



ELLIOTT BAY REVISED ACTION PROGRAM:

Storm Drain Monitoring Approach

DRAFT REPORT

March 1988

Prepared by
Tetra Tech, Inc.

Prepared for
U.S. Environmental Protection Agency
Region X - Office of Puget Sound
Seattle, Washington

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Tetra Tech, Inc.
11820 Northup Way, Suite 100
Bellevue, Washington 98005

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SECTION 1. INTRODUCTION

The 1987 Puget Sound Water Quality Management Plan, prepared by the Puget Sound Water Quality Authority (1987), included the recommendation that urban storm water control programs be developed and implemented to reduce pollutant loadings to Puget Sound. Under this plan, each city or urban area will be required to develop storm water control programs. As part of these programs, cities will be required to conduct storm drain investigations to determine the location of existing storm drain systems, determine land use characteristics in each drainage basin, and identify and monitor problem storm drains. The primary objective of this report is to provide an approach for identifying sources of pollution in storm drains in the Puget Sound area. Although specifically developed for the Puget Sound area, the storm drain monitoring approach can be adapted to other areas.

In this report, the following phased approach to conducting storm drain investigations is recommended:

- o Preliminary Investigation: Compile available information to define the storm drain system, drainage basin characteristics, and conditions in the receiving environment
- o Phase One - Initial Screening: Collect in-line sediment samples from near the mouths of major storm drains to identify contaminated drainage systems
- o Phase Two - Contaminant Tracing: Select problem drains for further intensive inspection and conduct sampling activities to trace contaminants and identify the ultimate source(s) of contamination
- o Phase Three - Confirmation: Confirm contaminant contributions from individual sources and pinpoint sources by collecting

water samples from side connections that discharge into the storm drain.

The procedures recommended for conducting storm drain investigations (Figure 1) are applicable to any storm drain system, however, it is expected that the entire process will not be applied in every case. As is shown in Figure 1, smaller drainage basins may not require phase two procedures. Study of these small basins could possibly bypass phase two and directly implement phase three. This situation will likely occur in simple drainage networks that serve a limit the number of potential sources. For larger basins, phase one and phase two efforts are designed to limit the size of the area investigated by eliminating non-contaminated sections of the drainage system from further analysis. This approach is intended to reduce the amount of sampling required for the storm drain investigations by focusing source identification activities only on contaminated areas.

The history of urban storm water pollution and rationale for recommending sediment sampling is presented in Section 2. In Section 3, the process for preliminary investigations is explained. In Section 4, initial screening of major storm drain systems is outlined. The process of contaminant tracing in high priority storm drain systems identified during initial screening is presented in Section 5. In Section 6, confirmation of contaminant sources to storm drain systems by further sampling is explained. Potential costs of the storm drain monitoring approach are outlined in Appendix 1 of this report.

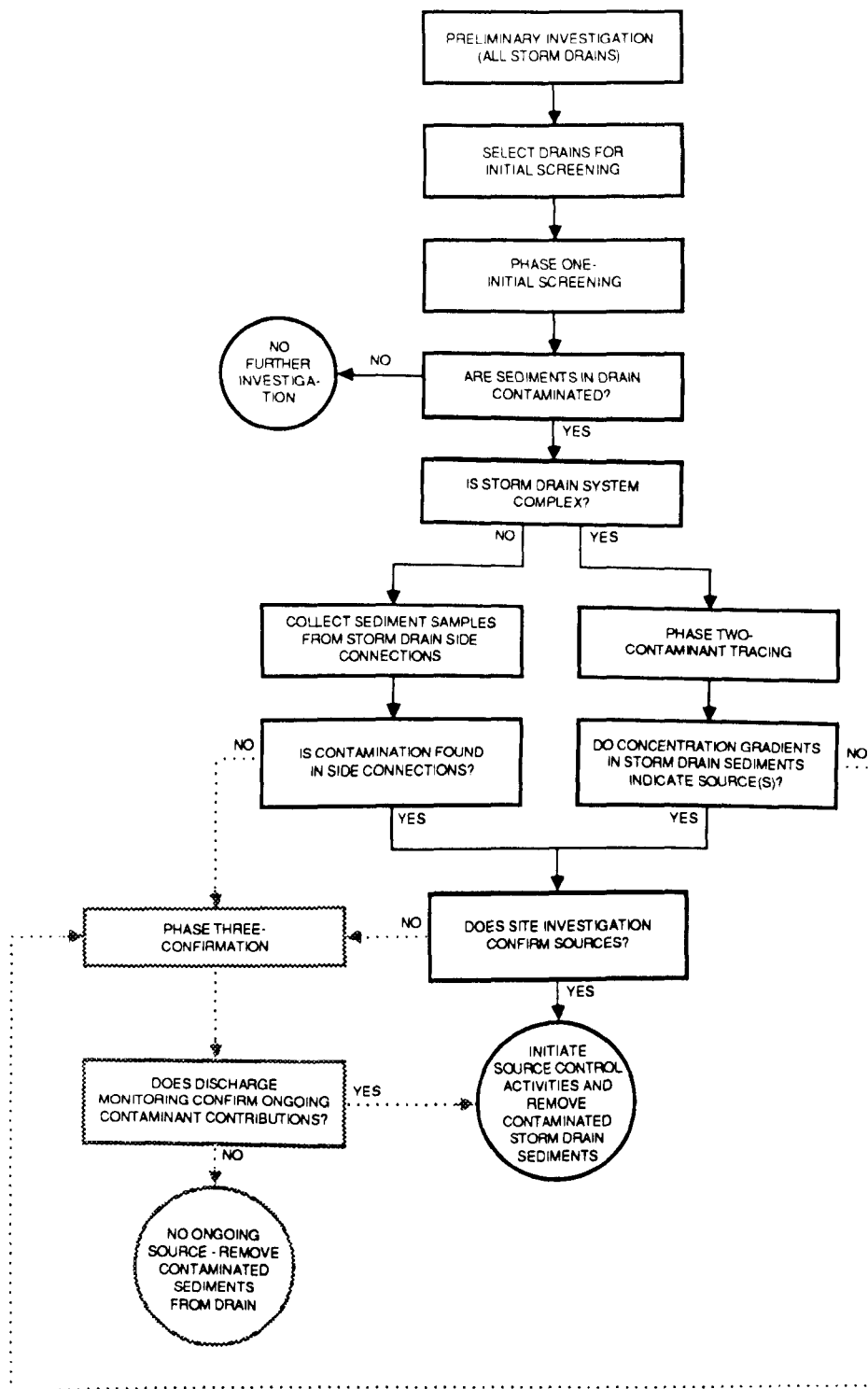


Figure 1. Overview of storm drain monitoring approach.

SECTION 2. BACKGROUND

Stormwater runoff is typically considered a nonpoint source of pollution, even though it is usually collected and routed to nearby surface waters for disposal via ditches and pipes (i.e., point source discharges). Nonpoint surface water pollution is generated when storm water comes into contact with pollutants that have accumulated on land. The contamination of stormwater runoff is generally related to land use in a drainage basin (i.e., industrial, commercial, and residential uses in urban areas; agricultural and silvicultural uses in rural areas). Sources of pollutants in urban stormwater runoff can be categorized as follows:

- o Atmospheric deposition (e.g., industrial stack emissions, uncovered material storage areas, unpaved roads and parking lots, construction and demolition sites, and landfill operations)
- o Traffic emissions (see Table 1)
- o Chemical spills
- o Waste and chemical storage and handling practices
- o Refuse deposition in streets
- o Urban erosion
- o Road deicing.

Stormwater runoff, particularly runoff from urban areas, has long been recognized as the source of a wide variety of pollutants to surface waters. Early investigations of urban runoff pollution focused on conventional

TABLE 1. TRAFFIC-RELATED SOURCES OF ROADWAY POLLUTION

Pollutant	Traffic Related Source
Asbestos	Clutch plates, brake linings
Copper	Thrust bearing, brushings, and brake linings
Chromium	Metal plating, rocker arms, crankshafts, rings, brake linings, and pavement materials
Lead	Leaded gasoline, motor oil transmission fluid, babbit metal bearings
Nickel	Brake linings and pavement material
Phosphorous	Motor oil
Zinc	Motor oil and tires

Reference: Krenkel and Novotny 1980.

pollutants (i.e., biochemical oxygen demand, total suspended solids, coliform bacteria, and nutrients). Recently, however, the concern has shifted toward toxic contaminants in urban runoff (i.e., metals and organic compounds). In response to these concerns, the U.S. Environmental Protection Agency (EPA) in 1978 initiated the National Urban Runoff Program (U.S. EPA 1983c). The program was developed to characterize water quality of urban runoff, determine the effects of different land uses on composition and volume of runoff, and to evaluate the effectiveness of management programs for controlling pollutant loads in runoff. The study concluded that metals, especially copper, lead, and zinc, are the most prevalent contaminants found in urban runoff. Organic compounds, although detected much less frequently than the metals, were also identified as a potential problem, but were considered site-specific rather than widespread (U.S. EPA 1983c).

MONITORING STORMWATER RUNOFF

Urban stormwater runoff is difficult to monitor because of its intermittent and highly variable nature. Volume and pollutant loadings associated with stormwater runoff are a function of many different variables, including precipitation conditions, land use and cover in the basin, antecedent moisture conditions, and illegal discharges (i.e., midnight dumpers). Peak runoff periods, and therefore the bulk of the contaminant loading, generally occur during intense rainfall events. Many pollutants adsorb onto soil particles and are transported by surface runoff as particulates, and under high flow conditions, sediments are scoured from drainage ditches and pipes, increasing the total loading to the receiving water body. As a result, it is difficult to obtain representative samples of discharge from any one drain. Therefore, storm water monitoring typically requires that samples be collected during several different storm events to characterize storm drain loading. Even then, it is nearly impossible to sample at the exact time when illegal discharges are occurring, so documentation of extreme cases of pollutant loading is rare.

Tidal influences must also be considered in monitoring storm drains in the Puget Sound area because many drains serving metropolitan areas along

the sound are tidally influenced. Consequently, sampling must be scheduled during periods of low tide to avoid tidal interferences. Because rainfall events can occur at any tidal stage, it is often difficult to catch a low tide storm event for discharge sampling. Collecting representative storm drain samples above the tidally influenced portion of the drain line is generally not an option because heavily developed areas are frequently located along the waterfront. As a result, samples collected upstream of the tidal area may exclude a significant portion of contaminant loading to the drain.

An alternate method of sampling storm drains has been developed to avoid the complications of storm water monitoring. This alternate sampling approach uses in-line sediment samples collected from low energy sections of the drainage system (i.e., manholes and shallow sloped lines) to screen drainage systems for contamination. Sediment sampling has several advantages over storm water monitoring. First, sediment samples are simply collected from the storm drain system during dry (i.e., non-rainfall) conditions and no coordination with rainfall events is required. This makes sediment sampling easier and therefore less expensive to collect than water samples. Second, storm drain sediments act as a natural sink for contaminants associated with the particular component of stormwater runoff. Sediments deposit in low energy areas of the storm drain system, accumulating through successive storms, and are probably flushed out of the system only during intense storm events. Therefore, they generally provide a composite of several storm events and can be used to characterize historical contamination in storm drain lines. As in the case of discharge sampling, sediment sampling is scheduled during low tide to enable entry to the manhole or drain line for sample collection.

As with discharge sampling, there are disadvantages to sediment sampling. First, sediment data cannot be used to calculate pollutant loadings (measured in lb/day) from the storm drain system. Information on pollutant loadings is often used as to prioritize pollutant sources by indicating the degree of potential effects on the receiving environment. Second, no specific criteria exist to aid in interpreting potential effects

of storm drain sediment data, while criteria do exist for water quality data. However, the recently developed Apparent Effects Threshold (AET) (Tetra Tech 1986b) approach for sediments can be used to assess toxicity of marine sediments. In addition, sediment data can be compared with data collected from receiving environment reference areas and with data from normal urban street dust (Galvin and Moore 1982). Third, like discharge sampling, sediment sampling suffers from inherent difficulties in obtaining representative samples. For example, runoff tidal action may disturb sediment deposits in the drain and affect contaminant distribution patterns. Fourth, storm drain sediment samples may be biased toward larger grained particles due to sedimentation processes within the storm drain lines, and therefore, may not be representative of sediments discharged to the receiving environment.

It should be emphasized, however, that storm drain sediment sampling is intended as a screening tool and has been used by the Municipality of Metropolitan Seattle (Metro) and the City of Seattle to trace contaminants in storm drain lines (see Appendix 2). Sediment data alone will probably not be sufficient to confirm contaminant sources, and other supporting evidence (e.g., documented spills and discharges, evidence of improper chemical storage at facilities, discharge monitoring) will be required. The storm drain sediment sampling approach outlined in this report should be used primarily for initial screening of large numbers of storm drains so that future, more intensive studies can be focused on major problem storm drain systems.

SECTION 3. PRELIMINARY INVESTIGATION

A preliminary investigation is recommended as the first step in conducting a storm drain investigation. This task will involve compiling existing information to define storm drain systems, drainage basin characteristics, and conditions in the receiving environment. This information will be used to select storm drain systems that should be screened during phase one for contaminants. The following are major activities to be conducted during the preliminary investigation:

- o Review city utility plans to determine location and layout of storm drain systems
- o Conduct shoreline reconnaissance to verify outfall locations and to identify unmapped outfalls
- o Contact private property owners to obtain storm drain maps
- o Trace drainage basin boundaries for each storm drain system, determine land use characteristics, and determine potential pollutant sources in each drainage basin
- o Compile and review available pollutant loading data and offshore sediment chemistry data for each storm drain.

Detailed maps of the storm drain system are needed to determine the location of existing drain lines, access points to the drain lines (i.e., manholes), and outfalls. Most cities maintain utility plans of their storm drain systems that are periodically updated to reflect changes and modifications in the system. These plans typically show the general layout of the system, manhole locations, and occasionally topographic information. Engineering plans may include detailed design information such as profiles of the storm drain system.

All storm drain system plans should be verified in the field. Field verification is required because many cities do not have as-built drawings for their storm drain system, and the system actually constructed may vary considerably from design plans. Field verification will involve inspecting drain lines, manholes, and outfall locations. In addition, a shoreline reconnaissance should be conducted to determine locations of outfalls not marked on existing utility plans. Shoreline inspections should be conducted at low tide when most outfalls will be exposed. In waterfront areas where the beach is not exposed, a small boat should be used for inspection of bulkheads and underneath piers.

Most cities require that private property owners inform them of any side connections to the storm drain system so the city can inspect and map these connections. Some cities maintain side sewer cards that show locations of side connections and catch basins within the storm drain system. These detailed plans are useful in defining drainage basin boundaries. However, private property owners often tie into the city storm drain system without reporting to the city. Therefore, the side sewer cards may not be accurate. This is frequently a problem along the waterfront where many industrial facilities are located and may tie into city storm drain systems without the city's knowledge. In addition, many large industrial complexes maintain their own storm drain systems that discharge directly to area waterways. To ensure that major storm drain systems are identified, it is recommended that private property owners, especially along the waterfront, be contacted to obtain storm drain system plans for their property. These plans should be field checked to verify the location of storm drain outfalls. Detailed inspection of the drain lines and manhole locations will probably not be needed until phase one screening.

Storm drain plans should be used to trace drainage basin boundaries for each storm drain system. In addition, contributing areas should be calculated, land use characteristics assessed, and potential pollutant sources in each basin mapped. Pollutant source information is generally available from local, state, or federal agencies. The U.S. EPA regional

program offices maintain lists of permitted facilities and potential hazardous sites in their region. CERCLIS, a list of Superfund sites in Region X can be obtained from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program office. The Resource Conservation and Recovery Act (RCRA) program office keeps a list of RCRA-permitted facilities and facilities that are in the process of applying for a RCRA permit. Washington Department of Ecology (Ecology) keeps records of all dischargers and daily monitoring reports for National Pollutant Discharge and Elimination System (NPDES)-permitted facilities. Other lists of specific problem sites may be available from individual program offices within Ecology. In addition, the state maintains a list of all businesses by address and Standard Industrial Code (SIC) for tax purposes. A list for specific areas can be purchased from the state.

The final activity during the preliminary investigation is to compile available storm drain pollutant loading data and offshore sediment chemistry data. U.S. EPA has only recently included storm drains in the NPDES permit program, therefore, little information is probably available on storm drain pollutant loadings. The best sources for storm drain information are Ecology, U.S. EPA, local universities, and Metro. In addition to these four sources, National Oceanic and Atmospheric Administration (NOAA) would have information on offshore sediment chemistry.

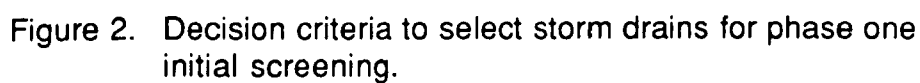
SECTION 4. PHASE ONE - INITIAL SCREENING

Phase one is designed to initially screen major storm drains in the study area for chemical contamination. The initial screening will involve collecting and analyzing sediment samples from manholes located near the mouth of each storm drain. Samples collected at the downstream end of the pipe will provide an indication of contaminants in the entire system. The results of this initial screening are used to focus future, more intensive storm drain investigations on only problem (i.e., contaminated) drains. This procedure is expected to minimize the amount of sampling required by eliminating non-contaminated storm drains early in the investigation. Phase one screening can be conducted in several steps with high priority storm drain systems sampled first, and lower priority storm drains sampled at a later date.

SELECTION OF STORM DRAINS

Selection of storm drains to be sampled during initial screening should be based on information compiled during the preliminary investigation. The first two points to consider are whether problem areas exist in offshore sediments or whether contamination problems exist in the drainage basin. If either of these situations exists, the storm drain system immediately qualifies for phase two contaminant tracing (Figure 2). If both of these situations do not exist, the following criteria should be considered:

- o Average annual discharge from the storm drain
- o Land use characteristics in the drainage basin
- o Sensitivity of offshore environment.



If available data reveal contamination in offshore sediments that cannot be attributed to a specific point source (e.g., chemical spill, industrial discharge), then the storm drain(s) that discharge nearby should automatically be selected for phase one screening. In addition, if the preliminary investigation identifies potential problem sites within the drainage basin (e.g., uncontrolled hazardous waste sites, industrial discharges to the storm drain, or improper chemical storage and handling practices), the storm drain serving the basin should be targeted for chemical screening.

Storm drain systems not associated with documented contaminated offshore sediments or contaminant sources in the drainage basin should be selected for chemical screening based on a priority ranking system. The criteria recommended for ranking include estimated average annual storm drain discharge, land use characteristics in the drainage basin, and existence of sensitive habitats in the receiving environment. These criteria provide an indication of potential loading from the drain and possible effects on the receiving environment. A schematic of the decision criteria involved in selecting storm drains for chemical screening is presented in Figure 2.

Average annual discharge is important because it can indicate the loading potential for each storm drain (Figure 2). Where data are available, average annual discharge should be estimated based on existing records. If no data are available, annual discharge can be approximated based on the drainage basin area, land use and cover in the basin, and average annual precipitation. Storm drains with the highest estimated annual discharge should be given high priority for chemical screening because these drains have a high probability of impacting the receiving environment. Impacts from smaller storm drains are expected to be less extensive and more localized. However, before ranking smaller storm drains as low in priority, it is recommended that conditions in the receiving environment be examined to determine existence of sensitive habitats (e.g., shellfish beds, eel grass and kelp beds, commercial/recreational fisheries, and nursery or spawning grounds) and potential of high contact recreational uses (i.e., boating and swimming). If sensitive habitats or heavy recreational use exist in the offshore environment, the small drains should be targeted for

chemical screening. Storm drains with low annual discharge and little potential for impacting a sensitive receiving environment can be given a low priority for chemical screening. Chemical screening of these low priority storm drains could be postponed, depending on the availability of funds, so that intensive sampling can be carried out as soon as possible in the high priority storm drains.

Land use characteristics in each drainage basin are recommended as a criteria in selecting storm drains for phase one (Figure 2). Land use and zoning maps of the area should be reviewed to determine distribution of industrial, commercial, residential, and undeveloped property in the drainage basin. Industrialized areas are suspected as a major source of contaminants to surface water runoff because of industrial plant emissions, possible improper storage and disposal of industrial chemicals, and chemical spills. Storm drains serving highly industrialized and commercial areas should be given a high priority for chemical screening. Non-industrialized, heavily developed (i.e., residential) and undeveloped areas should have conditions in the receiving environment investigated before being assigned a low priority. If sensitive habitats exist in the offshore environment, a high priority should be assigned to storm drains serving residential and undeveloped areas.

SAMPLE COLLECTION

Sampling

In-line sediment samples should be collected from manholes located near the mouths of each of the high priority storm drains. Tidally influenced drains must be sampled during low tides to enable access to the manholes for collection of sediment samples. All sampling activities should be coordinated with local drainage utilities. Coordination with local utilities is especially important in areas where catch basin and storm drain cleaning programs are conducted because these activities may interfere with sample collection.

A list of the equipment needed for storm drain sediment sampling activities is provided in Table 2. The following safety precautions and methods are recommended for manhole entry and sediment sampling (Conklin 1986):

- o When necessary, erect traffic barricades and markers around the area before the manhole is opened. If the manhole is located along a busy street or intersection, flaggers must be provided to divert traffic around the area.
- o Prior to entry, measure the depth of water in the manhole to determine whether manhole entry and sediment collection will be feasible. Test the atmosphere in the manhole to measure oxygen content, combustible gas, hydrogen sulfide, and organic vapor concentrations. This information will be used to determine the level of respiratory protection required.
- o In all cases, individuals entering the storm drain should wear at least Level C protective equipment (i.e., respirator, coveralls, gloves, boots, safety harness, and line). In addition, one rescue person at the surface should be dressed in similar protective clothing. If the atmosphere measurements indicate that conditions warrant Level B respiratory equipment [self-contained breathing apparatus (SCBA)], a decision should be made whether to enter the manhole or select an alternative manhole for sampling. Sampling of a different manhole may be necessary if manhole dimensions preclude entry with Level B SCBA and equipment.
- o Collect samples from the sediment deposits in the drain system using stainless steel sampling equipment. A sufficient quantity of sediment for the chemical and physical analyses (see "Chemical and Physical Analyses," Section 4) should be placed in a pre-cleaned stainless steel bucket and brought to the surface. Document sampling location(s) with a map

TABLE 2. LIST OF EQUIPMENT NEEDED FOR STORM DRAIN
SEDIMENT SAMPLING

Hard hats	Analysis request forms
Lights	Field data log forms
Maps	Field logbook
Camera and film	Sample tags
Manhole cover hook	Clear tape
Manhole depth and water level measuring device	Marking pens
Sledge hammer	Knife
Methanol	Sample tray
Squirt bottles	Kimwipes
Waste solvent bottle and funnel	Gloves (leather and chemical resistant)
Bags - garbage, ziploc	Coveralls (cotton and chemical resistant)
Rope	Respirators
Barricades, traffic cones, traffic signs	(including extra filters)
Sampling equipment:	Waders (two pair)
Stainless steel bucket	Duct tape
Extension pole	O ₂ /combustible gas meter and tubing
(2) Stainless steel scoops	Photoionization detector (PID)
Stainless steel spoons (long-handled and teaspoons)	meter and tubing
Aluminum foil	Drager tubes/bellows
Sample containers (organic compounds, metals, total organic carbon, oil and grease, grain size)	Decontamination sprayer
Coolers	Brushes (for decontamination)
Ice	Alconox
Custody seals	First aid kit
Chain-of-custody forms	Safety harness and rope
	Clipboard
	Tide tables
	Self-contained breathing apparatus (SCBA) equipment

showing where the sediment sample was collected (e.g., near discharge pipe in manhole or influent line to manhole).

- o If insufficient sediment is found at the proposed sampling station, select an alternate station farther upstream in the drain line.
- o Thoroughly homogenize the sediment sample in a bucket prior to filling the sample bottles. Label each sample container with sampling station location, date sample was collected, sampler's initials, and preservative used. Place a custody seal on both the glass and lid so that the custody seal must be broken to open the sample container. Immediately place the sample containers in a cooler and pack with ice. Complete a sample log form (Figure 3) and record samples on the summary sampling log (Figure 4).
- o Wash all sampling equipment with water and methanol to prevent cross-contamination of the samples between sampling stations. Cover the clean sampling containers with aluminum foil to prevent atmospheric contamination by dust and soot particles.
- o At the end of each day, complete a chain-of-custody record (Figure 5) and the sample analysis request form (Figure 6) for all samples.

Chemical and Physical Analyses

Analysis of storm drain sediments should be performed using methods recommended by Puget Sound Estuary Program (PSEP). In the past, collection and analysis of Puget Sound environmental samples in different studies were performed using non-standardized protocols. The data generated using these non-standardized protocols were acceptable for individual project objectives, but the differences in protocols limited comparability of data between studies. PSEP formulated a compendium of recommended methods (Tetra Tech

STORM DRAIN SAMPLING **Station Location and Sample Log**

DATE _____ TIME _____

STATION _____

LOCATION _____

METER _____ O₂ _____ HNu/OVA _____

READINGS COMB. GAS _____ H₂S _____

PERSON SAMPLING _____

SAMPLE _____

NUMBER _____

WATER:

DEPTH _____

FLOW _____

SEDIMENT:

TYPE _____

DEPTH _____

COLOR _____

ODOR _____

COMMENTS

SKETCH OF MANHOLE SAMPLING LOCATION

RECORDER _____

Figure 3. Example of station location and sample log form.

PAGE _____ OF _____

SURVEY: _____

[illegible]

RECORDED: _____ ORG. CODE: _____ DATE: _____

20

Figure 5. Example of chain-of-custody record.

SAMPLE ANALYSIS REQUEST

PACKING LIST

PROJECT: _____ SAMPLING CONTACT: _____ (name) _____ (phone)	SAMPLING DATE(S): _____ DATE SHIPPED: _____ TASK NAME/CODE: _____	SHIP TO: ATTN: _____	FOR LAB USE ONLY DATE SAMPLES RECEIVED: _____ RECEIVED BY: _____
---	--	--	--

SAMPLE NUMBERS

SAMPLE DESCRIPTION (ANALYSIS/MATRIX/CONCENTRATION/PRESERVATIVE)

1. _____	_____
2. _____	_____
3. _____	_____
4. _____	_____
5. _____	_____
6. _____	_____
7. _____	_____
8. _____	_____
9. _____	_____
10. _____	_____
11. _____	_____
12. _____	_____
13. _____	_____
14. _____	_____
15. _____	_____
16. _____	_____
17. _____	_____
18. _____	_____
19. _____	_____
20. _____	_____

Figure 6. Example of sample analysis request form.

1986d) to overcome these problems in future Puget Sound studies. The majority of commercial laboratories in the Puget Sound area are familiar with the PSEP methods and their application. The use of PSEP protocols is strongly recommended for storm drain sediment analysis to provide data that will be directly comparable on a regional basis.

Selection of appropriate variables for chemical and physical analyses is essential during the initial screening of storm drains for toxic pollutants. Because phase one is intended to screen storm drains for chemical contamination, it is recommended that a broad range of chemicals be analyzed. U.S. EPA has developed the Target Compound List (TCL) which contains all 126 priority pollutants and additional compounds targeted for Superfund site investigations. Analysis of storm drain sediments in the initial screening phase should be performed using PSEP protocols for the following classes of chemicals on the TCL:

- o Extractable organic compounds (Table 3)
- o Metals.

In addition, the following conventional variables are recommended for analysis:

- o Total solids
- o Total organic carbon
- o Oil and grease
- o Particle size.

The PSEP protocols provide two levels of analysis for extractable organics: screening and low level. The differences in the level of analysis are most evident in the detection limits achieved. Detection limits for the screening level analysis are 500-1000 ppb (dry weight) for

TABLE 3. EXTRACTABLE ORGANIC COMPOUNDS RECOMMENDED
FOR ANALYSIS DURING PHASE ONE SCREENING

Acid Extractables

Phenols	Substituted phenols
phenol	2-chlorophenol
2-methylphenol	2,4-dichlorophenol
4-methylphenol	4-chloro-3-methylphenol
2,4-dimethylphenol	2,4,6-trichlorophenol
4,6-dinitro-2-methylphenol	2,4,5-trichlorophenol
	pentachlorophenol
	2-nitrophenol
	2,4,-dinitrophenol
	4-nitrophenol
	4,6-dinitro-2-methylphenol

Base/Neutral Extractables

Low molecular weight aromatics	Halogenated ethers
naphthalene	bis(2-chloroethyl)ether
acenaphthylene	bis(2-chloroisopropyl)ether
acenaphthene	bis(2-chloroethoxy)methane
fluorene	4-chlorophenyl phenyl ether
phenanthrene	4-bromophenyl phenyl ether
anthracene	
High molecular weight aromatics	Phthalates
fluoranthene	dimethylphthalate
pyrene	diethylphthalate
benzo(a)anthracene	di-n-butylphthalate
chrysene	butylbenzylphthalate
benzo(b)fluoranthene	bis(2-ethylhexyl)phthalate
benzo(k)fluoranthene	di-n-octylphthalate
benzo(a)pyrene	
indeno(1,2,3-c,d)pyrene	
dibenzo(a,h)anthracene	
benzo(g,h,i)perylene	
Chlorinated aromatic hydrocarbons	Miscellaneous oxygenated compounds
1,3-dichlorobenzene	isophorone
1,4-dichlorobenzene	benzyl alcohol
1,2-dichlorobenzene	benzoic acid
1,2,4-trichlorobenzene	dibenzofuran
2-chloronaphthalene	
hexachlorobenzene	

TABLE 3. (Continued)

Base/Neutral Extractables (continued)

Organonitrogen compounds	Chlorinated aliphatic hydrocarbons
aniline	hexachloroethane
nitrobenzene	hexachlorobutadiene
N-nitroso-di-n-propylamine	hexachlorocyclopentadiene
4-chloroaniline	
2-nitroaniline	Substituted aromatics
3-nitroaniline	2-methylnaphthalene
4-nitroaniline	
2,6-dinitrotoluene	
2,4-dinitrotoluene	
N-nitrosodiphenylamine	
benzidine	
3,3'-dichlorobenzidine	
N-nitrosodiphenylamine	
benzidine	
3,3'-dichlorobenzidine	
Pesticides	PCBs
p,p'-DDE	Aroclor 1016
p,p'-DDD	Aroclor 1221
p,p'-DDT	Aroclor 1242
aldrin	Aroclor 1248
dieldrin	Aroclor 1254
chlordane	Aroclor 1254
alpha-endosulfan	Aroclor 1260
beta-endosulfan	
endosulfan sulfate	
endrin	
endrin aldehyde	
heptachlor	
heptachlor epoxide	
alpha-hexachlorocyclohexan (HCH)	
beta-HCH	
delta-HCH	
gamma-HCH (Lindane)	
toxaphene	

acid/neutral compounds, and 15-300 ppb (dry weight) for pesticides and PCBs. Detection limits for the low level analysis are 1-50 ppb (dry weight) for acid/neutral compounds, and 0.1-15 ppb (dry weight) for pesticides and PCBs. For phase one screening of storm drain sediments, low level analysis detection limits are recommended because screening level analysis detection limits for some compounds are higher than available sediment criteria. Metals recommended for analysis under PSEP protocols and their detection limits are presented in Table 4.

Total solids are determined so that sediment chemical concentrations can be converted from a wet-weight to a dry-weight basis. Total solids concentrations are normally determined as part of the extractable organic compounds and metals analyses, and should be specified for determination by the laboratory. Total organic carbon is a measure of the organic matter in a sample. Total organic carbon is commonly used to normalize contaminant concentrations to the amount of organic carbon. Oil and grease tests measure all materials that are soluble in a nonpolar solvent (e.g., Freon) under acidic conditions. Hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases, and related industrial compounds are included in the oil and grease concentrations. Particle size is analyzed so that contaminant concentrations can be normalized to the percent fines. Normalization of the contaminant concentration to the total organic carbon or particle size can be a useful tool for tracing distribution and fate of contaminants.

The analytical methods for PSEP specifies the minimum sample volumes required for chemical analysis, appropriate sample containers and preservatives for each chemical analysis, and recommended holding times for samples prior to analysis (Table 5). Based on the minimum sample volume requirements, approximately 500 g (minimum 1.75 L) will be required for analyses recommended for phase one. Specified containers are adequate for collection of the sediment sample plus an amount of sample sufficient for quality assurance/quality control (QA/QC) samples. Prior to collecting any samples, the laboratory performing the analyses should be consulted to confirm that the volumes of sediment collected will be sufficient for the requested analysis and any QA/QC samples.

TABLE 4. LIMITS OF DETECTION FOR SEDIMENT AND WATER BY INSTRUMENT^a

	Sediment ^b		ICP	Water ^c	
	ICP	GFAA		DFAA	GFAA
Antimony	3.2	0.1	0.032	0.2	0.003
Arsenic	--	0.1	0.053	--	0.001
Cadmium	4.0	0.1	0.004	0.005	0.0001
Copper	0.6	0.1	0.006	0.02	0.001
Iron	0.7	--	NA ^d	NA	NA
Lead	4.2	0.1	0.042	0.1	0.001
Mercury	0.01 (CVAA)		0.0002 (CVAA)		
Manganese	2.0	--	NA	NA	NA
Nickel	1.5	0.1	0.015	0.04	0.001
Silver	0.7	0.1	0.002	0.01	0.0002
Zinc	0.2	0.2	0.007	0.005	0.00005

^a ICP = Inductively coupled plasma atomic emission spectroscopy.

GFAA = Graphite furnace atomic absorption.

DFAA = Direct flame atomic absorption.

CVAA = Cold vapor atomic absorption.

^b ICP data are from Tetra Tech (1984); GFAA and CVAA data are detection limits that can be reasonably attained by various laboratories. Under strict conditions these limits can be lowered (Battelle 1985). Values are mg/kg dry weight for 5 g (wet) sediment in a 100 mL digest.

^c DFAA and GFAA data are from U.S. EPA (1938b); ICP data are from U.S. EPA (1984). Values are mg/L.

^d NA = Not applicable; iron and manganese are used as natural tracers for sediments only.

TABLE 5. SAMPLE CONTAINERS, PRESERVATION, AND
RECOMMENDED HOLDING TIMES FOR SEDIMENT SAMPLES

Variables	Minimum Sample Size ^a	Sample Container	Preservation and Handling	Holding Times ^b
Semivolatile organics	50-100 g	16-oz glass jar, PTFE ^c -lined lid	Cool (4 ^o C), or Freeze	7 days/40 days 1 yr ^d
Metals	50 g	8-oz linear poly- ethylene or boro- silicate glass, PTFE-lined lid	Cool (4 ^o C), or Freeze	6 mo (Hg 28 days) 6 mo (Hg 28 days) ^d
Total solids, Total organic carbon	75 g	8-oz glass or polyethylene jar	Freeze	6 mo ^d
Oil and grease	100 g	4-oz glass jar, PTFE-lined lid	Cool (4 ^o C), HCl, or Freeze	28 days ^d 6 mo ^d
Particle size	100-150 ^e	Glass or plastic jar, or sealable plastic bag (approx. 16-oz)	Cool (4 ^o C)	6 mo ^d

^a The minimum sample size (wet-weight) presented is for one laboratory analysis. If additional laboratory analyses are required (e.g., replicates), the sample size should be adjusted accordingly.

^b Where two times are given, the first refers to the maximum time prior to extraction, the second to the maximum time prior to instrumental analysis. U.S. EPA has not established holding times for sediment samples, however, the holding times for water samples should be met to help ensure the sample integrity.

^c PTFE = Polytetrafluoroethylene.

^d This is a suggested holding time. No U.S. EPA criteria exist for the preservation of this variable.

^e Large grain size samples (i.e., sand) require a larger sample size than silty samples.

Prepared sample containers can be obtained through commercial sources or from the laboratory performing the analyses. Sample containers should be documented by the supplier as to cleanliness, or container blanks should be analyzed to provide necessary documentation. The preservation and handling procedures can be met for the majority of variables by placing samples on ice following collection, and then transferring the samples to a freezer as soon as possible. Freezing of samples will require that sample containers have adequate headspace for the expansion of pore water. Because pore water expands, containers for samples that will be frozen should only be filled three quarters full. If oil and grease samples cannot be analyzed within 24 h, concentrated hydrochloric acid should be added at approximately 1 mL/80 g of sediment. The container should be sealed and inverted several times to mix the acid and sediment.

Holding times for sediment samples have not been established by U.S. EPA. The holding times cited for frozen samples are those recommended under PSEP protocols (Tetra Tech 1986d). The recommended holding times for unfrozen sediment cited in PSEP were based on U.S. EPA holding times for water samples (U.S. EPA 1987). Extract holding times (i.e., the time from extraction of a sample until instrumental analysis) of 40 days have been established for water samples and have also been recommended for extractable organic compounds in sediment (Tetra Tech 1986d).

Quality Assurance/Quality Control

Quality assurance (QA) is the program for assuring reliability of sampling procedures and analytical measurements. Quality control (QC) is the routine application of procedures by the analytical lab, such as periodic instrument calibration, to obtain prescribed standards of performance in monitoring and measurement. The integration of QA/QC into sample collection, analysis, and data reporting procedures is important for generating reliable data. When QA/QC procedures are defined at the inception of a project and adhered to during performance of the project, comparison of the procedures and results with QA/QC goals can be made to determine data reliability.

Sampling programs regulated by U.S. EPA and Washington Department of Ecology (Ecology) require preparation of a Quality Assurance Project Plan (QAPP). To ensure compliance with U.S. EPA QA/QC requirements, preparation of a QAPP is recommended. The QAPP details sampling and analysis procedures, data quality objectives (i.e., precision, accuracy, and completeness), and other procedures necessary for obtaining reliable data. Guidelines have been published (U.S. EPA 1983a) that describe the required elements of a QAPP. Additional guidelines on field QA/QC can be found in the PSEP protocols (Tetra Tech 1986d) and from U.S. EPA (1986b). Guidelines on laboratory QA/QC procedures can be found in the method references (U.S. EPA 1984, 1987) and in the PSEP protocols (Tetra Tech 1986d).

QA/QC samples collected in the field include the following:

- o Field replicates
- o Field rinsate blanks
- o Standard reference materials.

Field replicate samples are used to determine sample variability (i.e., analytical plus field variability). To collect field replicate samples, a volume of sediment sufficient for two or more sets of samples is collected, thoroughly homogenized, and individual aliquots are placed in separate sample containers. Field replicates should be labeled consistently with other samples and submitted blind to the laboratory (i.e., the laboratory should not know the samples are duplicates). One of the replicates can be designated as an analytical duplicate so that a comparison of field and laboratory variability can be made. One set of blind field replicate samples can also be analyzed by a different laboratory to evaluate laboratory accuracy.

Field rinsate blanks are used to assess potential contamination of samples during collection and equipment decontamination procedures. A field

rinsate blank is collected by pouring analyte-free water (i.e., distilled) through the appropriate sampling device and collecting the rinsate. The field rinsate blank should be collected following sample collection and decontamination of sampling equipment. The field blank serves to check effectiveness of decontamination procedures, and whether contamination occurred from field sources, or during shipping, storage, and analysis. The analyte-free water should be stored in a sample container that accompanies samples and sample containers through all stages of sampling, shipping, storage, and analysis.

The frequency for collecting field rinsate blanks should be determined by the project manager before beginning the project. For the majority of field sampling efforts, one field rinsate blank per day should be collected. Collecting and analyzing field rinsate blanks can add considerably to project costs. To help minimize costs, collection and analysis of one field rinsate blank and archiving subsequent field rinsate blanks is recommended. If problems with contamination are noted in the initial field rinsate blank, additional field rinsate blank analyses should be conducted on archived samples.

Standard reference materials (SRMs) are used to assess the accuracy of analysis. SRMs, usually provided through a government agency, have been sufficiently characterized for one or more analytes such that certified values are provided. SRMs are submitted as a sample to the laboratory for analysis.

Northwest National Oceanographic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS) has prepared a marine sediment sample SRM with PCBs, polynuclear aromatic hydrocarbons (PAH), and selected pesticides. The NOAA/NMFS SRMs are available from the U.S. EPA Office of Puget Sound. SRMs are also available from the National Bureau of Standards (NBS). An estuarine sediment sample containing trace metals is currently available, and SRMs with PCBs and organic compounds in marine sediments are currently in preparation. The recommended frequency and evaluation

procedures for SRM analysis are discussed in the PSEP protocols (Tetra Tech 1986d).

Laboratory QA/QC is performed by the analytical laboratory. A discussion of laboratory QA/QC requirements and the required minimum frequency of analysis is presented in the PSEP protocols (Tetra Tech 1986d), and the U.S. EPA Contract Laboratory Program (CLP) statement of work (U.S. EPA 1987). Prior to initiation of sampling efforts, the project manager should specify the frequency of analysis for laboratory QA/QC samples (i.e., method blanks, matrix spikes, method spikes, and analytical replicates). Technical evaluation of the data should be performed by an expert, and the results of all QA/QC analyses should be reported with the sample data.

Decontamination

Decontamination of sampling equipment and personal protective gear is required to prevent sample cross-contamination and to assist in maintaining health and safety of field personnel. The following general procedures are recommended for decontamination:

- o After sampling is completed at each station, remove sediment residues remaining on boots and sampling equipment with a high pressure sprayer filled with water. Sediment residues can be returned to the manhole.
- o Wash sampling equipment (e.g., spoons, buckets, shovels) with laboratory grade detergent solution (i.e., Alconox) and rinse with water. Detergent and rinse water can be disposed in a nearby sanitary sewer.
- o All sampling equipment should be rinsed with methanol. Solvents used for decontamination must be collected, placed in an approved waste container, and transported to a licensed waste recycling facility at the end of the project.

- o A final rinse with distilled water is also recommended.
- o Outer gloves worn by field personnel should be changed between each station to prevent cross-contamination of samples.

Documentation

All pertinent field survey and sampling information should be recorded in a bound logbook. Sufficient information should be provided for each day's activities so that someone can reconstruct the field activity without relying on the memory of the field crew. Entries should be made in indelible ink. At a minimum, entries in the logbook should include the following:

- o Date and time of starting work
- o Names of field task leader and team members
- o Purpose of proposed work effort
- o Description of sampling station locations, including map reference
- o Details of work effort, particularly any deviation from the proposed procedures
- o Field observations
- o Field measurements (e.g., oxygen, combustible gas, organic vapor meter readings, hydrogen sulfide measurements).

Photographs should be taken to document sampling station locations because they provide the most accurate record of the field worker's

observations. Each photograph should be documented with the following information:

- o Date and time
- o Name of photographer
- o Description of station location
- o General direction faced and description of the subject
- o Sequential number of the photograph and roll number.

Once a roll of film is developed, the slides or prints should be placed in the project file.

Sample Packaging and Shipping

Samples should be packed securely to prevent spills and breaking during sample shipment. Recommendations for packaging nonhazardous samples are presented below (49 CFR 173):

- o Place sample container in a 2-mil thick (or thicker) polyethylene bag, one sample per bag. Position identification tag so it can be read through the bag. Seal the bag.
- o Place sealed bags inside a strong outside container, such as a lined metal picnic cooler or a Department of Transportation (DOT)-approved fiber board box. The outside container should be lined with a polyethylene bag. Surround the sample containers with noncombustible cushioning material for stability during transport.
- o Seal the large polyethylene liner bag.

- o Place the laboratory and sampling paperwork in a large envelope and tape it to the inside lid of the shipping container.
- o Close and seal the outside container with fiberglass tape.

An additional packaging requirement is necessary for samples that are suspected of containing hazardous materials based on observations made during the field sampling or from information obtained during the preliminary investigation. For hazardous materials, it is recommended that each sealed bag containing a sample container be placed inside a metal can prior to packaging in a lined metal cooler or DOT-approved fiber board box. The metal can should be lined with enough noncombustible, absorbent material (e.g., vermiculite or diatomaceous earth) between the bottom and sides of the can and the sample bag to prevent breaking and to absorb any leakage. Pack only one bag per can using clips or tape to hold the can lid securely and tightly.

The outside of the shipping container should be marked with the laboratory name and address, and the return name and address of the sender. A "Cargo Aircraft Only" DOT label and the following descriptive information should be clearly printed on each shipping container: "Laboratory Samples," "This End Up," and "Inside packages comply with prescribed regulations." Hazardous materials should additionally be labelled with the DOT "Flammable Liquid n.o.s." label. Arrows pointing upward should be placed on all four sides of the shipping container.

Shipping documents must accompany the sample shipment and should be taped to the inside lid of the outside sample container. These documents are the chain-of-custody form (Figure 5) and sample analysis request form (Figure 6).

Scheduling

It is recommended that phase one screening be conducted during a dry period when rainfall will not greatly affect sediment accumulations in the storm drains. Access to manholes on tidally influenced storm drains will only be possible during low tide. Therefore, in many cases the scheduling of the sampling program must be based on tide schedule, as well as weather conditions. Sampling should also be coordinated with local stormwater drainage utilities to avoid potential interference from routine maintenance operations such as catch basin cleaning activities.

IDENTIFYING AND RANKING PROBLEM STORM DRAINS

Problem (i.e., contaminated) storm drains will be identified based on the in-line sediment chemistry measured during the initial screening. All problem drains will be included in the phase two of the sampling program. More intensive, phase two sampling is recommended for the high priority storm drains to trace contaminants so that ultimate source(s) can be identified. In addition, a ranking procedure has been developed to prioritize individual problem storm drains to aid in scheduling phase two. A schematic of the decision criteria recommended for identifying high priority storm drains is presented in Figure 7.

Evaluating Sediment Data

Although there are no specific criteria for storm drain sediments, several approaches can be used to identify and eventually rank problem storm drains based on contaminant levels. One approach to identifying problem storm drains involves comparing storm drain sediment data with available criteria for sediments in the receiving environment. Criteria for receiving environment sediments have recently been proposed for freshwater and marine sediments. Apparent Effects Threshold (AET) values are applicable to marine sediments (Tetra Tech 1986b) in Puget Sound, and screening level concentra-

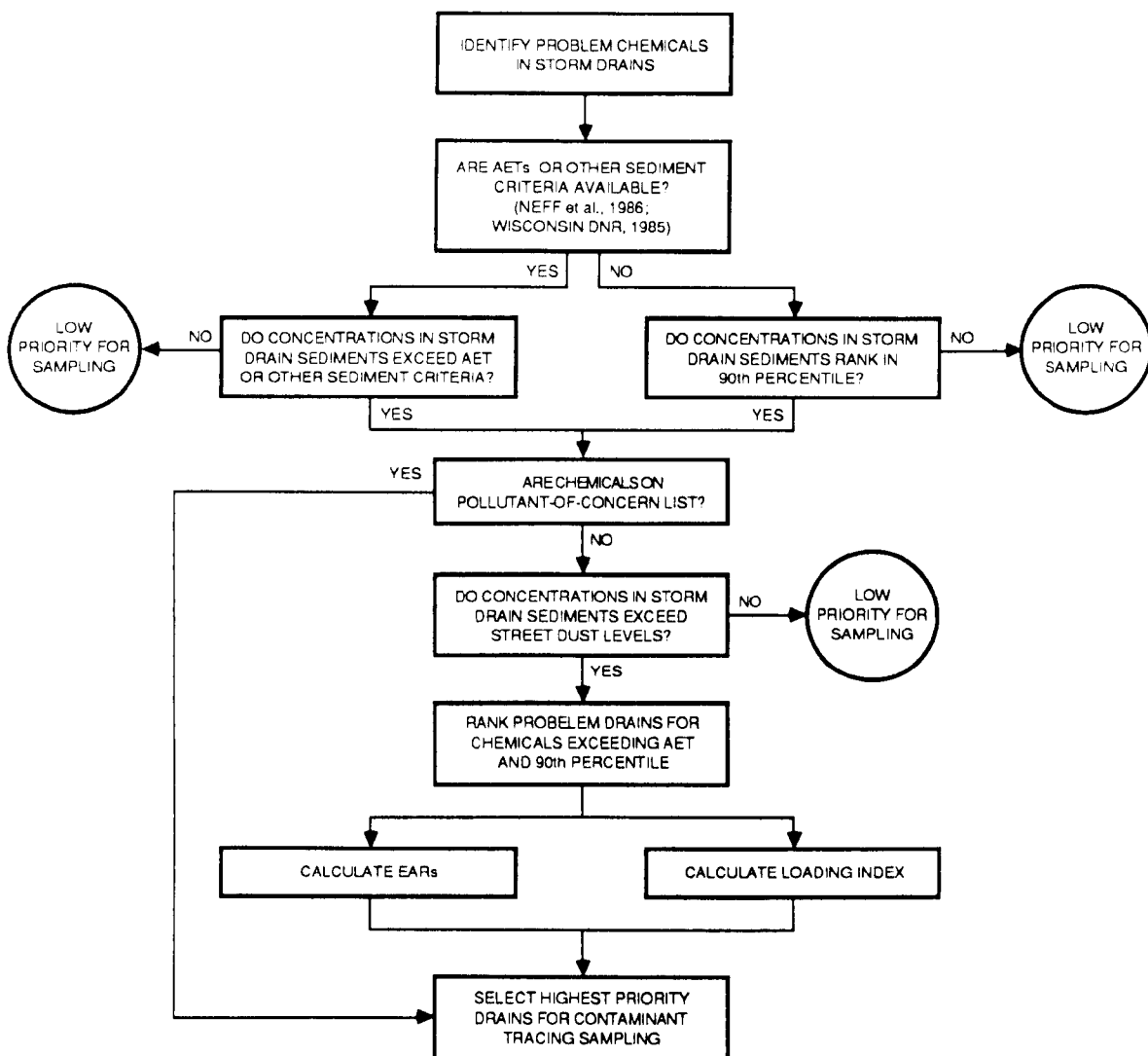


Figure 7. Decision criteria for selecting problem chemicals and ranking problem storm drains.

tions (Neff et al. 1986) and interim criteria (Wisconsin Department of Natural Resources 1985) are applicable to freshwater sediments. When no sediment criteria are available for specific contaminants, problem storm drains can be selected based on sediment contamination ranking in the 90th percentile of contaminant concentration measured for all storm drain sediment data. These criteria help in identification of problem storm drain systems based on contamination of storm drain sediments.

AET values have been proposed for the Puget Sound Dredged Disposal Analysis Program (Tetra Tech 1986b) and have recently been updated to include new environmental data sets (Tetra Tech 1987). AET values are based on sediment chemistry, toxicity (i.e., amphipod, oyster larva, and Microtox bioassays), and benthic infauna abundance data. For a given chemical and a specified biological indicator, the AET is the concentration above which statistically significant biological effects occurred in all samples of sediments analyzed. Because the AET approach was originally developed for marine sediments, it is not directly applicable to storm drain sediments. However, because there are no specific criteria yet available for storm drains, the AET approach is recommended as a conservative approach for evaluating contamination in storm drain sediments. The range of available AET values (Tetra Tech 1987) are listed in Table 6. It is expected that many chemicals present in storm drain sediments would exceed the lowest AET value. Therefore, the highest AET value will be used to identify problem concentrations of chemicals in storm drain sediments because it represents a less stringent and more practical criteria for evaluating contamination in storm drains. A problem storm drain, in this case, is defined as having at least one chemical in the in-line sediments with a measured concentration exceeding the highest AET value.

Because the AET values have been developed specifically for marine sediments, alternate sediment criteria are needed for storm drains that discharge into freshwater environments. Few criteria have been developed for freshwater sediments. Interim criteria have been proposed for PCBs and certain metals (i.e., arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) by the Wisconsin Department of Natural Resources (1985).

TABLE 6. PUGET SOUND AET
(UG/KG DRY WEIGHT FOR ORGANIC COMPOUNDS;
MG/KG DRY WEIGHT FOR METALS)

	Lowest AET	Highest AET
<u>LPAH^a</u>	5,200	6,100
Naphthalene	2,100	2,400
Acenaphthylene	560	640
Acenaphthene	500	980
Fluorene	540	1,800
Phenanthrene	1,500	5,400
Anthracene	960	1,900
<u>HPAH^b</u>	12,000	>51,000
Fluoranthene	1,700	9,800
Pyrene	2,600	11,000
Benzo(a)anthracene	1,300	4,500
Chrysene	1,400	6,700
Benzofluoranthenes	3,200	8,000
Benzo(a)pyrene	1,600	6,800
Indeno(1,2,3-c,d)pyrene	600	>5,200
Dibenzo(a,h)anthracene	230	1,200
Benzo(g,h,i)perylene	670	5,400
<u>Total PCBs</u>	130	2,500
<u>Total Chlorinated Benzenes</u>	170	680
1,3-Dichlorobenzene	>170	>170
1,4-Dichlorobenzene	110	260
1,2-Dichlorobenzene	35	>350
1,2,4-Trichlorobenzene	31	64
Hexachlorobenzene	70	230
Hexachlorobutadiene	120	290
<u>Total Phthalates</u>	3,300	>70,000
Dimethyl phthalate	71	700
Diethyl phthalate	>48	1,200
Di-n-butyl phthalate	1,400	>5,100
Butyl benzyl phthalate	63	>470
Bis(2-ethylhexyl) phthalate	1,900	>3,100

TABLE 6. (Continued)

	Lowest AET	Highest AET
<u>Pesticides</u>		
p,p'-DDE	9	15
p,p'-DDD	2	43
p,p'-DDT	3.9	11
<u>Phenols</u>		
Phenol	420	1,200
2-Methylphenol	63	>72
4-Methylphenol	670	1,200
2,4-Dimethyl phenol	29	>72
Pentachlorophenol	>140	>140
2-Methoxyphenol	930	930
<u>Miscellaneous Extractables</u>		
Hexachlorobutadiene	120	290
1-Methylphenanthrene	310	370
2-Methylnaphthalene	670	670
Biphenyl	260	270
Dibenzothiophene	240	250
Dibenzofuran	540	540
Benzyl alcohol	57	73
Benzoic acid	650	>690
n-Nitrosodiphenylamine	40	220
<u>Volatile Organic Compounds</u>		
Tetrachloroethene	140	>210
Ethyl benzene	33	>50
Total xylenes	100	>160
<u>Metals</u>		
Antimony	3.2	26
Arsenic	85	700
Cadmium	5.8	9.6
Copper	310	800
Lead	300	700
Mercury	0.41	2.1
Nickel	28	>120
Silver	>0.56	5.2
Zinc	260	1,600

^a LPAH = Low molecular weight polycyclic aromatic hydrocarbons.

^b HPAH = High molecular weight polycyclic aromatic hydrocarbons.

Reference: Tetra Tech (1987).

These criteria were developed to assess the suitability for open-water disposal of sediments dredged from the Great Lakes. The criteria are based on comparisons of current and historical sediment toxicant concentrations measured in the Great Lakes. In addition to the interim criteria, screening level concentrations (SLC) have been proposed by U.S. EPA for PCBs, chlor-dane, dieldrin, heptachlor epoxide, and DDT in freshwater sediment (Neff et al. 1986). The SLC approach uses synoptic field data on co-occurrence in sediments of benthic infaunal invertebrates and different concentrations of each organic contaminant. Each SLC is a conservative estimate of the highest organic carbon normalized concentration of a specific contaminant in sediment that can be tolerated by approximately 95 percent of benthic infauna. Available freshwater sediment criteria are summarized in Table 7. It is recommended that these values be used to evaluate storm drain sediment contaminant levels for drains discharging into a freshwater environment.

AET values and freshwater criteria have not been developed for many contaminants associated with storm drain sediments and discharges. Therefore, the 90th percentile concentration of a chemical is recommended to evaluate contamination levels in storm drain sediments. Using this method, storm drain sediments having a chemical concentration within the highest 10 percent of all sediments measured will be identified as a problem drain.

Results from the initial screening should also be compared with the data for normal urban street dust. Street dust has been identified as the primary source of suspended particulates in urban runoff (Galvin and Moore 1982), and therefore is directly associated with storm drain sediment accumulations. Street dust values may be more representative of general background contaminant levels in storm drain sediments than AET values or 90th percentile ranking. Representative street dust contaminant levels for urban areas are presented in Tables 8a and b. Phthalates and PAH are the only contaminants whose average concentration in urban street dust samples from Seattle and Bellevue exceeded the highest AET values. This suggests that, under normal background conditions, storm drain sediments can be expected to exceed AET criteria. This exceedance indicates that AET values may be too stringent for these contaminants. Therefore, it is recommended

TABLE 7. FRESHWATER SEDIMENT CRITERIA

Metals ^a	(mg/kg)
Arsenic	10
Cadmium	1.0
Chromium	100
Copper	100
Lead	50
Mercury	0.10
Nickel	100
Zinc	100
Organic Compounds ^b	(ug/kg)
Heptachlor epoxide	8
Chlordane	9.8
Dieldrin	21
PCBs	290
DDT	190

^a Interim criteria for open water disposal of dredged materials (Wisconsin Department of Natural Resources 1985). If concentration in dredged materials exceeds 125 percent of the interim criteria value, then sediment cannot be disposed in open water.

^b Estimated highest concentration in the sediment that can be tolerated by approximately 95 percent of benthic infauna (Neff et al. 1986). Values are based on the organic carbon normalized concentration in the sediment.

TABLE 8a. SUMMARY OF METALS MEASURED IN STREET DUST SAMPLES
COLLECTED FROM SEATTLE AND BELLEVUE^a

Chemical	Range (mg/kg dry wt)	Mean ^a (mg/kg dry wt)	Detection Frequency
Antimony	<1-2.0	1.1	8/12
Arsenic	11-39	25	12/12
Beryllium	0.17-0.34	0.26	12/12
Cadmium	0.6-2.0	1.0	12/12
Chromium	20-230	97	12/12
Copper	31-260	93	12/12
Lead	90-1300	520	12/12
Mercury	0.02-0.18	0.07	9/12
Nickel	20-44	32	12/12
Selenium	<0.6-<3	2	0.12
Silver	0.01-0.5	0.32	6/12
Thallium	<0.2-0.34	0.6	3/12
Zinc	110-970	310	12/12

^a Street dust sampled collected from five residential areas and three suburban arterials in Bellevue; two industrial and two commercial areas in Seattle.

^b Mean calculated using the reported detection limit for undetected values.

Reference: Galvin and Moore (1982).

TABLE 8b. SUMMARY OF ORGANIC COMPOUNDS
MEASURED IN STREET DUST SAMPLES COLLECTED FROM
SEATTLE AND BELLEVUE^a

Chemical	Mean ^b (mg/kg)	Range ^b (mg/kg)	Detection Frequency
<u>Pesticides</u>			
Alpha-Hexachlorocyclohexane	0.014	0.010-0.018	2/14
Gamma-Hexachlorocyclohexane	0.025	0.006-0.043	2/14
DDD	0.005	0.005	1/14
Heptachlor	0.048	0.048	1/14
<u>Halogenate Aliphatics</u>			
Trichloromethane	0.007	0.004-0.015	4/14
Tetrachloroethane	0.024	0.016-0.032	2/14
1,1,1-Trichloroethane	0.013	0.012-0.016	3/14
4-Chlorophenyl phenyl ether	0.24	0.24	1/14
<u>Monocyclic Aromatic Hydrocarbons</u>			
Benzene	0.021	0.01-0.032	2/14
Hexachlorobenzene	2.0	2.0	1/14
Ethylbenzene	0.012	0.005-0.025	3/14
Toluene	0.009	0.004-0.019	4/14
Nitrosodimethylamine	0.76	0.76	1/14
<u>Phenolics</u>			
Phenol	0.21	0.08-0.47	4/14
Pentachlorophenol	1.76	0.12-3.4	2/14
2,4-Dimethylphenol	0.02	0.01-0.03	2/14
4-Nitrophenol	0.11	0.11	1/14
<u>Phthalate Esters</u>			
Dimethyl phthalate	0.78	0.78	1/14
Diethyl phthalate	0.41	0.16-0.89	3/14
Di-n-butyl phthalate	0.70	0.22-2.4	7/14
Di-n-octyl phthalate	0.54	0.23-0.97	4/14
Butyl benzyl phthalate	6.2	0.22-0.35	7/14
Bis-2-ethylhexyl ph 11	38	2.4-90	9/14

TABLE 8b. (Continued)

Chemical	Mean ^b (mg/kg)	Range ^b (mg/kg)	Deletion Frequency
<u>LPAH^c</u>			
Acenaphthalene	0.21	0.16-0.25	2/14
Anthracene	0.35	0.1-0.6	5/14
Fluorene	0.23	0.2-0.25	2/14
Phenanthrene	1.5	0.18-2.4	14/14
<u>HPAH^d</u>			
Fluoranthene	1.7	0.36-2.6	14/14
Pyrene	1.7	0.32-2.5	13/14
Chrysene	1.04	0.11-2.0	11/14
Benzo(a)pyrene	0.63	0.08-0.90	7/14
Benzo(k)fluoranthene	1.1	0.27-1.5	8/14
Benzo(a)anthracene	0.63	0.20-0.85	7/14

^a Street dust samples were collected from five residential areas and three suburban arterials in Bellevue, and from two industrial and two commercial areas in Seattle.

^b Calculation based on detected values only.

^c LPAH = Low molecular weight polynuclear aromatic hydrocarbons.

^d HPAH = High molecular weight polynuclear aromatic hydrocarbons.

Reference: Galvin and Moore (1982).

that the average urban street dust concentrations, rather than the AET values, be used to assess phthalates and PAH.

Storm drains with chemical concentrations measured in the in-line sediments that exceed the AET value or that rank in the 90th percentile should be considered for additional sampling during phase two contaminant tracing (Figure 7). If chemicals in these drains are on the pollutant of concern list (Appendix 3), additional sampling under phase two is recommended. Pollutants of concern are chemicals that have been identified as potential problems in the Puget Sound receiving environment based on consideration of chemical toxicity, environmental persistence, bioaccumulation potential, high concentration in the water column, existence of known sources, high concentration in offshore sediments relative to reference area conditions, or widespread distribution in Puget Sound. If the chemical is not on the pollutant of concern list but exceeds normal urban street dust values, it should be considered in the ranking process. Additional sampling will consist of collecting in-line sediment samples from selected manholes to trace contaminants throughout the system and to isolate specific contaminated sections of the storm drain lines.

Ranking Procedure

A ranking procedure is provided to help prioritize problem storm drains (Figure 7). It is expected that cities may be unable to conduct intensive contaminant tracing sampling activities in all problem drains at once because of limitations in available funding. Therefore, the ranking procedure is provided to aid in scheduling the phase two contaminant tracing program so that the highest priority drains can be investigated as soon as possible. Two methods, elevation above reference (EAR) and loading indices, are recommended for ranking problem drains.

The elevation above reference (EAR) technique is a comparison of storm drain sediment data with data available for offshore receiving environment sediments. Sediment quality data are available for 10 reference areas in Puget Sound. These data (Tables 9a and b) are assumed to provide a

TABLE 9a. SUMMARY OF METAL CONCENTRATIONS IN SEDIMENTS
FROM PUGET SOUND REFERENCE AREAS

Chemical	Range (mg/kg dry wt)	Detection Frequency	Reference Sites ^a
Antimony	U0.1 ^b -2.79	16/36	1,2,3,4,7,8,9,10
Arsenic	1.9-17	38/38	1,2,3,4,7,8,9,10
Cadmium	0.1-1.9	28/28	1,2,3,4,6,9,10
Chromium	9.6-255	42/42	1-10
Copper	5-74	32/32	1,2,3,4,5,6,9,10
Lead	U0.1-24	25/32	1,2,3,4,5,6,9,10
Mercury	0.01-0.28	42/42	1-10
Nickel	4-140	30/30	1,2,3,4,5,9,10
Selenium	U0.1-1.0	18/28	1,2,3,4,6,9,10
Silver	U0.02-3.3	28/30	1,2,3,4,5,9,10
Zinc	15-102	30/30	1,2,3,4,5,9,10

^a Reference sites: 1. Carr Inlet 4. Case Inlet 7. Nisqually Delta
2. Samish Bay 5. Port Madison 8. Hood Canal
3. Dabob Bay 6. Port Susan 9. Sequim Bay
10. Port Susan

^b U = Undetected at the method detection limit shown.

References: (Site 1) Tetra Tech (1985b); Crecelius et al. (1975).
(Site 2) Battelle (1985).
(Site 3) Battelle (1985).
(Site 4) Crecelius et al. (1975); Malins et al. (1980).
(Site 5) Malins et al. (1980).
(Site 6) Malins et al. (1982).
(Site 7) Crecelius et al. (1975).
(Site 8) Crecelius et al. (1975).
(Site 9) Battelle (1985).
(Site 10) Tetra Tech (unpublished).

TABLE 9b. SUMMARY OF ORGANIC COMPOUND CONCENTRATIONS
IN SEDIMENTS FROM PUGET SOUND REFERENCE AREAS

Substance ^a	Range (ug/kg dry wt)	Detection Frequency	Reference Sites ^b
<u>Phenols</u>			
65 Phenol	U3.3-62 ^{c,d}	8/20	1,2,3,10
HSL 2-Methylphenol	U10	0/11	1,10
HSL 4-Methylphenol	U2-290	7/11	1,10
34 2,4-Dimethylphenol	U1-U14	0/13	1,10
<u>Substituted Phenols</u>			
24 2-Chlorophenol	U0.5-U500	0/13	1,10
31 2,4-Dichlorophenol	U0.5-50	0/13	1,10
22 4-Chloro-3-methylphenol	U0.5-50	0/13	1,10
21 2,4,6-Trichlorophenol	U0.5-U100	0/13	1,10
HSL 2,4,5-Trichlorophenol	U10-U100	0/11	1,10
64 Pentachlorophenol	0.1-U1000	0/13	1,10
57 2-Nitrophenol	0.1-U50	1/9	1,10
59 2,4-Dinitrophenol	U0.5-U50	0/9	1,10
60 4,6-Dinitro-o-cresol	U0.5-U100	0/9	1,10
58 4-Nitrophenol	U0.5-U100	0/9	1,10
<u>Low Molecular Weight Aromatic Hydrocarbons</u>			
55 Naphthalene	U0.5-U40	14/27	1-6,10
77 Acenaphthylene	U0.1-U40	2/27	1-6,10
1 Acenaphthene	U0.1-U40	4/27	1-6,10
80 Fluorene	U0.1-U40	7/28	1-7,10
81 Phenanthrene	4-170	18/24	1,2,3,6,7,10
78 Anthracene	U0.5-U40	11/24	1,2,3,6,7,10
HSL 2-Methylnaphthalene	0.3-U22	10/17	1,4,5,6,10
<u>High Molecular Weight Aromatic Hydrocarbons</u>			
39 Fluroanthene	5-100	24/29	1-7,10
84 Pyrene	5-120	23/29	1-7,10
72 Benzo(a)anthracene	2-U40	15/22	1,2,3,6,7,10
76 Chrysene	4-U40	15/22	1,2,3,6,7,10
74 Benzo(b)fluoranthene	U5-94	15/25	1-7,10
75 Benzo(k)fluoranthene	4.8-94	15/25	1-7,10

TABLE 9b. (Continued)

Substance ^a	Range (ug/kg dry wt)	Detection Frequency	Reference Sites ^b
<u>High Molecular Weight Aromatic Hydrocarbons (Continued)</u>			
73 Benzo(a)pyrene	U0.37-40	16/21	1,3,4,5,6,7,10
83 Indeno(1,2,3-c,d)pyrene	U0.37-30	10/19	1,4,5,6,7,10
82 Dibenzo(a,h)anthracene	0.4-U13	3/12	1,10
79 Benzo(g,h,i)perylene	1.2-20	8/13	1,7,10
<u>Chlorinated Aromatic Hydrocarbons</u>			
26 1,3-Dichlorobenzene	U0.06-U160	1/25	1,2,3,4,5,10
27 1,4-Dichlorobenzene	U0.06-U120	1/25	1,2,3,4,5,10
25 1,2-Dichlorobenzene	U0.06-65	1/25	1,2,3,4,5,10
8 1,2,4-Trichlorobenzene	U0.5-U190	0/13	1,10
20 2-Chloronaphthalene	U0.5-U50	0/13	1,10
9 Hexachlorobenzene (HCB)	0.01-U100	6/19	1,4,5,6,10
<u>Chlorinated Aliphatic Hydrocarbons</u>			
12 Hexachloroethane	U0.5-U.50	0/9	1,10
xx Trichlorobutadiene	U0.03-U25	5/12	1,4,5,6
xx Tetrachlorobutadiene Isomers	U0.04-U25	5/12	1,4,5,6
xx Pentachlorobutadiene Isomers	0.03-U400	5/19	1,4,5,6,10
52 Hexachlorobutadiene	U0.03-U25	0.07-8.5	1,4,5,6
53 Hexachlorocyclopentadiene	U200	0/3	10
<u>Halogenated Ethers</u>			
18 Bis(2-chloroethyl)ether	0.3-U20	1/9	1,10
42 Bis(2-chloroisopropyl)ether	U0.5-U10	0/9	1,10
43 Bis(2-chloroethoxy)methane	U10	0/9	1,10
40 4-Chlorophenyl phenyl ether	U0.5-U10	0/9	1,10
41 4-Bromophenyl phenyl ether	U0.5-U10	0/9	1,10
<u>Phthalate Esters</u>			
71 Dimethyl phthalate	U0.5-U50	1/12	1,10
70 Diethyl phthalate	9.0-11	4/8	1,10
68 Di-n-butyl phthalate	U20-760	6/8	1,10
67 Butyl benzyl phthalate	U0.5-U25	3/12	1,10
66 Bis(2-ethylhexyl) phthalate	U0.5-58	3/8	1,10
69 Di-n-octyl phthalate	U0.5-U56	5/12	1,10

TABLE 9b. (Continued)

Substance ^a	Range (ug/kg dry wt)	Detection Frequency	Reference Sites ^b
<u>Miscellaneous Oxygenate Compounds</u>			
54 Isophorone	U0.5-U130	0/12	1,10
HSL Benzyl alcohol	U10-U340	0/11	1,10
HSL Benzoic acid	U-430	4/11	1,10
129 2,3,7,8-Tetrachlorodibenzo-p-dioxin	Not Analyzed		
HSL Dibenzofuran	U5-14	4/11	1,10
<u>Organonitrogen Compounds</u>			
HSL Aniline	U1.0-U20	0/6	1
56 Nitrobenzene	U0.5-U10	0/8	1,10
63 n-Nitroso-di-n-propylamine	U0.5-U10	0/8	1,10
HSL 4-Chloroaniline	U10-U50	0/7	1,10
HSL 2-Nitroaniline	U10-U50	0/7	1,10
HSL 3-Nitroaniline	U50	0/7	1,10
HSL 4-Nitroaniline	U50	0/7	1,10
36 2,6-Dinitrotoluene	U0.5-U10	0/8	1,10
35 2,4-Dinitrotoluene	U.05-U10	0/8	1,10
62 n-Nitrosodiphenylamine	U0.5-U10	0/8	1,10
37 1,2-Diphenylhydrazine	U0.5-U5	0/6	1
5 Benzidine (4,4'-diaminobiphenyl)	U0.5	0/2	1
28 3,3'-Dichlorobenzidine	U0.5-U100	0/9	1,10
<u>Pesticides</u>			
93 p,p'-DDE	U1.0-U25	0/12	1,10
94 p,p'-DDD	U1.0-U25	0/13	1,10
92 p,p'-DDT	U1.0-U25	0/12	1,10
89 Aldrin	U0.5-U25	0/13	1,10
90 Dieldrin	U1.0-U25	0/13	1,10
91 Chlordane	U5.0-U50	0/13	1,10
95 Alpha-endosulfan	U.5-U25	0/8	1,10
96 Beta-endosulfan	U1.0-U25	0/8	1,10
97 Endosulfan sulfate	U1.0-U25	0/8	1,10
98 Endrin	U1.0-U25	0/13	1,10
99 Endrin aldehyde	U2.3-U25	0/9	1,10
100 Heptachlor	U0.5-U50	0/13	1,10
101 Heptachlor epoxide	U0.5-U25	0/9	1,10
102 Alpha-HCH	U0.5-U50	0/13	1,10
103 Beta-HCH	U0.5-U50	0/13	1,10

TABLE 9b. (Continued)

Substance ^a	Range (ug/kg dry wt)	Detection Frequency	Reference Sites ^b
<u>Pesticides (Continued)</u>			
104 Delta-HCH	U0.5-U25	0/13	1,10
105 Gamma-HCH (lindane)	U0.5-U50	0/13	1,10
113 Toxaphene	U10-U100	0/5	1,10
<u>PCBs</u>			
xx Total PCBs (primarily 1254/1260)	3.1-U170	7/26	1,2,3, 4,6,7,10
<u>Volatile Compounds</u>			
85 Tetrachloroethene	U3-U16	0/11	2,3,10
38 Ethylbenzene	U3-U16	0/11	2,3,10

^a Number indicates U.S. EPA priority pollutant number. TCL indicates Target Compound List.

^b Reference sites: 1. Carr Inlet 4. Case Inlet 7. Nisqually Delta
2. Samish Bay 5. Port Madison 10. Port Susan
3. Dabob Bay 6. Port Susan

^c An anomalously high phenol value of 1800 ug/kg dry weight was found at one station. For the purposes of developing reference area concentrations, the value has been excluded.

^d U = Undetected at the method detection limit shown.

Reference:

- (Site 1) Tetra Tech (1985b); Mowrer et al. (1977)
- (Site 2) Battelle (1985).
- (Site 3) Battelle (1985); Prah1 and Carpenter (1979).
- (Site 4) Malins et al. (1980); Mowrer et al. (1977).
- (Site 5) Malins et al. (1980).
- (Site 6) Malins et al. (1982).
- (Site 7) Barrick and Prah1 (1987); Mowrer et al. (1977).
- (Site 10) Tetra Tech (unpublished).

reasonable measure of the variability in contaminant concentration for relatively uncontaminated sediments, but are expected to represent fairly conservative levels of contaminant concentration for storm drain sediments. In previous Puget Sound studies (Tetra Tech 1985a,c,d), EARs were calculated based only on six Carr Inlet reference stations (Tables 10a and b). Only the Carr Inlet data, rather than the full range of Puget Sound reference area data, are used in ranking storm drain data for the following reasons:

- o The most complete reference data set is available for Carr Inlet and includes synoptic data for metals, organic compounds, grain size, organic carbon, and other conventional variables
- o The lowest reference detection limits for most substances of concern in Puget Sound embayments are available for Carr Inlet
- o EAR values for many urban embayments in Puget Sound (e.g. Commencement Bay, Elliott Bay, and Everett Harbor) have been calculated with these data, so direct comparisons with previous investigations is possible
- o Where chemicals were detected in more than one reference area, the Carr Inlet samples usually had comparable or lower values and on this basis appear to be reasonably representative of Puget Sound reference conditions.

EARs for each problem storm drain are calculated by dividing the measured concentration of a contaminant by the reference concentration. It is recognized that concentrations of chemical contaminants in storm drain sediments will generally exceed reference concentrations. Therefore, storm drains will be ranked based on the magnitude of exceedance of reference conditions for each problem chemical.

Loading indices are the second method for ranking problem storm drains. It will not be possible to calculate true discharge loading values for most

TABLE 10a. SUMMARY OF METAL CONCENTRATIONS IN
SEDIMENTS FROM CARR INLET REFERENCE AREA

Chemical	Range (mg/kg dry wt)	Mean ^a (mg/kg dry wt)	Detection Frequency
Antimony	0.1-0.14	0.11	4/6
Arsenic	2.4-3.8	3.4	6/6
Cadmium	0.29-1.5	0.95	6/6
Chromium	9.6-24.4	15	6/6
Copper	4.9-8.0	6.4	6/6
Lead	4.4-13	9.2	6/6
Mercury	0.01-0.098	0.04	6/6
Nickel	11-27.6	17	6/6
Selenium	0.1-0.1	0.7	0/6
Silver	0.02-0.12	0.09	2/6
Zinc	15-24.1	19	6/6

^a Mean calculated using the reported detection limit for undetected values.

Reference: Tetra Tech (1985b).

TABLE 10b. SUMMARY OF ORGANIC COMPOUND CONCENTRATIONS
IN SEDIMENTS FROM CARR INLET REFERENCE AREA

Substance ^a	Range (ug/kg dry wt)	Mean ^b (ug/kg dry wt)	Detection Frequency
<u>Phenols</u>			
65 Phenol	U10-62 ^{c,d}	33	3/13
HSL 2-Methylphenol	U1-U10	7.0	0/6
HSL 4-Methylphenol	U10-32	13	2/6
34 2,4-Dimethylphenol	U1-U10	6.8	0/6
<u>Substituted Phenols</u>			
24 2-Chlorophenol	U0.5-U5	3.5	0/6
31 2,4-Dichlorophenol	U0.5-U10	6.8	0/6
22 4-Chloro-3-methylphenol	U0.5-U10	6.8	0/6
21 2,4,6-Trichlorophenol	U0.5-U10	6.8	0/6
HSL 2,4,5-Trichlorophenol	U10	10	0/4
64 Pentachlorophenol	0.1-U50	33	1/6
57 2-Nitrophenol	0.1-U10	6.8	1/6
59 2,4-Dinitrophenol	U0.5	0.5	0/2
60 4,6-Dinitro-o-cresol	U0.5-U100	67	0/6
58 4-Nitrophenol	U0.5-U100	67	0/6
<u>Low Molecular Weight Aromatic Hydrocarbons</u>			
55 Naphthalene	1-13	6.8	3/5
77 Acenaphthylene	U0.5-U5	4.1	0/5
1 Acenaphthene	U0.5-U5	4.1	0/5
80 Fluorene	U0.5-U5	4.1	0/5
81 Phenanthrene	5-16	13	5/5
78 Anthracene	3-22	9.1	4/5
HSL 2-Methylnaphthalene	U1-U5	4.2	0/5
<u>High Molecular Weight Aromatic Hydrocarbons</u>			
39 Fluroanthene	11-20	15.4	5/5
84 Pyrene	11-18	14.4	5/5
72 Benzo(a)anthracene	U5-8	8.0	4/5
76 Chrysene	U5-19	10.8	4/5
74 Benzo(b)fluoranthene	3	3	1/1
75 Benzo(k)fluoranthene	5	5	1/1

TABLE 10b. (Continued)

Substance ^a	Range (ug/kg dry wt)	Mean ^b (ug/kg dry wt)	Detection Frequency
<u>High Molecular Weight Aromatic Hydrocarbons (Continued)</u>			
73 Benzo(a)pyrene	3-7.1	5.7	3/5
83 Indeno(1,2,3-c,d)pyrene	4-U5	4.8	1/5
82 Dibenzo(a,h)anthracene	0.4-U5	4.1	1/5
79 Benzo(g,h,i)perylene	3-U5	4.6	1/5
<u>Chlorinated Aromatic Hydrocarbons</u>			
26 1,3-Dichlorobenzene	U0.5-U5	3.5	0/6
27 1,4-Dichlorobenzene	U0.5-U5	3.5	0/6
25 1,2-Dichlorobenzene	U0.5-U5	3.5	0/6
8 1,2,4-Trichlorobenzene	U0.5-U5	3.5	0/6
20 2-Chloronaphthalene	U0.5-U5	3.5	0/6
9 Hexachlorobenzene (HCB)	U0.5-U10	6.8	0/6
<u>Chlorinated Aliphatic Hydrocarbons</u>			
12 Hexachloroethane	U0.5-U50	34	0/6
xx Trichlorobutadiene	U0.5-U25	15	0/6
xx Tetrachlorobutadiene isomers	U0.5-U25	15	0/6
xx Pentachlorobutadiene isomers	U0.5-U25	15	0/6
52 Hexachlorobutadiene	U0.5-U25	17	0/6
53 Hexachlorocyclopentadiene	U0.5	0.5	0/1
<u>Halogenated Ethers</u>			
18 Bis(2-chloroethyl)ether	0.3-U10	6.8	1/6
42 Bis(2-chloroisopropyl)ether	U0.5-U10	6.8	0/6
43 Bis(2-chloroethoxy)methane	U10	10	0/6
40 4-Chlorophenyl phenyl ether	U0.5-U5	3.5	0/6
41 4-Bromophenyl phenyl ether	U0.5-U5	3.5	0/6
<u>Phthalate Esters</u>			
71 Dimethyl phthalate	U0.5-U50	40	0/5
70 Diethyl phthalate	9.0-11	11	4/5
68 Di-n-butyl phthalate	U20-760	170	3/5
67 Butyl benzyl phthalate	U0.5-U25	17	0/5
66 Bis(2-ethylhexyl) phthalate	U0.5-U25	17	0/5
69 Di-n-octyl phthalate	U0.5-U25	20	0/5

TABLE 10b. (Continued)

Substance ^a	Range (ug/kg dry wt)	Mean ^b (ug/kg dry wt)	Detection Frequency
<u>Miscellaneous Oxygenate Compounds</u>			
54 Isophorone	U0.5-U25	20	0/5
HSL Benzyl alcohol	U10	10	0/4
HSL Benzoic acid	U25-430	140	3/4
129 2,3,7,8-Tetrachlorodibenzo-p-dioxin	U5	5	0/2
HSL Dibenzofuran	U5	3.7	0/4
<u>Organonitrogen Compounds</u>			
HSL Aniline	U1.0-U20	14	0/6
56 Nitrobenzene	U0.5-U5	4.1	0/5
63 n-Nitroso-di-n-propylamine	U0.5-U10	8.1	0/5
HSL 4-Chloroaniline	U50	50	0/4
HSL 2-Nitroaniline	U50	50	0/4
HSL 3-Nitroaniline	U50	50	0/4
HSL 4-Nitroaniline	U50	50	0/4
36 2,6-Dinitrotoluene	U0.5-U10	8.1	0/5
35 2,4-Dinitrotoluene	U0.5-U5	4.1	0/5
62 n-Nitrosodiphenylamine	U0.5-U5	4.1	0/5
37 1,2-Diphenylhydrazine	U0.5-U5	4.1	0/6
5 Benzidine (4,4'-diaminobiphenyl)	U0.5	0.5	0/2
28 3,3'-Dichlorobenzidine	U0.5-U100	67	0/6
<u>Pesticides</u>			
93 p,p'-DDE	U10-U25	10 ^e	0/5
94 p,p'-DDD	U10-U25	10 ^e	0/6
92 p,p'-DDT	U10-U25	10 ^e	0/5
89 Aldrin	U10-U25	10 ^e	0/6
90 Dieldrin	U10-U25	10 ^e	0/6
91 Chlordane	U10-U25	10 ^e	0/6
95 Alpha-endosulfan	U10-U25	10 ^e	0/5
96 Beta-endosulfan	U10-U25	10 ^e	0/5
97 Endosulfan sulfate	U10-U25	10 ^e	0/5
98 Endrin	U10-U25	10 ^e	0/6
99 Endrin aldehyde	U10-U25	10 ^e	0/5
100 Heptachlor	U10-U25	10 ^e	0/6
101 Heptachlor epoxide	U10-U25	10 ^e	0/6
102 Alpha-HCH	U10-U25	10 ^e	0/6
103 Beta-HCH	U10-U25	10 ^e	0/6

TABLE 10b. (Continued)

Substance ^a	Range (ug/kg dry wt)	Mean ^b (ug/kg dry wt)	Detection Frequency
<u>Pesticides (Continued)</u>			
104 Delta-HCH	U10-U25	10 ^e	0/6
105 Gamma-HCH (lindane)	U10-U25	10 ^e	0/6
113 Toxaphene	U10	10 ^e	0/2
<u>PCBs</u>			
xx Total PCBs (primarily 1254/1260)	<4.3-U7	6	2/6
<u>Volatile Compounds</u>			
85 Tetrachloroethene	-- ^f	--	--
38 Ethylbenzene	--	--	--

^a Number indicates U.S. EPA priority pollutant number. TCL indicates Target Compound List.

^b Mean calculated using the reported detection limit for undetected values.

^c An anomalously high phenol value of 1800 ug/kg dry weight was found at one station. For the purposes of developing reference area concentrations, the value has been excluded.

^d U = Undetected at the method detection limit shown.

^e The lower detection limit was used for the mean because it is probably more representative of reference area conditions.

^f -- = Not analyzed.

Reference: Tetra Tech (1985b).

storm drains because the necessary flow and water quality data are generally not available. However, sediment data collected during phase one screening can be used to calculate an index of contaminant loading. The loading index is defined as the product of the contaminant concentration measured in the storm drain sediment and the estimated average annual flow (see "Selection of Storm Drains," Section 4) for each storm drain. Loading indices should be calculated for each of the problem chemicals in each problem storm drain.

Problem storm drains should be prioritized based on the two ranking procedures; the EAR and the loading index. Problem storm drains ranking the highest using both procedures are recommended for immediate contaminant tracing activities performed during phase two. Lower priority drains can be sampled as funding allows. Highest priority should be given to storm drains with the greatest number of problem chemicals identified as pollutants of concern for the Puget Sound area.

SECTION 5. PHASE TWO - CONTAMINANT TRACING

The contaminant tracing phase of the investigation is an extension of the initial screening program. The objective during this phase is to isolate contaminated sections of storm drain line and associated drainage subbasins in problem storm drains identified during phase one screening. When this is done, source identification efforts can be focused on contaminated sections of storm drain lines while uncontaminated sections can be eliminated from further study. To trace contaminants to the sources, additional field sampling and continued investigation of land use in the drainage basin will be required. Phase two will entail collecting additional sediment samples from manholes throughout the storm drain system to trace contaminants in the problem storm drains. The phase two sampling effort will focus on problem chemicals and associated source categories identified during phase one and the preliminary investigation. The phase two sampling procedure is expected to be an iterative process because it may take several rounds of sampling to isolate contaminated sections of the storm drain system and identify the ultimate source(s) of contaminants. In addition to supporting source investigation, the contaminant tracing procedure will identify sections of the storm drain system where contaminated sediments have accumulated and should be removed to prevent contamination of receiving waterways. Information obtained during the preliminary investigation will be used to help select sampling station locations. In addition, a detailed investigation of industrial and commercial facilities operating in each drainage basin will be required to support the sampling program. The following sections provide recommendations on conducting a detailed contaminant tracing program in problem storm drain systems.

SELECTION OF SAMPLING STATIONS

Contaminant tracing sampling will have to be tailored to each problem storm drain so the unique characteristics of each drain, its service area, and specific problem chemicals are considered. This section of the report

provides general guidance on selecting sampling station locations. In general, the complexity of the storm drain system and the number of sampling stations required will increase as a function of drainage basin area. Large storm drain systems will serve several subbasins and have numerous branches in the storm drain network. Therefore, it will be important to carefully select sampling stations to minimize the number of samples required and to allow identification of contaminant sources. Sampling stations will be ultimately selected through a process of elimination. As non-contaminated sections of the storm drain system are identified, they will be eliminated from further investigation. Information obtained during the preliminary investigation will provide a basis for selecting sampling station locations. However, further detailed investigation of the storm water collection system and the facilities operating in the drainage basin will be required during this phase for accurate identification of sources.

It is recommended that sampling stations be selected in problem storm drains to satisfy the following three objectives (arranged in order of increasing level of detail):

- o Isolate subbasins with different land use characteristics
- o Determine contaminant gradients along major trunk lines, if possible
- o Isolate specific contaminant sources.

As the first step, sampling stations should be selected to isolate specific branches and subbasins within the problem drainage basins. The selection should be based on the layout of the storm drain system and the land use characteristics within each drainage subbasin. Sampling stations should be located at manholes on major junctions in the storm drain system. The intent is to isolate subbasins with a high potential of contributing to the contamination in the system from those with low contaminant potential. For example, in the hypothetical storm drain system shown in Figure 8, the service area can be divided into the following four major subbasins:

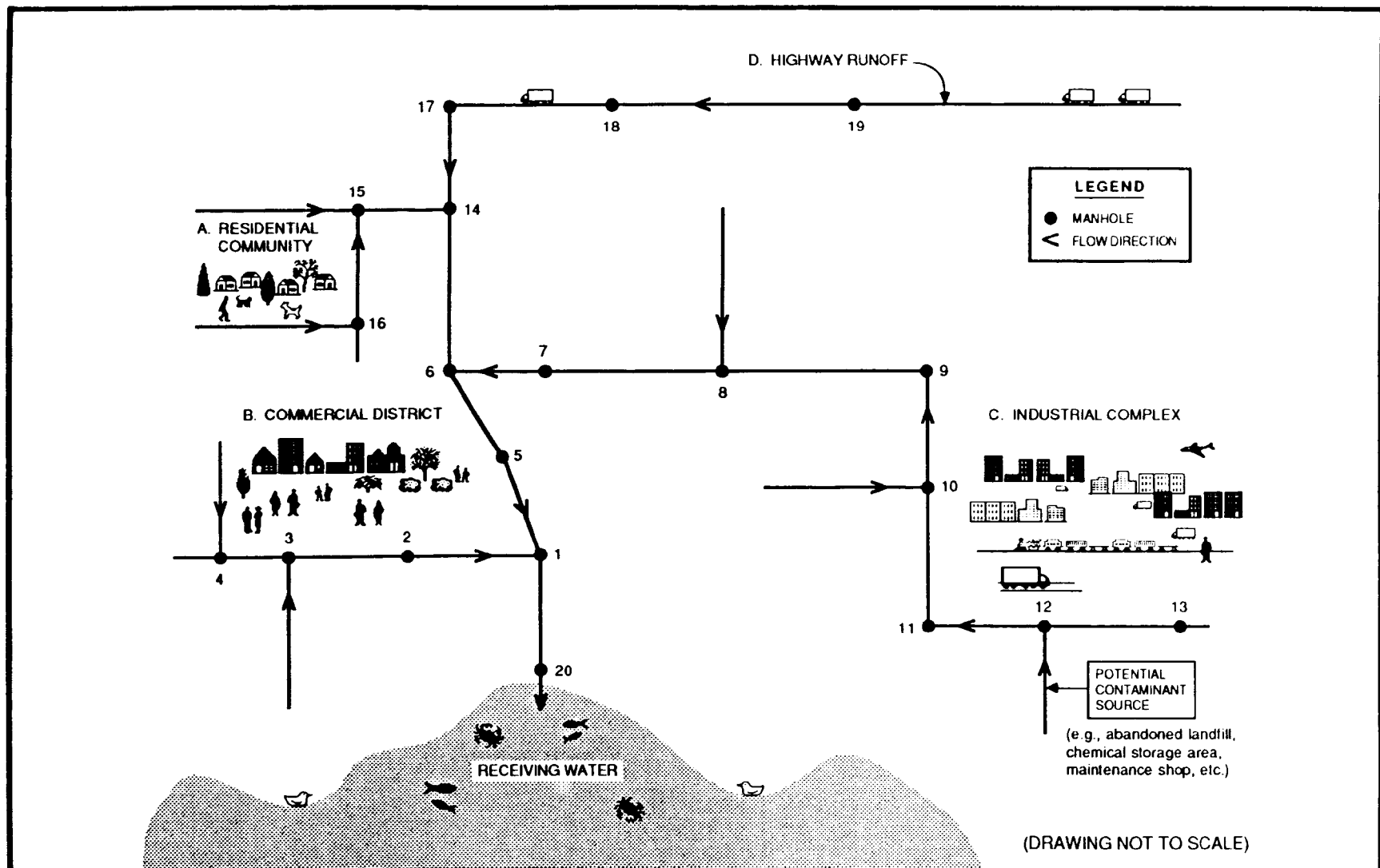


Figure 8. Schematic of a hypothetical storm drain system.

- o Subbasin A - Residential Community
- o Subbasin B - Commercial District
- o Subbasin C - Industrial Complex
- o Subbasin D - Highway Drainage.

For this system, approximately four sampling stations (i.e., Manholes 2, 7, 15, and 17) would be required to isolate the major subbasins connected to the trunk line.

The presence of concentration gradients in the storm drain system can be used to identify sources because contaminant concentrations in the sediment will generally decrease in the storm drain line upstream and downstream of the source input. Therefore, it is recommended that additional stations be sited along the major trunk line to identify potential contaminant concentration gradients. In the hypothetical storm drain system (Figure 8), additional stations at Manholes 5, 14, and 20 would be sufficient to determine if there are any discernable gradients in contaminant concentrations in the main trunk line.

Sampling stations should also be located at manholes upstream and downstream of suspected contaminant sources to determine if the suspected source has contributed significant amounts of contaminants to the storm drain. A specific source would be identified as a problem if contaminant concentrations in the storm drain sediments increase in the manhole below the source. In Figure 8, additional sampling stations are recommended at Manholes 12 and 13 to document contaminant contributions from the suspected source in Subbasin C.

The contaminant tracing program should focus on the specific problem chemicals identified during phase one. A recent study conducted as part of Puget Sound Estuary Program (PSEP) (Tetra Tech 1986c) identified pollutants of concern for the Puget Sound region. For a select subset of the pollutant of concern list, a matrix was developed for the report that linked chemicals

with specific source categories and industry types. This information, provided in Appendix 3, can be used in selecting sampling stations to focus on facilities in each subbasin that may have contributed specific problem chemicals to the storm drain system.

Multiple rounds of sampling will likely be required to trace contaminants through the storm drain system to the ultimate source(s) and the procedures above should be used to design subsequent sampling plans. Sampling activities should continually move upstream in the storm drain system toward the ultimate source(s). As sampling progresses, uncontaminated sections of the storm drain system are eliminated from further investigation, and problem side connections and branch lines are identified. The general progression in the contaminant tracing approach is as follows:

outfall > trunk line > branch line > side connection > catch basin > source.

INTERPRETATION OF SEDIMENT CHEMISTRY DATA

The decision to eliminate a portion of a storm drain system or a drainage subbasin from further sampling must include review of data QA/QC procedures and sediment characteristics. Review of contaminant data for a storm drain system must be performed to ensure that analytical results are properly interpreted, and detection of potential contaminant sources has not been missed due to field or laboratory constraints.

Data validation procedures should be specified in the Quality Assurance Project Plan (AQPP), and should include a QA summary report. In the QA summary report, results from the QA/QC checks performed in the field and laboratory should be compared against criteria established for the sampling program in the QAPP. QA review of data should include, as a minimum, assessment the following:

- o Method detection limits
- o Holding times for analyses

- o Documentation and chain-of-custody procedures
- o Frequency of QA/QC sample checks
- o Contamination of field and laboratory blanks by problem chemicals
- o Control limits for laboratory replicate and matrix spike results
- o Control limits for blind field replicate results
- o Control limits for Standard Reference Material (SRM) results.

If QA review indicates that any of the above QC checks do not meet data quality objectives, then data must be qualified. Guidelines for performing data review and qualification have been established for the U.S. EPA CLP (U.S. EPA 1985a,b), and can be of assistance when performing the data evaluation. Qualified data can be used in the decision process for tracking contaminant sources. However, data qualifiers must be taken into consideration when performing data comparisons. In some cases, high data variability or semi-quantitative results may require that resampling or reanalysis be performed to allow determination of contaminant concentration gradients. For example, if results from the blind field replicates are outside the control limits for data variability, then this high variability must be taken into consideration when comparing results from upstream and downstream sample points. The resulting wide confidence limits may not allow determination of significant contaminant concentration differences.

In addition to evaluating QA/QC procedures, relative concentrations of organic carbon and fine particulate matter in the samples should be assessed. In general, contaminant loading will be higher in samples containing higher concentrations of organic carbon and/or silt and clay because of the greater absorption capacity of organic matter and fine particulate. To account for these sample characteristics, data can be normalized to organic carbon

content by dividing the contaminant concentration by the total percent fines obtained from the particle size data.

After the data QA review and characterization of sediment are completed, results from the storm drain sample analyses can be compared to determine which drainage subbasins require additional contaminant tracing and which can be eliminated from further investigation. The data should first be reviewed to determine whether the TOC and percent fines content of sediments within each storm drain line are comparable (i.e., within the variability of the test method). If TOC and/or percent fines content of the sediment samples collected from each drain are not comparable, then data should be normalized prior to the contaminant concentration comparisons. Further phase two contaminant tracing activities will be required in a specific drainage subbasin if the concentration of the problem chemical in the upstream station is equal to or greater than the concentration measured in the downstream station.

A subbasin can automatically be eliminated from further investigation if 1) the problem chemicals identified in the downstream station are undetected in the sediment from the upstream station, and 2) the criteria used to identify problem chemicals (i.e., AET values, proposed freshwater sediment criteria, 90th percentile, or street dust levels) are at least 5 times greater than the analytical detection limits.

Elimination of drainage subbasins from further investigations where the problem chemicals are detected (i.e., quantified) in sediments from the upstream station, but at lower concentrations than the sediments from the downstream station, will require careful data interpretation. For these cases, it is recommended that data first be evaluated to determine whether the differences in concentration between upstream and downstream stations are significant. The following two steps are recommended:

- o The concentration of the problem chemical in the sediments from the upstream and downstream station must be at least 5 times greater than the method detection limit to ensure that concentrations are in the quantifiable range of the method

- o The concentration of the problem chemical in the sediments from the upstream station must be outside the confidence limits (based on the QA review) for the concentration reported in the downstream station.

An example of the latter point follows. Assume that the confidence limits for the downstream station are ± 20 percent and the measured concentration of the problem chemical in the downstream station is 100 ug/kg. Concentration of the problem chemical in the upstream station must be <80 ug/kg or >120 ug/kg for a significant difference in contaminant concentration to exist between the two stations. If the data are not qualified, then control limits from the QA assessment can be used for the data comparisons. However, the data are qualified, confidence limits must be established case by case.

Once it has been determined that significant differences in concentration between two stations exist, an examination should be made of contaminant gradients along the main trunk line. In most cases, it is expected that concentration gradients will point in the direction of a particular source. However, if a concentration gradient cannot be established for a problem chemical after sampling in the upper reaches of a subbasin, then the possibility of a nonpoint source of contaminants should be considered.

Additional data evaluation can include comparisons of the overall chemical composition of the upstream and downstream sediment samples. Ratios of chemical concentration within sediment stations can be compared to determine if the relative contaminant composition (i.e., chemical signature) changes between sampling stations. A change in chemical signature between two stations may indicate multiple sources.

ADDITIONAL INVESTIGATIONS

In some cases, additional investigative activities will be required to complete phase two and the source identification process. The following

additional activities are recommended to support the contaminant tracing program:

- o Distribute questionnaires to businesses in the problem drainage basin to obtain information on current operations
- o Conduct inspections at key industries in the problem drainage basin to locate, identify, and characterize wastes and pretreatment processes and to provide information on proper waste handling and disposal practices at the facilities
- o Conduct dye and/or smoke tests to verify side connections to the storm drain system and to identify improper connections.

Questionnaire surveys are an effective way of obtaining information on operations, waste discharges, and waste handling procedures for the businesses operating in the problem drainage basins. Questionnaires have been used in recent contaminant source investigations in the Puget Sound area (Romberg et al. 1987), and mailing lists can be obtained from the state tax records (see Section 3). Questionnaires can be designed to target particular industry types and the information obtained can be used to select which businesses should be inspected. The following are suggestions for the type of information that should be requested:

- o Water use and volume (e.g., restroom, rinsing, cooling, product manufacturing, floor cleaning, washdown)
- o Types of connections to the storm drain system (e.g., catch basins, floor drains, sumps)
- o Types of chemicals used or stored onsite
- o Type of business (e.g., product manufacture or service).

Inspections of industries will provide detailed information on possible contaminant sources in the drainage basin. In addition, inspections can be

used to inform the facility of recommended waste handling practices to reduce contaminant loading to the storm drain system. During these inspections, dye or smoke tests can be used if identification and verification of individual side connections to the storm drain system are necessary.

SAMPLE COLLECTION

Recommended storm drain sediment sampling procedures, decontamination procedures, documentation, sample packaging and shipping requirements, and scheduling are as described in "Sample Collection," Section 4. It is recommended that chemicals analyzed for during the contaminant tracing program be those identified during phase one. Chemical analyses and quality assurance/quality control (QA/QC) recommendations for phase two are presented in the following sections.

Chemical and Physical Analyses

Analysis of sediment samples for phase two contaminant tracing should include, at a minimum, the problem chemicals identified during phase one screening and the preliminary investigation. If a particular compound or class of compounds was not detected during phase one screening, or is not indicated as important during the preliminary investigation, a smaller number of variables may be analyzed than in phase one screening. A technical expert should be consulted prior to contaminant tracing to select appropriate variables for this phase.

Analysis of a smaller number of target analytes may reduce costs incurred from the laboratory. However, cost is determined by the required analytical procedures, and the difference between analyzing a few target compounds and a broader range of compounds may not be substantial. Relative costs and analytical methods should be discussed with the analytical laboratory prior to sample collection.

Protocols developed under PSEP (Tetra Tech 1986d) should be used to collect and analyze sediment samples for extractable organic compounds, metals, and conventional variables. Analysis of conventional variables

(e.g., total solids, total organic carbon, and grain size) is recommended during the contaminant tracing effort to permit comparison to sediment samples collected during phase one screening.

Quality Assurance/Quality Control

Collection of field QA/QC samples specified for the phase one screening is also appropriate for phase two contaminant tracing. A detailed discussion of field QA/QC samples and collection procedures is presented in "Sample Collection," Section 4, and should be followed during phase two sampling efforts.

Laboratory QA/QC requirements are described in the PSEP protocols (Tetra Tech 1986d) and the U.S. EPA CLP statement of work (U.S. EPA 1987). Prior to collection of sediment samples during phase two, the project manager should specify the frequency of analysis for laboratory QA/QC samples (i.e., method blanks, matrix blanks, method spikes, and analytical replicates). The assessment of data quality should be performed by a QA/QC expert and reported with the sample data.

SECTION 6. PHASE THREE - CONFIRMATION

The information obtained from phase one screening and phase two contaminant tracing, combined with the supporting evidence from the site inspections, is expected to provide sufficient evidence to identify contaminant sources for many of the problem drains. However, in some cases, additional sampling efforts may be required to confirm contaminant contributions from specific sources. Source confirmation sampling performed during phase three will require that samples be collected from the actual discharge(s) to the storm drain rather than from sediment deposits in the drain. This section provides general recommendations on how to collect and interpret discharge monitoring data.

The following situations may warrant discharge sampling:

- o To distinguish between historical and ongoing source contributions
- o To confirm sources where volatile organic compounds are suspected as the major contaminant
- o To determine compliance for NPDES-permitted sources
- o To document source contaminant loading conditions for enforcement cases.

Storm drain sediments may represent historical rather than ongoing source contributions. For example, when contaminants are present in storm drain sediments, but cannot be associated with current activities in the drainage basin, it may be necessary to monitor stormwater discharges to determine whether there are ongoing sources in the basin. If no ongoing sources are identified in the problem drainage basins, the adverse effects on the receiving environment may be reduced by simply cleaning the storm

drain system. Storm drain cleaning includes removal and disposal of contaminated sediments from the drain lines and catch basins. However, if ongoing contaminant discharges to the storm drain system are identified, then source control efforts and storm drain cleaning will be required.

Volatile organic compounds have not been recommended for analysis during phase one screening and phase two contaminant tracing because available data indicate that volatile organic compounds are not frequently detected in storm drain sediments. As part of the Puget Sound Estuary Program (PSEP), volatile organic compounds were analyzed in sediment samples from 20 storm drains discharging into Elliott Bay and the lower Duwamish River (Tetra Tech unpublished). These drains were suspected of having a high potential for contamination based on the visual appearance of the sediment and odors reported during sample collection. Detection frequencies for the volatile organic compounds in these samples ranged from 0 to 40 percent. Compounds detected most frequently included trans-1,2-dichloroethene (40 percent), trichloroethene (35 percent), and ethyl benzene (35 percent). The remaining volatile organic compounds were detected in 20 percent or less of the samples analyzed. However, storm drain monitoring conducted by Galvin and Moore (1982) and U.S. EPA (1983c) indicate that volatile organic compounds are one of the most frequently detected class of organic compounds found in stormwater runoff. Consequently, analysis of volatile organic compounds is recommended for discharge samples rather than storm drain sediments in drains where potential sources of volatile organic compounds exist.

NPDES permits typically limit the concentration and loading of contaminants in a facility's effluent, and do not set limits for sediments. Therefore, to determine compliance with permit conditions, it will be necessary to monitor a plant's effluent. Although NPDES-permitted facilities are required to monitor their effluent, toxic contaminants are not usually included in the variables measured. Therefore, additional discharge monitoring will be required to confirm the contaminant contributions from these potential sources.

Enforcement cases typically require detailed information on the source(s), including the type of discharge (i.e., stormwater runoff from property, process water, illegal discharge), type of contaminants and their concentration in the discharges to the storm drain system, contaminant loading, and the effects on the receiving environment. The presence of contaminants in sediments collected from catch basins at the facility suspected of contaminating storm drains should be sufficient to document contaminant problems associated with stormwater runoff. However, confirmation of contaminant contributions from process water and other plant discharges to the storm drain system will require collecting water samples and monitoring flow in the discharge to the storm drain.

DISCHARGE MONITORING TECHNIQUES

In general, discharge monitoring is more complex than storm drain sediment sampling because it is typically event-oriented and must consider rainfall conditions and variability in flow and water quality conditions of the discharge. Discharges to the storm drain system may consist of storm water runoff or industrial effluent, such as noncontact cooling water or process water. Storm water monitoring must be carefully coordinated with rainfall conditions. For other types of discharges to the storm drain, timing of the sampling event will not be as critical. In addition, sampling events will have to be scheduled during periods of low tide to avoid tidal interferences in tidally influenced drains.

The following sections provide general recommendations for discharge sampling in the storm drain system. The discharge monitoring program is designed to complete the source identification process begun during phases one and two by measuring concentration of contaminants and flow rate in discharges to the storm drain system. Included in the recommendations are a general discussion of sample collection procedures, analytical requirements, and data interpretation techniques.

An important issue in designing a discharge sampling plan is whether to use bulk water only, or the particulate fraction of the discharge for chemical analyses. Separate analysis of bulk water and the particulate

fraction is normally recommended to obtain lower detection limits for problem chemicals (Tetra Tech 1986a). Separate analyses are often required because many contaminants associated with the particulate fraction may not be detected in analyses of bulk water only. Separate collection and analysis of the particulate fraction concentrates contaminants adsorbed to solids which improves quantification of the contaminants. The following section provides guidance on selecting between bulk water only and particulate fraction analysis.

Bulk Water Vs. Particulate Fraction Analysis

Particulate fraction analysis of a discharge is recommended only if the problem chemicals are difficult to detect due to low concentrations in the bulk water discharge. By separating and collecting the particulate in the discharge, contaminants adsorbed to the particulate can be more readily quantified. If high concentrations of contaminants are expected in the bulk water samples (i.e., greater than 5 times the method detection limit), then particulate fraction analysis is not required. In cases where relative pollutant loadings from drainage subbasins are difficult to assess because concentrations of the contaminants are low in the bulk water samples, particulate fraction analysis can improve the ability to quantify relative contaminant concentrations. However, collection of adequate particulate fraction for laboratory analysis requires specialized equipment (e.g., continuous centrifuge or filtration apparatus) and can be labor intensive. Therefore, particulate fraction analysis should be considered only if no other means of contaminant tracing are available. Alternatives to particulate fraction analysis include modifying analytical techniques to improve detection limits, tracing the contaminant source further upstream to minimize dilution, or diverting a potential source of dilution water during sample collection.

If particulate fraction analysis is to be performed, the total suspended solids content of the bulk water sample should be determined prior to particulate sample collection. The quantity of particulate in a discharge can vary widely. Discharges consisting primarily of noncontact cooling water may contain less than 5 mg/L of suspended material, while stormwater

runoff may contain greater than 1,000 mg/L suspended material during an intense rainfall event. If a discharge consists primarily of cooling water containing minimal particulate, then collection of an adequate quantity of the discharge for particulate analysis may not be practical. For example, if the suspended solids content of the discharge is 10 mg/L, approximately 2,000 L of water would be required to obtain the sediment necessary for analysis of extractable organic compounds (i.e., approximately 20 g). Processing 2,000 L of sample would require 8 h using a continuous centrifuge that processes approximately 4 L of sample/min. Manual collection of a sufficient volume of discharge water for analysis of the particulate fraction would not be feasible in this situation.

The decision whether to analyze bulk water or the particulate fraction will depend upon project objectives and funds, expected total suspended solids content in the discharge, availability of a continuous centrifuge, and hydrogeographic characteristics of the drainage subbasin. General guidance on bulk water and particulate sampling is provided in the following sections.

SAMPLE COLLECTION

Sampling conducted during phase three confirmation should follow the same equipment decontamination, documentation, sample packaging, and shipping procedures recommended for phase one screening (see "Sample Collection," Section 4).

Bulk Water Sampling

It is recommended that continuous composite samples be collected for bulk water chemical analysis to provide representative samples of the storm drain discharges. Samples should be collected with an automatic sampler that composites samples in proportion to flow. If continuous, flow-proportioned samples cannot be collected, manually composited samples can be substituted. If samples are manually composited, the individual grab samples should be collected no longer than 30 min apart if feasible.

The length of time for compositing samples will be dependent on the type of discharge sampled because flow characteristics will vary depending on the source type (e.g., storm water, process water). Samples of industrial process discharges should be composited over a 12 h period. Storm water samples should be composited over the duration of the storm event or 12 h, whichever is shorter. It will probably not be possible to achieve these compositing periods for tidally-influenced drains. However, samples from tidally-influenced drains should, at a minimum, be composited for the duration of the low tide. In addition, rainfall must be recorded for all stormwater runoff sampling events to enable comparisons with other storm events.

If automatic samplers are used, the sampler should have a capacity at least as large as the total volume required for the chemical analysis (see "Chemical Analysis," Section 6) to avoid changing collection bottles during sampling. In addition, access to samplers located inside storm drain manholes may be infeasible during storm events. Equipment needed to collect discharge samples is summarized in Table 11. General guidance on collecting discharge samples for bulk water chemical analysis is provided below:

- o Automatic samplers and meters can be installed inside the manhole on side connections to the problem drain. Sampling equipment should be installed above the mean high tide elevation in tidally influenced storm drains. Recommended manhole entry procedures are described in "Sample Collection," Section 4. If manhole installation is not feasible, and the equipment cannot be installed in a secure area, provisions will have to be made to protect the equipment from vandalism during the sampling period. Consult the manufacturer's instruction for proper installation and operation of the equipment.
- o Set equipment to collect samples for the appropriate time interval (e.g., 12 h for process waste streams). Insure that sample collection bottles in the automatic sampler contain the appropriate preservatives (see "Chemical Analyses," Section

TABLE 11. LIST OF EQUIPMENT NEEDED FOR STORM DRAIN
DISCHARGING SAMPLING

Hard hats	Clear tape
Calculator	Marking pens
Lights	Knife
Maps	Sample tray
Camera and film	Kimwipes
Manhole cover hook	Gloves (leather and chemical resistant)
Manhole depth and water level measuring device	Coveralls (cotton and chemical resistant)
Sledge hammer	Respirators ^a
Methanol	(including extra filters)
Squirt bottles	Waders (two pair) ^a
Waste solvent bottle and funnel	Duct tape ^a
Bags - garbage, ziploc	O ₂ /combustible gas meter and tubing ^a
Rope	Photoionization detector (PID) ^a
Barricades, traffic cones, traffic signs	meter and tubing ^a
Sampling equipment:	Drager tubes/bellows ^a
Extension pole	Decontamination sprayer ^a
Automatic sampler/flow meter	Brushes (for decontamination) ^a
1-gal glass container	Alconox
Aluminum foil	First aid kit
Sample containers (organic compounds, metals, total suspended solids, volatile organic compounds)	Safety harness and rope ^a
Coolers	Clipboard
Ice	Tide tables
Custody seals	Self-contained breathing apparatus (SCBA) equipment ^a
Chain-of-custody forms	pH meter
Analysis request forms	Flow meter
Field data log forms	Continuous flow centrifuge ^b
Field logbook	Pump/tubing ^b
Sample tags	Filtration equipment ^b

^a Required if personnel must enter manhole to install sampling equipment.

^b Required for collection of particulate material.

6). Beginning and ending times should be recorded. Sampling equipment should be checked periodically during the sampling period to ensure that it is functioning properly.

- o A separate grab sample must be collected for sources requiring analysis of volatile organic compounds because composite samples are not suitable. Completely fill the sample bottle to eliminate air bubbles and prevent loss of compounds.
- o If sampling stormwater runoff, the sampling equipment should be set up prior to the event. Set the equipment to begin sampling at the start of the rising limb of the runoff hydrograph, and to stop when flow returns to pre-storm conditions or 12 h later, whichever is shorter.
- o For manual compositing, grab samples can be collected from the side connection to the storm drain. Manhole entry may not be required. In some cases, samples may be collected by attaching the sampling container to the end of an extension rod that reaches into the manhole. Samples should be collected in 1-gal glass containers at 30 min intervals. A minimum container size of 1-gal is recommended to ensure that sufficient sample volume is collected for compositing. Each sample bottle should be fixed with preservative, sealed, and placed on ice in a cooler. In addition, flow measurements must be recorded each time a grab sample is collected so samples can be composited in proportion to flow and to determine when the stormwater runoff has subsided. At the end of the sampling period, a single flow-proportioned composite sample should be prepared by removing aliquots from each grab sample and combining them in a single container.

Particulate Fraction Sampling

As explained earlier, separate analysis of bulk water and the particulate fraction of a discharge sample would only be recommended under special

conditions due to cost and difficulty in collecting samples. The following discussion presents general guidance for collecting separate bulk water and particulate fraction samples.

Filtration and centrifugation techniques are commonly used to separate the particulate fraction from the bulk water sample for analysis. Filtration is recommended for most routine analyses because it requires less expensive equipment and provides a sample suitable for direct chemical analysis (i.e., residue on a filter that can be extracted or digested). Centrifugation techniques can yield comparable results, but require careful and complete transfer of the sample from the centrifuge tubes prior to analysis. The amount of material required for chemical analysis and the concentration of suspended solids in the waste stream are the major factors affecting the choice between filtration and centrifugation techniques. These two factors determine the volume of sample that must be processed, and therefore, the time required to collect each sample.

Most metals of interest are found at much higher concentrations than the organic compounds and are more easily analyzed using a small sample size. Generally, a minimum of 4 L of composited sample is sufficient for analysis of metals in the particulate fraction (Tetra Tech 1986a). An additional 2 L of sample is required for mercury analysis. These volumes can yield sufficient amounts of particulate by filtration without special techniques or extremely long filtration times. Because of the potential for contamination in the field, and the time required to process the samples, it is recommended that filtration procedures be conducted in a field laboratory. Filtration procedures are summarized in "Analytical Methods for U.S. EPA Priority Pollutants and Particulate Matter from Discharges and Receiving Waters" (Tetra Tech 1986a). General equipment requirements include a filter apparatus capable of efficiently handling the required sample volume (i.e., 4-6 L), glass fiber filters, distilled water, and appropriate glassware. Samples would be collected in the field using the same procedures described in "Bulk Water Sampling," Section 6. However, a larger volume of sample would have to be collected to meet the requirements for both the bulk water and particulate fraction chemical analyses.

Much larger sample volumes are generally required to obtain low detection limits for organic compounds. As explained in the example presented in "Bulk Water Vs. Particulate Fraction Analysis," as much as 2,000 L of sample may have to be processed to obtain a sufficient amount of particulate material for organic compound analyses. Filtration of this volume of sample would be impractical. Therefore, centrifugation techniques are typically used to process samples for organic analysis on particulate fraction. Because of the large volumes required, samples are typically processed in the field using a continuous flow centrifuge (Ongley 1982). Several field models are available that are capable of processing between 4 and 8 L/min of sample (Tetra Tech 1986a). The specialized equipment required for field centrifugation of particulate samples includes a portable (i.e., truck-mounted), continuous flow centrifuge pump and chemically inert tubing to collect the sample and route it through the centrifuge, and a generator.

Scheduling

Scheduling requirements for phase three sampling activities will depend on the type of source sampled. For example, stormwater runoff samples must be collected during a rainfall event. Therefore, weather forecasts should be monitored to aid in predicting rainfall conditions so field crews can be mobilized in time to sample the event. Sampling of industrial discharges (i.e., process waste, noncontact cooling water) can be scheduled to coincide with a particular plant operation suspected as a potential contaminant source. Automatic samplers can sometimes be used to monitor illegal discharges. For this, samplers are placed in-line and programmed to collect samples during a period when illegal discharges are suspected.

Chemical Analyses

Chemical analyses of discharge samples for phase three confirmation should include problem chemicals identified in the storm drain sediment samples collected during phase one and phase two. In addition, other chemical compounds (e.g., volatile organic compounds) identified as potential contaminants in process waste streams or stormwater runoff during the

preliminary investigation should be included in the analyses. A technical expert should be consulted prior to discharge sampling to determine appropriate variables. Groups of chemicals that may be included in the analysis of samples for phase three confirmation are listed below:

- o Metals
- o Extractable organic compounds
- o Volatile organic compounds
- o Conventional (i.e., pH, total suspended solids, total dissolved solids).

Metals analyses can be conducted using PSEP protocols (Tetra Tech 1986d). A list of metals of concern and their recommended detection limits in water is provided in Table 4. However, PSEP does not make recommendations for the analysis of volatile organic compounds, extractable organic compounds, and conventional variables in water samples. Therefore, for these analyses, it is recommended that analytical procedures approved under the Clean Water Act be used (U.S. EPA 1984). The analytical methods, sample containers, preservation, and holding times for water samples collected during phase three confirmation are presented in Table 12.

The analysis of extractable organic compounds and pesticides/PCBs can be performed on the same sample extract, so the collection of separate samples is not required. Detection limits of 0.1-25 ug/L for acid/neutral compounds and 0.002-1.0 ug/L for pesticides/PCBs are required under U.S. EPA CLP (U.S. EPA 1987). These detection limits will provide adequate sensitivity for source tracing. Methods for the preparation and analysis of water samples are discussed in the U.S. EPA CLP statement of work (U.S. EPA 1987).

Analysis of discharge samples for volatile organic compounds (see Table 13) requires that detection limits of 0.5-1 ug/L be attained. These detection limits are necessary for determining the trace levels of volatile organic compounds which may be present in the system. The detection limits

TABLE 12. RECOMMENDED METHODS, SAMPLE CONTAINERS, PRESERVATION,
AND HOLDING TIMES FOR WATER SAMPLE ANALYSIS

Variable	Sample Container	Preservation and Handling	Holding Time ^a	Method ^b	Reference
Semivolatile organics	2-L glass bottle; PTFE-lined cap	Keep on ice (4 ⁰ C)	7 days/40 days	Extraction, GC/MS	U. S. EPA 1984
Pesticides/PCBs	2-L glass bottle; PTFE-lined cap	Keep on ice (4 ⁰ C)	7 days/40 days	Extraction, GC/ECD	U. S. EPA 1984
Volatile organics	Two 40-mL glass vials; PTFE-lined silicon septum caps	Fill, leaving no air space, keep in dark on ice (4 ⁰ C)	14 days	Purge and trap, GC/MS	U. S. EPA 1984
Metals (total)	1-L glass or linear polyethylene bottle, PTFE-lined cap	HNO ₃ to pH<2	6 mo (Hg 28 days)	ICP, FLAA, GFAA, CVAA	Tetra Tech 1986c
Total dissolved solids, total suspended solids	2-L glass or plastic, PTFE-lined cap	Cool (4 ⁰ C)	7 days	Methods 160.1, 160.2	U. S. EPA 1983b
Oil and grease	2-L glass, PTFE-lined cap	Cool (4 ⁰ C), H ₂ SO ₄ to pH<2	28 days	Method 413.1 or 413.2	U. S. EPA 1983b

^a Where two times are given, the first refers to the maximum time prior to extraction, the second to the maximum time prior to instrumental analysis.

^b GC/MS = Gas chromatography/mass spectroscopy.
GC/ECD = Gas chromatography/electron capture detection.
ICP = Inductively coupled plasma atomic emission spectroscopy.
FLAA = Flame atomic absorption.
GFAA = Graphite furnace atomic absorption.
CVAA = Cold vapor atomic absorption.

^c PTFE = Polytetrafluoroethylene.

TABLE 13. VOLATILE ORGANIC COMPOUNDS RECOMMENDED
FOR ANALYSIS OF DISCHARGE SAMPLES

Halogenated Alkanes	Halogenated Alkenes
chloromethane	vinyl chloride
bromomethane	1,1-dichloroethene
chloroethane	trans-1,2-dichloroethene
methylene chloride	cis- and trans-
1,1'-dichloroethane	1,3-dichloropropene
chloroform	trichloroethene
1,2-dichloroethane	tetrachloroethene
1,1,1-trichloroethane	
carbon tetrachloride	Aromatic Hydrocarbons
bromodichloromethane	benzene
1,2-dichloropropane	toluene
chlorodibromomethane	ethylbenzene
1,1,2-trichloroethane	styrene
bromoform	total xylenes
1,1,2,2-tetrachloroethane	
Chlorinated Aromatic Hydrocarbons	Ethers
chlorobenzene	2-chloroethylvinylether
Unsaturated Carbonyl Compounds	Miscellaneous
acrolein	carbon disulfide
acrylonitrile	vinyl acetate
Ketones	
acetone	
2-butanone	
2-hexanone	
4-methyl-2-pentanone	

specified for the CLP analysis of volatile organic compounds (5-10 ug/L; U.S. EPA 1987) may not prove adequate in some instances for tracing contaminants. Low level detection limits for volatile organic compounds should be specified when arranging laboratory analyses.

Quality Assurance/Quality Control

Field QA/QC samples that should be collected and analyzed during discharge sampling are summarized below:

- o Field replicates
- o Field rinsate blanks
- o Transfer blanks
- o Trip blanks
- o Standard reference materials.

Field replicate samples should be collected from a completely mixed discharge composite sample. When grab samples are collected for volatile organic compound analysis, the order of collection of the field replicate volatile organic compound samples should be noted on the summary sampling log (Figure 4) and in the field logbook. Analysis of a blind field replicate by an independent laboratory can be used to assess the accuracy of results.

Field rinsate blanks, transfer blanks, and trip blanks should be collected during discharge sampling to assess potential contamination of samples during sample collection, shipping, storage, and analysis. Techniques for collecting field rinsate blanks are discussed in "Sample Collection," Section 4. A transfer blank is a container filled with analyte-free water that accompanies the sample containers and samples through all stages of sampling, shipping, storage, and analysis. The transfer blank is opened in the field concurrently with the collection of a sample, and serves as a check on possible contamination from field sources, shipping, storage,

and analysis. Any preservatives used for samples should also be added to the transfer blank to assess the potential contamination from this source. A trip blank is a sample container with analyte-free water that is not opened in the field. Trip blanks are used when samples for volatile organic compounds are collected as a check on cross-contamination of samples. The frequency of collection of field rinsate blanks, transfer blanks, and trip blanks should be determined by the project manager prior to initiation of the sampling effort. The overall frequency of field QA/QC sample collection is normally 5-20 percent of the total number of field samples.

A SRM with trace metals in water is available from the National Bureau of Standards. A certified SRM with organic constituents in water is presently unavailable. Holding times for organic compounds in water (7 days until extraction) preclude the availability of a prepared SRM. Organic compound SRMs are available in ampules that can be added to a specified volume of water. The minimum frequency of submittal and analysis of SRMs is 1 per 50 samples. The results of SRM analysis should be evaluated according to procedures outlined in the PSEP protocols (Tetra Tech 1986d) to provide an estimate of the accuracy of sample analysis.

Laboratory QA/QC is performed by the analytical laboratory. A discussion of laboratory QA/QC requirements and the recommended minimum frequency of analysis is presented in the PSEP protocols (Tetra Tech 1986d), and the U.S. EPA CLP statement of work (U.S. EPA 1987). Prior to initiation of the sampling efforts, the project manager should specify the frequency of analysis of laboratory QA/QC samples (i.e., method blanks, matrix spikes, method spikes, and analytical replicates). Technical evaluation of the data should be performed by an expert, and results of all QA/QC analyses should be reported with sample data.

Data Interpretation

Contaminant concentrations measured in discharge samples collected during phase three can be compared with available water quality criteria to evaluate potential impacts on the receiving environment. Available freshwater and saltwater criteria (U.S. EPA 1986a) are summarized in Table

14. These values are based on acute and chronic toxicity to aquatic life. Although the ambient water quality criteria are not enforceable standards, they are commonly used general guidelines for interpreting water quality data. A discharge sample that exceeds ambient water quality criteria for a problem chemical may indicate that the storm drain system warrants further consideration to determine if source control actions are needed. However, because large variations may occur in contaminant concentrations and loading from many potential sources, non-exceedance of criteria for a single sampling event does not confirm the lack of a potential source of contaminants. If results of the discharge sampling conflict with available information from site investigations, further sampling may be warranted.

Contaminant loadings for problem chemicals should be calculated for each stormwater discharge based on the contaminant concentration and flow data. These loadings can be used to compare different sources. Relative contaminant contributions from individual sources are often used to rank and select major contaminant sources for remedial action. In addition to ambient water quality criteria and contaminant loading data, it is recommended that contaminant concentrations measured in NPDES-permitted discharges be compared with the permit limitations. This will help determine whether a facility is in compliance with its permit requirements, and whether it could be a potential source of contaminants to a storm drain system.

TABLE 14. SUMMARY OF AVAILABLE WATER QUALITY CRITERIA (MG/L)

	<u>Freshwater Aquatic Life^a</u>		<u>Saltwater Aquatic Life^a</u>	
	Acute Toxicity	Chronic Toxicity	Acute Toxicity	Chronic Toxicity
<u>Metals</u>				
Antimony	(9,000)	(1,600)	b	b
Arsenic	360	190	69	36
Beryllium	(130)	(5.3)	b	b
Cadmium	1.8 ^c	0.66 ^c	43	9.3
Chromium	980 ^c /16 ^d	120 ^c /11 ^d	1,100	50
Copper	9.2 ^c	6.5 ^c	2.9	2.9
Lead	34 ^c	1.3 ^c	140	5.6
Mercury	2.4	0.012	2.1	0.025
Nickel	790 ^c	88 ^c	75	8.3
Selenium	20	5.0	300	71
Silver	1.2 ^c	(0.12)	2.3	b
Thallium	(1,400)	(40)	(2,130)	b
Zinc	65 ^c	59 ^c	95	86
Cyanide	22	5.2	1	1
<u>LPAH</u>				
Naphthalene	(2,300)	(620)	(2,350)	b
Acenaphthylene	b	b	b	b
Acenaphthene	(1,700)	(520)	(970)	(710)
Fluorene	b	b	b	b
Phenanthrene	b	b	b	b
Anthracene	b	b	b	b
HPAH	b	b	b	b
Fluoranthene	(3,980)	b	(40)	(16)
Pyrene	b	b	b	b
Benzo(a)anthracene	b	b	b	b
Chrysene	b	b	b	b
Total benzofluoranthenes	b	b	b	b
Benzo(a)pyrene	b	b	b	b
Indeno(1,2,3-c,d)pyrene	b	b	b	b
Dibenzo(a,h)anthracene	b	b	b	b
Benzo(g,h,i)perylene	b	b	b	b
PAH Total	b	b	(300)	b

TABLE 14. (Continued)

	<u>Freshwater Aquatic Life^a</u>		<u>Saltwater Aquatic Life^a</u>	
	Acute Toxicity	Chronic Toxicity	Acute Toxicity	Chronic Toxicity
<u>Phenols</u>				
Phenol	(10,200)	(2,560)	(5,800)	b
2,4-Dichlorophenol	(2,020)	(365)	b	b
4-Chloro-3-methyl phenol	(30)	b	b	b
2,4-Dimethylphenol	(2,120)	b	b	b
Pentachlorophenol	13 ^e	7.9 ^e	13	(7.9)
2,3,5,6-Tetrachloro- phenol	b	b	b	(440)
2,4,5-Trichlorophenol	b	b	b	b
2,4,6-Trichlorophenol	b	(970)	b	b
Nitrophenols	(230)	(150)	(4,850)	b
2-Chlorophenol	(4,380)	(2,000)	b	b
4-Chlorophenol	b	b	(29,700)	b
Phthalate esters	(940)	(3)	(2,944)	(3.4)
<u>Pesticides</u>				
Aldrin	3.0	b	1.3	b
DDT	1.1	0.001	0.13	0.001
DDE	(1,050)	b	(14)	b
TDE	(0.06)	b	(3.6)	b
Demeton	b	0.1	b	0.1
Dieldrin	2.5	0.0019	0.71	0.0019
Endosulfan	0.22	0.056	0.034	0.0087
Endrin	0.18	0.0023	0.037	0.0023
Guthion	b	0.01	b	0.01
Heptachlor	0.52	0.0038	0.053	0.0036
Hexachlorocyclohexane (Lindane)	2.0	0.06	0.16	b
Malathion	b	0.1	b	0.1
Methoxychlor	b	0.03	b	0.03
Mirex	0.001	b	0.001	b
Parathion	0.065	0.013	b	b
Toxaphene	0.73	0.002	0.21	0.0002
<u>PCBs</u>	2.0	0.014	10	0.03

TABLE 14. (Continued)

	<u>Freshwater Aquatic Life^a</u>		<u>Saltwater Aquatic Life^a</u>	
	Acute Toxicity	Chronic Toxicity	Acute Toxicity	Chronic Toxicity
<u>Volatiles</u>				
Acrylonitrile	(7,550)	(2,600)	b	b
Acrolein	(68)	(21)	(55)	b
Benzene	(5,300)	b	(5,100)	(700)
Trichloromethane (chloroform)	(28,900)	(1,240)	b	b
Tetrachloromethane (carbon tetrachloride)	(35,200)	b	(50,000)	b
1,2-dichloroethane	(118,000)	(20,000)	(113,000)	b
Dichloroethylenes	(11,600)	b	(224,000)	b
Dichloropropanes	(23,000)	(5,700)	(10,300)	(3,040)
Dichloropropenes	(6,060)	(244)	(790)	b
Ethyl benzene	(32,000)	b	(430)	b
Halomethanes	(11,000)	b	(12,000)	(6,400)
Pentachlorinated ethanes	(7,240)	(1,100)	(390)	(281)
Tetrachloroethanes	(9,320)	b	b	b
1,1,2,2-Tetrachloroethane	b	(2,400)	(9,020)	b
Tetrachloroethylene	(5,280)	(840)	(10,200)	(450)
Toluene	(17,500)	b	(6,300)	(5,000)
Trichloroethanes	(18,000)	b	b	b
1,1,1-Trichloroethane	b	b	(31,200)	b
1,1,2-Trichloroethane	b	(9,400)	b	b
Trichloroethylene	(45,000)	(21,900)	(2,000)	b
<u>Misc. Oxygenated Compounds</u>				
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	(0.01)	(0.00001)	b	b
Isophorone	(117,000)	b	(12,900)	b
<u>Organonitrogen Compounds</u>				
Benzidine	(2,500)	b	b	b
Dinitrotoluene	(330)	(330)	(590)	(370)
Nitrobenzene	(27,000)	b	(6,680)	b
Nitrosamines	(5,850)	b	(3,300,000)	b
1,2-Diphenylhydrazine	(270)	b	b	b

TABLE 14. (Continued)

	<u>Freshwater Aquatic Life^a</u>		<u>Saltwater Aquatic Life^a</u>	
	Acute Toxicity	Chronic Toxicity	Acute Toxicity	Chronic Toxicity
<u>Chlorinated Aliphatic Hydrocarbons</u>				
Hexachloroethane	(980)	(540)	(940)	b
Hexachlorobutadiene	(90)	(9.3)	(32)	b
Hexachlorocyclopenta- diene	(7)	(5.2)	(7)	b
<u>Ethers</u>				
Chloroalkyl ethers	(238,000)	b	b	b
Haloethers	(360)	(122)	b	b
<u>Chlorinated Aromatic Hydrocarbons</u>				
Chlorinated benzenes	(250)	(50)	(160)	(129)
Chlorinated naphtha- lenes	(1,600)	b	(7.5)	b
Dichlorobenzenes	(1,120)	(763)	(1970)	b

^a () = Where insufficient data are available to derive criteria, concentrations representative of apparent threshold levels for acute and/or chronic toxic effects are described in the U.S. EPA criteria documents. These concentrations, along with associated narrative descriptions, are intended to convey some information about the degree of toxicity of a pollutant in the absence of established criteria. In some instances, the documents provide separate toxicity concentrations for algae. These have not been included in this table.

^b No criteria or toxicity thresholds are presented in the water quality criteria documents.

^c Freshwater quality criteria for some chemicals are a function of hardness. The relationship is not linear and the equations specific to each chemical are found in the criteria documents. For this table, a criteria concentration based on a hardness value of 50 mg/L calcium carbonate is provided. Exact criteria values must be calculated from the equations.

^d The first value is for trivalent chromium (III) and the second value is for hexavalent chromium (VI).

^e Freshwater quality criteria for some chemicals are a function of pH. The relationship is not linear and the equations specific to each chemical are found in the criteria documents. For this table, a criteria concentration based on a pH value of 6.5 is provided. Exact criteria values must be calculated from the equations.

Reference: U.S. EPA (1986a).

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APPENDIX 1
STORM DRAIN MONITORING
APPROACH COSTS

APPENDIX 1: STORM DRAIN MONITORING APPROACH COSTS

ANALYTICAL COSTS

A summary of the costs for analytical procedures recommended in the storm drain monitoring approach is presented in Table 1-1. The costs presented for each procedure can vary depending on the following factors:

- o Number of samples submitted for analysis
- o Sample characteristics
- o Level of services provided
- o Sample matrix (soil/sediment vs. water)
- o Turnaround time
- o Identification of additional organic compounds.

Most laboratories will negotiate a price break for samples submitted in groups, reducing the per sample price as the number of samples submitted rises. Price reductions of up to 20 percent can often be negotiated with a laboratory when submitting large groups of samples (i.e., 20 or more).

Sample characteristics, such as high concentrations of target analytes or interferences, may require that sample preparation and analysis procedures be modified. A sample that contains oil or other interferences often requires some form of sample cleanup (e.g., gel permeation chromatography) before analysis. Samples that contain high concentrations (i.e., ≥ 1 percent) of target analytes often require cleanup and must often undergo one or more dilutions before satisfactory results and detection limits can be obtained. The analytical laboratories will perform the necessary dilutions, however an additional cost is often incurred for sample cleanup.

TABLE 1-1. SUMMARY OF ANALYTICAL COSTS

Variable	Approximate Cost Per Sample (\$)	Method ^a
Target Compound List		
Volatile organic compounds	Water: 200-250 Sediment: 250-300	Purge & trap GC/MS ^b
Extractable ABN ^c organic compounds	Water: 375-750 Sediment: 475-800	GC/MS
Pesticides/PCBs	Water: 135-160 Sediment: 160-200	GC/ECD
Priority pollutant metals	Water: 150-210 Sediment: 200-275	AAS, CVAA, ICP, GFAA
Total solids	10-20 ^b	Gravimetric
Total volatile solids	25-40	Gravimetric
Total organic carbon	Water: 30-50 Sediment: 45-65	Elemental analysis
Oil and grease	Water: 40-70 Sediment: 45-65	Gravimetric, spectrophotometric
Particle size	45-125	Sieve and pipet

^a GC/MS = Gas chromatography/mass spectroscopy.
 GC/ECD = Gas chromatography/electron capture detection.
 AAS = Atomic absorption spectroscopy.
 CVAA = Cold vapor atomic absorption.
 ICP = Inductively coupled plasma atomic emission spectroscopy.
 GFAA = Graphite furnace atomic absorption.

^b Total solids measurements are normally included with other analyses at no additional cost.

^c ABN = Acid and base/neutral.

References: Tetra Tech (1986a), U.S. EPA (1983b, 1984, 1987).

Tabulated analytical results are often the only data a laboratory will provide without payment of an additional fee. Quality assurance/quality control (QA/QC) information is necessary to perform data review and validation. Obtaining QA/QC information necessary for a thorough data validation review (see U.S. EPA 1987) can raise the cost of sample analysis by 60 percent, depending on laboratory and procedure.

Analysis of sediment samples costs more than the same analysis of water samples. Increased costs of sediment sample analysis relative to water sample analysis are due to sample characteristics. Matrix interferences often necessitate the use of sample cleanup procedures to achieve the required detection limits for sediment samples, while water samples tend to have fewer matrix effects.

Sample turnaround time is usually from 14 to 40 days. When a shorter turnaround time is requested, an additional fee is often charged.

Identification of organic compounds other than priority pollutants and Target Compound List (TCL) compounds may be requested for volatile and extractable organic compounds. A library search can be performed that compares mass spectra of standards with mass spectra generated during sample analysis. Costs for the library search and reporting of additional organic compounds can increase analytical costs up to 75 dollars per sample, depending on the method and number of additional compounds requested.

The analysis requested from the laboratory may be for a particular compound, class of compounds (e.g. pesticides), or a full scan of priority pollutants. Conventional variables (i.e., oil and grease, total solids, particle size, total organic carbon) should be analyzed to allow for comparison with other data. In some cases, the initial full scan of priority pollutants may detect only certain compounds or classes of compounds in a discharge. Additional analyses of samples from a drainage basin, where only a limited suite of toxic pollutants have been detected, can be tailored to measure only the variables of interest.

FIELD SAMPLING COSTS

Field costs are divided into labor and equipment charges. Because of variability in hourly rates for field personnel, labor cost estimates are presented as total person hour requirements rather than as a dollar value. Purchase price and/or rental fees are presented for sampling equipment, protective clothing, protective gear, and meters that are unique to storm drain monitoring. Costs for sampling materials such as plastic bags, tape, and ice have not been provided because these items are considered standard sampling materials and are not necessarily unique to the sampling effort described in this report.

Field costs will vary depending on the type of samples collected (i.e., sediment or storm water). In general, it will cost more per station to collect water samples due to sample compositing. Estimated costs for conducting sediment versus storm water sampling programs are discussed below.

Storm Drain Sediment Sampling

Approximate personnel costs for a typical storm drain sediment sampling program are summarized in Table 1-2. Labor costs have been determined based on a four person field crew consisting of the sampler, a safety/rescue person, a field note taker, and a traffic control person (needed for manholes located in busy intersections). Based on experience from Puget Sound Estuary Program (PSEP) sampling efforts, it is estimated that approximately 1 h will be spent at each station to complete sample collection, equipment decontamination, documentation, and sample packaging and shipping procedures. A travel time estimate of about 15 min between each station has been included in costs. Because it is not cost effective to mobilize an entire crew for a single sampling station, the costs have been estimated based on a total of 20 sampling stations. In addition, it has been assumed that, due to tidal interferences, sampling will only be possible for a 4-h period each day (i.e., 5-day sampling event). Based on these assumptions, approximately 150 person hours will be required to complete a sediment sampling program for 20 sampling stations.

TABLE 1-2. APPROXIMATE PERSONNEL COSTS FOR FIELD SAMPLING - SEDIMENT

	Estimated Time Requirements/ Sampling Event/Station	Total Person Hour Requirements ^a
Equipment Mobilization	10 h	10
Sample Collection (1 h/station) ^b		
Sampler (1) ^c		
Safety and rescue (1)		
Field note taker (1)		
Traffic controller (1) (if needed)		
Subtotal	4 h/station	80
Travel Time ^d (4)	2 h/day	40
Documentation (1)	2 h/day	10
Equipment Demobilization	10 h	10
TOTAL		150

^a Based on the following assumptions: 20 sampling stations, 4 h/day sampling period due to tidal interferences, 5-day sampling event.

^b Time requirements per station = 1 h.

^c Indicates number of people.

^d Includes travel time between sampling stations and travel to and from site.

Approximate rental or purchase costs for the major field sampling equipment are summarized in Table 1-3. Protective gear and clothing are the most expensive items. Protective clothing is expendable, and therefore, will have to be purchased for each sampling effort. However, protective gear is considered nonexpendable and could be rented to reduce costs of the sampling effort.

Discharge Sampling

Approximate personnel costs for a typical discharge monitoring program are summarized in Table 1-4. Labor costs have been determined based on a two person field crew. Based on the sample compositing requirements of 12 h intervals, an estimated 13 h will be required at each station to complete sample collection, equipment decontamination, documentation, and sample packaging and shipping procedures. For comparison with personnel requirements for the sediment sampling program, costs have been estimated based on a total of 20 sampling stations.

Approximate rental or purchase costs for the major field sampling equipment are summarized in Table 1-5. The automatic sampler and continuous flow centrifuge are the most expensive items. Therefore, these items would probably be rented, particularly for small sampling projects.

REMOVAL COSTS

The cost for removing contaminated sediment deposits from storm drains will be determined by the following major factors:

- o Diameter of the storm drain
- o Length of the drain lines that need to be cleaned
- o Amount of sediment accumulation in the storm drain.

Other factors will also indirectly affect the cost of removal operations as follows:

TABLE 1-3. APPROXIMATE COSTS FOR SAMPLING EQUIPMENT - SEDIMENT^a

	Approximate Purchase Cost (\$)	Approximate Weekly Rental Cost (\$)
Sampling Equipment		
1 Stainless steel bucket	40	NA ^b
2 Stainless steel scoops	80	NA
1 Large stainless steel spoon	5	NA
Small stainless steel spoons	5	NA
1 Telescoping extension plate	50	NA
Coolers	60 each	NA
Protective Clothing		
Chemical resistant gloves		
Inner gloves	2.80/pair	NA
Outer gloves	3.50/pair	NA
Chemical resistant coveralls	3.50/pair	NA
Hip waders, 2 pair	50.00/pair	NA
Protective Gear		
2 Respirators	240	32
Filter cartridges	3.33 each	^c
1 Safety harness/rope	150	12
2 SCBA	2,600	210
Meters		
O ₂ /combustible gas	1,500	120
PID meter	6,000	300
Draeger bellows	200	20
H ₂ S tubes	3.50/tube	NA

^a Costs may vary depending on supplier.

^b NA = Not applicable.

^c Cost included in respirator rental fee.

TABLE 1-4. APPROXIMATE PERSONNEL COSTS FOR FIELD SAMPLING - DISCHARGE

	Estimated Time Requirements/ Sampling Event/Station	Total Person Hour Requirements ^a
Equipment Mobilization	10 h	10
Sample Collection (13 h/station) ^b		
Samplers (2) ^c	26 h/station	520
Documentation	1 h/day	20
Equipment Demobilization	10 h	10
TOTAL		560

^a Based on the following assumptions: 20 sampling stations, 1 station/day.

^b Time requirements per station = 13 h. This includes equipment set up and decontamination.

^c Indicates number of people.

TABLE 1-5. APPROXIMATE COSTS FOR SAMPLING EQUIPMENT - DISCHARGE^a

	Approximate Purchase Cost (\$)	Approximate Weekly Rental Cost (\$)
Sampling Equipment		
1 Telescoping extension rod	50	NA ^b
Coolers	60 each	NA
Automatic sampler/flow meter	5,000	800
pH meter	200	25
Flow meter ^b	2,000	300
Continuous flow centrifuge	27,000	2,500
Pump/tubing	500	75
Generator	300	45
Filtration equipment	400	60
Protective Clothing		
Chemical resistant gloves		
Inner gloves	2.80/pair	NA
Outer gloves	3.50/pair	NA
Chemical resistant coveralls	3.50/pair	NA
Hip waders, 2 pair	50.00/pair	NA
Protective Gear		
2 Respirators	240	32
Filter cartridges	3.33 each	c
1 Safety harness/rope	150	12
2 SCBA	2,600	210
Meters		
O ₂ /combustible gas	1,500	120
PID meter	6,000	300
Draeger bellows	200	20
H ₂ S tubes	3.50/tube	NA

^a Costs may vary depending on supplier.

^b NA = Not applicable.

^c Cost included in respirator rental fee.

- o Tidal interferences
- o Season that cleanup activities are conducted
- o Medical monitoring requirements for personnel.

In tidally influenced drains, cleanup will only be feasible during low tides. Tidal interferences will limit the number of hours during the day when cleanup can occur. Tidal interferences may force cleanup crews to work long or irregular shifts resulting in potential overtime charges. The season the cleanup is conducted will affect how long cleanup crews can work. During hot summer months, crews will have to take frequent breaks to avoid heat stress. Heat stress is a particular problem due to amount of safety equipment and clothing that must be worn in the potentially hazardous environment of the storm drain. A medical monitoring program consisting of a baseline medical examination, and a follow-up examination at the completion of the project is recommended to ensure the health and safety of cleanup personnel.

Another cost to be considered when budgeting a sediment removal operation is disposal of the contaminated sediments after removal from the storm drain. Although disposal costs are not considered during removal operations, they may significantly affect the overall costs of cleanup. Sediments that classify as a hazardous substance will have to be disposed of at a licensed facility.

Because there are many variables involved in determining costs, it will not be possible to develop accurate cost prediction procedures applicable to all storm drains cleanup operations. However, cost figures are available for several storm drain cleanup operations recently conducted in the Puget Sound area. These costs, and a general description of the cleanup operations, are presented below to provide a reference for overall costs of cleanup activities.

Lander Street CSO/SD

Sediments in the Lander Street drain [combined sewer overflow/storm drain (CSO/SD) #105] contained lead at concentrations as high as 35 percent. The lead contamination was traced to atmospheric deposition and surface runoff from the area surrounding a secondary lead smelter (see Appendix 2). In October 1984, the City of Seattle removed approximately 20 yd³ of contaminated sediments from 1,600 ft of 36-in and 42-in lines in the SW Lander Street drain system. Sediments were dislodged from the pipes using a high pressure jet water wash and were collected at the downstream end of the system. Weirs were installed at two locations in the drain using sandbags to retain wash water. Water and sediments were removed at each of the weirs by Vactor equipment. All materials removed from the drain were transported to the smelter to recover lead prior to sediment disposal. The cost of removing contaminated sediments from Lander Street CSO/SD #105 are as follows (Clendaniel, B., 25 January 1985, personal communication): \$8,090.27 for labor and \$5,661.00 for equipment. The total cost of this cleanup project was \$13,751.27.

SW Florida Street CSO/SD

Municipality of Metropolitan Seattle (Metro) sampled the SW Florida Street (CSO/SD #098) drain system in 1984 and reported elevated concentrations of PCBs, pentachlorophenol, arsenic, copper, and PAH. Approximately 30 yd³ of contaminated sediments were removed from the SW Florida Street drain in 1985 by the City of Seattle. Sediments were removed by bucket and dragline in a 400 ft section of 36-in line that had the largest accumulations of sediment. After dragline operations were completed, the line was flushed with a high pressure jet wash. Sandbag weirs were constructed in the downstream end of the line to retain all wash water. Debris was collected at the downstream end using Vactor equipment. The remaining 1,449 ft of 36-in to 48-in line was cleaned with a high pressure jet wash and the debris was removed using Vactor equipment. In addition, all catch basins connected to the contaminated section of the storm drain were cleaned using Vactor equipment. All material removed by Vactor equipment was placed in three lined settling ponds. Decant liquids from the ponds were discharged into

the City of Seattle sanitary sewer system. Solids were removed from the ponds and temporarily stored on the nearby Wyckoff property (Standifer, J., 17 May 1985, personal communication; Schwartz, L., 1 August 1985, personal communication; Clendaniel, B., 1 July 1985, personal communication).

Approximately 30 yd³ of contaminated sediments were removed from the SW Florida Street drain, and total cost of the removal operations was \$38,656.09. These costs include all charges to labor (approximately 60 percent) and equipment (approximately 40 percent).

Georgetown Flume

In 1984, Metro discovered that sediments in the Georgetown Flume, which discharges into the head of Slip 4, were contaminated with PCBs (see Appendix 2). In November 1985, a contractor hired by Seattle City Light removed the contaminated sediments from the flume. All visible sediments were removed, treated at a treatment/storage/disposal facility, and shipped to a licensed landfill for disposal. Removal operations were similar to those described for the SW Florida Street drain. In addition, debris was removed from the downstream end of the flume and placed in storage tanks. Decant water in the storage tanks was tested periodically. When the PCB concentration decreased to below 0.001 mg/L, the decant water was discharged to the sanitary sewer system.

Removal costs (includes labor and equipment costs) for each section of the storm drain was as follows: \$10,500.00 for 547 ft of 6-in to 8-in pipe; \$12,500.00 for 240 ft of 15-in pipe; and \$40,200.00 for 2,000 ft of open flume. An additional \$9,600.00 was spent to collect 50,500 gal of storm water from a large rainstorm that occurred during cleanup operations. The total cost of this project was \$72,800.00.

APPENDIX 2
SUMMARY OF PREVIOUS
STORM DRAIN INVESTIGATIONS

APPENDIX 2: SUMMARY OF PREVIOUS STORM DRAIN INVESTIGATIONS

Municipality of Metropolitan Seattle (Metro) and the City of Seattle have successfully used the storm drain sediment sampling approach to investigate contamination problems in several storm drain systems in the Seattle area.

Metro developed the Duwamish Clean Water Plan in 1983 using funds from a Clean Water Act 208 grant. The plan was designed to identify and control pollution problems in the Duwamish River and was adopted by the Metro Council in 1984. Metro received a 205(j) grant to implement part of the plan that focused on industrial sites in the lower Duwamish River and sampling of the major storm drain systems discharging into the river. As part of the program, sediment samples were collected at key junctions in 12 storm drain systems along the Duwamish River. The results were compared with offshore sediment chemistry data and available data for urban street dust in the Seattle area (Galvin and Moore 1982). Significant problem areas were identified in 4 of the 12 combined sewer outfall/storm drains (CSO/SD) (Lander Street, Florida Street, Slip 4, and Fox Street).

LANDER STREET CSO/SD

The Lander Street drain (CSO/SD #105) serves a 54 ac area on the interior of Harbor Island between 16th Avenue SW and 13th Avenue SW. In March 1984, Metro collected sediment samples from the city CSO/SD #105 and from a 21-in private drain located on the north side of Lander Street. Samples were analyzed for metals. Results, summarized in Figure 2-1, showed that the city drain was contaminated with lead at concentrations as high as 370,000 mg/kg (37 percent). These values are 800 times greater than the levels measured in typical urban street dust (460 mg/kg; Galvin and Moore 1982). Lead concentrations in sediments offshore of the Lander Street drains were measured at 18,000 mg/kg (1.8 percent).

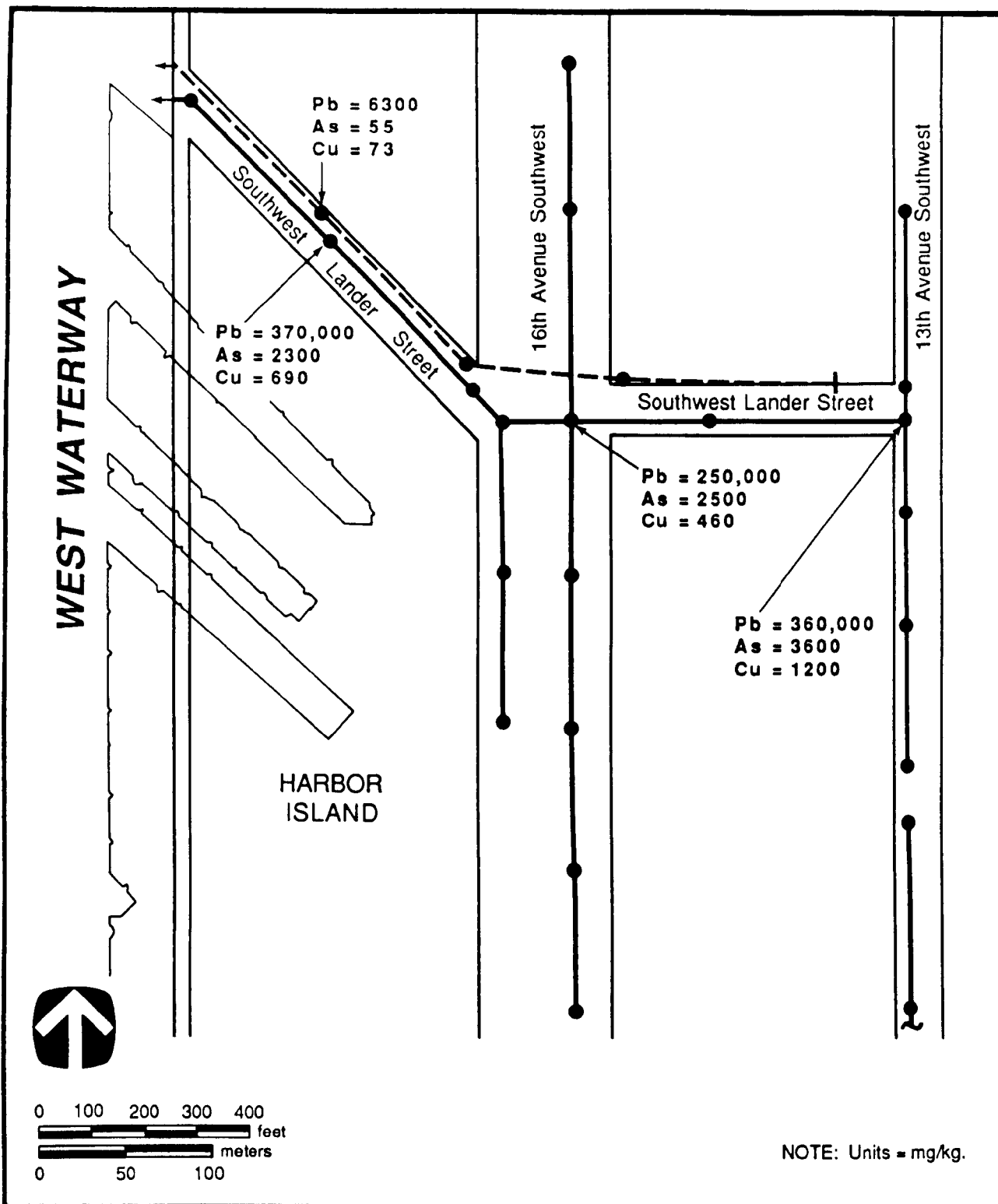


Figure 2-1. Metals concentration in sediments collected from the Lander Street drains.

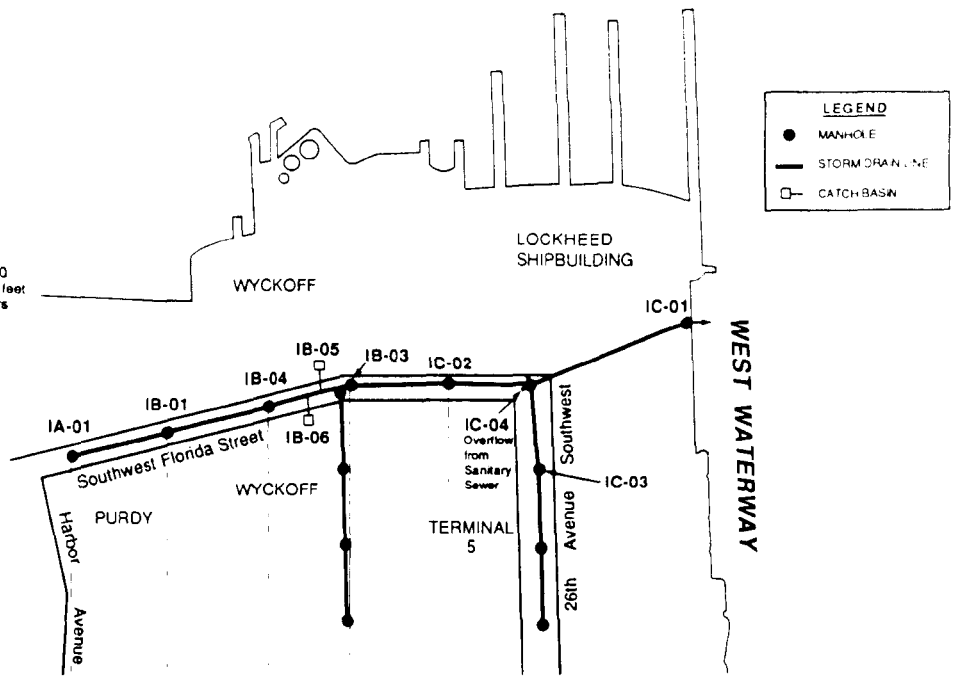
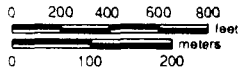
The source of lead was traced to stack emissions from a former lead smelter (Metro 1987) located in the city CSO/SD #105 drainage basin. The smelter operated lead smelting, refining, and battery recycling facilities from 1937 to 1984. Lead concentrations as high as 180,000 mg/kg (18.0 percent) were reported in soil samples collected near the smelter property by the Puget Sound Air Pollution Control Agency in 1979 (Metro 1987). Consequently, it was recommended that parking lots near the smelter be paved to reduce contamination of surface water runoff. Paving was completed in 1983.

In 1984, the City of Seattle removed approximately 20 yd³ of contaminated sediments from the Lander Street drain. The sediments were shipped to a lead smelter for recovery (Metro 1987). When U.S. Environmental Protection Agency (EPA) resampled the Lander Street drain in 1985 as part of the Elliott Bay Toxics Action Program, they found that new sediment deposits in the drain were again contaminated with lead up to a concentration of 52,800 mg/kg. Metro also reported elevated lead concentrations (150,000 mg/kg) in sediments collected from the Lander Street drain during 1986 (Sample, T., 23 October 1987, personal communication). These data indicate that residual contamination from the lead smelter is an ongoing source of lead in the Lander Street drain.

SW FLORIDA STREET CSO/SD

The SW Florida Street drain (CSO/SD #098) serves an approximately 25 ac area between Harbor Avenue SW and 26th Avenue SW, and discharges into the West Waterway. Metro collected sediment samples from 10 stations in the drainage system, including 6 stations on the main trunk line (SW Florida Street line), 1 station on the 26th Avenue SW line, 1 station at the sewer overflow point, and 2 stations in catch basins connected to the SW Florida Street trunk line. Major contaminants found in the drainage system are summarized in Figure 2-2. With the exception of PCBs, all contaminants found in the Florida Street drain system are used in the wood treatment process. Arsenic, pentachlorophenol, and high molecular weight polycyclic aromatic hydrocarbons (HPAH), a component of creosote, are found in wood preservatives. Profiles of arsenic, pentachlorophenol, and HPAH concentra-

PLAN VIEW



CONTAMINANT CONCENTRATION PROFILES

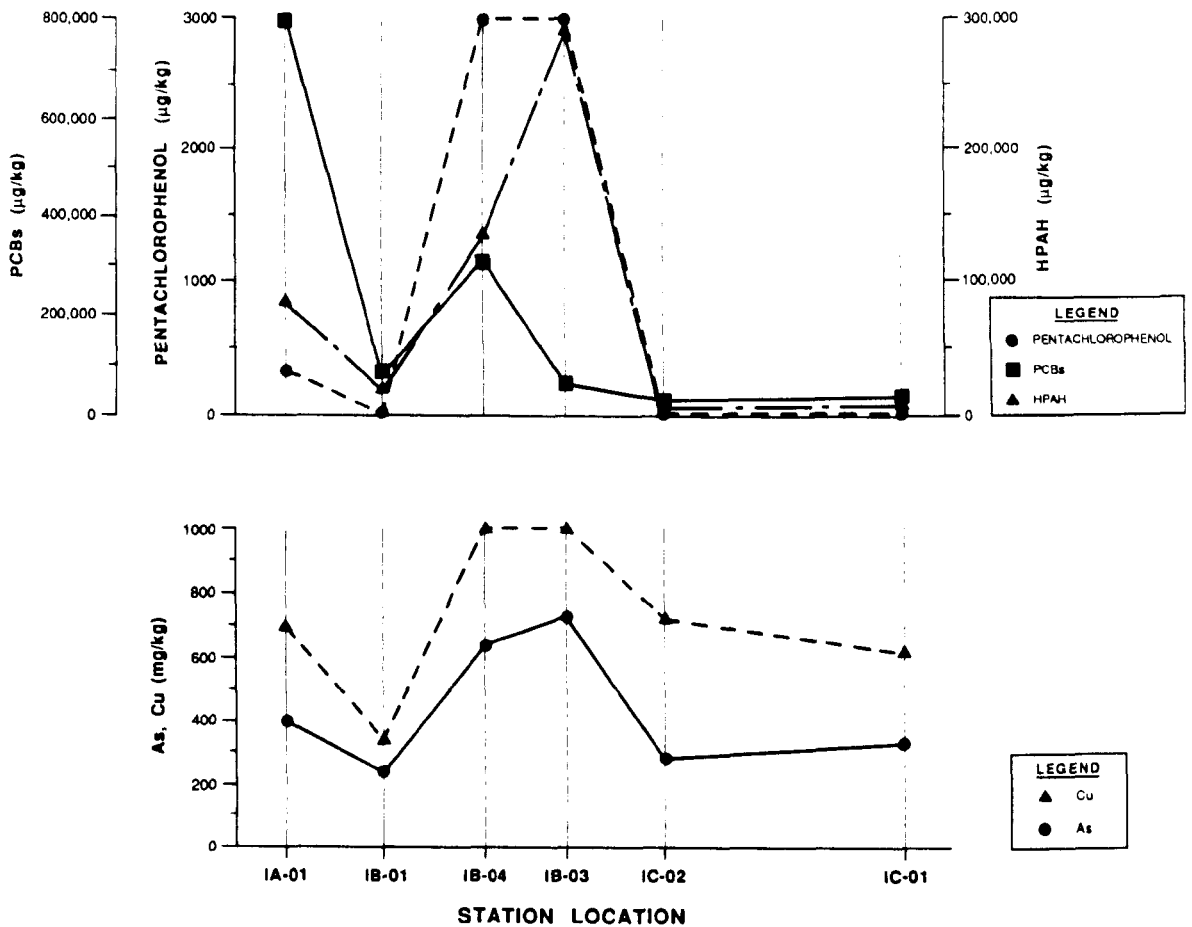


Figure 2-2. In-line sediment data for stations on SW Florida Street CSO/SD.

tions along the SW Florida Street trunk line show a distinct peak approximately 1,700 ft upstream of the outfall adjacent to the Wyckoff wood treating facility. These results match information obtained by U.S. EPA during their 1983 investigation of the Wyckoff facility. U.S. EPA determined that Wyckoff was illegally discharging hazardous wastes containing arsenic, creosote, and pentachlorophenol into a catch basin connected to the SW Florida Street drain. As a result, the company was convicted on criminal charges, fined, and placed on probation.

The PCB contamination in the SW Florida Street drain exhibited a distinctly different pattern than the arsenic, HPAH, and pentachlorophenol contamination. PCB concentrations in storm drain sediments were highest (810,000 ug/kg) at the station upstream of the Wyckoff facility (Figure 2-2). Metro investigated properties in the vicinity of this station, and found that the Purdy scrap yard had recycled old transformers containing PCBs. However, there is some discrepancy in data from soil sampling conducted at the Purdy property and the exact location of the PCB contaminated soils has not been determined (Cargill, D., 25 February 1988, personal communication).

The City of Seattle removed about 30 yd³ of contaminated sediments from the SW Florida Street trunk line in 1984. Sediments were shipped to a licensed hazardous waste facility in Oregon for disposal. Even so, subsequent sampling of a catch basin on the Wyckoff property has shown continued contamination of surface water runoff from contaminated soil at the Wyckoff facility (Hadley 1987).

SLIP 4 DRAINS

Elevated concentrations of PCBs have been measured in the surficial sediments in Slip 4 (Figure 2-3). Samples collected by U.S. EPA from the head of Slip 4 in 1982 and 1983 exhibited PCB concentrations between 1,600 and 5,600 ug/kg. Five drains discharge into Slip 4 (I5 SD, Slip 4 CSO/SD #117, Slip 4 SD, Georgetown Flume, and East Marginal Pump Station CSO W043). Descriptions of each drain are presented in Table 2-1. In 1984, Metro collected sediment samples from the four storm drains discharging into Slip 4 to determine the source of the PCB contamination in offshore sediments.

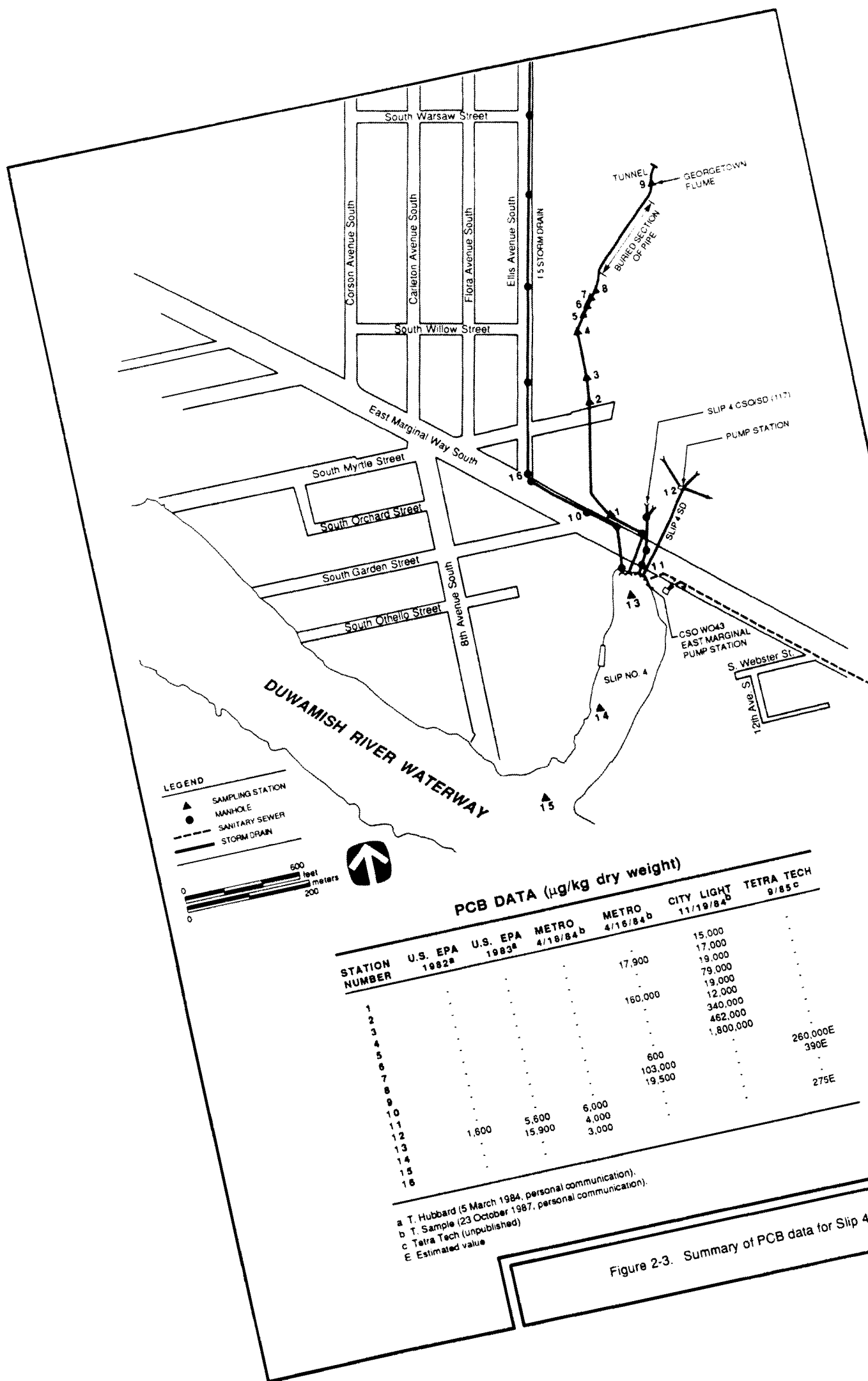


Figure 2-3. Summary of PCB data for Slip 4 drains.

TABLE 2-1. DESCRIPTION OF DRAINS
DISCHARGING INTO SLIP 4

Name	Outfall Diameter (in)	Drainage Basin Area (ac)	Description of Service Area
I-5 SD ^a	66	30	Drains approximately 1.5 mi of I-5 between S. Dawson and S. Myrtle Streets and part of Georgetown area.
Georgetown Flume	60	--	Open wood flume originally installed to discharge cooling water from Seattle City Light's Georgetown Steam Plant. Exact service area unknown. Numerous other side connections have been identified. All side connections have been plugged by Seattle City Light.
Slip 4 CSO ^b /SD #117	24	150 (SD) 74.6 (CSO)	Drain for the north end of King County Airport.
Slip 4 SD	60	170	Serves portions of King County Airport.
East Marginal Pump Station CSO W043	36	318	Emergency sewer overflow for Metro pump station.

^a SD = Storm drain.

^b CSO = Combined sewer overflow.

The results indicated that three of the four storm drains (i.e., Georgetown Flume, Slip 4 CSO/SD #117, and Slip 4 SD) were contaminated with PCBs (Figure 2-3). PCB levels were measured at 17,900-160,000 ug/kg in the Georgetown Flume, 103,000 ug/kg in Slip 4 CSO/SD, and 19,500 ug/kg in Slip 4 SD. These concentrations exceed the average level reported for urban street dust from eight cities in the U.S. (770 ug/kg; Galvin and Moore 1982) by 2-3 orders of magnitude. PCB concentrations in the sediments collected from the I5 SD were 2-3 orders of magnitude lower than the concentrations measured for the other three storm drains, and did not exceed levels reported for urban street dust. Therefore, I5 SD has not been considered a source of PCBs to Slip 4.

Seattle City Light (City Light) collected sediment samples in 1984 from various locations along the Georgetown Flume to trace contamination (Figure 2-3). The highest PCB concentration (1,800,000 ug/kg) was found in sediments collected from the downstream side of the tunnel in the flume (Figure 2-3). PCB contamination was subsequently traced to a City Light property at the head of the flume where soil contained PCBs in concentrations as high as 91,000,000 ug/kg. These soils were excavated to depths of 4-6 ft to obtain cleanup levels of 150-200 ug/kg (Geissinger, L., 9 December 1987, personal communication) and contaminated sediment deposits were removed from the flume. City Light has plugged all side connections to the flume to prevent future contamination, and sediment traps were installed in the flume to collect sediments prior to discharge to Slip 4. City Light plans to fill the flume to prevent it from being used in the future (Geissinger, L., 9 December 1987, personal communication).

The source of PCBs in Slip 4 CSO/SD #117 has not been identified to date. During cleanup activities in Georgetown Flume, City Light collected sediment samples from Slip 4 CSO/SD and found PCB concentrations as high as 10,000 ug/kg (Smukowski, D., 14 December 1987, personal communication). Boeing Company worked with Metro to trace contamination in this storm drain line that crosses their property. However, they were not able to locate a PCB source in the area. In 1985, Boeing removed contaminated sediments from the Slip 4 CSO/SD. This drain has since been rerouted to the pump station on the Slip 4 SD system and discharges to Slip 4 via this 60-in line (Smukowski, D., 14 December 1987, personal communication).

PCB contamination has not been fully investigated in the Slip 4 SD system to date. Consequently, it is not known whether there is an ongoing source of PCBs in this drainage basin.

FOX STREET CSO/SD

The Fox Street drain serves an area of about 30 ac located on the west side of East Marginal Way just south of Slip 3 (Figure 2-4). Metro collected sediment samples from the storm drain and from the Duwamish River upstream and just offshore of the storm drain, and soil samples in the drainage basin. Sampling station locations are shown in Figure 2-4.

The results of the sampling and analyses for metals, summarized in Table 2-2, indicate that the drain in the lower part of the drainage basin contained elevated concentrations of metals. Metals concentrations in storm drain sediments from Manhole 1 (Figure 2-4) located at the junction of the north and south branch lines, are as much as 150 times greater than the average concentrations reported in urban street dust (Galvin and Moore 1982). However, metals concentrations in the sediments from Manhole 2 (on the south branch line; Figure 2-4) are only 1.2-6.2 times greater than the average street dust levels (Galvin and Moore 1982). This suggests that metals contamination in the Fox Street CSO/SD probably originates in the north branch line service area (i.e., east of South Fox Avenue).

Elevated metals concentrations measured in sediment samples collected from catch basins on Marine Power and Equipment property indicate that stormwater runoff from the property may also be a source of metals to the Fox Avenue storm drain. Marine Power and Equipment is a shipbuilding and repair facility, and occupies the lower portion of the drainage basin immediately downstream of the junction of the north and south branch lines. Metal concentrations in the catch basin sediment samples from the property are as high or higher than concentrations found in the most contaminated storm drain sediments (i.e., sediments from Manhole 1). During a 1984 site visit, Metro inspectors reported that sandblast grit was present throughout most of the Marine Power and Equipment property (Hubbard, T., 15 March 1988,

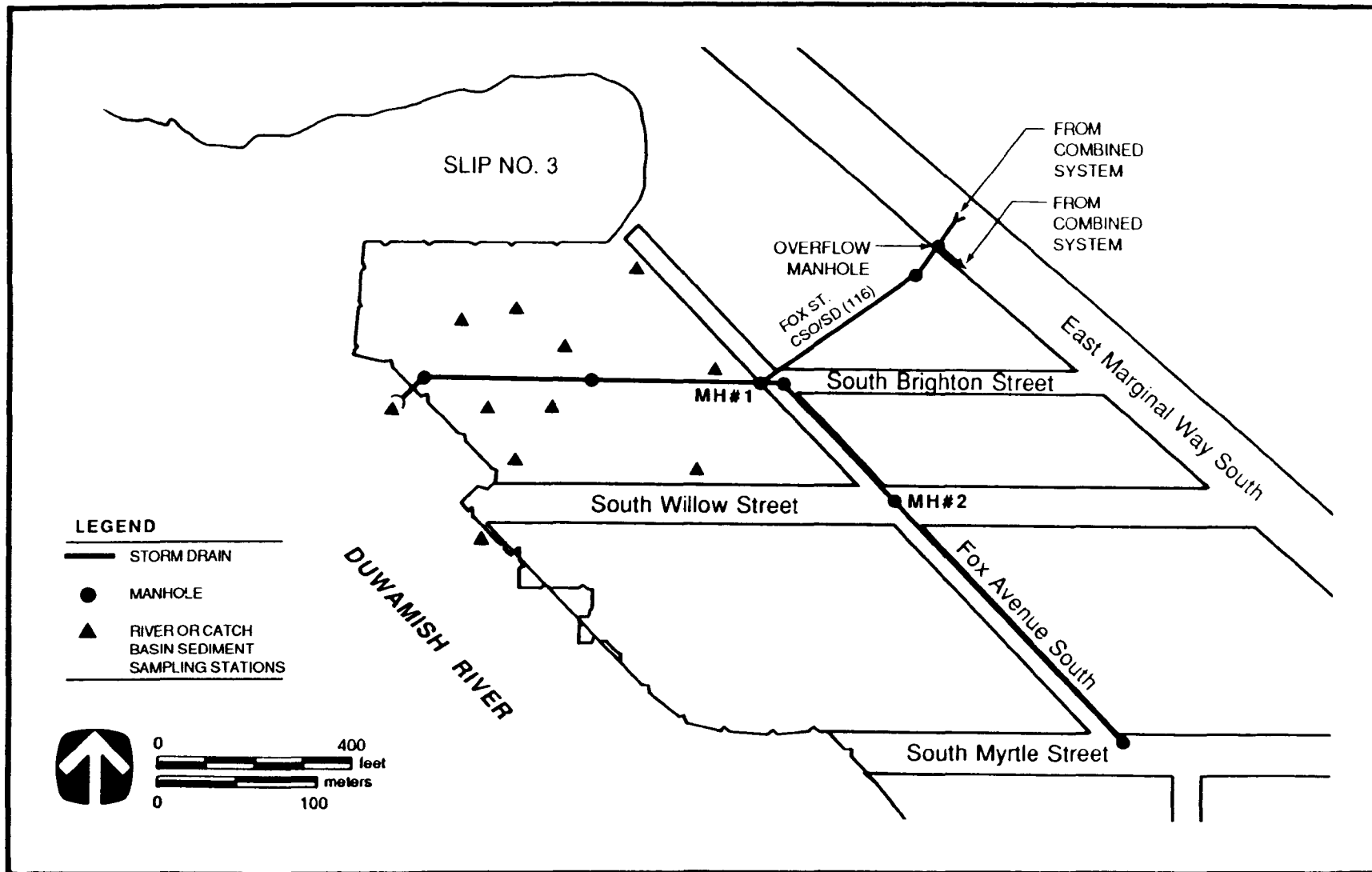


Figure 2-4. Metro sampling stations on Fox Street CSO/SD (#116).

TABLE 2-2. SUMMARY OF METALS CONCENTRATIONS IN SEDIMENT
SAMPLES FROM FOX STREET CSO/SD #116 AND SURROUNDING AREA (mg/kg)^a

	Date Sampled	As	Cd	Cu	Pb	Zn
<u>Fox Street CSO/SD #116</u> MH ^b #1	4/5/84	3,800	4.4	1,200	1,400	5,600
	2/25/85	1,200	6.7	900	900	2,300
	3/27/86	1,200	5.4	710	730	2,300
	MH#2 3/27/86	110	6.2	380	620	850
<u>Duwamish River Sediments</u>						
Upstream of Drain	4/18/84	21	<0.3	60	51	160
Offshore of Drain	4/18/84	210	0.5	290	150	1,000
<u>Sediment Samples from Catch Basins^c</u>	2/25/85	1,000-	9.5-	2,300-	950-	6,200-
		3,900 ^d	19	7,600	1,900	15,000
		(2,200) ^e	(14)	(5,000)	(1,400)	(10,000)
<u>Mean Street Dust Levels^f</u>	--	25	1.0	93	520	310

^a Stations shown on Figure 2-4.

^b MH = Manhole.

^c Catch basins connected to the Fox Street drain downstream of Manhole #1.

^d Range in concentration for nine stations.

^e Mean value from n = 9.

^f Galvin and Moore (1982).

personal communication). Marine Power and Equipment is currently under a Consent Decree because of unpermitted discharges of sandblasting materials from their dry dock facility directly to the Duwamish River. Under the Consent Decree, Marine Power and Equipment is required to remove contaminated sediments from the Duwamish River adjacent to their property. In addition, a new National Pollutant Discharge Elimination System (NPDES) permit has been issued which requires that Marine Power and Equipment implement best management practices to control the release of spent sandblast grit from their facility [Washington Department of Ecology (Ecology) 1987].

DENNY WAY CSO INVESTIGATION

The Denny Way CSO is the largest and most frequent overflow point in Metro's combined sewer system. The Denny Way CSO discharges into Elliott Bay north of the Seattle downtown area at Denny Way. It produces a total average overflow volume of 500 million gal/yr from approximately 30 to 60 overflow events. The service area consists of almost 1,900 ac of mixed residential and commercial land. Studies from the late 1970s on have shown contaminated sediments offshore from the Denny Way CSO and adverse effects on benthic communities. As a result, the Denny Way CSO was identified in the interim Elliott Bay Toxics Action Plan as a significant problem area (Tetra Tech 1985c).

In 1986, Metro (Romberg et al. 1987) conducted a trial study in the Denny Way CSO drainage basin to determine if toxicant sources could be identified and reduced pending a structural solution to eliminate CSO discharges. As part of the investigation, Metro developed an inventory of 530 potential sources in the drainage basin based on Standard Industrial Codes (SIC) and addresses from tax records. A questionnaire on wastewater discharges and chemical use was sent to each potential source. Ninety-six potential sources were visited by Metro inspectors to confirm the questionnaire survey information and collect information to help develop practical source control strategies. In addition, sediment and wastewater samples were collected at key points within the CSO system (Figure 2-5) and analyzed for metals and organic toxicants. Wastewater samples were collected for two

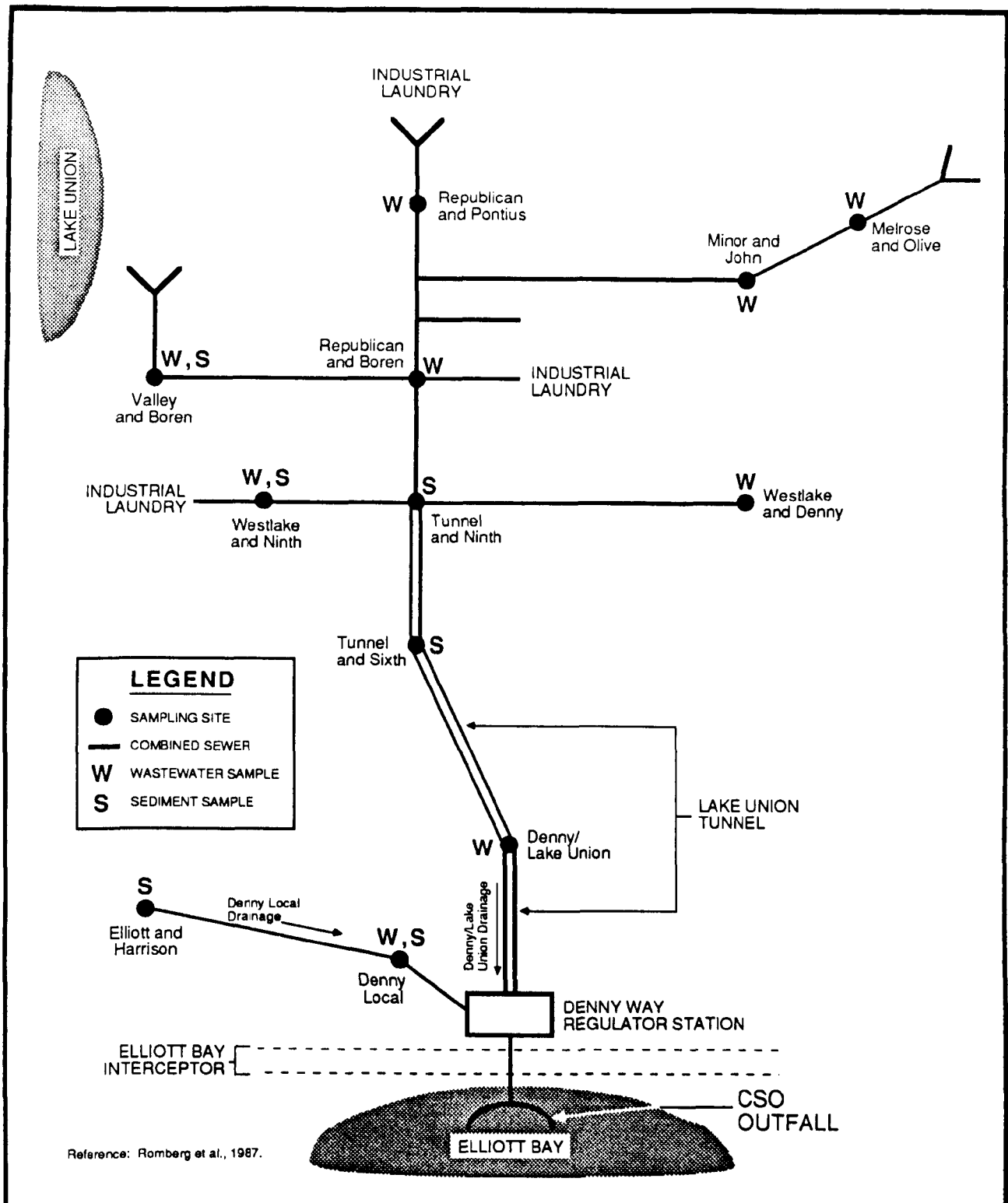


Figure 2-5. Sampling stations in Denny Way CSO source toxicant investigation.

different events at most stations and sediment samples were collected once at each station.

The highest metals concentrations in both wastewater and sediment samples were consistently measured in stations downstream of two industrial laundries that discharge wastewater to the Denny Way CSO. In addition, a large volume of accumulated sediments in one part of the CSO system (Lake Union Tunnel), located downstream of both laundries, was found to have high metals concentrations. Both laundries installed new pretreatment equipment in 1986 to reduce the toxicant loadings in their discharges. Based on preliminary data, metals loadings in sediments and wastewater were estimated to be reduced by 50 percent for copper, 77 percent for lead, and 24 percent for zinc (Romberg et al. 1987) after the pretreatment systems were installed. Therefore, it has been determined that the contaminated sediments in the drain were caused by historic discharges rather than ongoing discharges. Metro is currently evaluating removal of the contaminated sediments to prevent them from flushing into Elliott Bay. In addition, improvements to the storm water routing program to enhance in-line storage, and a notification and control system to reduce source toxicant discharges when overflows occur are under consideration (Romberg et al. 1987).

A discharge of chromium and mercury was traced to a movie film developing operation based on wastewater analyses in the Denny Way CSO. The facility has been directed to use proper disposal practices, and as a result, the toxicant input from this source is expected to be eliminated or greatly reduced (Romberg et al. 1986).

Analyses of organic compounds were generally not as effective in tracing contaminant sources as analyses of metals because of large variations in organic compound concentrations between different sampling events at one station. However, concentrations of toluene, tetrachloroethane, and ethyl benzene were typically highest (50-200 ug/L) in the wastewater samples collected downstream of the two industrial laundries. These three volatile organic compounds were also present at relatively high concentrations (300-800 ug/kg wet weight) in sediment samples collected immediately downstream of the laundries. In addition, naphthalene appeared to be associated with

the industrial laundries because it was only present (8.5-170 ug/L) in wastewater samples collected downstream of these two industrial laundries.

LAKE UNION AND SHIP CANAL STORM DRAIN INVESTIGATION

The City of Seattle, as part of a multi-year water quality management program, conducted an investigation of 20 storm drains discharging to Lake Union and the Ship Canal (Kennedy/Jenks/Chilton 1987). The study was designed to 1) characterize the chemical composition of sediments that accumulate in storm drains, 2) monitor the quality of stormwater discharges 3) model quality and quantity of stormwater runoff, and 4) estimate annual pollutant loading to Lake Union. Sampling conducted during the investigation included collecting in-line sediment samples from 11 storm drains, monitoring flow and water quality during two rainfall events in 4 storm drains, and hydraulically modeling the storm drain system to estimate average annual stormwater discharges for each drainage basin. A first flush storm event was also monitored in one drainage basin that had experienced 45 days of dry weather prior to the sampling event.

The results of the investigation indicated that storm water quality in the Lake Union drains was generally better than that reported for other urban areas (Kennedy/Jenks/Chilton 1987). However, total Kjeldahl nitrogen concentrations were higher than other comparison cities, and metals concentrations were generally higher than those reported for the City of Bellevue. Data from storm water sampling also showed that weather conditions prior to the sampling event affected the quality of discharge. The basin sampled immediately following a 45-day dry period exhibited considerably higher concentrations for many pollutants when compared with results from a typical winter storm event in the same basin. Conventional pollutants (i.e., total suspended solids, settleable solids, and turbidity) concentrations were up to 6 times greater for the first flush event and metals concentrations were 1-3 orders of magnitude greater for the first flush event. Metals concentrations in storm drain sediments (Table 2-3) exceeded the proposed freshwater and saltwater criteria for sediments used in comparisons at most of the sampling stations. Based on these results, the city recommended that efforts to control storm water volume and solids loading would be most

TABLE 2-3. SUMMARY OF METAL CONCENTRATIONS IN SEDIMENTS
COLLECTED FROM STORM DRAINS DISCHARGING INTO LAKE UNION

Chemical	Range (mg/kg dry wt)	Mean ^a (mg/kg dry wt)	Detection Frequency
Arsenic	0.74-1,700	210	11/11
Beryllium	<0.25-7.3	1.1	4/10
Cadmium	0.42-39	8.2	11/11
Chromium	19-350	96	11/11
Copper	22-1,300	360	11/11
Lead	210-2,700	1,000	11/11
Mercury	0.036-2.29	0.71	10/10
Nickel	21-660	190	10/10
Selenium	0.23-3.0	1.4	3/7
Silver	0.54-9.6	2.7	7/7
Zinc	280-7,600	180	10/10

^a Mean calculated using the reported detection limit for undetected values.

Reference: Kennedy/Jacobs/Chilton 1987.

effective in the two largest basins and four medium size basins that exhibited the highest pollutant concentrations. In addition, three small basins were recommended for source control investigations because of elevated metals concentrations observed in the storm drain sediments (Kennedy/Jenks/Chilton 1987).

APPENDIX 3
POLLUTANTS OF CONCERN

TABLE 3-1. INORGANIC CONTAMINANTS OF POTENTIAL CONCERN IN PUGET SOUND^a

Antimony	Copper ^b	Silver ^b
Arsenic ^b	Lead ^b	Zinc
Cadmium ^b	Mercury ^b	Cyanide
Chromium ^c	Nickel	Organotins ^d

^a The elements listed are 11 of the 14 U.S. EPA priority pollutant metals. The remaining three priority pollutant metals not recommended are beryllium, thallium, and selenium.

Beryllium and thallium are toxic but have not been found at concentrations that exceed reference levels in Puget Sound (see Tetra Tech 1986a, Appendix A).

High selenium concentrations have been reported in sediments in a single Puget Sound study; these values are considered to be elevated likely because of spectral interferences during the particular instrumental analysis used (see Tetra Tech 1986a, Appendix A). Other studies using alternative techniques have not found sediment levels of selenium in excess of reference conditions.

^b These elements have been suggested previously as contaminants of concern in Puget Sound based on elevated sediment concentrations, bioaccumulation potential, or toxicity (see Konasewich et al. 1982; Jones and Stokes 1984).

^c Although not found at elevated concentrations in Puget Sound sediments, chromium may be of concern in localized areas where chromium-rich waste are being discharged (e.g., chrome plating industries).

^d Organotins, especially tributyltin, are highly toxic components of some antifouling paints used on ships. Analytical techniques are not readily available and very little data are available for these compounds in Puget Sound waters. Because of the large number of shipyard industries in the Puget Sound area, organotins may be of concern.

TABLE 3-2. ORGANIC CONTAMINANTS OF POTENTIAL
CONCERN IN PUGET SOUND

Phenols

65^a phenol^c
HSL^b 2-methylphenol^c
HSL 4-methylphenol^c
34 2,4-dimethylphenol

Substituted Phenols

24	2-chlorophenol	HSL	2,4,5-trichlorophenol
31	2,4-dichlorophenol	64	pentachlorophenol ^d
22	4-chloro-3-methylphenol	57	2-nitrophenol
21	2,4,6-trichlorophenol	59	2,4-dinitrophenol ^e
		60	4,6-dinitro-o-cresol ^e

Miscellaneous Organic Acids (guaiacols/resin acids)^f

2-methoxyphenol (guaiacol)
3,4,5-trichloroguaiacol
4,5,6-trichloroguaiacol
tetrachloroguaiacol
mono- and di- chlorodehydroabietic acids

Low Molecular Weight Aromatic Hydrocarbons^d

55	naphthalene	80	fluorene
77	acenaphthylene	81	phenanthrene
1	acenaphthene	78	anthracene

Alkylated Low Molecular Weight Aromatic Hydrocarbons^{d,g}

HSL 2-methylnaphthalene
1-methylnaphthalene
1-, 2-, and 3-methyl phenanthrenes

High Molecular Weight PAH

39	fluoranthene	75	benzo(k)fluoranthene
84	pyrene	73	benzo(a)pyrene
72	benzo(a)anthracene	83	indeno(1,2,3-c,d)pyrene
76	chrysene	82	dibenzo(a,h)anthracene
74	benzo(b)fluoranthene	79	benzo(g,h,i)perylene

TABLE 3-2. (Continued)

Chlorinated Aromatic Hydrocarbons

26	1,3-dichlorobenzene	8	1,2,4-trichlorobenzene
27	1,4-dichlorobenzene	20	2-chloronaphthalene
25	1,2-dichlorobenzene	9	hexachlorobenzene (HCB)

Chlorinated Aliphatic Hydrocarbons

12	hexachloroethane
52	hexachlorobutadiene ^d

Phthalates^d

71	dimethyl phthalate	67	butyl benzyl phthalate
70	diethyl phthalate	69	di-n-octyl phthalate
68	di-n-butyl phthalate		

Miscellaneous oxygenated compounds

54	isophorone	polychlorinated dibenzofurans ^{d,j}
HSL	benzyl alcohol ⁱ	polychlorinated dibenzodioxins ^j
HSL	benzoic acid ⁱ	
HSL	dibenzofuran ⁱ	

Organonitrogen Compounds^k

62	N-nitrosodiphenylamine
	9(H)- carbazole ^l

Pesticides

93	p,p'-DDE ^{dm}	98	endrin ^d
94	p,p'-DDD ^{dm}	100	heptachlor
92	p,p'-DDT ^{dm}	102	alpha-HCH
89	aldrin ^{dm}	103	beta-HCH
90	dieldrin ^d	104	delta-HCH
91	alpha-chlordane	105	gamma-HCH (lindane)

PCBsⁿ

Total PCBs (this class includes monochloro-
through decachlorobiphenyls)

TABLE 3-2. (Continued)

Volatile Halogenated Alkanes^a

45	chloromethane	6	carbon tetrachloride ^e
46	bromomethane	48	bromodichloromethane ^e
16	chloroethane ^e	32	1,2-dichloropropane
44	dichloromethane	51	chlorodibromomethane ^e
13	1,1'-dichloroethane	14	1,1,2-trichloroethane
23	chloroform	47	bromoform ^e
10	1,2-dichloroethane ^e	15	1,1,2,2-tetrachloroethane ^e
11	1,1,1-trichloroethane ^e		

Volatile Halogenated Alkenes^a

88	vinyl chloride	33	cis-1,3-dichloropropene
29	1,1'-dichloroethene		trans-1,3-dichloropropene
30	trans-1,2-dichloroethene	87	trichloroethene
		85	tetrachloroethene

Volatile Aromatic and Chlorinated Aromatic Hydrocarbons^a

4	benzene	HSL	styrene (ethenylbenzene)
86	toluene	HSL	total xylenes
38	ethylbenzene	7	chlorobenzene

NOTE: Compounds not recommended from the U.S. EPA priority pollutant list include:

- o Halogenated ethers (two volatile and five semivolatile compounds) are rarely reported in Puget Sound and are not expected to persist in sediments.
- o Hexachlorocyclopentadiene has not been confirmed to be present in Puget Sound sediments, is easily degraded during laboratory analysis, and has no suspected sources in Puget Sound.
- o Acrolein and acrylonitrile have not been detected in Puget Sound sediments and are difficult to analyze for in routine volatiles analysis.
- o Other priority pollutants not recommended are indicated in the following footnotes.

^a Indicates U.S. EPA priority pollutant number.

^b U.S. EPA Hazardous Substance List (HSL) compound.

TABLE 3-2. (Continued)

c Phenol, a U.S. EPA priority pollutant, has been reported at elevated concentrations in several areas of Puget Sound. Phenol is toxic and may be associated with effects observed at selected sites in Commencement Bay, but because of its slightly polar character, does not have a high bioaccumulation potential. Industrial chemical synthesis is one of many sources of phenol. 2-Methylphenol is an HSL compound and is a known component of Kraft pulp effluents. 4-Methylphenol is an HSL compound that was reported at high concentration in numerous areas of Commencement Bay. There are little or no historical data available for this compound and it is unknown whether 4-methylphenol derives principally from degradation of other compounds or is present directly in industrial discharges. The occurrence of 4-methylphenol was highly correlated with sediment toxicity and effects on benthic biota in a problem area near a pulp and paper operation in Commencement Bay. The compound may also be derived as a ground-water contaminant in other areas.

d Compound or group of compounds has been designated previously as a contaminant of concern in Puget Sound based on elevated sediment concentrations, bioaccumulation potential, or toxicity (Jones and Stokes 1984, Konasewich et al. 1982, Quinlan et al. 1985).

e Compound is seldom or not reported, possibly due to analytical problems presented by the compounds or limited number of analyses.

f Guaiacol was reported in Commencement Bay and is useful as an indicator of pulp mill effluent. The chlorinated guaiacols have toxicity comparable to phenolic priority pollutants, are persistent, and are good indicators of chlorinated pulp mill effluents. Chlorinated dehydroabietic acids are also good indicators of chlorinated pulp effluent and are expected to be toxic and persistent (based on studies of unchlorinated dehydroabietic acid).

g These non-priority pollutant (U.S. EPA) compounds are often detected in Puget Sound sediments. Although this is not an exhaustive list of alkylated aromatic compounds, the compounds shown are accessible as analytical standards and are useful for determining alkylated/non-alkylated ratios used to indicate PAH sources.

h HCBD is a toxic and carcinogenic U.S. EPA priority pollutant that has been reported in various regions of Puget Sound. It is largely a byproduct of chlorinated hydrocarbons (e.g., tri- and tetrachloroethylene) manufacture.

i Dibenzofuran, benzyl alcohol, and benzoic acid are HSL compounds and have been detected frequently in Commencement Bay.

TABLE 3-2. (Continued)

j Both classes of compound are of concern because of their severe toxic affects on higher organisms. Dedicated chemical analyses are required for these compounds, and few such analyses have been performed on Puget Sound samples. Thus, the occurrences of these compounds are unknown but are nonetheless of great potential concern.

k The remaining 7 priority pollution organic bases are seldom detected in Puget Sound and often present analytical problems (e.g., benzidine and 3,3-dichloro-benzidine).

l 9(H)-carbazol is a component of creosote and coal tar and has been reported in Puget Sound regions with these sources.

m DDT and its chlorinated hydrocarbon metabolites, DDE and DDD, are U.S. EPA priority pollutants that are persistent, readily bioaccumulated, and very toxic; DDT itself is a carcinogen. Of the U.S. EPA priority pollutant pesticides, these compounds are most frequently reported in Puget Sound sediments and biota although not nearly as often as the other compounds recommended. Aldrin, another pesticide priority pollutant, has not been widely reported in Puget Sound but is of concern because of its extremely high acute toxicity.

n PCBs are a class of U.S. EPA priority pollutants that are widely distributed among sediments and biota of Puget Sound. PCBs are persistent and have a high potential to bioaccumulate. PCBs are the only substances present in Commencement Bay tissue samples that were judged to present a significant health risk, and were also highly correlated with sediment toxicity. Commercial PCB mixtures are suspected of containing carcinogens or co-carcinogens and were used historically in enclosed systems (e.g., capacitors and transformers) that have often been discarded into the environment.

o Some of the volatile organic compounds are of concern because of their use in industry and their potential for contamination of groundwater.

TABLE 3-3. POLLUTANT OF CONCERN LIST

Pollutant of Concern	Point Sources			Nonpoint Sources (d)	Soils (e)
	Municipal (a)	Industrial (b)	CSOs (c)		
Antimony	A	C,CA,LS,OR	A	UR,IR	OS
Arsenic	A	C,OR,LS,(S)	A	UR	OS
Cadmium	A	CP,C,(M)	A	UR	
Chromium	A	F,CP,(S)	A	UR	C
Copper	A	P,C,CP,OR,CA,LS,(M),(L),(S)	A	UR,IR,SW	OS
Lead	A	C,OC,CA,OR	A	UR,IR,SW	OS
Mercury	A	CA,B,OC,CA,OR	A	UR,IR,SW	C,OS
Nickel	A	C,CA,OC,(M)	A	UR	
Silver	A	(CP)	A	UR,IR,SW	
Zinc	A	C,OC,CA,OR,LS,(M)	A	UR	OS
Cyanides	A	CP,C,(F),(M)	A	UR	
LPAH	A	L,(M)	A	UR	O
Naphthalene	A	L,P	A	UR	O
Acenaphthylene	C	L	B		O
Acenaphthene	B	L	B		O
Fluorene	B	L	A		O
Phenanthrene	A	L	A	UR	O
Anthracene	A	L	B		O
HPAH	A	L,(M)	A	UR	O
Fluoranthene	A	L	A	UR	O
Pyrene	A	L	A	UR	O
Benzo(a)anthracene	A	L	A		O
Chrysene	A	L	A	UR	O
Total benzofluoranthenes	A	L			O
Benzo(a)pyrene	A	L	B		O
Indeno(1,2,3,c,d)pyrene	A	L	A		O

TABLE 3-3. (Continued)

Pollutant of Concern	Point Sources			Nonpoint Sources (d)	Soils (e)
	Municipal (a)	Industrial (b)	CSOs (c)		
Dibenzo(a,h)anthracene	B	L	B		O
Benzo(a,h,i)perylene	A	L	B		O
Total PCBs	B		A		C
Hexachlorobenzene	C		C		
Hexachlorobutadiene	C	OC	C		
1,3-dichlorobenzene	B		B	IR	
1,4-dichlorobenzene	B		B	IR	
4,4'-DDT	C		C	AR	
4,4'-DDE	C			AR	
4,4'-DDD	C		C	AR	
Aldrin	C		C	AR	
Dieldrin				AR	
gamma-HCH				UR,AR	C
Phenol	A	OC, IC, OR, P, L, LS	A	UR, IR	
4-Methylphenol		(P)			
Pentachlorophenol	B	P, OC, IC, L	C	UR, IR	
Dibenzofuran		L			
2-Methoxyphenol		(P)			
2-Methylnaphthalene	A				O
N-nitrosodiphenylamine	C		B		
Trichloroethene	A	P, OC, CA, (DC)	A	GW	
Tetrachloroethene	A	P, OC, IC, CA, (DC)	A	GW	
Ethylbenzene	A		A		O
Chloroform	A	P	A		
2,3,7,8-Tetrachlorodioxin					
Organotin					

TABLE 3-3. (Continued)

a. Municipal

A = Chemical occurs in >25 percent of samples from Puget Sound municipal discharges.
 B = Chemical occurs in <25 percent of samples from Puget Sound municipal discharges.
 C = Chemical not detected based on available information.
 Blanks indicate that there are insufficient data to categorize.

b. Industrial: Industries in which chemical may be found.

S = Ship building/repair
 P = Pulp mills
 C = Copper smelters
 CP = Chrome plating, silver plating
 F = Ferro, silicon, chrome industries
 CA = Chloralkali plants
 B = Bleach plant
 L = Log/wood treatment facility
 OC = Organic chemical manufacturing
 IC = Inorganic chemical manufacturing
 LS = Log sort yards
 M = Primary production of ferros and non-ferros metals
 OR = Oil refining
 DC = Dry-cleaning
 Codes in parentheses indicate industries which are potential sources but have not been documented in Puget Sound.
 Blanks indicate that there are insufficient data to categorize.

c. CSOs

A = Chemical occurs in >25 percent of samples from Puget Sound CSOs.
 B = Chemical occurs in <25 percent of samples from Puget Sound CSOs.
 C = Chemical not detected based on available information.
 Blanks indicate that there are insufficient data to categorize.

d. Nonpoint Sources: Types of nonpoint sources where chemical may be found.

UR = Urban runoff
 AR = Agricultural runoff
 IR = Industrial runoff
 GW = Groundwater
 Blanks indicate that there are insufficient data to categorize.

e. Spills: Kinds of spills where chemical may be found.

O = Oil spills
 C = Miscellaneous product spills
 OS = Ore spills
 Blanks indicate that there are insufficient data to categorize.