SOUTH LAKE UNION PILOT PROJECT REPORT

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Land Use and Transportation Project
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ABSTRACT

The City of Seattle conducted a pilot project to obtain a comprehensive picture of South Lake Union from the Lake Union Drydock Company vicinity (north of the City Light Steam Plant) to the site of the proposed new City park. Two water samples and fifteen sediment samples were collected. Standard analytical procedures were used to analyze conventional water quality and sediment quality parameters, metal levels in water and sediment samples, and organic priority pollutant levels in sediment samples. Microtoxicity bioassays were performed on the interstitial water from the sediment samples. None of the conventional water quality parameters violated state Lake Class water quality standards or exceeded federal water quality criteria for protection of aquatic life or human health. With the possible exception of mercury, metal levels in the water samples did not exceed either drinking water standards or water quality criteria. None of the conventional sediment quality parameters appear to be high enough to threaten benthic community health. Metal levels in several sediment samples and polychlorinated biphenyl (PCB) levels in most sediment samples exceeded concentrations measured elsewhere in Lake Union/Ship Canal and exceeded interim sediment quality values proposed for Puget Sound sediments. Polycyclic aromatic hydrocarbons (PAHs) were found at lower levels than in previously tested Gas Works Park sediments, but some PAH levels in the South Lake Union samples exceeded interim sediment quality values. The interstitial water in sediments from three stations (near the Drydock Company and Steam Plant) is very toxic compared to microtoxicity bioassay results from the other sediment samples, Elliott Bay sediments and West Point sewage. Additional studies that will be conducted are: analyses of PCB and metal levels in edible tissue of crayfish harvested from South Lake Union; and additional biological testing (sediment bioassays, benthic community analyses) to correlate levels of toxic chemicals in South Lake Union sediments with impacts on biota.

SOUTH LAKE UNION PILOT PROJECT REPORT

1. INTRODUCTION

Investigations of water and sediment quality have been performed in some areas of Lake Union and the Ship Canal. However, there is a paucity of data in other areas, such as the south end of the Lake. There is also a paucity of information on what species of aquatic organisms are currently found in Lake Union/Ship Canal and correlation of biological data with sediment toxicant levels. Bioassays have not been performed on sediment samples anywhere in Lake Union. In summary, there is no comprehensive picture of any section of Lake Union.

The City of Seattle has conducted a pilot project in order to obtain a comprehensive picture of South Lake Union. This comprehensive overview includes water quality, sediment quality (chemistry, effects on biota) and implications of water and sediment quality for recreational uses, e.g., swimming, fishing. The South Lake Union area was selected for the pilot project because of interest in the impacts of specific past and present land uses on water quality.

The proposed South Lake Union park was selected as the first specific section of South Lake Union for the pilot project because interest has been expressed in water contact sports (swimming, windsurfing) at the new park. South Lake Union does not flush as well as other parts of the Lake. Hence, toxicants from industries, CSO outfalls and storm drains in the area may be present at higher concentrations in the water column and sediments here than elsewhere in the Lake. Sediment sampling in 1984 at two stations in South Lake Union near the proposed park (see Figure 1) showed the presence of a polychlorinated biphenyl (PCB) mixture at concentrations up to 1.8 parts per million (ppm) (Hileman et al., 1985). Although no freshwater sediment quality criteria have been established indicating the concentrations of PCBs that could affect aquatic life or human health, the Food and Drug Administration (FDA) has established a health standard of 2 ppm in fish and shellfish (Frost et al., 1984). In addition to PCBs, heavy metals (chromium, copper, nickel, zinc, silver, arsenic, mercury, cadmium, lead) were found at levels comparable to those in Gas Works Park sediments.

The Seattle City Light Steam Plant area was selected as the second section of South Lake Union for the pilot project. PCBs were used in electrical transformers in Steam Plant operations. The Environmental Protection Agency (EPA) banned the manufacture and use of PCBs in 1977 because these chemicals were discovered to be carcinogenic. However, PCBs are persistent in the environment. Although the Steam Plant has not operated since the 1970's, 811,000 gallons of fuel oil at the Plant are currently contaminated with an average of 75 ppm PCBs. (Seattle City Light, 1985).

Sediment sampling in 1984 at two stations near the Steam Plant (see Figure 1) showed the presence of PCBs at concentrations up to 11.6 ppm. PCBs were either found at much lower levels (e.g., 0.6 ppm - 4.5 ppm) or were not found at all at the 31 other Lake Union stations sampled in 1984 (Hileman et al., 1985). This previous data suggests that there may be "hot spots" of PCB contamination near the Steam Plant.

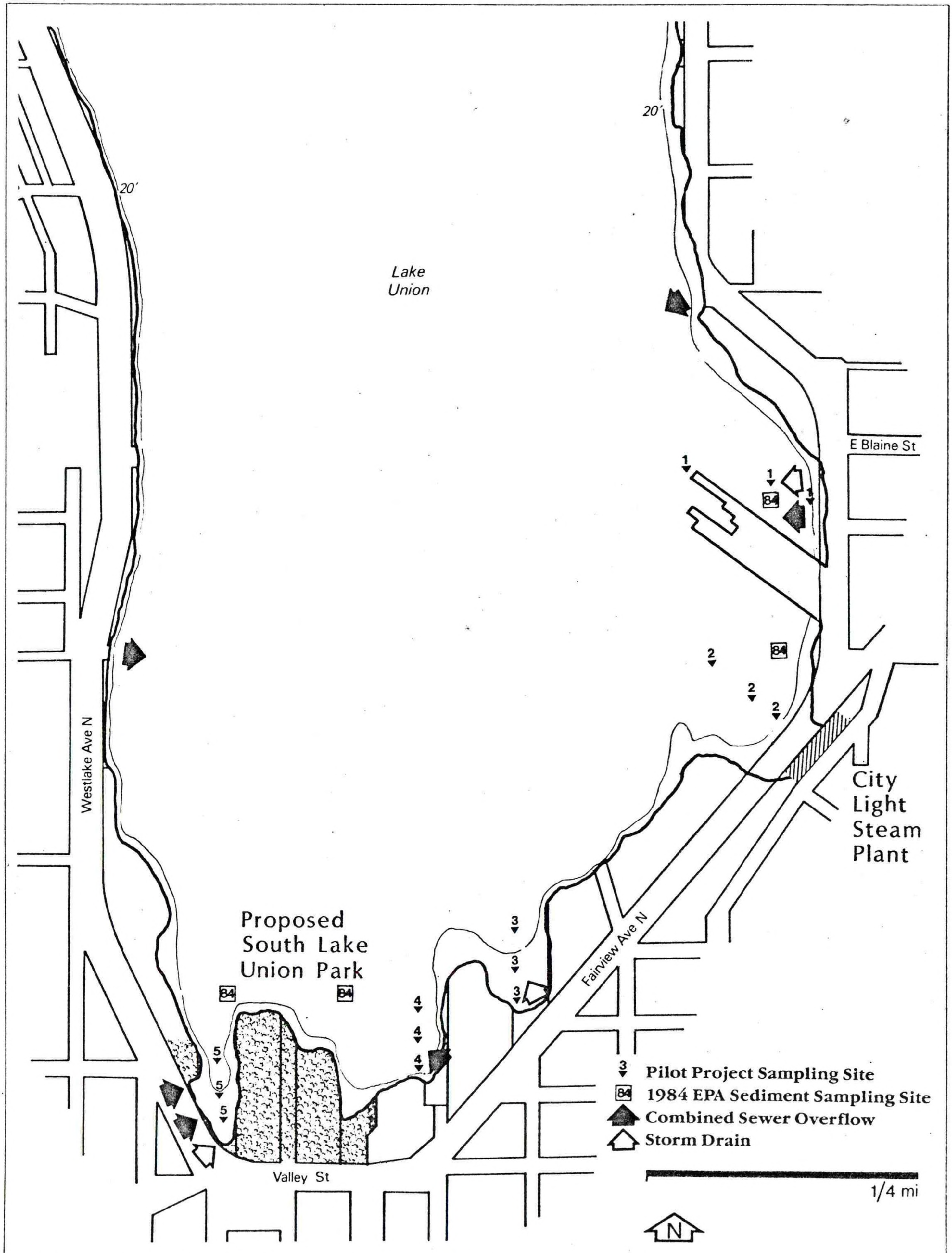

Figure 1: South Lake Union Pilot Project

In addition to PCBs, sediments in the two stations near the Steam Plant contained the same heavy metals as were found in the proposed park area samples. Concentrations of chromium, copper, lead and zinc were higher at these stations than in Gas Works Park sediment samples. PCBs and heavy metals may also have migrated to adjacent sediments. These adjacent sediments or the water column may contain priority pollutants at concentrations that could affect ecosystems.

Questions to be answered by the pilot project include:

- o Do toxicant levels in the water column in the Steam Plant and South Lake Union park area exceed current water quality criteria for protection of aquatic biota and human health?
- o What are the concentrations of priority pollutants in the sediments in the Steam Plant and South Lake Union park areas?
- o Are priority pollutants in the sediments toxic to aquatic biota?
- o Are there pollutant "hot spots" in South Lake Union? What are the worst pollutants?

II. SAMPLING AND ANALYTICAL PROCEDURES

The pilot project covered the South Lake Union area from the vicinity of the Lake Union Drydock Company (north of the City Light Steam Plant) to the site of the proposed new City park. The work for the pilot project was performed in May-June, 1986. See Figure 1 for location of sampling stations. There were five general stations where sampling took place and three specific sampling sites at each station - at distances of 50', 150' and 300' from the shoreline.

Sampling Procedures

Water samples were collected by Metro from stations 2-300 and 5-300. Van Doren bottles were lowered to one meter below the surface and tripped. Once the bottles were brought aboard the sampling ship, the water was split among individual sample containers. Metro retained a set of samples for analyses of conventional water quality parameters and gave a set of samples to Pacific Analytical Laboratory Services (Bremerton) for analyses of metal levels.

Sediment samples were collected by Metro at all 15 stations. See Appendix A for a qualitative description of the sediments at each station, percent solids in the sediments, and the depths at which the sediments were taken.

Five grabs were taken at each of the 15 stations using a Van Veen grab sampler. Two "cookies" (2 inches in diameter) were taken per grab with a stainless steel, organically cleaned "cookie cutter". The ten "cookies" were placed in a four liter organically cleaned glass beaker. Using a Teflon bar, the sample was homogenized to form a composite sample of the five grabs. The composite was then split into individual sample containers. Metro retained a set of samples for microtoxicity bioassays. Pacific Analytical Laboratory Services obtained a set of samples for analysis of biological oxygen demand, (BOD), chemical oxygen demand, (COD), oil and grease, and metals. Am Test, Inc. obtained a set of samples for analysis of total organic carbon (TOC) and EPA priority pollutant organic chemicals.

Analytical Procedures

Standard analytical procedures were used for conventional water quality parameters: pH, total dissolved solids (TDS), total suspended solids (TSS), BOD, COD, nitrite and nitrate, Kjeldahl nitrogen, ammonia, total phosphate, orthophosphate, total coliforms and fecal coliforms. Metal levels in the water samples were analyzed by atomic absorption spectroscopy using a graphite furnace, following EPA methods.

BOD was analyzed in the sediment samples in accordance with EPA method 507. COD was analyzed in accordance with EPA method 508 with a slight modification recommended by Washington Department of Ecology (preparation of a sediment-water slurry). Oil and grease levels were determined by freon extraction and infrared spectroscopy in accordance with EPA method 503B. The heavy metals were determined in the sediment samples after digestion with nitric acid and hydrogen peroxide. Arsenic levels were analyzed by graphite furnace atomic absorption, mercury levels by cold vapor, and the remaining seven metals by flame atomic absorption.

TOC and organic priority pollutants in sediments were analyzed using the following approved EPA methods:

Total Organic Carbon	EPA	9060
Organic Priority Pollutants		
Volatiles	EPA	8240
Acid/Base - Neutral	EPA	8270
PCBs and Pesticides	EPA	8080

Microtoxicity bioassays were performed by centrifuging sediments to separate the interstitial water from the solids and then exposing suspensions of bioluminescent bacteria to various dilutions of the interstitial water. Measurements were made of interstitial water concentrations that caused 50 percent light reduction after 5, 15, and 30 minutes of exposure.

The EPA Contract Laboratory Program Quality Assurance/Quality Control (QA/QC) requirements were followed. QA/QC checks on the analytical procedures included: standard additions, blanks, duplicates and sample spikes. Detection limits for metals and organic priority pollutants were in accordance with the proposed limits of the Puget Sound Estuary Program.

III RESULTS

Water Quality

Conventional Water Quality Parameters. Appendix B presents the results of the conventional water quality analyses in the two water samples. None of the parameters violated State of Washington water quality standards for Lake Class waters or exceeded federal water quality criteria for protection of aquatic life or human health. Total dissolved solids levels were far below the drinking water standard of 500 ppm. Total suspended solids levels were low enough so that they will not cause turbidity problems in the Lake. Biological oxygen demand (BOD) and chemical oxygen demand (COD) levels are judged not to be a cause for concern as they will not deplete dissolved oxygen (DO) from the water.

(Rick Albright, EPA, personal communication). The DO levels of 10.1 ppm are in the range normally found in Lake Union surface waters in late spring (9.5 to 12.6 ppm) and above the levels required for protection of aquatic life. Ammonia levels will not threaten fish survival or human health. Nutrient levels (nitrogen as nitrite, nitrate and Kjeldahl nitrogen, phosphorus as total phosphate and orthophosphate) are below the levels that would stimulate excessive growth of algae and lake eutrophication.

Coliform counts do not exceed State of Washington standards for Lake Class waters. This means that the counts are below the levels (240 organisms/100 ml total coliforms and 50 organisms/100 ml fecal coliforms) that would cause concern in terms of the potential for waterborne illness among swimmers.

Metals

Appendix C compares heavy metal concentrations found in the two water samples. In the absence of water quality criteria for swimming safety based specifically on toxicant levels, metal concentrations were compared with (1) drinking water standards and (2) federal criteria for protection of aquatic life and human health based on daily ingestion of two liters of minimally treated surface water.

Levels of all metals except arsenic were below limits of detection proposed by the Puget Sound Estuary Program. Arsenic levels did not exceed levels considered "safe" for municipal drinking water supplies and did not exceed water quality criteria for protection of aquatic life. This was also the case for the other tested metals with the possible exception of mercury. Data from mercury analysis indicates only that mercury concentrations were below the 20 ppb detection limit; we do not know at this point if the concentrations were below drinking water standard of 1 ppb. It may be worthwhile to analyze mercury levels again, using a procedure that would allow a lower limit of detection. In terms of the other metals, it would probably be safe to say that swimmers who accidentally swallow some Lake Union water would not be exposed to concentrations that would threaten their health.

Sediment Quality

No standards or criteria have been established for health hazards in freshwater caused by contact with polluted sediments. In the absence of well-defined criteria, sediment quality data from the fifteen sampling stations in South Lake Union were compared with (1) sediment quality data obtained elsewhere in Lake Union; (2) sediment quality data obtained from other lakes; and (3) interim sediment quality values proposed for Puget Sound sediments, based on toxicant levels in the sediments that will affect benthic community health ("apparent effects thresholds".)

Conventional Sediment Quality Parameters. Appendix D indicates conventional sediment quality parameters: biological oxygen demand (BOD), chemical oxygen demand (COD), oil and grease, and total organic carbon (TOC). These parameters are used as screens to indicate the amount of organic matter in the sediments that could take away oxygen from benthic animals. The numbers for BOD, COD, oil and grease and TOC do not differentiate between organic matter from organic chemical pollutants in the sediments and organic matter from decaying biota. Thus, a high number often, but not always, reflects a high level of pollution.

BOD and COD levels are probably not high enough to threaten DO levels for the benthic community (personal communication with Carl Kassebaum, EPA). The COD levels in all the sediment samples were below the 10 percent considered to cause concern.

Oil and grease levels were highest in the sediment samples near CSO and storm drain outfalls. These levels were compared with interim criteria developed by the Puget Sound Dredged Disposal Analysis Program for unconfined open water disposal of dredged material. Levels in all fifteen sediment samples were well below the 500 ppm "precaution level" and the 1000 ppm level that requires analysis of dredged materials for priority pollutants before the materials are approved for disposal. TOC levels in all sediment samples were below the 15 percent interim sediment quality value based on benthic community health effects.

Metals. Appendix E indicates heavy metal (mercury, zinc, copper, chromium, lead, arsenic, cadmium, silver, nickel) levels and which metals in which samples exceed interim sediment quality values. Mercury concentrations were higher in all sediment samples (except 4-300) than concentrations in previously analyzed Gas Works Park and Ship Canal sediments. Concentrations also exceeded interim sediment quality values in all samples except 4-300 (See Figure 2).

Concentrations of zinc, copper, chromium, lead and arsenic exceeded concentrations measured elsewhere in Lake Union, the Ship Canal, Lake Washington and McAllister Creek (a non-urban body of freshwater). Several samples had metal levels exceeding interim sediment quality values (see Appendix E and Figures 3-5). Sample 1-300 (taken near the end of the Lake Union Drydock Company) contained especially high concentrations of all of these metals. Samples 1-50 and 1-150 contained elevated levels of some of these metals as well. This data suggests that there may be "hot spots" of heavy metal contamination in sediments near the Lake Union Drydock Company and near a CSO outfall and storm drain outfall north of the Drydock Company.

Organic Priority Pollutants. Appendix F indicates levels of organic priority pollutants in the 15 sediment samples and which chemicals in which samples exceed interim sediment quality values.

PCB mixtures (Aroclor 1242, Aroclor 1254, Aroclor 1260) were found at higher concentrations in most South Lake Union sediment samples than in (1) previously tested (1984) Gas Works Park sediment samples, and (2) previously tested (early 1980's) sampling stations in other parts of Lake Union and the Ship Canal. Concentrations also exceeded interim sediment quality values in most samples (see Figure 6).

Polycyclic aromatic hydrocarbons (PAHs) were found at lower levels than in previously tested Gas Works Park sediments. However, some chemicals in this group were found at higher levels in some South Lake Union sediment samples than in other Lake Union/Ship Canal sediments: acenaphthene, anthracene, fluorene, naphthalene, phenanthrene, benzo(a)anthracene, benzo(a)pyrene, benzo(b) fluoranthene/benzo(k)fluoranthene, chrysene, fluoranthene, indeno (1,2,3-cd) pyrene, and pyrene. Some PAH levels exceeded benthic "apparent effects threshold" interim sediment quality values (see Figure 7).

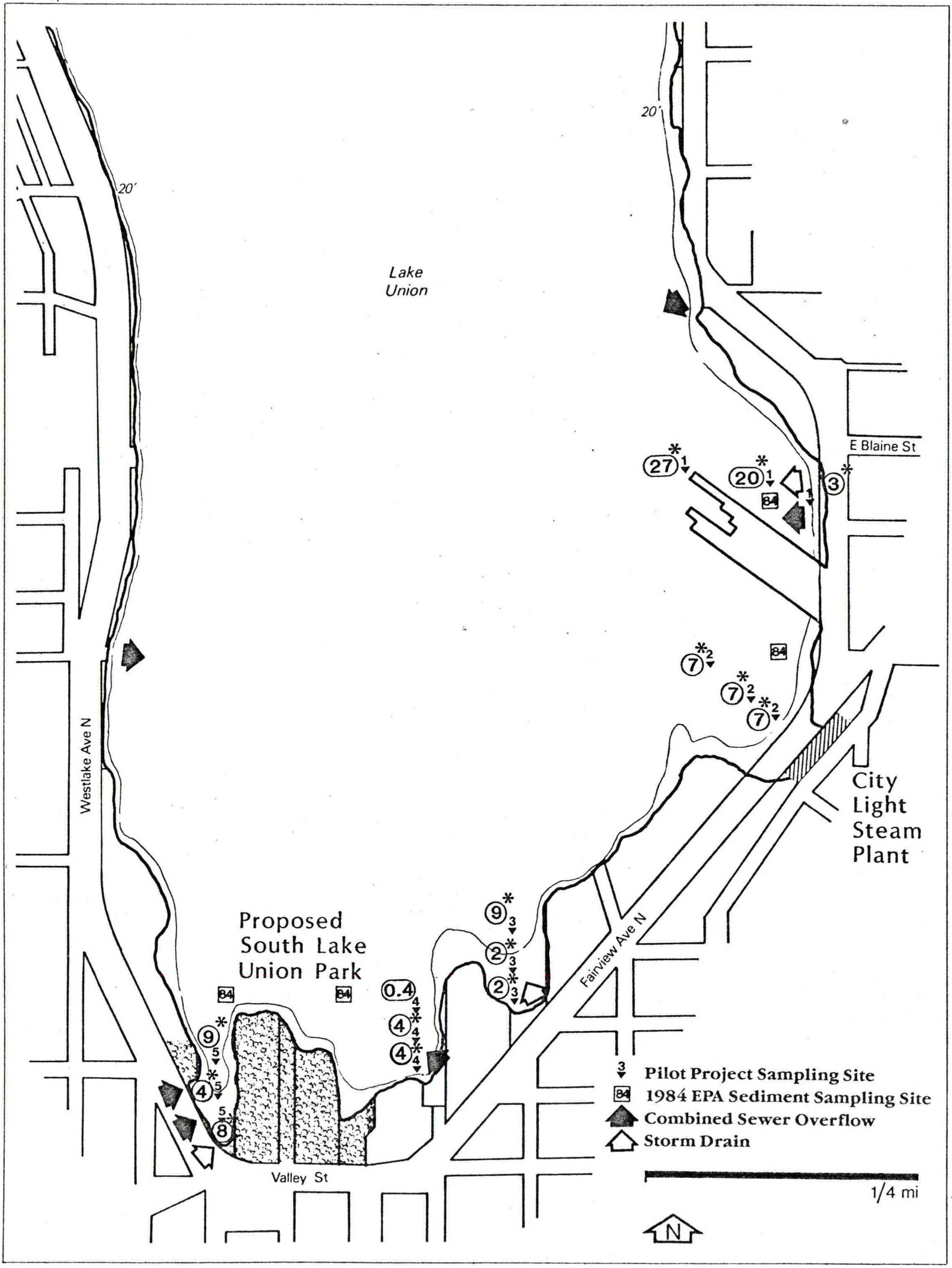

Figure 2: Mercury Levels in Sediments (expressed in ppm)

***Figures exceed interim sediment quality values.**

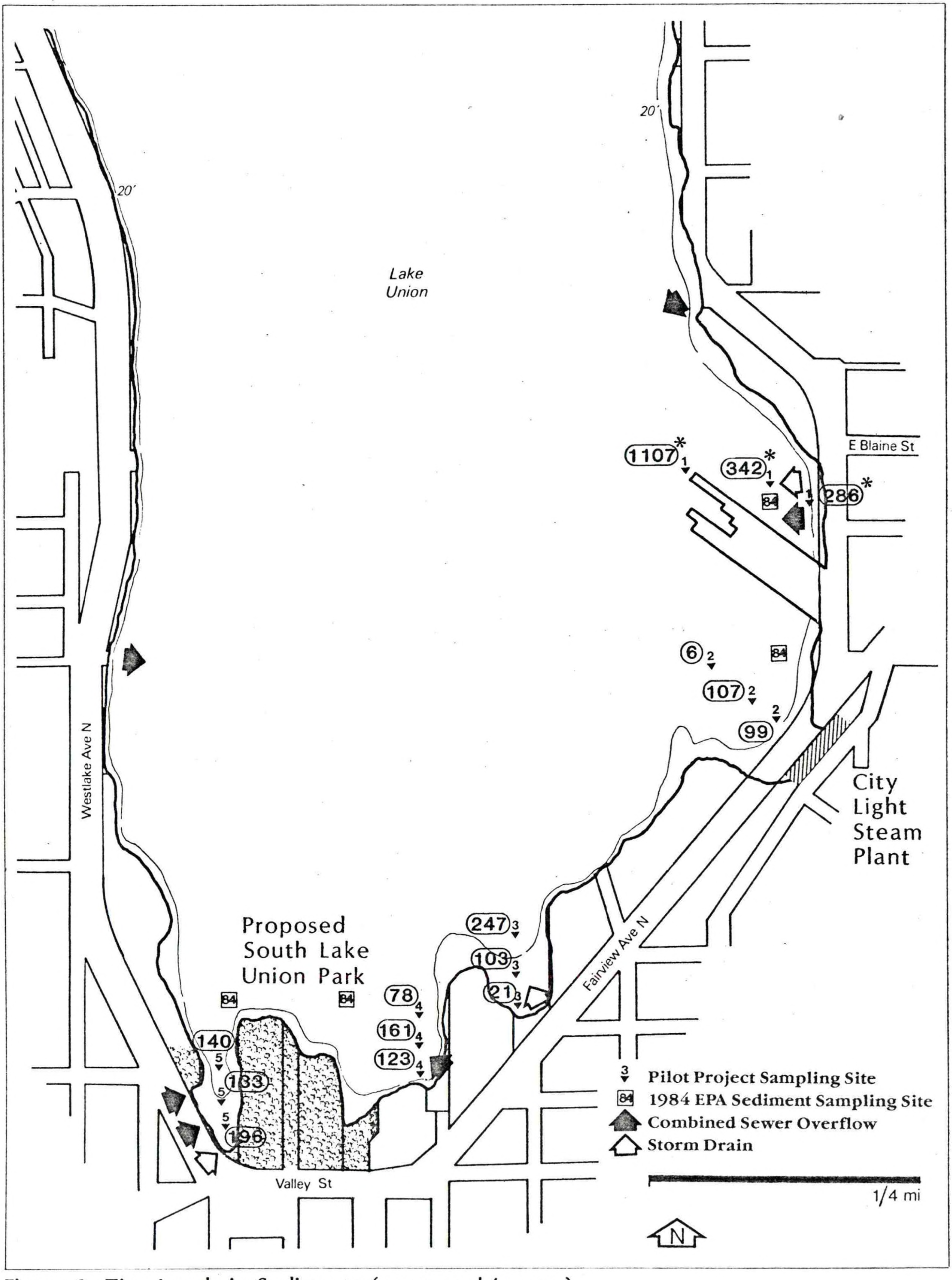

Figure 3: Zinc Levels in Sediments (expressed in ppm)
***Figures exceed interm sediment quality values.**

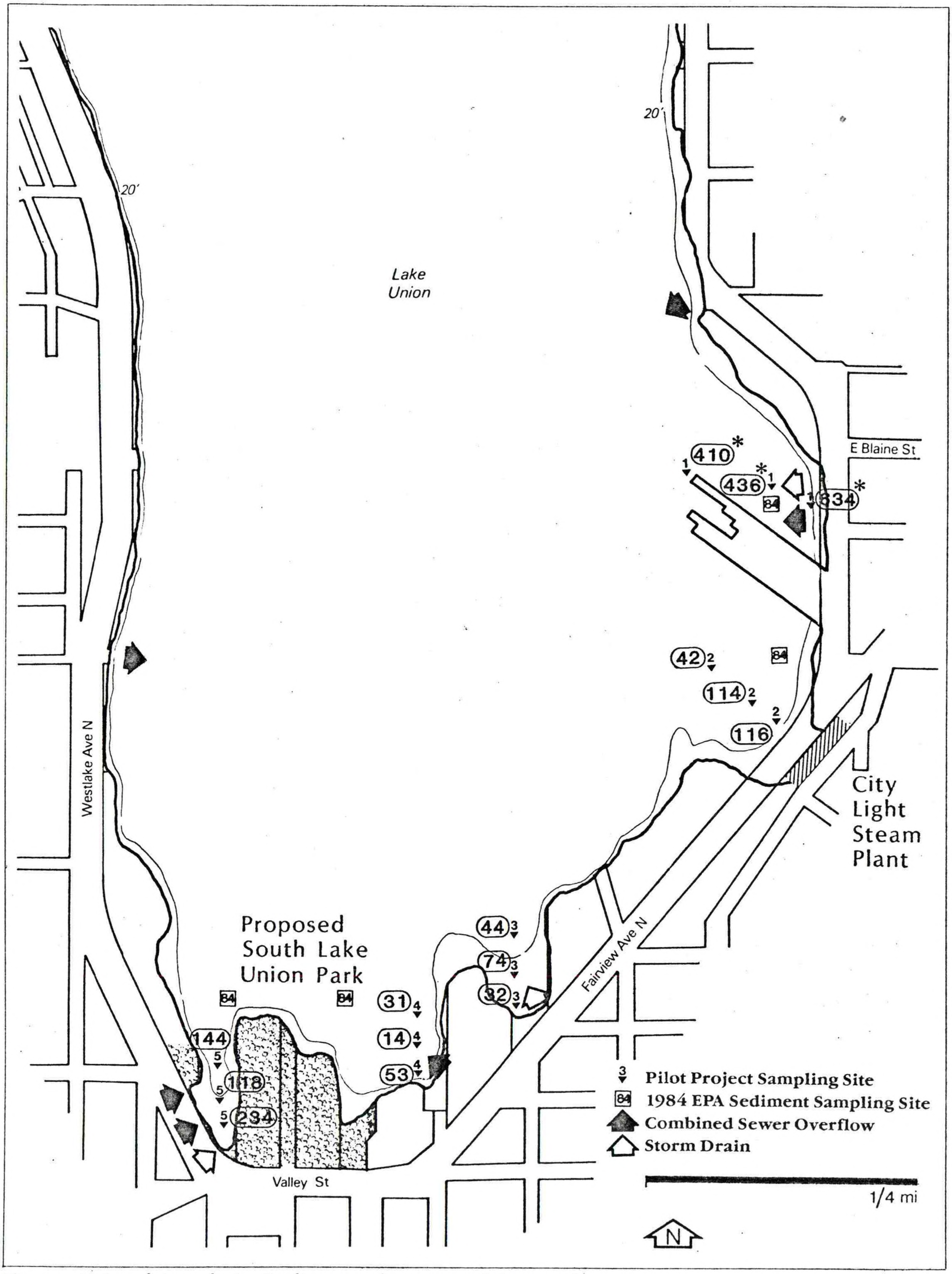

Figure 4: Lead Levels in Sediments (expressed in ppm)
*Figures exceed interim sediment quality values.

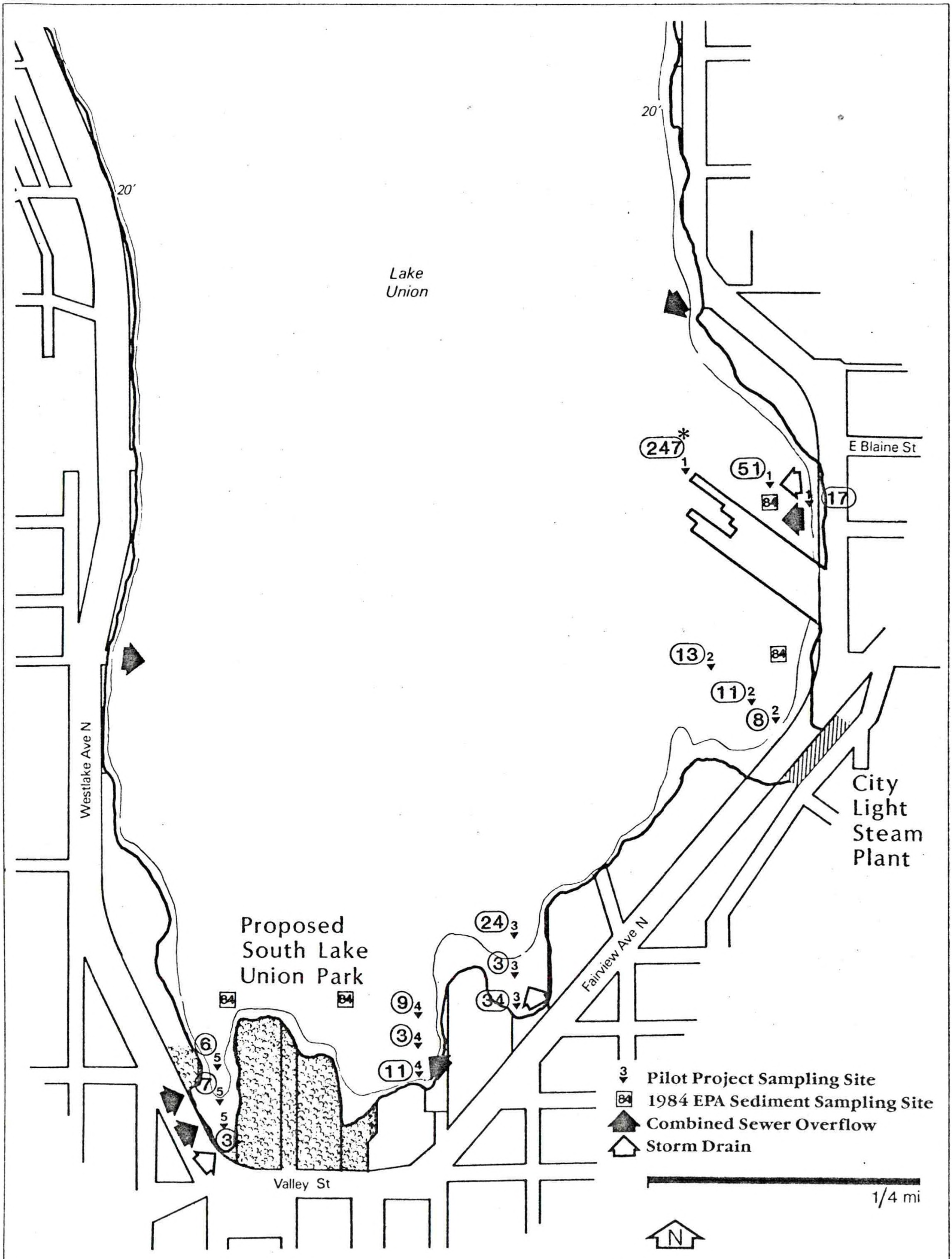

Figure 5: Arsenic Levels in Sediments (expressed in ppm)
Figures exceed interim sediment quality values.

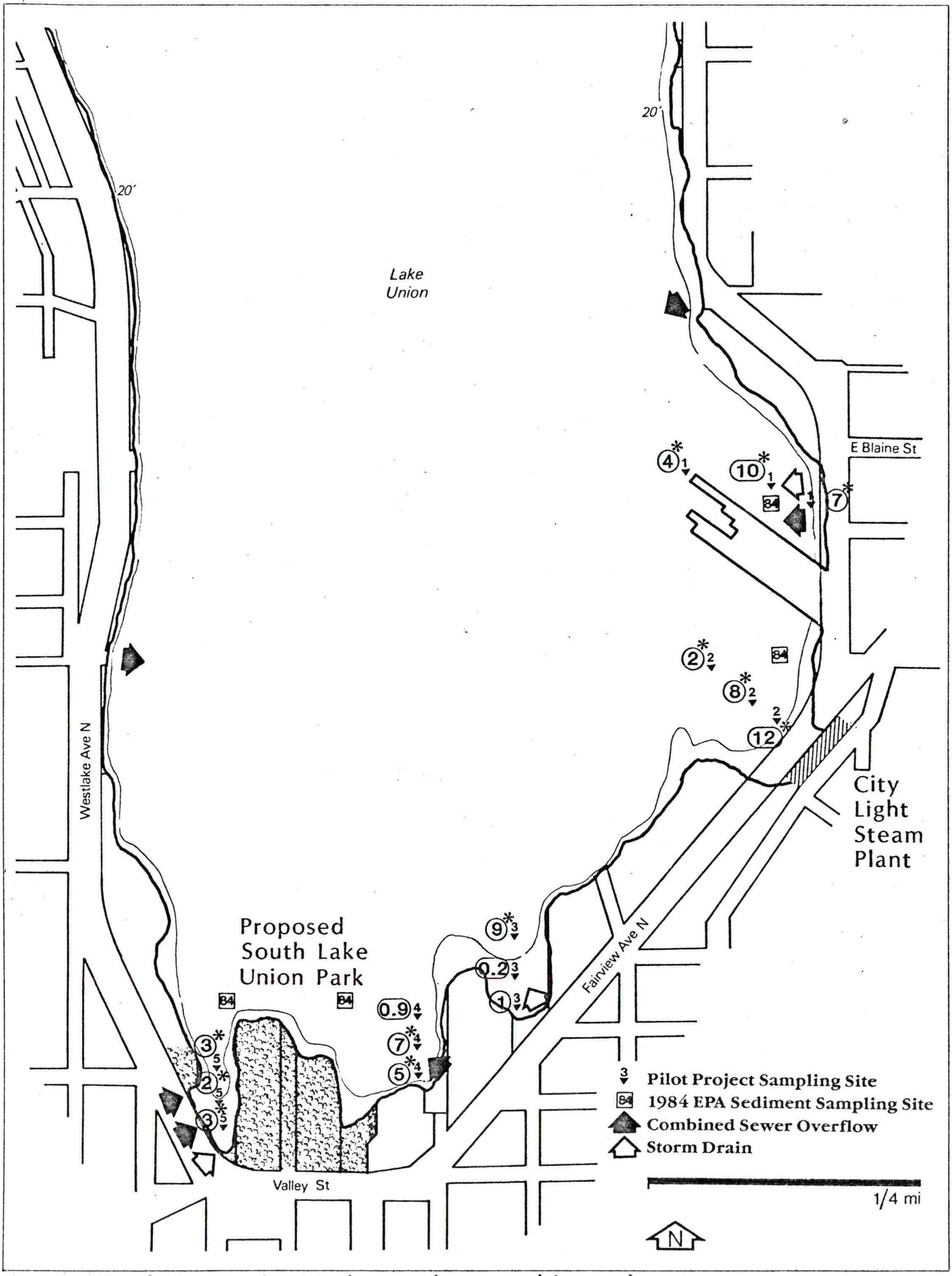

Figure 6: Total PCB Levels in Sediments (expressed in ppm)
*Figures exceed interim sediment quality values.

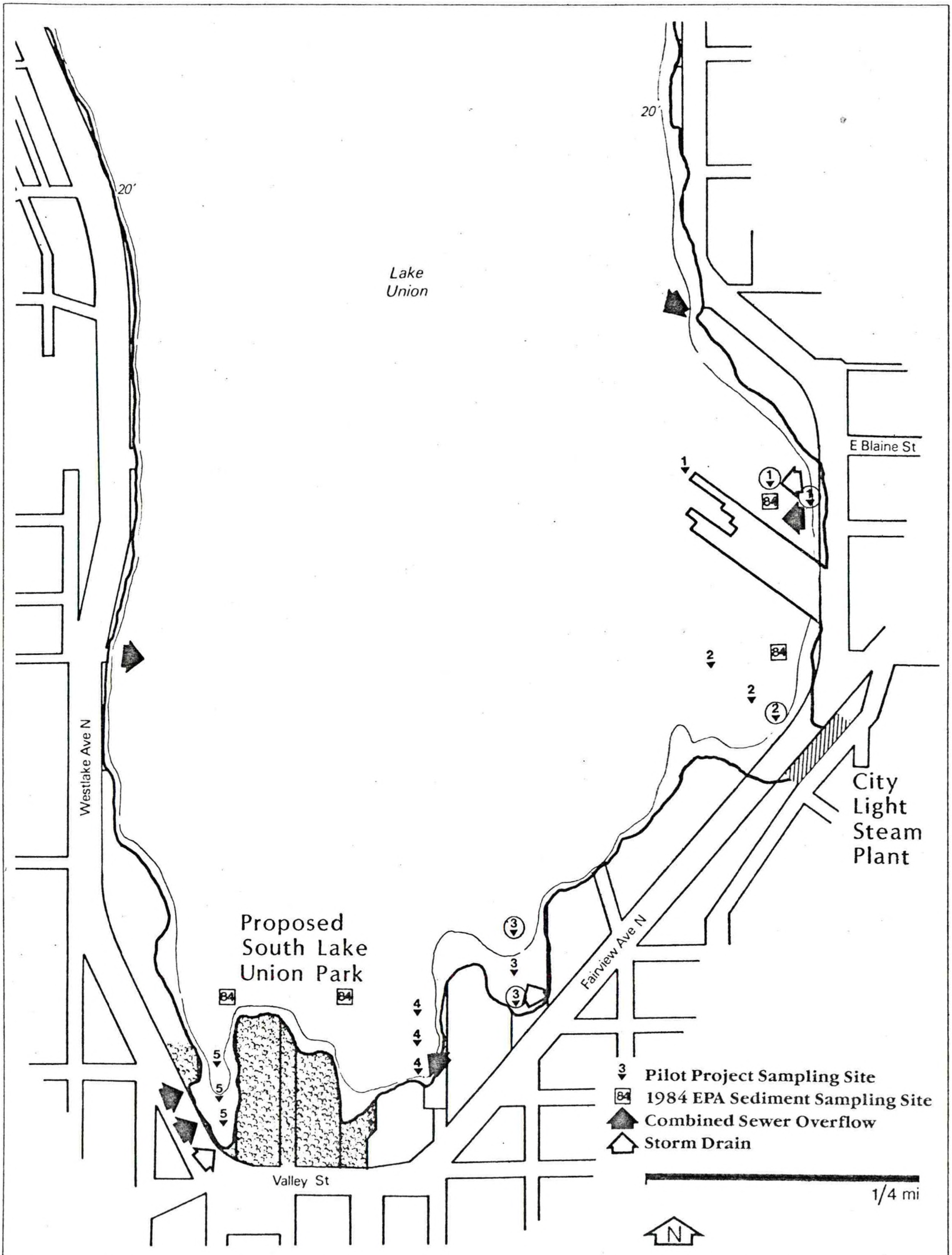

Figure 7: PAH s Exceeding Interim Sediment Quality Values (sampling sites circled)

Bioassays

Appendix G presents the microtoxicity bioassay results; i.e., concentration of interstitial water that caused 50 percent reduction in light emitted by bioluminescent bacteria after 5, 15, and 30 minutes exposure. This bioassay procedure is a screen to identify toxic sediments. The interstitial water in sediments from stations 1-150, 2-50 and 2-150 is very toxic when compared to the results from the other sediment samples and when compared to results from Elliott Bay sediment samples, many types of industrial waste from Seattle area industries, and West Point sewage treatment plant influent and effluent. Data from this bioassay probably reflects metal toxicity because metals are water soluble whereas most organic chemicals are not. In order to screen toxicity of PCBs and PAHs to aquatic biota, it would be necessary to include an organic extraction step in the bioassay procedure.

IV ADDITIONAL STUDIES

Metal and PCB Levels in Crayfish Tissues

Another question to be explored in the pilot project is whether crayfish harvested from the South Lake Union area contain toxicant levels that exceed FDA standards for dietary consumption or exceed levels found in other commonly harvested fish and shellfish.

Crayfish burrow in the sediments and migrate in the water column throughout Lake Union. As indicated previously, the FDA standard for PCBs in fish and shellfish is 2 ppm. Fish and shellfish bioaccumulate PCBs at concentrations higher than in the surrounding water or sediments.

Several heavy metals and PCB mixtures were found at elevated levels in many of the sediment samples near the Lake Union Drydock Company, the City Light Steam Plant and the proposed new City park. In August 1986, crayfish will be harvested by baited traps from sections 2 and 5 of the pilot project area. Both raw and cooked edible (tail) tissue will be analyzed for metal and PCB levels.

Data obtained from the study will indicate if contaminated sediments near the Steam Plant or proposed City park pose a human health hazard from ingestion of crayfish, and if the new park should be designed to encourage or discourage fishing.

Benthic Community Analyses

Depending on funding availability, additional biological testing (sediment bioassays, benthic community analyses) will be performed to correlate levels of toxic chemicals in sediments with impacts on biota. For example, amphipod mortality tests could be conducted on sediments that were highly toxic in the microtoxicity bioassay (sampling sites 1-150, 2-50, 2-150) and/or contained high concentrations of metals and PCBs. In addition, the infaunal trophic index could be determined for the benthic community in sediments from these sites. The infaunal trophic index is a measurement of species abundance, diversity, and dominance. Benthic communities in highly polluted sediments may show less species diversity than benthic communities in nonpolluted sediments. Species that dominate a polluted area differ from species that dominate a nonpolluted area. The infaunal trophic index for each of the sediment samples will be correlated with levels of toxic chemicals in the sediments and the results of the micro-toxicity bioassays. This additional biological testing will provide more complete information on biological effects of contaminated sediments.

GLOSSARY

Amphipod Mortality Test -- A bioassay procedure in which amphipods (a large group of crustaceans composed of sand fleas and other related forms of animals) are exposed to various concentrations of sediments and percent mortality is measured.

Apparent Effects Threshold -- The concentration of a toxicant above which statistically significant biological effects would be expected.

Benthic Organisms -- Organisms that live in or on the bottom of a body of water.

Bioassay -- A laboratory test using a response of a test plant or animal (e.g., its growth of death) to measure the effect of a physical, chemical or biological variable.

Bioconcentration (bioaccumulation) -- Concentration or accumulation of a toxicant in an organism at levels many times higher than in the surrounding water or sediments.

Biological Oxygen Demand (BOD) -- The quantity of oxygen-demanding biological materials present in a sample as measured by a specific test. BOD is defined as a conventional pollutant under the Federal Clean Water Act.

Bioluminescence -- The production of light by living organisms.

Biota -- The animal and plant life of a particular region.

Carcinogenic -- Cancer-causing.

Chemical Oxygen Demand (COD) -- The quantity of oxygen-demanding chemical materials present in a sample as measured by a specific test. COD is defined as a conventional pollutant under the Federal Clean Water Act.

Coliform Bacteria -- A type of bacteria which includes many species. Fecal coliform bacteria are those coliform bacteria which are found in the intestinal tracts of warm blooded animals. The presence of high numbers of fecal coliform bacteria in a water body can indicate the release of untreated sewage, and/or the presence of animals, and may indicate the presence of pathogens.

Combined Sewer Overflow (CSO) -- A pipe that discharges untreated wastewater during storms, from a sewer system that carries both sewage and stormwater. The overflow occurs because the system does not have the capacity to transport and treat the increased flow caused by stormwater runoff.

Conventional Pollutant -- One of the pollutants specified under the Federal Clean Water Act. The list includes total suspended solids, coliform bacteria, BOD, COD, pH, and oil and grease.

Dissolved Oxygen -- Oxygen which is present (dissolved) in water and therefore available for fish and other aquatic animals to use. If the amount of dissolved oxygen in the water is too low or zero, then exposed aquatic animals will die.

Dredging -- Any physical digging into the bottom of a water body.

Ecological Magnification -- Increasing concentration of a toxicant as the food web is ascended, higher levels of toxicant in each predator than in its prey (i.e. higher levels in fish or shellfish than in aquatic insects; higher levels in humans than in fish or shellfish).

Eutrophication - The process by which a lake reaches a higher trophic state, caused by the addition of nutrients and its consequences.

Hot Spot -- A sediment area that has especially high concentrations of a particular pollutant, compared with other areas.

Hydrocarbon -- An organic compound that contains carbon and hydrogen.

Industrial Discharge -- The release of wastewater or contaminants from industrial practices to the environment. A direct discharge flows directly into surface waters (e.g., lakes) while an indirect discharge enters a sewer system.

Infaunal Trophic Index - Measurement of abundance, species diversity and species dominance of benthic animals that live beneath the sediment.

Land Use -- The way land is developed and used in terms of the types of activities allowed (residences, commercial establishments, industries, etc.) and the size of buildings and structures permitted.

Nutrients -- Essential chemicals needed by plants or animals for growth. Excessive amounts of one nutrient or several nutrients can lead to the growth of excessive numbers of particular plants and/or degradation of water quality.

Organic Chemical -- A chemical that contains carbon.

Pathogens -- Microorganisms, such as bacteria, that cause disease.

pH -- A measure of the acidity or alkalinity of a substance. A pH of 7.0 indicates neutral water. A pH of 6.5 indicates slightly acidic water. A pH of 8.5 indicates alkaline (basic) water. The pH of water influences many of the types of chemical reactions that will occur in it.

Polychlorinated Biphenyls (PCBs) -- A group of ubiquitous, environmentally persistent chlorinated hydrocarbons (between 12%-68% chlorine). PCBs were formerly used in insulating fluids in capacitors and transformers, in the plastics industry, and in hydraulic fluids and lubricants. PCBs can cause cancer. They have caused birth defects in laboratory animals and are believed to be capable of causing birth defects in humans also.

Polycyclic Aromatic Hydrocarbons (PAHs) (sometimes called polynuclear aromatics or PNAs) -- Many ringed organic chemicals containing carbon and hydrogen. They are formed as a result of incomplete combustion of organic materials, e.g., coal, coke, wood, tobacco. Some PAHs can cause cancer.

ppb -- Parts per billion; 1 ppb of a chemical means 1 gram of that chemical in every 1,000,000,000 grams (1,000,000 liters) of water. A liter of water weighs 1,000 grams (about 2.2 pounds) and is slightly more than a quart in volume.

ppm -- Parts per million; 1 ppm of a chemical means 1 gram of that chemical in every 1,000,000 grams (1,000 liters) of water.

Priority Water Pollutants -- 126 toxic water pollutants so designated by EPA under the Federal Clean Water Act because they have several of the following properties: 1) demonstrated ability to kill aquatic organisms; 2) cause cancer; 3) ability to bioconcentrate; 4) environmentally persistent; 5) ubiquitous; 6) volume of production or use by industry; 7) capability of analytical detection. The list includes metals, asbestos, cyanide, and organic (carbon-based) chemicals such as PCBs, PAHs, and pesticides.

Sediment -- Material suspended in or settling to the bottom of a liquid. As used here, it refers to the sand and mud that makes up much of the shorelines and bottom of Lake Union/Ship Canal.

Species Diversity -- A measure of the number and types of species found in a particular community of plants and animals, e.g., a benthic community. Species diversity can be an indicator of pollution. Benthic communities in highly polluted sediments may show less species diversity than benthic communities in nonpolluted sediments.

Species Dominance -- A measure of which species of plants and animals are most numerous in a particular community, e.g., a benthic community. Species dominance can be an indicator of pollution. Species that dominate a polluted area differ from species that dominate a nonpolluted area.

Toxicant -- A chemical that poses a risk of producing an adverse biological effect or in some way damaging a living oranism.

Turbidity -- A measure of the amount of material suspended in the water. Increasing the turbidity of the water decreases the amount of light that penetrates the water column. High levels of turbidity are harmful to aquatic life.

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APPENDIX A. SEDIMENT DESCRIPTION, PERCENT SOLIDS AND DEPTH

Station Number 1/	Sample Description	% Solids	Depth (meters)
1-50	some surface oil, smells of oil, lots of fiber and roots.	36.1	7.2
1-150	very oily, black, gel-like (one grab caught a paint can lid)	26.1	10.8
1-300	black, gel-like, some sand-like granules, iron appears to be on surface.	40.1	12.8
2-50	similar to 1-300 with gray streaks through it, not much sand.	19.1	9.5
2-150	soft, crust-like and brown on surface; gray and smooth beneath; some light rusty brown clay with gray streaks (each grab different).	17.1	11.1
2-300	no information	37.1	8.9
3-50	sand, mud, wood fibers, black, rubber odor, a lot of debris and plastic bags (several grabs missed rocks and wood chips)	58.8	5.0
3-150	sandy mud, a lot of gravel	65.3	5.1
3-300	soft black and gray mud	42.3	10.4
4-50	lots of debris and bottles (hard to get sediment grabs)	79.5	3.2
4-150	black gel mud, oil odor	30.9	8.3
4-300	no information	41.1	6.6
5-50	black muck, oil	43.4	6.5
5-150	black mud, some sand, burnt oil odor	40.3	6.0
5-300	surface rusty brown, dark gray and black mud with thin layer of wood chips, not much odor	31.0	8.1

1/ The second part of the number indicates distance in feet from the shoreline.

APPENDIX B. CONVENTIONAL WATER QUALITY PARAMETERS 1/

Parameter	Station (see Figure 5) 2-300	5-300
Temperature	19.2°C	17.7°C
pH	7.8	7.9
Dissolved oxygen	10.1	10.1
Total dissolved solids	68.5	70.5
Total suspended solids	1.6	2.0
Kjeldahl nitrogen	0.29	0.27
Biological oxygen demand	1.4	1.5
Chemical oxygen demand	6.11	6.11
Ammonia	0.005	0.007
Orthophosphate	0.006	0.003
Nitrite and nitrate	0.082	0.082
Total phosphate	0.0123	0.0052
Total coliforms	110/100 ml	220/100 ml
Fecal coliforms	23/100 ml	30/100 ml

1/All figures are given in parts per million (ppm) except for temperature, pH and coliforms.

APPENDIX C. HEAVY METAL LEVELS IN SOUTH LAKE UNION WATER SAMPLES (ppb)

Stations	Metals								
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc
2-300	4.0	<0.1	<1.0	<1.0	<1.0	<20.	<1.0	<0.2	<1.0
5-300	4.0	<0.1	<1.0	<1.0	<1.0	<20.	<1.0	<0.2	<1.0
Detection Limit	1.0	0.1	1.0	1.0	1.0	20.	1.0	0.2	1.0
Drinking Water Standard	10.0	2.0	10.0	NA	1.0	1.0	NA	10.0	NA
Freshwater Acute Criteria	360.0	3.9	16(Cr^{+6}) 1700(Cr^{+3})	18.0	8.2	2.4	1800	4.1	320
Freshwater Chronic Criteria	190.0	1.1	11(Cr^{+6}) 210(Cr^{+3})	12.0	3.2	0.012	96	0.12	47
Water Quality Criteria Based on Water Ingestion	NA	10 µgs.	50 µgs. (Cr^{+6})	170 mgs.	50 µgs.	144 µgs.	13.4 µgs.	50 µgs.	5 mgs.

NA = Not applicable. This means that there is no standard or criterion for this particular metal.

APPENDIX D. CONVENTIONAL SEDIMENT QUALITY PARAMETERS

Station	BOD(ppm)	COD(%)	Oil and Grease(ppm)	Total Organic Carbon(%)
1-50	2042	2.6	277	7.70
1-150	3388	4.8	66	5.79
1-300	2901	1.4	15	1.35
2-50	2349	4.2	21	4.83
2-150	2671	2.9	22	3.95
2-300	1079	2.3	13	2.60
3-50	2321	3.5	269	2.85
3-150	1799	1.5	208	1.93
3-300	2823	6.8	400	6.83
4-50	1368	0.2	171	0.66
4-150	3438	2.9	134	4.15
4-300	1752	7.1	16	0.83
5-50	3069	4.8	303	5.44
5-150	3510	5.0	380	5.79
5-300	2216	4.1	112	5.34

APPENDIX E. METAL LEVELS IN SOUTH LAKE UNION SEDIMENT SAMPLES

SAMPLE SITE	CONCENTRATION (ppm)								
	ZINC	COPPER	CHROMIUM	LEAD	ARSENIC	MERCURY	CADMIUM	SILVER	NICKEL
1-50	*286.	77.9	11.5	*634.	17.4	*2.97	1.07	1.23	12.2
1-150	*342.	180.	12.0	*436.	51.24	*20.4	1.17	0.251	12.4
1-300	*1107.	*471.	*57.2	*410.	*247.	*27.3	0.912	0.149	11.5
2-50	99.1	77.3	5.95	116.	7.94	*6.56	0.679	0.183	7.41
2-150	107.	73.2	6.45	114.	11.3	*7.24	0.412	0.150	7.09
2-300	5.73	34.4	8.08	41.6	13.1	*7.10	0.417	0.135	12.5
3-50	20.7	43.9	13.5	31.6	33.6	*2.11	0.881	0.364	18.0
3-150	103.	23.4	10.3	73.9	2.80	*2.02	0.596	0.242	16.8
3-300	247.	64.5	12.7	43.5	23.9	*9.18	1.49	0.242	14.0
4-50	123.	42.8	8.62	52.6	11.1	*3.92	0.661	0.749	12.4
4-150	161.	53.3	10.9	13.6	2.92	*3.60	0.928	0.299	12.3
4-300	78.2	18.5	5.47	31.3	9.45	0.352	0.451	0.414	5.39
5-50	196.	45.9	9.43	234.	2.96	*7.78	0.942	0.588	13.6
5-150	133.	31.8	6.80	118.	7.30	*3.85	0.667	0.198	10.6
5-300	140.	39.3	7.94	144.	6.45	*8.94	0.751	0.343	11.0
Interim Sediment Quality Value	260	310	59	300	85	0.88	5.8	5.2	49

Asterisked samples are those in which the metal level exceeds interim sediment quality values (for Puget Sound sediments), based on benthic community health effects.

APPENDIX F. ORGANIC PRIORITY POLLUTANT LEVELS 1/ IN SOUTH LAKE UNION SEDIMENT SAMPLES 2/ (expressed as parts per million (ppm) dry weight)

	PCBs			PAHs	
Station	A-1242	A-1254	A-1260	Acenaphthene	Acenaphthylene
1-50	ND	4.65*	2.18*	0.39	ND
1-150	ND	8.37*	2.09*	0.35	0.49
1-300	ND	3.06	0.91	0.21	ND
2-50	ND	9.06*	3.41*	0.38	ND
2-150	ND	5.50*	2.01*	0.28	ND
2-300	ND	0.98	0.58	0.11	ND
3-50	0.19	1.05	0.26	0.67	ND
3-150	ND	0.16	0.08	0.35	ND
3-300	0.83	6.22*	2.43*	5.23*	ND
4-50	ND	4.73*	0.55	0.31	ND
4-150	ND	4.87*	2.54*	0.37	ND
4-300	ND	0.92	ND	0.21	ND
5-50	ND	1.94*	0.81	0.21	ND
5-150	ND	1.36*	0.78	0.11	ND
5-300	ND	2.10*	0.77	ND	ND
Interim Sediment Quality Value	1.10	1.10	1.10	0.50	0.64
Detection Limit	0.04	0.04	0.04	0.10	0.18

1/ Asterisked samples are those in which the chemical level exceeds interim sediment quality values (for Puget Sound sediments), based on benthic community health effects.

2/ Includes only those chemical concentrations above the minimum quantifiable limit.

ND = Not detected in the samples.

PAHs

Station	Anthracene	Benzo(a) Anthracene	Benzo(a) Pyrene	Benzo(b) Fluoranthene	Benzo(k) Fluoranthene
1-50	1.13	2.58	1.36	1.71	1.00
1-150	3.54*	0.51	0.90	0.63	0.63
1-300	0.22	0.11	ND	2.10 (TOTAL)	
2-50	ND	1.27	ND	ND	ND
2-150	ND	1.41	0.53	1.34 (TOTAL)	
2-300	0.19	ND	0.35	0.58 (TOTAL)	
3-50	1.08	0.60	3.04	4.30 (TOTAL)	
3-150	0.34	0.76	0.80	1.40 (TOTAL)	
3-300	0.55	2.21	1.60	5.02 (TOTAL)	
4-50	0.47	1.40	1.08	0.94	1.05
4-150	0.31	1.12	0.82	1.07 (TOTAL)	
4-300	ND	0.65	0.32	0.97 (TOTAL)	
5-50	0.56	1.33	2.89	5.75 (TOTAL)	
5-150	0.26	0.68	0.64	1.14 (TOTAL)	
5-300	0.28	0.96	0.97	1.41 (TOTAL)	
Interim Sediment Quality Value	1.30	4.50	6.80	8.00	8.00
Detection Limit	0.10	0.10	0.13	0.24	0.13

PAHs

Station	Benzo(ghi) Perylene	Chrysene	Dibenzo(ah) Anthracene	Fluoranthene	Fluorene
1-50	ND	3.75	ND	6.89*	0.79*
1-150	ND	2.80	ND	3.98	0.50
1-300	ND	2.45	ND	3.13	0.24
2-50	ND	1.58	ND	1.89	2.00*
2-150	ND	1.73	ND	3.03	0.25
2-300	ND	0.76	ND	1.05	0.17
3-50	2.16	4.63	0.65	7.90*	0.79*
3-150	0.61	0.78	ND	2.02	0.36
3-300	ND	3.31	ND	5.12	0.50
4-50	0.97	1.51	ND	2.60	0.43
4-150	0.44	1.23	ND	1.75	0.41
4-300	ND	0.67	ND	0.76	0.11
5-50	1.83	2.34	0.50	4.95	0.32
5-150	0.67	0.81	ND	2.07	0.16
5-300	0.74	1.20	ND	2.75	0.24
Interim Sediment Quality Value	5.40	6.70	1.20	6.30	6.40
Detection Limit	0.21	0.13	0.13	0.11	0.10

PAHs

Station	Indeno(1,2,3-cd) Pyrene	Naphthalene	Phenanthrene	Pyrene
1-50	ND	0.76	5.25*	6.10
1-150	ND	0.19	2.98	3.43
1-300	ND	ND	1.30	2.73
2-50	ND	0.17	1.46	1.77
2-150	ND	0.23	1.45	2.70
2-300	ND	0.21	0.63	1.06
3-50	3.09	0.57	7.13*	6.94
3-150	0.80	0.58	1.91	2.15
3-300	ND	0.37	3.85	4.98
4-50	1.19	0.33	2.55	2.28
4-150	0.49	0.32	1.75	1.54
4-300	ND	ND	0.99	0.56
5-50	1.66	0.91	3.11	5.03
5-150	0.49	0.54	1.30	2.33
5-300	0.53	0.67	1.38	2.89
Interim Sediment Quality Value	5.20	2.10	3.20	7.30
Detection Limit	0.19	0.08	0.27	0.10

OTHER CHEMICALS

Station	Chloroform	Methylene Chloride	Xylene	Bis(2-ethylhexyl) phthalate
1-50	ND	ND	0.13	18.30*
1-150	0.04	ND	ND	2.74*
1-300	ND	0.07	ND	4.23*
2-50	ND	0.23	ND	3.78*
2-150	ND	0.17	ND	29.40*
2-300	ND	ND	ND	25.30*
3-50	ND	ND	ND	25.10*
3-150	ND	ND	ND	2.55*
3-300	ND	0.10	ND	84.60*
4-50	ND	0.15	ND	1.27
4-150	ND	ND	ND	3.37*
4-300	ND	ND	ND	2.71*
5-50	ND	ND	ND	17.60*
5-150	ND	ND	ND	10.20*
5-300	ND	ND	ND	16.40*
Interim Sediment Quality Value	not available	not available	1.20	1.90
Detection Limit	0.03	0.06	0.07	0.13

OTHER CHEMICALS

Station	Butyl Benzyl-phthalate	Di-n-butyl-phthalate	Di-n-octyl phthalate	1-4-Dichloro-benzene	Phenol
1-50	2.75*	0.67	1.91	0.73*	0.08
1-150	0.30	0.60	ND	ND	0.12
1-300	1.10*	0.67	3.85	ND	ND
2-50	ND	0.39	ND	ND	ND
2-150	0.56	0.42	1.57	ND	ND
2-300	ND	0.31	2.14	ND	ND
3-50	1.58	0.79	1.10	ND	ND
3-150	0.24	0.23	1.27	ND	0.08
3-300	4.69	0.47	6.05	ND	ND
4-50	0.34	ND	0.17	ND	ND
4-150	0.26	0.32	0.60	ND	ND
4-300	ND	0.15	0.29	ND	ND
5-50	1.09*	0.33	1.56	ND	ND
5-150	0.51*	0.18	0.93	ND	ND
5-300	0.54*	0.27	1.47	ND	0.08
Interim sediment quality value	0.47	5.10	68.00	0.12	1.20
Detection limit	0.13	0.10	0.10	0.27	0.08

APPENDIX G. MICROTOXICITY BIOASSAY RESULTS

PPM INTERSTITIAL WATER CAUSING
50% LIGHT REDUCTION (EC50)

Station	EC50-5 min	EC50-15 min	EC50-30 min
1-50	NT	NT	NT
1-150	36,000	33,000	45,000
1-300	314,000	230,000	202,000
2-50	47,000	42,000	51,000
2-150	45,000	38,000	49,000
2-300	184,000	135,000	168,000
3-50	946,000	NT	NT
3-150	NT	NT	NT
3-300	NT	NT	NT
4-50	194,000	156,000	140,000
4-150	387,000	318,000	358,000
4-300	217,000	195,000	203,000
5-50	208,000	150,000	141,000
5-150	225,000	189,000	314,000
5-300	171,000	114,000	154,000
Elliott Bay (mean of 14 samples)			404,000
West Point influent	452,000	175,000	150,000
West Point effluent (without chlorination)	373,000	249,000	199,000
West Point effluent (with chlorination)	81,000	64,000	69,000

NT = Non-toxic

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