A Department of Ecology Report

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Lilliwaup Bay Bacterial Source Identification Monitoring

Abstract

This report describes the results of water quality monitoring on Little Lilliwaup Creek and Lilliwaup Creek in 1997-98. In 1997, the Department of Health (DOH) marine sampling stations in Lilliwaup Bay showed an increase in bacteria levels; two of the three stations no longer met the criteria for shellfish harvest. In cooperation with DOH, the Department of Ecology (Ecology) conducted bacterial source identification monitoring on Little Lilliwaup and Lilliwaup creeks. Results showed that Little Lilliwaup Creek met freshwater quality standards for fecal coliform and was not a significant contributor of bacterial loading to the bay except during heavy rainfall. Lilliwaup Creek, a major source of loading to Lilliwaup Bay, did not meet water quality standards at three of five monitoring stations. In the wet season possible sources of bacteria in the upper watershed include land use on private property and wildlife use. Possible dry season sources in the lower Lilliwaup basin warrant further investigation.

Introduction

The DOH Office of Shellfish Programs is charged with classifying all commercial shellfish growing areas in Washington State. As part of this program, DOH conducts ambient water quality monitoring in commercial shellfish growing areas. Recent monitoring results from Lilliwaup Bay on Hood Canal indicate that two of the three marine stations (Figure 1) show an increase in fecal coliform levels. As a result, DOH has closed Lilliwaup Bay for recreational and commercial shellfish harvesting.

The DOH shellfish office is concerned that the two creeks that flow into Lilliwaup Bay may be the source of the higher bacterial counts. The Ecology Environmental Assessment Program worked cooperatively with DOH to conduct water quality monitoring on Lilliwaup and Little Lilliwaup creeks to determine the possible source or sources of fecal coliform. DOH data from Lilliwaup Bay show no seasonal pattern in bacterial levels or increase in bacterial levels due to rainfall events (Melvin, 1997).

Project Area

Lilliwaup Bay is on the western shore of Hood Canal approximately four miles north of the town of Hoodsport. There are two tributaries that enter Lilliwaup Bay: Lilliwaup Creek and Little Lilliwaup Creek. The unincorporated community of Lilliwaup is located along the shores of Lilliwaup Bay and Lilliwaup Creek. Most of the homes are vacation homes used during summer months.

by Debby Sargeant
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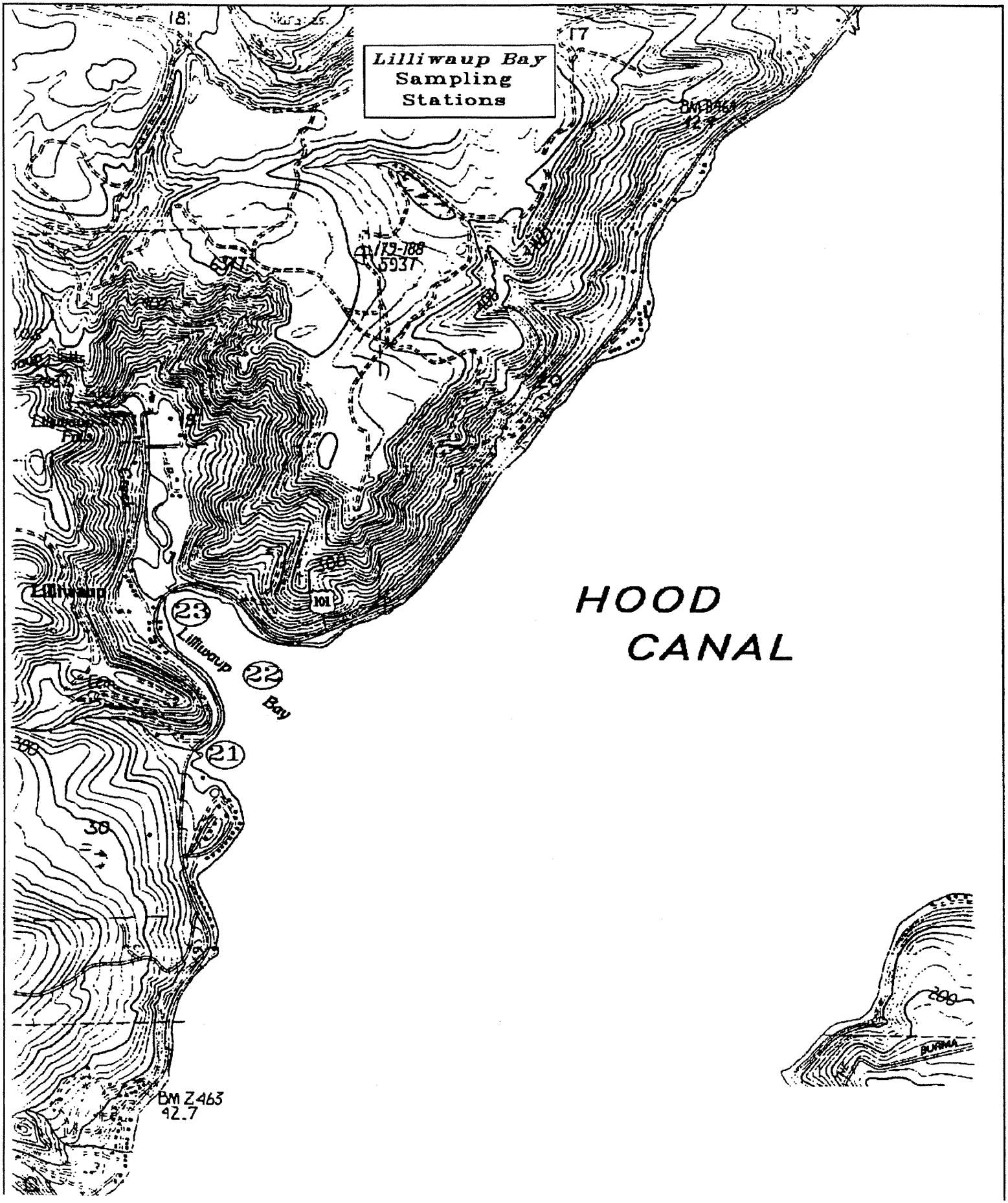


Figure 1. Department of Health Marine Sampling Stations.

On Lilliwaup Creek the nonprofit group *Long Live the Kings* runs a fish hatchery just upstream of the community of Lilliwaup on Lilliwaup Creek. Upland land use is primarily forestry and recreation, with some scattered private property holdings. There is a large wetland in the upper reaches of Lilliwaup Creek that supports a wide variety of wildlife including a migratory herd of elk. A portion of the wetland is privately owned, and a residence is located on the property. Price Lake, an undeveloped lake, drains to Lilliwaup Creek just downstream of the wetland. A Department of Natural Resources (DNR) campground is located a mile upstream of the wetland.

There is sparse development on Little Lilliwaup Creek. Land use includes two residential dwellings near the sampling area and possible wildlife use. One home is directly adjacent to the creek; the other is approximately 500-600 feet from the creek. Land use in the uplands is primarily forestry.

Little Lilliwaup and Lilliwaup creeks are Class AA waterbodies, according to Washington Administrative Code Chapter 173-201A. A water quality classification is not specified for Little Lilliwaup and Lilliwaup creeks. In accordance with the water quality standards all unclassified surface waters that are tributaries to Class AA waters are classified as Class AA. Hood Canal is classified as Class AA marine water.

For Class AA, freshwater fecal coliform standards are as follows: fecal coliform organism levels shall both not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceed 100 colonies/100 mL.

Project Objectives

1. To determine the freshwater source or sources of fecal coliform loading to the shellfish beds.
2. To determine fecal coliform loading to Lilliwaup Bay.

Methods

All sampling was conducted in accordance with the Quality Assurance Project Plan (Sargeant, 1997). Sampling was conducted September 1997 through September 1998. The approach used for meeting the first objective was to sample upstream and downstream of possible bacterial sources in the wet and dry season. Sample sites are shown in Figure 2. Site descriptions and the land uses bracketed by sampling sites are described below:

Sites

Lilliwaup Creek

Two sites were used to represent the mouth of Lilliwaup Creek. During the winter months, sample sites at the mouth of Lilliwaup Creek varied because of tidal influence. Normally, sampling occurred at the mouth of Lilliwaup Creek just upstream of the Highway 101 bridge (LiCM 0.0). However, on November 17, December 15, 1997, and January 28, 1998, sampling occurred a quarter mile upstream at creek mile (CM) 0.25 due to tidal inundation at the mouth sites.

LiCM 0.0: This site is at the mouth of Lilliwaup Creek at the Highway 101 bridge. There are two channels at this site, the right and left bank channels. The left bank channel has the majority of the flow; flow in the channel near the right bank is very slow.

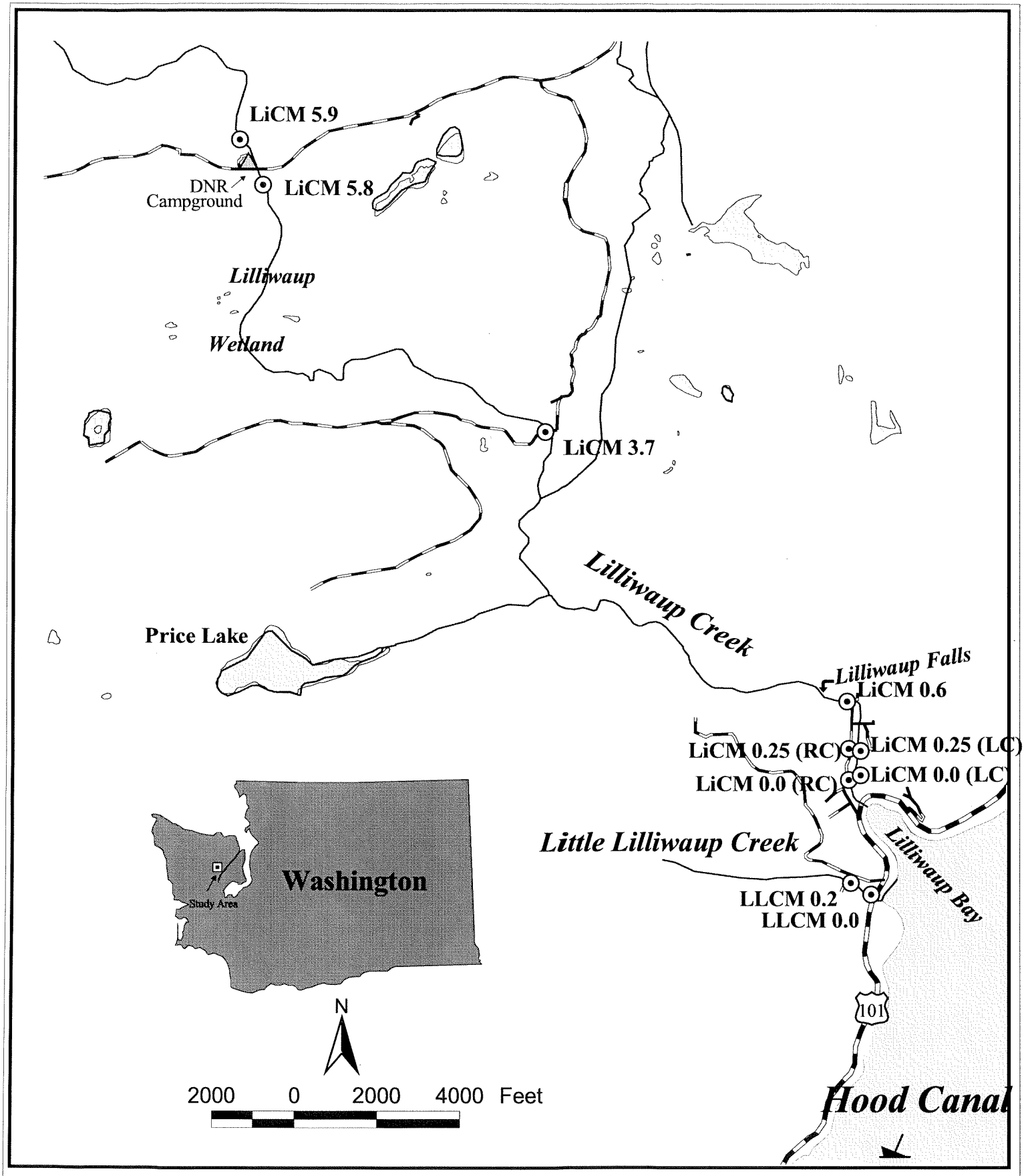


Figure 2. Sampling Stations on Little Lilliwaup and Lilliwaup Creeks.

LiCM 0.25: This site is 0.25 miles upstream of LiCM 0.0. There are two channels at this site, the right and left bank channels. The right bank channel is the main channel with most of the flow; the left bank channel has lower slower flows.

Land use above the mouth (LiCM 0.0) on the right bank includes residential and vacation homes that use on-site sewage treatment systems (a road separates the homes from the shoreline). A flock of 10-15 waterfowl were observed during most sample events.

Upstream of LiCM 0.25 are a few homes on both sides of the river, and a small fish hatchery run by *Long Live the Kings* on the left bank of the river.

LiCM 0.6: This site is just downstream of Lilliwaup Falls, above all residential development in the community of Lilliwaup. Land use upstream is primarily forestry and recreation.

LiCM 3.7 (Dry season only): This site is downstream from a large wetland, Lilliwaup Swamp, and upstream of the outlet from Price Lake. Land use upstream includes forestry, recreation, and wildlife, with some sparse residential use.

LiCM 5.8 (Dry season only): This site is just downstream from the DNR Lilliwaup Creek Campground. Land use upstream includes forestry and recreational camping. The campground has a primitive toilet facility.

LiCM 5.9 (Dry season only): This site is just upstream from the DNR Lilliwaup Creek Campground. Upstream land use is primarily forestry and recreation.

Little Lilliwaup Creek

LLCM 0.0: This site is just upstream of the Highway 101 bridge. Land use upstream includes two residential dwellings that use on-site sewage treatment systems. Both homes are located on the left bank: one home is located on the creek, the other is located well away from the creek.

LLCM 0.2: This site is just upstream of a small bridge that crosses the creek. Upland land use is primarily forestry.

Sample Timing

When possible, sampling was conducted at the same time as DOH marine sampling of Lilliwaup Bay. Seven wet season and three dry season sample events were conducted. The wet season sample events were conducted on September 16 and 18, October 15, November 17, and December 15, 1997, as well as January 28, and February 17, 1998. Wet season sampling was conducted on Lilliwaup Creek at LiCM 0.0 or LiCM 0.25, and LiCM 0.6, and at Little Lilliwaup Creek at LLCM 0.0 and LLCM 0.2.

Three dry season sample events were conducted at all sites on July 6, August 18, and September 8, 1998. Monitoring was expanded in Lilliwaup Creek to include three sites above Lilliwaup Falls. Two of the summer sample events occurred after high use weekends at the campground, July 4 and Labor Day. On August 8, 1998, fecal coliform samples for station LiCM 5.9 and field replicate samples were not run by the laboratory due to confusion regarding sample size.

Field and Laboratory Measurements

Laboratory samples for fecal coliform were collected at all sites. The DOH laboratory in Seattle analyzed all samples except those taken on September 16, 1997, July 6, August 18, and September 8, 1998. These samples were analyzed at the Manchester Environmental Laboratory (MEL). All fecal coliform samples were analyzed using the MPN method (A-1 medium), Standard Method 9221E (APHA, 1992). Immediately following collection, samples were placed in the dark, on ice. Samples were delivered to DOH on the day of sampling for transport to the DOH laboratory in Seattle, or to MEL the following day after sample collection.

Field measurements for temperature, pH, conductivity and salinity were made during the surveys. Streamflow discharge measurements were obtained when possible. Flow measurements were discontinued from November 1997 through February 1998 at Lilliwaup Falls due to concern about damaging the salmon redds. Flow measurements were not obtained at the mouth of Lilliwaup Creek on November 17 and December 15, 1997 because the flow meter malfunctioned. Flows were estimated by correlating to flows at either the mouth of Little Lilliwaup or another station on Lilliwaup Creek.

Data Quality

To estimate the precision of field sampling, the percent relative standard deviation (%RSD) was calculated for each field replicate pair; results are shown in Table 1. Values less than the detection limit were assumed to be the detection limit. The target RSD was 50%. Field data quality was good. The total average %RSD was 24%. The MEL %RSD was 32%, and the DOH laboratory 17%. Replicates run at MEL are shown in italics in Table 1.

The target %RSD was not met on January 28 (LiCM 0.6), July 6, (LiCM 5.9), and September 8, 1998 (LiCM 5.9). These data were used with caution.

Table 1. Percent Relative Standard Deviation for Fecal Coliform Field Replicates.

Date	Station	Sample (MPN\100mL)	Replicate (MPN\100mL)	%RSD
9/16/97	*LLCM 0.0*	*110*	*70*	*32*
9/18/97	LLCM 0.2	4.5	4.5	0
9/18/97	LiCM 0.6	350	240	26
10/15/97	LiCM 0.0 (LC)	7.8	7.8	0
10/15/97	LLCM 0.0	2.0	< 1.8	7
11/17/97	LLCM 0.0	< 1.8	< 1.8	0
12/15/97	LiCM 0.25 (RC)	22	33	28
1/28/98	LiCM 0.6	46	14	76
2/17/98	LLCM 0.2	< 1.8	< 1.8	0
7/6/98	*LiCM 5.9*	*4.5*	*13*	*69*
7/6/98	*LiCM 0.6*	*23*	*23*	*0*
9/8/98	*LiCM 5.9*	*2.0*	*7.8*	*84*
9/8/98	*LiCM 0.6*	*7.8*	*9.3*	*12*
9/8/98	*LiCM 0.6*	*170*	*220*	*18*
9/8/98	*LLCM 0.2*	*1.8*	*2.0*	*7*

Italics - replicates analyzed by Manchester Environmental Laboratory.

All field meters used in the survey were calibrated and used in accordance with their manuals.

Data Analysis

Sample values were compared to the Class AA fresh water quality standard. Data collected from the mouth stations were compared to freshwater standards due to the sample timing, which was at low tide. Low salinity, less than 10 parts per thousand, is the key factor for determining if marine or freshwater standards apply. Loading rates were calculated for each station where flow discharge measurements were obtained or estimated.

For load calculations, statistical analysis, and graphs field replicate values were averaged, and data from the two channels at the mouth of Lilliwaup Creek were averaged using a flow- weighted average calculation. Error bars describe the combined possible measurement error for flow discharge and fecal coliform concentration. Error was calculated using a first order error equation (Reckhow and Chapra, 1983).

To compare watershed moisture conditions, the Antecedent Precipitation Index (API) was calculated for each sample event (Linsley et al., 1975). The API was calculated using precipitation data for the 14 days preceding the first day of sampling using an Io of 0, and a k of 0.9. Precipitation for the sample day and preceding 24, 48, 72-hour rainfall (as of 12:00 a.m.), and the API for each sampling day is shown in Table 2. Rainfall information was obtained from a NOAA gauging station at the Cushman Powerhouse on Hood Canal.

Table 2. Previous Rainfall and API for Lilliwaup Sample Trips.

Sample date	Precipitation day of sampling	Preceding 24 hour rainfall in inches	Preceding 48 hour rainfall in inches	Preceding 72 hour rainfall in inches	Antecedent precipitation index in inches
9/16/97	4.02	0.37	1.64	2.27	5.86
9/18/97	0.00	1.41	5.43	5.80	6.02
10/15/97	0.00	0.10	0.25	0.26	3.29
11/17/97	0.53	1.16	1.16	1.16	1.92
12/15/97	4.30	0.35	0.37	0.50	5.14
1/28/98	0.20	0.22	0.34	1.22	7.37
2/17/98	0.80	0.19	0.33	0.51	4.14
7/6/98	0.00	0.00	0.01	0.11	0.13
8/18/98	0.00	0.10	0.10	0.12	0.12
9/8/98	0.00	0.00	0.00	0.00	0.00

For Little Lilliwaup Creek and Lilliwaup Creek, regression analyses were done comparing fecal coliform concentration and loads to rainfall the day of sampling, the previous 24, 48, and 72-hour rainfall, and a 14-day API. Comparisons were made for the both sites on Little Lilliwaup Creek and the station LiCM 0.6 and the mouth stations on Lilliwaup Creek because these stations had the most complete data sets.

In Lilliwaup Creek, data analysis showed a different pattern in the summer versus the winter. Therefore the data was stratified by season (wet and dry) using the API. A 14-day API of greater than 1.00 determined a wet season event. In Little Lilliwaup Creek, no seasonal pattern was apparent, and the data were not stratified.

The fecal coliform mean concentration and load for each site was calculated, by season. The result was compared for each upstream/downstream pair of sites. To determine if fecal coliform loading rates were significantly different, comparisons were done by season of upstream and downstream stations using a paired t-test with a statistical significance level of 0.05 (Zar, 1984). Relative fecal coliform loading contributions to Lilliwaup Bay from Lilliwaup Creek were compared to Little Lilliwaup Creek.

Results and Discussion

Lilliwaup Creek

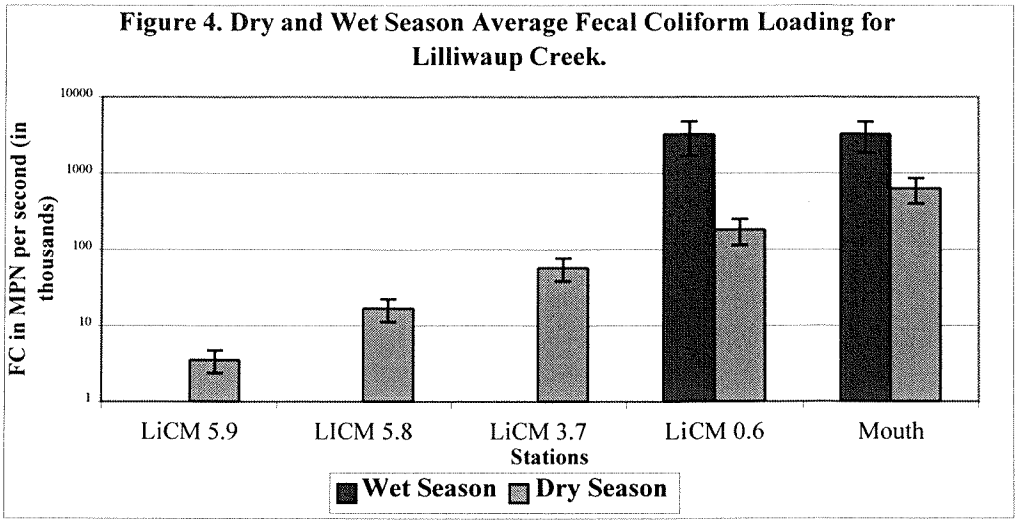
Field and laboratory results for Lilliwaup Creek are shown in Appendix A. Figure 3 in Appendix B compares fecal coliform loading between LiCM 0.6 and the mouth stations. Statistical analysis showed no statistically significant difference in fecal coliform loading or concentration between any of the stations during the wet or dry season.

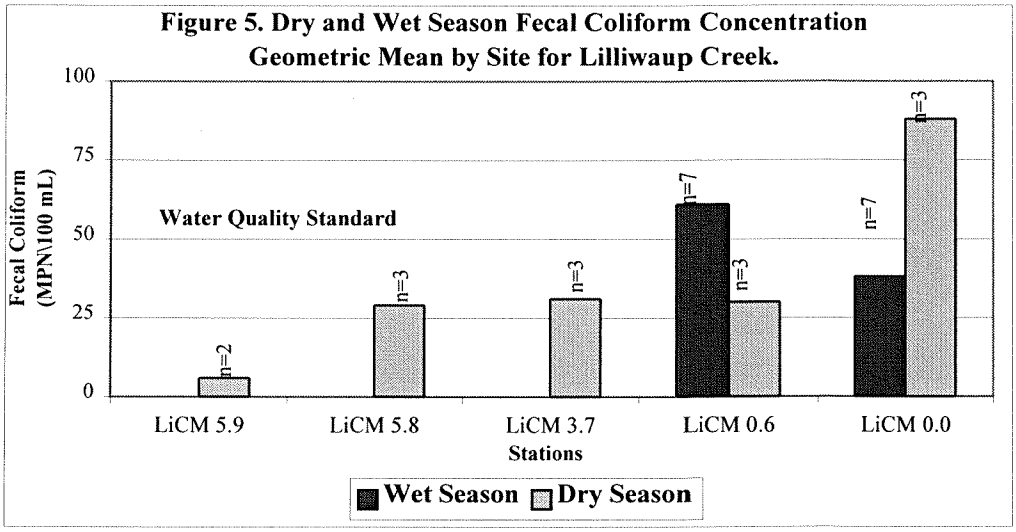
Comparisons of fecal coliform results to standards are shown in Table 3. Station LiCM 5.9 and 5.8 were the only sites to meet both parts of the fecal coliform standard. Temperature and pH met water quality standards at all sites.

Table 3. Fecal Coliform Results for Lilliwaup Creek.

Site	Geometric mean (GM) below #50/100 mL?	10% or less of all samples for calculating GM exceed #100/100 mL?
WET SEASON		
LiCM 0.6	NO (GM=61)	NO, 3 of 7 samples exceeded 100
LiCM (mouth)	YES (GM=38)	NO, 2 of 7 samples exceeded 100
DRY SEASON		
LiCM 5.9	YES (GM=7)	YES
LiCM 5.8	YES (GM=29)	YES
LiCM 3.7	YES (GM=31)	NO, 1 of 3 samples exceeded 100
LiCM 0.6	YES (GM=30)	NO, 1 of 3 samples exceeded 100
LiCM (mouth)	NO (GM=88)	NO, 2 of 3 samples exceeded 100

Figure 4 presents the 1997-98 average bacterial loading rate for each site on Lilliwaup Creek, and Figure 5 presents the geometric mean concentration for each site, by season.



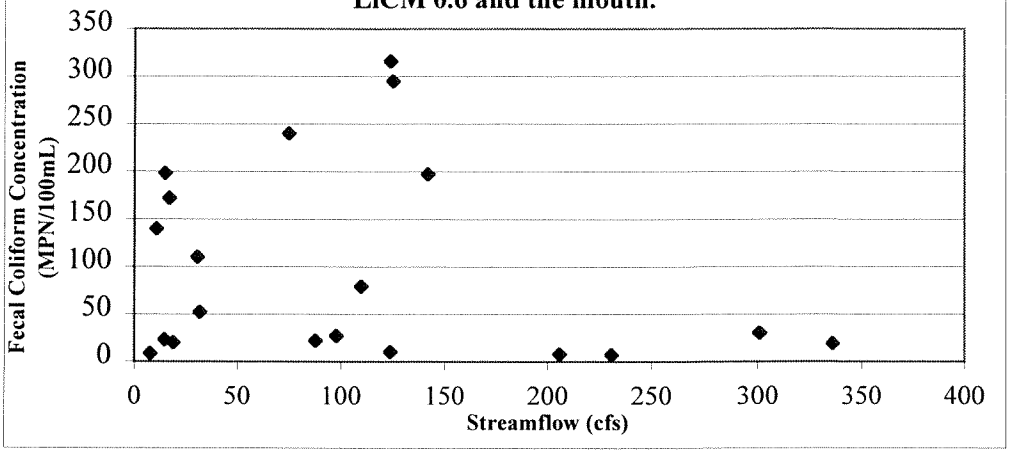


The graphs show a dry season increase in loading upstream to downstream, with the greatest increases seen between LiCM 5.9 and 5.8, and LiCM 0.6 and LiCM 0.0. The loading and geometric mean concentration at LiCM 5.9 appears to be lower than the other sites because results for only two dates, July 6 and September 8, 1998, were available for analysis at LiCM 5.9. For the upstream Lilliwaup stations the highest fecal coliform values were found on August 18th. It is interesting to note the highest bacterial concentrations were seen on August 18, 1998, downstream of the campground (a Tuesday) and not after one of the high use weekends at the campground.

In examining the relationship between flow and fecal coliform concentration, higher concentrations occur at low to mid-level flows, with relatively low concentrations at higher flows (Figure 6). This indicates that the most significant sources are introduced to the creek by rainfall and the runoff process. The relatively high concentrations at low flows indicate that there are also continuous

sources independent of rainfall. At the highest flows, it appears that the sources have been exhausted by previous runoff, or the concentrations are less due to dilution.

Figure 6. Lilliwaup Creek Streamflow vs FC concentration at LiCM 0.6 and the mouth.



To examine the relationship between bacteria results and rainfall and API, regressions were performed using bacterial data at LiCM 0.6 and the mouth for all data (n=10) and for the wet season data (n=7). The stronger the relationship, the higher the coefficient of determination (r^2), with r^2 ranging from 0 to 1. Fecal coliform concentrations were regressed against sampling day rainfall, 24, 48, and 72 hour preceding rainfall, and API. Results are described in Table 4.

Table 4. Coefficients of determination (r^2) for Lilliwaup fecal coliform concentration and loads regressed against sampling day rainfall, previous 24, 28, 72-hour rainfall, and API.

Fecal Coliform Concentration\Load	Rainfall day of Sampling	Previous 24-hour rainfall	Previous 48-hour rainfall	Previous 72-hour rainfall	API
Lilliwaup mouth (all data)					
Concentration	0.02	0.29	0.16	0.12	0.10
Load	0.08	0.87	0.87	0.85	0.15
Lilliwaup mouth (wet season)					
Concentration	0.00	0.85	0.43	0.39	0.03
Load	0.21	0.91	0.88	0.88	0.15
LiCM 0.6 (all data)					
Concentration	0.00	0.48	0.37	0.34	0.02
Load	0.07	0.82	0.81	0.77	0.15
LiCM 0.6 (wet season)					
Concentration	0.04	0.58	0.44	0.39	0.03
Load	0.29	0.78	0.78	0.72	0.00

The strongest relationships were seen at both sites with wet season fecal coliform concentrations and previous 24-hour rainfall. This difference in response for the downstream station when dry season data is included in the regression, points to other pollutant loading mechanisms occurring during the dry season just upstream from the mouth.

Little Lilliwaup Creek

Field and laboratory results for Little Lilliwaup Creek are shown in Appendix C. Both the downstream and upstream station met freshwater fecal coliform standards. Figure 7 presents the 1997-98 average bacterial loading rate for each site on Little Lilliwaup Creek, and Figure 8 presents the geometric mean concentration for each site, by season. When sampling occurred during intense rainfall (> 4.00" the day of sampling) fecal coliform concentrations and loading at the downstream station were the highest.

Temperature and pH met water quality standards at all sites.

Figure 7. Dry and Wet Season Average Fecal Coliform Loading for Little Lilliwaup Creek.

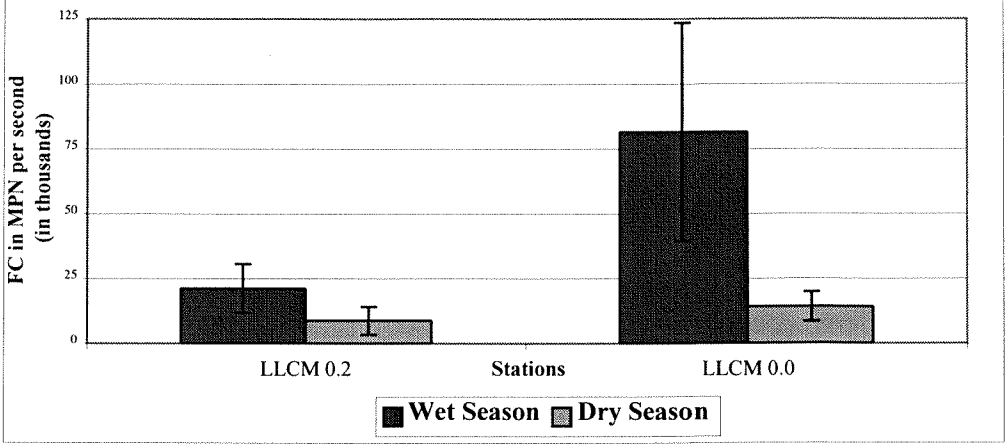
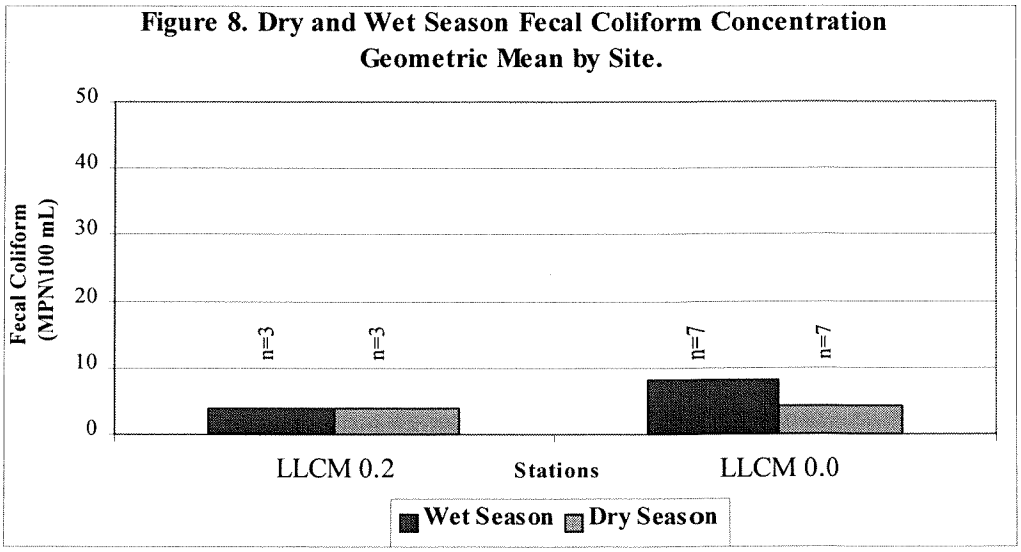


Figure 8. Dry and Wet Season Fecal Coliform Concentration Geometric Mean by Site.



A paired t-test showed no statistically significant difference between upstream and downstream bacterial loading rates. Fecal coliform concentrations at the upstream station had a geometric mean of 3.2; the downstream station was 7.8 cfu/100 mL.

Regressions were done using Little Lilliwaup Creek fecal coliform concentrations and rainfall the day of sampling, 24, 48, and 72- hour preceding rainfall, and API. Ten pairs served as the basis for

correlation. The strongest correlation was between downstream fecal coliform concentrations and rainfall the day of sampling (Table 5). This indicates a rapid response to rainfall in the Little Lilliwaup Creek basin.

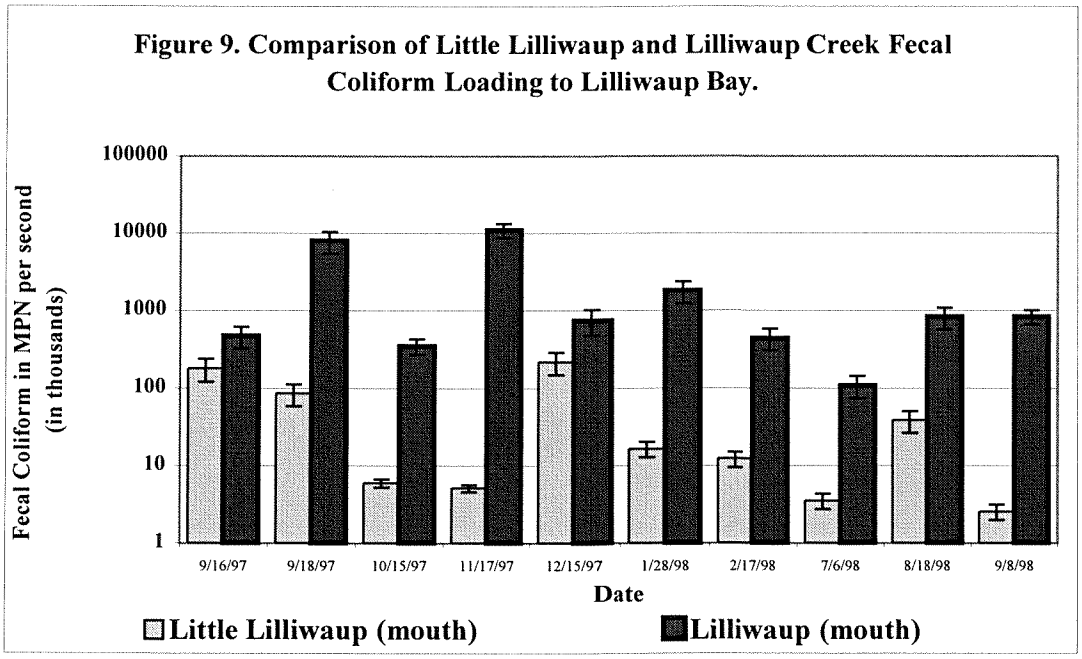
Table 5. Coefficients of determination (r^2) for Little Lilliwaup fecal coliform concentrations regressed against sampling day rainfall, previous 24, 28, 72-hour rainfall, and API.

Fecal coliform concentration	Rainfall day of Sampling	Previous 24-hour rainfall	Previous 48-hour rainfall	Previous 72-hour rainfall	API
LL 0.0 (all data)					
Concentration	0.53	0.04	0.14	0.15	0.12
Load	0.89	0.03	0.07	0.09	0.25
LL 0.2 (all data)					
Concentration	0.01	0.01	0.02	0.01	0.00
Load	0.03	0.05	0.00	0.00	0.05

Loading to Lilliwaup Bay

Figure 9 presents fecal coliform loading rates for the mouth of Lilliwaup Creek and Little Lilliwaup Creek. Loading from Lilliwaup Creek was much greater than Little Lilliwaup Creek for 9 of 10 sample events. Greater loading from Little Lilliwaup Creek occurred during intense rainfall.

Figure 9. Comparison of Little Lilliwaup and Lilliwaup Creek Fecal Coliform Loading to Lilliwaup Bay.



Regressions were done using DOH August 1994 through May 1998 marine data to determine if there was a relationship between fecal coliform and salinity. The three DOH stations were examined (stations 21-23); 30 pairs served as the basis for correlation. No relationship was found between bacteria and salinity for any station.

Freshwater sampling and DOH marine sampling occurred on the same day during five wet season sample events: September 18, October 15, November 17, and December 15, 1997, and February 17, 1998. Regressions were performed to examine the relationship between bacterial concentrations at the mouth of Lilliwaup and Little Lilliwaup Creeks, and the three DOH stations (stations 21-23).

Results show a strong correlation between bacteria levels at the mouth of Lilliwaup Creek and DOH marine station 23, with a correlation coefficient of 0.73.

Conclusions

Lilliwaup Creek

- During the wet season there is a strong positive relationship between 1) 24-hour previous rainfall and 2) fecal coliform loading and concentration.

- Lilliwaup Creek contributes far more fecal coliform loading to Lilliwaup Bay than does Little Lilliwaup Creek.

- There is a strong correlation between high fecal coliform concentrations at the mouth of Lilliwaup Creek and higher concnetrations at DOH marine station 23.

- During the winter season the major source of fecal coliform on Lilliwaup Creek appears to be upstream of Lilliwaup Falls. Possible sources include on-site systems on private property or wildlife.

- During the dry season an increase in fecal coliform loading from upstream to downstream was observed. Increasing bacterial levels were seen below the DNR campground, but the water quality standards were met and the increase may be a sampling artifact. A pattern of higher bacterial levels was seen between LiCM 0.6 and 0.0, but it was not statistically significant. These higher levels could be due to waterfowl or failing on-site systems in the Lilliwaup area.

Little Lilliwaup Creek

- Little Lilliwaup Creek is not a significant bacterial loading source to Lilliwaup Bay. There may be a minor source of fecal coliform between the upstream and downstream stations on Little Lilliwaup Creek.

Recommendations

- The Lilliwaup Bay shellfish areas that do not meet DOH criteria should be closed to commercial and recreational shellfish harvest due to bacterial contamination from Lilliwaup Creek.

- Investigate a provisional opening of shellfish beds during periods of little or no previous rainfall during the wet season.

- Investigate possible on-site sewage treatment sources in the Lilliwaup area.

- Investigate land ownership and practices in the upper watershed, including the function and siting of on-site sewage treatment systems.

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Appendix A
1997-98 Lilliwaup Creek Field and Laboratory Data
(paired values are field replicates)

Site Location	Site Description	Date	Time	Temperature °C	pH	Conductivity umho/cm	Salinity ppt	Fecal Coliform MPN\100mL			Discharge cfs/sec		FC-Load #\sec
LiCM 5.9	Upstream of DNR Campground	7/6/98	12:00	11.5	&	69	n\a		4.5	13		2	5.3E+03
LiCM 5.9	Upstream of DNR Campground	8/18/98	11:20	11.0	7.6	62	n\a					2	
LiCM 5.9	Upstream of DNR Campground	9/8/98	14:50	11.9	7.8	70	n\a		2.0	7.8		2	2.2E+03
LiCM 5.8	Downstream of DNR Campground	7/6/98	12:30	12.0	&	68	n\a		23			2	1.1E+04
LiCM 5.8	Downstream of DNR Campground	8/18/98	11:45	11.2	7.5	60	n\a	J	79			2	3.5E+04
LiCM 5.8	Downstream of DNR Campground	9/8/98	14:30	12.3	7.9	66	n\a		14			1	5.4E+03
LiCM 3.7	Downstream of Lilliwaup Wetland	7/6/98	13:30	16.0	&	104	n\a		13			5	1.9E+04
LiCM 3.7	Downstream of Lilliwaup Wetland	8/18/98	12:15	13.8	7.4	62	n\a	J	170			3	1.5E+05
LiCM 3.7	Downstream of Lilliwaup Wetland	9/8/98	15:30	15.2	8.0	67	n\a		13			1	4.1E+03
LiCM 0.6	Downstream of Lilliwaup falls	9/16/97	11:00	11.5	7.6	83	n\a		110			31	9.6E+05
LiCM 0.6	Downstream of Lilliwaup falls	9/18/97	13:50	12.5	7.6	69	n\a		350	240		125	1.1E+07
LiCM 0.6	Downstream of Lilliwaup falls	10/15/97	13:00	10.4	7.6	63	n\a		79			110	2.5E+06
LiCM 0.6	Downstream of Lilliwaup falls	11/17/97	11:18	7.4	7.5	65	n\a		240		E	75	5.1E+06
LiCM 0.6	Downstream of Lilliwaup falls	12/15/97	13:00	5.5	7.8	63	n\a		22		E	88	5.5E+05
LiCM 0.6	Downstream of Lilliwaup falls	1/28/98	10:30	6.7	7.5	64	n\a		46	14	e	301	2.6E+06
LiCM 0.6	Downstream of Lilliwaup falls	2/17/98	13:50	6.8	7.9	55	n\a		7.8		e	206	4.6E+05
LiCM 0.6	Downstream of Lilliwaup falls	7/6/98	9:00	14.5	7.0	73	n\a		23	23		15	9.7E+04
LiCM 0.6	Downstream of Lilliwaup falls	8/18/98	9:50	11.8	8.2	113	n\a	J	140			11	4.3E+05
LiCM 0.6	Downstream of Lilliwaup falls	9/8/98	12:00	12.0	8.0	73	n\a		7.8	9.3		8	1.9E+04
LiCM 0.25 (LC)	Lilliwaup Ck left channel	10/15/97	13:20						13			&	
LiCM 0.25 (LC)	Lilliwaup Ck left channel	11/17/97	12:35	8.8			1		130			&	
LiCM 0.25 (LC)	Lilliwaup Ck left channel	12/15/97	12:00	7.2	7.1	590	3		33			3	2.5E+04
LiCM 0.25 (LC)	Lilliwaup Ck left channel	1/28/98	11:05	7.0	7.5	200	0		33			49	4.6E+05
LiCM 0.25 (RC)	Lilliwaup Ck right channel	11/17/97	12:30	7.8	7.4	80	0		350			&	
LiCM 0.25 (RC)	Lilliwaup Ck right channel	12/15/97	11:55	5.7	7.8	99	0		22	33	E	95	1.5E+05
LiCM 0.25 (RC)	Lilliwaup Ck right channel	1/28/98	11:00	6.8	7.5	50	0		17			287	1.4E+06
LT LiCM 0.0 (LC)	Lilliwaup Ck 101 bridge left channel	9/16/97	11:30	11.5	7.5	510	0		49			29	4.0E+05
LT LiCM 0.0 (LC)	Lilliwaup Ck 101 bridge left channel	9/18/97	12:02	12.5	7.7	350	0		220			119	7.4E+06
LT LiCM 0.0 (LC)	Lilliwaup Ck 101 bridge left channel	10/15/97	10:35	10.1	7.5	290	0		7.8	7.8		99	2.2E+05
LT LiCM 0.0 (LC)	Lilliwaup Ck 101 bridge left channel	2/17/98	14:40	7.2	7.7	220	0		7.8			199	4.4E+05
LT LiCM 0.0 (LC)	Lilliwaup Ck 101 bridge left channel	7/6/98	10:00	14.0	7.5	1488	0.5		17			18	8.8E+04
LT LiCM 0.0 (LC)	Lilliwaup Ck 101 bridge left channel	8/18/98	9:00	12.6	6.9	2770	1.4	J	170			14	6.6E+05
LT LiCM 0.0 (LC)	Lilliwaup Ck 101 bridge left channel	9/8/98	12:35	13.7	7.7	2650	1.3		170	220		13	7.4E+05
RT LiCM 0.0 (RC)	Lilliwaup Ck 101 bridge right channel	9/16/97	11:45	12.6	6.8	800	4		79			3	7.7E+04
RT LiCM 0.0 (RC)	Lilliwaup Ck 101 bridge right channel	9/18/97	12:45	12.5	7.4	1500	2		79			23	5.1E+05
RT LiCM 0.0 (RC)	Lilliwaup Ck 101 bridge right channel	10/15/97	11:00	10.9	7.4	850	0		17			25	1.2E+05
RT LiCM 0.0 (RC)	Lilliwaup Ck 101 bridge right channel	2/17/98	15:05	7.4	7.7	540	0		3.3			32	3.0E+04
RT LiCM 0.0 (RC)	Lilliwaup Ck 101 bridge right channel	7/6/98	10:30	16.0	7.2	5980	3		70			1	1.0E+03
RT LiCM 0.0 (RC)	Lilliwaup Ck 101 bridge right channel	8/18/98	9:15	14.4	6.6	8100	4	J	180			3	1.4E+05
RT LiCM 0.0 (RC)	Lilliwaup Ck 101 bridge right channel	9/8/98	12:55	16.6	7.2	7700	4		220			2	1.4E+05

* Fecal coliform samples analyzed at Mancester Environmental Laboratory for 9/16/97, 7/6/98, 8/18/98, and the 9/8/98 sample event.

< Less than the reported result

J Analyte was positively identified. The associated numerical result is an estimate.

& Did not obtain flows, equipment malfunction.

E Flows are estimated from flow measurements obtained at the downstream Little Lilliwaup station.

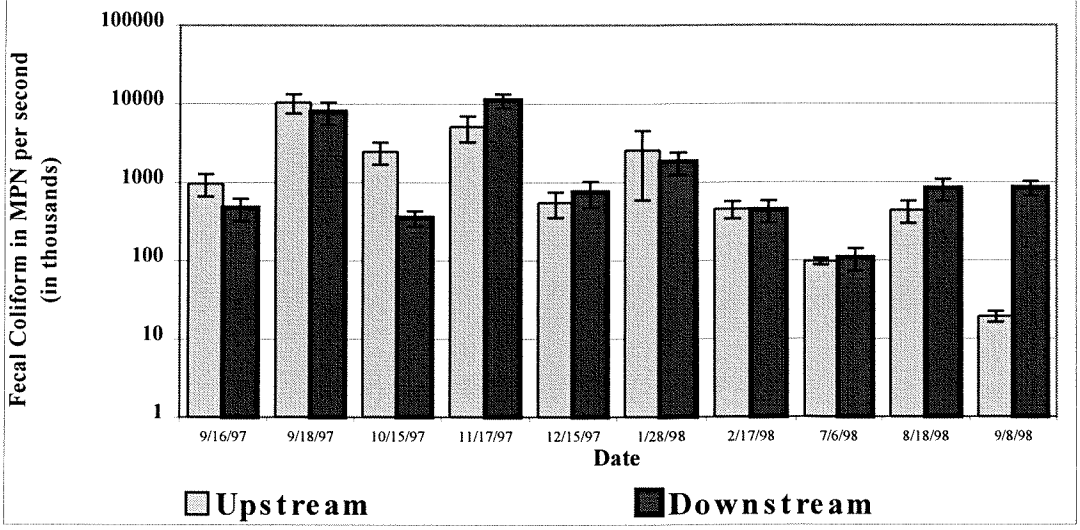
e Flows are estimated from flow measurements obtained at the downstream stations.

Appendix B.

Comparison of Fecal Coliform Loading at LiCM 0.6 and the mouth of Lilliwaup Creek.

Figure 3 compares fecal coliform loading between LiCM 0.6 and the mouth stations. For most sample events loading was the same or greater from upstream to downstream, on October 15, 1997 loading was greater upstream at LiCM 0.6. This is probably due to sample timing; the upstream site was sampled 2½ hours after the downstream site.

Figure 3. Comparison of Fecal Coliform Loading at LiCM 0.60 (upstream) and LiCM 0.25\0.00 (mouth) of Lilliwaup Creek.



Appendix C.
1997-98 Little Lilliwaup Creek Field and Laboratory Data
(paired values are field replicates)

Site Location	Site Description	Date	Time	Temperature °C	pH	Conductivity umho/cm	Salinity ppt	Fecal Coliform MPN\100mL*		Discharge cfs/sec	FC-Load #\sec
LLCM 0.2	Upstream Little Lilliwaup by bridge	9/16/97	13:30	9.0	7.0	110	n\a	17		10	4.7E+04
LLCM 0.2	Upstream Little Lilliwaup by bridge	9/18/97	15:00	9.5	7.5	85	n\a	4.5	4.5	7	9.0E+03
LLCM 0.2	Upstream Little Lilliwaup by bridge	10/15/97	12:10	9.2	7.5	80	n\a	23		9	5.9E+04
LLCM 0.2	Upstream Little Lilliwaup by bridge	11/17/97	10:30	8.6	7.5	67	n\a	< 1.8		8	4.2E+03
LLCM 0.2	Upstream Little Lilliwaup by bridge	12/15/97	11:00	8.1	7.9	76	n\a	< 1.8		11	5.6E+03
LLCM 0.2	Upstream Little Lilliwaup by bridge	1/28/98	12:45	8.3	7.5	64	n\a	< 1.8		25	1.3E+04
LLCM 0.2	Upstream Little Lilliwaup by bridge	2/17/98	14:15	8.2	7.9	62	n\a	< 1.8	< 1.8	22	1.1E+04
LLCM 0.2	Upstream Little Lilliwaup by bridge	7/6/98	10:45	9.0	7.3	87	n\a	< 1.8		5	2.8E+03
LLCM 0.2	Upstream Little Lilliwaup by bridge	8/18/98	10:25	8.7	7.4	63	n\a	J 14		5	2.1E+04
LLCM 0.2	Upstream Little Lilliwaup by bridge	9/8/98	11:30	8.7	7.7	74	n\a	< 1.8	2.0	5	2.7E+03
LLCM 0.0	Mouth of Little Lilliwaup Creek	9/16/97	12:30	9.1	6.8	230	0	110	70	7	1.8E+05
LLCM 0.0	Mouth of Little Lilliwaup Creek	9/18/97	11:30	10.0	7.6	79	0	23		13	8.7E+04
LLCM 0.0	Mouth of Little Lilliwaup Creek	10/15/97	11:45	9.4	7.6	80	0	2	< 1.8	11	5.4E+03
LLCM 0.0	Mouth of Little Lilliwaup Creek	11/17/97	11:40	8.7	7.5	87	0	< 1.8	< 1.8	10	5.3E+03
LLCM 0.0	Mouth of Little Lilliwaup Creek	12/15/97	11:30	8.0	7.8	73	0	70		11	2.2E+05
LLCM 0.0	Mouth of Little Lilliwaup Creek	1/28/98	12:20	8.2	7.6	64	0	2		29	1.6E+04
LLCM 0.0	Mouth of Little Lilliwaup Creek	2/17/98	15:40	8.2	7.7	67	0	< 1.8		24	1.2E+04
LLCM 0.0	Mouth of Little Lilliwaup Creek	7/6/98	11:00	10.5	7.6	69	0	< 1.8		7	3.6E+03
LLCM 0.0	Mouth of Little Lilliwaup Creek	8/18/98	8:30	8.8	7.7	89	0	J 27		5	3.6E+04
LLCM 0.0	Mouth of Little Lilliwaup Creek	9/8/98	13:25	9.2	7.9	88	0	< 1.8		5	2.5E+03

* Fecal coliform samples analyzed at Mancester Environmental Laboratory for 9/16/97, 7/6/98, 8/18/98, and the 9/8/98 sample event.
< Less than the reported result.
J Analyte was positively identified. The associated numerical result is an estimate.