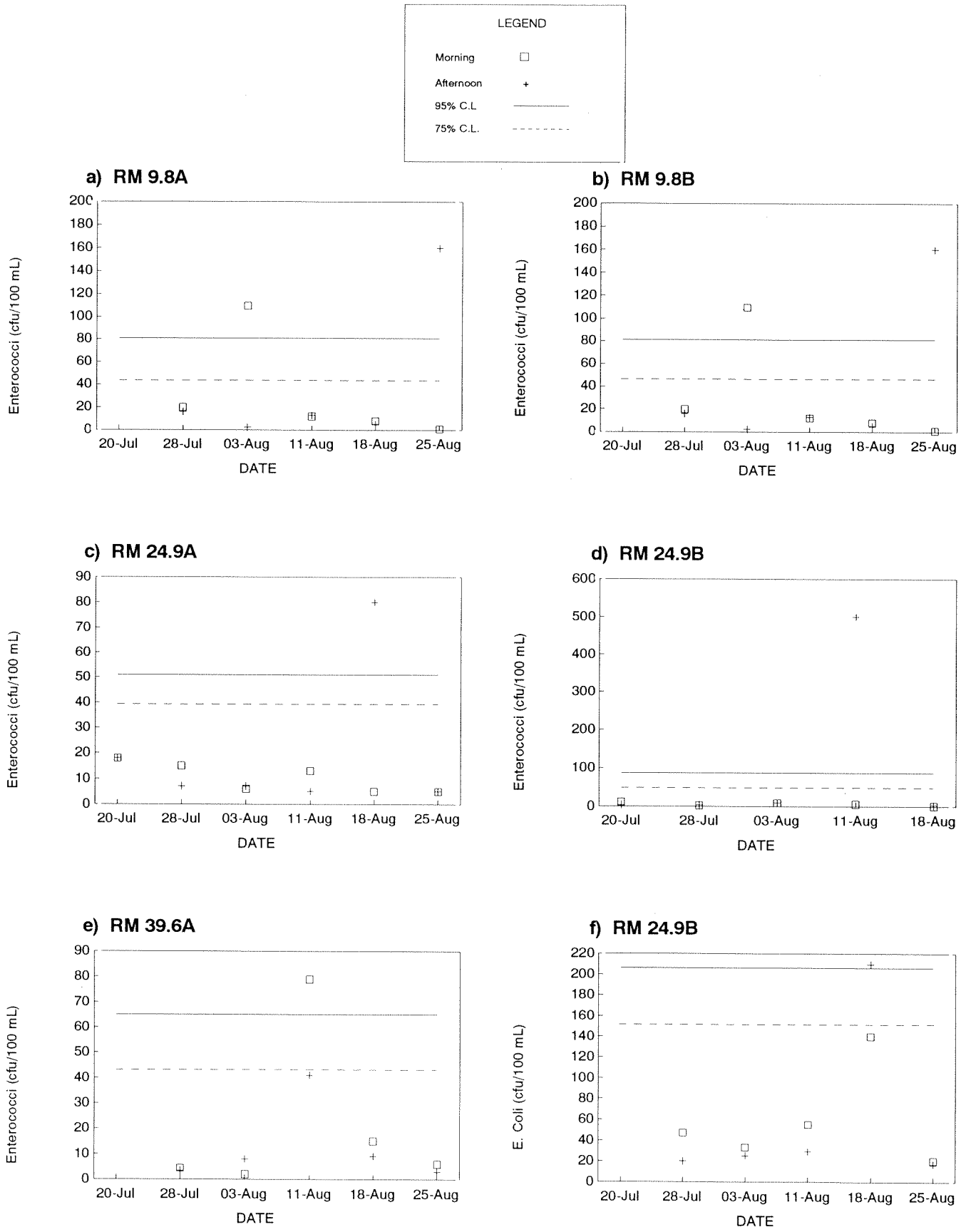

Figure 5. Graphs a) - e) illustrate those sites on the Snoqualmie River with samples exceeding the site specific 95% C.L. for enterococci. Graph f) illustrates the only sample that exceeded the 95% C.L. for E. coli at any site.

- Three of the five swimming areas that we monitored had elevated bacterial levels that may pose public health risks. These areas are prioritized below for further investigation of bacterial sources and implementation of source controls.

RM 9.8 at Duvall

This beach was one of the most popular swimming areas and has been proposed for park development (Richard Haag Associates, 1992). Further investigation into bacterial sources leading to periodic excursions of the federal criteria for enterococci should be a priority before this area becomes a designated swimming beach.

RM 24.9 above Carnation

This swimming area was also very popular. Sources of the bacteria leading to excursions of the state criterion for FC and the federal criteria for enterococci and *E. coli* should be investigated.

RM 39.6 below Snoqualmie WWTP

Although this swimming area was not as popular, swimmers were often observed at locations just upstream. Bacterial problems were not as severe at this area, however, further investigation of sources leading to the single excursion of the federal criteria for enterococci may be warranted.

ACKNOWLEDGEMENTS

We would like to express our appreciation to all the people who helped with this project. Joe Joy (Washington State Department of Ecology) helped with site selection, data analysis, and peer review of the draft report. Dave Hallock (Ecology) and Dave Wright (Ecology, NWRO) also peer reviewed the draft. Bob Cusimano (Ecology) and Rob Plotnikoff (Ecology) assisted with statistical analysis of the data. Will Kendra (Ecology) provided valuable guidance on our initial draft. Keith Seiders (Ecology) and Chad Stüssy (Ecology) provided field assistance. Barbara Tovrea (Ecology) prepared the final document. Thanks also to those people at the Manchester Laboratory who managed and analyzed the samples.

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APPENDICES

Appendix A. Site descriptions, sampling methods, and QA/QC for the Snoqualmie River Bacteria Study, July 20 - August 25, 1992.

Site Descriptions

RM 9.8 at Duvall, is approximately one mile downstream of the Duvall WWTP. Both sites are near the right bank on the same side of the river as the WWTP. Site A is immediately downstream of the beach area; site B is mid-beach. Swimmers were observed on five of the six sampling days.

RM 14.7, at the NE 124th Street bridge, is about five miles upstream of Duvall. Site A is on the left bank and downstream of the bridge. Site B is also on the left bank and upstream of the bridge at the primary beach area. On two occasions there were people fishing at Site B. Swimmers were observed on one occasion at this area.

RM 24.9, approximately one mile upstream of Carnation, is at a Department of Wildlife boat launch. Site B is located directly out from the boat launch near the right bank and site A is 50 feet downstream and closer to the mid-section of the river. People were observed swimming at site B on five of the six sampling days. There is another popular swimming area 500 feet downstream at the confluence of the Tolt River.

RM 36.2, at Fall City, is just downstream of the Raging River confluence, a boat launch, a large campground, and a golf course. Site A is near the left bank, closest to the parking area and most popular with swimmers. Site B is also near the left bank approximately 200 feet upstream, closer to the confluence of Raging River, and usually had fewer swimmers. Swimmers were observed on five of the six sampling days. People were also observed swimming upstream of both sites at the boat launch.

RM 39.6, approximately one mile downstream of the Snoqualmie WWTP, is at a Department of Wildlife boat launch and beach on SE Hatchery Road, downstream of the confluence with Tokul Creek. Site A is near the right bank at the swimming beach. Site B is also near the right bank, approximately 200 feet upstream of the beach. Swimmers were observed on one of the six sampling days. The stretch between the confluence of Tokul Creek and the site contains other popular swimming areas.

Sampling Methods

Sampling was done downstream to upstream to avoid sample contamination. Grab samples were collected 8-12 inches beneath the surface by wading into the river to a depth of approximately two feet. All three bacteria types were analyzed from the same 500 mL glass autoclaved bottle. Samples were stored on ice and shipped within 24 hours to the EPA/Ecology Laboratory in Manchester, Washington. Sample containers, processing, and analysis by the membrane filter technique conformed to procedures described by USEPA (1983), Huntamer (1986), and APHA *et al.* (1989).

QA/QC

In order to assess field variability, randomly selected replicate samples were taken in the morning and afternoon at one of the swimming areas. The replicate sample was taken at the site that appeared to be most popular for swimming. The geometric mean of replicate samples was used in subsequent calculations.

A separate 500 mL sample was collected for each bacteria type in the afternoon at the same swimming area but at the other sampling site. These samples were split at the lab to assess lab variability. These values were not included in data analysis.

The relative percent difference (RPD) was determined for each set of replicates and each set of splits. The RPD is the difference between two values expressed as a percentage of their mean. Figure A-1 illustrates the replicate RPDs and the split RPDs using box plots. For both replicates and splits the RPD was generally below 50% for FC and *E. coli*. These values are acceptable considering the natural patchiness of bacteria. The higher RPD for enterococci is also acceptable due to concentrations close to the detection limit yielding an artificially high RPD (e.g., replicate values of 1 and 3 per 100 mL yield an RPD of 100%).

Values with a 'U' qualifier (the analyte was not detected at or above the reported result) were included in data analysis at the detection limit. It was determined that this would not skew data analysis because the limit was equal to one and far below criteria values.

Sample site locations were changed slightly after the first day of sampling on July 20 to better reflect the stretch of each beach. Data collected on July 20 from relocated sites were not included in data analysis.

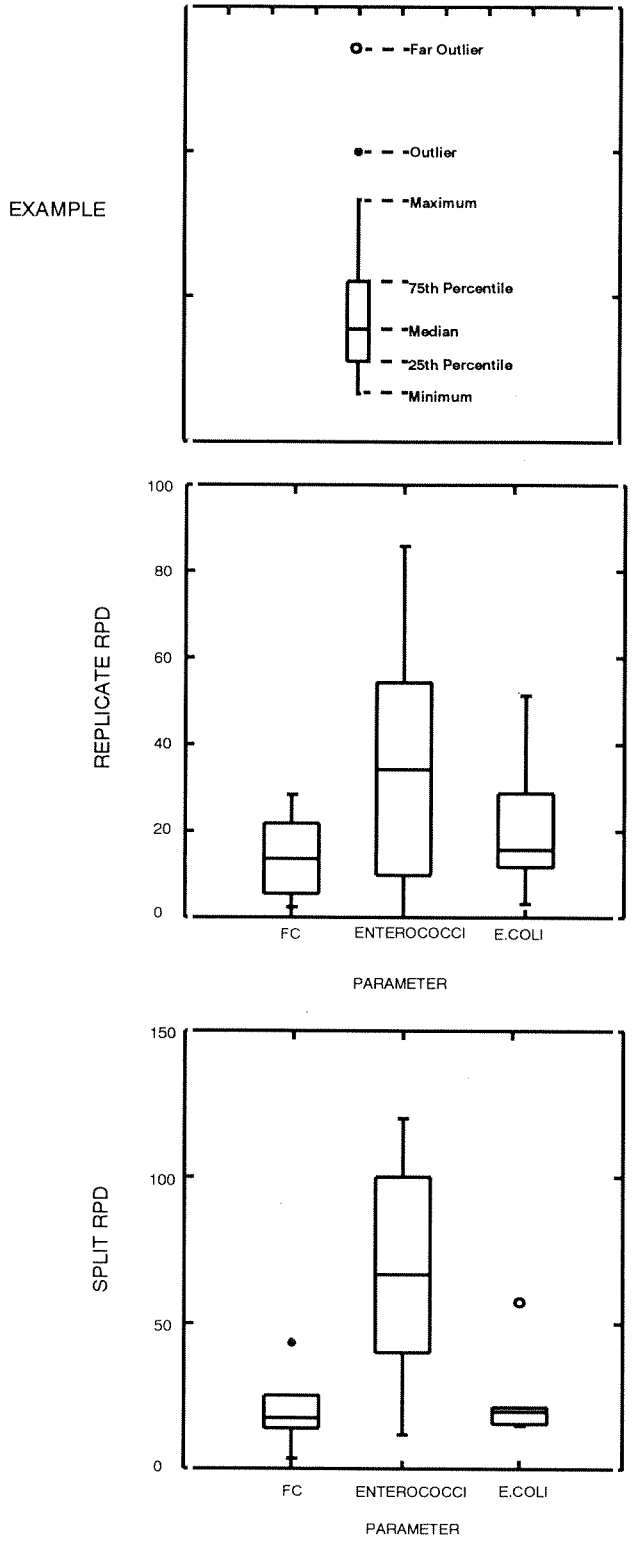

Figure A1. Relative percent difference (RPD) of replicates and splits for each parameter sampled weekly on the Snoqualmie River, July 20 - August 25, 1992.

Appendix B. Snoqualmie River Bacteria Study data, July 20 - August 25, 1992.

Site	Date	Time	Rep/ Split	Lab#	Swimmers	Fecal Coliform (cfu/100 mL)	Enterococci (cfu/100 mL)	E. Coli (cfu/100 mL)
9.8A	20-Jul-92	1005		308091	No	81	11	52
	20-Jul-92	1005	R	308089	No	84	12	88
	20-Jul-92	1320		308101	No	170	8	130
	20-Jul-92	1320	R	308103	No	160	13	100
	20-Jul-92	1320	SP	308102	No	130	9	100
	20-Jul-92	1320	SP	308104	No	160	8	120
	28-Jul-92	1015		318115	No	59	17	43
	28-Jul-92	1315		318127	Yes	48	17	39
	03-Aug-92	1025		328150	No	78	100	45
	03-Aug-92	1305		328138	Yes	52	4	40
	03-Aug-92	1305	SP	328141	Yes	48	1	39
	03-Aug-92	1305	SP	328152	Yes	55	3	48
	11-Aug-92	1015		338166	No	84	19	35
	11-Aug-92	1310		338177	Yes	75	7	51
	18-Aug-92	1005		348190	No	32	4	28
	18-Aug-92	1315		348202	Yes	49	1	32
	25-Aug-92	1005		358214	No	52	3	40
	25-Aug-92	1305		358227	Yes	63	170	47
9.8B	28-Jul-92	1015		318116	No	64	20	48
	28-Jul-92	1315		318128	Yes	60	16	49
	03-Aug-92	1025		328151	No	88	150	47
	03-Aug-92	1025	R	328153	No	71	80	44
	03-Aug-92	1305		328139	Yes	43	2	39
	03-Aug-92	1305	R	328141	Yes	49	3	35
	11-Aug-92	1015		338167	No	72	12	41
	11-Aug-92	1310		338178	Yes	44	13	29
	18-Aug-92	1005		348191	No	67	8	33
	18-Aug-92	1315		348203	Yes	49	5	37
	25-Aug-92	1005		358215	No	57	1	48
	25-Aug-92	1305		358228	Yes	69	160	55
14.7A	20-Jul-92	1025		308087	No	64	8	45
	20-Jul-92	1340		308099	No	64	5	47
	28-Jul-92	1035		318113	No	31	11	25
	28-Jul-92	1335		318125	No	32	6	24
	03-Aug-92	1040		328148	No	45	22	36
	03-Aug-92	1330		328136	No	23	2	22
	11-Aug-92	1030		338164	No	41	14	28
	11-Aug-92	1330		338175	No	31	4	27
	18-Aug-92	1025		348186	No	43	6	31
	18-Aug-92	1340		348198	No	23	3	20
	18-Aug-92	1340	SP	348188	No	28	3	24
	18-Aug-92	1340	SP	348200	No	29	2	28
	25-Aug-92	1025		358211	No	36	6	29
	25-Aug-92	1320		358222	Yes	17	2	16
	25-Aug-92	1320	SP	358213	Yes	20	2	19
	25-Aug-92	1320	SP	358225	Yes	23	1	22

R = Replicate sample
SP = Split sample to check lab variability
S = Spreader (colonies possibly masked by other bacteria).
U = The analyte was not detected at or above the reported result.

Appendix B. Continued.

Site	Date	Time	Rep/ Split	Lab#	Swimmers	Fecal Coliform (cfu/100 mL)	Enterococci (cfu/100 mL)	E. Coli (cfu/100 mL)
14.7B	28-Jul-92	1035		318114	No	43	11	29
	28-Jul-92	1335		318126	No	24	5	20
	03-Aug-92	1040		328149	No	39	13	28
	03-Aug-92	1330		328137	No	31	1	28
	11-Aug-92	1030		338165	No	60	20	40
	11-Aug-92	1330		338176	No	47	7	32
	18-Aug-92	1025		348187	No	39	6	32
	18-Aug-92	1025	R	348189	No	40	9	27
	18-Aug-92	1340		348199	No	35	1	25
	18-Aug-92	1340	R	348201	No	37	1	29
	25-Aug-92	1025		358212	No	35	4	31
	25-Aug-92	1025	R	358213	No	37	10	32
	25-Aug-92	1320		358224	Yes	15	2	12
	25-Aug-92	1320	R	358226	Yes	19	1 U	17
24.9A	20-Jul-92	1055		308085	No	64	18	47
	20-Jul-92	1410		308097	Yes	35	18	28
	28-Jul-92	1105		318111	No	51	15	35
	28-Jul-92	1405		318123	Yes	35	7	31
	03-Aug-92	1110		328146	No	41	6	33
	03-Aug-92	1400		328134	Yes	19	7	16
	11-Aug-92	1100		338161	No	150	13	110
	11-Aug-92	1355		338173	Yes	51	5	35
	18-Aug-92	1050		348184	No	180	5	130
	18-Aug-92	1405		348196	Yes	160	80	120
	25-Aug-92	1045		358209	No	27	5	21
	25-Aug-92	1345		358220	No	33	5	28
24.9B	28-Jul-92	1105		318112	No	61	11	47
	28-Jul-92	1405		318124	Yes	23	4	20
	03-Aug-92	1110		328147	No	41	2	33
	03-Aug-92	1400		328135	Yes	32	4	25
	11-Aug-92	1100		338162	No	83	9	55
	11-Aug-92	1355		338174	Yes	40	9	29
	18-Aug-92	1050		348185	No	220	6	140
	18-Aug-92	1405		348197	Yes	280	500	210
	25-Aug-92	1045		358210	No	25	1 U	20
	25-Aug-92	1345		358221	No	18	3	17
36.2A	28-Jul-92	1125		318109	Yes	40	9	29
	28-Jul-92	1420		318121	Yes	18	7	17
	03-Aug-92	1130		328144	Yes	28	3	23
	03-Aug-92	1415		328132	Yes	22	9	20
	11-Aug-92	1115		338157	Yes	92	14	32
	11-Aug-92	1115	R	338159	Yes	69	14	41
	11-Aug-92	1410		338169	Yes	52	39	29
	11-Aug-92	1410	R	338171	Yes	45	35	33
	18-Aug-92	1110		348182	Yes	72	13	37
	18-Aug-92	1420		348194	Yes	31	7	29
	25-Aug-92	1100		358207	No	22	14	18
	25-Aug-92	1400		358218	Yes	16	4	14

R = Replicate sample

SP = Split sample to check lab variability

S = Spreader (colonies possibly masked by other bacteria).

U = The analyte was not detected at or above the reported result.

Appendix B. Continued.

Site	Date	Time	Rep/ Split	Lab#	Swimmers	Fecal Coliform (cfu/100 mL)	Enterococci (cfu/100 mL)	E. Coli (cfu/100 mL)
36.2B	20-Jul-92	1120		308083	No	72	23	47
	20-Jul-92	1434		308095	No	63	19	39
	28-Jul-92	1125		318110	No	21	4	13
	28-Jul-92	1420		318122	Yes	21	1 U	20
	03-Aug-92	1130		328145	Yes	21	1 U	19
	03-Aug-92	1415		328133	Yes	24 S	5	22
	11-Aug-92	1115		338158	No	77	11	27
	11-Aug-92	1410		338170	Yes	44	2	24
	11-Aug-92	1415	SP	338160	Yes	35	3	17
	11-Aug-92	1415	SP	338172	Yes	45	6	21
	18-Aug-92	1110		348183	Yes	29	11	26
	18-Aug-92	1420		348195	Yes	43	5	36
	25-Aug-92	1100		358208	No	19	5	14
	25-Aug-92	1400		328219	Yes	11	1	8
39.6A	20-Jul-92	1145		308081	Yes	100	26	40
	20-Jul-92	1450		308093	No	63	14	40
	28-Jul-92	1145		318105	No	25	4	16
	28-Jul-92	1145	R	318107	No	31	5	22
	28-Jul-92	1440		318117	No	16	3	14
	28-Jul-92	1440	R	318119	No	20	4	16
	03-Aug-92	1150		328142	No	25	2	23
	03-Aug-92	1440		328130	No	24	8	17
	11-Aug-92	1135		338155	No	43	79	27
	11-Aug-92	1440		338167	No	27	41	19
	18-Aug-92	1125		348180	No	35	15	29
	18-Aug-92	1440		348192	Yes	22	9	19
	25-Aug-92	1120		358205	No	28	6	20
	25-Aug-92	1420		358216	No	18	3	13
39.6B	28-Jul-92	1145		318106	No	32	5	22
	28-Jul-92	1440		318118	No	24	1	20
	28-Jul-92	1440	SP	318108	No	20	4	15
	28-Jul-92	1440	SP	318120	No	31	1	27
	03-Aug-92	1150		328143	No	23	1	22
	03-Aug-92	1440		328131	No	22	8	17
	11-Aug-92	1135		338156	No	53	18	31
	11-Aug-92	1440		338168	No	22	1	10
	18-Aug-92	1125		348181	No	37	1	29
	18-Aug-92	1440		348193	Yes	28	5	25
	25-Aug-92	1120		358206	No	43	2	29
	25-Aug-92	1420		358217	No	13	4	9

R = Replicate sample
SP – Split sample to check lab variability
S = Spreader (colonies possibly masked by other bacteria).
U = The analyte was not detected at or above the reported result.

Appendix C. Calculating confidence limits for the federal criteria for enterococci and *E. coli*.

To understand how confidence limits are calculated, an example of the calculations for RM9.8A for enterococci is provided:

Use the equation x% C.L. = antilog (GM_{log} + $t_{(1-x)}(s_{log})$ / $n^{1/2}$)
Where:

x = The level chosen depending on how heavily the beach is used.
GM = The geometric mean federal criteria for enterococci = 33 cfu/100mL
s = The log standard deviation of RM9.8A sample results = .62
n = The sample size = 12
$t_{(1-x)}$ is the area under the normal probability curve for the t distribution, found in the tables of all standard statistics texts (McClave and Dietrich, 1991)

$t_{.05}$ for a 95% C.L. = 1.796
$t_{.10}$ for a 90% C.L. = 1.363
$t_{.18}$ for a 82% C.L. = 1.03
$t_{.25}$ for a 75% C.L. = .697

Using the above equation and substituting in the values, the confidence limits for RM 9.8 are as follows:

95% C.L. = antilog (log(33) + 1.796 * .62 / $(12)^{1/2}$) = 70
90% C.L. = antilog (log(33) + 1.363 * .62 / $(12)^{1/2}$) = 58
82% C.L. = antilog (log(33) + 1.03 * .62 / $(12)^{1/2}$) = 51
75% C.L. = antilog (log(33) + .697 * .62 / $(12)^{1/2}$) = 44

On August 25, the sample concentration at RM 9.8A was 170 cfu/100 mL. This concentration exceeded even the least restrictive 95% C.L. If there had been a sample result with a concentration of 55 cfu/100 mL, there would have been exceedances of the 75% and 82% C.L.

Appendix D. Confidence limits (cfu/100 mL) for each site on the Snoqualmie River with the number of samples that exceeded the 95% C.L. No samples fell between the 75% and 95% C.L. at any site.

	ENTEROCOCCI CONFIDENCE LIMITS					E. COLI CONFIDENCE LIMITS				
SITE	75%	82%	90%	95%	# OF SAMPLES > 95% C.L.	75%	82%	90%	95%	# OF SAMPLES > 95% C.L.
9.8A	44	51	58	70	2	136	141	146	153	
9.8B	47	55	65	81	2	132	135	138	142	
14.7A	38	41	44	48		134	138	143	148	
14.7B	42	47	53	62		134	138	143	148	
24.9A	39	42	46	51	1	145	155	165	180	
24.9B	48	57	69	87	1	152	167	183	206	1
36.2A	39	42	45	50		136	141	146	153	
36.2B	41	46	51	59		139	146	153	163	
39.6A	43	49	55	65	1	133	137	140	145	
39.6B	42	47	53	62		139	145	152	161	