CHARACTERIZATION OF FORMER RAILWAY LANDS AT THE PACIFIC PLACE SITE

by

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ABSTRACT

This paper presents an analysis of data from railway lands at the former EXPO 86 site in downtown Vancouver, B.C. The data collection, data presentation and methods of analysis are discussed for the railway lands which are representative of non-specific contamination sources. The shallow contamination resulting from the railway activity is rather randomly distributed over the railway lands. The assessment of sufficient sample size, areal distribution of sampling locations, and the statistical analysis of chemical data are discussed. The results of this review and the implications for subsequent remedial planning are presented for two parcels from the overall site.

Keywords: railway lands, site characterization, soil contamination, student t-distribution, F-test statistics.

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INTRODUCTION

The former EXPO 86 property is an 83 hectare (205 acre) site situated on the north shore of False Creek in Vancouver, British Columbia (Figure 1). The property was purchased by Concord Pacific Developments in May 1988 and is currently being developed for mixed residential/commercial land uses. The property, now designated as the Pacific Place site, has had a long history of industrial uses. As a result, the Soils Remediation Group (SRG) has been retained by the Province of British Columbia to investigate soil and groundwater contamination at the site and to recommend site remediation measures required to meet the objectives of protecting human health and the environment in accordance with regulatory standards and requirements — the Standards — establish for this site (B.C. MOE,1989).

The Pacific Place site is a large, complex site. Potential contaminant sources have included a wide range of industries such as:

- coal gasification plants
- numerous sawmills, planning and shingle mills
- dip tank operations
- fuel pipelines and storage tanks
- numerous factories and warehouses
- railyards, the former C.P.R. Roundhouse and various other buildings associated with the railyards

In addition, contaminants may have been introduced to the site through the use of contaminated fill during site infilling as False Creek was reclaimed commencing in the late 1800s.

The results of the field investigations conducted to date indicate that the volume of fill present at the Pacific Place site is in excess of 2 million cubic meters and up to 13 m thick near the shoreline. The large volume of fill and numerous contaminant sources has made the task of characterizing the site for remedial planning a difficult and challenging one.

The Pacific Place site can be divided into subareas having common land use and historical activities. Within the various subareas there are two broad contamination scenarios: localized and defined contamination versus irregular and quasi-random contamination[1]. These two classes of contamination have very different investigative objectives. For example, delineation sampling in areas of local extensive contamination exceeding the Standards which is associated with past activities such as the coal gasification plant and dip tank areas as compared with systematic sampling in areas of quasi-random contamination such as railway areas. For

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[1] the term quasi-random is used throughout this paper because the rail track locations, rail yard activities and the resulting contamination through surface discharges or burial are not considered truly random events.

those areas thought to contain quasi-random contamination the areas may be best characterized with the assistance of statistical techniques.

This paper focuses on the characterization of areas where the contamination may be considered quasi-random in nature and utilizes published data collected from the railway lands at the Pacific Place site for illustration purposes.

Following a brief description of the former railway lands activity the paper outlines the original hypotheses set out as investigative objectives, the results and comparison with these hypotheses, and finally the potential use of these results for remediation planning and field monitoring.

FORMER RAILWAY LANDS - HISTORICAL USE

Development on the north shore of False Creek was initiated in 1885 when the government reserve was granted to the Canadian Pacific Railway (CPR). The first development on the site was in 1887 with the erection of the CPR Roundhouse. The shoreline gradually moved into False Creek using random fill materials from undocumented sources. Most of the rail tracks were constructed between 1900 and 1940 and remained in use until the early 1980s. For the purposes of this discussion, the railway lands are defined as the former tracked areas and adjacent freight sheds within the area shown on Figure 2.

Contamination sources at the former railway lands include spillage or leakage during cargo transfer and storage, oil spraying for dust control, leachate from creosote-treated railway ties, drainage of chromate-treated cooling water from engine boilers, and spillage or discharges during the general use of oils and cleaning solvents. The list of analytical parameters chosen for the Phase 1 investigation is presented as Table 1 and reflects this broad range of contamination sources both in the fill zone at placement and subsequent impacts from the railway activities.

INVESTIGATION PLANNING

To focus the site investigations and minimize expenditures a phased program was planned. Phase 1 of the program consisted of an initial field screening of the areas using soil vapor surveys and geophysical investigations at sites of potential underground storage tanks followed by a soil and groundwater sampling program. The field screening assisted in developing a sampling plan which was to provide an indication of the general presence and nature of contamination over the site. A second, more focused investigation program formed Phase 2 of the work which provides delineation of contamination sources identified in the Phase 1 program, collects baseline data in utility corridors, and provides supplementary data in those areas where the fill could remain in place and systematic sampling of the fill zone is required for characterization purposes in support of risk assessments or other remedial planning requirements.

The Phase 1 program was initially developed on a Parcel by Parcel basis rather than considering the entire site, to meet the developers planning schedules. Consequently, there were often other controlling factors such as utility corridors and planned excavations which dictated the location and resulting areal frequency of sampling over the site. In the area of the former railway lands, a sampling and analysis plan was developed which took into consideration the possible sources of contamination and historical information about the fill types and thicknesses. The focus of the Phase 1 investigation in these areas was to investigate the possible contamination in the following stratigraphic units:

1. **Recent Fill**: over most of the railway lands a thin zone of clean granular fill was placed as part of the EXPO 86 developments.

2. **Older Fill**: this fill zone varies in thickness over the site and reflects the history of the False Creek shoreline filling. Contamination in the fill zone may have originated at the source of the fill and deposited at the site; resulted from the subsequent railway activities through local discharges, fill mixing or burial; or originated outside the railway areas and migrated through the fill or was moved onto the site from adjacent areas during site grading.

3. **Native Deposits**: geotechnical borings in the area indicated that the native deposits consist of silty sands, clayey silts and glacial till

The soil sampling plan was targeted to the 'Older Fill' zone where the majority of the soil contamination was suspected. In addition, fewer samples were collected in the Recent Fill and Native Deposits to confirm the absence of significant soil contamination in these units. Sampling locations were chosen to provide systematic coverage of the railway lands with targeted sampling in the areas of underground tanks, warehousing, and the like. Samples selected for chemical analysis were biased towards those where staining was present, elevated soil vapor readings were detected and where the fill was of general poor quality (i.e., contains woodwaste, demolition debris, etc.).

Grid or random sampling was not used in the railway lands during the Phase 1 investigation since it is not particularly useful in identifying relatively small isolated zones of contamination unless a very fine sampling grid is used. For example, in order to achieve a 80% probability of hitting a 20 m diameter contaminant source would necessitate spatial sampling on a 22.6 m grid based on geometric probabilities. This would correspond to over 1,600 sampling points across the entire Pacific Place site.

Soil vapor measurements at the Pacific Place site were made at an approximately 50 m grid across the site. Using a steel bar punch, 1.5 cm diameter holes were driven approximately

0.5 to 0.75 m into the soil. Soil vapours were drawn through a temporary probe consisting of 1.0 cm diameter PVC tubing placed in the hole and sealed at the ground surface. Organic vapours were measured using a Hnu Model 101 photo ionization detector (PID) while potentially combustible gases such as methane were measured using a Gastech 1238 combustible gas meter. Elevated soil vapour concentrations were encountered in a limited number of locations and were further investigated during the soil and groundwater sampling program.

Soil samples were collected from both borings and test pits during the Phase 1 program. Boreholes were drilled using a hollow stem auger with soil samples collected using a 2 inch I.D. split spoon at 0.76 m intervals. Between 3 and 5 samples per borehole were submitted for chemical analysis with preference given to samples from soil horizons which appeared to be contaminated based on visual or olfactory evidence. At test pit locations, samples included composite soil samples taken over the entire depth range of the test pit (usually 3 to 4 m) as well as discrete soil samples taken from different soil horizons. In most cases only the composite test pit sample was submitted for chemical analysis during the Phase 1 investigation.

The data and analysis presented in this paper represents the Phase 1 investigation results which are reported in public documents available at the SRG offices (SRG, 1989 a, b, c). Characterization of groundwater contamination on this site is not discussed herein is the subject of a separate technical paper.

RESULTS OF PHASE 1 INVESTIGATIONS

The Phase 1 field investigation at the former lands involved soil sampling and analysis from thirty test pits and thirty-six boreholes. At most locations three discrete samples from each borehole and one composite sample from each test pit were submitted for analysis. The test pit samples were generally composited over a 3 to 4 m range, except when the fill was shallow; in which case, the sample was limited to the total fill thickness. Boring and test pit log descriptions indicate that fill is generally between 1 and 3 m thick except at the east end of Parcel 3 and over much of Parcel 2 and 2E, where the fill is up to 7 m thick. The fill generally consists of a thin (between 0.1 and 1.5 m) layer of recent sand and gravel fill placed as a subbase for asphaltic surfacing prior to EXPO 86 overlying a more heterogeneous silt, sand and gravel fill ("Older" fill) with occasional occurrences of construction debris and woodwaste. At most sampling locations a black or brown stained fill layer was observed along the former ground surface.

The results of the Phase 1 chemical analysis confirmed that the anticipated distribution and quasi-random nature of contamination at the site which was limited to the Older Fill zone. The main constituents having moderately high levels of contamination relative to the Standards at a limited number of locations were Oil & Grease (O&G), arsenic, barium, chromium, copper, lead, tin, light aliphatic hydrocarbons (LAH) and polycyclic aromatic hydrocarbons (PAH). A summary of these results is presented in Table 2 which lists the minimum, maximum, median and arithmetic mean concentration for selected constituents in the Older Fill zone. Exceedances of the BC MOE Level C Standard were limited to O&G at 3 locations, LAH at 2 locations, arsenic at 2 locations and lead at 1 location. Numerous samples had concentrations between the Level B and C Standard including O&G at 15 locations, LAH at 9 locations and chromium at 12 locations. Almost all of the samples exceeded the Level B Standard for barium.

These results were found to be consistent with the historical review data and indicate that the data distributions for most constituents is lognormal or skewed more than lognormal with the exception of barium and chromium which appear to be approximately normally distributed.

ANALYSIS OF RESULTS

Prior to developing a remedial plan for the former railway lands, there are several questions to be addressed:

- how best should the data be presented and analyzed?
- has the fill zone been adequately characterized with the Phase 1 sampling grid?
- can data from the entire former railway land area at the site be considered a single data population?
- how best can the data be used for remedial planning?
- are there frequent localized "hot spots" requiring special remedial action?

To address these types of questions, the SRG has used a statistical summary of the data set as a tool for assisting in the application of engineering judgement. The use of statistical techniques are considered useful but have limitations when applied to data of the nature discussed in this paper.

There are a variety of useful data presentation techniques which can assist in evaluating the data set. Plan and section views of the data, which correspond to the geological information, provide a useful tool in correlating fill characteristics to chemical results. For example, a correlation of black staining or poor quality fill with high concentrations of oil & grease and PAH has been useful for many parts of the site. Another useful data presentation technique for some constituents is to plot concentration vs depth. For example, Figure 3 presents the concentration with depth for oil & grease, total PAH, copper and barium at the railway lands. The results show a clear trend of decreasing concentration with depth for oil & grease and total PAH concentrations with elevated levels in the upper 2 meters of the fill zone suggesting a surface discharge origin of the constituents. On the other hand, elevated copper concentrations are generally found at greater depths suggesting the contamination found may be a result of contaminated fill brought to the site. The barium concentrations, which are relatively constant with depth, indicate that railway activities and fill quality do not appear to impact this constituent. Other data presentation techniques such as 3-D surface analysis of concentration vs area and kriging have been used with limited success for selected constituents.

In planning an investigation program for railway lands or sites with similar quasi-random contamination sources, one is faced with the difficult question of how many sampling locations and data points are required to properly characterize the target zones. The SRG has used systematic sampling to develop a statistically significant data set for these areas. It is common practice to utilize indicator compounds for initial screening studies to provide an indication of potential contamination. While this approach .may have a sound basis at many sites, its application for railway lands is questionable. For example, Figure 4 presents the correlation between PAH compounds with oil & grease and with LAH. In both cases, there is no correlation over the wide data range encountered. These results demonstrate the importance of selecting sufficient samples for a detailed analysis of the chemicals of concern.

The distribution of concentration for many of the analytical parameters studied form normal or lognormal frequency distributions. For example, chromium over the railway lands formed an approximately normal distribution pattern as shown on Figure 5. This indicates that chromium concentration can be well represented using statistical techniques such as the mean, standard deviation and confidence limits for the mean concentration. Most of the other constituents formed a more skewed distribution as demonstrated by the frequency distribution for oil & grease shown on Figure 5. The proportion of composited samples from test pits versus discrete samples from either test pits or boreholes can also have a significant affect on the shape of the distribution observed. For example, for the oil and grease distribution shown in Figure 5, the maximum oil and grease concentration from composited test pit samples was 2420 mg/kg while the maximum oil and grease concentration from discrete samples was 26600 mg/kg. A Phase 1 sampling program using only composited samples would have led to quite different conclusions.

The complex nature of soil contamination at the Pacific Place site makes the application of statistical analyses of questionable value. The most useful application of statistics, however, is in areas where contamination is at similar levels over a widespread zone (i.e., oil and grease contamination along the former railway yard ground surface or in areas where the contamination is isolated, non-extensive and possibly random in nature [i.e., contamination resulting from spills or from imported fill brought to the site]). Under these circumstances, probabilistic methods can be used to estimate confidence limits for the "true" mean using the calculated arithmetic mean and the student t-distribution or other appropriate techniques. The one sided confidence interval for the upper limit (UL) of the "true mean" is:

$$UL = \bar{x} + \frac{s}{\sqrt{n}} \, t\,\alpha, n\text{-}1$$

where $\bar{x}$ = arithmetic mean
s = standard deviation
$n-1$ = degree of freedom
t = t distribution

The student t-distribution can be used to estimate the mean of a population when the sample size is less than 30 and the population is approximately bell shaped. For log normal distributions the confidence intervals can be calculated using statistics for the lognormal distribution or by a normal distribution which will result in a conservative estimate of the upper confidence limit. The Student t-distribution approaches the standard normal distribution as the number of samples approaches 30. As the number of samples decrease the sample variance and the confidence limit about the mean increases. The optimum number of samples is about 20 to 25. Fewer samples widen the confidence limit whereas further sampling generally does not significantly improve the estimate of the mean.

The effect of sample size on mean concentrations and upper confidence limits of the "true mean" for selected constituents is summarized on Table 3. The effect of sampling size was modelled by dividing the railway lands into several subareas and randomly choosing sampling locations. These results demonstrate the sensitivity to sample size and the utility of increasing the sample population for quasi-randomly occurring constituents. For example, the arithmetic mean for total PAH, chromium, copper and lead is rather insensitive to the number of sampling locations increasing from twenty to sixty. Similarly, the upper 95% confidence limit for the "true" mean changes only marginally when the sample size is tripled for these constituents. The arithmetic mean and standard deviation for oil & grease, however, demonstrates a marked decrease as sample size increases. Similarly, the upper 95% confidence limit on the mean reduces from 4284 to 1805 as the sampling locations increase from 20 to 60, respectively. The usefulness of a large sample database for most constituents at railway land sites should be carefully reviewed at the planning phase of the investigation program.

Population means for two sub-areas can also be compared using the Student t-distribution or the use of F-test statistics (i.e., the analysis of variance) by testing the hypothesis that the mean concentration is one sub-area is different than another sub-area for a particular level of significance. However, the question of whether a set of data points belongs to the population within the defined area or whether the points are associated with another population (i.e., another source or activity) can usually best be determined by inspection (i.e., best professional judgement of stratigraphy, history, land use, measured contamination and mechanisms of contamination migration).

An example of the application of the F-test statistic to the database discussed herein is presented in Table 4. There were two areas in the railway lands which appeared to have localized activity which influenced the metal concentrations. To evaluate the observation, the sample population from these two areas, Parcel 8 and Lot 3.1 of Parcel 3 (Figure 2), were compared to the data set from the rest of the railway lands on the Pacific Place site. The results are presented in Table 4 and indicate that, with the exception of chromium, the concentrations of arsenic, copper and lead in Parcel 8 would appear to be a separate and distinct population from the remainder of the railway lands.

In contrast, there appeared to be localized metals contamination within Parcel 3 in Lot 3.1. However, a comparison of selected constituents listed in Table 4 indicates that there is a reasonable probability that the mean value for these constituents is the same as that for the remainder of the railway lands. This would indicate that this data set would not form a separate and distinct population and should be considered as such in remedial planning for the railway lands. Therefore, the expected zone of metals contamination would be limited in areal extent. This type of data analysis has proven useful in evaluating the rational for selected removal of "hotspots" vs field monitoring or the application of risk assessment methods for remedial planning.

In contrast to the classical statistical analyses described above, geostatistics considers the spatial correlation of observed concentrations and used variogram analysis and kriging to provide a fuller understanding of the contamination present. Examples of environmental applications where geostatistical methods can be of use are characterizing lead and cadmium concentrations in soils surrounding smelter sites and outdoor atmospheric NO_2 concentrations in urban areas. Geostatistical applications are of limited usefulness at the Pacific Place site given the size and complexity of the site. At best, geostatistics could be used to provide contour maps of contamination concentrations in localized areas where closely spaced sampling points have been used to define contamination resulting from a known historical land use such as a dip tank operation or coal gasification plant.

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TABLE 1

Constituents for Analysis for Phase 1 Investigation

Constituent	Soil	Groundwater	Soil Gas**
Oil and Grease/Light Aliphatic Hydrocarbons	x	x	
Polycyclic Aromatic Hydrocarbons (PAH) Scan	x	x	
Volatile Organics Scan		x	x
Cyanide (Total and Free)	x	x	
Ammonia	x	x	
Metals by ICAP, (As, Cd, Cr, Cu, Pb, Hg, Zn and others)	x	x	
Major Ions (Cl, SO_4, NO_3, NO_2, Ca, Mg, Na, K)	x		
Conductivity	x	x	
pH	x	x	
Alkalinity		x	
Phenolics (total) x	x		
Polychlorinated Biphenyls (PCB)*	x	x	
Other soil gases (CH_4, CO, CO_2, O_2)			x

* for selected samples only

** supplementary analyses pending field survey

TABLE 2

Summary of Concentrations for Selected Constituents in Fill for Phase 1 Results – Railway Lands

Constituent	Minimum $(^{mg}/_{kg})$	Maximum[1] $(^{mg}/_{kg})$	Median[1] $(^{mg}/_{kg})$	Arithmetic Mean $(^{mg}/_{kg})$
Oil and Grease	< DL	26600	117	1054
Light Aliphatic Hydrocarbons	< DL	2020	20	94.1
Total PAH	< DL	40.2	0.35	3.33
Benzo(a) Pyrene	< DL	4.64	0.022	0.24
Arsenic	< DL	137	3.71	5.64
Barium	481	973	658	669
Chromium	89	381	175	183
Copper	5.5	422	22	33.7
Lead	< DL	1944	10	65.7
Zinc	17.4	842	49	64.0

Means and medians are "non-elevated", i.e., zero was used for concentrations below the detection limit.

TABLE 3

Effect of Varying Number of Sampling Locations on Mean Concentrations and Upper Confidence Limits

Constituent	Number of Sampling Locations	Arithmetic Mean (mg/kg)	Standard Deviation (mg/kg)	Upper 95% Confidence Limit (mg/kg)	B.C. MOE Level B (mg/kg)
Total PAH	20	5.6	7.5	8.5	20
	39	5.2	7.5	7.2	20
	60	4.8	7.3	6.3	20
Oil & Grease	20	2033	5835	4284	1000
	39	1366	4323	2505	1000
	60	1054	3535	1805	1000
Chromium	20	184	55	205	250
	39	185	61	201	250
	60	183	58	195	250
Copper	22	45	69	70	100
	43	38	54	51	100
	66	34	45	43	100
Lead	22	71	152	127	500
	43	87	260	152	500
	66	66	217	110	500

TABLE 4

Comparison of Mean Concentrations Using F-Test Statistics (Analysis of Variance)

I. Parcel 8 to Population (rest of railway lands excluding Parcel 3 - Lot 3.1).

Constituent	Sample Mean Parcel 8 ($^{mg}/_{kg}$)	Population Mean ($^{mg}/_{kg}$)	F-Statistic	Probabilitity Means are the same
Arsenic	13.8	4.1	5.92	0.017
Chromium	184.3	181.7	0.09	0.760
Copper	51.4	28.9	4.48	0.037
Lead	171.8	33.9	7.24	0.008

II. Parcel 3 - Lot 3.1 to Population (rest of railway lands excluding Parcel 8).

Constituent	Sample Mean Parcel 3 - Lot 3.1 ($^{mg}/_{kg}$)	Population Mean ($^{mg}/_{kg}$)	F-Statistic	Probabilitity Means are the same
Arsenic	3.9	4.1	.23	0.630
Copper	30.6	28.9	0.085	0.77
Lead	47.3	33.9	0.517	0.47

Number of Samples:

Parcel 8	: 31
Parcel 3 Lot 3.1	: 21 (includes Phase 2 data)
Rest of Railway Lands	: 73

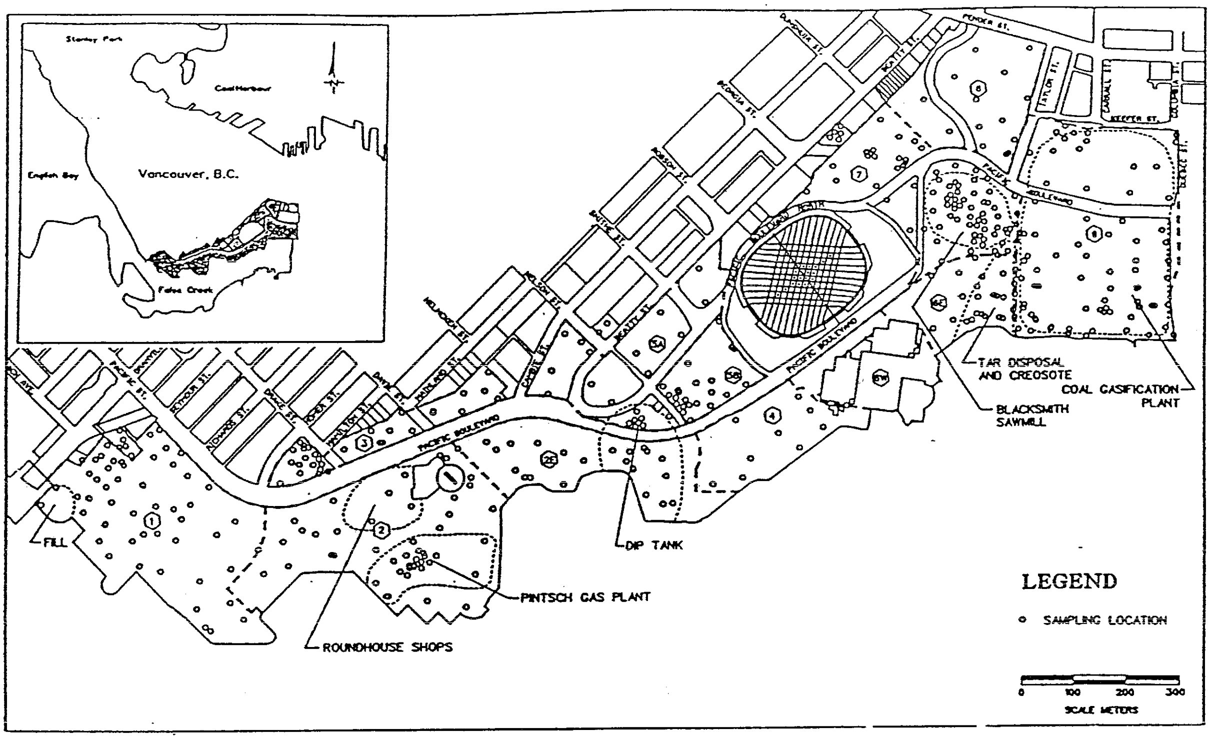


FIGURE 1 : Site plan with sampling locations and major areas of contamination.

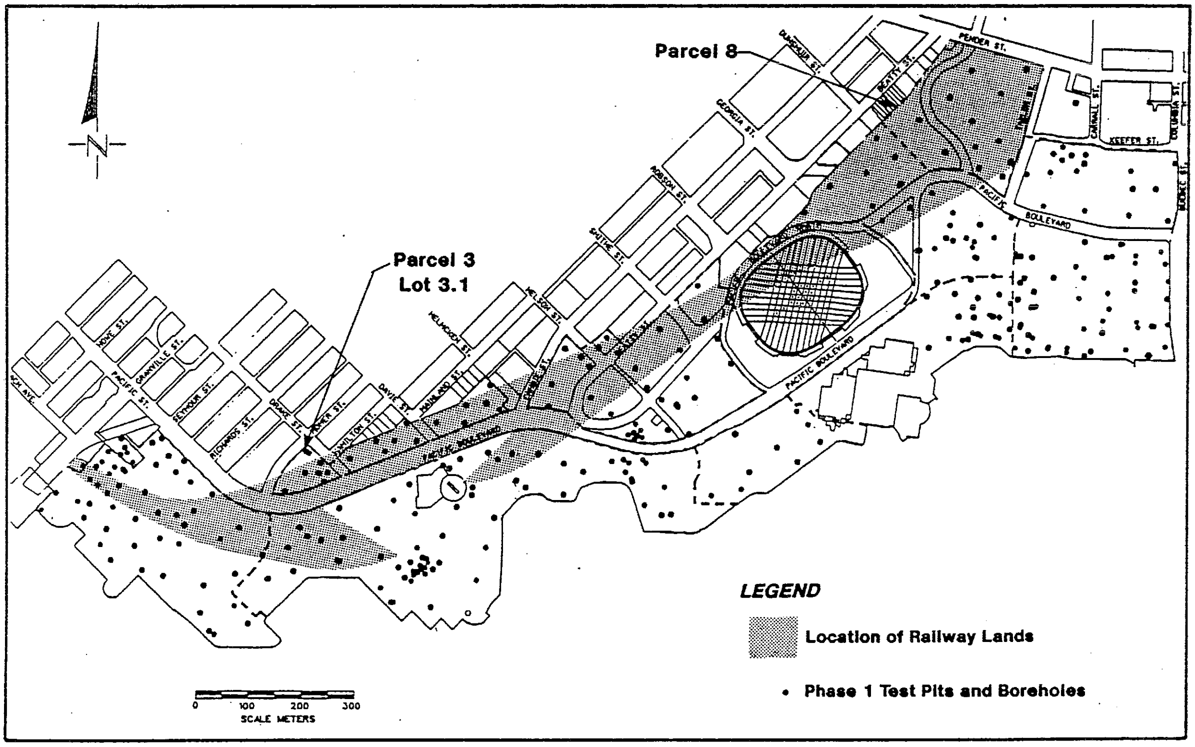


Figure 2: LOCATION OF RAILWAY LANDS AND PHASE 1 TEST PITS AND BOREHOLES

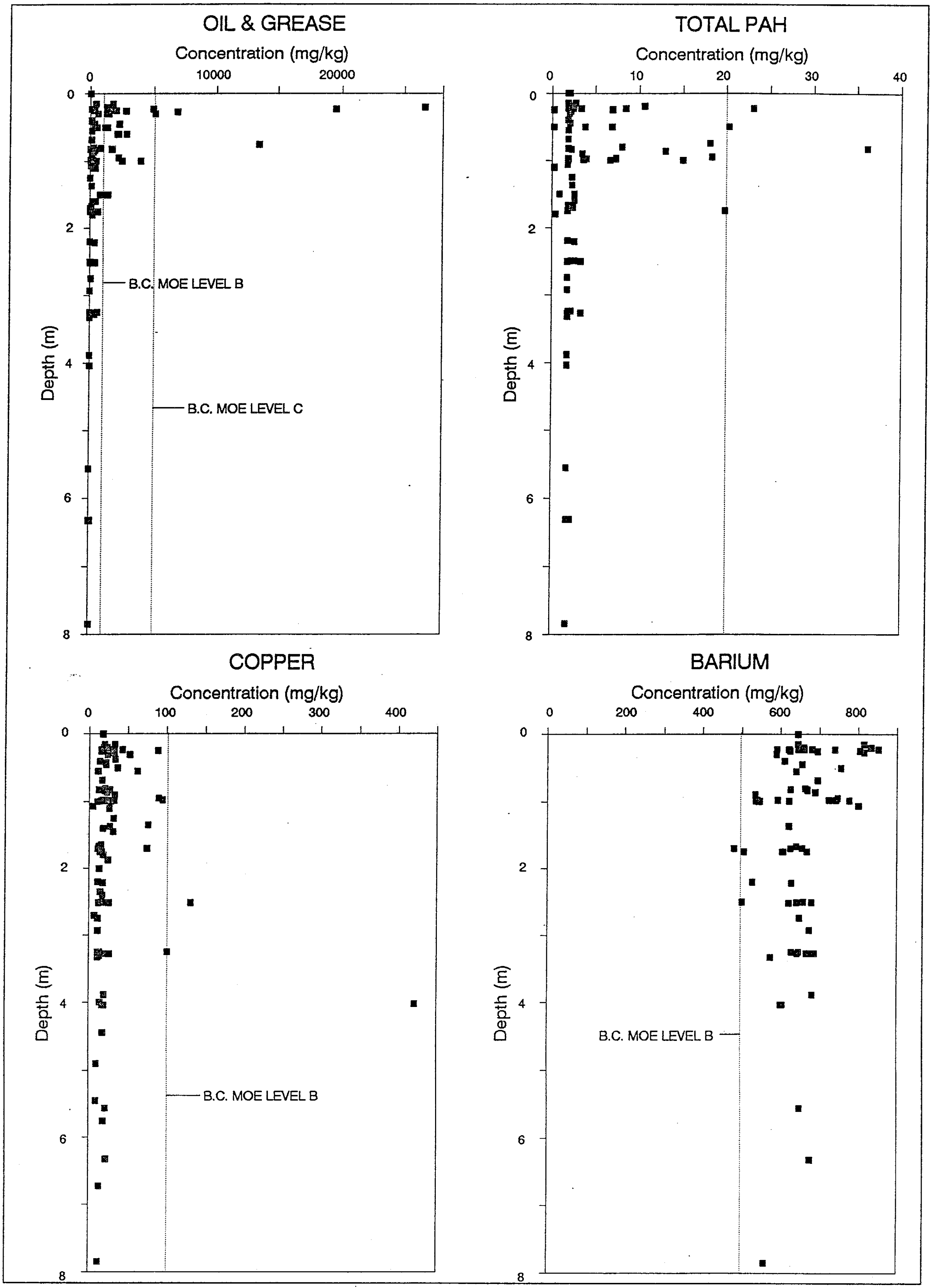
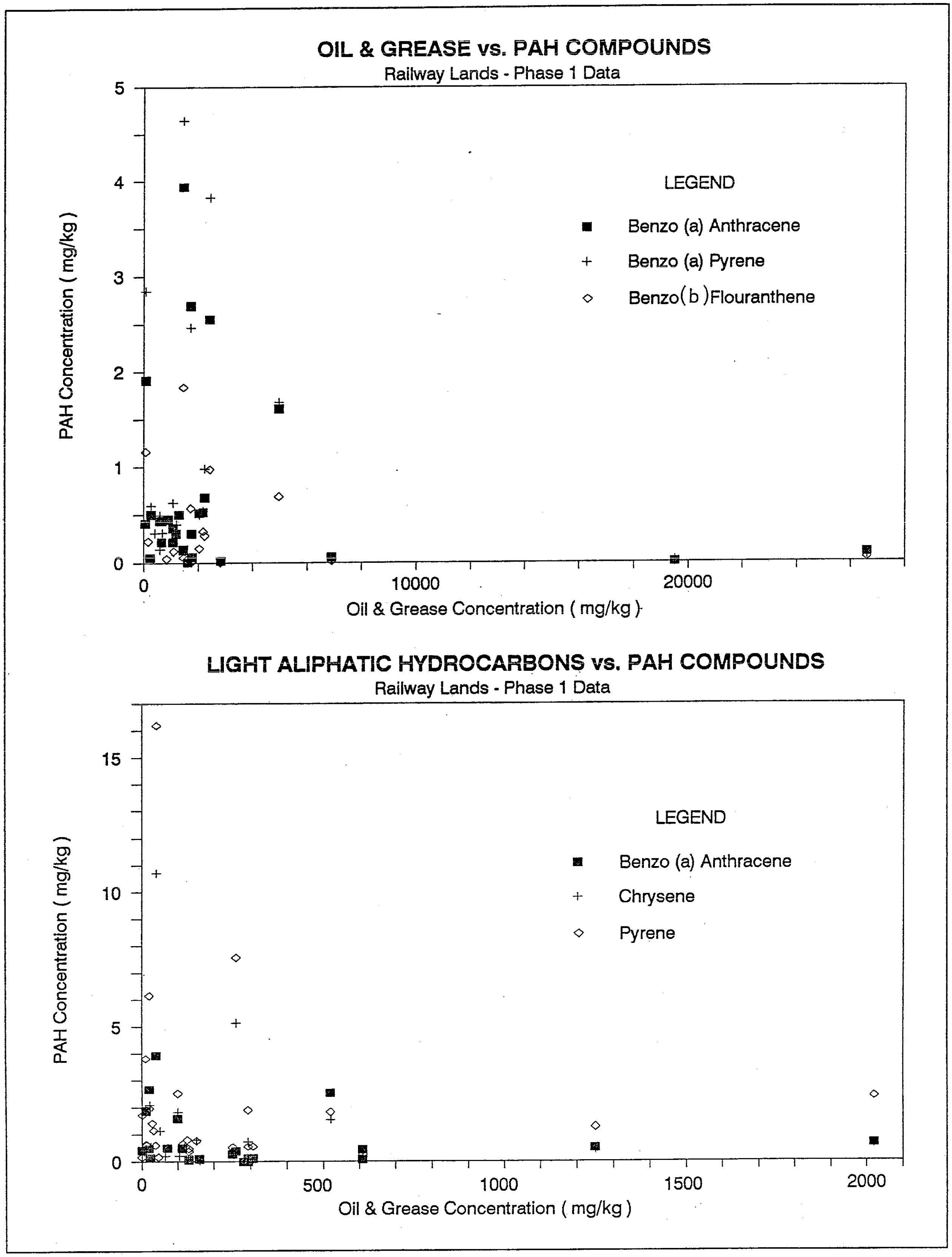


FIGURE 3 : CONCENTRATION vs DEPTH FOR SELECTED CONSTITUENTS AT RAILWAY LANDS



OIL & GREASE vs. PAH COMPOUNDS

Railway Lands - Phase 1 Data

LIGHT ALIPHATIC HYDROCARBONS vs. PAH COMPOUNDS

Railway Lands - Phase 1 Data

FIGURE 4: USE OF INDICATOR COMPOUNDS

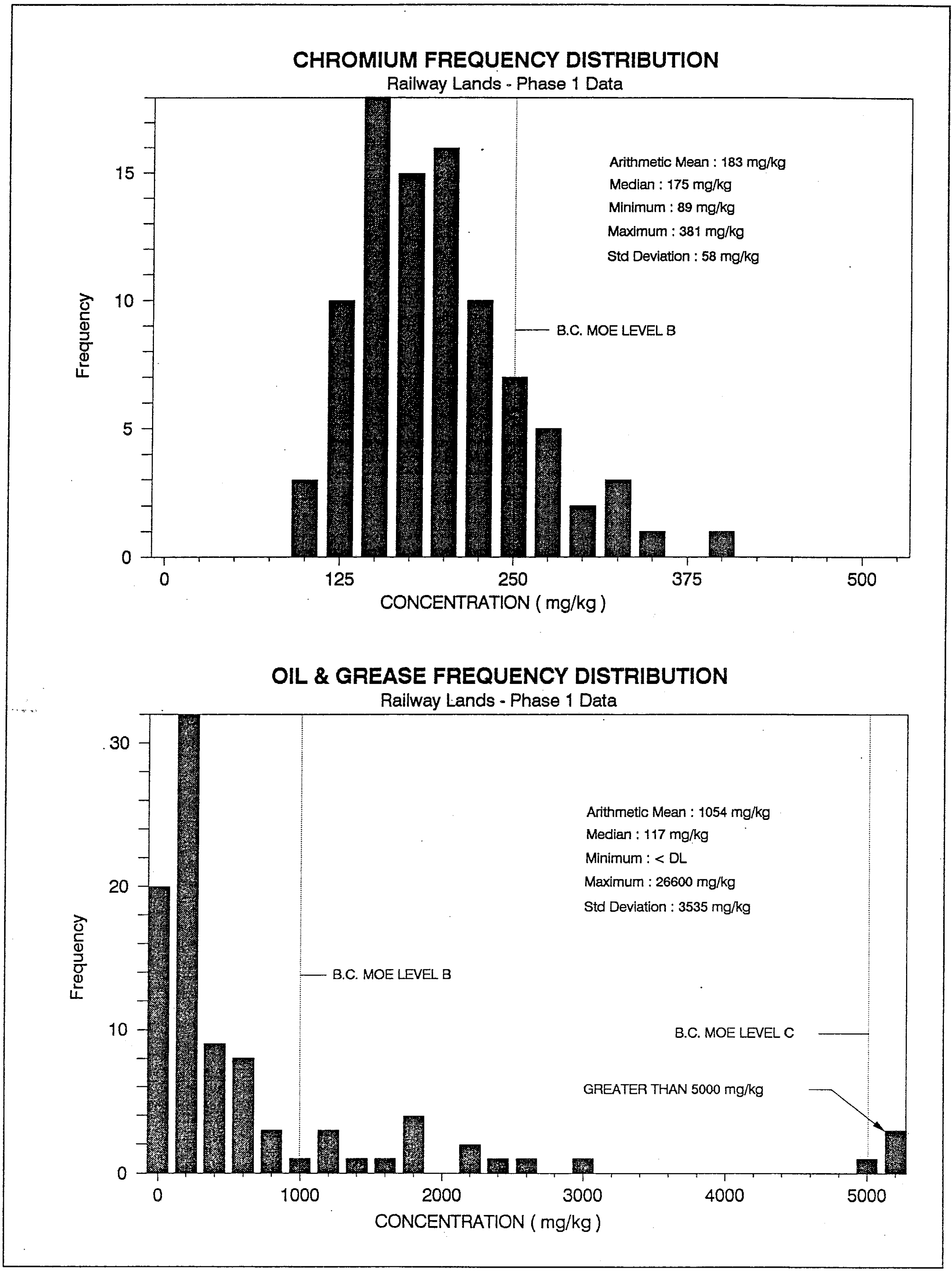


FIGURE 5 : FREQUENCY DISTRIBUTIONS FOR OIL & GREASE AND CHROMIUM