TC 3015
Final Report

GAS WORKS PARK
SUPPLEMENTAL SOILS TESTING
PHASE I SURFACE SOILS ANALYSIS

by

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for

Seattle Parks Department
Seattle, WA

September, 1985

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INTRODUCTION

This report presents the soil testing results for polynuclear aromatic hydrocarbons (PAH), cyanide, and physical observations obtained during the Phase I Supplementary Soils Testing at Gas Works Park in Seattle, Washington (Tetra Tech 1985a). Tetra Tech, Inc., and its subcontractor Hokkaido Drilling & Developing Inc., obtained 251 surface soil samples and 6 tar samples from the Park property. Sampling was conducted from March 15 through March 22, 1985. Of these samples, soils from 34 sites located throughout the park plus additional replicate samples for quality assurance were analyzed under funds allocated to the Phase I effort. The remaining samples were retained in frozen storage for testing originally scheduled under a Phase II effort. These analyses will now be conducted only if the City should identify the need for further data on surface soils of the park.

BACKGROUND

The sampling activities and soil testing summarized in this report were conducted in response to the City of Seattle's desire to supplement the earlier findings of the U.S. Environmental Protection Agency (EPA) and the University of Washington. During 1983 and 1984, government and university investigators initiated sampling for toxic materials in offshore sediments, and surface and subsurface soils. As a result of health concerns related to benzo(a)pyrene and other contaminants, Mayor Charles Royer temporarily closed the park on April 21, 1984, until further analyses could be made. The Mayor established a Health Advisory Committee and subsequently reopened portions of the park deemed to be safe by the Committee. The Committee and the Mayor recommended that it would be prudent to conduct additional testing and investigations of the site. The surface soil sampling was conducted in order to meet these additional testing requirements.

The Phase I project included as part of its scope of services the development of a plan for investigating groundwater quality at the Park. This plan was submitted to the Parks Department on April 24, 1985 (Tetra Tech 1985b) and is under consideration for eventual Phase II implementation.

FIELD METHODS

The placement of stations, soil sampling methods, and analytical procedures are described in detail in the Sampling and Analysis Plan (Tetra Tech 1985a). The objectives of the field operations were to:

- Establish a randomly positioned, evenly spaced sampling grid for locating sampling stations (random systematic sampling)
- Obtain five surface subsamples (top 2 inches of soil below the root zone) within a 10 ft diameter circle at each station and mix together (composite) to provide a minimum 8 oz soil sample
- Obtain additional surface soil samples to estimate the extent of "hot-spot" areas identified by previous investigators
- Follow quality assurance/quality control and safety plans to assure safe, effective program execution.

A total of 235 samples plus 16 replicate samples were collected from 235 stations located within the park boundries. Of these stations, 183 were located on intersections of a regular, triangular grid system. An additional 5 sampling sites were located at midpoints between intersections of the grid to ensure sampling of a ravine in the park. The grid had a station-to-station distance of 70 ft and was oriented so that lines and stations are parallel to latitude and longitude lines defined by City of Seattle Department of Engineering topographic maps for Sections 19 and 20. Finally, a total of 47 sampling sites were selected by locating up to 8 more closely spaced stations in each of 7 areas identified in previous investigations as containing soils with high concentrations of PAH.

During sampling, each station was photographed, and the sampler noted any unusual observations (i.e. oily residues in the soil) in the field log book.

Sample collection and delivery were conducted in accordance with chain-of-custody procedures prescribed by the National Enforcement Investigations Center (U.S. EPA 1978).

SOIL TESTING

Under the limitations of the Gas Works Park Phase I analytical program, soils from 34 of the 235 sampling sites were submitted for determination of polynuclear aromatic hydrocarbons (PAH) concentrations. An additional 4 replicate soil samples and a certified reference standard were submitted to the laboratory as part of the quality assurance (QA) program. These QA samples included:

- Laboratory duplicate samples prepared from soils homogenized in the field and submitted for 2 of the 34 sites to assess laboratory precision
- Field duplicate samples submitted for the same 2 sites to assess sampling plus analytical variability at each site
- A certified reference standard of urban dust available from the U.S. National Bureau of Standards to assess the accuracy of the PAH results.

The laboratory mistakenly analyzed all the provided QA soil samples in duplicate resulting in the reporting of data for multiple replicates at each of the 2 sites used for QA analysis. These additional data were used to provide a better measure of the variability associated with the sampling and analyses than had been originally planned.

ANALYTICAL METHODS

Sample Preparation

Aliquots of Gas Works Park soil samples and QA samples were analyzed for PAH in March-April 1985 by California Analytical Laboratories under contract with Tetra Tech. To gain a representative estimate of the variability associated with the material present at each site, samples were not seived through screens or ground to a fine powder. However, twigs, leaves, grass, litter, and all objects larger than 0.5 inches in diameter were excluded from the samples in the field by the sampling crew. No additional material was permitted to be excluded from the sample by the analytical laboratory. Soil aliquots were analyzed by the laboratory after reasonable efforts were made to homogenize each sample by stirring. Soils were not dried prior to analysis to avoid loss of the more volatile PAH.

Extraction and Cleanup Procedures

Soil extracts were prepared from 5 to 30 g wet weight aliquots using a continuous liquid-solid (Soxhlet) extraction device with pre-extracted cellulose thinbles. A 4:6 solvent mixture of high purity methylene chloride/acetone was used to extract the samples for a minimum of 16 hours as specified in EPA Method 3540. The soil/solvent mixtures were stirred at least twice during the extraction procedure to prevent solvent channeling.

Water and acetone were removed from the resulting extracts by fractionating against 50 mL of organic-free water in a separatory funnel, with sodium chloride added as needed to reduce emulsions. The aqueous phase was further extracted with two 50 mL portions of dichloromethane. The pooled organic phases containing the PAH were back-extracted with 50 mL of aqueous sodium chloride to enhance removal of water, dried with sodium sulfate, concentrated to a minimum volume of 1 mL while exchanging the solvent to methanol.

Major interfering substances were removed from the extracts using disposable 3 mL solid phase extraction columns (SPE; Baker-10 Octadecyl columns) prior to analysis by high pressure liquid chromatography (HPLC). All SPE columns were precleaned by washing with 10 mL of methanol. Sample extracts were transferred to the SPE columns and PAH were eluted through the columns with a total of 10 mL of methanol and concentrated. If a reduction to a final minimum volume of 0.5 mL was required, the volume was reduced below 1 mL by gentle evaporation under purified nitrogen gas.

Instrumental Analysis

All sample extracts were analyzed for PAH by reverse-phase HPLC with both ultraviolet (UV) and fluorescence detection according to EPA Method 610/8310. Aromatic hydrocarbons quantified by UV detection included naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, and chrysene. Compounds quantified by fluorescence detection included fluoranthene, pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)-fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene. Planned verifications of compound identities by gas chromatography-mass spectroscopy in selected samples were not conducted under the constraints of Phase I funding.

QUALITY ASSURANCE / QUALITY CONTROL

All data were generated in accordance with approved EPA quality assurance procedures for laboratory analyses including the use of standard calibration curves for instrumental analyses, replicate analyses, the analysis of a certified standard reference material. Data were reviewed by the laboratory before release and subjected to an independent QA review by Tetra Tech. All data were checked for outliers, and a portion of the data reports (10 of the 44 data reports received) were verified back to original instrument data sheets provided by the laboratory.

Calculations

No major errors in transcription of data from original data sheets were encountered during QA review. Final dry weight data values referenced to standard calibrations and areas integrated for each sample peak were automatically calculated by computer in one step on the original data sheets. Minimum detection limits attained for each compound were as specified (i.e., 0.1 ug/kg dry weight or less). Samples with residual interferences, or samples requiring dilution because of high concentrations of some PAH, necessitated elevation of the minimum detection limits by either one or two orders of magnitude. This adjustment was appropriate based on review of the chromatograms provided. Critical PAH such as benzo(a)pyrene were well resolved from all interfering peaks in all chromatograms reviewed.

Checks on Laboratory Contamination

Analyses of blanks (i.e., reagents carried through the entire procedure in the absence of sample) demonstrated that there were no contamination from the laboratory procedure above the minimum detection limit.

Accuracy

Summary accuracy data are given in Table 1. These data were generated from the analysis of a sample of urban dust containing certified concentrations of PAH in the 1 to 10 ppm range. Duplicate analyses of the reference material were requested but were overlooked by the laboratory. Because the laboratory had already analyzed an excess of QA samples and additional reference material was not readily available, the single analysis provided was accepted.

The data demonstrate good to excellent agreement with available NBS reference data (Table 1) for almost all compounds. An exception was the concentration of benzo(g,h,i)perylene, which was more than twice as high as certified for the reference material. The single benzo(g,h,i)perylene data value reported by the laboratory is anomolous and may be due to co-elution of an interfering substance. The significance of this anomolous value is difficult to interpret without replicate data for the standard reference material. Such anomolies are not apparent in a review of the Gas Works soil data. Benzo(g,h,i)perylene concentrations reported relative to other PAH concentrations in Gas Works Park soils are similar to the ratios observed in many environmental samples contaminated with PAH.

Precision

Summary precision data for analytical (laboratory) and site (sampling) variability of PAH analyses are given in Table 2. Precision data were available for samples from two grid sites. Soil from one of these sites contained PAH concentrations near or less than the 1 mg/kg (ppm; dry weight)

TABLE 1. SUMMARY OF ACCURACY DATA

Compound	Amount Recovered (mg/kg)	NBS LC[a] Results (mg/kg)	NBS Certified (mg/kg)	Percent Recovery
Low Molecular Weight PAH				
Naphthalene	U17	NR	NR	--
Acenaphthylene	U17	NR	NR	--
Acenaphthene	U34	NR	NR	--
Fluorene	3.7	NR	NR	--
Phenanthrene	4.5	4.5	NR	100
Anthracene	0.34	NR	NR	--
High Molecular Weight PAH				
Fluoranthene	7.0	6.9	7.1	101 [99][b]
Pyrene	10	6.2	NR	161
Benz(a)anthracene	2.8	2.6	2.6	108 [108]
Chrysene	3.3	3.6	NR	92
Benzo(b)fluoranthene	6.1	6.2	NR	98
Benzo(k)fluoranthene	2.0	2.0	NR	100
Benzo(a)pyrene	2.2	2.6	2.9	85 [76]
Dibenz(a,h)anthracene	U6.7	0.41	NR	--
Benzo(g,h,i)perylene	11	4.6	4.5	239 [244]
Indeno(1,2,3-cd)pyrene	5.2	3.5	3.3	149 [158]

a Average of two National Bureau of Standards liquid chromatography methods provided with the standard reference material Urban Dust (Reference No. 1649).

b Values in brackets are the recovery values based on NBS certified values for the reference material.

U Undetected at the detection limit shown.

TABLE 2. SUMMARY OF PRECISION DATA

	Precision of Analyses[a]			
	Analytical Variability		Site Variability	
Compound	C-27 (n = 3)[b]	J-14 (n = 4)	C-27 (n = 6)	J-14 (n = 6)
Low Molecular Weight PAH				
Naphthalene	U1 ± 0%	U10 ± 0%	<1.1 ± 22%	U10 ± 0%
Acenaphthylene	U1 ± 0%	U10 ± 0%	U1 ± 0%	U10 ± 0%
Acenaphthene	U2 ± 0%	U20 ± 0%	U2 ± 0%	U20 ± 0%
Fluorene	U0.2 ± 0%	3.7 ± 55%	0.4 ± 110%	3.3 ± 52%
Phenanthrene	0.9 ± 30%	23 ± 36%	1.8 ± 150%	18 ± 55%
Anthracene	0.1 ± 38%	3.5 ± 32%	0.2 ± 150%	2.8 ± 50%
High Molecular Weight PAH				
Fluoranthene	1.6 ± 38%	40 ± 49%	2.2 ± 110%	32 ± 63%
Pyrene	2.6 ± 35%	67 ± 42%	3.4 ± 99%	54 ± 54%
Benz(a)anthracene	0.8 ± 40%	19 ± 32%	1.0 ± 90%	15 ± 53%
Chrysene	1.1 ± 35%	24 ± 34%	1.3 ± 86%	20 ± 46%
Benzo(b)fluoranthene	0.9 ± 33%	16 ± 28%	1.1 ± 73%	13 ± 41%
Benzo(k)fluoranthene	0.4 ± 31%	8.2 ± 29%	0.5 ± 71%	6.6 ± 47%
Benzo(a)pyrene	1.0 ± 30%	22 ± 28%	1.3 ± 80%	18 ± 42%
Dibenz(a,h)anthracene	U4 ± 0%	U4 ± 0%	U4 ± 0%	U4 ± 0%
Benzo(g,h,i)perylene	1.8 ± 29%	24 ± 20%	1.9 ± 55%	20 ± 33%
Indeno(1,2,3-cd)pyrene	1.3 ± 23%	20 ± 27%	1.6 ± 64%	17 ± 38%

[a] Precision data are reported in ug/kg (dry weight) ± the coefficient of variation (i.e., relative percent standard deviation) of the measurement. The number of replicate analyses (n) used in each determination is indicated for the two grid sites C-27 and J-14.

[b] One of a set of four analytical replicates for site C-27 was excluded because consistently high values were reported relative to the other three replicates. The data are believed to reflect environmental variability in the levels of PAH because of inhomogeneous sampling of the soil aliquot analyzed rather than laboratory analytical variability. The data for this sample are included in the summary of replicates reported for site variability at grid site C-27. Without this one replicate, the variability at grid site C-27 was reduced to nearly identical values as reported for the variability observed at grid site J-14.

U Undetected at the detection limit shown.

level per component. Soil from the second site contained much higher PAH concentrations ranging from 10 to 100 mg/kg per component.

The precision of the analytical measurements was nearly identical at each site (i.e., was independent of the actual level of contamination). Determinations of analytical precision reported in Table 2 are based on analyses of multiple aliquots of a single soil sample composited from each site. Coefficients of variation (i.e., the percent relative standard deviation) ranged from 20 to 55 percent at the two sites for compounds that were detected. Sources of variability include subsampling variability as well as analytical error. The range in total analytical variability is somewhat higher than the 20 percent target in the QA plan, but is acceptable given the inhomogeneous nature of the soils submitted for analysis.

The variability of replicate field analyses for each site was typically greater than the analytical variability. Two separate soil composites were collected at each of the two QA sites and multiple aliquots of each composite were analyzed. Field sampling variability was estimated by determining the coefficient of variation for all replicates (i.e., a total of 6) analyzed from the two soil composites collected at each site. Sampling variability ranged from 33 to 63 percent for detected compounds at grid site J-14. Sampling variability ranged from 55 to 150 percent for detected compounds at grid site C-27. The greater variability at grid site C-27 was associated with much lower PAH concentrations than at grid site J-14. When the consistently high values of one of the six replicates from grid site C-27 were excluded, the sampling variability at the two sites was nearly identical.

TEST RESULTS

Polycyclic Aromatic Hydrocarbons (PAH)

The concentration of total PAH and benzo(a)pyrene for the 34 sites analyzed are shown in Figure 1. A summary of data by individual PAH and grid site is given in Table 3. Data are reported as mg/kg (ppm) dry weight (i.e., corrections for the percent moisture in each sample have been made).

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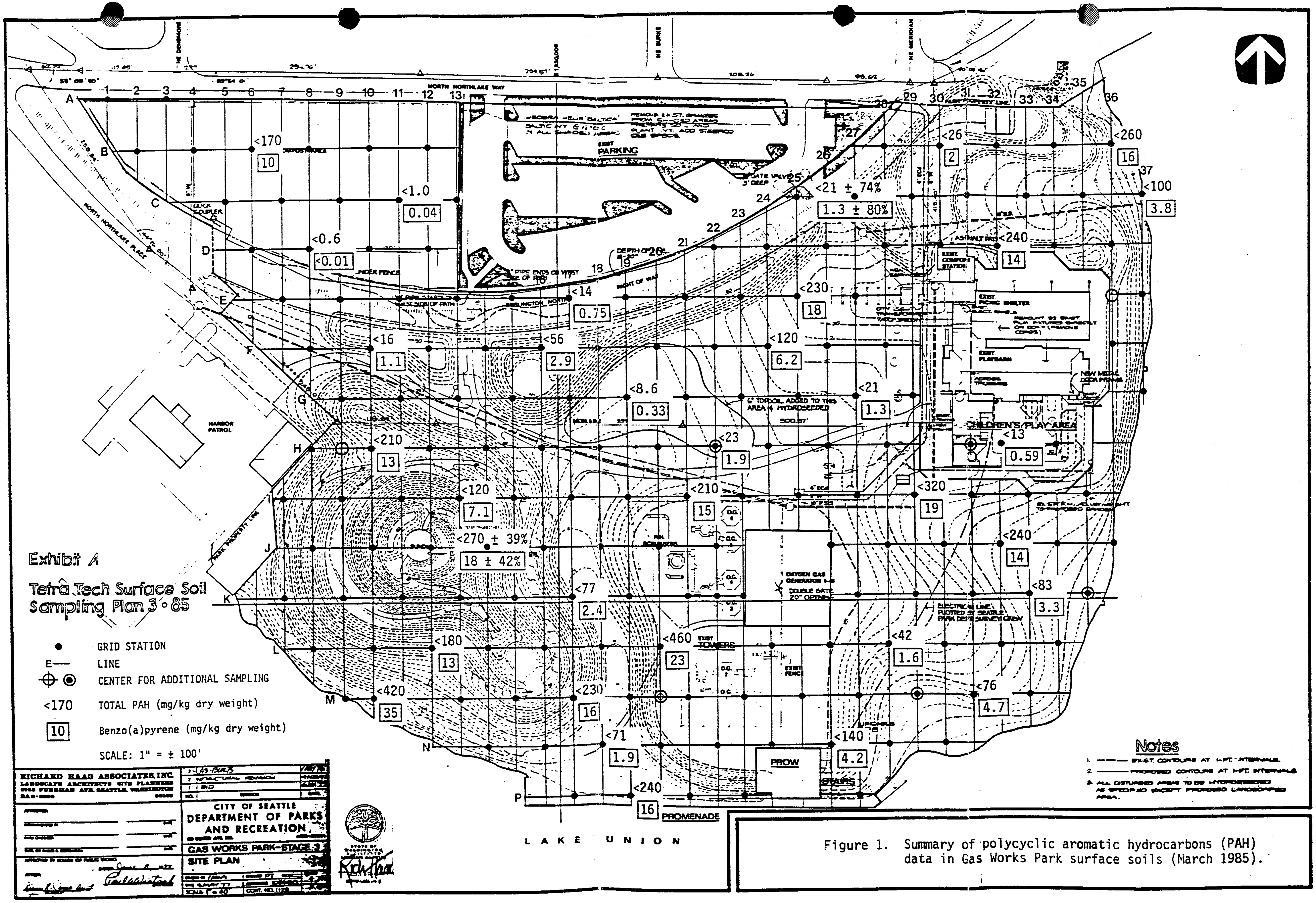

Figure 1. Summary of polycyclic aromatic hydrocarbons (PAH) data in Gas Works Park surface soils (March 1985).

TABLE 3. SUMMARY OF PAH DATA
(mg/kg dry weight)

	Grid Site													
Compound	**B6-00**	**B30-00**	**B36-00**	**C11-00**	**C27-00**	**C27-00a**	**C27-10a**	**C27-10a**	**C27-20a**	**C27-20a**	**C37-00**	**D8-00**	**D32-00**	**E17-00**
naphthalene	U 10	U 1	U 10	U 0.1	U 1	U 1	1.6	U 1	U 1	U 1	U 10	U 0.1	U 10	U 1
acenaphthylene	U 10	U 1	U 10	U 0.1	U 1	U 1	U 1	U 1	U 1	U 1	U 10	U 0.1	U 10	U 1
acenaphthene	U 20	U 2	U 20	U 0.2	U 2	U 2	U 2	U 2	U 2	U 2	U 20	U 0.2	U 20	U 2
fluorene	U 2	0.2	7.4	U 0.02	U 0.2	U 0.2	1.2	U 0.2	U 0.2	U 0.2	U 2	U 0.02	U 2	U 0.2
phenanthrene	4.4	1.4	32	0.033	0.67	1.2	7.4	0.84	0.36	0.39	7.5	0.0097	11	1.1
anthracene	0.64	0.18	3.9	U 0.002	0.068	0.15	0.88	0.11	0.045	0.047	2.0	U 0.002	2.3	0.14
fluoranthene	15	2.5	32	0.067	1.0	1.5	7.2	2.2	0.78	0.69	9.2	0.01	34	1.1
pyrene	28	4.5	49	0.090	1.7	2.6	10	3.5	1.4	1.1	12	U 0.02	56	1.8
benzo(a)anthracene	8.6	1.6	4.5	0.030	0.46	0.89	2.7	1.1	0.42	0.36	3.3	U 0.01	15	0.53
chrysene	12	2.0	21	0.048	0.67	1.2	3.5	1.4	0.57	0.52	6.1	U 0.01	18	0.96
benzo(b)fluoranthene	10	1.6	12	0.047	0.60	0.91	2.5	1.2	0.58	0.49	3.0	0.0089	11	0.65
benzo(k)fluoranthene	4.7	0.7	5.9	0.022	0.27	0.43	1.1	0.52	0.24	0.24	1.3	U 0.005	5.4	0.30
benzo(a)pyrene	10	2.0	16	0.040	0.70	1.1	3.3	1.3	0.67	0.62	3.8	U 0.01	14	0.75
dibenzo(a,h)anthracene	U 4	U 0.4	U 4	U 0.04	U 0.4	U 0.4	U 0.4	U 0.4	U 0.4	U 0.4	U 4	U 0.04	U 4	U 0.4
benzo(g,h,i)perylene	16	2.9	21	0.11	1.2	2.1	3.9	2.1	1.3	1.0	3.3	U 0.02	15	1.3
indeno(1,2,3-c,d)pyrene	13	2.5	16	0.074	1.0	1.3	3.5	1.6	0.95	0.95	3.6	U 0.01	13	1.1

Compound	**E25-00**	**F10-00**	**F16-00**	**F24-00**	**G19-00**	**G27-00**	**H10-00**	**H22-00**	**H32-00**	**I13-00**	**I21-00**	**I29-00**	**J14-00**	**J14-00a**
naphthalene	U 10	U 1	1.0	U 10	U 1	U 1	U 10	U 1	U 1	U 10	U 10	U 10	U 10	U 10
acenaphthylene	U 10	U 1	U 1	U 10	U 1	U 1	U 10	U 1	U 1	U 10	U 10	U 10	U 10	U 10
acenaphthene	U 200	U 2	U 20	U 20	U 2	U 2	U 20	U 2	U 2	U 20	U 20	U 20	U 20	U 20
fluorene	6.4	0.34	1.9	U 2	U 0.2	1.3	4.6	0.47	U 0.2	U 2.0	2.9	4.4	4.7	6.0
phenanthrene	15	0.56	1.8	5.2	0.16	1.2	12	0.92	0.70	4.1	14	35	21	31
anthracene	2.3	0.072	0.28	0.91	U 0.02	0.19	2.2	0.14	0.074	0.81	2.1	3.9	3.4	4.8
fluoranthene	20	1.2	4.7	7.9	0.53	1.8	22	1.6	1.1	10	19	44	27	47
pyrene	38	2.2	7.8	15	0.84	3.2	38	3.3	1.9	16	34	63	47	80
benzo(a)anthracene	12	0.66	2.0	4.8	0.25	1.1	12	1.2	0.57	5.4	12	19	15	26
chrysene	14	0.87	2.6	5.9	0.37	1.2	15	1.5	0.79	7.1	15	22	17	33
benzo(b)fluoranthene	13	0.88	2.3	4.5	0.34	1.3	11	1.5	0.53	6.4	11	15	12	19
benzo(k)fluoranthene	5.7	0.38	1.0	1.8	0.14	0.57	4.5	0.57	0.23	2.6	5.0	6.9	5.3	8.0
benzo(a)pyrene	18	1.1	2.9	6.2	0.33	1.3	13	1.9	0.59	7.1	15	19	16	27
dibenzo(a,h)anthracene	U 4	U 0.4	0.48	U 4	U 0.4	U 0.4	U 4	U 0.4	U 0.4	U 4	U 4	U 4	U 4	U 4
benzo(g,h,i)perylene	22	1.9	3.2	10	0.54	2.4	14	2.9	0.91	9.4	21	24	20	29
indeno(1,2,3-c,d)pyrene	19	1.4	2.6	8.0	0.43	1.3	14	2.8	1.2	9.1	15	18	15	25

TABLE 3. (Continued)

Compound	Grid Site												
	J14-10[a]	J14-10[a]	J14-20[a]	J14-20[a]	J32-00	K17-00	K33-00	L12-00	L20-00	L28-00	M10-00	M17-00[b]	M31-00	M18-00
naphthalene	U 10	U 10	U 10	U 10	U 10	U 10	U 10	U 10	U 10	U 1	U 10	U 10	1.3	U 10
acenaphthylene	U 10	U 10	U 10	U 10	U 10	U 10	U 10	U 10	U 10	U 1	U 10	U 10	U 1	U 10
acenaphthene	U 20	U 20	U 20	U 20	U 20	U 20	U 20	U 20	U 20	U 20	U 20	U 20	U 20	U 20
fluorene	U 2	U 2	U 2	U 2	U 2	U 2	U 2	U 2	20	2.2	U 2	U 2	1.6	U 2
phenanthrene	26	12	10	6.3	9.7	3.2	2.5	11	79	1.2	14	9.4	2.2	1.5
anthracene	3.6	2.1	1.7	1.1	2.7	0.3	U 0.2	1.9	10	0.21	2.8	1.6	0.36	0.21
fluoranthene	65	22	19	12	42	4.4	4.6	2.0	65	1.9	57	24	6.8	2.8
pyrene	100	41	34	24	56	6.8	6.7	36	100	3.2	100	41	11	4.5
benzo(a)anthracene	23	13	8.0	6.0	13	1.2	2.7	11	27	1.1	32	12	3.5	1.4
chrysene	28	17	13	9.6	16	2.8	3.3	14	29	1.5	27	16	4.2	1.8
benzo(b)fluoranthene	20	12	9.0	6.7	12	2.0	3.2	11	17	1.3	28	13	3.7	2.0
benzo(k)fluoranthene	8.3	11	3.8	2.9	5.7	0.8	1.2	4.4	8.0	0.59	13	5.4	1.7	0.79
benzo(a)pyrene	28	18	12	9.4	14	2.4	3.3	13	23	1.6	35	16	4.7	1.9
dibenzo(a,h)anthracene	U 4	U 4	U 4	U 4	U 4	U 4	U 4	U 4	U 4	U 0.4	U 4	U 4	3.1	U 4
benzo(g,h,i)perylene	26	19	14	12	7.3	3.6	4.9	16	18	2.6	27	24	5.6	4.4
indeno(1,2,3-c,d)pyrene	23	15	11	10	14	3.4	4.8	16	20	1.9	29	19	5.3	3.5

Compound	N26-00	P19-00
naphthalene	U 10	U 10
acenaphthylene	U 10	U 10
acenaphthene	U 20	U 20
fluorene	U 2	U 2
phenanthrene	5.4	15
anthracene	2.8	2.6
fluoranthene	19	36
pyrene	26	48
benzo(a)anthracene	5.8	11
chrysene	7.8	14
benzo(b)fluoranthene	4.9	12
benzo(k)fluoranthene	2.1	5.5
benzo(a)pyrene	4.2	16
dibenzo(a,h)anthracene	U 4	U 4
benzo(g,h,i)perylene	10	15
indeno(1,2,3-c,d)pyrene	8.4	14

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[a] Replicate samples analyzed for grid sites C27 and J14. Additional codes indicate: -00 = original sample; -10 = analytical replicate prepared from the same soil composite as the -00 sample; -20 = field replicate prepared from a separate composited soil at the same site. Duplicate sample numbers are reported for each code because the laboratory mistakenly split and analyzed each submitted QA sample in duplicate.

[a] Reported on a wet-weight basis. All other values are on dry-weight basis.

U = Undetected at the detection limit shown.

Total PAH concentrations ranged from <0.6 to <460 mg/kg dry weight. These totals represent the sum of concentrations for the 16 EPA priority pollutant PAH and include detection limits for those compounds that were not detected (indicated by a sum preceded by a "<" symbol). Naphthalene, acenaphthalene, and acenaphthylene were undetected in most samples (Table 3). Higher molecular weight compounds, with the exception of dibenzo(a,h)-anthracene, were detected in almost all samples. Benzo(a)pyrene concentrations ranged from U 0.01 to 35 mg/kg dry weight (the U denotes undetected at the lower range of concentrations). The maximum benzo(a)pyrene value detected is comparable to benzo(a)pyrene concentrations in a reference soot sample analyzed by the University of Washington (1984), and exceeds benzo(a)pyrene concentrations analyzed in a National Bureau of Standards reference urban dust sample by over a factor of 10 (Table 1).

The range of PAH concentrations found in the surface 2 inches of Gas Work Park soils is less than the range reported in past EPA studies of soils composited over 6 inches and 3 feet (U.S. EPA 1984). The range of benzo(a)pyrene concentrations is comparable to that reported in a study of the surface 1 inch of Gas Work Park soils (University of Washington 1984). Benzo(a)pyrene concentrations in all but one sample exceed the range of concentrations reported for Seattle Park reference areas (i.e., four Greenlake and Volunteer Park samples ranging from undetected at 0.005 ppm to detected at 0.036 ppm ; University of Washington 1984).

Cyanide

Historical EPA data (U.S. EPA 1984) indicated that cyanide concentrations were elevated to several hundred ppm in 6 inch and 3 foot composite samples collected near grid site H-22 (Figure 1). Cyanide data for 4 separate surface samples collected at grid site H-22 are reported in Table 4. Cyanide analyses were conducted by Am Test, Inc. under contract to Tetra Tech, Inc. The maximum concentration found for these soils was 73 mg/kg dry weight, of which 4.9 mg/kg was determined to be present as weak acid dissociable cyanide.

TABLE 4. CONCENTRATION (mg/kg dry weight) OF TOTAL AND WEAK ACID DISSOCIABLE CYANIDE AT GRID SITE H-22

Grid Site	Total Cyanide (mg/kg dry weight)	Weak Acid Dissociable Cyanide (mg/kg dry weight)
H-22-01	38	--
H-22-03	73 ± 2.9%	4.9
H-22-05	17	--
H-22-07	U 0.5	--

U: Undetected at the detection limit shown.

SUMMARY OF PHYSICAL OBSERVATIONS

The Phase I supplementary soils testing included a review of the park history and physical observations at the park to assist in identifying the potential locations of contaminants. The historical review included analyses of photographs, reports, and interviews with individuals involved with park construction. Previous geotechnical investigations conducted in the park and recorded with the City Engineer were also extensively reviewed and were summarized in the groundwater investigation plan (Tetra Tech 1985). Physical observations included photographs and comments entered by the field samplers in the field logbook.

HISTORICAL REVIEW

Aerial photographs of Brown's Point (Walker & Associates Inc. 1936, 1946, and 1960) taken prior to park construction were obtained and included in the project file. The 1946 and 1960 photographs show the presence of the American Tar facilities in the northwest corner of the park (south of the railroad right-of-way). Seventeen vertical tanks located inside a bermed area were also present south of the playbarn (compressor plant) and were probably part of the light oil plant. All three photographs show the presence of black, granular material in piles near the present location of the prow (south of the oxygen generator towers).

An oblique aerial photograph (Figure 2) taken in 1970 (City of Seattle Engineering Department, File No. 25862-1) shows the condition of the inactive gas plant prior to the park development. The two fixed-roof tanks located in the bermed area at the northwest corner of the park have been demolished and the large floating-roof gas tank is partially demolished. The slightly elevated mound that formed the base for kite hill can also be seen in the west portion of the site. The American Tar facilities are at their present location north of the park.

Review of photographs (1973 - 1978) taken during and after park construction and on file at the Parks Department showed that a layer of black granular material was placed in the kite hill mound prior to its completion.

Figure 2. Gas Works Park site prior to park development, September 1970.

Comparison of the present-day shoreline with that shown on a 1907 plat map supplied by the Seattle Engineering Department shows the amount of lake shore filling that has occured during this century. This earlier shoreline is shown on the site map accompanying the field operations plan for the Phase II groundwater investigation (Tetra Tech 1985b).

An earlier report on the history of Gas Works Park (Richard 1983) provides a summary of the park construction and background on the remaining structures.

FIELD OBSERVATIONS

General observations of the park shoreline and interior were made during the sampling program. Outcrops of solid slag materials were observed in the vicinity of the shoreline, particularly under the prow structure and west of the prow. Other outcropings were noted at the shoreline south and southwest of kite hill and at several points along the eastern shoreline. These observations confirm the extent of initial filling that has extended the shoreline outward.

Some tar and oily residues have also been observed at the foundations and bases of various retained plant equipment. These structures include the oxygen generator and scrubber towers (enclosed in a fence) in the center of the park, precipitators (southwest corner of the playbarn) and other towers in the park area. Some of these materials were removed during the recent cleanup and painting of the playbarn interior.

Tar was also observed seeping up through the asphalt sidewalk in the northwest section of the park, south of the railroad right-of-way. This area is the general vicinity of the old tar plant originally located on the site. The city has attempted to pave (seal) some of the larger seeps (5 or 6 inches in diameter). However, they continue to penetrate the asphalt, particularly during the warmer months.

Contaminants observed during sampling at each station are listed in Table 5. Photographs of soil samples were also viewed in order to identify those displaying a dark, blackish, oily or slag color. The corresponding stations are listed in Table 6. The locations of the stations in Tables 5 and 6 are shown in Figure 3. Two of these stations are located in the northwest (walled-in) area on an older surface adjacent to a storage area for newer fill material. Three dark-colored samples were obtained from the railroad right-of-way and correspond with the oily soils observed in this area. Both dark-colored samples from the kite hill area were obtained from approximately the same elevation. These samples may be associated with the layer of deposited slag observed in the construction photographs; although additional subsurface exploration would be necessary for confirmation. Other samples listed in Tables 5 and 6 are in the vicinity of the old compressor plant and light oil plant (south of the playbarn).

TABLE 5. FIELD LOGBOOK OBSERVATIONS

Grid Site	Observation
B12	mostly slag in sample
B28	pieces of asphalt (probably from sidewalk)
C7	mostly slag in sample
D28	pieces of slag in sample
F22	large lump of coal material removed from sample
H9	large piece of slag observed
I23	organic odor noted at this location
J32	damp, surface seep
K35-01	surface seep
M29-01, M29-02	sawdust in samples

TABLE 6. GRID SITES WITH DARK-COLORED SOILS

B12
C33
C35
E9
E11
E19
E36
F20
H14
H22
H26
J32
K18
K35-01

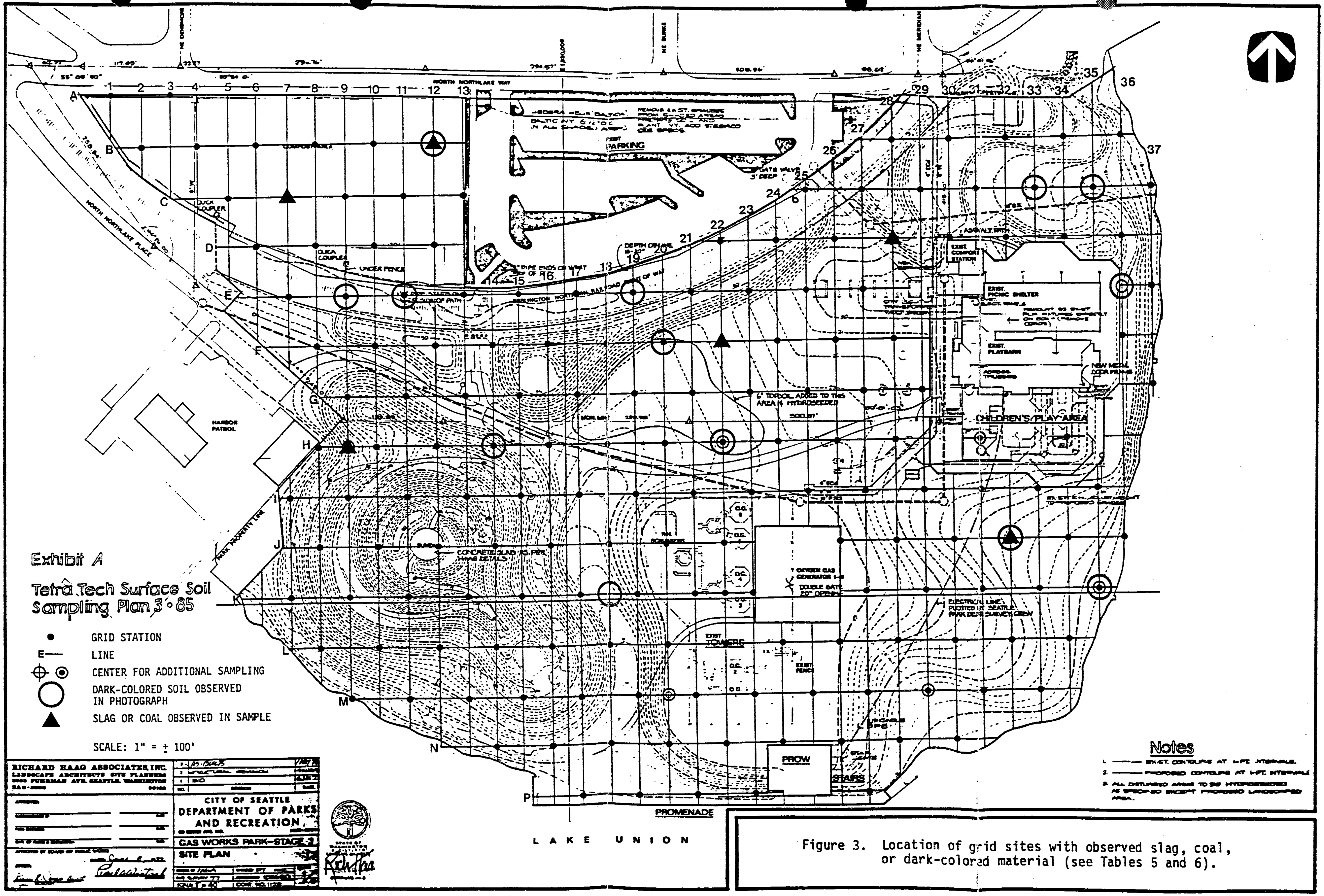

Figure 3. Location of grid sites with observed slag, coal, or dark-colored material (see Tables 5 and 6).

RECOMMENDATIONS FOR CONTINUED MONITORING

Soil samples from the remaining 148 untested grid sites may be analyzed for PAH content during a subsequent project phase (Phase II). There are several alternatives for prioritizing the sample analysis:

1. Test samples where slag or dark-colored soils were observed (Tables 5 and 6): 21 samples (plus a minimum of 5 percent replicate QA samples)

2. Test samples obtained from surfaces that are at or below the original site elevation of the gas plant (e.g. not covered by new fill material): approximately 70 samples (plus a minimum of 5 percent replicate QA samples)

3. Test samples obtained from high-density public-use areas (as suggested by EPA reviewers). These areas can be identified by inspecting aerial visual or infrared photographs obtained during peak-use days: approximately 100 samples (plus a minimum of 5 percent replicate QA samples)

4. Test all samples held in archive: 213 samples (includes the remaining 12 replicate QA samples collected).

Each option represents an increase in the initial number of samples tested (and testing costs). The third option is recommended since it is based, in part, on the original objective of the supplementary soils testing program: protection of public health. It would also include a majority of the samples included in the first two options. The analysis of at least duplicate standard reference samples (i.e., NBS Urban Dust) is also recommended to establish the accuracy and comparability of the analyses.

Once a baseline for park soil contamination is established, long term monitoring should focus on three key areas in the park:

1. Areas where contaminants are migrating vertically (e.g., the old tar-plant location)

2. Any areas that exceed contaminant criteria established by the City that might be identified during the Phase II testing

3. Areas where soil and vegetative cover applied during the park construction may be erroding, exposing underlying materials.

The latter areas include the elevated land behind (north of) the prow, the southeast shoreline area, and the low-lying drainages that cut into the park interior from the shoreline. Some of these eroded areas have already been covered over with soil/grass seed mixtures to maintain the park lawn and control erosion.

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