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Investigation of Bacterial Contamination of the Inner Harbor of Oakland Bay 1987-88 Winter Study

by
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ABSTRACT

A 1987 water quality study identified stormwater, industrial effluent, and Goldsborough and Shelton Creeks as important sources of bacteria to Shelton's inner harbor in Oakland Bay. These sources were further investigated in this study to observe the impact of winter wet weather conditions on bacteria concentrations and loading. Since drought conditions prevailed during the study, impact from typical wet weather conditions was not assessed. Results were consistent with the previous study, with the exception that industrial effluent is no longer a problem due to changes in operating conditions. As a result of the previous study a sanitary sewer collection system improvement program has been developed. Impact of the program is discussed. Recommendations are made for further investigation and protection of the watershed.

INTRODUCTION

In January of 1987 the Washington State Department of Social and Health Services (DSHS) reclassified Oakland Bay from an area that was "conditionally approved" for shellfish harvest to "restricted." The restricted status was based on water quality surveys done by DSHS during December 1986 and January 1987 (DSHS, 1987). These surveys indicated fecal coliform bacteria (FC) concentrations were greater than U.S. Food and Drug Administration (FDA) standards allowed for commercial harvest of shellfish. In February of 1987, the Department of Ecology began an investigation of the sources of bacteria to the bay. The investigation focused on the inner harbor area where bacteria sources were most likely and where bacteria concentrations appeared to be highest. The objectives of the 1987 investigation included an inventory of pipes discharging to the inner harbor, monitoring streams that flow into the inner harbor, evaluating the magnitude and extent of bacterial pollution from each source, and assessing the seasonality of the bacterial pollution problem.

Results from the 1987 study indicated the primary FC sources to the inner harbor of Oakland Bay were the city of Shelton stormwater, effluent from ITT Rayonier's research laboratory, and Shelton and Goldsborough Creeks (Michaud, 1987). With the exception of the ITT effluent, all of these sources could be expected to be seasonally impacted.

The 1987 study was begun late in February near the end of the wet weather season. Many non-point source pollutants enter local water systems during the wet weather season when watershed soils are saturated and rainfall is frequent. At this time there is greater potential for on-site septic systems to fail, sanitary sewers to overflow, and greater washoff of pollutants from the watershed. Because of the importance of this time period, it was recommended the study be continued the following wet weather season. To differentiate between the two study periods, the February-to-May sampling that occurred in 1987 is referred to as the "spring" study event though some of the sampling occurred during winter months. Conversely, the October-through-February 1987-88 results are referred to as the "winter" study.

The objectives of the follow-up study were: (1) further investigate bacteria sources to the inner harbor during wet weather conditions, and (2) estimate the contribution of stormwater from industrial sources in the inner harbor.

BACKGROUND

Oakland Bay in Southern Puget Sound is about four miles long and three quarters of a mile wide at its widest point (Figure 1). It flows into the northern end of Totten Inlet via Hammersley Inlet. The outer bay is a Class A water, and the inner harbor area (west of longitude 123° 05' W) is a Class B water. As such it must meet state water quality standards for these classifications (WAC 173-201). Oakland Bay historically has been very important to the Washington State shellfish industry. This bay alone accounts for over a third of the state's hardshell clam production (E. Hurlbert, 1987). DSHS is responsible for evaluating the sanitary quality of shellfish growing waters in Washington. Periodic bacteriological studies of the water are used to determine whether standards set by the U.S. Food and Drug Administration (U.S.DSHS, 1986) are being met. If the outer bay meets Class A water quality fecal coliform standards, it will also meet FDA requirements. (Class A and B fecal coliform standards are described in the data tables.)

A flushing study of the bay was done for part of one tidal cycle in June of 1974 (Department of Health Education and Welfare, 1975). The researchers concluded "there does not appear to be much displacement by different water" and "it is conceivable that most of the same water in Oakland Bay could move up and down the bay with the tides." Due to the limited duration of the study, these results are not conclusive. However they indicate pollutants may take a long time to be "flushed" out of the bay.

The city of Shelton is located at the southern end of the bay. Simpson Timber Company, ITT Rayonier Research Laboratory, and Manke Lumber Company are all located along the shoreline of the inner harbor. Goldsborough and Shelton Creeks and stormwater from the city of Shelton discharge to the inner harbor. Prior to 1979 the discharge of sewage from the Shelton wastewater treatment plant (WTP) was the principal reason for the permanent closure of the bay to commercial shellfish harvest. At that time primary treated wastes were discharged directly to the inner harbor. The existing WTP discharges secondary treated wastes through an outfall located at the western end of Hammersley Inlet (Figure 1). The discharge is not considered to be an inner harbor source, but was included in the survey because of its past importance and because it still represents the largest wastewater discharge to Oakland Bay.

Goldsborough Creek contributes the largest volume of water to the inner harbor. It is approximately ten times the size of Shelton Creek. Although it flows directly through the city, its shoreline is not densely developed. It is partially protected on the southern side by a steep ravine, railroad tracks, and a small city park. Consequently, the streambank remains comparatively natural and provides some buffer against pollutants. However, stormwater from Shelton and the inner harbor industrial area is discharged to the creek in a number of places. Goldsborough Creek flows into the center of the inner harbor shoreline (Figure 2). Chinook, Coho, Chum, and Steelhead salmon and Cutthroat and Rainbow trout are found in

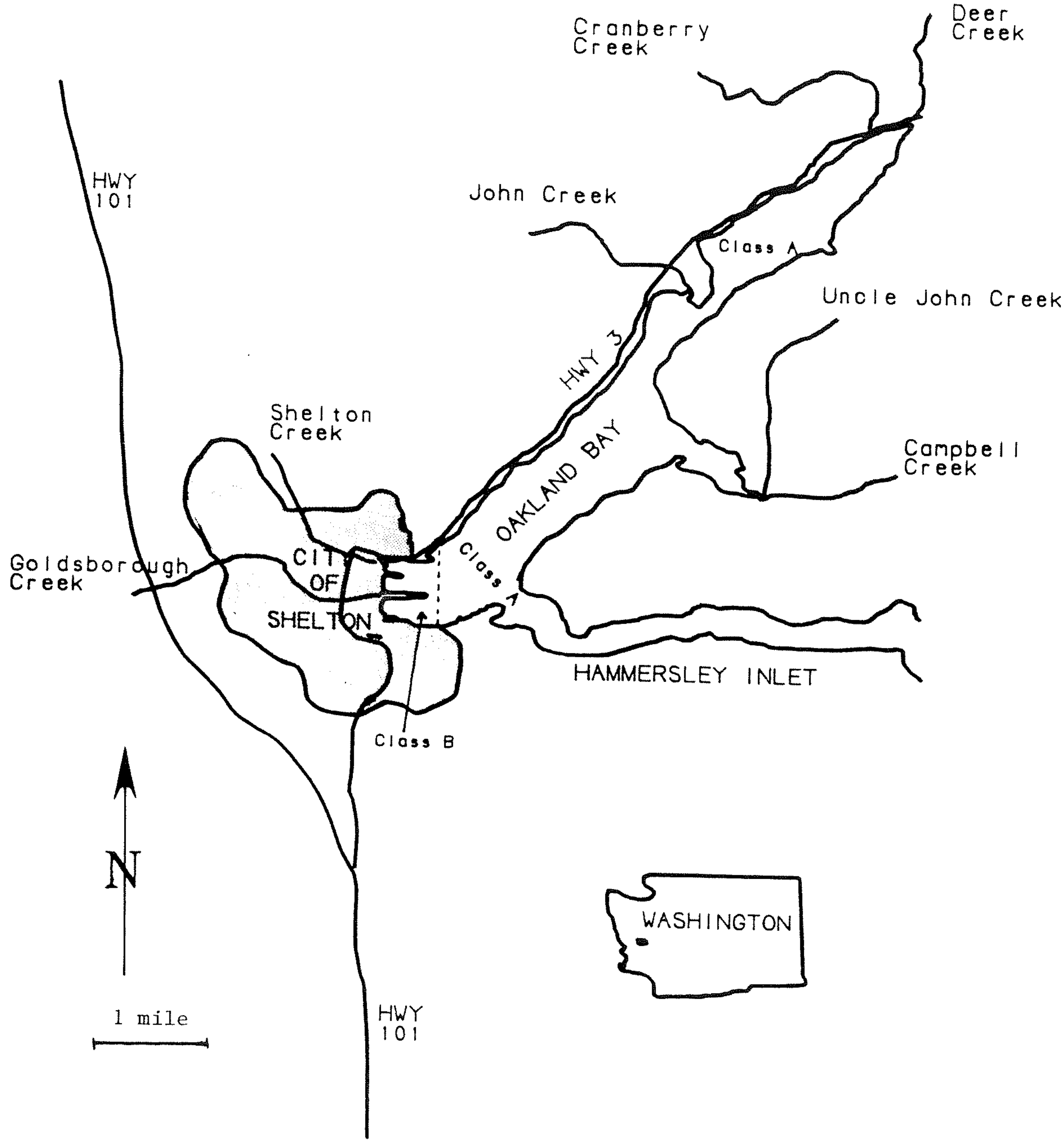


Figure 1. Oakland Bay Study Area.

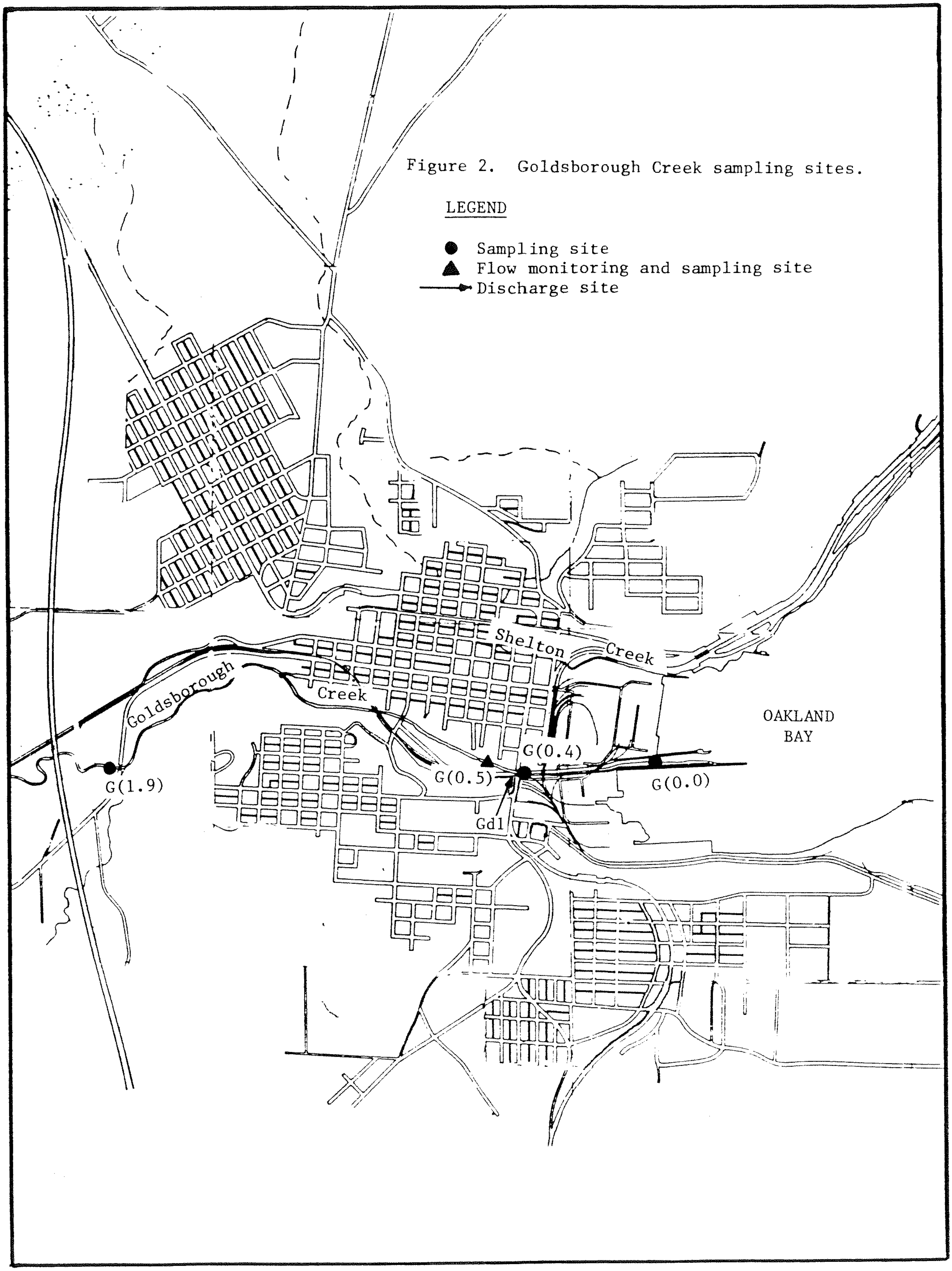


Figure 2. Goldsborough Creek sampling sites.

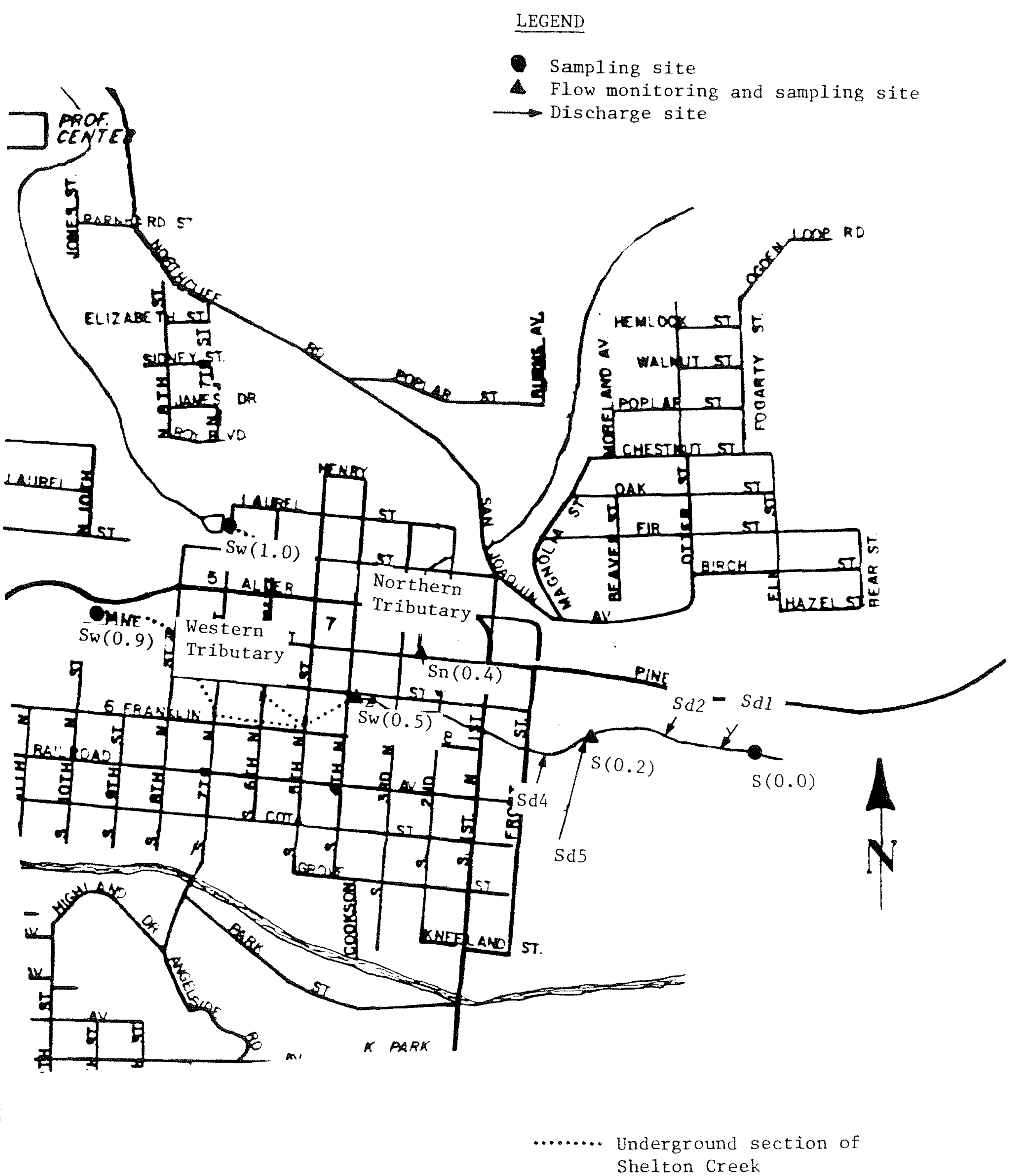
the creek. Goldsborough Creek is a Class A water and must meet state water quality standards for this classification.

Shelton Creek drainage, where it flows through town, is more complex than Goldsborough. The northern tributary of the creek (Town Creek) originates in a marsh northeast of the city of Shelton. The northern tributary contributes the most flow to the mainstem. It passes through a deep, wooded ravine, then through town, and joins the western tributary (Figure 3). The western tributary originates from two forks. Both forks form part of the city stormwater system and flow underground for most of their course. Their approximate path is shown in Figure 3 as a dotted line. Much of the creek where it flows through town is contained within a concrete channel. Development occurs immediately adjacent to the stream. There is no natural streambank. The stormwater discharges and the creek's proximity to the urban environment increase the probability of impact from failing septic systems, sewer line leaks or misconnections, and urban stormwater runoff. Shelton Creek flows into Oakland Bay along the northern edge of the inner harbor. Chum and Coho salmon and Cutthroat trout are the primary game species using the creek. It is also a Class A water.

The spring study identified the city stormwater system as one of the major fecal coliform bacteria loading sources to the inner harbor (Michaud, 1987). It was concluded in the report, "during the critical wet-weather period, it [stormwater] can become the major contributor of bacteria." During rainy periods the rising groundwater table and increased stormwater infiltrate the sewage collection system causing excessive flows and a very dilute sewage at the wastewater treatment plant. In addition to the added cost for treating storm- and ground water, the treatment plant also does not operate effectively when the influent is dilute. The WTP is required to meet specific effluent limitations that are listed in its National Pollutant Discharge Elimination System (NPDES) permit. The permit specifies concentration limits as well as requirements for "percent removal" of pollutants. Due to the highly diluted nature of the influent, it is the percent removal requirement for total suspended solids (TSS) that is violated seasonally at the Shelton WTP. In extreme cases the excess infiltration causes back-up of the sewer system, and untreated sewage overflows into the stormwater system which discharges to the creeks and bay.

An Ecology order (No. DE 87-S172) required the city of Shelton to develop a basic comprehensive sewer plan, report collection system overflow or surcharging events, and monitor fecal coliform bacteria (FC) and flow at the main sanitary sewer overflow location; the Harvard Street (54-inch) stormdrain. The city received a grant from Ecology to study their storm and sewer collection systems. The resultant sewer plan "City of Shelton Infiltration and Inflow Control Program" (Brown and Caldwell, 1988A) identifies the sewer basins that are severely impacted by infiltration and inflow and describes a 30- to 50-year implementation program for collection system improvements. The immediate goal of the implementation program is aimed at eliminating overflow events. This is scheduled to be achieved by 1995. Some of the other goals described in the report include eliminating major sources of inflow to the sewer system, monitoring and testing sewer basins to determine problem areas, replacing and repairing poor sewer lines and laterals, revising sewer ordinances and instituting strict construction standards for sewers and laterals, and evaluating alternative collection systems for expansion to unsewered areas. The implementation plan focuses on removing stormwater

Figure 3. Shelton Creek sampling sites.



and groundwater sources from the sanitary sewer collection system, and rerouting them to the stormwater system (e.g., to Goldsborough and Shelton Creeks and the inner harbor area).

In addition to city stormwater, stormwater from the inner harbor industries is also discharged to the harbor and the two creeks through separate stormwater pipes and as overland flow.

There are two remaining active National Pollutant Discharge Elimination (NPDES) permits regulating discharges to the bay.

- The ITT Rayonier research facility located at the southern end of the inner harbor holds a permit. The existing permit limits biochemical oxygen demand (BOD), total suspended solids (TSS), pH, temperature, and discharge volume. The discharge complies with these requirements. The permit is currently being reviewed by Ecology. Additional effluent characteristics are being studied that may result in revisions to the permit.

- The Shelton WTP permit limits TSS, BOD, pH, temperature, flow, fecal coliform bacteria, and residual chlorine. As described previously, the plant is presently not meeting its percent removal limits for TSS during wet weather conditions.

Historically, Simpson Timber Company maintained three discharge permits for non-contact cooling water. During the past year Simpson modified their process and now uses air for cooling; consequently, the permits are no longer active. Simpson's process wastewaters continue to be discharged to the Shelton sanitary sewer.

METHODS

Stations selected and methods followed were consistent with the spring study. ITT's effluent, the 54-inch city stormwater culvert (Harvard Street), and Simpson Timber Company's stormwater discharges were the principle pipes monitored in the inner harbor. Shelton and Goldsborough Creeks were sampled near the mouth and at select upstream stations. (Creek station names are not consistent with those used in the spring study. Stations are now identified by a letter corresponding to the creek name and the river mile the station is located at. Appendix III contains a key to the station names.) Samples were also collected at marine stations. Marine station names were consistent with those sampled in the spring. They included three nearshore stations (#15, #16,and #17), three mid-inner harbor stations (#32, #33, and #34), and inner harbor transect stations (#21 through #26). Figures 2, 3, and 4 show sampling locations and flow monitoring sites. Stream mouth and marine samples were collected during ebbing tides.

Creek and pipe velocities were measured with a Model 2100 Swoffer meter. Velocities and cross-sectional areas were used to estimate total discharge. Where the meter could not be used, the time required to fill a bucket of known volume was used to estimate discharge. Discharge volume and concentration were used to estimate instantaneous fecal coliform bacteria loading to the inner harbor.

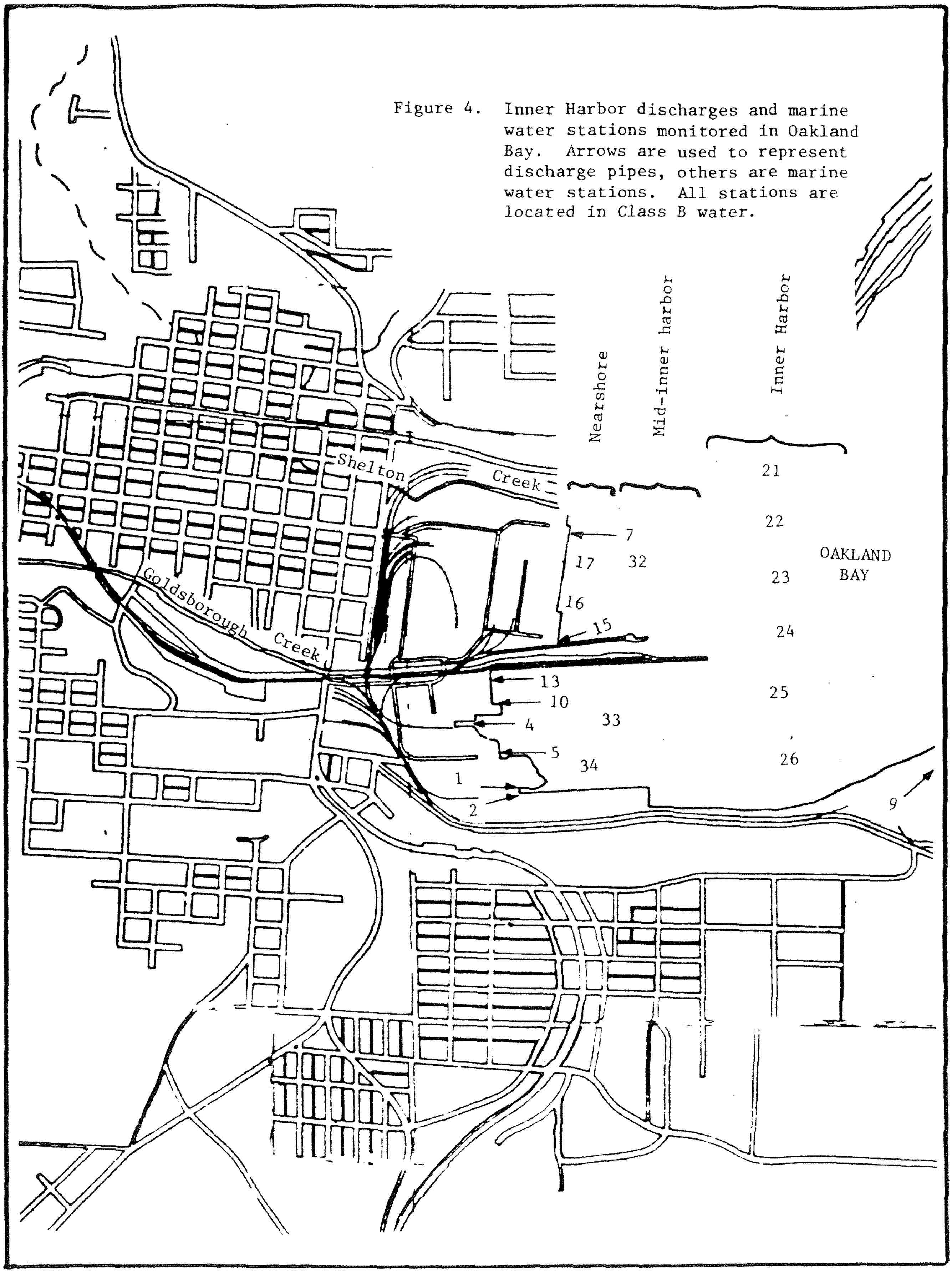


Figure 4. Inner Harbor discharges and marine water stations monitored in Oakland Bay. Arrows are used to represent discharge pipes, others are marine water stations. All stations are located in Class B water.

The sampling period began in October and ended in the middle of February. Stations were monitored once a month during October, November, and February and twice monthly during December and January. Most of the data from the winter study are included in tables within this report. Appendices I and II contain the entire data set for the winter and spring studies, respectively.

Fecal coliform bacteria concentrations were measured using the membrane filter (MF) technique (APHA, 1985). Some bacteria that test positive using this technique may be unrelated to fecal waste. An additional test is used to determine what percentage of the fecal coliform bacteria concentration can be attributed to bacteria not always associated with fecal waste. The results are reported as percent KES, where KES represents the bacteria Klebsiella sp., Enterobacter sp., and Serratia sp. This test was used during the investigation to aid in distinguishing bacteria sources.

Due to the impact of precipitation on non-point pollution sources (e.g., increases in septic system failures, stormwater runoff, and sanitary sewer overflows), it is important to track weather conditions during sampling periods. Daily precipitation is recorded at the ITT Rayonier research facility in Shelton, Washington. Precipitation data were used to record both the one-day and three-day accumulations of rain for each of the sampling days. The Antecedent Precipitation Index (API) was also calculated for each sampling day. The index is used to estimate differences in watershed moisture conditions between sampling dates. It was calculated using precipitation data for the 14 days preceding the first day of sampling and the equations (after Linsley Kohler, and Paulhus, 1975):

For I_1 to I_{15}:

$$I_1 = P_1$$
$$I_2 = I_1(k) + P_2$$
$$I_3 = I_2(k) + P_3$$
$$\vdots$$
$$I_{15} = I_{14}(k) + P_{15}$$

where:

I = Antecedent Precipitation Index (API)
I_1 = API 14 days before the first day of sampling
I_{15} = API on first day of sampling
k = Recession factor for evaporation (Range: 0.85-0.98)
P_1 = Precipitation 14 days before the first day of sampling

RESULTS AND DISCUSSION

Weather

Table 1 contains rainfall information for each sampling date. Figure 5 is a comparison of a 20-year average monthly rainfall in Shelton Washington to rainfall during the two study periods (NCDC, 1988). During the spring study (February through May), rainfall was slightly above average with the area receiving 1.34 inches more rain than normal for the period. During the winter study each month had a lower-than-average rainfall, except December. The area received 16.89 inches less rain than normal for the October-through-February period. This represents 37 percent below-normal rainfall for the period. As stated previously, the objective of the winter study was to investigate FC sources to the inner harbor during wet weather conditions. The survey was scheduled for the November-through-February period when western Washington typically receives a heavy proportion of its annual rainfall. Due to the lack of rainfall during the study period, the original study objectives were not fully met.

Table 1. Precipitation characteristics for the winter study period sampling events.

	1987				1988		
Date	10/07	11/16	12/02	12/22	01/11	01/25	02/08
API	0.0	1.9	4.1	5.1	1.9	4.6	2.3
3-day	0.0	0.5	2.6	0.9	1.1	0.0	1.5
1-day	0.0	0.2	1.1	0.3	0.4	0.0	0.8

API = Antecedent Precipitation Index

1-day = Cumulative rainfall for the day of the sampling event (inches).

3-day = Cumulative rainfall for two days preceding sampling event plus the rainfall received on the sampling day (inches).

Goldsborough Creek

Goldsborough Creek sampling results are shown in Table 2. The key stations monitored were the same as during the spring study. They included a station upstream of city stormwater input (G(1.9), a station to represent water quality after it has received the majority of city stormwater discharges (G(0.5)), and a station at the mouth of the creek to reflect the additional input of industrial stormwater (G(0.0)). Bacteria concentrations in Goldsborough Creek were similar to those measured in the spring study. Station G(1.9) FC concentrations ranged from 3-72 org./100 mL with a geometric mean value (GMV) of 9. The concentration at G(0.5) ranged from 9-96 org./100 mL (GMV = 19). Both of these stations were well within the state water quality standard of 100 org./100 mL for Class A fresh water. According to the Mann-Whitney test, there was no significant difference between the concentrations measured at these two stations. Station G(0.5) is upstream of industrial stormwater influence and at least one known city stormwater discharge (Gd1). Station G(0.4) is located downstream of this city discharge.

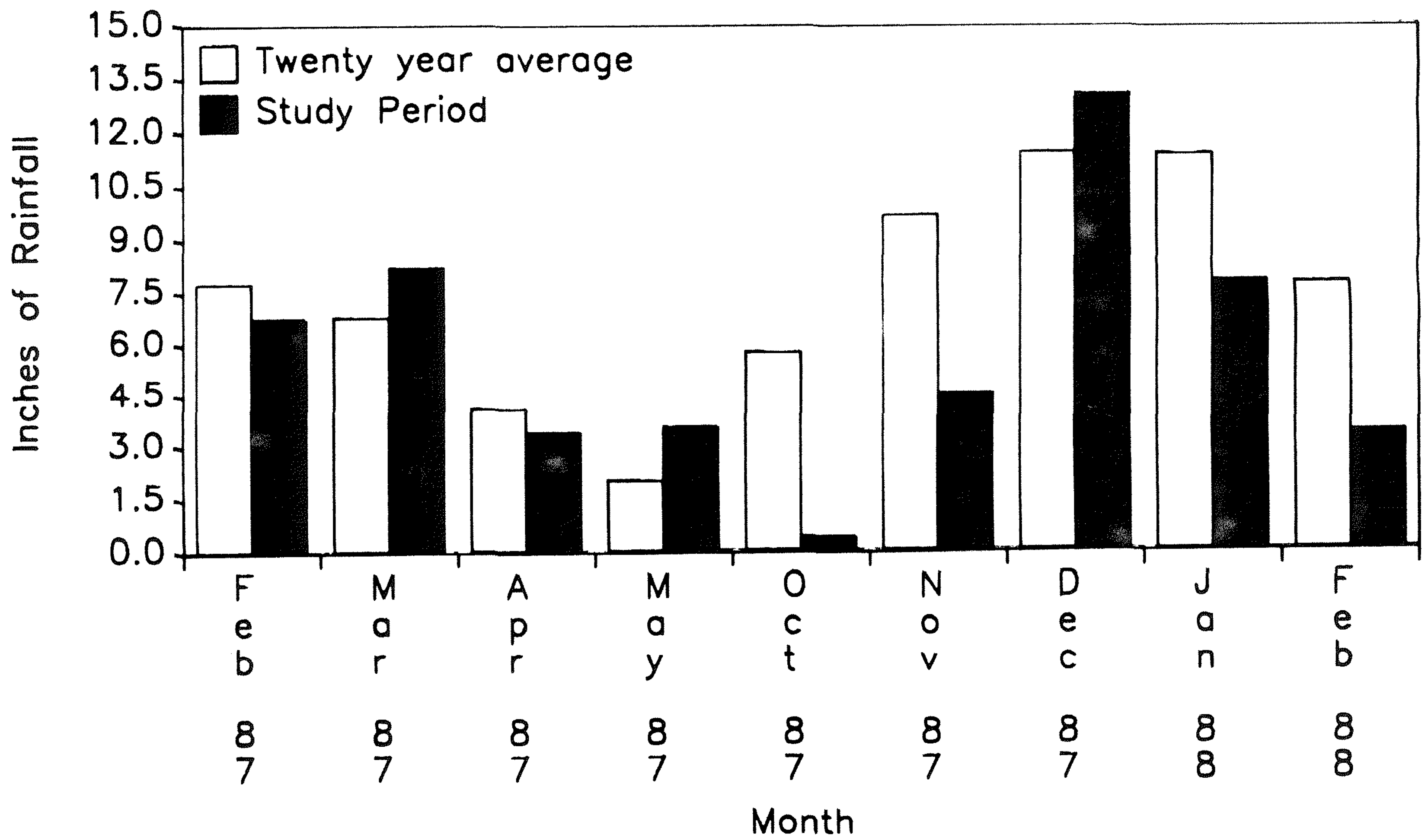


Figure 5. Comparison of twenty year average rainfall to rainfall during the study period.

Table 2. Fecal coliform bacteria concentrations, stream flow, and calculated bacteria loading results for Goldsborough Creek during the winter study period.

Station	1987				1988				Geo-metric	Flow Range	Loading Range
Number	10/07	11/16	12/02	12/22	01/11	01/25	02/08	02/09	Mean	(cfs)	(#/day x 10^7)
G(0.0)	49		250	970	250	17	71		124		
G(0.4)					17	6	45		21		
Gd1							970				
G(0.5)	9	13	96	26	10	9	18	33	19	19.4-192.6	42.8 - 2960
G(1.9)	6	2	72	15	6	3	21		9		

Class A freshwater quality standards require a geometric mean value below 100 org./100 mL, with fewer than 10 percent of the samples exceeding 200 org./100 mL.

FC concentrations here were similar to those measured at Station G(0.5) (Table 2). However, this station was sampled only three times. A one-time rain event sample taken directly from the stormwater discharge (Gd1) resulted in a concentration of 970 org./100 mL. No difference was measured in FC concentrations between G(0.5) and G(0.4) on that day. FC concentrations at the creek mouth G(0.0) ranged from 17-970 org./100 mL (GMV = 124). State water quality standards were not met at station G(0.0).

Under the conditions of this study, the many city stormwater discharges located along Goldsborough Creek were not seen to impact FC concentrations when compared to upstream concentrations and water quality standards. Sources located along the last half-mile of the river did cause a measurable increase in FC concentrations and a violation of the standard. This is consistent with results from the spring study. Both city and industrial stormwater inputs would be affected by wetter conditions. Under more typical wet weather conditions water quality violations may occur at G(0.5).

Flow ranged from 19-193 cfs at Station G(0.5); these can be considered low flows for the winter period due to the drought conditions experienced during 1987-88. In fact, this "wet weather" flow range was similar to the range measured the previous year during the March-through-May period (63-183 cfs).

Figure 6 shows the relationship between calculated bacteria loadings and flow at Station G(0.5). The figure was developed using data from both study periods. The solid line describes the mathematical relationship formed from the measured data. (It should be noted that flow is used to calculate loading. Thus the apparently smooth relationship formed is deceptive due to auto-correlation error.) The dashed line represents the loading that would occur if added stormwater had a bacteria concentration similar to "background" Goldsborough Creek concentrations (here assumed to be 10 org./100 mL). According to these estimates, at 120 cfs the majority of the load (88 percent) can be accounted for by a simple increase in flow of a source with low bacteria concentrations (10 org./100 mL). Apparently, at flows greater than 120 cfs, there is an increase in either the number of sources or their respective bacteria concentrations.

The relationship shown in Figure 6 and the results discussed above may change during higher flow conditions. The relationship was based on measured flows below 200 cfs. Yet according to hydrograph information estimated for station G(0.5) (WDOE, 1983), flows are greater than 200 cfs 50 percent of the time during the December-through-March period. Thus conditions that typically occur 50 percent of the time are not represented by the data. Both the FC concentration and volume of stormwater would likely increase with higher flows, so that the impact on water quality would be even greater (i.e., the slope of the curve described in Figure 6 would be greater). It should also be noted the relationship was formed by using data from Station G(0.5) that is not influenced by industrial sources and met water quality standards during the study period. If FC concentrations at Station G(0.0) had been used, that too would result in a steeper curve, depicting a greater impact.

The lack of typical wet weather data limits the conclusions that can be drawn from the studies as to the true impact stormwater may be having on water quality and the contribution of FC

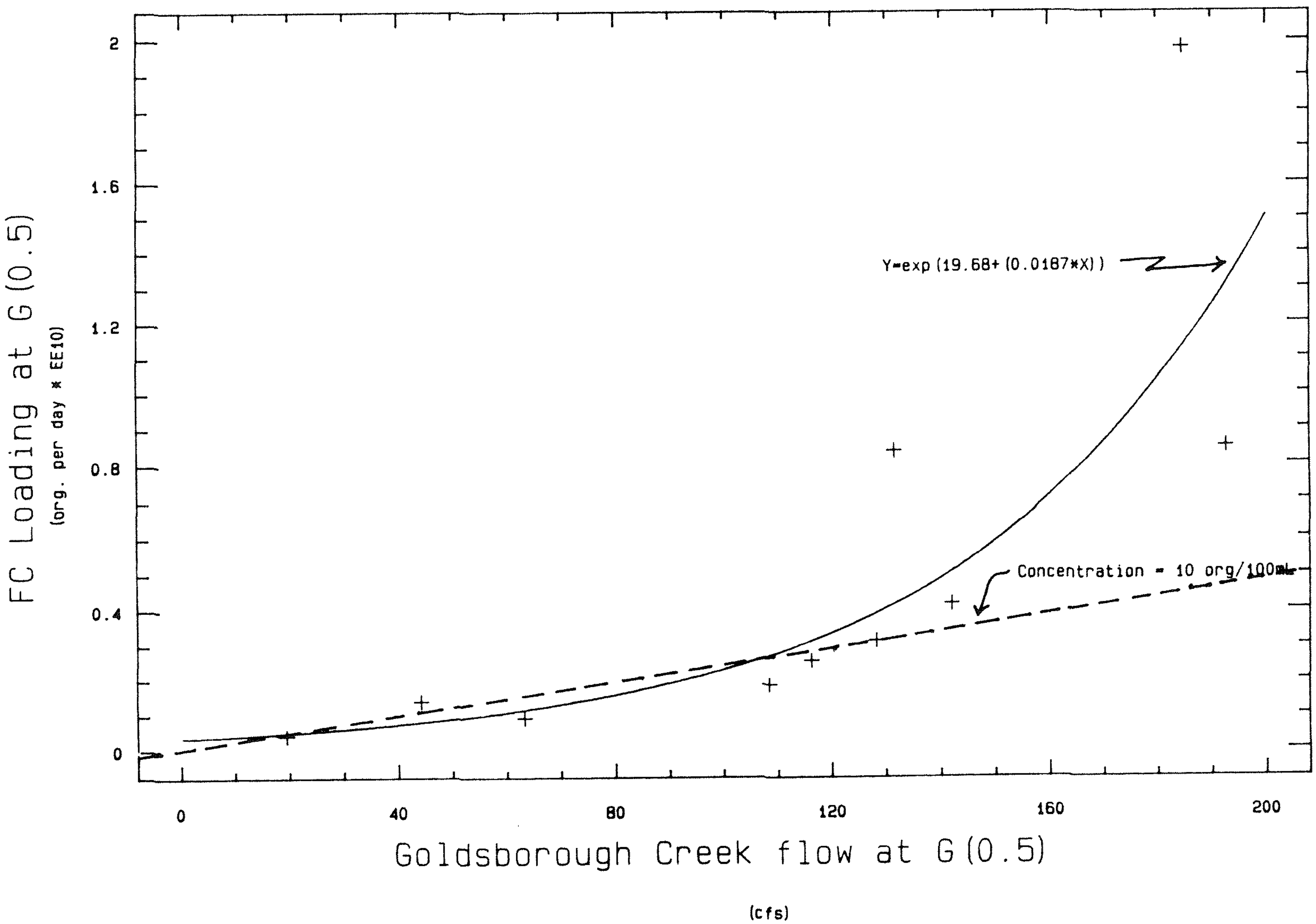


Figure 6. Comparison of Goldsborough Creek Fecal coliform bacteria loading to flow.

loading by Goldsborough Creek to the inner harbor. Two of the three common sanitary sewer overflow points discharge to Goldsborough Creek, thus there is a large potential for contamination of this creek by untreated wastes during a surcharging event.

Shelton Creek

Shelton Creek sampling results are in Table 3. Sampling focused on stations located on the western (Sw(0.5)) and northern (Sn(0.4)) tributaries of Shelton Creek just upstream of their confluence and near the mouth (S(0.2)) of the Creek. These locations were selected to allow comparison of stormwater discharge and bacteria loading between the tributaries and to estimate their impact on total loading at the mouth of the creek. Station S(0.2) was selected far enough upstream to allow flow measurements to be taken during most tides. However, between Station S(0.2) and the mouth of the creek there are a number of miscellaneous discharges that belong to both Simpson Timber Company and the city. Two of these discharges were routinely sampled (Sd1 and Sd2), others apparently only discharge during rain events and were not routinely monitored. Another station (S(0.0)) was established at the mouth of the creek. When tide levels allowed, this station was sampled in order to provide an estimate of the additional impact from the many miscellaneous discharge pipes. Station Sw(0.9) was also routinely sampled. This station is located where the western tributary enters the main part of town just upstream of where the tributary goes below ground and becomes primarily a stormwater conduit. Station Sw(0.9) was selected to represent water quality upstream of the city proper.

As indicated in Table 3, Station Sw(0.9) usually had very low bacteria concentrations. The exceptions were on December 2, 1987, and February 8, 1988, which were storm events (Table 1). Thus Station Sw(0.9) does appear to be affected by stormwater. The two tributaries (Sw(0.5) and Sn(0.4)) also had peak concentrations on these two days. Concentrations (and loadings) were much higher at these stations than at Station Sw(0.9), showing the impact of city sources on water quality. At Station S(0.2), near the mouth, concentrations were consistently higher than at Sw(0.5) and Sn(0.4). Not enough data was collected at Station S(0.0) to discern whether industrial site runoff and city stormwater discharges located between Station S(0.0) and S(0.2) were affecting bacteria concentrations. However, Station Sd2, a city-owned concrete culvert, had continually high FC concentrations (GMV = 478 org./100 mL), consistent with the results from the previous study. This culvert and Sd1 were flowing even during very dry conditions, thus it appears they carry more than just stormwater. It is unknown what the source of water and therefore bacteria is to these culverts. Station Sd5 is a small stormwater discharge from Simpson Timber Company property. Only one sample was collected from Sd5 because it only discharges during a rain event. Impact from Sd5 and other industrial stormwater discharges is discussed in the following section. Only Station Sw(0.9) on Shelton Creek met Class A water quality standards. These results are consistent with those reported previously (Michaud, 1987).

Table 4 contains information on loading comparisons between Stations S(0.2), Sw(0.5) and Sn(0.4). Data are included from both study periods. The western (Sw(0.5)) and northern (Sn(0.4)) tributaries together contributed 71 percent of the load to the creek as measured at Station S(0.2) and 98 percent of the flow. This implies that there are loading sources between

Table 3. Fecal coliform bacteria concentrations, stream flow, and calculated bacteria loading results for Shelton Creek during the winter study period.

Station Number	1987 10/07	1987 11/16	1987 12/02	1987 12/22	1988 01/11	1988 01/25	1988 02/08	1988 02/09	Geometric Mean	Flow Range (cfs)	Loading Range (#/day x 10^7)
S(0.0)	600	200				34					
Sd1	40	28	56	27	1	1			11	0.03-0.68	0.07-9.32
Sd2	8,000	43	210	2,750	100	152	1,890		478	0.16-0.41	1.68-333
Sd5							2,300				
S(0.2)	84	1,500	3,100	28	38	11	2,400	270	147	3.21-9.30	24.3-5,140
Sd4						3					
Sn(0.4)	92	35	700	17	43	22	110	240	76	2.10-9.54	17.5-1,020
Sw(0.5)	4	84	1,100	15	3	3	1,700	100	41	0.26-4.41	0.37-1,830
Sw(0.9)	1	7	500	0	9	1	180		9		
Sw(1.0)	1		1								

Class A freshwater quality standards require a geometric mean value below 100 org./100 mL, with fewer than 10 percent of the samples exceeding 200 org./100 mL.

Table 4. Comparison of flow and bacteria loading in Shelton Creek.

	Loading (#/day x 10^7)			Percent of Load to Station S(0.2)		Percent of Flow to Station S(0.2)	
Date	S(0.2)	Sw(0.5)	Sn(0.4)	Sw(0.5)	Sn(0.4)	Sw(0.5)	Sn(0.4)
03/02/87		326.00	4,220.00				
03/04/87	400.00	102.00	257.00	25	64	24	80
03/18/87	229.00	0.24					
03/31/87	48.90	8.65	54.80	18	112	44	52
04/15/87	621.00	71.70	178.00	12	29	34	44
04/28/87	50.40	0.87	45.30	2	90	45	54
05/27/87	32.00		236.00			39	55
10/07/87	66.00	0.37	47.30	1	72	12	65
11/16/87	1,270.00	5.34	24.40	0	2	8	82
12/02/87	5,140.00	447.00	1,020.00	9	20	25	88
12/22/87	52.50	10.90	17.50	21	33	39	55
01/11/88	86.50	2.16	100.00	2	116	32	103
01/25/88	24.30	2.41	18.40	10	76	36	38
02/08/88		1,830.00	121.00				
			Mean*	8	63	30	68

*Means calculated by using arcsine transformation.

the confluence of the tributaries and the near-mouth station that have high bacteria concentrations. There is a large city stormwater discharge just upstream of Station S(0.2); (Sd4). Monitoring of this discharge by city and county personnel has indicated bacteria concentrations, though typically low, can be elevated during rain events (Brown and Caldwell, 1988B). The northern tributary (Sn(0.4)) is calculated to represent 68 percent of the flow to Station S(0.2) and 63 percent of the loading. Thus the loading contributed by this tributary is proportional to its flow. The western tributary represents 30 percent of the flow to S(0.2) and only 8 percent of the loading. This implies that the western tributary does not have as large an impact as the northern tributary on Shelton creek. As shown in the table, there was a wide range in the percent loading from each tributary, though the northern tributary contributed consistently higher loads throughout the study period. As described in the discussion on Goldsborough Creek, these loading relationships, the magnitude of impact to water quality, and the degree of influence from the different tributaries, may change during higher flows or wetter conditions.

Stormwater from the unsewered portion of the city (Capital Hill) also drains to the northern tributary and the lower portion of Shelton Creek. Contaminated runoff from failing septic systems in the Capital Hill area may be a contributing source of bacteria to Shelton Creek.

<u>City of Shelton Storm and Sewer Systems</u>

Fecal coliform concentrations in the WTP effluent ranged from 1-33 org./100 mL during this study period. This is well below the limit of 200 org./100 mL set by their NPDES permit. Although the treatment plant is operating well there are problems that remain to be resolved with the city sewer system. As described previously, during periods of heavy rain the flow in the sanitary sewer lines may exceed line capacity. This causes overflow into the stormwater system. Contaminated stormwater is then discharged via numerous outfalls to the creeks or directly to the inner harbor. Figure 7 depicts the sanitary sewer service area and common overflow points. The Capitol Hill area, which drains to Shelton Creek is not sewered. According to a recent septic system survey of the area, 75 percent of the homes surveyed had "satisfactory" septic systems. The remaining 25 percent were questionably satisfactory (8.2 percent), substandard (11.9 percent), or unsatisfactory (4.6 percent) (Brown and Caldwell, 1988B).

As described previously, the city received an order from Ecology requiring a plan for attaining compliance with their NPDES permit. One of the order requirements is that city monitor stormwater at the Harvard Street overflow point and notify both Ecology and DSHS of surcharging events. Table 5 contains results from the city's monitoring at the Harvard Street overflow and another common overflow point located on Park Street (overflow locations are shown in Figure 7). At both sites FC concentrations vary widely. Extreme values of 12,200 and 13,000 were measured during a surcharging event at Harvard and Park Street, respectively. On January 28 after a mild rainfall (0.38 inches/72 hours), flow was 4.76 and 0.27 cfs at Harvard and Park Streets, respectively. The flow would be much greater than this after a heavy rain and may be many times this value during a surcharging event. Five surcharging events occurred between December 1987 and April 1988. There are no records from past years to determine

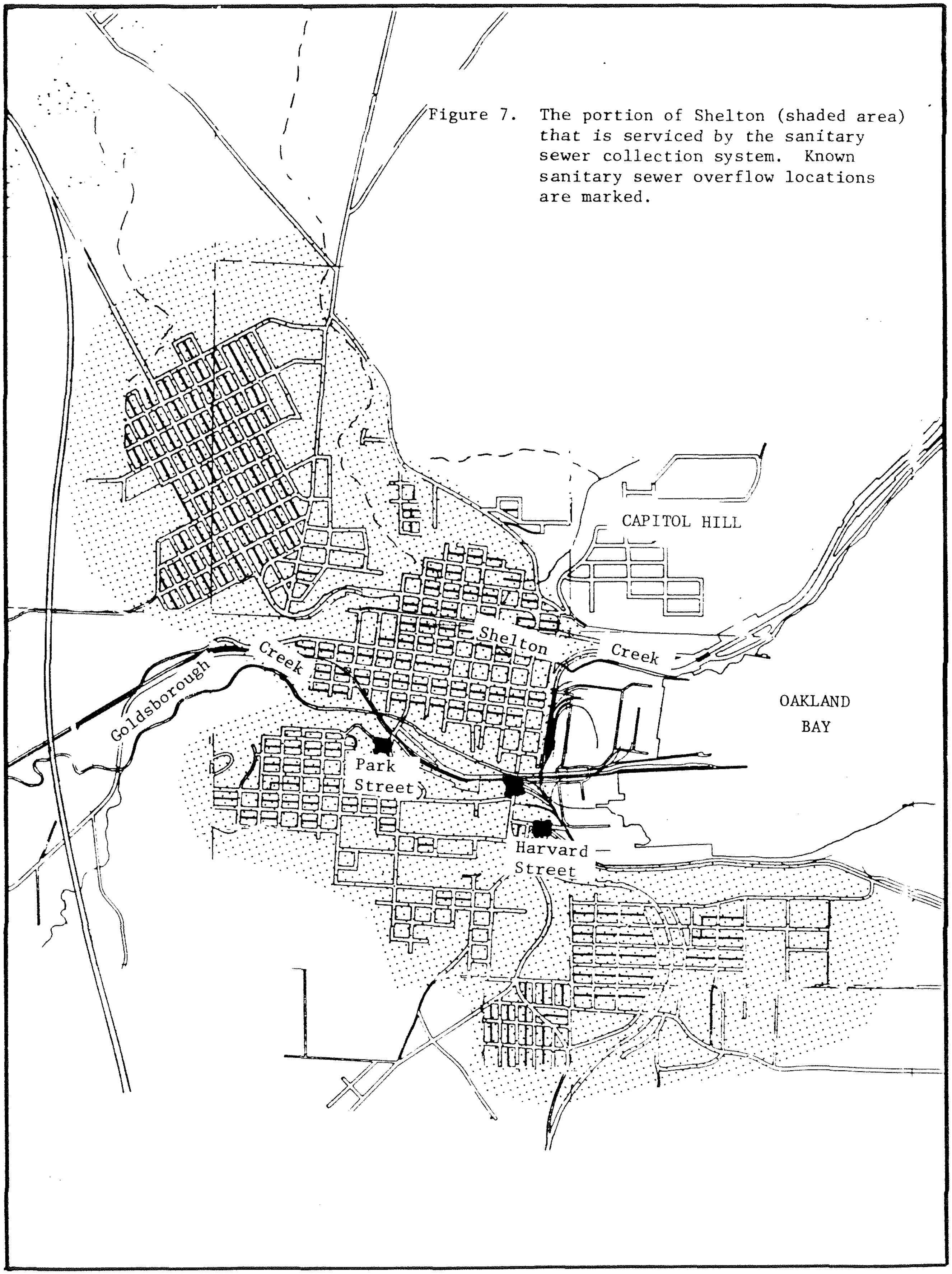


Figure 7. The portion of Shelton (shaded area) that is serviced by the sanitary sewer collection system. Known sanitary sewer overflow locations are marked.

Table 5. City of Shelton monitoring results from Harvard and Park Streets stormdrains (from: J. Ozga, 1988).

	Harvard		Park			
Date	FC Conc. (#/100 mL)	Flow (cfs)	FC Conc. (#/100 mL)	Flow (cfs)	Surcharge*	72-hour Rainfall
12/07/87	110	--	--	--	Yes	1.94
12/09/87	9,700	--	780	--	Yes	4.97
01/14/88	12,200	--	1,600	--	Yes	3.83
01/15/88	--	--	13,000	--	Yes	3.89
01/28/88	1,300	4.76	1,480	0.27	No	0.38
02/03/88	10	0.45	60	--	No	0.20
02/17/88	40	--	1,270	--	No	0.72
03/02/88	150	--	500	--	No	0.33
03/16/88	10	--	10	--	No	0.00
04/06/88	5,100	--	--	--	Yes	2.93
04/14/88	10	--	10	--	No	0.10

*A surcharge occurs when inflow to sanitary sewers exceeds line capacity and untreated sewage enters the stormwater system or local water bodies.

the average frequency. Five events may represent a conservative number due to the dry conditions experienced during the 1987-88 wet weather season.

Table 6 contains stormwater data collected by Ecology during both years of study. Station 4 is the large city stormwater culvert that discharges directly to the bay. The high concentration measured on March 4, 1987, represents a surcharging event. The remainder of the samples were collected during normal stormwater flow. Results are similar to those obtained by the city (i.e., FC concentrations can vary widely). Because discharge from the culvert can only be measured during low tides, there is little flow data. No flow data are available from a heavy rainfall or surcharging conditions. Consequently, the magnitude of the impact during worse case conditions is not known. The information available indicates both flow and concentration may be very high. These data reinforce the importance of this discharge as an FC loading source to Oakland Bay.

Sd1 and Sd2 are two small stormwater discharges located in the lower end of Shelton Creek. Sd2 has been identified as an important FC source. Although the volume being discharged from this source is not great, the concentration is consistently high (Table 6). Both of these discharges continue to flow even during relatively dry conditions. County personnel have reported measurable discharge during summertime sampling and have also stated the concentration in Sd2 is frequently high during this period (K. Seiders, 1988).

Sd4 is a large vertical culvert that is part of the formal stormwater collection system for the city. It was monitored by county personnel. Measured FC concentrations in this discharge ranged from 1-1950 org./100 mL (GMV=55) (Brown and Caldwell, 1988b). This discharge too appears to flow year round, and the volume discharged appears quite high, although flow measurements were never taken at this standpipe. It is not known what the source of water is to Sd4 (S. Symes, 1988). The typically low concentration and high volume indicate that perhaps the source is ground water and the infrequently high FC concentrations measured are due to stormwater influence.

It is apparent from the information described that city stormwater is impacting water quality in the creeks and inner harbor. Because there are little data on the volume being discharged and still no data from a typical wet weather period, it is difficult to determine the magnitude of the impact or to further pinpoint specific problem areas. The few discrete stormwater samples collected indicate; 1) FC loading varies widely due to extreme changes in flow and concentration, and 2) during surcharging events, stormwater quality is severely impacted.

Eliminating overflow events has been identified as the first goal for rehabilitation of the sanitary sewer system (Brown and Caldwell, 1988A). The implementation program also will address a plan for extending the sewer system to include unsewered portions of the city, such as Capitol Hill. Rehabilitation of individual sewer basins will also occur over time. The primary goal of the sanitary sewer improvement project is to redirect storm and groundwaters from the sanitary sewer line to the stormwater system (i.e., Goldsborough and Shelton Creeks and the inner harbor). Given the redirected stormwater has bacteria concentrations similar to the stormwater currently entering the creek, an increase may occur in bacteria loading to Goldsborough Creek during typical wet weather flow conditions. However, it is expected

Table 6. Fecal coliform bacteria concentrations and flows measued in city stormwater discharges during both study periods.

Station	4		Sd1		Sd2		Sd4*	Gd1
	FC Conc. (#/100 mL)	Flow (cfs)	FC Conc. (#/100 mL)	Flow (cfs)	FC Conc. (#/100 mL)	Flow (cfs)	FC Conc. (#/100 mL)	FC Conc. (#/100 mL)
02/25/87	570							
03/04/87	56,000							
03/18/87	<4	1.83	6,700		1	0.19		
03/31/87	11		8		>600			
04/15/87	1,200	2.16	60	0.15	2,100	0.63		
04/28/87	180	1.44	19	0.16	340	0.41		
05/27/87	9	0.80	3	0.06	290	0.14		
10/07/87	88		40	0.25	8,000	0.17		
11/16/87			28	0.03	43	0.16		
12/02/87	600		56	0.68	210	0.36		
12/22/87	23		27		2,750	0.34		
01/11/88	60		1	0.08	100	0.41		
01/25/88	71		1	0.30	152	0.26	3	
02/08/88	310	1.89			1,890			970

*Sd4 also was sampled by city of Shelton personnel during the 1988 wet weather period. The range in concentrations measured was 1-1,950 org./100 mL. The geometric mean value was 55 org./100 mL.

rehabilitation of the sanitary sewer system will result in discovery and removal of some sanitary sources to the stormwater system. Also inclusion of unsewered portions of town in the sanitary system will result in removal of septic sources. These changes may cause an improvement in the overall quality of the stormwater being discharged. Thus even though the quantity will be increased, possible negative effects may be counteracted by the improved quality. In any case, elimination of sanitary sewer inputs from surcharging events should have a marked effect on decreasing the total load of FC to the bay.

Industrial Dischargers

Fecal coliform concentrations in the ITT discharge have been greatly decreased. The geometric mean concentration for the spring study was 24,200 org./100 mL (Appendix II). This compares to 45 org./100 mL for the winter study (Appendix I). The improvement is due to bypassing an equalization tank in the discharge line (P. Hamlin, 1987). Apparently the tank served as an incubation vessel for the bacteria. The discharge permit for ITT is still under review by Ecology. It is likely a new permit will include monitoring requirements for fecal coliform bacteria.

Simpson Timber Company no longer discharges non-contact cooling water to the bay. However, the pipes remain and convey stormwater. Station 7 (Figure 4) was previously a cooling water discharge and part of the routine monitoring program in the spring study. It was sampled during the winter study when there was enough discharge from the pipe to merit sampling. High bacteria concentrations were measured at these times (Table 7). Station 10 was also a non-contact cooling water discharge during the spring study. This station had consistently low FC concentrations during the spring. After the cooling water was removed the low volume precluded sampling. Station 13 was also a non-contact cooling water discharge. As with Station 10, FC concentrations were typically low. One high concentration (3000 org./100 mL) was measured during a storm event when the discharge was very turbid. This and other results indicate that concentrations although quite low on the average in these stormwater discharges, can occasionally become very high. However, data on winter wet weather conditions are necessary to determine the typical concentrations and flow during this critical period.

Simpson stormwater impact was indirectly measured at Stations 15, 16, and 17 (Table 7). Station 15 is an inaccessible stormwater discharge except at very low tides. As a result samples were typically collected from the discharge plume. Station 15 had high FC concentrations even though a mixed sample (stormwater and marine water) was usually collected. The average percent KES was 35, which indicates the majority of the bacteria were definitely of mammalian origin (E. coli). Stations 16 and 17 are located about 15 feet offshore of where stormwater discharges are thought to be located. FC concentration at Stations 16 and 17 was usually high; very little of the bacteria population at these stations (0-7 percent) could be attributed to bacteria forms other than E. coli.

There are also many small pipes on the Simpson shore of lower Shelton Creek. These pipes only flow after rain events. A one-time sampling of one of these pipes during a rainstorm resulted in a bacteria concentration of 2300 org./100 mL. Sampling results for this station and

Table 7. Stormwater discharge and nearshore station fecal coliform bacteria concentration results for assessment of industrial runoff impacts. Numbers in parenthesis represent the number of samples collected.

	Number of Samples	Range of Results	Geometric Mean (1987-88)	Geometric Mean (1988)	Geometric Mean (1987)
Stormwater					
7	3*	124-18,000	3,293		
15	11**	6- 5,000	267	450 (7)	
13	5	<1- 3,000	31		
10	1*	1			
3	1	3,700			
5	8	3- 34			
Sd5	1	2,300			
Nearshore Stations					
16	11	6- 1,600	102 (11)	159 (7)	47 (4)
17	12	<2- 3,300	41 (12)	77 (7)	17 (5)
32	11	6- 1,100	83 (11)	194 (7)	13 (4)
33	12	3- 1,600	48 (12)	67 (7)	29 (5)
34	13	9- 5,200	222 (13)	84 (7)	280 (6)

*Previously a cooling water discharge. Consequently, results from only the 1988 study year have been used.

**Majority of samples were collected from the discharge plume and are therefore not discrete stormwater samples.

Class B Marine water quality standards require a geometric mean value below 100 org./100 mL, with fewer than 10 percent of samples exceeding 200 org./100 mL.

other infrequently monitored industrial stormwater stations are included in Table 7. As shown, FC concentrations can be quite high at these stations. However, the volume discharged appears to be small.

Estimating the impact of stormwater discharges from Simpson Timber Company is very difficult. There are many points of discharge located along the inner harbor and Goldsborough and Shelton Creeks. Many are not readily accessible for monitoring. The data that have been collected indicate that both flow and concentration are highly variable, as would be expected. High concentrations of FC bacteria are common in runoff from forest products industries, but these should test high for percent KES, indicating a non-mammalian origin for the bacteria. This was not the case in most of the samples. The samples collected from Stations 7 and 15 indicate FC concentrations can be quite high. The high concentrations appear to be reflected at Stations 16, 17, and 32 (mid-inner harbor).

In the past runoff from Manke Lumber Company property has been very turbid with a visible sheen from oils and grease. The poor quality runoff water was from the unpaved log sort yard and truck wash facility located on the property. Ecology's Southwest Regional Office had required the company to develop a plan for control of their runoff. A new closed-loop truck wash system was installed on the property and operating during the 1988 study period. The system should have decreased the discharge of solvents, oil and grease, and suspended solids from the property. Two samples of stormwater runoff collected from Manke property during the winter study had high bacteria concentrations (3300 and 20,670 org./100 mL). This indicates the log sort yard remains a large source of bacteria during storm events.

<u>Oakland Bay Water Quality</u>

Oakland Bay was again declared "Restricted" for shellfish harvest from early December 1987 to mid-May 1988. The restriction was based on samples collected by DSHS between mid-November and early December. During the Ecology winter study period, the inner harbor did not meet State water quality standards for a Class B water (Table 8). During the spring study the inner harbor had met Class B standards. The Mann-Whitney test indicated there was a significant difference between the two sampling periods.

Ecology results from the mid-inner harbor stations (#32, #33, and #34) also reflect a change from the spring study. Concentrations appear to be higher at Stations 32 and 33. Conversely, Station 34 had lower FC concentrations. This station was selected to represent the impact of the ITT discharge. The lower concentrations measured assumably correspond to the much lower ITT effluent bacteria concentrations. The higher concentrations measured at Stations 32 and 33 are consistent with the measured increase at the other marine water stations. As stated previously, there was no increase in FC loading from the inner harbor streams during the winter study period; flow, concentration, and API were similar to what had been measured in the spring. However, as shown in Figure 5, even with drought conditions, there was greater rainfall during the winter study period. Thus even though the calculated "instantaneous" loadings were similar between the study periods, it is likely a more constant higher load of FC bacteria was being discharged during the winter study. This may account in part for the increased inner harbor concentrations.

Table 8. Fecal coliform bacteria concentrations, stream flow, and calculated bacteria loading results for Shelton Creek during the winter study period.

Station Number	1987 10/07	1987 11/16	1987 12/02	1987 12/22	1988 01/11	1988 01/25	1988 02/08	Geometric Mean (winter)	Geometric Mean (spring)
14						2	90		14
15	43	400	400	650	74	2,300	5,000	450	107
16	240	1,500	230	1,600	8	9	270	159	47
17	20	745	460	200	3	6	660	77	17
21	28	76	18	59		2	160	30	
22	45	190	37	88	3	3	110	31	17
23			37		8				
24	45	160	220	100	26	20	400	85	31
25	37	120	200	80	54	17	210	75	17
26	16	210		47	8	18	63	39	
32		740	200	1,100	10	40	815	194	13
33	3	500	770	62	9	6	1,600	67	29
34	310	370	34	31	9	43	620	84	280
Geometric Mean	38	320	134	150	11	16	367		
Percent Greater Than 200	20	99	63	27	0	9	75		

All stations are within the portion of Oakland Bay classified as a Class B water. To meet Class B water quality standards, the geometric mean value must be less than or equal to 100 org./100 mL, with no more than 10 percent of the samples greater than 200.

The increased concentration could also be due to increased loading from outer bay streams. Some monitoring of streams discharging to the outer bay was conducted by both Mason County and DSHS (Brown and Caldwell, 1988B). FC bacteria concentrations were periodically high in some of the creeks. However, inner harbor FC concentrations continued to be higher than those measured in the outer bay, indicating an inner harbor source for the bacteria. (A more detailed discussion of results from outer bay sampling will be developed by the city's consultant [Brown and Caldwell] and will be included in the Oakland Bay Watershed Action Plan.)

It has been suggested that sanitary sewer overflow events are "supercharging" the bay with bacteria. These bacteria might then be available in the sediments for long periods after the overflow event. With each rainfall, additional bacteria would be added and the bay continually recharged. However, high concentrations were measured in Oakland Bay in mid-November well before the first surcharging event, though right after the first good rainfall of the season. This emphasizes the probable importance of stormwater alone to bay water quality. There are also physical and biological conditions that vary between seasons and affect bacteria concentrations. Tidal exchange, temperature, and photoperiod may be affecting dilution, predator activity levels, and bacterial survival rates. These factors may play a role in determining how much influence a given stream loading may have on resultant bay FC concentrations.

CONCLUSIONS

Neither Shelton nor Goldsborough Creeks met Class A water quality standards and both are important fecal coliform bacteria loading sources to the inner harbor. Goldsborough Creek met the standard at Station G(0.5) above the industrialized portion of the city. However, standards were not met at the creek mouth, implicating industrial discharges in the last half river mile as important sources. Shelton Creek appeared to have higher concentrations and be more affected by rain events than Goldsborough. It did not meet water quality standards below Station S(0.9) (i.e., below the influence of city inputs). The difference in impact of pollutants on the two systems is likely due to the lower ratio of water volume to urban watershed in Shelton Creek. These results and relationships discussed may change under high flow or wet weather conditions.

Both city and industrial stormwater sources impact water quality in the creeks and the inner bay. This is supported by the fact that bacteria concentrations increase with distance downstream and with rain events. It is expected these impacts would be more significant during a typical wet weather period. There are no other known remaining discharges that are likely to be affecting stream or inner bay quality. The ITT Rayonier discharge now has quite low FC concentrations, Simpson no longer maintains cooling water discharges, and the wastewater treatment plant discharge continues to meet the requirements of its NPDES permit in terms of bacteria concentrations. Overflowing of sanitary sewers to the stormwater system can cause extreme case loading conditions, but overflowing occurs too infrequently to account for the continually high wet weather bay concentrations. The Federal Water Quality Act of 1987 requires EPA to issue regulations for stormwater from smaller cities (populations less than 100,000) by October 1992. The city of Shelton will be required to meet the new regulations. In the meantime, a watershed management committee has been formed for Oakland bay. The committee is developing an "Action Plan" for protection of the Bay from non-point pollution sources. One of the elements of this plan will address stormwater control strategies.

Shelton's sewer collection system improvement program will result in a direct improvement to creek and harbor water quality by eliminating or greatly decreasing the frequency of overflow events. The program will cause an increase in the amount of stormwater that enters the creeks and bay, but should also result in an improvement in the quality of stormwater discharged.

The objective of the winter study was to assess the impact of wet weather conditions on FC bacteria concentrations and to estimate the impact from industrial stormwater. These objectives were not fully met due to the drought conditions experienced. The lack of rainfall resulted in stream flows and bacteria concentrations that were no higher than those measured in the earlier spring study. In addition, FC concentrations in the ITT effluent were greatly decreased. Therefore, the total FC loading to the inner harbor should have been lower than what was measured during the spring of 1987 when the inner harbor met Class B water quality standards. Yet inner harbor FC concentrations were higher during this study; Class B standards were not met in the inner harbor, and the bay was "restricted" to shellfish harvest throughout the wet weather period.

In conclusion, Oakland Bay water quality continued to be poor during the winter study even though there was comparatively little rainfall and an important bacteria source (ITT) was greatly decreased. It is likely the bay will continue to be placed on restricted status for shellfish harvest during winter months for the foreseeable future. Sanitary sewer problems will be corrected as a result of the collection system improvement program. However, stormwater quality and quantity issues are not being directly addressed. Industrial stormwater discharges also appear to be a problem source. There are no known plans for control of this source.

RECOMMENDATIONS

- City and county staff should continue monitoring creeks and stormwater during the wet weather period. Monitoring should be used to determine which stormwater basins are most important in terms of FC loads and influence by rain events. Simultaneous stream monitoring must occur to determine whether stormwater impact changes as the implementation program progresses.

- By 1992, the important initial steps of the collection system improvement plan will be near or have been completed; sanitary sewer overflow events will be greatly reduced, and the most critical sewer sub-basins will have been upgraded. By this time new federal regulations for stormwater should also have been written. The collection system implementation program should then be reassessed to determine whether to go forward with implementation as designed or to address stormwater control and treatment.

- Inner harbor and other bayside industries need to develop stormwater control plans, including areas such as log sort yards which contribute large amounts of bacteria, suspended solids and other pollutants.

- A new permit for ITT Rayonier should define a fecal coliform bacteria limit and monitoring requirements.

- Further investigation into the magnitude and impact of industrial site runoff on inner harbor water quality is needed.

- To protect the watershed during future development, city and county ordinances pertaining to stormwater control, on-site systems, and zoning restrictions should be reviewed, or developed, and enforced.

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APPENDICES

Appendix I. Monitoring results from Oakland Bay winter study - 1987-88

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Point Sources					
1	10/07/87	700	0	0.93	1.59E+09
	11/16/87	96 J	J	0.54	1.27E+08
	12/02/87	17	25	0.63 *	2.62E+07
	12/22/87	0		0.63 *	0.00E+00
	01/11/88	13		0.63 *	2.00E+07
	01/11/88	9	42	0.63 *	1.39E+07
	01/25/88	230 J		0.63 *	3.55E+08
	01/25/88	47 J	10	0.63 *	7.25E+07
	02/08/88	210	19	0.63 *	3.24E+08
2	12/02/87	3300 M	30		
	02/08/88	20670	0		
3	12/02/87	3700 M		0.00	1.81E+07
4	10/07/87	88 J	11 J		
	12/02/87	600	11		
	12/22/87	23			
	01/11/88	60			
	01/25/88	71			
	02/08/88	310		1.89	1.43E+09
	02/09/88	390	3		
5	10/07/87	1 U		0.05	1.22E+05
	12/02/87	34		0.00	2.50E+05
	01/11/88	9			
	01/25/88	7		0.04	6.85E+05
7	12/02/87	16000 P		0.01	3.13E+08
	01/11/88	124			
	02/08/88	18000			
9	10/07/87	6			
	11/16/87	7			
	12/02/87	3			
	12/22/87	13			
	01/11/88	1 U			
	01/11/88	2			
	01/25/88	33			
10	10/07/87	1	0		
13	12/02/87	1400 M	33		
8	10/07/87	16	0		
14	01/25/88	2			
	02/08/88	90			

Appendix I - continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Inner Bay Stations					
15	10/07/87	43	10		
	11/16/87	400	1		
	12/02/87	400 J	0		
	12/22/87	650 J	82		
	01/11/88	74	39		
	01/25/88	2300 J	100		
	02/08/88	5000	14		
16	10/07/87	240			
	11/16/87	1500	2		
	12/02/87	230	0		
	12/22/87	1600	0		
	01/11/88	8 U	NA		
	01/25/88	9	0		
	02/08/88	270	4		
16b	01/25/88	46	0		
17	10/07/87	20			
	11/16/87	745	6		
	12/02/87	460	7		
	12/22/87	200	0		
	01/11/88	3 U	NA		
	01/25/88	6	0		
	02/08/88	660			
21	10/07/87	28			
	11/16/87	76			
	12/02/87	18			
	12/22/87	59			
	01/25/88	2			
	02/08/88	160			
22	10/07/87	45			
	11/16/87	190			
	12/02/87	37			
	12/22/87	88			
	01/11/88	3			
	01/25/88	3			
	02/08/88	110			
23	12/02/87	37			
	01/11/88	8	0		
24	10/07/87	45			
	11/16/87	160			
	12/02/87	220			
	12/22/87	100			
	01/11/88	26			
	01/25/88	20	0		
	02/08/88	400	3		

Appendix I - continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Inner Bay Stations - continued					
25	10/07/87	37			
	11/16/87	120			
	12/02/87	200			
	12/22/87	80			
	01/11/88	54	0		
	01/25/88	17			
	01/25/88	17			
	02/08/88	210	0		
26	11/16/87	210			
	12/22/87	47			
	01/11/88	8			
	01/25/88	18			
	02/08/88	63			
32	11/16/87	740	3		
	12/02/87	200	10		
	12/22/87	1100	0		
	01/11/88	10	0		
	01/25/88	40	0		
	02/08/88	970	0		
	02/08/88	660			
33	10/07/87	3	0		
	11/16/87	500	0		
	12/02/87	770	0		
	12/22/87	62	0		
	01/11/88	9	50		
	01/25/88	6	0		
	02/08/88	1600	0		
34	10/07/87	310	0		
	11/16/87	370 J	0		
	12/02/87	34	0		
	12/22/87	31	0		
	01/11/88	9	0		
	01/25/88	43 J	44		
	02/08/88	620	8		
Stream Stations					
Shelton S(0.0)	10/07/87	600	0		
	11/16/87	200			
	01/25/88	34	0		
Sd1	10/07/87	40		0.25	2.45E+07
	11/16/87	28		0.03	2.06E+06
	12/02/87	56		0.68	9.32E+07
	12/22/87	27			
	01/11/88	1 U		0.08	1.96E+05
	01/25/88	1 U		0.30	7.34E+05

Appendix I - continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Stream Stations - continued					
Shelton - continued					
Sd2	10/07/87	8000		0.17	3.33E+09
	11/16/87	43		0.16	1.68E+07
	12/02/87	210		0.36	1.85E+08
	12/22/87	2750 J	0	0.34	2.29E+09
	01/11/88	100		0.41	1.00E+08
	01/25/88	152	8	0.26	9.67E+07
	02/08/88	1890			
S(0.2)	10/07/87	84		3.21	6.60E+08
	11/16/87	1500		3.46	1.27E+10
	12/02/87	3100		6.77	5.14E+10
	12/22/87	28		7.67	5.25E+08
	01/11/88	38		9.30	8.65E+08
	01/25/88	11		9.02	2.43E+08
	01/25/88	11			
	02/08/88	2400			
	02/09/88	270			
Sd4	01/25/88	3 U			
Sd5	02/08/88	2300			
Sn(0.4)	10/07/87	92		2.10	4.73E+08
	11/16/87	35		2.85	2.44E+08
	12/02/87	700		5.98	1.02E+10
	12/22/87	17		4.21	1.75E+08
	01/11/88	43		9.54	1.00E+09
	01/25/88	22		3.41	1.84E+08
	02/08/88	110		4.49	1.21E+09
	02/09/88	240			
Sw(0.5)	10/07/87	4		0.38	3.72E+06
	11/16/87	84		0.26	5.34E+07
	12/02/87	1100	6	1.66	4.47E+09
	12/22/87	15		2.98	1.09E+08
	01/11/88	3		2.94	2.16E+07
	01/25/88	3		3.28	2.41E+07
	02/08/88	1700		4.41	1.83E+10
	02/09/88	100			
Sw(0.9)	10/07/87	1			
	11/16/87	7 J		0.27	4.62E+06
	12/02/87	500			
	12/22/87	0			
	01/11/88	9			
	01/25/88	1 U			
	02/08/88	180			
Sw(1.0)	10/07/87	1 U			
	12/02/87	1 U			

Appendix I - continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Stream Stations - continued					
Goldsborough					
G(0.0)	10/07/87	49	0		
	12/02/87	250	0		
	12/22/87	970			
	01/11/88	250			
	01/25/88	17	0		
	02/08/88	71	0		
Gd1	02/08/88	970			
G(0.4)	01/11/88	17			
	01/25/88	6			
	02/08/88	57			
	02/08/88	34			
G(0.5)	10/07/87	9		19.44	4.28E+08
	11/16/87	13		44.23	1.41E+09
	12/02/87	96		125.94	2.96E+10
	12/22/87	26		131.69	8.38E+09
	01/11/88	10		128.12	3.13E+09
	01/25/88	9	0	116.12	2.56E+09
	02/08/88	18		192.60	8.48E+09
	02/09/88	33			
G(1.9)	10/07/87	6			
	11/16/87	2			
	12/02/87	72			
	12/22/87	15			
	01/11/88	6			
	01/25/88	3			
	02/08/88	21			

J= Many background organisms
M= MPN procedure used due to high turbidity of sample.
U= Less than
P= Greater than

*An average of measured flows was used to calculate loadings because flow variations were random and not seasonally affected.

Appendix II. Monitoring results from Oakland Bay spring study - 1987

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
<u>Point Sources</u>					
1	02/25/87	90000	0	0.47	1.0E+11
	02/25/87	72000	0	0.47	8.3E+10
	03/04/87	10000	100	0.59	1.4E+10
	03/04/87	13000	100	0.59	1.9E+10
	03/18/87	22000	100	0.67	3.6E+10
	03/31/87	27000	100		
	03/31/87	41000			
	04/15/87	36500	100	0.54*	4.8E+10
	04/28/87	10000	100	0.49	1.2E+10
	05/27/87	18300	100	1.03	4.6E+10
1M	03/04/87	24000	100		
	03/31/87	27000	100		
2	03/10/87	3000	73		
9	02/25/87	20	0		
	02/25/87	69	0		
	03/04/87	160			
	03/04/87	260			
	03/31/87	55			
	04/15/87	2			
	04/28/87	6			
	05/27/87	<3			
4	02/25/87	900	8		
	02/25/87	240	0		
	03/04/87	57000	1		
	03/18/87	<4	0	1.83	0.0E+00
	03/31/87	11	0		
	04/15/87	1200		2.16	6.3E+09
	04/28/87	180	0	1.44	6.3E+08
	05/27/87	9		0.80	1.8E+07
4b	03/04/87	800	0		
	03/18/87	26			
Barge	05/27/87	<3		0.16	0.0E+00
5	02/25/87	8	0	0.05	9.8E+05
	02/25/87	9	0		
	03/18/87	4	0		
	03/18/87	12			
	04/28/87	3		0.05	3.7E+05
7	02/25/87	11	0	0.12	3.2E+06
	03/18/87	270	100	0.11	7.3E+07
	03/18/87	300			
	03/31/87	16	50		
	03/31/87	14			
	04/15/87	TNTC		0.16	
	04/28/87	34	86	0.10	8.3E+06
	05/27/87	4000			
7b	04/28/87	210	81		

Appendix II- continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Point Sources - continued					
10	02/25/87	18	0	0.32	1.4E+07
	02/25/87	11	0		
	03/18/87	8		1.10	2.2E+07
	03/31/87	4			
	05/27/87	6			
13	02/25/87	<1		0.01	0.0E+00
	03/10/87	3000	0		
	03/31/87	<1	NA		
	04/28/87	<1	NA		
30	03/04/87	<4			
Inner Bay Stations					
21	03/18/87	2			
22	02/25/87	3	6		
	03/04/87	180			
	03/18/87	7			
	03/31/87	54			
	04/15/87	8			
	04/28/87	20			
	05/27/87	14	0		
23	03/18/87	10	40		
	03/31/87	66			
24	02/25/87	1	0		
	03/04/87	41			
	03/18/87	12			
	03/31/87	96			
	04/15/87	76			
	04/28/87	80	5		
	05/27/87	100			
25	02/25/87	1	<1		
	03/04/87	59			
	03/18/87	<4	0		
	03/31/87	53			
	04/15/87	150			
	04/28/87	46			
	05/27/87	23			
26	03/18/87	18			
	05/27/87	34	0		
8	04/15/87	97	4		
	04/28/87	34			
YC	04/15/87	<3			
14	03/04/87	240			
	03/18/87	<7			
	03/31/87	6			
	04/15/87	6			
	04/28/87	72			

Appendix II - continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
<u>Inner Bay Samples</u> - continued					
15	03/18/87	70	31		
	03/31/87	140	31		
	04/15/87	2200	3		
	04/18/87	6	50		
16	03/18/87	6	0		
	03/31/87	48			
	04/15/87	130	0		
	04/28/87	130	0		
17	03/18/87	<2	0		
	03/31/87	120			
	04/15/87	3200	50		
	04/28/87	4	0		
32	03/18/87	28	0		
	03/31/87	16			
	03/31/87	28			
	04/15/87	8			
	04/28/87	6	0		
33	03/18/87	6	0		
	03/31/87	60			
	04/15/87	56			
	04/28/87	6	20		
	05/27/87	180			
34	02/25/87	900	0		
	02/25/87	1200	0		
	03/04/87	2600			
	03/31/87	48	58		
	04/15/87	5200			
	04/28/87	<10	NA		
	05/27/87	700	100		
<u>Stream Stations</u>					
G(0.0)	02/25/87	23	0		
	02/25/87	71	6		
	03/04/87	45	6	1158.00	1.3E+11
	03/04/87	40			
	03/31/87	84			
G(0.5)	02/25/87	3			
	03/04/87	35			
	03/02/87	86	0		
	03/18/87	10			
	03/31/87	12			
	04/15/87	44		184.00	2.0E+10
	04/28/87	7		108.40	1.9E+09
	05/27/87	6		63.31	9.3E+08

Appendix II - continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Stream Stations - continued					
G(1.9)	02/25/87	5		126.84	1.6E+09
	03/04/87	33			
	03/02/87	69			
	04/28/87	6			
	04/27/87	40			
Gd2	03/02/87	96	0		
Gd3	03/02/87	130	19		
	04/28/87	6			
	05/27/87	92			
S(0.0)	03/18/87	360		13.30	1.2E+10
	03/31/87	2500			
	04/15/87	260		11.81	
	04/28/87	23		8.49	
	05/27/87	69	0	6.73	
Sd1	03/18/87	6700		0.61	1.0E+10
	03/31/87	8			
	04/15/87	60		0.15	2.2E+07
	04/28/87	19		0.16	7.4E+06
	05/27/87	3		0.06	4.4E+05
Sd2	03/18/87	1		0.19	4.6E+05
	03/31/87	TNTC			
	04/15/87	2100		0.63	3.2E+09
	04/28/87	340		0.41	3.4E+08
	05/27/87	290		0.14	9.9E+07
S(0.2)	02/25/87	15	0	8.48	3.1E+08
	02/25/87	15			
	03/02/87	500	14		
	03/04/87	75	0	21.80	4.0E+09
	03/18/87	75		12.50	2.3E+09
	03/31/87	20			
	04/15/87	230		11.03	6.2E+09
	04/28/87	26		7.92	5.0E+08
	05/27/87	20		6.53	3.2E+08
Sn(0.4)	03/02/87	670		25.76	4.2E+10
	03/04/87	60		17.50	2.6E+09
	03/31/87	43			
	04/15/87	150		4.86	1.8E+09
	04/28/87	43		4.31	4.5E+08
	05/27/87	270		3.57	2.4E+09
Sw(0.5)	02/25/87	1			
	03/02/87	270		4.93	3.3E+09
	03/04/87	80		5.21	1.0E+09
	03/31/87	8			
	04/15/87	79		3.71	7.2E+08
	04/28/87	1		3.55	8.7E+06
	05/27/87	<3		2.54	0.0E+00

Appendix II - continued.

Station	Date	Fecal Coliform (#/100 mL)	Percent KES	Flow (cfs)	Loading (#/day)
Stream Stations - continued					
Sw(0.9)	03/02/87	60			
Sw(1.0)	02/25/87	1		4.22	1.0E+07
	03/02/87	190		3.27	1.5E+09
	03/04/87	110		4.66	1.3E+09
	05/27/87	3		2.66	2.0E+07
Uncrk	03/18/87	5			

APPENDIX III. Description of sampling stations monitored in the Oakland Bay studies.

Station	Description
Point Sources	
1	ITT Rayonier research laboratory effluent collected from the end of the outfall pipe.
1M	ITT Rayonier research laboratory effluent collected from a manhole just upstream of the outfall pipe.
2	Overland runoff from Manke Lumber Company property.
3	Industrial stormwater discharge pipe.
4	City of Shelton 54" stormwater discharge culvert.
4b	Uncontained flow discharging alongside the 54" stormwater culvert.
Barge	Uncontained flow discharging under the barge located next to the 54" stormwater culvert.
5	Industrial stormwater discharge pipe.
7	Non-contact cooling water plus stormwater discharge during the spring study. Stormwater discharge only during the winter study.
7b	Uncontained flow discharging near #7.
9	City of Shelton wastewater treatment plant discharge.
10	Non-contact cooling water discharge plus stormwater discharge during the spring study. Stormwater discharge only during the winter study.
13	Industrial stormwater discharge.
30	Stormwater discharge from the steep hillside along the southern shore of the inner harbor.
Inner Bay Stations	
21-26	Transect stations located across the mouth of the inner harbor.
8	Marine station located near the southern shore of the inner harbor, south of the last transect station.

APPENDIX III. - continued.

Station	Description
Inner Bay Stations - continued	
YC	Marine station located near the Shelton Yacht Club.
14	Marine station just north of the mouth of Shelton Creek and the boat ramp.
15	Simpson stormwater discharge.
16	Marine station located approximately fifteen feet offshore from where a Simpson stormwater discharge is believed to exist.
16b	Marine station approximately twenty feet south of station 16.
17	Marine station located approximately fifteen feet offshore from where a Simpson stormwater discharge is believed to exist.
32	Marine water station located in the northern section of the inner harbor; east of stations 16 and 17, but west of the transect stations.
33	Marine water station in the southern section of the inner harbor; east of discharges #4,10, and 13, but west of the transect stations.
34	Marine water station located approximately 150 feet offshore from the ITT Rayonier effluent discharge.
Stream Stations	
S(0.0)	Shelton Creek station at the river mouth. Previously named S1m.
Sd1	Stormwater discharge on northern bank of Shelton Creek approximately fifteen feet upstream of S(0.0).
Sd2	Stormwater discharge on northern bank of Shelton Creek at approximately river mile 0.05.
Sd4	Large vertical city stormwater discharge located on the southern bank of Shelton Creek behind the Front St. pump station, upstream of S(0.2).
S(0.2)	Shelton Creek at river mile 0.2. Previously named S1.

APPENDIX III. - continued.

Station	Description
Stream Stations - continued	
Sd5	Industrial stormwater discharge located on the southern bank of Shelton Creek near S(0.2).
Sn(0.4)	Station on the northern tributary of Shelton Creek located 0.4 river miles upstream of the mouth, just upstream of the confluence with the northern tributary. Previously named Strm.
Sw(0.5)	Station on the western tributary of Shelton Creek located 0.5 river miles upstream of the mouth, just upstream of the confluence with the northern tributary. Previously named Sm.
Sw(0.9)	Shelton Creek station located on the western tributary 0.9 river miles upstream of the mouth. Previously named S2.
Sw(1.0)	Shelton Creek station located on the western tributary 1.0 river miles upstream of the mouth. Previously named Strh.
G(0.0)	Goldsborough Creek at the river mouth. Previously named G1.
Gd1	City stormwater discharge located on the southern bank of Goldsborough Creek at the Front St. bridge.
Gd2	Industrial stormwater runoff that discharges to the northern bank of Goldsborough Creek at river mile 0.3.
Gd3	Industrial stormwater runoff that discharges to the northern bank of Goldsborough Creek at river mile 0.3.
G(0.4)	Goldsborough Creek station located just below the Front St. bridge at river mile 0.4.
G(0.5)	Goldsborough Creek station located above the Front St. bridge at river mile 0.5. Previously named Gm.
G(1.9)	Goldsborough Creek station located above the influence of city stormwater at river mile 1.9. Previously named G2.