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MEMORANDUM

April 9, 1985

To: Jim Krull

From: Dale Norton and Art Johnson, Water Quality Investigations Section

Subject: Completion Report on WQIS Project 4 for the Commencement Bay Nearshore/Tideflats Remedial Investigation: Sources of Sediment Contamination in Sitcum Waterway, With Emphasis on Ores Unloaded at Terminal 7

ABSTRACT

Some of the highest sediment concentrations of zinc, copper, and lead in Commencement Bay waterways occur in Sitcum Waterway. To investigate the sources of contamination, metals concentrations were measured in various ores unloaded at Sitcum's Terminal 7 and stormwater discharges to the waterway.

High concentrations of zinc, lead, copper, arsenic, antimony, and mercury were present in zinc, copper, and lead ores. Alumina had uniformly low concentrations of target metals. The "North Corner" storm drain accounted for 80 to 98 percent of the zinc, copper, lead, and arsenic loads in runoff to the waterway. These facts coupled with metals concentration gradients observed in the sediments, indicate ore spillage from Terminal 7 and discharge from the North Corner drain appear to be the major current metals sources to Sitcum Waterway.

Based on the results of the Standard Elutriate test, zinc, copper, and lead ores and copper ore concentrate have the potential to adversely affect marine organisms when spilled into Sitcum Waterway.

INTRODUCTION

The Water Quality Investigations Section (WQIS) had responsibility for five projects† in the Commencement Bay Nearshore/Tideflats Remedial Investigation.

†WQIS projects:
- No. 1 - Assessment of Log Sort Yards as Metals Sources to Commencement Bay Waterways
- No. 2 - Metals in Hylebos Creek Drainage
- No. 3 - Point Source Monitoring
- No. 4 - Source Identification of Metals in Sitcum Waterway Sediments
- No. 5.1 - Priority Pollutants in City Waterway Storm Drains
- No. 5.2 - Metals in City Waterway sediments off American Plating, Martinac Shipbuilding, and Fick Foundry
- No. 5.3 - Petroleum Compounds in D Street Groundwater and Adjacent City Waterway Sediment

Project 4, reported here, involved an investigation of the high metals concentrations, primarily zinc, lead, copper, and arsenic, in Sitcum Waterway sediment first reported by NOAA in 1980 (Malins, et al., 1980).

The primary objective of this investigation was to obtain and analyze samples of the various metal ores unloaded at Terminal 7 on the northeast shore of the waterway. These data were then compared to the concentration and distribution of metals in Sitcum sediments. Some sediment sampling was done to better define concentration gradients in the waterway. Storm drains discharging to the waterway were also sampled to ascertain if they were significant metals sources.

A second objective was to determine if the metals in ore are available to the water column. This was assessed through the Extraction Procedure (EP) toxicity and Standard Elutriate tests of ore in addition to limited water column sampling.

SITE DESCRIPTION

Sitcum Waterway, shown in Figure 1, was first dredged in 1946. Port of Tacoma records indicate that between 1946 and 1983, roughly 3.5 million cubic yards of material were removed, primarily to create and maintain four berths along a 2,700-foot pier on the northeast shore of the waterway to serve the Terminal 7 complex (Figure 2). Berths A and B located near the head of the waterway were constructed in 1961, followed by berth C in 1966, and berth D at the seaward end in 1973 (see Figure 5). Terminal 7 currently provides depths ranging from 35 feet at MLLW in berth A to 50 feet at MLLW in berth D. Dredging was also conducted in 1979 to create the West Sitcum Terminal along the southwest shore, which provides an additional 250 feet of pier frontage (Kuzinski, 1984). Table 1 summarizes the dredging history of Sitcum Waterway.

Table 1. Dredging history of Sitcum Waterway.

Completed	Contract Number	Purpose and Amount	Disposal
1946	19	Initial dredging 2,736,800 yd^3	Landfill bordered by east 11th Street, Lincoln Avenue, Milwaukee Way, and Port of Tacoma Road ("quadrangle")
1956	49	385,000 yd^3	Landfill adjacent to Sitcum Waterway behind Terminal 7, Berth A
October 1961	99	Dredging for Berths A & B 43,000 yd^3	Commencement Bay deepwater disposal site
February 1966	179	Dreding for Berth C	(no information)
June 1968	214	77,947 yd^3	Commencement Bay deepwater disposal site
1973	339	Dredging for Berth D	(no information)
March 1979	456	Made West Sitcum terminal (TOTE facility) 82,000 yd^3	Landfill west side of Sitcum Waterway (TOTE facility)
September 1982	488	Maintenance dredging Berth B 29,708 yd^3	Four Mile Rock, Elliott Bay
February 1983	525	West shoal dredging 90,000 yd^3	Commencement Bay deepwater disposal site

Source: Gary Kuzinski, Port of Tacoma, 2/1/84.

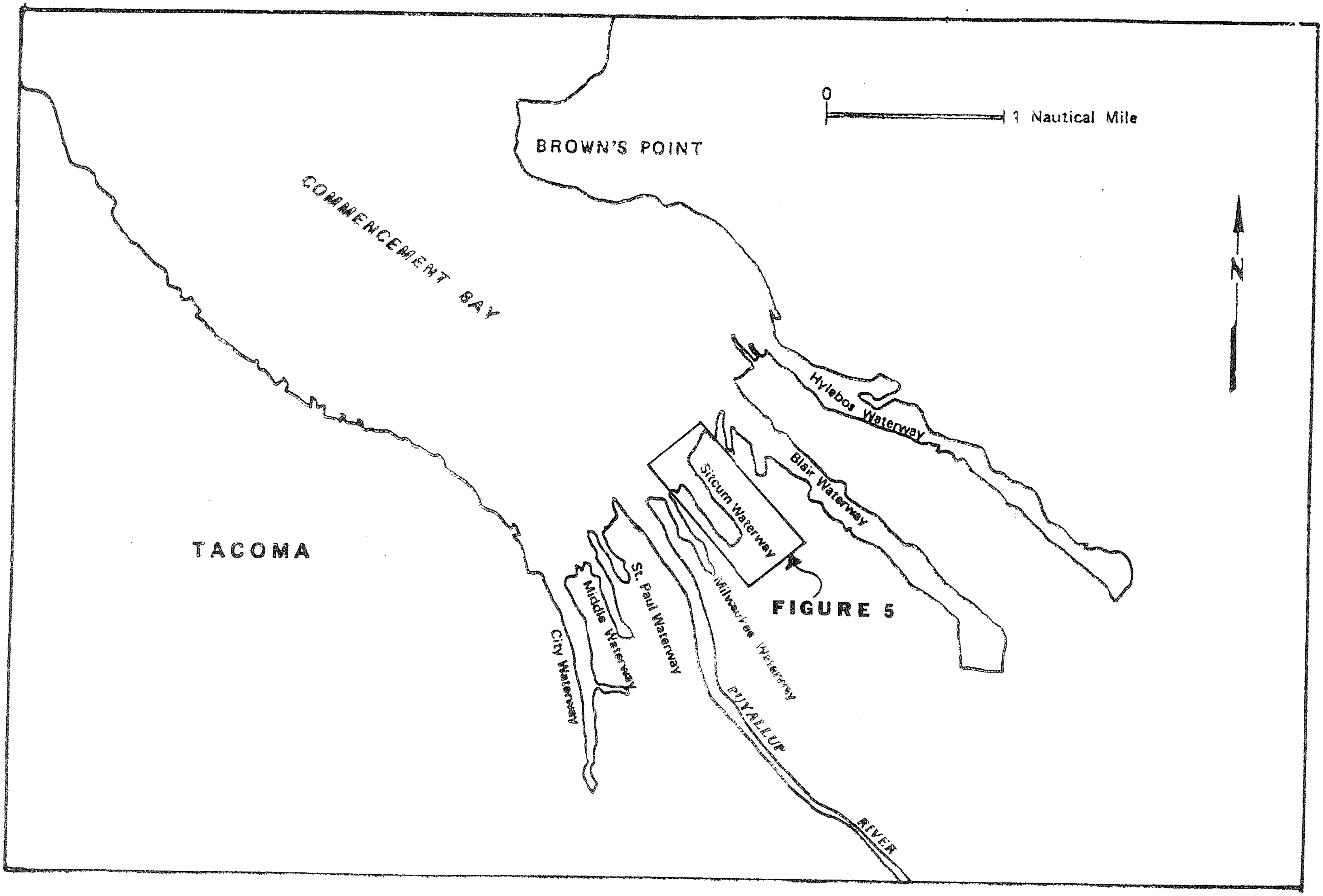


Figure 1. Location of Sitcum Waterway.

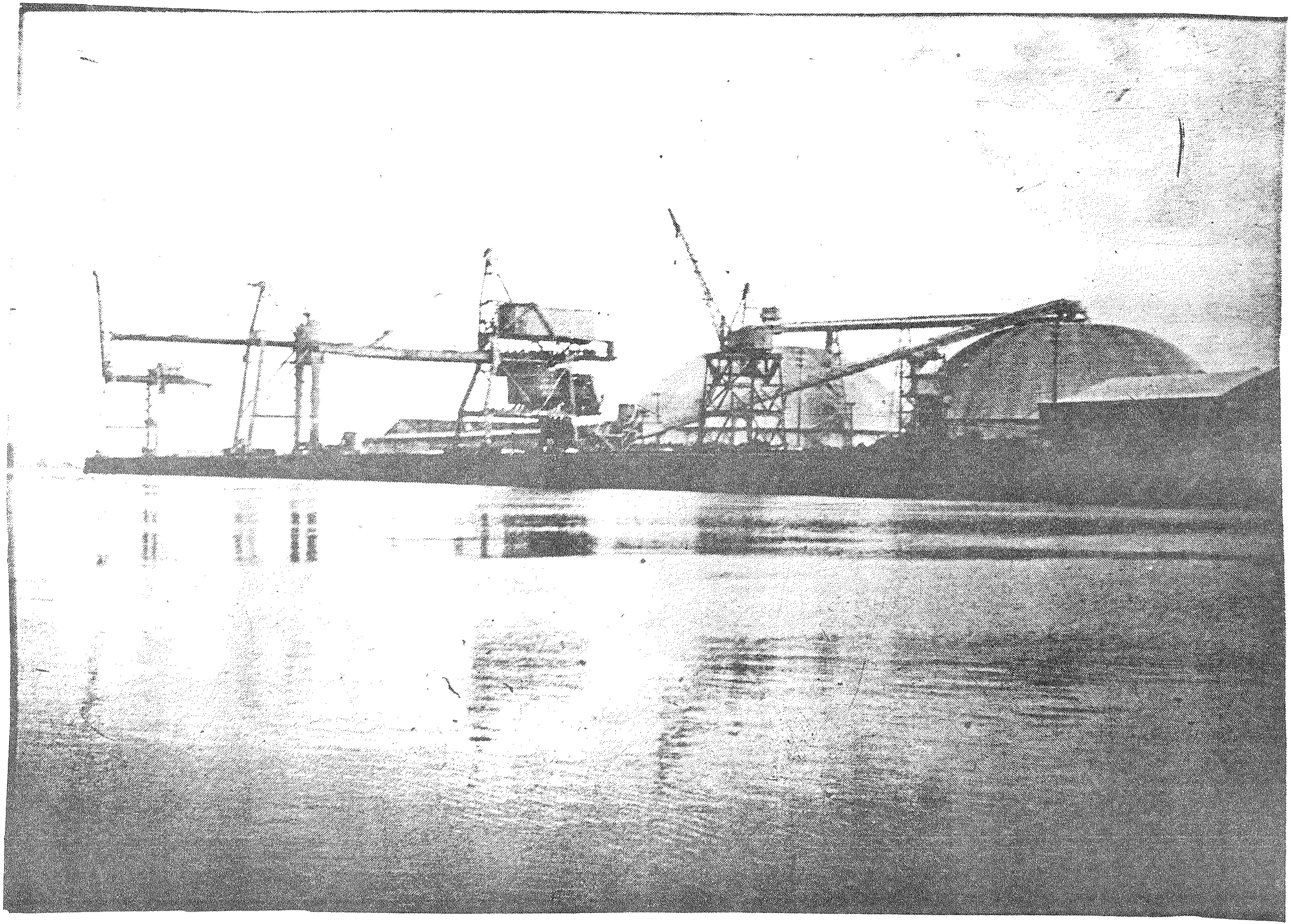


Figure 2. Port of Tacoma Terminal 7, Sitcun Waterway.

Facilities at Terminal 7 include multipurpose cranes for container handling and bulk unloading of alumina, various ores, and ore concentrates--primarily zinc, copper, and lead. Between 1973 and 1983, an average of 520,000 metric tons/year of alumina and 145,000 metric tons/year of bulk ore/nitrate were handled at Terminal 7 (Kuzinski, 1984). An average of one alumina and two ore shipments arrive in Sitcum Waterway each month. Copper ore and ore concentrate have been handled only since 1980 (Bush, 1984).

Most of the alumina brought into Terminal 7 is transferred by clamshell bucket to a conveyor system which carries the alumina directly to two storage domes. The domes, which were constructed in 1966 and 1968, have a combined capacity of 136,000 metric tons. Alumina is shipped out via containerized rail cars from Terminal 7. Other types of ores are also unloaded by clamshell bucket, but are transferred directly to open rail cars for inland distribution (Figure 3).

The West Sitcum Terminal has three finger piers for ramp loading/unloading of commodities. The remainder of the approximately 170 acres of paved area surrounding the waterway is presently used for warehouse space, container storage, Port of Tacoma adminfstative offices and parking.

In the process of unloading alumina and ore, spillage occurs on the dock area (Figure 4). WDOE Southwest Regional Office (SWRO) records indicate that it has been the Port of Tacoma's standard practice to sweep up what material can be recovered and wash the remainder into Sitcum Waterway. WDOE also has received requests from the Port to allow discharge of cargo hold washwater directly into the waterway rather than the normal practice of discharge at sea.

Between 1936 and 1975, Cascade Pole operated a wood preserving plant near Terminal 7 located between the present site of the two alumina domes and 11th Street. According to their 1970 Washington State Discharge Permit Application, wood preservatives used at the plant included pentachlorophenol, creosote, chrome, and arsenic. Wastewaters from the facility were passed through an API oil/water separator and sorbent filters prior to being discharged into Sitcum Waterway under Terminal 7.

METHODS

Sampling

Samples of lead, zinc, and copper ores, and alumina were collected between February 3 and March 27, 1984, while these materials were being unloaded at Terminal 7. Approximately 1 kilogram of each type was taken.

Four Sitcum Waterway sediment samples were collected with a 0.1 m^2 VanVeen grab on April 26, 1984, at the sites shown in Figure 5. Coordinates for these stations and other location information are in Appendix I. The surface 2 cm layer of each grab was removed with a stainless steel spoon, placed in a one-gallon glass jar, and homogenized by stirring. Subsamples of this homogenate were then placed in separate 4.5-ounce polyethylene cups for metals and dry weight determinations, and in one-pint glass jars for grain size, total organic carbon (TOC), and nitrogen analyses.

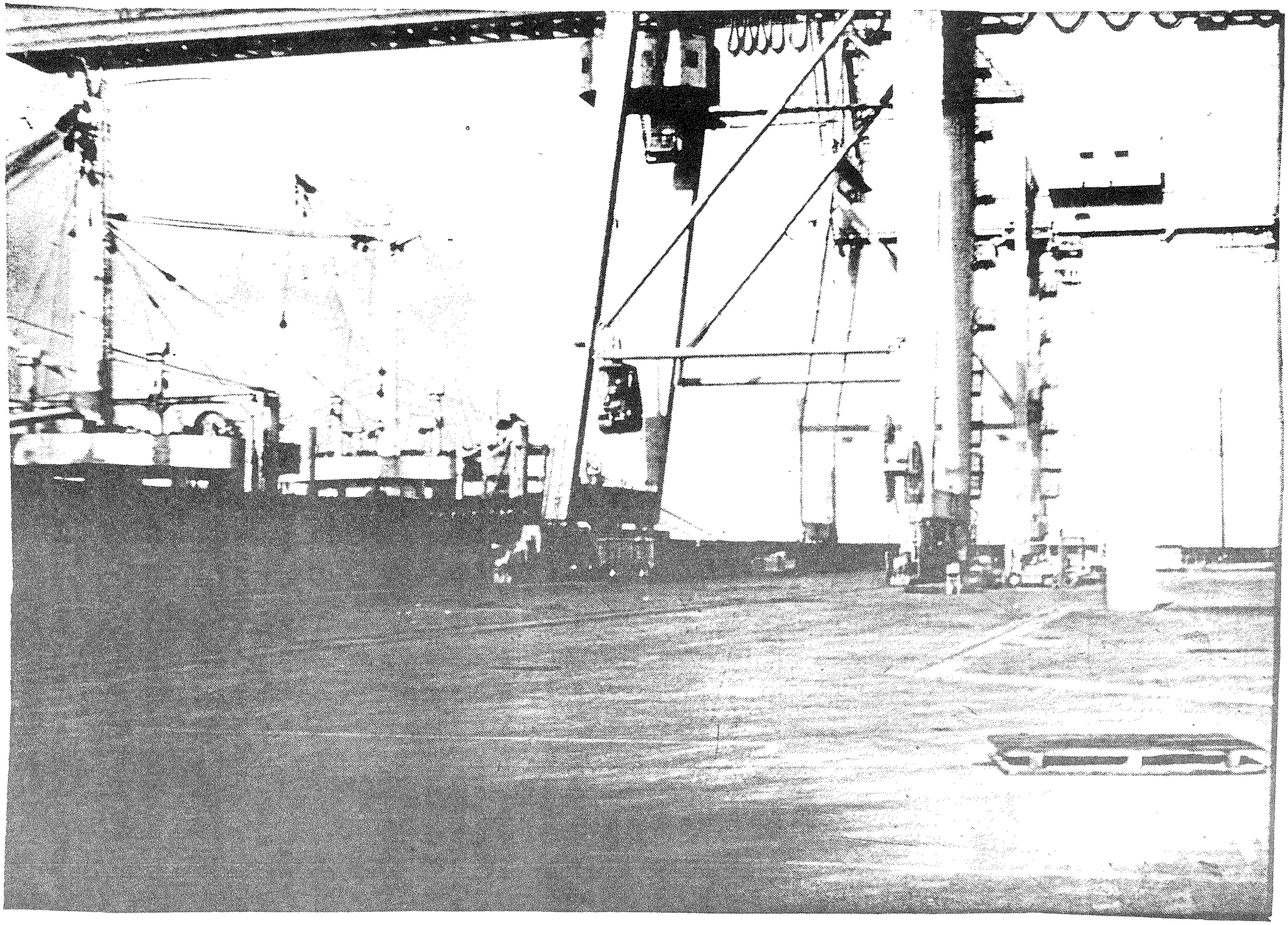


Figure 3. Ore unloading facilities at Terminal 7, Sitcum Waterway, March 27, 1984.

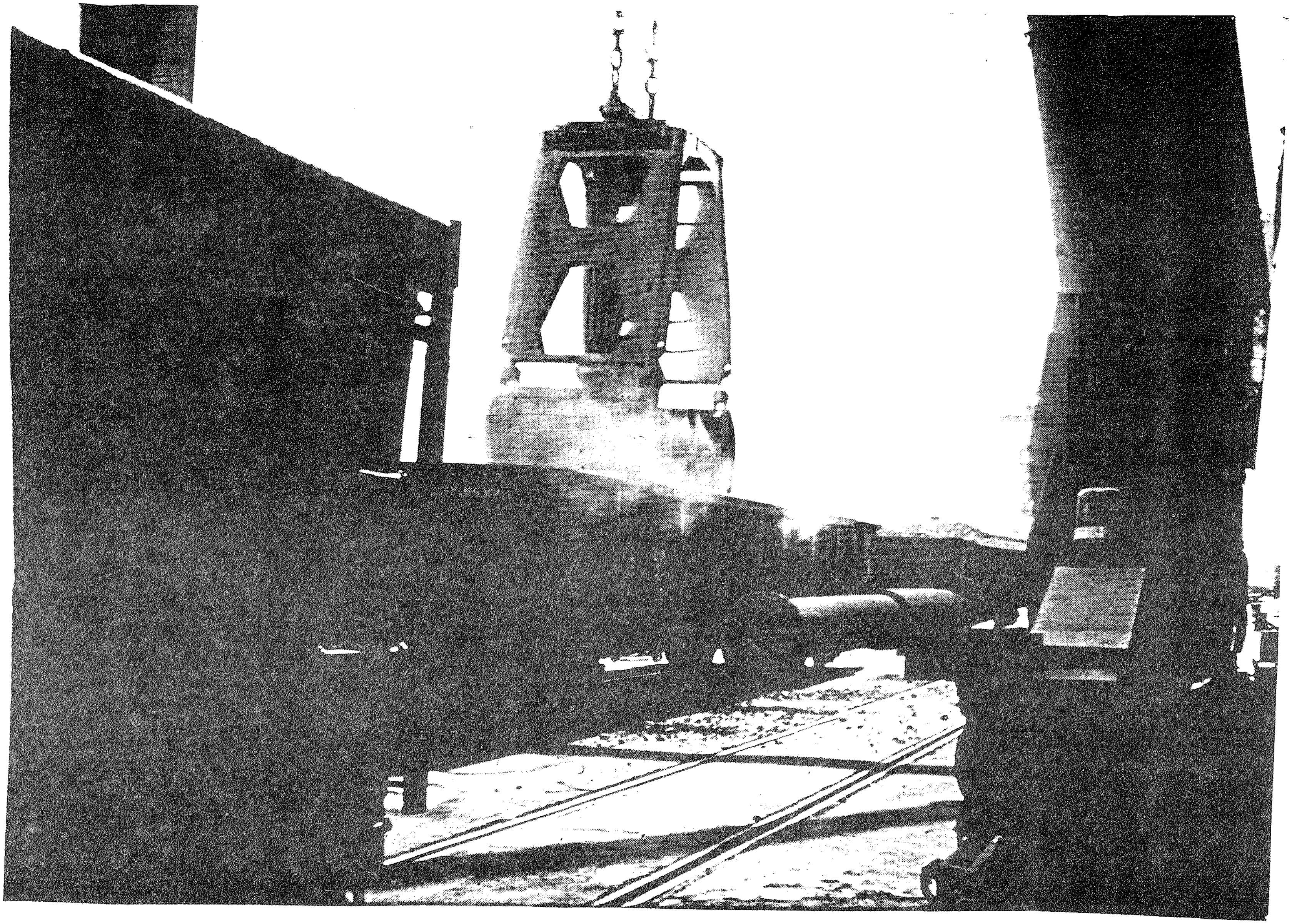


Figure 4. Ore spillage during unloading at Terminal 7, Sitcum Waterway, March 27, 1984.

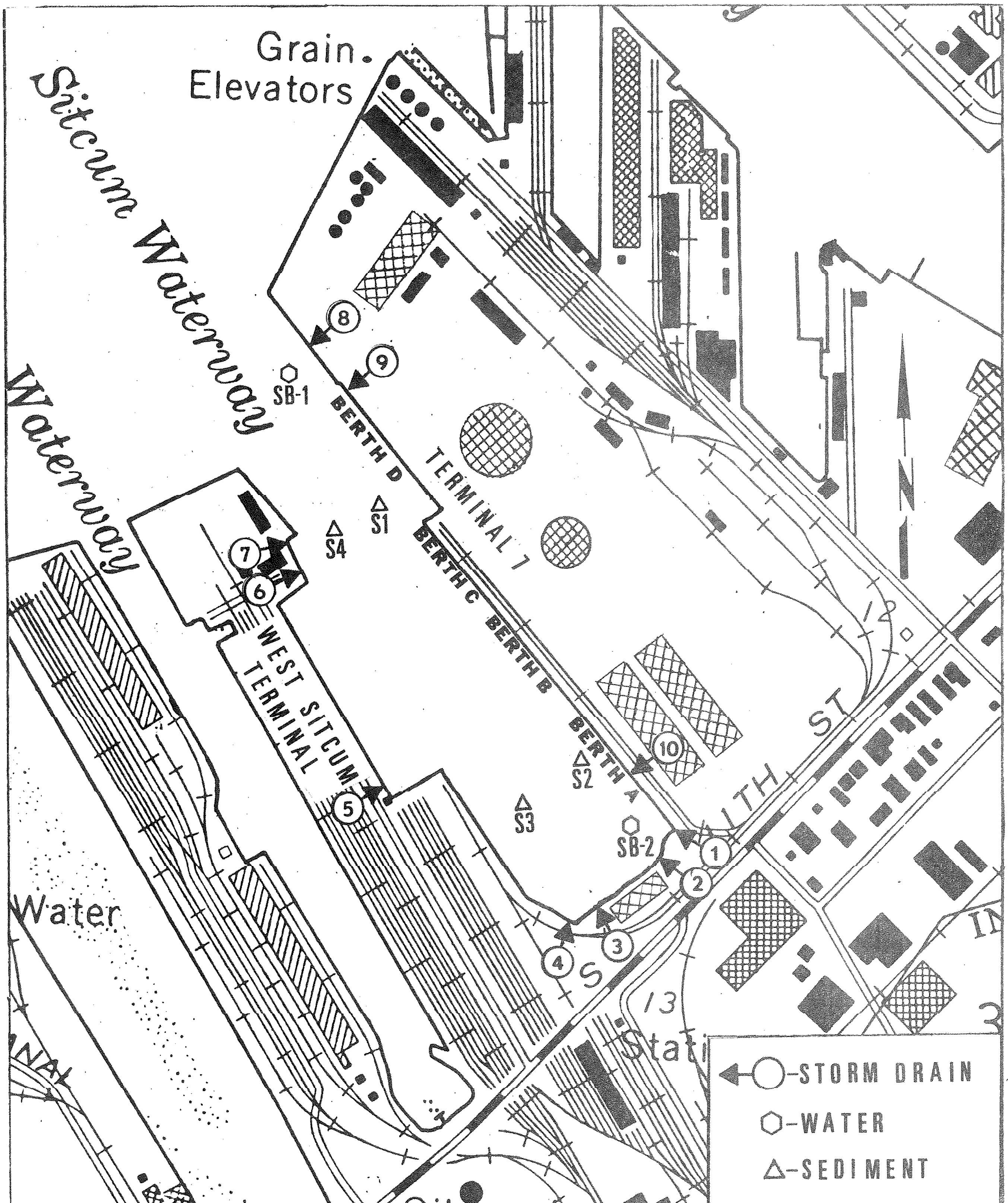


Figure 5. Locations of WDOE storm drain, receiving water, and sediment sampling sites in Sitcum Waterway, April-August 1984.

Runoff from the ten major storm drains to Sitcum Waterway were sampled during a storm event on June 26, 1984. Drain locations are shown in Figure 5. These samples were grabs of one liter each in new polyethylene cubitainers previously rinsed with de-ionized water. Flows were determined with a Marsh-McBirney magnetic flow meter and top-setting rod or alternately with a bucket and stopwatch.

Water column samples were collected on two occasions, both in the absence of ore unloading operations at Terminal 7. The first samples were taken during late flood tide on June 26, 1984, from a depth of 35 feet at the mouth of the waterway. This water was used in the Standard Elutriate test described below in the analysis section. A second group of samples was collected August 21, 1984. These were also bottom water samples but were collected at both the mouth during mid-flood and head of the waterway at high slack/early ebb to determine if a change in metals content could be detected in incoming bottom waters after a period of residence in the inner waterway. These sampling sites are also shown in Figure 5.

All water column samples were collected with a General Oceanics ten-liter, teflon-lined, Go-Flo bottle; teflon-coated messenger; and Phillystran Kevlar/polyester sampling rope. Dissolved metals concentrations were determined for the August samples by transferring a portion of the Go-Flo sample to an Amicon fiberglass reservoir, pressurizing the reservoir with nitrogen, and filtering through a 0.45 micron Nucleopore polycarbonate membrane filter. All tubing, fittings, and filter holders used were teflon. All components of the system, including the membrane filters, were washed with HNO_3/HCl and rinsed with de-ionized water before use.

The June water column sample containers were identical to those used to collect storm runoff. The August samples were collected in one-liter, high-density, polyethylene bottles cleaned by a rigorous HNO_3/HCl leaching procedure (Moody and Lindstrom, 1977).

All water and sediment samples were placed on ice immediately after collection. WDOE chain-of-custody procedures were followed.

Analysis

Metals analyses were done at the EPA/WDOE laboratory in Manchester, Washington. Sediment and ore samples were first digested with HNO_3 and H_2O_2, as described in Test Methods for Evaluating Solid Waste (EPA, 1982). Sample analysis was by atomic absorbtion spectrometry using a graphite furnace, except mercury which was done by the cold vapor technique. Analysis followed Methods for Chemical Analysis of Water and Wastes (EPA, 1979).

Grain size, TOC, and nitrogen in sediment were analyzed at Rocky Mountain Analytical Laboratory in Arvada, Colorado, an EPA contractor. Grain size was done by the method of seives and pipettes. Carbon and nitrogen were measured on a Perkin-Elmer elemental analyzer. These methods are described in Procedures for Handling and Chemical Analysis of Sediment and Water Samples (EPA/COE, 1981). The WDOE Tumwater laboratory determined percent solids in the sediment samples following the EPA 1979 manual previously mentioned.

The EP toxicity test done on the ore samples is designed to simulate leaching conditions in upland disposal situations. Briefly, the method involves a 24-hour extraction with distilled water maintained at pH 5 with acetic acid. Contaminant concentrations (metals in this case) in the leachate are then compared to threshold values established for dangerous and hazardous wastes as derived from drinking water standards. The EP toxicity test is method 1310 in Chemical Testing Methods for Complying with the State of Washington Dangerous Waste Regulation (WDOE, 1983). The WDOE Redmond, Washington, laboratory did this analysis.

The second test used to assess metals availability from ore was the Standard Elutriate test described in the EPA/COE, 1981, manual previously referenced. It is a short-term leaching procedure where known volumes of sample (ore) and site water are agitated together, the suspension filtered, and filtrate analyzed for constituents of concern. The test's primary application is assessment of materials released during dredge and fill operations. This analysis was done at the EPA/WDOE Manchester laboratory. A 1:4 weight-to-volume ratio of ore to seawater was used (e.g., 100 g ore:400 mL seawater), contact time was 1 1/2 hours (1/2 hour agitation; 1 hour settling), and filter pore size was 0.45 micron.

Quality Assurance

These surveys were done in accordance with a quality assurance program (WDOE, 1983) developed following requirements and guidelines set down in The Final QA Program Plan for Commencement Bay Nearshore/Tideflats Remedial Investigation (Tetra Tech, 1983).

Prior to analyzing sediment and ore samples, the accuracy of the Manchester laboratory analytical methods was assessed for selected metals by analysis of National Bureau of Standards (NBS) #1646 standard estuarine sediment with the results shown below in Table 2:

Table 2. Results of EPA/WDOE Manchester laboratory analysis of NBS standard estuarine sediment #1646.

Metal	NBS Stated Value (mg/Kg)	EPA/WDOE Measured Value (mg/Kg)	EPA/WDOE Value as Percent of Stated Value
Zinc	138 ± 6	114	82.6
Lead	28.2 ± 1.8	24.1	85.5
Copper	18 ± 3	20	110
Arsenic	11.6 ± 1.3	11.7	101
Chromium	76 ± 3	50	66
Cadmium	0.36 ± 0.07	0.38	110
Mercury	0.063 ± 0.012	0.062	98

The Manchester laboratory measurements coincide with the NBS-determined values for copper, arsenic, cadmium, and mercury, but were slightly lower for zinc and lead. Because of the substantial discrepancy between Manchester and NBS for chromium, a second sample of the standard was re-analyzed by the same method with a resulting improved chromium value of 61 ± 3 mg/Kg (mean ± 1 SD of six replicates). Since digestion with HNO_3 and H_2O_2 is not a total sediment digestion procedure, the low chromium values obtained by Manchester are probably the result of incomplete recovery of the chromium present in the NBS standard (Bailey, 1985). In the opinion of the analyst, accuracy of the Manchester chromium analysis for the data reported here probably lies somewhere between 66 percent to 80 percent of the actual values (Stinson, 1984).

The Manchester laboratory achieved ± 3 percent accuracy on EPA performance evaluation water samples (EMSL Cincinnati, Ohio) run as internal standards; spike recoveries obtained on water were within the range of 85 to 110 percent (Arp, 1984). Method blanks for sample bottles and filtration apparatus used in the field collection and elutriate test had metals concentrations at or below detection limits in all cases. Therefore, no blank corrections were applied to the water data.

Grain size, TOC, and nitrogen analyses were reviewed by Robert Barrick, Tetra Tech, Inc., Bellevue, Washington, QA officer for the Commencement Bay investigations. TOC and nitrogen duplicates exceeded QA limits in four of seven samples, which was attributed to sample heterogeneity. The average of duplicate results is used in this report.

RESULTS

Distribution of Metals in Sitcum Sediments

Figures 6a through 6c† show the horizontal distribution of zinc, lead, copper, arsenic, antimony, and mercury in Sitcum Waterway surface sediments as measured by Tetra Tech, Inc. in March 1984, EPA in August 1980, and WDOE during the present survey. These data sets were selected for comparison because equivalent strata were sampled and similar sample digestion (HNO_3 + H_2O_2) and analysis (atomic adsorbtion spectrometry for most metals) methods were used. The results of metals and conventionals analyses on the WDOE sediment samples are tabulated in Appendix II.

†Tetra Tech data supplied by T. Ginn and R. Barrick; figures prepared by R. Feins, Tetra Tech, Inc.

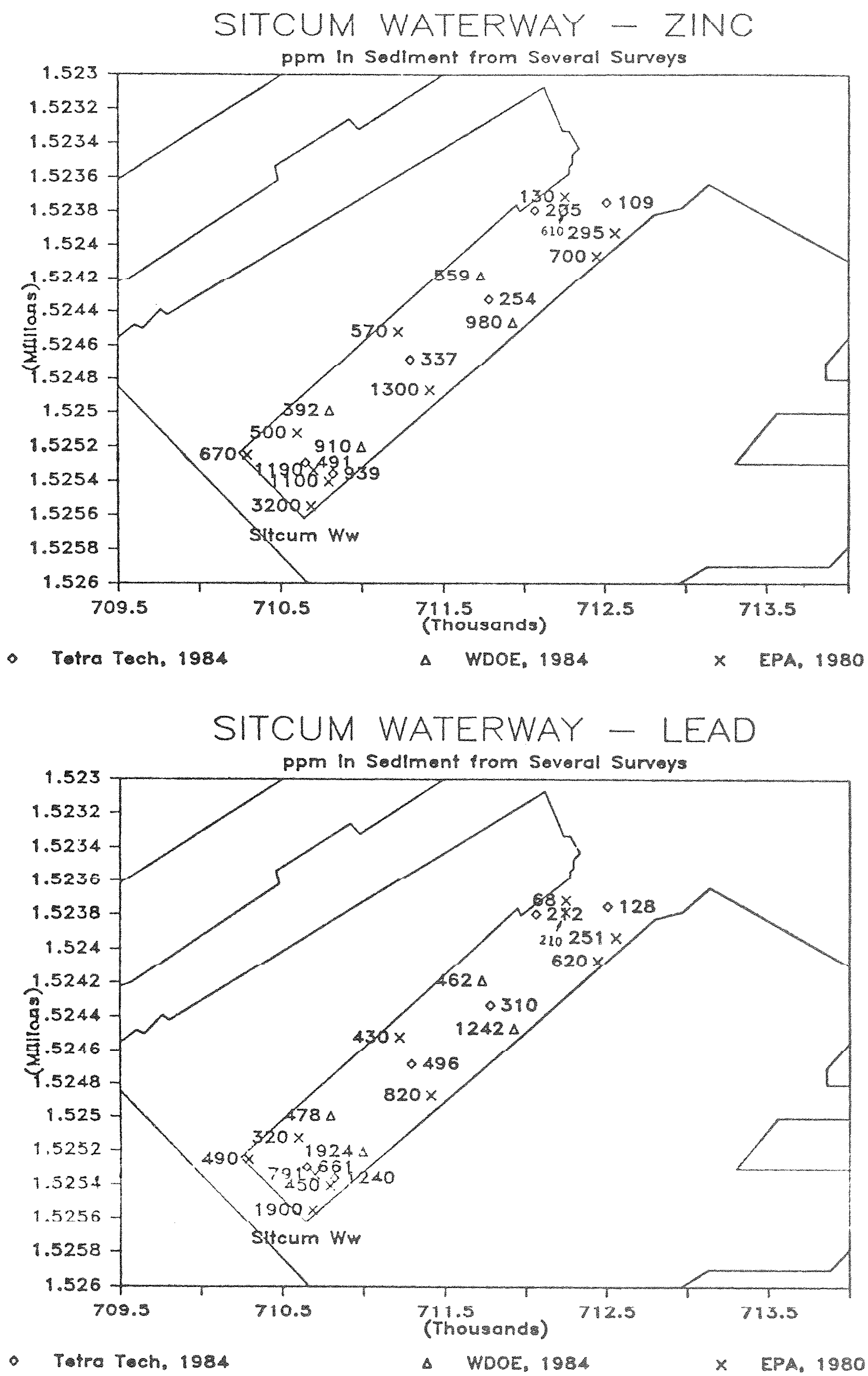
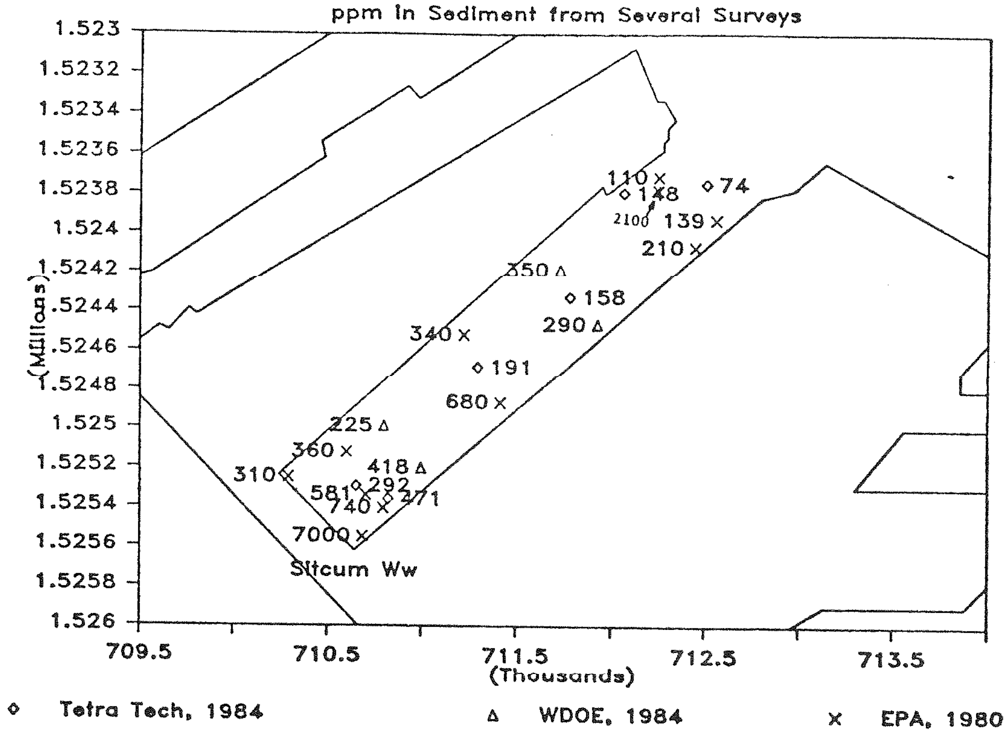


Figure 6a. Metals concentrations in Sitcum Waterway sediments collected by EPA, Tetra Tech, and WDOE (State Plane Coordinates).

SITCUM WATERWAY – COPPER

ppm in Sediment from Several Surveys



SITCUM WATERWAY – ARSENIC

ppm in Sediment from Several Surveys

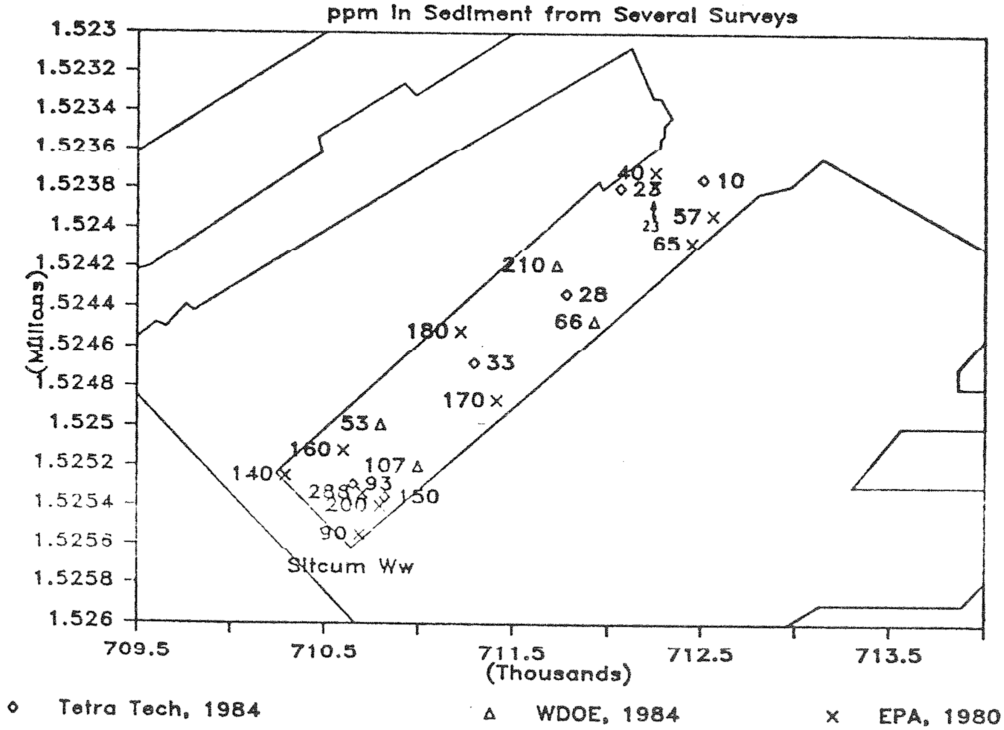
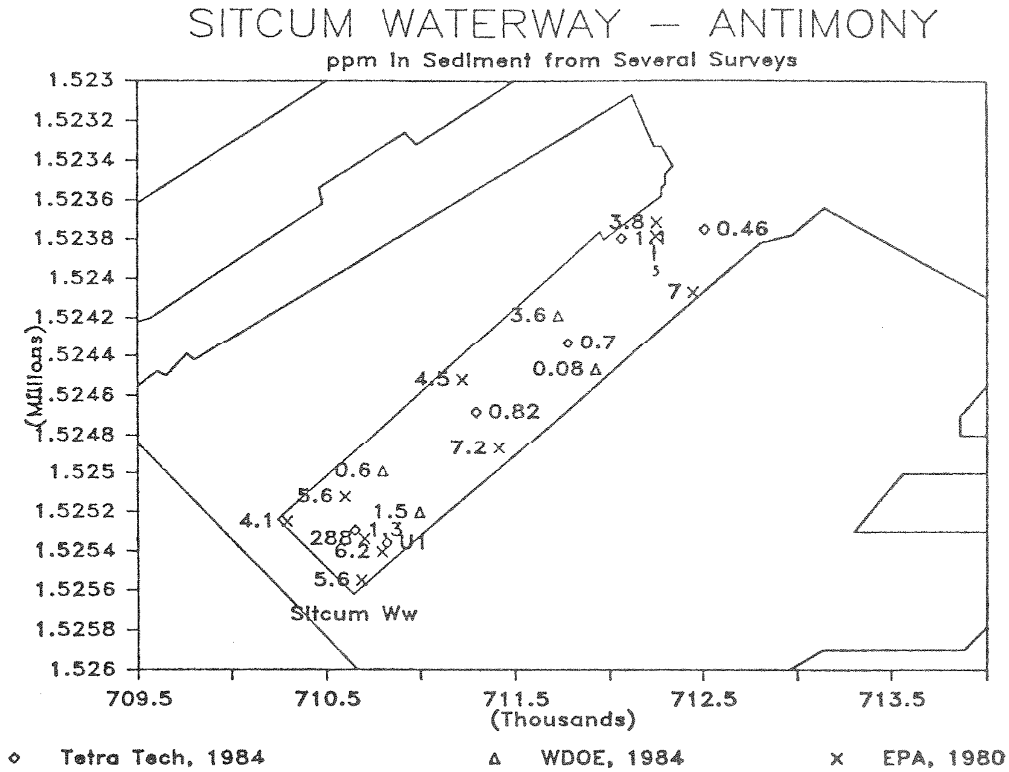


Figure 6b.


SITCUM WATERWAY — ANTIMONY
ppm in Sediment from Several Surveys
(Millions)
(Thousands)
709.5
710.5
711.5
712.5
713.5
1.523
1.5232
1.5234
1.5236
1.5238
1.524
1.5242
1.5244
1.5246
1.5248
1.525
1.5252
1.5254
1.5256
1.5258
1.526
3.8
0.46
7
3.6
0.7
0.08
4.5
0.82
7.2
0.6
5.6
1.5
4.1
6.2
5.6
Sitcum Ww
Tetra Tech, 1984
WDOE, 1984
EPA, 1980

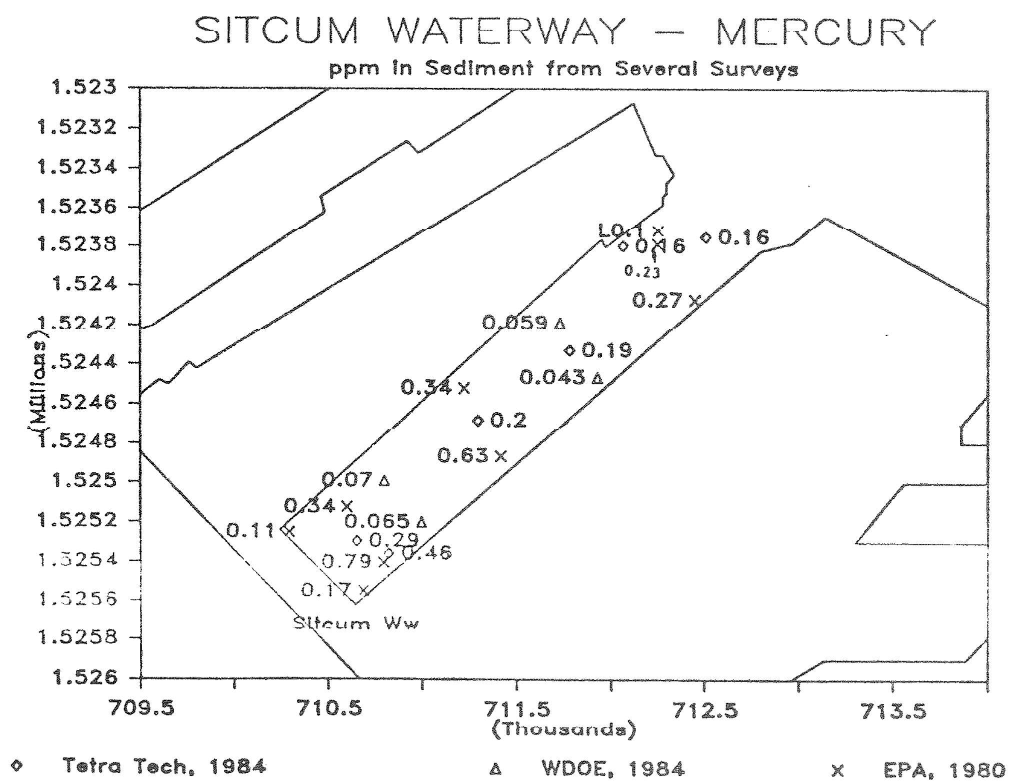

SITCUM WATERWAY — MERCURY
ppm in Sediment from Several Surveys
(Millions)
(Thousands)
709.5
710.5
711.5
712.5
713.5
1.523
1.5232
1.5234
1.5236
1.5238
1.524
1.5242
1.5244
1.5246
1.5248
1.525
1.5252
1.5254
1.5256
1.5258
1.526
0.16
0.23
0.27
0.059
0.19
0.043
0.34
0.2
0.63
0.07
0.34
0.065
0.11
0.29
0.79
0.46
0.17
Sitcum Ww
Tetra Tech, 1984
WDOE, 1984
EPA, 1980

Figure 6c.

Metals concentrations increase moving from the mouth toward the head of the waterway. Substantially higher levels of zinc, lead, copper, and mercury are present on the Terminal 7 side of Sitcum Waterway than on the West Sitcum Terminal side. This strongly suggests that ore spillage during unloading operations at Terminal 7, which has been documented on several occasions, and the Port of Tacoma's standard practice of washing spilled ore into the waterway are the sources of contamination. A similar transverse gradient is not apparent for arsenic and antimony. The disparity in antimony levels reported by Tetra Tech versus EPA and WDOE may be due to analytical differences between the EPA contract laboratory which performed Tetra Tech's analysis and the EPA/WDOE laboratory. The HNO_3 and H_2O_2 digestion procedure used by both laboratories is not a total sediment digestion procedure for all metals. Variable results can be obtained when a partial digestion procedure is used, depending on the exact time period and temperature used for the digestion (EPA/COE, 1981). Unless both laboratories employed the same digestion time and temperature, variable extraction of the acid soluble antimony could result.

Tetra Tech has also collected one deep core from inner Sitcum Waterway along the Terminal 7 pier face near the corner of the waterway in berth A. The results, shown below in Table 3, indicate a slight increase in metals concentration for the 10-to-30-cm layer relative to overlying sediments. An abrupt decrease in metals concentrations of four to ten times for zinc, lead, copper, arsenic, antimony, and cadmium occurs between 30 cm and the limit of core penetration at 41 cm.

Table 3. Tetra Tech, Inc. data on metals concentrations in a sediment core from Sitcum Waterway collected May 1984 (mg/Kg, dry weight).

Station	Sample	Depth (cm)		Moisture (%)	Total Organic Carbon (%)	Grain Size			Metal						
		Upper	Lower			Sand (%)	Silt (%)	Clay (%)	Zinc	Lead	Copper	Arsenic	Antimony	Mercury	Cadmium
SI-60	B02-H1	0	10	60.1	2.46	16.65	62.65	19.16	939	1240	471	150	1u	0.46	6.7
"	B02-H2	10	30	58.1	2.34	16.37	66.55	16.42	1100	1670	669	210	6.3	0.65	8.0
"	B02-H3	30	41	54.2	2.96	3.04	67.68	29.29	150	160	128	44	1u	0.25	1.9

u = Not detected at detection limit shown.

The highest concentrations of zinc (3,200 mg/Kg) and copper (7,000 mg/Kg) and second highest concentration of lead (1,900 mg/Kg) in Sitcum Waterway sediments occur intertidally near the large storm drain in the northeast corner of the waterway, commonly referred to as the "North Corner" drain (Discharge #1, Figure 5). Spillage of ore from rail cars which travel along Terminal 7 above this area as well as discharge from the North Corner drain itself could be responsible for the elevated levels of these three metals. In addition, this drain receives runoff from the railroad switching yard located along Milwaukee Way which could be an indirect route for ore to reach the waterway.

To put Sitcum Waterway sediments in perspective, see Table 4 which compares the most recent and comprehensive data available on metals concentrations in sediments from other Commencement Bay waterways and Carr Inlet, the reference station selected for the Commencement Bay Nearshore/Tideflats Investigation. These data are from mid-channel transects sampled by Tetra Tech on March 11-18, 1984.

Table 4. Comparison of metal concentrations† in subtidal sediments from Commencement Bay waterways and Carr Inlet collected by Tetra Tech, Inc. March 11-18, 1984.

Waterway	Sample Size	Metal (mg/Kg dry weight)					
		Zinc	Lead	Copper	Arsenic	Antimony	Mercury
Sitcum	5	254(109-491)	310(128-661)	158(74-292)	28(10-93)	0.82(0.46-1.3)	0.2(0.16-0.46)
City	11	234(44-325)	291(49-725)	166(40-203)	8(1.1-33)	0.94(0.22-1.4)	0.28(0.1-1.1)
Hylebos	24	137(21-273)	79(8.3-134)	111(14-204)	30(5.8-86)	0.88(0.1u-3.4)	--
Blair	11	68(35-85)	54(28-64)	54(28-64)	19(7-36)	0.52(0.18-0.70)	--
St. Paul	5	60(29-106)	24(11-52)	56(29-82)	7.0(5.5-12)	0.44(0.13-0.72)	0.17(0.094-0.36)
Middle	3	178(158-208)	190(188-303)	311(176-554)	39(15-67)	1.1(0.1u-1.9)	0.32(0.18-3.4)
Milwaukee	5	105(63-135)	62(48-78)	60(46-77)	10(9.5-19)	0.48(0.38-0.54)	0.16(0.12-0.18)
Carr Inlet	6	18(15-24.1)	11(4.4-13)	6.3(4.9-8.0)	3.8(2.4-3.8)	0.1(0.1u-0.14)	0.042(0.01-0.098)

Median(range)

† = Data supplied by T. Ginn and R. Barrick, Tetra Tech, Inc.

-- = No data.

Based on median concentrations, Sitcum Waterway has the highest zinc and lead levels and the third highest copper and arsenic concentrations of any inner Commencement Bay waterway. Compared to reference levels (Carr Inlet), Sitcum Waterway sediments are approximately fourteen times higher in zinc, twenty-five times higher for lead and copper, and five to seven times higher in arsenic, antimony, and mercury.

As is the case for Sitcum Waterway, localized hot spots also exist within several of these other waterways that are not reflected by the mid-channel samples. For example, elevated levels of zinc, copper, and arsenic are present near J.M. Martinac Shipbuilding Corp. in City Waterway (WDOE, 1984a) and also near several log sort yards located on Blair and Hylebos Waterways (WDOE, 1984b).

Metals Concentrations in Ore

Metals concentrations in the several ore samples collected during unloading at Terminal 7 are shown in Table 5. 513,000 mg/Kg zinc, 214,000 mg/Kg copper, and 6,660 mg/Kg lead were measured in zinc ore, copper ore concentate, and lead ore, respectively. The concentration of lead (0.66%) in the lead ore appears to be unusually low. According to Steve McCaan, ASARCO chemist at East Helena, Montana, a lead concentration of approximately 200,000 mg/Kg (20%) is typical of this type of ore. In his opinion, the HNO_3 and H_2O_2 digestion employed in the analysis of this ore sample is not rigorous enough to extract all of the lead from the ore (McCaan, 1985). The total lead content of the lead ore was probably higher than the 0.66% reported here. In addition to the primary metals mentioned above, a review of Table 5 shows elevated concentrations of several secondary metals were present in these ores. High concentrations of arsenic (47,500 mg/Kg) and antimony (5,240 mg/Kg) were measured in copper ore concentrate. Copper and lead ore contained 9,460 and 3,200 mg/Kg arsenic, respectively. Copper and lead ores and copper ore concentrate also had high mercury concentrations (14.7 mg/Kg, 15.7 mg/Kg, and 41.0 mg/Kg, respectively) relative to zinc ore (2.83 mg/Kg) and alumina (0.004 mg/Kg). Nickel, chromium, and cadmium concentations were low in all ore samples. All target metal concentations were low in alumina.

Table 5. Metals concentrations in ores unloaded at Terminal 7, Sitcum Waterway, February-March 1984 (mg/Kg, dry weight).

Ore Type	Zinc	Copper		Lead	Alumina
Point of Origin	Peru	Peru/Argentina		Callao, Peru	Queensland, Australia
Destination	--	Trail, B.C. (Cominco)		Helena, MT (Asarco)	Mead, WA (Kaiser)
Vessel Name	"El Conquistador"	"Cotopaxi"		"Almiranti Storni"	"Oak Pearl"
Berth	D	C		D	C
Sample Date	2/7/84	3/27/84		2/3/84	3/1/84
Zinc	513,000	1,414*	594**	90,300	7.7
Lead	1,580	1,580	243	6,660†	3.7
Copper	2,310	47,500	214,000	32,200	2.2
Arsenic	200	9,460	47,500	3,200	0.7
Antimony	288	2,080	5,240	125	0.1
Mercury	2.83	14.7	41.0	15.7	0.004
Nickel	5.6	9.3	20.8	11.6	0.2u
Chromium	4.9	8.4	9.7	2.9	0.6
Cadmium	4.2	5.0	2.3	4.1	0.04

*Unprocessed ore
**Ore concentrate
u = Not detected at detection limit shown
-- = No information
† = Questionable value; see text under "Metals Concentrations in Ore."

Availability of Metals in Ore

The EP toxicity test results on ore in Table 6 show the concentrations of metals in distilled water maintained at pH = 5 with acetic acid, after 24-hour contact with the five ore samples. Lead concentrations of 7.0 mg/L for zinc ore put it at the lower end of concentrations sufficient to designate it as a dangerous waste under WDOE's 1984 Dangerous Waste Regulations, if the ore were to be spilled or discharged into the environment. Lead ore had an EP toxicity lead concentration of 380 mg/L, well within the dangerous waste category. Other metals for which criteria exist (arsenic, mercury, chromium, cadmium, silver, and barium) were below dangerous waste concentrations. Substantial amounts of zinc were leached out of all ores except alumina, but there are no dangerous waste criteria for this metal. Copper, another metal not addressed in the dangerous waste regulations, was easily leached from both types of copper ore tested. Alumina, as expected, leached only small concentrations of metals, most being below detection limits.

Table 6. Results of EP toxicity test on samples of ore unloaded at Terminal 7, Sitcum Waterway, February-March 1984.

Metal		Zinc	Copper (unprocessed)	Copper (concentrate)	Lead	Alumina
Zinc†	(mg/L in leachate)	38	2.8	4.4	13	0.04
Lead	" " "	/7.07/	0.30	0.10	/3807/	0.35
Copper†	" " "	0.02u	60	305	0.02u	0.02u
Arsenic	" " "	0.011	0.157	0.275	0.010	0.007
Antimony†	" " "	0.022	0.119	0.338	0.133	0.001u
Mercury	" " "	0.0002u	0.0002u	0.0002u	0.0002u	0.0002u
Nickel†	" " "	0.08	0.05	0.15	0.10	0.05
Chromium	" " "	0.02u	0.02u	0.10	0.02u	0.02u
Cadmium	" " "	0.52	0.02	0.02	0.21	0.01u
Silver	" " "	0.02u	0.02u	0.02u	0.02u	0.02u
Barium	" " "	0.15	0.08u	0.30	0.08	0.30

†No dangerous waste criteria exist for these metals.

u = Not detected at detection limit shown.

/ / = Exceeds dangerous waste criteria of 5 - 500 mg Pb/L. State of Washington Dangerous Waste Regulations, 1984.

More indicative of potential impacts to Sitcum Waterway biota are the results in Table 7 from the Standard Elutriate test. Comparison of results from this test with EPA criteria for the protection of saltwater aquatic life indicate there is the potential that the following ores could adversely affect marine life when ore is spilled into the waterway; zinc ore - zinc, lead, copper (perhaps nickel, chromium, cadmium); copper ore - zinc, lead, copper, mercury, nickel; copper concentrate - zinc, copper, arsenic, mercury, nickel (perhaps chromium, cadmium); lead ore - zinc, lead (perhaps cadmium). The greatest potential for short-term toxicity is from copper in copper concentrate (elutriate 64,000 times greater than acute criteria), copper in copper ore (elutriate 13,000 times greater than acute criteria), and zinc in zinc ore (elutriate 4,300 times greater than acute criteria). While water column effects from spills would be sporadic and short-term, a chronic toxicity problem could also exist for organisms living on or in sediments contaminated with ore.

Table 7. Results* of standard elutriate test with Commencement Bay water and samples of ore unloaded at Terminal 7, Sitcum Waterway January-March 1984.

Metal		Ore Type: Zinc	Ore Type: Copper (unprocessed)	Ore Type: Copper (concentrate)	Ore Type: Lead	Ore Type: Alumina	Seawater† Control	De-ionized Water Blank	EPA Criteria for Protection of Marine Life (CFR Vol. 45, No. 231. 1980) Acute	EPA Criteria Chronic
Zinc	(ug/L in filtrate)	725,000	6,640	16,950	8,180	83	1u	1u	170	58
Lead	" " "	22.190	9.030	10	22,030	1u	3	1u	668	25
Copper	" " "	77	291,700	1,469,000	1u	1u	1u	1u	23	4.0
Arsenic	" " "	47	210	715	90	59	13	1u	508	--
Antimony	" " "	6	123	703	231	23	6	1u	--	--
Mercury	" " "	0.051u	69	275	0.051u	0.051u	0.051u	0.051u	3.7	0.01
Nickel	" " "	11	207	329	1u	1u	1u	1u	140	7.1
Chromium	" " "	22	4	439	5	6	1u	1u	1260	18
Cadmium	" " "	39	3.4	10.3	35	1.0	0.2u	0.2u	59	4.5

*Average of duplicate samples

†pH = 7.8, TSS = 6 mg/L, salinity = 28.8%

u = Not detected at detection limit shown

Metal Loads from Runoff

Data collected on metals concentrations and flow of runoff to Sitcum Waterway are summarized in Table 8. These data were used to calculate the metals loads to the waterway shown in Table 9, below.

Table 8. Metals concentrations in runoff to Sitcum Waterway June 26, 1984 (total metal in unfiltered samples).

	Head of Waterway				West Sitcum Terminal Drains			Terminal 7 Drains		
Drain Number	1	2	3	4	5	6	7	8	9	10
Flow (MGD)	5.2	0.048	0.039	0.090	0.39	0.009	0.016	0.058	0.048	0.56
Spec. Cond. (umhos/cm)	17	16	269	482	299	88	22	69	25	25
T. Susp. Solids (mg/L)	180	17	12	21	250	62	7	17	5	21
pH (S.U.)	8.0	7.6	7.2	6.8	7.4	9.9	6.9	8.3	7.9	7.1
Zinc (ug/L)	553	100	58	155	537	406	144	336	152	263
Lead "	199	93	59	40	479	62	44	204	178	194
Copper "	176	51	45	41	118	75	53	81	44	78
Arsenic "	118	12	7	1	21	14	4	10	1	12
Chromium "	30	2	3	12	116	10	3	5	2	2
Antimony "	10	2	1	2	6	1u	1	2	3	5
Cadmium "	2.3	0.2	0.2	0.9	5.2	2.4	0.3	1.3	0.4	0.9
Nickel "	1u	1u	1u	1u	1u	1u	1u	1u	1u	1u
Mercury "	0.155	0.103	0.051u	0.051u	0.051u	0.051u	0.051u	0.051u	0.051u	0.051u

u = Not detected at detection limit shown

Table 9. Metal loads in runoff to Sitcum Waterway calculated from concentration and flow data of June 26, 1984 (pounds/day).

Drain Number	Load from Head of Waterway 1-4	West Sitcum Terminal Load 5-7	Terminal 7 Load 8-10	Total Load
Metal				
Zinc	24	1.8	1.5	27
Lead	8.7	1.6	1.1	11
Copper	7.7	0.39	0.42	8.5
Arsenic	5.1	0.069	0.061	5.2
Chromium	1.3	0.38	0.013	1.7
Antimony	0.44	0.020	0.025	0.49
Cadmium	0.10	0.017	0.0050	0.12
Mercury	0.0068	ND	ND	0.0068
Nickel	ND	ND	ND	ND

ND = Not detected.

The West Sitcum Terminal and Terminal 7 drains were contributing low and roughly equivalent loads of zinc, lead, copper, arsenic, and antimony. Runoff from the West Sitcum Terminal represented much greater chromium and cadmium loads than that from Terminal 7, but these loads were still only fractions of a pound per day. The predominant source of metals in runoff to Sitcum Waterway was from the North Corner drain at the head of the waterway. This drain accounted for approximately 80 percent of the flow; 80 to 90 percent of the zinc, lead, and copper load; and 98 percent of the arsenic load to Sitcum Waterway from all ten storm drains sampled.

The North Corner drain (Discharge #1, Figure 5) has been the object of routine monitoring by WDOE for the source assessment portion of the Commencement Bay Nearshore/Tideflats Investigations. Table 10, below, summarizes the metals loads from this drain measured during routine monitoring, including data from the present survey. These data show much lower loads than observed in the June 1984 storm event samples are typical of this drain.

Table 10. Metals loads from the North Corner drain to Sitcum Waterway, based on WDOE data collected September 1983 - June 1984.

Metal	Number of Observations	Load (pounds/day)		
		Median	Maximum	Minimum
Zinc	6	0.33	24*	0.076
Lead	7	0.053	8.6*	0.018
Copper	5	0.092	7.6*	0.038
Arsenic	7	0.082	5.1*	0.006
Chromium	7	0.007	1.3*	<0.002
Antimony	7	0.023	0.43*	<0.001
Cadmium	7	0.001	0.10*	0.0005
Nickel	7	0.016	0.043	0.0016
Mercury	6	<0.00013	0.007*	<0.00005

*Load from June 1984 storm-event sampling

Metals in Water Column

The results of water column sampling in Table 11, show equivalent metals concentrations in bottom samples collected as flood waters first entered the waterway and later during the following high slack/early ebb at the head of the waterway. Low concentrations, well within EPA criteria for the protection of saltwater aquatic life, were observed in all samples. The results for arsenic, although low, are approximately two times higher than levels reported in the literature for Puget Sound waters (Carpenter, 1978). The single high nickel value in one of the three bottom water samples from the head of the waterway appears to be an anomaly. Nickel concentrations in all other water column samples are uniformly low.

Table 11. Metals concentrations in bottom water samples from mouth and head of Sitcum Waterway, August 21, 1984 (ug/L unless otherwise stated).

Sample Site		Mouth of Waterway (mid flood*)			Head of Waterway (early ebb*)			Blank No. 1	Blank No. 2
Station			SB-1			SB-2			
Depth (feet)			49			50		--	--
Depth of Sample (ft)			40			40		--	--
Time		1030	1050	1100	1510	1525	1545	--	--
Salinity (o/oo)		29.7	29.6	28.9	29.7	29.7	29.1	--	--
pH (S.U.)		7.9	8.0	8.0	7.9	7.9	7.9	--	--
TSS (mg/L)		10	11	16	30	18	11	--	--
TOC (mg/L)		4	5	4	4	5	4	--	--
Zinc	(total)	1u	1u	1u	1u	1u	1u	1u	N/A
	(dissolved)	1u	1u	N/A	1u	1u	N/A	1u	1u
Lead	(total)	2	2	2	2	4	3	1u	N/A
	(dissolved)	1u	2	N/A	1u	3	N/A	1u	1u
Copper	(total)	5	1u	1u	1u	1u	1u	1u	N/A
	(dissolved)	1u	1u	N/A	1u	1u	N/A	1u	1u
Arsenic	(total)	4	13	1u	4	3	1u	1u	N/A
	(dissolved)	1u	11	N/A	3	6	N/A	1u	1u
Antimony	(total)	7	6	6	5	8	5	1u	N/A
	(dissolved)	6	4	N/A	8	5	N/A	1u	1u
Mercury	(total)	0.056u	0.056u	0.056u	0.056u	0.056u	0.056u	0.05u	N/A
	(dissolved)	0.056u	0.056u	N/A	0.056u	0.056u	N/A	0.05u	0.05u
Nickel	(total)	1u	2	1u	33	1	1	1u	N/A
	(dissolved)	2	1u	N/A	21	1u	N/A	1u	1u
Chromium	(total)	1u	1u	1u	1u	1u	1u	1u	N/A
	(dissolved)	1u	1u	N/A	1u	1u	N/A	1u	1u
Cadmium	(total)	0.1u	0.1u	0.1u	0.6	0.1u	0.1u	0.1u	N/A
	(dissolved)	0.1u	0.4	N/A	0.1u	0.1	N/A	0.1u	0.1u

*LLW 0710, 0.7'; HHW 1509, 10.1'.
u = Not detected at detection limit shown.

SUMMARY

The major findings of this investigation are as follows:

1. A transverse gradient is present in Sitcum Waterway sediments for zinc, lead, copper, and mercury, which are higher on the northeast side of the waterway along Terminal 7. Longitudinal gradients are also present for zinc, lead, copper, arsenic, and antimony which increase moving from the mouth to the head of the waterway.

2. The highest concentrations of zinc (3,200 mg/Kg) and copper (7,000 mg/Kg), and the second highest concentration of lead (1,900 mg/Kg) in Sitcum sediments occur intertidally near the North Corner storm drain.

3. Based on median concentrations in mid-channel sediment transects, Sitcum Waterway has the highest zinc and lead levels and the third highest copper and arsenic concentrations of any inner Commencement Bay waterway. Compared to reference (Carr Inlet) levels, these sediments are also 14 times higher in zinc, 25 times higher for lead and copper, and 5 to 7 times higher in arsenic, antimony, and mercury.

4. High concentrations of zinc, copper, lead, arsenic, antimony, and mercury were measured in zinc, copper, and lead ores unloaded at Terminal 7. A uniformly low target metals content was characteristic of alumina.

5. EP toxicity test results indicate that zinc and lead ores have sufficient extractable lead concentrations to designate these two ores, if they are spilled or discharged into the environment, as dangerous wastes under WDOE 1984 Dangerous Waste Regulations.

6. A comparison of Standard Elutriate test results with EPA criteria for the protection of saltwater aquatic life suggests that zinc, copper, and lead ores and copper ore concentrate have the potential to adversely affect marine life when these ores are spilled into Sitcum Waterway. While water column effects from spills would be sporadic and short-term, a chronic toxicity problem could also exist for organisms living on or in sediments contaminated with ore.

7. The predominant source of metals in runoff to Sitcum Waterway was from the North Corner drain located at the head of the waterway. This drain accounted for 80 to 90 percent of the total zinc, copper, and lead load; and 98 percent of the arsenic load in runoff from all storm drains sampled during the present survey.

8. Based on a limited number of samples, low metals concentations, well within EPA criteria for the protection of saltwater aquatic life, were present in bottom water samples from the mouth and head of Sitcum Waterway.

CONCLUSIONS

The mutual occurrence of high concentrations of zinc, copper, and lead in ores unloaded at Terminal 7 and in subtidal sediments along this side of the waterway implies spillage of ore during unloading operations at Terminal 7 is a major source of metals to the waterway.

The highest concentrations of zinc and copper and second highest concentrations of lead in Sitcum Waterway sediments occur intertidally near the North Corner drain. Loading calculations indicated that this drain accounted for 80 to 90 percent of the total zinc, copper, and lead load in runoff to the waterway. Therefore, the North Corner drain must also be considered as a major metals source to sediments in Sitcum Waterway. The old Cascade Pole facility may have been a historical source of arsenic.

The results from the Standard Elutriate test indicate that ore spilled into the waterway could result in elevated metals concentrations which could, in turn, adversely affect marine organisms. Metals concentrations were not elevated in water column samples collected near the bottom of Sitcum Waterway. However, ore was not being off-loaded at the time these samples were collected.

RECOMMENDATIONS

1. The WDOE SWRO should pursue control of the major metals sources (i.e., ore spillage from Terminal 7 and discharge from the North Corner drain) to Sitcum Waterway identified during the present survey.

2. The possiblity of site contamination at Cascade Pole's former wood preserving facility should also be investigated.

DN:AJ:cp

Attachments

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Appendix I: Location of sediment samples collected by WDOE from Sitcum Waterway, April 26, 1984.

Station Number	Station Description	Depth at MLLW (feet)	Latitude 47°	Longitude 122°
S1	Sitcum Waterway, 1800 feet from head along northeast shore	51	16'11"	24'56"
S2	" " 600 " " " " " "	36	16'02"	24'45"
S3	" " " " " " " southwest "	41	16'00"	24'48"
S4	" " 1800 " " " " " "	36	16'09"	25'00"

Appendix II: Conventional parameters and metals concentrations in subtidal surface sediment collected by WDOE from Sitcum Waterway April 26, 1984.

Station Number	Sample Number	Time	Depth at MLLW (feet)	Moisture (%)	Total Organic Carbon (%)	Nitrogen (%)	Grain Size Sand (%)	Grain Size Silt (%)	Grain Size Clay (%)	Grain Size Total (%)	Metals (mg/Kg dry weight) Zn	Pb	Cu	As	Cr	Sb	Cd	Ni	Hg
S1	340016	1325	51	57.8	1.89	0.11	7.36	71.6	21.1	100	980	1242	290	66	18	0.8	2.9	15	0.04
S2	340017	1340	36	52.5	2.82	0.087	31.6	51.8	16.6	100	910	1924	418	107	23	1.5	3.4	18	0.06
S3	340018	1355	41	57.4	1.84	0.97	20.6	58.9	20.5	100	392	478	225	53	22	0.6	1.1	20	0.07
S4	340019	1400	36	59.0	2.05	0.098	21.0	64.4	14.6	100	559	462	350	210	19	3.6	0.9	17	0.05