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IMPACT OF WESTERN PROCESSING ON WATER QUALITY IN MILL CREEK (KENT, WA)

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Introduction

Early in 1984, state and federal attention on the Western Processing site in Kent focused on planning and implementing cleanup activities. Studies by the Environmental Protection Agency (EPA, 1982 and 1984) and water quality sampling by the Washington State Department of Ecology (WDOE) had identified contamination of surface waters (Mill Creek and the Railroad Ditch) near Western Processing (see Figures 1 and 2). Water quality problems which appeared to be associated with the site included elevated concentrations of several metals (zinc, cadmium, nickel, and copper) and chlorinated volatile organic compounds including trichloroethylene.

Additional water quality problems in the Mill Creek drainage were identified by reviewing receiving water quality monitoring data provided by the Water Resources Section of the Municipality of Metropolitan Seattle (METRO). The most extensive of these records were those for station 0317, located on Mill Creek at the 16th Street Bridge in Renton (Figure 1). Water quality problems identified by these data included chronically low dissolved oxygen concentrations, elevated concentrations of ammonia and nitrate, and periods of high turbidity.

In March 1984, the Water Quality Investigations Section (WQIS) of WDOE proposed a two-phased program to address anticipated water quality data needs in Mill Creek. This proposal was presented to the Hazardous Waste Remedial Action Section of WDOE, and was accepted. Field work began in April 1984. The two phases of the project were:

1. Establishing Routine Ambient Monitoring Sites

   Two water quality monitoring sites were located on Mill Creek, one upstream and one downstream of the Western Processing site. Beginning in April, these stations have been sampled monthly for a wide range of water quality parameters including flow, conventional pollutants, trace metals, and volatile organic priority pollutants (VOAs). Purposes for establishing this data base included; (a) defining "background" (upstream) water quality conditions in Mill Creek, (b) providing a basis for assessing improvements in Mill Creek water quality as cleanup and remedial actions at the Western Processing site proceed, (c) defining the impact of the Western Processing site on Mill Creek water quality on a seasonal basis, and (d) providing necessary ancillary data for determining appropriate water quality criteria for Mill Creek (for instance, a record of hardness data is needed to determine water quality criteria for a number of trace metals).

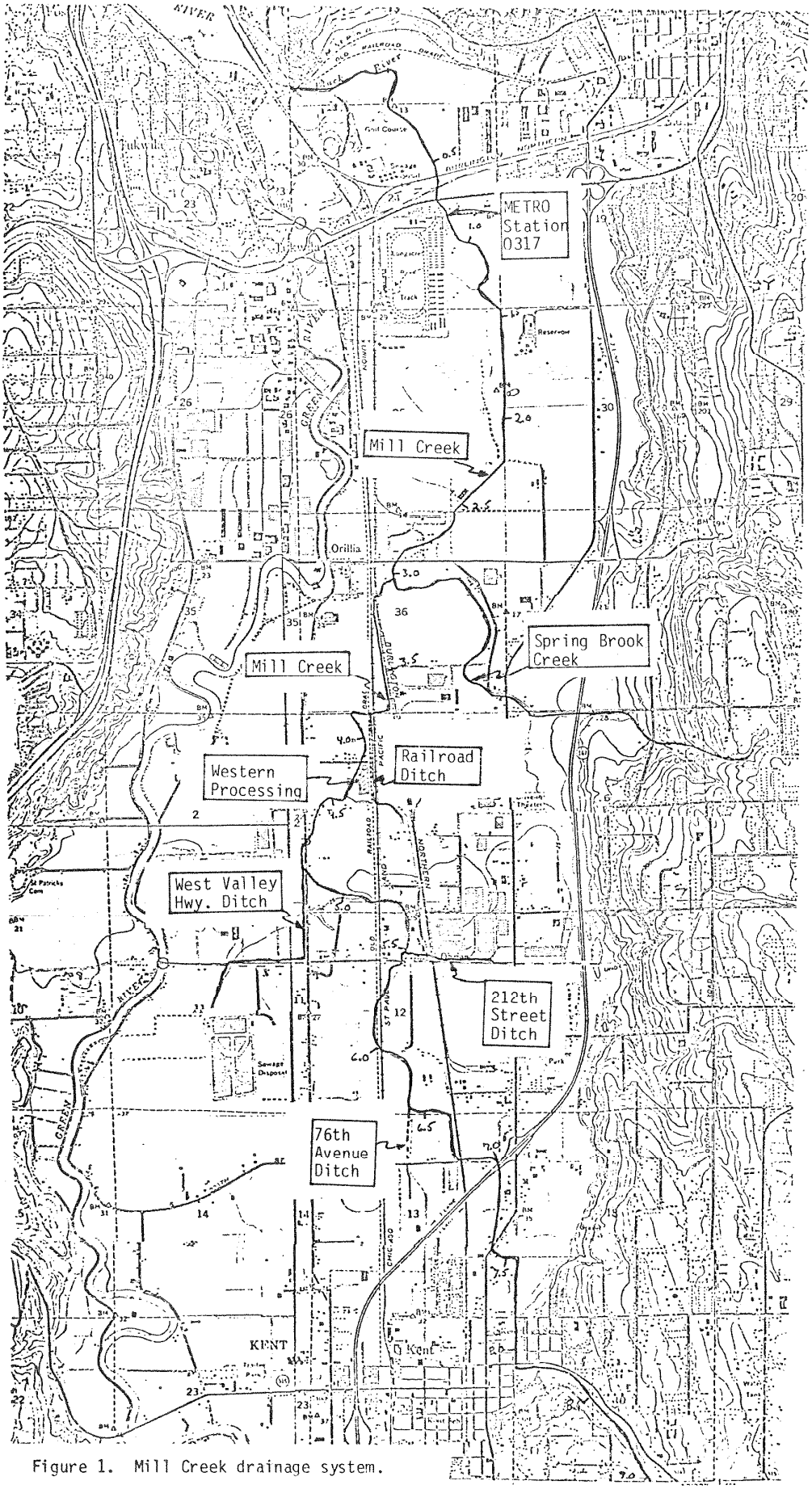
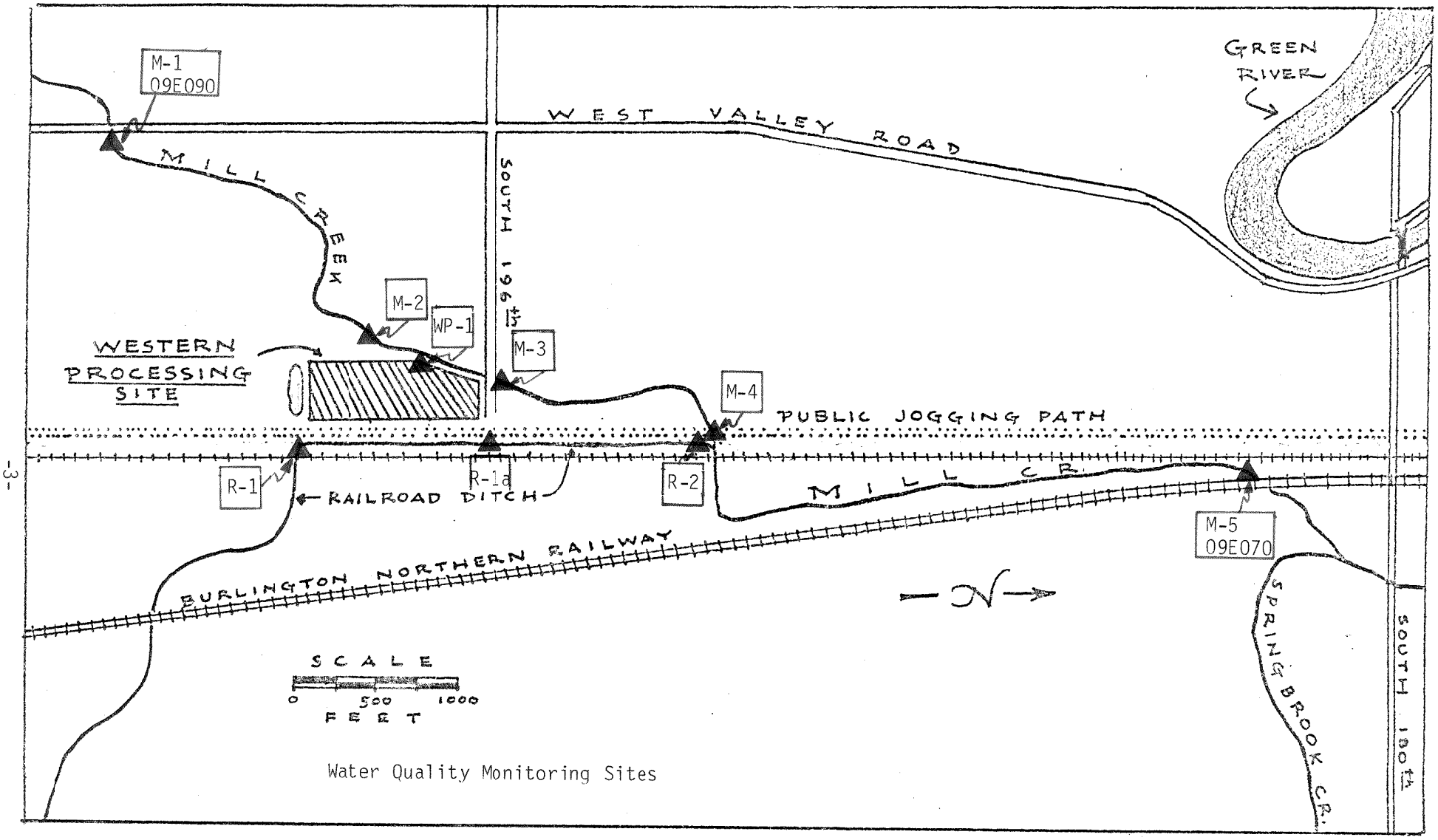


Figure 1. Mill Creek drainage system.



Water Quality Monitoring Sites

Figure 2. Study area: Mill Creek, Railroad Ditch, and Western Processing site.

2. Intensive Surveys on the Mill Creek Drainage in the Vicinity of Western Processing

The original, primary purpose for conducting intensive surveys was to determine if the Western Processing site was contributing to the conventional water quality problems observed at the METRO monitoring station. Secondary purposes included determining approximately where metals and volatiles were entering Mill Creek and the railroad ditch, sampling during both storm- and dry-weather conditions to determine if there were changes in the patterns or degree of contamination, sampling the runoff from the paved portion of the site to determine the extent of pollutant loadings from this source during a rainfall event, and providing a more extensive benchmark data base so that changes in the pattern or degree of contamination after completion of remedial actions could be assessed by post-cleanup receiving water studies.

In addition to the projects outlined above, samples were collected at a number of stations upstream of the Western Processing site in an attempt to better define the dissolved oxygen problem in Mill Creek. Although the root causes of depressed oxygen concentrations in Mill Creek were not fully determined, data and observations stemming from this effort are included. It is hoped that information from this effort will provide a useful base for future work to define and correct the chronically depressed dissolved oxygen concentrations observed.

Setting

The lower Mill Creek drainage system is shown in Figure 1. The lower half-mile of the drainage is a remnant of the Black River which flows into the Green/Duwamish River. The Mill Creek drainage system consists of two streams; Mill Creek and Springbrook Creek. In this report, we adopt the convention of referring to the stream below the confluence of these two creeks as Mill Creek. Both streams arise in the hills east of the Green River Valley and flow west and south along the flat valley flood plain. Much of the length of each stream has been re-routed by channelization. This has resulted in streambanks which are characteristically steep; numerous relatively deep, slow-moving reaches of stream; and a dirt- or silt-covered stream bottom. Small tributaries to Mill Creek are typically dredged ditches paralleling road or railroad right-of-ways.

Land use in the drainage consists primarily of rapidly expanding commercial and light industrial activities interspersed with undeveloped and agricultural parcels.

Figure 2 shows the area near the Western Processing site, and will be discussed in more detail later.

Mill Creek is classified by state law (WAC 173-201-070) as a Class A stream. Applicable water quality standards are given in Table 1.

Table 1. Class A, Freshwater Quality Standards.

Water Quality Parameter	Water Quality Standard
Fecal coliform bacteria	Geometric mean shall not exceed 100 organisms/100 mL. Not more than 10% of samples shall exceed 200 organisms/100 mL.
Dissolved oxygen	Shall exceed 8.0 mg/L.
Temperature	Shall not exceed 18.0°C due to human activities.
pH	Shall be with the range of 6.5 to 8.5.
Turbidity	Shall not exceed 5 NTU over background turbidity when background turbidity is 50 NTU or less. Shall not be more than 10% over background turbidity when background turbidity is more than 50 NTU.
Toxic, radioactive, or deleterious materials	"Concentrations shall be below those of public health significance, or (that) which may cause acute or chronic toxic conditions to aquatic biota, or which may adversely affect any water use."

Routine Ambient Monitoring

As noted in the introduction, two routine ambient monitoring stations were established on Mill Creek in April 1984. These two stations are shown in Figure 2 and are defined below in Table 2.

Table 2. Mill Creek ambient monitoring station information.

Station Name	Routine Network Station Number	Intensive Survey Station Number	Location with Respect to Western Processing	River Mile
Mill Creek - Kent on West Valley Highway	09E090	M-1	upstream	4.66
Mill Creek (Kent) at Orillia	09F070	M-5	downstream	3.14

These stations have been sampled monthly since April 1984 and will continue to be sampled for an, as yet, undefined period into the future. Appendix I lists the April-through-September 1984 data for these stations. Parameters include flow, conventional pollutants, seven metals, and the volatile priority pollutant organics.

Table 3 summarizes ambient monitoring data for parameters for which water quality standards or criteria exist. Concentration ranges and means are listed for each station and compared to appropriate state standards or federal criteria.

General observations about Mill Creek water quality (based on Appendix I and Table 3) follow:

Conventional Pollutants

During the period of record, water quality standards for fecal coliforms and dissolved oxygen were regularly violated. These excursions were noted at both stations and do not appear to be directly related to Western Processing. It is interestng to note that fecal coliform counts at the downstream station were generally lower than upstream. Whether this is due to natural die-off or some increased toxicity between the two stations is unknown. Turbidity was also quite high at both stations.

Several conventional parameters, not listed in Table 3, generally increased as Mill Creek passed the Western Processing property. These are noted in table 4.

Table 4. Conventional water quality parameters in Mill Creek which appear to increase as a result of discharges near Western Processing.

	Mill Creek - West Valley Highway 09E090		Mill Creek (Kent) at Orillia 09E070	
Parameter	Range	Mean	Range	Mean
Specific conductivity (umhos/cm)	250-328	290	184-530	390
Color (S.U.)	130-260	182	160-270	225
NH_3-N (mg/L)	0.32-0.54	0.45	0.57-1.3	1.1
NO_3-N (mg/L)	0.17-0.43	0.32	0.36-1.8	1.1

The only standards or criteria addressing these parameters are the criteria for un-ionized ammonia. Concentrations of un-ionized ammonia in Mill Creek were low, primarily because pH values were less than 7.2. Although the increases in color, conductivity, ammonia, and nitrate do not pose a problem from the perspective of water quality standards or criteria, they do represent water quality degradation apparently associated with groundwater influx in the vicinity of Western Processing.

Table 3. Summary of Mill Creek ambient monitoring data: comparisons to standards and criteria.

Parameter (units)	Standard*		Mill Creek at West Valley Hwy. - 09E090 Range	Mean	Mill Creek at Lower Railroad Crossing - 09E070 Range	Mean
Conventional Pollutants						
fecal coliforms (#/100 mL)	<100 (geometric mean)		80-4400	623†	63-940	298†
dissolved oxygen (mg/L)	>8.0		3.4-7.7	4.8	3.1-6.8	5.3
temperature (°C)	<18.0		10.1-16.7	14.3	10.4-17.7	14.9
pH (S.U.)	6.5 - 8.5		6.7-7.2	6.9	6.8-7.1	7.0
turbidity (NTU)	<5 over background		20-68	35	32-90	52
	Criteria**					
	Chronic	Acute				
Metals (ug/L)††						
cadmium	2.1-6.6[1]	2.1-6.6[1]	0.1u-0.6	(0.2)	6.8-25	17
chromium	44-98[1]	900-2000[1]	1u-13	(4)	1u-24	(12)
copper	6.0-15[1]	8.7-21[1]	1u-33	(19)	30-72	49
lead	1.1-4.0[1]	27-100[1]	1u-14	(8)	1u-70	(26)
mercury	0.20[2]	1.1[2]	0.05u-0.33	(0.09)	0.05u-0.16	(0.06)
nickel	58-120[3]	1100-2300[3]	1u-5	(1)	12-195	102
zinc	47[3]	190-420[3]	3-128	54	415-1915	1105
Volatile Organics (ug/L)						
methylene chloride	--	11,000	2u	<2	2u-42	(17)
chloroform	1,240	28,900	2u-2m	<2	2u-18	(8)
1,1-dichloroethane	--	--	2u	<2	2u-2m	<2
1,1-dichloroethylene	--	11,600	2u	<2	2u-2m	<2
1,2-transdichloroethylene	--	11,600	2u	<2	2u-2m	<2
1,1,1-trichloroethane	--	18,000	2u	<2	2u-8	(3.4)
trichloroethylene	--	45,000	2u-2m	<2	11-31	17
tetrachloroethylene	840	5,280	2u	<2	2m-2.7	(2)
toluene	--	17,500	2u-2m	<2	2u-2m	<2
benzene	--	5,300	2u-2m	<2	2u	<2

*Washington State Water Quality Standards - Class A Freshwaters.
**Federal criteria for the protection of aquatic organisms.

[1]Proposed criteria from Federal Register, V. 49(28), 2/7/84. Concentrations given as "active metal" concentrations. Criteria variable with respect to total hardness. Range listed for hardnesss values measured at both stations.

[2]Proposed criteria from Federal Register, V. 49(28), 2/7/84. Concentrations are "active metal" concentrations.

[3]Criteria from Federal Register, V. 45(231), 11/28/80. Concentrations are "total recoverable metal" concentrations. Criteria variable with respect to total hardness. Range listed for hardness values measured at both stations.

†Geometric mean.
††Metals concentrations measured in Mill Creek as "total recoverable metals."

( ) = Approximate mean.

u = not detected at detection limit given.
m = present, but less than level of quantification given.

Metals

Based on ambient monitoring data, concentrations of all metals (except mercury) measured in Mill Creek increased below Western Processing. Increases in cadmium, nickel, and zinc concentrations were substantial with average concentrations for these metals increasing by 20 to 100 times over upstream concentrations.

The status of federal criteria for several of the metals is currently in a state of flux. Criteria for zinc and nickel were published in 1980 and remain in force. Modified proposed criteria for cadmium, chromium, copper, lead, and mercury were published in February 1984 for public comment, with publication of final criteria slated for January 1985. Status of the proposed criteria was checked with the EPA, Criteria and Standards Division (Tom Purcell, personal communciation), and every effort made to report criteria in Table 3 which would be published in January.

One major difference between the 1980 metals criteria, the 1984 proposed metals criteria, and the metals concentrations measured in Mill Creek is the form in which metals concentrations are reported. The 1980 criteria are given as "total recoverable metals," the February 1984 proposed criteria were originally given as "active metals" and have subsequently been changed to "acid soluble metals." The metals analyses for the present study were performed for "total metals" and "dissolved metals." Given below in order of expected metals recovery from high to low, are brief descriptions of these definitions.

Term	EPA Method[1]	Definition
total metals	4.1.3	HNO_3 digestion of sample, if followed by graphite furnace analysis
total recoverable metals	4.1.4	Digestion only with preserving HNO_3, if followed by graphite furnace analysis
acid soluble metals	--	Adjustment of sample to pH 1, followed by filtration through 0.45 u filter
active metals	--	Adjustment of sample to pH 4, followed by filtration through 0.45 u filter
dissolved metals	4.1.1	Filtration through 0.45 u filter, followed by pH adjustment to ≤ 2

[1]EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020

Based on the information above, the metals fractions measured during this study bracket the criteria fractions. Table 5 gives the average percentage of each of the metals which was reported in the dissolved fraction.

Table 5. Average dissolved metals percentages of total metals.

Metal	Mill Creek at West Valley Highway	Mill Creek at Orillia
Cadmium	<36%	68%
Chromium	<22%	<13%
Copper	<8%	27%
Lead	<14%	<8%
Nickel	--	59%
Zinc	<35%	63%

Based on Table 5, a relatively low percentage of many of the metals was present in the dissolved form; however, the metals of concern (zinc, nickel, cadmium) which were substantially elevated at the downstream station were present primarily in the dissolved form (average of 59 to 68 percent).

The comparison of Mill Creek metals concentrations to criteria in Table 3 takes the conservative approach of comparing "total metals" concentrations to the criteria. Based on this approach, there are violations of at least the chronic criteria at the upstream site for copper, lead, and zinc. Most of the excursions are marginal. Downstream of Western Processing there are severe violations of the zinc and cadmium criteria, substantial excursions of the copper and lead criteria, and marginal violations of the nickel criteria.

Volatile Organic Priority Pollutants

A number of chlorinated volatile organics have been associated with the contamination from the Western Processing site (EPA, 1982, 1984). The routine monitoring data confirms increases in the concentrations of these compounds (most notably trichloroethylene, methylene chloride, chloroform, trichloroethane, and tetrachloroethylene). All concentrations are well below criteria for the protection of aquatic organisms.

Intensive Surveys

As noted in the introduction, two intensive surveys were conducted on surface waters in the Mill Creek drainage near Western Processing. The wet-weather (storm-related) survey was conducted on May 22, 1984, and the dry-weather survey was conducted on June 27, 1984.

Figure 2 shows the stations used during the intensive surveys. Station WP-1 (drainage from the Western Processing site) was active only during the wet-weather survey. Table 6 lists and locates these stations by river mile (r.m.).

Table 6. Intensive survey stations.

Station Name	Routine Network Station Number	Intensive Survey Station Number	River Mile
Mill Creek at West Valley Highway	09E090	M-1	4.66
Mill Creek at Old (Railroad Flatcar) Bridge	--	M-2	4.25
Mill Creek at 196th Street Bridge	--	M-3	4.10
Mill Creek at Jogging Path Bridge	--	M-4	3.82
Confluence of Mill Creek and Railroad Ditch			3.81
Mill Creek at Railroad Trestle	09E070	M-5	3.14
Western Processing Surface Runoff Pipe	--	WP-1	4.19
Railroad Ditch Upstream of Western Processing	--	R-1	0.50
Railroad Ditch At Mouth	--	R-2	0.01

Methods used during both surveys were consistent. Flows were calculated from cross-stream velocity profiles determined using a Marsh-McBirney magnetic flow meter with top-setting rod. Temperature, pH, and specific conductance were determined in the field. Dissolved oxygen samples were colletced and fixed in the field, then titrated (Winkler method, azide modification) within twenty-four hours. Water samples were collected using standard techniques and stored on ice until delivered to the laboratories performing the water quality analyses. Metals samples were collected and returned to the laboratory where an aliquot was filtered through a 0.45 micron filter. Both filtered and raw fractions were then acid-preserved prior to analysis. Analyses were conducted at two laboratories; the WDOE Water Quality Laboratory in Tumwater, and the WDOE/EPA laboratory in Manchester. Table 7 summarizes the location of analysis for each of the water quality parameters.

Table 7. Location of water quality analyses.

Parameter	Field	WDOE-Tumwater	WDOE/EPA-Manchester
Flow, dissolved oxygen, temperature	X		
pH, conductivity	X	X	
Nutrients, solids, COD, turbidity, color, hardness, fecal coliforms		X	
Metals, VOAs			X

Conditions during the wet-weather survey were transient--the creek was rising rapidly; while conditions during the dry-weather survey were more stable. Interpretation of the dry-weather survey results is more straightforward, and will, therefore, be discussed first.

Dry-Weather Survey (June 27, 1984)

Discussion of these results must be prefaced by an explanation of some problems experienced with flow measurements during this survey. As can be noted in Table 8, the flows measured in Mill Creek were somewhat erratic during this survey and show wider variation than would normally be expected during a survey of this type. It is believed that much of this variation is real based on two factors: (1) previous flow measurements using the same equipment have been both accurate and precise (± 5 percent); and (2) while measuring flow at station M-2, the depth of Mill Creek increased by approximately 0.5 foot over the course of one minute. Subsequent upstream investigations and contact with regional personnel (Mike Dawda, personal communication) did not clarify the cause of this fluctuation. A Manning dipper flow meter was used on two subsequent occasions (July 11 and 18, 1984) to provide a record of water level in Mill Creek at the 196th Street bridge. The July 11 record showed no appreciable change over a four-hour period. The July 18 record showed a gradual drop in water level over a five-hour period. Rapid level fluctuations were not recorded during either of these subsequent tests. Based on these observations, flow values reported here should be used judiciously. Subsequent work requiring precise flow measurements (for instance, determining groundwater influx) should probably be done in concert with continuous stream-level monitoring to assure that fluctuations in stream flow do not compromise the results.

The results of water quality analyses are summarized in Table 8. Violations of Washington State water quality standards or federal water quality criteria are flagged. Water quality standards violations for fecal coliforms in Mill Creek, temperature in the Railroad Ditch, and dissolved oxygen in both surface waters do not appear to be directly related to Western Processing. Violations of water quality criteria for nickel, copper, cadmium, and zinc are apparently associated with contamination from the Western Processing site.

Figure 3 shows changes in concentrations for several water quality parameters in both Mill Creek and the Railroad Ditch as they flow by Western Processing. Many of the same parameters noted previously increased in the vicinity of Western Processing; conductivity, color, nitrate, ammonia, cadmium, nickel, zinc, and volatile organics. The major increases in toxic pollutants (metals, volatiles) occur between stations M-2 and M-3. The increase in nitrates also occurs primarily in the same reach. Volatiles appear to attenuate below Western Processing, probably due to loss to the atmosphere, while metals concentrations remain relatively stable.

Table 8. Results of dry-weather survey (June 27, 1984).

Station Number	M-1	M-2	M-3	M-4	R-1	R-2	M-5
Station Name	Mill Creek/ West Valley Highway	Mill Creek/ Old Bridge	Mill Creek @ 196th St.	Mill Creek/ Jogging Path	Railroad Ditch/ Upstream	Railroad Ditch at Mouth	Mill Creek/ Railroad Trestle
Time	0935	1010	1045	1110	1130	1150	1215
Flow (cfs)	5.6*	4.6*	5.0*	6.3*	0.06*	0.08*	5.0*
Temperature (°C)	16.3*	16.5*	17.0*	17.5*	(21.4*)	(19.0*)	17.7*
Spec. Cond. (umhos/cm)	260*	387*	405*	402*	1000*	1020*	405*
pH (S.U.)	6.7*	7.0*	6.8*	6.8*	6.5*	6.6*	6.8*
Dissolved Oxygen (mg/L)	[4.2*]	[3.6*]	[3.5*]	[3.6*]	[0.0*]	[0.0*]	[3.1*]
D.O. Percent Saturation	42.6%	36.7%	36.0%	37.4%	0.0%	0.0%	32.0%
COD (mg/L)	24	28	32	32	168	92	32
Un-ionized NH_3-N (mg/L)	0.001	0.002	0.002	0.002	0.003	0.005	0.002
NH_3-N (mg/L)	0.49	0.72	1.1	1.1	2.0	3.1	1.1
NO_2-N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05	<0.01
NO_3-N (mg/L)	0.18	0.19	1.2	1.2	<0.05	<0.05	0.95
O-PO_4-P (mg/L)	†	†	†	†	†	†	†
T-PO_4-P (mg/L)	0.12	0.06	0.10	0.08	0.30	0.45	0.09
Total Solids (mg/L)	200	260	280	290	810	720	270
TNVS (mg/L)	150	190	210	230	590	550	200
TSS (mg/L)	16	17	21	24	120	72	16
TNVSS (mg/L)	8	11	14	19	74	40	10
Turbidity (NTU)	34	34	44	44	110	53	37
Color (S.U.)	185	176	223	336	1033	903	248
Total Hardness (mg/L)	92	104	108	108	240	220	80
Fecal coliforms (#/100 mL)	[610]						[300]
Metals (ug/L)							
Cadmium - Total	0.4	<0.1	[[14.1]]	[[13.1]]	0.6	7.7	[[18.5]]
Dissolved	<0.1	<0.1	[[14.0]]	[[12.2]]	<0.1	0.3	?
Chromium - Total	13	5	31	25	11	8	24
Dissolved	<1	1	4	5	7	1	5
Copper - Total	([20])	4	[[54]]	[[61]]	[[61]]	16	[[50]]
Dissolved	<1	<1	[[29]]	[[23]]	<1	<1	[[23]]
Lead - Total	(14)	(3)	<1	[8]	2	[11]	[[70]]
Dissolved	<1	?	<1	<1	<1	6	8
Nickel - Total	5	11	[116]	[118]	14	31	[117]
Zinc - Total	20	29	[[1117]]	[[1032]]	[262]	[[2810]]	[[935]]
Dissolved	4	11	[[1016]]	[[872]]	[50]	[[1961]]	[[877]]
Volatile Organics (ug/L)							
methylene chloride	2u	2u	2u	9.2	2u	26	8.7
chloroform	2u	12	19	17	2u	2.5	14
1,1-dichloroethane	2u	2u	2.3	2u	2u	2u	2u
1,1-dichloroethylene	2u	2u	2u	2u	2u	12	2u
1,1,1-trichloroethylene	2u	2u	7.8	2u	2u	27	5
trichloroethylene	2u	11	47	37	2u	105	27
tetrachloroethylene	2u	2.5	3.4	2.3	2u	2u	2.2
toluene	2u	2u	2u	2u	27	11	2u

* = Field analysis.
? = Analomous value, apparent laboratory error.
† = Interference
[ ] = Violation of standard or chronic criteria (see notes, Table 3)
[[ ]] = Violation of acute criteria (see notes, Table 3)
< = less than
u = Not detected at detection limit given
m = Present, but below quantification limit given

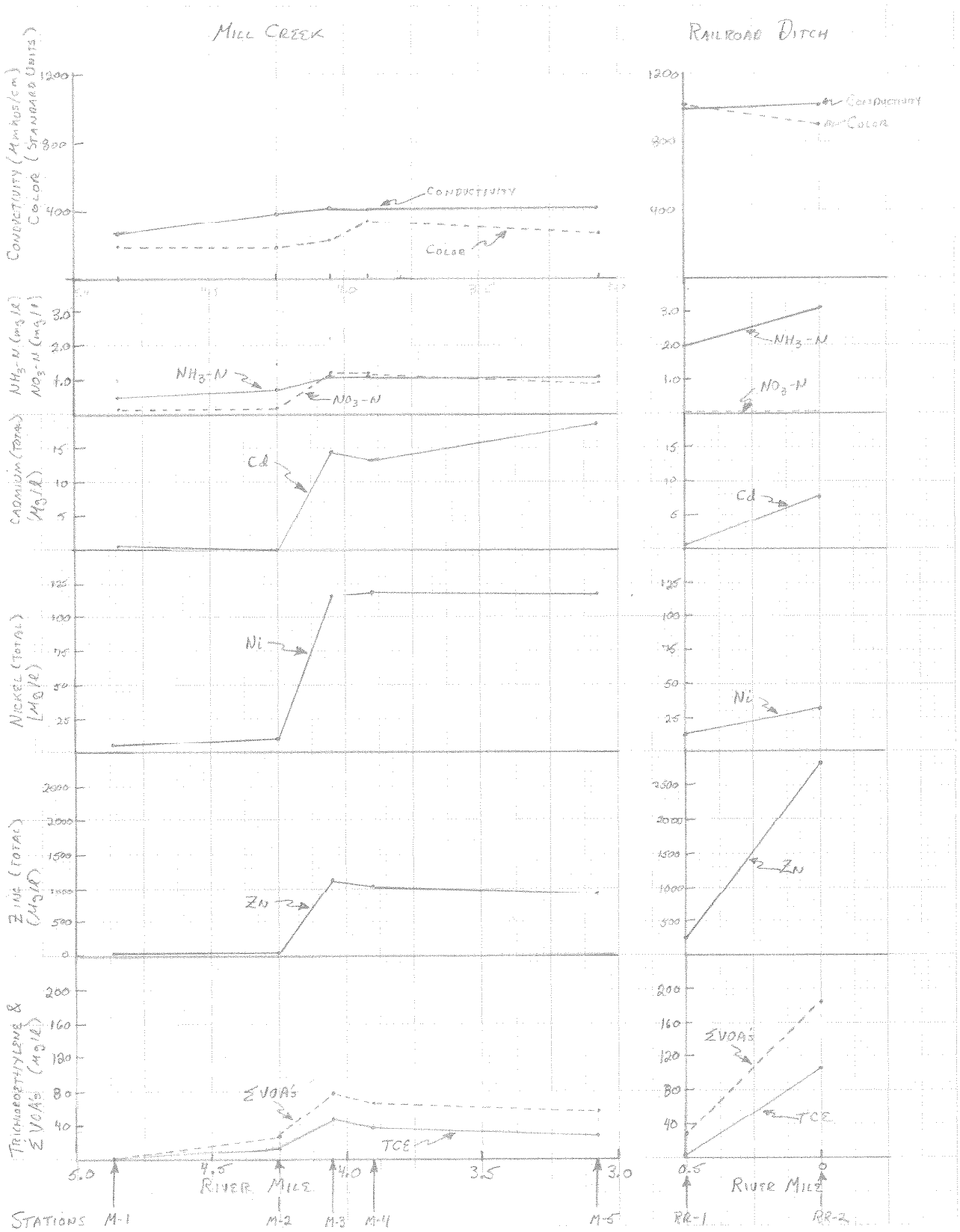


Figure 3. Pollutant concentration versus river mile (June 27, 1983).

Although concentrations of pollutants in the Railroad Ditch are often higher than those in Mill Creek, the small volume of flow (<2 percent of Mill Creek flow) minimizes the impact of this source on Mill Creek. Note that pollutant concentrations at stations M-4 and M-5 are generally similar. None the less, it is clear that some of the contaminated groundwater from the Wesern Processing site is making its way into the Railroad Ditch. In addition to the sampling done during the dry- and wet-weather surveys, the Railroad Ditch was also sampled during reconnaissance surveys on April 11 and 18, and again on May 17, 1984. During the May 17 sampling, an additional station (R-1a, Railroad Ditch at 196th Street) was also sampled to provide a more precise assessment of where contamination was entering this system. The results from these three surveys are presented in Table 9.

Based on results summarized in Tables 8 and 9, several observations can be made:

1. The Railroad Ditch is substantially contaminated prior to confluence by the Western Processing site. This contamination is characterized by low dissolved oxygen, high organic content (COD), high conductivity, high ammonia concentrations, and elevated concentrations of several metals including copper, lead, and zinc. The June 27, 1984, samples also showed elevated upstream concentrations of chromium, cadmium, and nickel.

2. Based on the May 17, 1984, survey, further increases in contamination of the ditch occur upstream of 196th Street. Pollutants showing marked concentration increases near Western Processing are ammonia, zinc, cadmium, volatile organics (Table 8), and, to a lesser extent, nickel. These are generally the same contaminants reaching Mill Creek in this area.

Wet-Weather Survey (May 22, 1984)

The wet-weather (storm-related) survey was conducted on May 27, 1984. Rainfall at the Sea-Tac weather station was 0.67 inch on this day, with rainfall light in the morning, intensifying toward noon, and remaining heavy during the afternoon. Flow in Mill Creek (West Valley Highway station M-1) was 8.1 cfs at 10:00 a.m. and rose to 62 cfs (Orillia station, M-5) by 3:45 p.m.

Stations sampled are shown in Figure 2 and listed in Table 6. The results of water quality analyses from this survey are given in Table 10. Violations of state water quality standards and federal water quality criteria are flagged. Again as during the dry-weather survey, the Western Processing site appears to be responsible for violations of criteria for several metals. Again, increased concentrations were recorded for zinc, cadmium, copper, and nickel. The overland runoff from the site (WP-1) showed elevation of these same metals; although based on the respective flows of this source and Mill Creek, as well as a comparison of metals concentrations in the runoff and lower Mill Creek; this overland runoff was a relatively minor source of metals to Mill Creek.

Table 9. Railroad Ditch water quality results (May 15 and April 11 and 18, 1984.

Date	5/15/84	5/15/84	5/15/84	4/11/84	4/18/84
Station Number	R-1	R-1a	R-2	R-2	R-2
Station Name	Railroad Ditch above Western Processing	Railroad Ditch at 196th Street	Railroad Ditch at Mouth	Railroad Ditch at Mouth	Railroad Ditch at Mouth
Time	1030	1120	1210	1450	1415
Parameter					
Flow (cfs)			0.18*	0.6*	0.35*
Spec. Cond. (umhos/cm)	2000*	2100*	1950*	1690	2170*
pH (S.U.)	6.7	6.6	6.9	6.6	6.9*
Temperature (°C)	16.0*	16.9*	18.4*	11.3*	18.2*
Dissolved Oxygen (mg/L)				2.4*	3.1*
D.O. Percent Saturation				22.1%	32.9%
COD (mg/L)	180	120	88	140	120
NH_3-N (mg/L)	1.1	2.6	1.5	2.1	2.0
NO_2-N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.05
NO_3-N (mg/L)	0.02	0.37	0.07	0.35	0.15
T. PO_4-P (mg/L)	0.14	0.12	0.07	0.11	0.14
Turbidity (NTU)	100	77	65	38	39
Color (S.U.)	750	740	720	550	
Total Hardness (mg/L)	130	150	130	120	
Total Solids (mg/L)	1300	1200	1100	1000	
TNVS (mg/L)	1200	1100	1000	930	
TSS (mg/L)	110	110	21	34	
TNVSS (mg/L)	69	40	18	12	
Metals (ug/L)					
Cadmium - Total	0.4	8.4	6.4	7.6	
Dissolved	<0.1	4.4	0.3	1.1	
Chromium - Total	<1	<1	<1	3	
Dissolved	<1	<1	<1	<1	
Copper - Total	61	11	9	26	
Dissolved	<1	<1	<1	1	
Mercury - Total	0.046	0.046	<0.046	<0.057	
Lead - Total	22	2	4	11	
Dissolved	<1	<1	<1	2	
Nickel - Total	<1	36	26	45	
Dissolved	<1	11	<1	8	
Zinc - Total	85	7360	4040	3290	
Dissolved	21	5880	2730	2520	

* = Field measurement.

Table 10. Results of wet-weather survey (May 22, 1984).

Station Number	M-1	M-2	WP-1	M-3	M-4	R-1	R-2	M-5
Station Name	Mill Creek/ West Valley Highway	Mill Creek/ Old Bridge	West. Proc. Stormwater Discharge	Mill Creek @ 196th St.	Mill Creek/ Jogging Path	Railroad Ditch/ Upstream	Railroad Ditch at Mouth	Mill Creek/ Railroad Trestle
Time	0955	1045	1035	1120	1150	1335	1405	1445
Flow (cfs)	8.1*	7.4*	0.14*	13.3*	21.8*	2.0*	4.5*	62.0*
Temperature (°C)	11.6*	11.5*	15.2*	11.8*	12.6*	13.2*	13.2*	12.8*
Spec. Cond. (umhos/cm)	350*	351*	25*	344*	239*	1550*	1090*	184*
pH (S.U.)	6.8*	7.0*	6.2*	6.9*	6.9*	6.4*	6.5*	7.0*
Dissolved Oxygen (mg/L)	[5.3*]	[5.4*]	10.4*	[5.1*]	[6.4*]	[3.5*]	[1.9*]	[6.8*]
D.O. Percent Saturation	48.6%	49.4%	103%	47.0%	60.0%	33.4%	18.1%	64.0%
Un-ionized NH_3-N (mg/L)	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001
NH_3-N (mg/L)	0.54	0.60	0.20	0.78	0.56	1.1	1.9	0.56
NO_2-N (mg/L)	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
NO_3-N (mg/L)	0.42	0.37	0.08	0.81	0.59	0.18	0.13	0.36
O-PO_4-P (mg/L)	†	†	0.04	†	†	†	†	†
T-PO_4-P (mg/L)	0.05	0.06	0.11	0.08	0.06	0.04	0.02	0.06
Total Solids (mg/L)	260	290	42	280	230	2200	1400	240
TNVS (mg/L)	210	230	26	210	160	2000	1200	180
TSS (mg/L)	24	24	1	31	41	1100	770	74
TNVSS (mg/L)	18	16	<1	18	31	1000	650	61
Turbidity (NTU)	68	45	16	57	53	1200	770	90
Color (S.U.)	260	300	42	300	230	340	400	160
Total Hardness (mg/L)	120	100	24	110	76	96	84	60
Fecal coliforms (#/100 mL)	[160]							[520]
Metals (ug/L)								
Cadmium - Total	0.1	0.4	[[2.2]]	[[9.9]]	[[7.5]]	1.6	[[17.3]]	[[6.6]]
Dissolved	<0.1	<0.1	[[2.2]]	[[6.9]]	[[4.6]]	0.1	<0.1	0.9
Chromium - Total	4	4	3	8	5	[124]	[74]	13
Dissolved	2	1	<1	1	<1	<1	<1	<1
Copper - Total	<1	<1	[7]	[[34]]	[[29]]	[[149]]	[[119]]	[[30]]
Dissolved	<1	<1	<1	7	3	<1	<1	<1
Mercury - Total	<0.046	0.092	<0.046	<0.046	0.092	0.138	0.092	?
Lead - Total	[6]	[7]	[[26]]	[13]	[22]	[[62]]	[[51]]	[[50]]
Dissolved	<1	<1	[[11]]	<1	1	<1	<1	<1
Nickel - Total	<1	<1	<1	15	23	[218]	(133]	12
Dissolved	<1	<1	<1	10	<1	<1	<1	<1
Zinc - Total	[60]	[99]	[[260]]	[[596]]	[[455]]	[[436]]	[[2060]]	[[415]]
Dissolved	41	[58]	[[238]]	[[566]]	[[351]]	[73]	[181)	[113]
Volatile Organics (ug/L)								
chloroform	2u	8.3	2u	8.2	5.8	2u	2u	2u
1,1,1-trichloroethylene	2u	2u	2u	2u	3.2	2u	5.5	2.6
trichloroethylene	2u	9	2u	18	12	2u	13	4.9
tetrachloroethylene	2u	2u	2u	2u	2.3	2u	2u	2m
toluene	2u	2u	2u	2u	2u	23	19	2u
ethylbenzene	2u	2u	2u	2u	2u	2m	2u	2u

* = Field analysis.
? = Analomous value, apparent laboratory error.
† = Interference
[ ] = Violation of state water quality standard or federal chronic criteria
[[ ]] = Violation of federal acute criteria
< = less than
u = Not detected at detection limit given
m = Present, but below quantification limit given

Because flows in the Mill Creek system were increasing throughout the sampling period, concentrations recorded at each of the sampling stations are not strictly comparable. Dilution increased during the day as storm flows increased, and there were probably some increases in loadings for pollutants associated with increased runoff throughout the drainage. Resuspension of streambed sediments may have been one of these storm-event-related sources. Suspended solids concentrations measured in Mill Creek during this survey were elevated, particularly at the downstream Mill Creek stations.

Despite non-steady state conditions in the creek, most of the same pollutants noted during the dry-weather survey again appeared to be entering the drainage near the Western Processing site. One observation unique to this data set is that it appears that there may be a fairly significant metals source in the Railroad Ditch upstream of Western Processing.

Another interesting aspect of the data from this survey is that when compared to the dry-weather data, many of the high-flow samples had a much lower percentage of metals present in the dissolved form. Figure 4 is based on all data (including routine and intensive monitoring data) for the Mill Creek at Orillia station (M-5, 09E070). The percentage of several metals present in the dissolved form is plotted against the suspended solids concentrations in that sample. Points representing the storm-survey data are located in the lower right-hand corner of the plot. Each of the metals plotted (cadmium, copper, nickel, and zinc) shows an inverse relationship between suspended solids concentration and the percentage of that metal present in solution. There are two likely explanations for this phenomenon: (1) during high flows, streambed sediments with high metals concentrations are resuspended; and (2) dissolved metals discharged in groundwater subsequently bind with suspended sediments; as suspended solids concentrations increase, a larger fraction of metals is then associated with these sediments. It is probable that both mechanisms occur.

The relationship between streamflow and pollutant loadings to Mill Creek is dealt with in the following section.

Streamflow/Pollutant Loading Relationships

In reviewing the results of the wet-weather survey and the data generated at the downstream routine monitoring site (09E070, M-5), it became apparent that there was a relationship between streamflow and in-stream loadings of a number of the pollutants associated with the Western Processing site. Table 11 summarizes these data. The increase in loadings (lbs/day) in Mill Creek from upstream of Western Processing (09E090, M-1) to downstream (09E070, M-5) are tabulated along with the associated streamflow at the downstream station. There is one caveat that needs to be mentioned with regard to these data. The increases in Mill Creek metals loadings for the highest flow event (wet-weather survey, May 22) may be somewhat overestimated because streamflow increased substantially between sampling at the upstream station and sampling at the downstream station, and because there was some

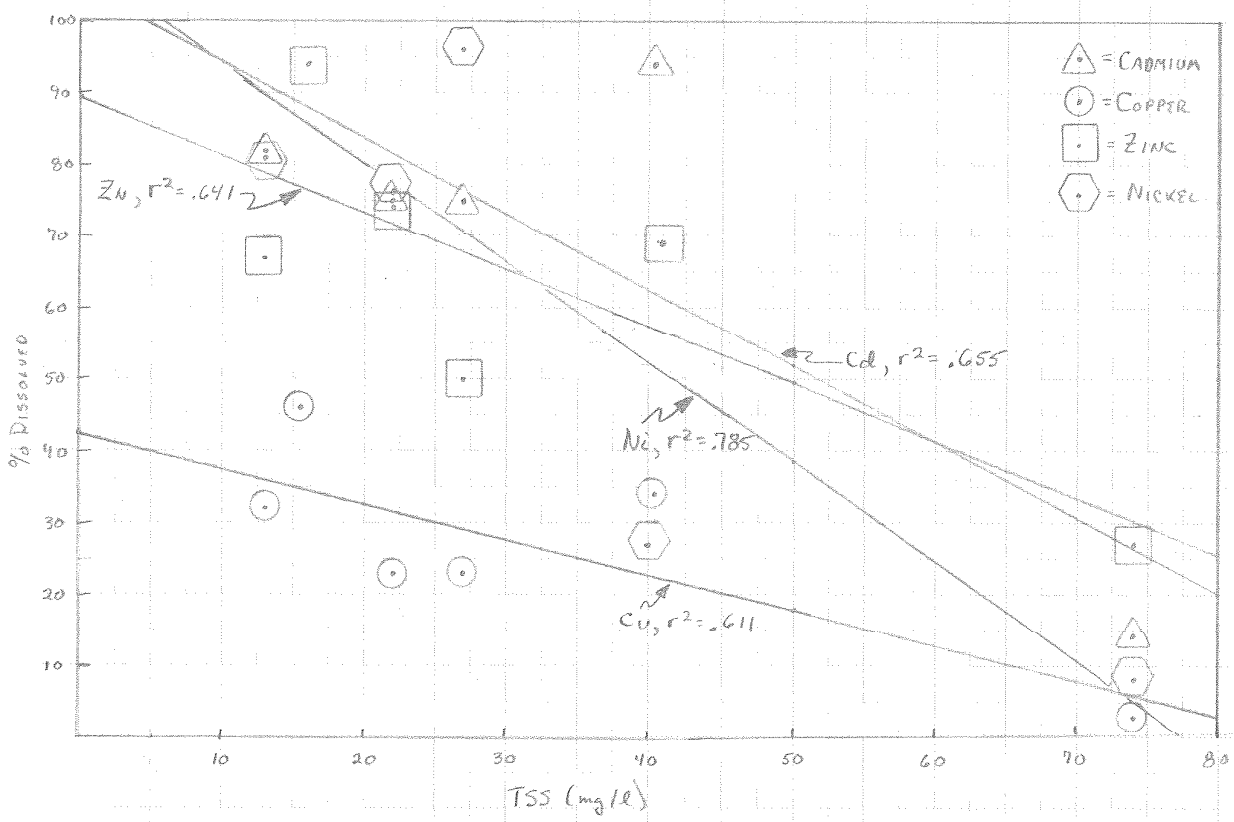


Figure 4. Suspended solids concentrations versus percent of various metals in dissolved fraction. Data from Station M-5 (09E070).

metals load in the railroad ditch upstream of the Western Processing site which is not accounted for when loads at 09E090 are subtracted from loads at 09E070. These problems are probably not significant for the volatile organics because volatile loads at the upstream sites were very low to undetectable.

Table 11. Net increases in pollutant loadings (lbs/day) in Mill Creek (Station 09E090 to 09E070) from April through September 1984.

Date	4/11	5/22	6/27	7/11	8/07	9/19
Parameter						
Flow* (cfs)	16.2	62	5.0	3.7	2.0	1.5
Trichloroethylene (TCE, lbs/day)	0.96	1.64	0.72	0.62	0.16	0.11
Total Volatile Priority Pollutants (lbs/day)	1.97	2.84	1.52	1.35	0.68	0.55
Cadmium (total, lbs/day)	0.54	2.20	0.48	0.50	0.21	0.19
Copper " "	1.92	10.0	0.76	0.58	0.34	0.33
Nickel " "	8.64	4.01	2.98	1.63	1.13	1.56
Zinc " "	50.5	136	24.4	25.0	15.1	14.3

*Flow at Mill Creek (Kent) near Orillia (Railroad Trestle) - 09E070, M-5.

The loads and flow data in Table 11 are presented graphically in Figure 5. For each of these pollutants, net increases in loads in Mill Creek appear to increase with streamflow. The major portion of this increase in pollutant loads is probably associated with increased contaminated groundwater discharge to Mill Creek during the higher flow periods. At extreme high flows, some portions of the increased load may be associated with the resuspension of contaminated sediments and/or surface water runoff from the Western Processing site.

Bond, et al. (Battelle, 1984) developed a groundwater model for the Western Processing site and used it to predict trichloroethylene (TCE) concentrations in Mill Creek at two flows. Using their results (p. 31), the model predicts a TCE load of 0.65 lb/day at a streamflow of 3 cfs, and a load of 0.81 lb/day at a flow of 15 cfs. These points are included on Figure 5 and fall close to the TCE loads measured during this project. There are at least two implications of this relationship between flows and loads:

1. It appears that the rate of groundwater flow to Mill Creek may be seasonal in nature and respond relatively quickly to changes in soil saturation and rainfall.

2. Any future attempts to look at long-term trends in concentrations or loads in pollutant concentrations in Mill Creek (particularly downstream of Western Processing) should account for this relationship. Loadings and concentrations could be normalized with respect to flow to minimize the confounding effects of transient pollutant loads.

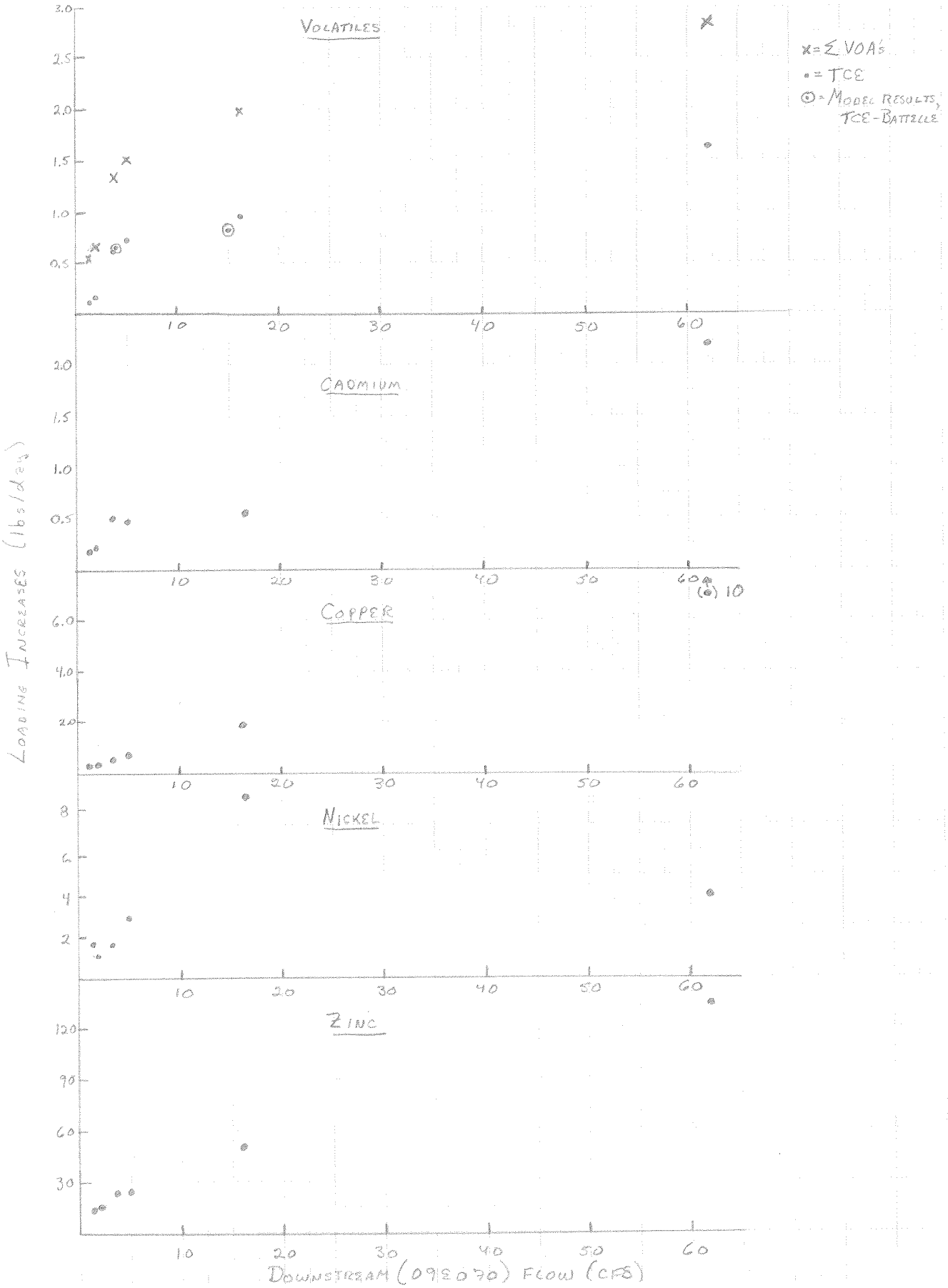


Figure 5. Net increase in pollutant loading in Mill Creek (Station 09E090 to 09E070) versus streamflow (09E070).

Ancillary Studies (dissolved oxygen problems and other observations)

During the course of conducting studies previously addressed in this report, it became apparent that there were problems with Mill Creek water quality and, very likely, aquatic communities in addition to those which were associated with Western Processing. Although investigation of these problems was not part of the original scope of the project, some of these issues were pursued (on a limited basis) to attempt to better define them.

Two major issues with regard to Mill Creek are: (1) chronically low dissolved oxygen concentrations in the stream, and (2) the paucity or total lack of most aquatic organisms in much of the stream for several miles upstream of Western Processing.

In an attempt to address these issues, field water quality analyses and limited laboratory analyses were conducted at a number of locations along Mill Creek and at the mouths of the several small tributary drains to the creek. These sites are listed in Table 12 and shown in Figure 6. The results of water quality analyses which have not been tabulated elsewhere in this report are summarized in Appendix II.

In addition, most of Mill Creek from r.m. 7 to r.m. 4.7, the length of the 212th Street ditch, and the lower mile of the West Valley Ditch were walked. The primary purpose of these streamwalks was to identify any obvious discharges to the system. Numerous apparent storm drains were noted along Mill Creek and its tributary ditches, but none were observed discharging. Other observations relating to the stream are summarized below.

At Earthworks Park (r.m. 8.2), Mill Creek is clear, swiftly flowing, and well-shaded. The substrate is primarily small rocks, and there are healthy populations of benthic invertebrates including snails, trichoptera (caddis fly larvae), and ephemeroptera (may fly nymphs). Just downstream from Earthworks Park, the creek reaches the valley floor, is channelized, and cover (shading trees and shrubs) decreases or disappears entirely. What appeared to be a small trout (approximately 7 inches) was seen at r.m. 7.3; several smaller, unidentified fingerlings or minnows were noted between r.m. 7 (Fischer Industrial Park) and r.m. 6.45 (just upstream of the 76th Avenue culvert). No fish were seen downstream of this point. After reaching the valley floor at r.m. 8, the stream substrate grades from sand to silt and mud with a few isolated areas having a rock or cobble substrate. These areas of cobble bottom are limited primarily to locations near bridges. One small crayfish was seen near Fischer Industrial Park (r.m. 7), but no other benthic invertebrates were noted although rocks were examined for snails and immature insects at several locations downstream of this point (r.m. 6.02, 5.6, and 4.66). During the streamwalks, the creek water appeared clear from r.m. 8.2 (Earthworks Park) to r.m. 6.4, where the first sign of discoloration appeared in the discharge from the 76th Avenue culvert. The waters of lower Mill Creek (downstream from r.m. 6.4) are increasingly discolored, usually a red-brown. Rocks from r.m. 7 downstream were covered with a reddish floc. It is likely that both phenomena are largely due to precipitation of iron hydroxide and iron oxides. Total iron was analyzed at several sites from Earthworks Park (r.m. 8.2) to the West Valley Highway (r.m. 4.66) on July 18 (see Appendix II). Concentrations of total iron increased from 0.57 mg/L to 4.4 mg/L.

Table 12. Station locations for ancillary studies.

Station Number	Station Name/Location	River Mile
	- Mill Creek - Main Stem Stations -	
M-A	Mill Creek at Earthworks Park	8.20
M-B	Mill Creek at Fischer Industrial Park (228th Street)	7.00
M-C	Mill Creek above 76th Avenue Culvert	6.42
M-D	Mill Creek at North End of 76th Avenue	6.20
M-E	Mill Creek at Interurban Avenue Trail Bridge	6.02
M-F	Mill Creek above 212th Street	5.60
M-G	Mill Creek at Old Concrete Bridge	5.30
M-H	Mill Creek at North End of 72nd Avenue	5.00
M-J	Mill Creek above West Valley Highway Ditch	4.80
M-1	Mill Creek at West Valley Highway	4.66
M-2	Mill Creek at Old (Railroad Flatcar) Bridge	4.25
M-3	Mill Creek at 196th Street Bridge	4.25
M-4	Mill Creek at Jogging Path Bridge	3.82
M-K	Mill Creek above Confluence with Springbrook Creek	3.05
M-L	Mill Creek at 16th Avenue	0.82
	- Tributary Stations -	River Mile at which Tributary Joins Mill Creek
S-A	76th Avenue Culvert at Mouth	6.41
T-A	212th Street Ditch At Mouth	5.51
W-A	West Valley Highway Ditch at Mouth	4.79
SB-A	Springbrook Creek at Mouth	3.04

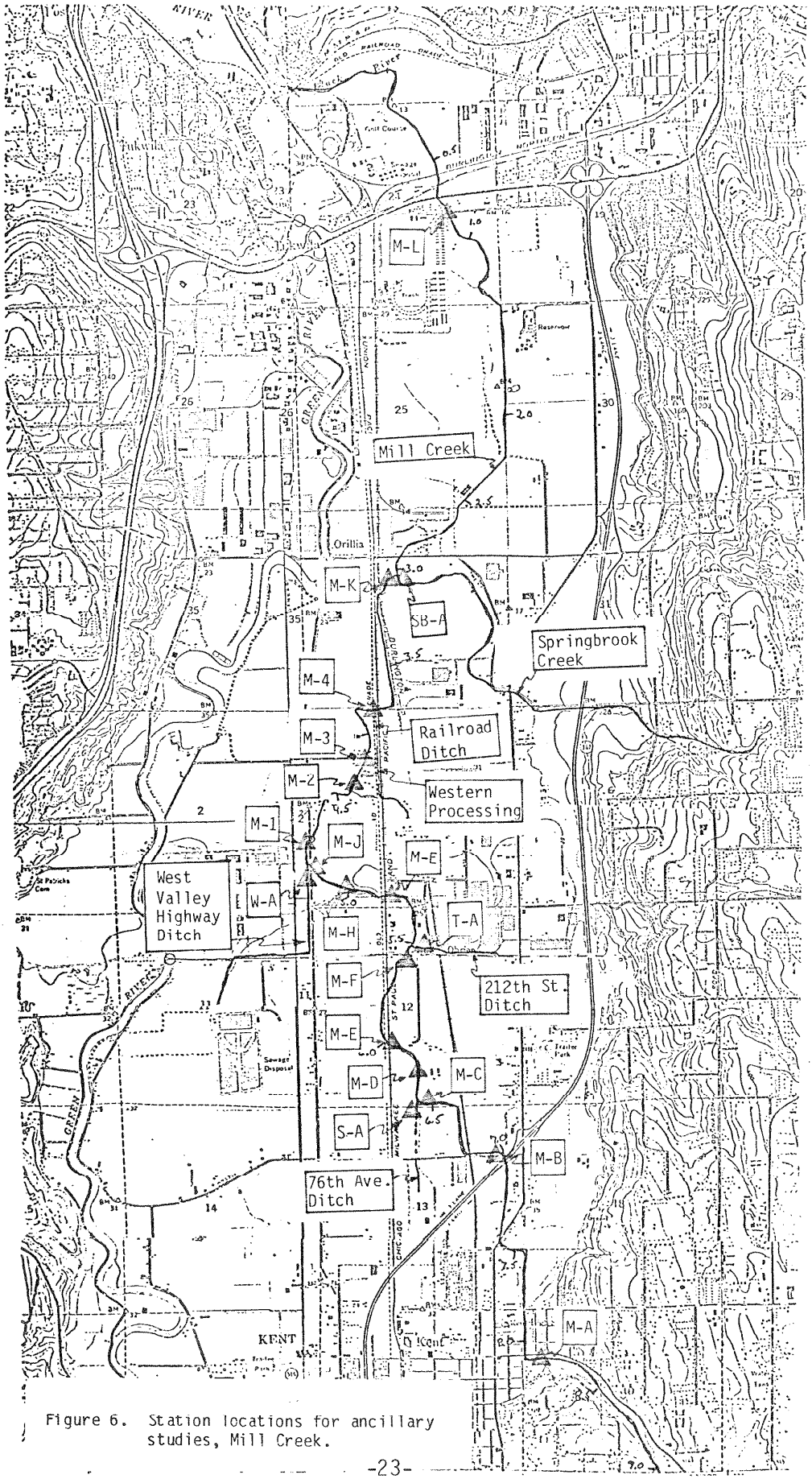


Figure 6. Station locations for ancillary studies, Mill Creek.

The tributaries to Mill Creek (76th Avenue culvert, 212th Street ditch, and West Valley Highway ditch) generally have poorer water quality than the main stem. The worst visual conditions were noted on September 19 in the 212th Street ditch. The lower half-mile of this tributary was covered with an oil/gasoline-type sheen and the water itself was yellow in color with a distinct odor which could not be identified. Rain storms apparently later flushed this ditch out and its subsequent appearance was less degraded.

The reason for the apparent lack of normal communities of aquatic organisms in Mill Creek downstream of approximatley r.m. 6.4 is not obvious. Changes in stream characteristics including increasingly unstable substrate; absence of cover in many stretches, which in combination with slow stream velocities leads to elevated summer water temperature (temperatues up to 23.4°C were recorded); periods of depressed dissolved oxygen concentrations in certain reaches (discussed subsequently); and somewhat elevated metals concentrations (zinc, lead, copper) recorded at the West Valley Highway station (Appendix I) probably bear some of the responsibility. These factors, however, do not appear to adequately explain the nearly complete absence of normal biological communities between r.m. 6.4 and 4.6.

The precise cause or causes of depressed dissolved oxygen concentrations in lower Mill Creek also remain an enigma. Figure 7 shows stream profiles for dissolved oxygen (percent saturation) and conductivity during numerous sampling periods from April to October 1984. As can be seen, the onset of significant depression of dissolved oxygen levels (less than 80 percent saturation) varied from r.m. 6.6 to 4.6. However, during only one occasion (May 17, 1984) was saturation at the West Valley Highway station (r.m. 4.66) greater than 70 percent. It is clear that most or all of the cause of depressed oxygen concentrations was upstream of Western Processing. All of the tributaries sampled during these surveys had lower dissolved oxygen concentrations than adjacent portions of Mill Creek. However, none of them appeared to have sufficient flow, low enough dissolved oxygen concentrations, or high enough organic (COD) concentrations to account for the dissolved oxygen depression observed in Mill Creek.

It is clear that depressed dissolved oxygen in Mill Creek was <u>not</u> due to nitrification of ammonia. There is little evidence of nitrification, and ammonia levels were not high enough to account for subsequent dissolved oxygen depletion.

Chemical oxygen demand (COD) levels were relatively high in the impacted reaches of Mill Creek (9 to 44 mg/L) and tributaries (16 to 65 mg/L). Although these data are less than complete, they suggest an increase in COD concentrations from Fischer Industrial Park (r.m. 7) to the West Valley Highway (r.m. 4.66), followed by a subsequent decline.

Although the data collected during these surveys is inadequate to fully explain the cause or causes of depressed oxygen concentrations in Mill Creek, it is likely that groundwater discharge to the system is a significant factor. Groundwater can act to depress oxygen concentrations by way of several mechanisms: groundwater itself is often low in dissolved oxygen, and shallow groundwater in soils high in organic matter often contains relatively high concentrations of dissolved organic matter and reduced forms of iron, manganese, and sulfur. Organic matter, iron, manganese, and sulfur consume oxygen as they are oxidized. For instance, the oxidation/reduction reaction for ferrous and ferric ions is given below:

$$1/2\ O_2 + 2\ Fe^{++} + 2\ H \quad 2\ Fe^{+++} + H_2O$$ (Stumm and Morgan, 1970)

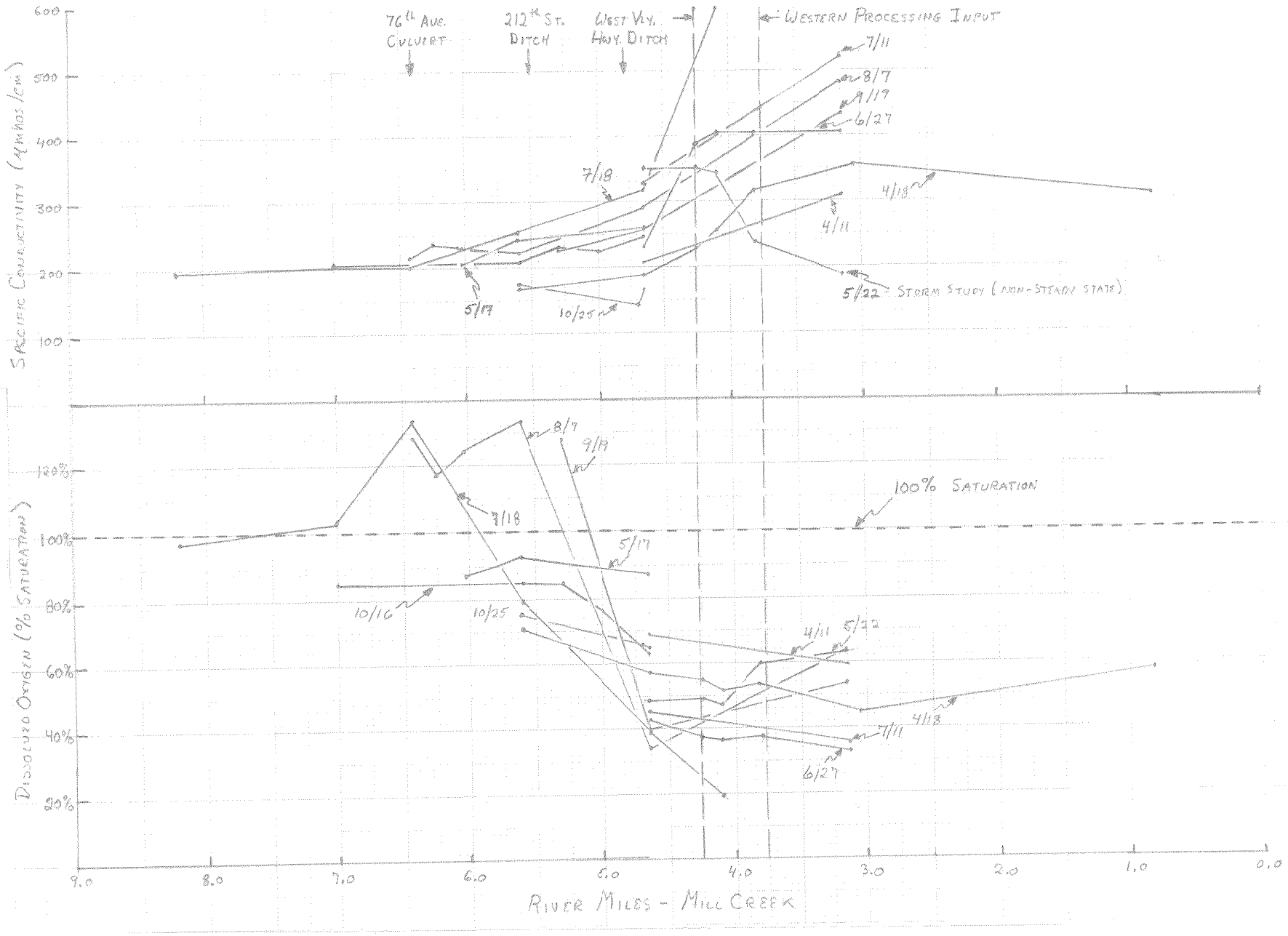


Figure 7. Dissolved oxygen and conductivity profiles for Mill Creek: April to October 1984.

Based on this equation and the atomic weights of iron and oxygen, one would expect the consumption of about 0.143 gram of O_2 per gram of ferrous iron oxidized to the ferric form. Total iron concentrations in Mill Creek samples of up to 4.4 mg/L were detected in Mill Creek during the July 18 sampling (Appendix II), and METRO has recorded total iron concentrations of about 6 mg/L (iron) upstream of Western Processing (station X317) and 6 to 12 mg/L (iron) downstream. If one assumes that all of this iron entered Mill Creek in the ferrous form, then 4 to 12 mg/L (iron) could consume about 0.6 to 1.7 mg oxygen/L. Measurements of iron concentrations in Mill Creek water samples may underestimate iron loadings to the system because ferric ions would rapidly form ferric hydroxide ($Fe[OH]_3$) which would form a floc and settle out (probably this is the cause of the reddish coatings on rocks and sediment in the creek). This loss indicates that potential oxygen depletion due to iron may be greater than calculated above.

The added effects of reduced sulfur and manganese (neither of which was measured during these studies) may increase the oxygen-consuming potential of the groundwater.

One set of observations which appears to support the oxygen-poor/oxygen-consuming character of groundwater in this area was made on October 25. Flow in the West Valley ditch increased from essentially zero to 0.20 cfs from 212th Street to the ditch's confluence with Mill Creek. No overland discharge to the ditch was noted; therefore, the flow of this ditch appeared to be entirely due to shallow groundwater inflow. The dissolved oxygen concentration at the mouth of the ditch was 0.6 mg oxygen/L.

Although, on the face of it, the changes in the stream location where the oxygen sag begins would seem to argue against a relatively stable phenomenon like groundwater input, there may be a rational explanation for this as well. Note in Figure 7 the progressive downstream movement of sag onset apparent in the data from July 18, August 7, and September 19. It may be that as groundwater levels fall during the summer, the groundwater input at upstream locations dries up, and the initial impact of groundwater is seen progressively farther downstream.

Although groundwater appears to be an important potential cause of depressed oxygen concentrations in the Mill Creek drainage, there is also a substantial probability that a portion of the dissolved oxygen problem is associated with other causes; possible contaminated surface runoff, currently unidentified point discharges, agricultural activity, and so on. A number of pipes were noted at various locations along the stream banks and although most were not discharging when observed, they may well contribute pollutants intermittently. Approximately a dozen cattle were observed in and near Mill Creek near r.m. 6.1. The high fecal coliform counts noted in Mill Creek at the West Valley Highway (M-1, 09E090) indicate a high probability of waste contamination from warm-blooded animals.

One further observation is that Mill Creek appears to be particularly susceptible to the effects of oxygen depletion because of relatively poor reaeration. This is in part due to the low gradient of the stream which limits physical

reaeration (turbulance). Dredging the stream has led to stream reaches which are comparatively deep and stream velocity which is very low. Lack of riffles and adequate vertical mixing abet low reaeration rates. The dissolved oxygen data (Figure 7) indicate some photosynthetic aeration in upper Mill Creek (supersaturation between r.m. 6.5 and r.m. 5.5). However, there was litle indication of photosynthetic activity in the lower reaches. Whether this is due to changes in substrate; shading by the relatively high, dredged banks; or other unfavorable conditions for algae and rooted aquatic plants is unknown. It should be noted, however, that this is the same stretch of stream that was void of normal aquatic fauna.

Further studies will be necessary to adequately explain the causes of depressed dissolved oxygen concentrations and lack of normal aquatic communities in lower Mill Creek.

Conclusions and Recommendations

1. Routine ambient monitoring stations were established on Mill Creek upstream and downstream from the Western Processing site. Data from these stations show increases in conductivity, nitrate, ammonia, several metals (zinc, copper, cadmium, and nickel), and a range of chlorinated, volatile organic compounds including trichloroethylene, chloroform, and methylene chloride.

2. These ambient monitoring stations should continue to be sampled monthly to provide long-term data which can be used to evaluate the efficacy of remedial actions at the Western Processing site. Future trend analysis of this data must take into account relationships between streamflow and pollutant loading.

3. Low (base) flow and high (storm) flow studies reported here reconfirm many of the findings made by previous EPA studies. Most of the pollutant loading appears to be entering Mill Creek by way of the groundwater between stations M-2 (Mill Creek at Old [flatcar] Bridge, r.m. 4.25) and M-3 (Mill Creek at 196th Street Bridge, r.m. 4.10). Zinc and chlorinated volatile organics are also entering the Railroad Ditch near Western Processing, although the loading of these pollutants to the east of the Western Processing site is much lower than that to Mill Creek on the west.

4. Based on the results of intensive surveys and the routine ambient monitoring, the pollutants associated with the Western Processing site which pose the greatest threat to aquatic organisms in the Mill Creek drainage are zinc, cadmium, and copper. Lead and nickel may pose secondary threats.

5. Mill Creek has several problems which do not appear to be associated with contamination from the Western Processing site. The two major problems are chronically low dissolved oxygen concentrations and the apparent absence of normal communities of aquatic organisms in several miles of Mill Creek upstream from the Western Processing site. Determining the causes of these problems was outside the scope of this project; however, it appears that groundwater influx to Mill Creek may be responsible for a substantial portion of the depressed oxygen concentrations. Future investigations should focus on the potential roles of organic content and reduced forms of iron, manganese, and sulfide in the shallow groundwater system feeding the Mill Creek system, as well as potential anthropogenic sources including surface runoff, point discharges, and agricultural activities in the drainage.

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APPENDIX I

Routine Ambient Monitoring Data

DEPARTMENT OF ECOLOGY

AGENCY 21540000 RETRIEVAL --- 29 NOVEMBER 1984

OFFICE OF WATER PROGRAMS
WATER QUALITY MANAGEMENT DIVISION
WATER QUALITY INVESTIGATIONS SECTION

09E090 MILL CR--KENT ON WEST VALLEY HWY

STORET MINOR BASIN: PUGET SOUND STORET SUB BASIN: DUWAMISH-GREEN

LATITUDE: 47 25 15.0 ELEVATION (FEET): 25 WATER CLASS: A
LONGITUDE: 122 14 55.0 COUNTY: KING SEGMENT: 04-09-09

AGENCY: 21540000 STATE: WASHINGTON STA TYPE: RNPTOX

TERMINAL STREAM	1ST LEV MILES	2ND LEV MILES	3RD LEV MILES	4TH LEV MILES	5TH LEV MILES	6TH LEV MILES
1311143	011.00	000.80	004.66			

DATE FROM TO	TIME	DEPTH METERS	00060 STREAM FLOW CFS-AVG	00010 WATER TEMP DEG-C	00300 DISSOLVED OXYGEN mg/l	00301 DO PERCENT SATURATN	00400 pH STANDARD UNITS	00095 CONDUCTVY @ 25 C MICROMHOS	00530 SOLIDS SUSPENDED mg/l	31616 FECAL COLIFORM /100ml MF	00070 TURBIDITY TURBMETER NTU	00080 COLOR PT-CO UNITS
84/04/11	1400		16.2	10.1	7.7	68.2	6.8	250	13	80	20.0	190
84/05/22	0955		8.1	11.6	5.3	48.5	6.8	350	24	160	68.0	260
84/06/27	0935		5.6	16.3	4.2	42.6	6.7	260	16	610J	34.0	180
84/07/11	1030		3.0	15.0	4.6	45.4	6.7	328	10	4400J	41.0	180
84/08/07	0955		2.0	16.7	3.4	34.7	7.0	290	18	2500	25.0	130
84/09/19	1020		1.4	16.2	3.8	38.4	7.2	260	14	680	20.0	150

DATE FROM TO	TIME	DEPTH METERS	00620 NITRATE T NO3-N mg/l	00615 NITRITE T NO2-N mg/l	00610 AMMONIA T NH3-N mg/l	00671 DIS-ORTHO PHOSPHRUS mg/l P	00665 TOTAL PHOSPHRUS mg/l P	00900 HARDNESS TOT CaCO3 mg/l	71900 MERCURY TOTAL Hg ug/l	01030 CHROMIUM DIS Cr ug/l	01040 COPPER DIS Cu ug/l	01049 LEAD DIS Pb ug/l
84/04/11	1400		0.36	0.01K	0.44		0.12	52.0	0.06K	1.0K	2.0	2.0
84/05/22	0955		0.42	0.01K	0.54		0.05	120.0	0.05K	2.0	1.0K	1.0K
84/06/27	0935		0.18	0.01K	0.49		0.12	92.0		1.0K	1.0K	1.0K
84/07/11	1030		0.43	0.01K	0.42		0.08	110.0	0.33	1.0K	2.0	1.0
84/08/07	0955		0.17	0.01K	0.53	0.30	0.37		0.05K	1.0K	1.0K	1.0K
84/09/19	1020		0.36	0.01	0.32		0.16	120.0	0.06K	0.3	12.7	1.0K

DATE FROM TO	TIME	DEPTH METERS	01090 ZINC DIS Zn ug/l	01025 CADMIUM DIS Cd ug/l	00340 COD HI LEVEL mg/l	00008 LAB LOG NUMBER	01065 NICKEL DIS Ni ug/l	01034 CHROMIUM TOT REC ug/l Cr	01042 COPPER TOT REC ug/l Cu	01051 LEAD TOT REC ug/l Pb	01092 ZINC TOT REC ug/l Zn	01027 CADMIUM TOT REC ug/l Cd
84/04/11	1400		19	0.20K	26	1555	1K	1.0K	13.0	14.0	102	0.60
84/05/22	0955		41	0.10K		2371	1K	4.0	1.0K	6.0	60	0.10
84/06/27	0935		4	0.10K	24	2894		13.0	20.0	14.0	20	0.40
84/07/11	1030		1K	0.10K	30	3096	1K	1.0K	18.0	11.0	3	0.10K
84/08/07	0955		1K	0.20K	29	3443	1K	1.0K	29.0	4.0	11	0.20K
84/09/19	1020		85	0.20K	37	4129	1K	3.1	32.7	1.0K	128	0.20

DATE FROM TO	TIME	DEPTH METERS	01067 NICKEL TOT Ni ug/l	34210 ACROLEIN TOT WATER ug/l	34215 ACRYLONI-TRILE TOT H2O ug/l	34030 BENZENE TOTAL ug/l	32102 CARBON TETRA Cl TOT ug/l	34301 CHLORO-BENZENE TOT ug/l	34531 12-DICHL OROETHANE TOT ug/l	34506 111-TRICL OROETHANE TOT ug/l	34496 11-DICHL OROETHANE TOT ug/l	34511 112-TRICL OROETHANE TOT ug/l
84/04/11	1400		1K	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/05/22	0955		1K	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/06/27	0935		5	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/07/11	1030		1K	10.0U	5.0U	2.0M	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/08/07	0955		1K	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/09/19	1020		1K	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U

DATE FROM TO	TIME	DEPTH METERS	34516 1122TETRA CLOROTHNE TOT ug/l	34311 CHLOROE THANE TOT ug/l	34576 2-CHLOROE THYL VINY TOT ug/l	32106 CHLOROFRM WHOLE H2O TOT ug/l	34501 110ICHLOR OETHYLENE TOT ug/l	34546 12TRDICHL ORETHYLEN TOT ug/l	34541 120ICHLOR OPROPANE TOT ug/l	34561 130ICHLOR OPROPENE TOT ug/l	34371 ETHYL BENZENE TOT ug/l	34423 METHYLENE CHLORIDE TOT ug/l
84/04/11	1400		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/05/22	0955		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/06/27	0935		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/07/11	1030		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/08/07	0955		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/09/19	1020		2.0U	2.0U		2.0M	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U

DATE FROM TO	TIME	DEPTH METERS	34418 METHYL CHLORIDE TOT ug/l	34413 METHYL BROMIDE TOT ug/l	32104 BROMOFORM WHOLE H2O ug/l	32101 BROMODICL OROMTHANE TOT ug/l	34488 TRICHLORO FLRMTHANE TOT ug/l	34668 DICHLORO DIFRMTHNE TOT ug/l	32105 DIBROMOCH LOROMTHNE TOT ug/l	34475 TETRACHLO ROETHYLNE TOT ug/l	34010 TOLUENE IN WATER TOT ug/l	39180 TRICHLORO ETHYLENE TOT ug/l
84/04/11	1400		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/05/22	0955		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/06/27	0935		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/07/11	1030		2.0U	2.0U	2.0U	2.0M	2.0U	2.0U	2.0U	2.0U	2.0M	2.0U
84/08/07	0955		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/09/19	1020		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0M

DATE FROM TO	TIME	DEPTH METERS	39175 VINYL CHLORIDE TOT ug/l
84/04/11	1400		2.0U
84/05/22	0955		2.0U
84/06/27	0935		2.0U
84/07/11	1030		2.0U
84/08/07	0955		2.0U
84/09/19	1020		2.0U

DEPARTMENT OF ECOLOGY

AGENCY 21540000 RETRIEVAL --- 29 NOVEMBER 1984

OFFICE OF WATER PROGRAMS
WATER QUALITY MANAGEMENT DIVISION
WATER QUALITY INVESTIGATIONS SECTION

09E070 MILL CREEK (KENT) AT ORILLIA

STORET MINOR BASIN: PUGET SOUND STORET SUB BASIN: DUWAMISH-GREEN

LATITUDE: 47 26 21.0 ELEVATION (FEET): 12 WATER CLASS: A
LONGITUDE: 122 14 23.0 COUNTY: KING SEGMENT: 04-09-09

AGENCY: 21540000 STATE: WASHINGTON STA TYPE: RAPTOX

TERMINAL STREAM	1ST LEV MILES	2ND LEV MILES	3RD LEV MILES	4TH LEV MILES	5TH LEV MILES	6TH LEV MILES
1311143	011.00	000.80	003.14			

DATE FROM TO	TIME	DEPTH METERS	00060 STREAM FLOW CFS-AVG	00010 WATER TEMP DEG-C	00300 DISSOLVED OXYGEN mg/l	00301 DO PERCENT SATURATN	00400 pH STANDARD UNITS	00095 CONDUCTVY @ 25 C MICROMHOS	00530 SOLIDS SUSPENDED mg/l	31616 FECAL COLIFORM /100ml MF	00070 TURBIDITY TURBMETER NTU	00080 COLOR PT-CO UNITS
84/04/11	1520		16.2	10.4	6.7	59.7	6.8	309	41	63	51.0	220
84/05/22	1445		62.0	12.8	6.8	63.9	7.0	184	74	520	90.0	160
84/06/27	1215		5.0	17.7	3.1	32.3	6.8	405	16	300	37.0	250
84/07/11	1120		3.7	15.5	3.6	35.9	7.0	530	22	940	61.0	270
84/08/07	1110		2.0	17.5	6.1	63.3	7.0	480	27	400	38.0	270
84/09/19	1115		1.5	15.7	5.3	53.0	7.1	430	13	190	32.0	180

DATE FROM TO	TIME	DEPTH METERS	00620 NITRATE T NO3-N mg/l	00615 NITRITE T NO2-N mg/l	00610 AMMONIA T NH3-N mg/l	00671 DIS-ORTHO PHOSPHRUS mg/l P	00665 TOTAL PHOSPHRUS mg/l P	00900 HARDNESS TOT CaCO3 mg/l	71900 MERCURY TOTAL Hg ug/l	01030 CHROMIUM DIS Cr ug/l	01040 COPPER DIS Cu ug/l	01049 LEAD DIS Pb ug/l
84/04/11	1520		0.70	0.01K	0.57		0.07	100.0	0.06K	1.0K	12.0	1.0
84/05/22	1445		0.36	0.01K	0.56		0.06	60.0		1.0K	1.0K	1.0K
84/06/27	1215		0.95	0.01K	1.10		0.09	80.0		5.0	23.0	8.0
84/07/11	1120		1.50	0.01K	1.30		0.08	140.0	0.16	1.0K	10.0	1.0
84/08/07	1110		1.30	0.01K	1.30		0.26		0.05K	1.0K	14.0	1.0K
84/09/19	1115		1.80	0.01K	1.30	0.08	0.08	120.0	0.06K	2.4	23.1	1.0K

DATE FROM TO	TIME	DEPTH METERS	01090 ZINC DIS Zn ug/l	01025 CADMIUM DIS Cd ug/l	00340 COD HI LEVEL mg/l	00008 LAB LOG NUMBER	01065 NICKEL DIS Ni ug/l	01034 CHROMIUM TOT REC ug/l Cr	01042 COPPER TOT REC ug/l Cu	01051 LEAD TOT REC ug/l Pb	01092 ZINC TOT REC ug/l Zn	01027 CADMIUM TOT REC ug/l Cd
84/04/11	1520		470	6.40	34	1557	32	9.0	35.0	13.0	680	6.80
84/05/22	1445		113	0.90		2376	1K	13.0	30.0	50.0	415	6.60
84/06/27	1215		877		32	2900		24.0	50.0	70.0	935	18.50
84/07/11	1120		936	18.90	45	3097	62	1.0K	44.0	8.0	1262	25.20
84/08/07	1110		710	14.50	57	3444	104	8.0	61.0	12.0	1425	19.30
84/09/19	1115		1274	19.40	48	4130	157	19.1	71.9	1.0K	1915	23.70

DATE FROM TO	TIME	DEPTH METERS	01067 NICKEL TOT Ni ug/l	34210 ACROLEIN TOT WATER ug/l	34215 ACRYLONI-TRILE TOT H2O ug/l	34030 BENZENE TOTAL ug/l	32102 CARBON TETRA Cl TOT ug/l	34301 CHLORO-BENZENE TOT ug/l	34531 12-DICHL OROETHANE TOT ug/l	34506 111-TRICL OROETHANE TOT ug/l	34496 11-DICHL OROETHANE TOT ug/l	34511 112-TRICL OROETHANE TOT ug/l
84/04/11	1520		99	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	2.8	2.0M	2.0U
84/05/22	1445		12	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	2.6	2.0U	2.0U
84/06/27	1215		117	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	5.0	2.0U	2.0U
84/07/11	1120		82	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	8.0	2.0U	2.0U
84/08/07	1110		106	10.0U	5.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/09/19	1115		195	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0M	2.0U

DATE FROM TO	TIME	DEPTH METERS	34516 1122TETRA CLOROTHNE TOT ug/l	34311 CHLORDE THANE TOT ug/l	34576 2-CHLORDE THYL VINY TOT ug/l	32106 CHLOROFRM WHOLE H2O TOT ug/l	34501 11DICHLOR OETHYLENE TOT ug/l	34546 12TRDICHL ORETHYLEN TOT ug/l	34541 12DICHLOR OPROPANE TOT ug/l	34561 13DICHLOR OPROPENE TOT ug/l	34371 ETHYL BENZENE TOT ug/l	34423 METHYLENE CHLORIDE TOT ug/l
84/04/11	1520		2.0U	2.0U	2.0U	6.4	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/05/22	1445		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
84/06/27	1215		2.0U	2.0U	2.0U	14.0	2.0U	2.0U	2.0U	2.0U	2.0U	8.7
84/07/11	1120		2.0U	2.0U	2.0U	18.0	2.0U	2.0U	2.0U	2.0U	2.0U	8.6
84/08/07	1110		2.0U	2.0U	2.0U	2.0U	2.0M	2.0U	2.0U	2.0U	2.0U	41.0
84/09/19	1115		2.0U	2.0U		9.6	2.0M	2.0M	2.0U	2.0U	2.0U	42.0

DATE FROM TO	TIME	DEPTH METERS	34418 METHYL CHLORIDE TOT ug/l	34413 METHYL BROMIDE TOT ug/l	32104 BROMOFORM WHOLE H2O ug/l	32101 BROMODICL OROMTHANE TOT ug/l	34488 TRICHLORO FLRMTHANE TOT ug/l	34668 DICHLORO DIFRMTHNE TOT ug/l	32105 DIBROMOCH LOROMTHNE TOT ug/l	34475 TETRACHLO ROETHYLNE TOT ug/l	34010 TOLUENE IN WATER TOT ug/l	39180 TRICHLORO ETHYLENE TOT ug/l
84/04/11	1520		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0M	2.0M	11.0
84/05/22	1445		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0M	2.0U	4.9
84/06/27	1215		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.2	2.0U	27.0
84/07/11	1120		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.5	2.0U	31.0
84/08/07	1110		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.7	2.0M	15.0
84/09/19	1115		2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0M	2.0U	14.0

DATE FROM TO	TIME	DEPTH METERS	39175 VINYL CHLORIDE TOT ug/l
84/04/11	1520		2.0U
84/05/22	1445		2.0U
84/06/27	1215		2.0U
84/07/11	1120		2.0U
84/08/07	1110		2.0U
84/09/19	1115		2.0U

APPENDIX II

Ancillary Data

Appendix II. - Data from ancillary studies

Date	April 18, 1984								May 17, 1984		
Station Number	M-F	M-1	M-2	M-3	M-4	M-K	SB-A	M-L	M-E	M-F	M-1
Time	1005	1020	1100	1125	1345	1530	1515	1545	1520	1440	1415
Flow (cfs)		15.6*			12.1*		8.6*				
Conductivity (umhos/cm)	168*	188*	230*	255*	313*	355*	212*	308*	204	240*	260*
pH (S.U.)	6.8*	6.8*	6.9*	6.9	6.9*	6.8*	7.0*	6.9*	7.1		
Temperature (°C)	12.0*	11.0*	11.5*	12.0*	14.9*	14.0*	15.0*	13.9*	18.5*	18.5*	17.0*
Dissolved Oxygen (mg/L)	7.6*	6.3*	6.0*	5.6*	5.4*	4.6*	8.7*	6.0*	8.2*	8.7*	8.5*
D.O. (% saturation)	70.3%	57.0%	54.9%	51.8%	53.2%	44.4%	85.8%	57.8%	86.9%	92.2%	87.4%
COD (mg/L)		44	36	40	28		16			27	31
NH_3-N (mg/L)		0.38	0.52	0.67	0.60		0.19				
NO_2-N (mg/L)		<0.05	<0.05	<0.05	<0.05		<0.01				
NO_3-N (mg/L)		0.45	0.45	0.85	0.90		0.84				
O-PO_4-P (mg/L)		†	†	†	†		†				
T-PO_4-P (mg/L)		0.10	0.10	0.11	0.12		0.14				
Turbidity (NTU)		63	51	56	33		11				

Date	July 18, 1984							August 7, 1984				
Station Number	M-A	M-B	M-C	S-A	M-F	M-1	M-3	M-C	S-A	M-D	M-E	M-F
Time	1300	1155	1500	1420	1100	1035	1000	1310	1320	1410	1340	1500
Flow (cfs)		0.88*	1.09*	0.41*		3.2*		0.81*	0.15*			1.03*
Conductivity (umhos/cm)	193	201	200	302	254	316	595*	214*	303*	237*	230*	220*
pH (S.U.)	7.6*	7.2*	7.4*	6.9*	7.3*	7.1*	6.9*	7.6*	7.1*	7.4*	7.5*	7.7*
Temperature (°C)	17.3*	17.1*	23.4*	17.6*	18.1*	17.1*	17.4*	20.5*	17.9*	20.7*	21.5*	23.0*
Dissolved Oxygen (mg/L)	9.4*	10.0*	11.5*	6.1*	7.5*	3.7*	1.9*	11.6*	4.9*	10.6	11.1	11.5
D.O. (% saturation)	97.3%	103.1%	133.8%	63.5%	78.9%	38.2%	19.7%	127.9%	51.8%	117.3%	124.7%	132.8%
COD (mg/L)	11	15	26	38	38	45				12		
NH_3-N (mg/L)				0.73		0.40						
NO_2-N (mg/L)				<0.01		<0.01						
NO_3-N (mg/L)				0.52		0.32						
O-PO_4-P (mg/L)				†		†						
T-PO_4-P (mg/L)				0.10		0.06						
Turbidity (NTU)	7	9	10	32	15	40				13	12	
Color (S.U.)	21	21	83	92	176	205						
Fecal coliform (#/100 mL)					1400						540	
Total Fe (mg/L)	0.57	2.1	2.1	4.5	2.6	4.4						

*Field measurement.
†Interference.

Appendix II. - Data from arcillary studies - continued.

Date	Sept. 19, 1984		October 16, 1984							October 25, 1984				
Station Number	T-A	M-G	M-B	M-F	T-A	M-G	M-H	W-A	M-I	M-F	T-A	M-J	W-A	M-I
Time	1440	1500	1230	1135	1350	1315	1255	1650	1055	1315	1350	1125	0955	1215
Flow (cfs)									2.23*	2.39*	0.28*		0.20*	2.9*
Conductivity (umhos/cm)	280*	222*	202*	208*	310*	230*	222*	340*	246*	172*	152*	140*	328*	157*
pH (S.U.)	7.4*	8.0*	7.3*	7.3*	7.0*	7.25*	7.2*	6.85*	6.9*	7.2*	7.0*	7.1*	6.7*	7.0*
Temperature (°C)	17.2*	17.1*	9.8*	9.4*	9.9*	10.9*	9.8*	11.4*	8.7*	12.1*	12.0*	11.6*	11.6*	11.7*
Dissolved Oxygen (mg/L)	6.4*	12.4*	9.6*	9.7*	5.4*	9.3*	8.65*	3.6*	7.3*	8.1*	5.6*	7.1*	0.6*	7.0*
D.O. (% saturation)	66.1%	127.8%	84.5%	84.6%	47.6%	83.9%	76.1%	32.9%	62.6%	75.1%	51.8%	65.1%	5.5%	64.3 %
COD (mg/L)				16	20		20	32	24	9	39		65	44
NH3-N (mg/L)	0.34	0.10		0.23	1.2		0.65	0.69	0.50	0.15	0.70		1.2	0.34
NO2-N (mg/L)	<0.01	0.01		<0.01	<0.05		<0.05	<0.05	<0.05	<0.01	<0.01		<0.01	<0.01
NO3-N (mg/L)	0.38	0.58		0.68	<0.1		0.45	<0.1	0.35	0.45	0.10		<0.05	0.35
O-PO4-P (mg/L)	0.14	0.13		†	†		†	0.10	0.10	0.08	†		†	†
T-PO4-P (mg/L)	0.22	0.18		0.08	0.06		0.10	0.10	0.12	0.09	0.06		0.06	0.10
Turbidity (NTU)	65	18		16	63		21	63	34	110	180		380	96
Color (S.U.)	350	100		84	240		130	260	160	26	51		360	35
Hardness (mg/L)	150	100												
Total Solids (mg/L)				170	220		170	270	190	150	140		510	140
TNVS (mg/L)				110	150		130	200	130	110	96		420	98
TSS (mg/L)				28	13		24	54	21	14	14		310	16
TNVSS (mg/L)				22	7		20	39	15	6	7		260	10

*Field measurement.
†Interference.