Survey of Typical Soils Arsenic Concentrations in Residential Areas of the City of University Place

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Survey of Typical Soils Arsenic Concentrations in Residential Areas of the City of University Place

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Abstract

The Asarco Tacoma Smelter, located in Ruston, Washington, operated from 1890 to 1986. Deposition of smelter emissions containing arsenic and lead have caused soil contamination in areas of King and Pierce counties. The City of University Place is, at its closest point, three miles south-southwest of the smelter site. A survey of the arsenic concentration in soils of 59 University Place properties was conducted by the Washington State Department of Ecology (Ecology) during May through June 2000. The purpose of the survey was to determine typical arsenic concentrations in residential soils in a study area with known elevated background conditions. University Place was chosen for the study because a previous study found elevated background conditions in that city; however, it is believed that other areas are likely to be similarly affected by deposition from the smelter.

Soil samples consisting of five subsamples were collected from depths of 0-2", 2-6", and 6-12". Front and back yards were sampled separately. The mean soils arsenic concentration from the properties sampled was 26.4 parts per million (ppm). The highest single sample result was 163 ppm. Eighty percent of the properties had average arsenic concentrations of 40 ppm or lower. Approximately 60% of the properties sampled had higher concentrations than the 20 ppm Model Toxics Control Act (MTCA) cleanup level for arsenic for residential areas.

The age range of the structures on the properties correlated strongly with arsenic concentration. Properties with younger residential structures tended to have arsenic concentrations below the 20 ppm MTCA cleanup level, while properties with older structures had higher concentrations. Front yards tended to have lower arsenic concentrations than back yards. Though not recorded in this study, the extent and timing of landscaping activities such as cutting, filling, working the soil, or adding topsoil may be factors in reducing the influence of aerial deposition of arsenic in University Place soils.
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Acknowledgements

The author would like to thank the following individuals for their help with this study:

- Participating residents of University Place who graciously allowed sampling to be performed on their properties.
- Gregory Glass for his valuable input concerning background and study design, review of the project plan, and help in analyzing the relationship between arsenic and lead concentrations.
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  - ◊ Dale Norton, Contaminant Studies Unit supervisor, for providing guidance and reviewing the quality assurance project plan and the study report.
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Introduction

Arsenic, lead, and other metals were emitted by a stack at the Asarco Tacoma Smelter between 1890 and 1985 (Figure 1). Discharge of metals from the smelter has been found to cause increased metal levels in soils in areas of King and Pierce counties. This study was initiated in response to a recent study that found elevated background conditions of arsenic in University Place (City of Tacoma and Glass, 1999). Although this study was limited to University Place, other areas may be similarly affected. This report presents the results of a survey designed to determine typical arsenic levels in residential soils within a study unit in the city of University Place. Limited lead analyses of some of the samples collected were also conducted.

The Asarco Tacoma Smelter is located near Point Defiance in Ruston, Washington (Figure 1). The smelter operated first as a lead smelter, and later as a copper smelter that processed ores containing high levels of arsenic (EPA, 1991). Smelting operations were discontinued in 1985, and the facility closed permanently in 1986. During the time it operated, the Asarco Smelter used high temperature furnaces to melt the metals away from raw materials. The smelter stack and other parts of the plant released dust particles containing arsenic, lead, and other metals into the air. Much of the dust settled onto soils throughout Ruston and north Tacoma. However, increased concentrations in soils have been found in other parts of Pierce and King counties. Most of the dust that fell on land remains in the soil today (EPA, 1991). Contamination at the facility and in its vicinity has been addressed by a federal Superfund project.

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Results of Previous Studies

After the smelter closed, studies were conducted to determine the extent of nearby soil contamination. In 1988 Ecology collected 288 soil samples from an area approximately 950 acres surrounding the smelter. In 1989 EPA collected 222 additional samples. EPA concluded that the highest levels of arsenic and other contaminants are generally found on properties located closest to the smelter, with concentrations decreasing with distance from the smelter. Test results showed that the amount of arsenic in surface soils in the Ruston and north Tacoma residential study area ranged from 2 parts per million (ppm) to 3,000 ppm (EPA, 1991). The MTCA Method A soil cleanup level for arsenic is 20 ppm for residential areas, uncontrolled use.

Most soil monitoring efforts that had occurred prior to the present study had concentrated on the Asarco Smelter site and nearby surrounding area. The highest known arsenic concentration near University Place was 166 ppm on the eastern end of Fox Island. A background study of 177 sampling locations on Maury and Vashon islands and King County mainland was conducted in 1999-2000 (Seattle-King County Health Dept. and Glass, 2000). The results of the discrete samples indicated soils arsenic contamination ranging from 8 to 460 ppm in south Vashon and Maury islands, and 3 to 140 ppm in north Vashon Island (Seattle-King County Health Dept. and Glass, 2000). The samples were of 0-2" and 2-6" depth intervals.

University Place is, at its closest point, three miles south-southwest of the smelter (Figure 1). The prevailing wind direction during portions of the summer is from the north-northeast, placing University Place in the expected plume of the Asarco stack part of the year. A recent study of surface soil samples from undisturbed locations in University Place five to seven miles from the smelter provided the first data indicating elevated soils arsenic concentrations in University Place (City of Tacoma and Glass, 1999). The study took place after significant lead and arsenic contamination was found at a site owned by Tacoma Water where two water tanks had been sandblasted. When Tacoma Water discovered elevated levels of arsenic and lead in soils beyond the area directly affected by the sandblast grit, they conducted a study to determine whether an area-wide problem existed.

The area background study evaluated the concentrations of arsenic and lead in surficial soils from 64 sampling locations at seven undeveloped sites in and near University Place (City of Tacoma and Glass, 1999). This study showed elevated arsenic and lead concentrations in relatively undisturbed soils. Maximum values were 281 ppm and 1,175 ppm for arsenic and lead, respectively. The MTCA Method A soil cleanup level for lead is 250 ppm. Statistical analyses were performed on the University Place data according to Ecology guidance, resulting in calculated background values of 265 ppm and 561 ppm for arsenic and lead, respectively (City of Tacoma and Glass, 1999). These results were for discrete samples. Discrete sample results can be expected to be more variable, and therefore result in greater extremes for a given number of analyses than the composite sample results of the present study.

Figure 1. Location Map

Methods

Study Area

University Place can be described as consisting of a northern portion that is predominantly residential and densely developed, and a southern portion that is less densely developed. Because the data were to be pooled to describe the overall characteristics of the study area, it was decided to establish a study area with a relatively uniform density of housing units. The study area selected was composed of the more densely developed northern portion of University Place. This portion of the city contains the majority of the city's housing units. The study area is bounded by the city's northern and western boundaries and on the east by 67th Avenue West. It is bounded on the south by a line extending from the portion of Cirque Drive West that runs east-west through the center of the city (Figure 2).

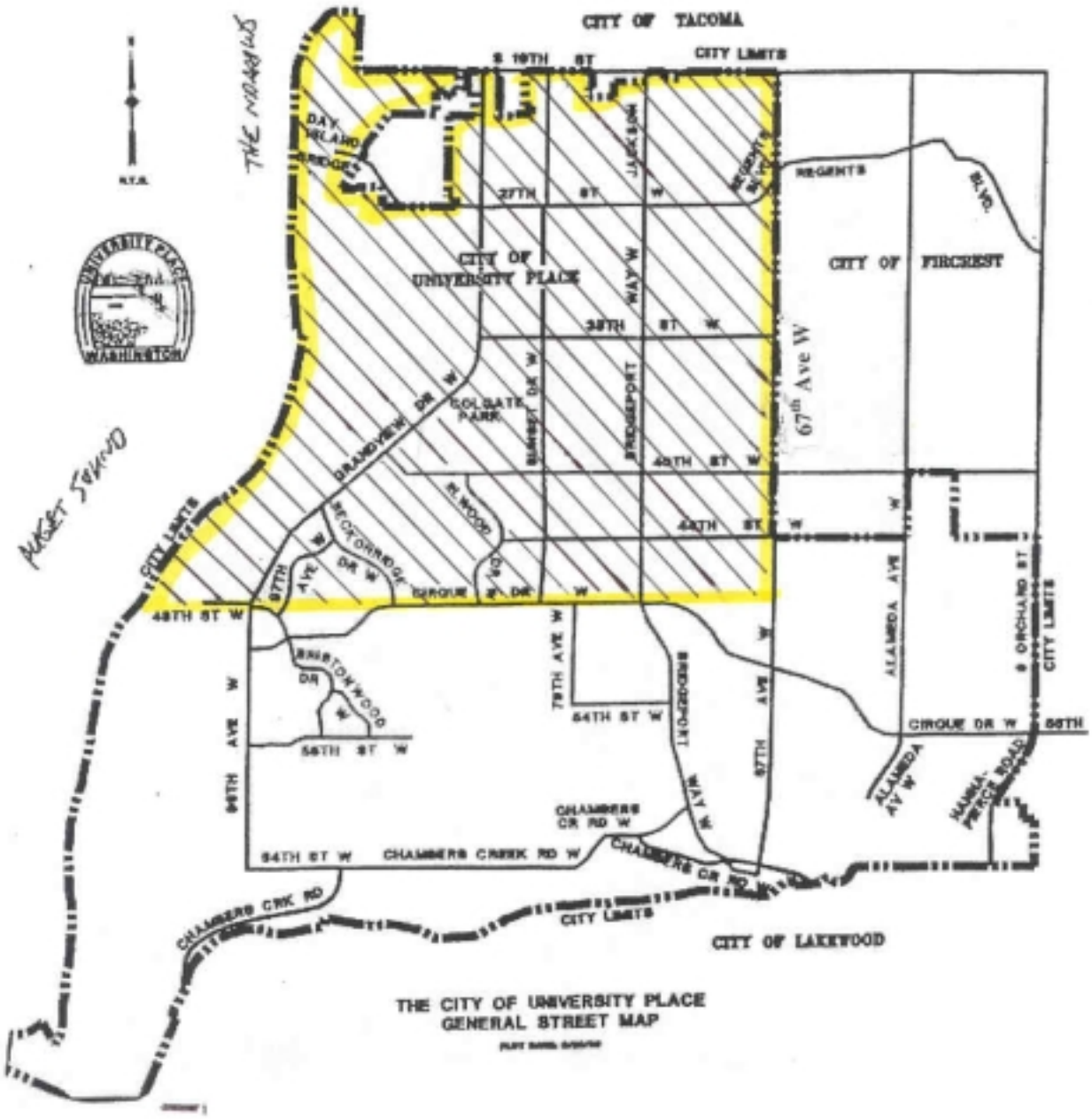
Study Description and Design

Samples were collected from the front and back yards of 59 residential properties in northern University Place and analyzed for arsenic. Arsenic was chosen as the primary metal of concern based on results from the 1999 University Place background study indicating it was the highest with respect to MTCA cleanup levels (City of Tacoma and Glass, 1999). Laboratory analyses were conducted by the Ecology Manchester Environmental Laboratory. Selected soil samples collected for arsenic analysis were also analyzed for lead.

The objective of this survey was to characterize typical arsenic concentrations in residential soils from the University Place area. It is not within the scope of this study to gain the depth of information needed to describe any spatial differences in the data or link specific data sets with particular residential properties. In order to address property owner concerns about the confidentiality of results, field ID, information about samples, and sample locations were dissociated from the sample containers. Before samples were sent to the laboratory they were labeled with random numbers. Although samples were not labeled to provide identification of particular properties, front and back yard samples were paired and identified as coming from the same property so that average arsenic concentrations for the properties sampled could be calculated. The age range of the residence associated with each front and back yard sample was also identified. Age ranges were grouped in ten-year intervals. Because elevated lead concentrations were found in the Tacoma Water area background study (City of Tacoma and Glass, 1999), 20 of the samples were analyzed for lead. Selected samples were also archived for the possibility of further analysis of some samples.

Property Selection

Properties to be sampled were randomly selected using Arcview with a Geographic Information System (GIS) database. To select individual properties, a 50-foot grid was overlayed onto the



City of University Place Boundaries

Study Area

Figure 2. Study Area

study area, and grid cells within the study area were chosen from the grid by random number generation. A sample size of 60 properties was chosen based on budget constraints. A list of 60 randomly chosen cells was developed, and the residential property within or closest to each cell was selected for sampling. If no residential property was present within the cell or an adjacent cell, a residential property was chosen from an alternative cell. Additional randomly generated lists of cells were developed for this purpose and to make up for properties where permission to sample could not be obtained.

Consideration was given to the possibility that some of the residential yards included in this study may be on former orchard lands. In the past, lead arsenate has been applied on some Washington orchard lands, resulting in elevated levels of lead and arsenic in the affected soils. Glass found relatively low levels of arsenic (32 ppm maximum) in soils from two orchards in University Place. It may be that while lead arsenate use was common in the large orchards of eastern Washington, it was not used in University Place area orchards (Glass, 2000). Consequently, historical land use was not a criteria for sample site selection in this study.

After the list of potential sampling sites was generated, property owners and residents were contacted for permission to sample soils on their properties. Those residents whose phone numbers could not be determined were contacted by mail. Ecology provided consent forms and stamped return envelopes. The background and intent of the study was discussed with each potential participant. Of those contacted by telephone and letter, 52% agreed to participate in the study. Appendix A summarizes the responses of residents and owners to Ecology's request to sample their properties.

After permission had been obtained to sample 55 properties, it was observed that when plotted on a map the central portion of the study area, consisting of relatively smaller lots and older structures, was under represented. In order to establish a more even coverage of samples, four residential properties in the central area were added to the study. Approval for sampling of these additional properties was obtained from telephone contacts. The response to telephone requests by Ecology personnel asking for permission to sample in this central area confirmed differences in participation rate between portions of the study area. While for the study overall, 69% of those contacted by telephone granted permission for sampling, in the central area only 30% granted permission. This confirms the supposition that the reason the central area was under represented in the initial sample selection was that a large proportion of people in this area turned down requests to sample. Differences in response may have caused older houses to be under represented, not only in the central portion of the study area but in the overall study area.

The locations of the original 55 properties and four additional properties are shown in Figure 3. The 59 properties sampled represented 1.6% of the approximately 3,645 residential lots in the study area. Ecology was unable to obtain permission to sample a sixtieth property within the time frame of the study.

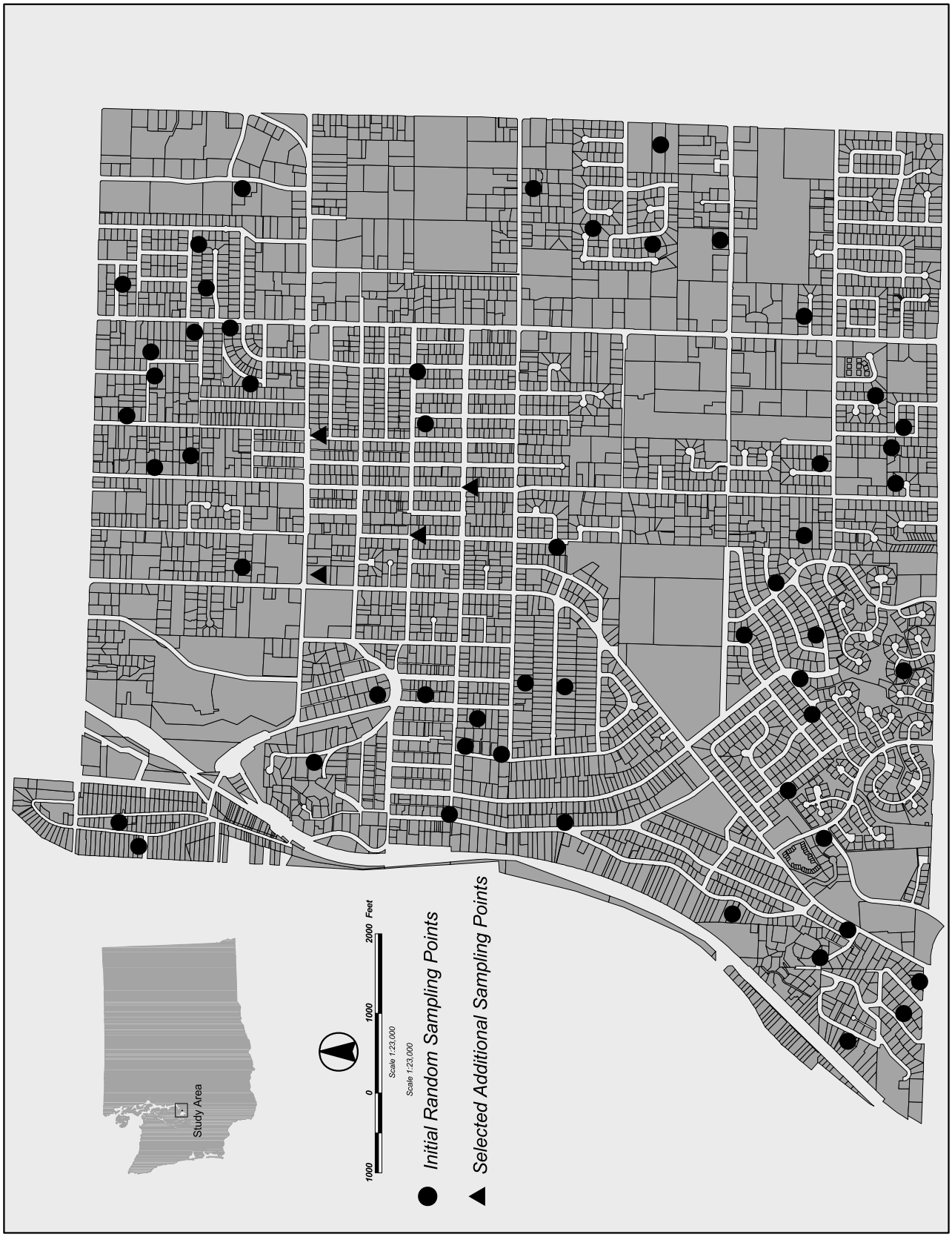


Figure 3. Sampling Locations

Sampling Strategy

Two hundred and sixty soil samples were collected from 59 residential properties, with an additional 40 samples taken as split samples and field replicate samples. Representativeness within each property sampled was enhanced by increasing the number of subsamples included in each composite sample. It was recognized that the compositing of samples can mask extreme results.

Soil was sampled from five locations in each front yard and each back yard. The five subsamples from the front yard formed one composite sample while the five subsamples from each back yard formed another composite sample. The front and back yard composite samples were analyzed separately. Yard size varied from small residential lots to several acres.

Including five subsamples in each sample of a front or back yard is consistent with the sampling design used for the initial soils sampling study for the smelter site in Everett, Washington. In the Everett study, a minimum of five subsamples was found adequate to provide an initial characterization of the arsenic concentration of a property. A review of results from sampling for arsenic in residential yards in north Tacoma (Hydrometrics, 1999) also gives an indication that five subsamples per sample can be expected to yield results close to those that could be obtained by increasing the number of subsamples per front or back yard beyond five.

Separate soil samples were taken at 0-2", 2-6", and 6-12" depths. Soil sampling for this survey was limited to a depth of 12" because this is the depth interval for which can be expected the greatest potential human exposure. The 0-2" depth represents surface soil that residents, particularly children, are most readily exposed to. Data collected at these intervals can be compared with data collected at these same depth intervals in previous studies, such as in Everett (Aldrich, 1998) and in the 1999 University Place area background arsenic study. For comparison, Ruston/north Tacoma soil samples were collected at depth intervals of 0-1", 1-6", and 6-12".

For properties from which 12" samples were collected, the Utility Underground Location Center was notified, as required by law, two business days to one week prior to sampling so that underground utilities would be marked.

Table 1 summarizes the samples collected, including quality assurance samples. Samples were collected at two depths at 47 residential properties and at three depths at 12 residential properties, for a total of 59 residential properties sampled.

Table 1. Sampling Summary.

Primary Samples

47 properties		
(188 samples)	front yard	0-2 inch depth
		2-6 inch depth
	back yard	0-2 inch depth
		2-6 inch depth
12 properties		
(72 samples)	front yard	0-2 inch depth
		2-6 inch depth
		6-12 inch depth
	back yard	0-2 inch depth
		2-6 inch depth
		6-12 inch depth

Quality Assurance Samples

Split sample composites at 4 properties		
(16 samples)	front yard	0-2 inch depth
		2-6 inch depth
	back yard	0-2 inch depth
		2-6 inch depth
Field replicate samples at 6 properties		
(24 samples)	front yard	0-2 inch depth
		2-6 inch depth
	back yard	0-2 inch depth
		2-6 inch depth

All samples consist of a composite of 5 subsamples.

TOTAL SAMPLES = 316

Collection Procedures

Prior to use, all sampling equipment was decontaminated with Liquinox soap and water, ultrapure deionized water, and 10% nitric acid followed by a deionized water rinse. Samples were collected with 2" ID stainless steel pipe samplers. The samplers were made for Ecology in three lengths: 2", 6", and 12". Each sampler consisted of a stainless steel pipe with a stainless steel rectangular plate welded on one end. The samplers were driven into the ground with a sledge. Nitrile disposable powder-free gloves were worn by personnel during sampling. The

surface layer of vegetative material was removed, and consecutive samples from each sampling hole were collected at 0-2", 2-6", and 6-12". Samples were thoroughly mixed in stainless steel mixing bowls and protected from wind so as not to lose fine material. Composite samples were mixed until the entire sample was of uniform consistency. Rocks, vegetation, debris, and other large materials were removed in the field. Samples were transferred to laboratory-cleaned jars with teflon lids. Sample splits were transferred from the mixing bowls to sample containers. Sample containers were placed in ice chests, and chain-of-custody procedures were followed to ensure security of the samples. All samples were sieved in the laboratory (2 mm sieve) before analysis.

The locations of individual collection points in each yard were chosen using the following procedure: Using a compass and measuring tape, sampling spots were located at an estimated center point and midway between the center point and the edge of the property at compass bearings northeast (45°), southeast (135°), southwest (225°) and northwest (315°) from the center point. Field replicate samples were collected at the center of the lawn and lawn midpoints east (90°), south (180°), west (270°) and north (0°) compass bearings.

Samples were taken from grassy lawn areas only. When a potential sampling spot was located in a garden, the sampling spot was relocated to the nearest grassy spot away from the center of the lawn, three feet from the edge of the garden. When a tree or utility was in the way, or a potential sampling site was within five feet of a road or within three feet of a structure, the sample was taken from the nearest available location outside of these limits. A field sampling plan appears in Appendix B.

Analytical Procedures and Data Quality

This project is a screening level study. The intent is primarily informative and descriptive, and is not intended as a thorough evaluation of the arsenic concentrations in the study area or as an evaluation of site-specific arsenic concentrations. During the planning stage of this project, desired data quality was specified as providing for the determination of mean and median arsenic concentrations with an accuracy of +/- 10%. A reporting limit below the 20 ppm MTCA cleanup level was also specified.

Samples were sieved in the laboratory as part of sample preparation. The portion of the samples passing a 2-mm sieve were analyzed for arsenic by Graphite Furnace Atomic Absorption (GFAA) (EPA SW846, Method 7060A). The samples were first digested by Method 3050B. Analyses were performed by the Manchester Environmental Laboratory. The inductively coupled plasma (ICP) method was initially chosen for the project because of its lower cost. GFAA was chosen instead because of availability of analytical equipment and ability to meet data quality objectives.

A laboratory Quality Assurance and Quality Control case narrative appears in Appendix C.

Field replicate samples were collected from six properties. Split samples were collected from four of these properties. Split results showed an average relative percent difference (RPD) of 7% between sample and split (Appendix D). Relative percent difference is the difference between two values divided by the average of the values expressed as a percentage. Most sample/split pairs had RPDs between 4% and 8%. This is an indication of the precision of the data and is consistent with the project having achieved an overall accuracy within the desired 10%. Field replicate samples were collected at angles offset 45° from the principal samples. The results of the field replicate sample analyses showed an average RPD between samples and field replicate samples of 22%, most pairs having RPDs between 8% and 34%. This variability, greater than that of the sample splits, reflects the variability in the samples. Although the samples and field replicates consisted of five subsamples each, creating a physical averaging effect, the 22% average RPD between field replicate and sample results shows that there was considerable variability from one location to another within each yard.

NIST 2711 (Montana soil) was used in the laboratory as a standard reference material for this project. NIST 2711 is a soil with an arsenic concentration of 105 +/- 8 mg/Kg (ppm) which is within the anticipated range of the results for this study. The Manchester Environmental Laboratory achieved acceptable results on duplicate analysis of the Montana soil (101 and 98 mg/Kg-dw).

Results

The results of analyses of the soils from the University Place study area are summarized in Table 2. Table 2 shows the average (mean) arsenic concentrations for the 3 soil-depth intervals sampled. Median concentrations are also shown. The median concentration is the concentration for which half of the properties have higher concentrations and half have lower concentrations.

Table 2. Soils Arsenic Concentrations (ppm)*

Depth Interval	0-2"	2-6"	6-12"	0-12" overall
Mean	28.1	27.1	25.3	26.4
Median	24.8	24.4	21.2	22.9
Minimum concentration	3.8	4.9	4.7	4.6
Maximum concentration	113.3	85.7	45.7	70.3
75^{th} percentile	9-47	11-43	13-35	12-40

* Average for property, both front and back yards.

For the 59 properties sampled in University Place, the mean soils arsenic concentration was 26.4 parts per million (ppm). The median soils arsenic concentration was 22.9 ppm. The majority of properties sampled had arsenic concentrations that were higher than the MTCA cleanup level of 20 ppm for residential soils. The highest arsenic concentration obtained in all composites was 163 ppm (0-2"depth). The lowest arsenic concentration obtained was 2.1 ppm (also at 0-2" depth).

The mean concentration at all sampling depth intervals was between 25.3 ppm and 28.1 ppm, showing that there was little variation with sampling depth. For all depth intervals sampled, the mean was greater than the median. This is the result of the highest arsenic concentrations being disproportionately high. Table 2 also shows the range of results from the properties. The 75^{th} percentile is the arsenic concentration range that includes the results of 75% of the properties sampled. The results for the properties with the minimum and maximum arsenic concentrations averaged over front and back yards are also shown in Table 2. Split and field replicate results appear in Appendix D. All data appear in Appendix E.

Figure 4 summarizes the results of average property arsenic concentrations (an average of front and back yard results for each property). Figure 5 summarizes the results of each property's high yard, that is the yard for each property with the higher soils arsenic concentration. For both Figures 4 and 5, results for 0-2" and 2-6" depth intervals are represented by single best-fit lines, because results were found to be similar. The 6-12" depth interval is represented by a dashed line in each figure.

Figure 4 shows that approximately 40% of the properties had average soils arsenic concentrations below the 20 ppm MTCA cleanup level at all depth ranges sampled. From Figure 4, it can be seen that 80% of all properties had average arsenic concentrations below 40 ppm at 0-2" and 2-6" depth ranges. The figure shows that the concentration was approximately 32 ppm for 80% of all properties at the 6-12" depth range.

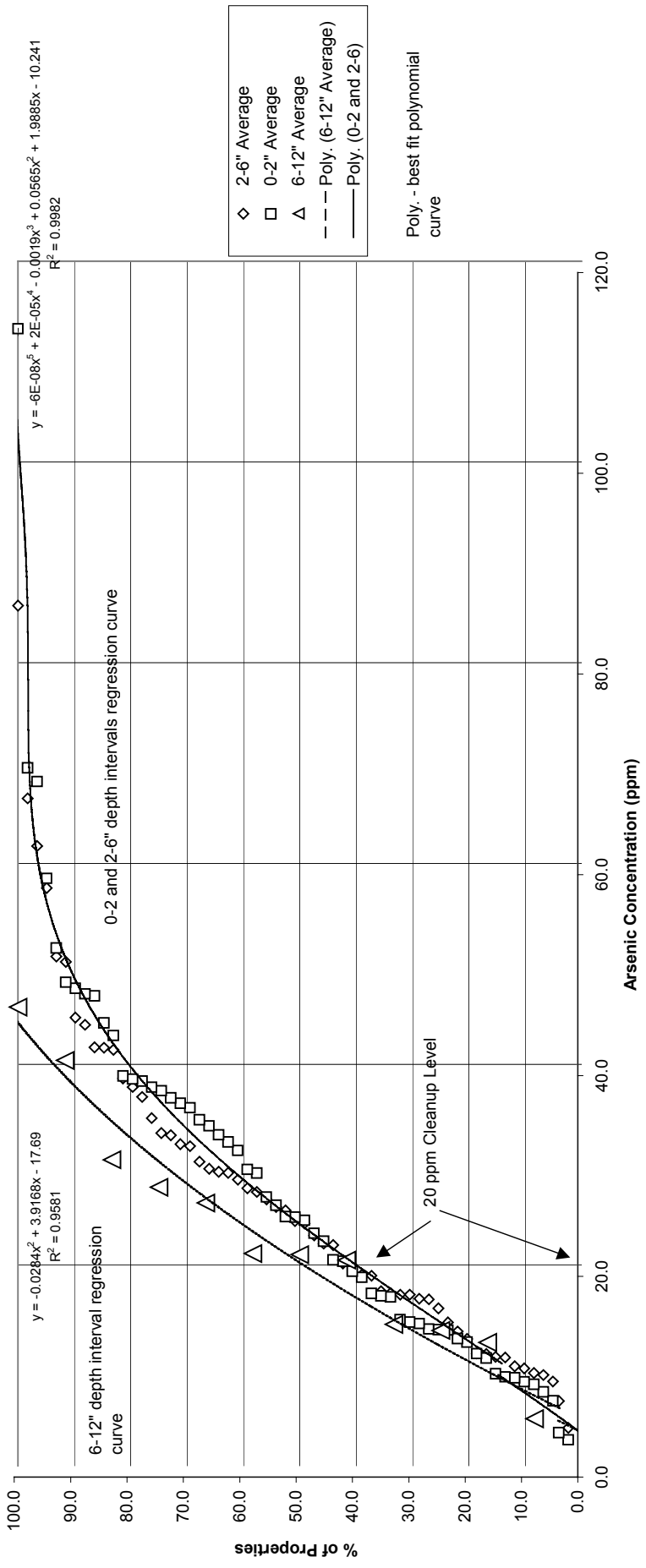


Figure 4. Cumulative Percent Arsenic Concentration by Each Property's Average Front and Back Yard Concentration

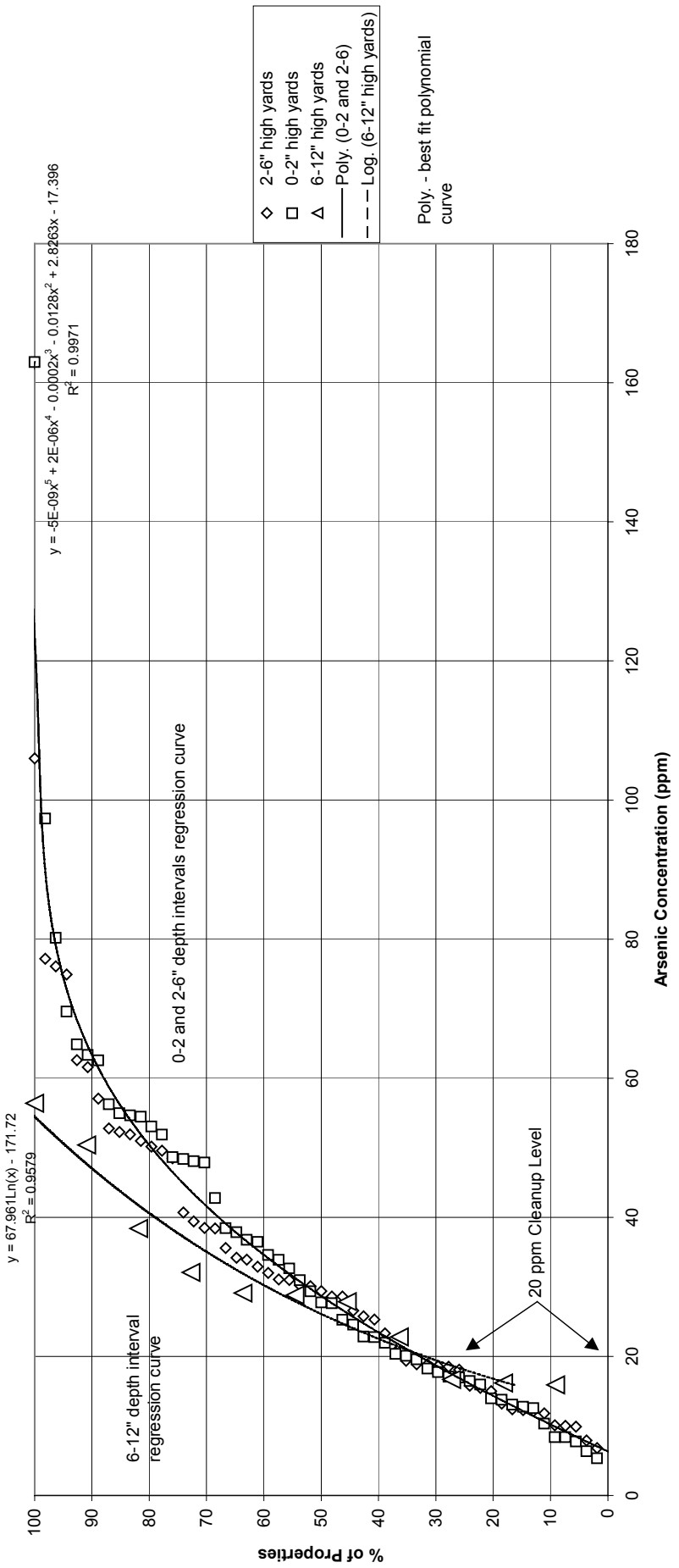


Figure 5. Cumulative Percent Arsenic Concentration by Each Property's Yard with the Highest Concentration

Since front and back yards often have different landscaping histories and patterns of use, an analysis was performed to characterize the typical yard that was the higher of a property's two yards. Figure 5 shows that of each property's two yards, the yard with the higher arsenic concentration averaged approximately 27 ppm. For approximately 87% of the properties sampled, the yard with the higher arsenic concentration had an average concentration of 60 ppm or lower.

Figure 6 shows the distribution of arsenic concentrations for the three sampling depth ranges. From Table 2 and Figures 4 and 6, it can be seen that while arsenic concentration did not vary greatly with depth, the highest arsenic concentrations were found at the 0-2" and 2-6" depth intervals. There was a slight decline in arsenic concentration as sampling depth increased. The average arsenic concentration in the 0-2" depth interval was significantly higher than the concentration in the 6-12" depth interval at a 95% level of confidence. The finding of higher arsenic concentrations near the ground surface is consistent with the source of the arsenic being aerial deposition.

The highest arsenic concentrations were typically present near the surface (0-2"). Landscaping activities, including topsoil addition, can be expected to reduce arsenic concentrations. Landscaping tends to affect soils near the surface more than deeper layers. This may explain why some soils near the surface have lower arsenic concentrations than deeper soils have.

Figure 7 shows how arsenic concentrations were distributed for the three sampling depth intervals. Figure 7 shows the greatest range of arsenic concentrations was found in samples from the 0-2" depth range. This figure also indicates that most properties sampled (60%) had arsenic concentrations greater than the 20 ppm MTCA cleanup level.

Soils Arsenic Concentrations in University Place and the MTCA Cleanup Level

The overall mean and median arsenic concentrations of 26.4 and 22.9 ppm were both higher than the 20 ppm MTCA cleanup level for residential areas, uncontrolled use (Table 2). Sixty percent of all residences sampled had average soils concentrations exceeding the 20 ppm MTCA cleanup level for the 0-2" and 2-6" depth range. Sixty-four percent of all residences sampled had average soils concentrations exceeding the 20 ppm cleanup level for the overall 0-12" depth range.

All results in this report reflect concentrations in composite samples. That is, the result for each front or back yard represents the concentration from five subsamples mixed together. The result for a property (the average in Figures 4, 5, and 6) represents the average of front and back yard results. In effect, this is an average of ten subsamples (five from each yard). It is likely that some individual subsamples within each sample had actual concentrations higher or lower than the mixed composite sample.

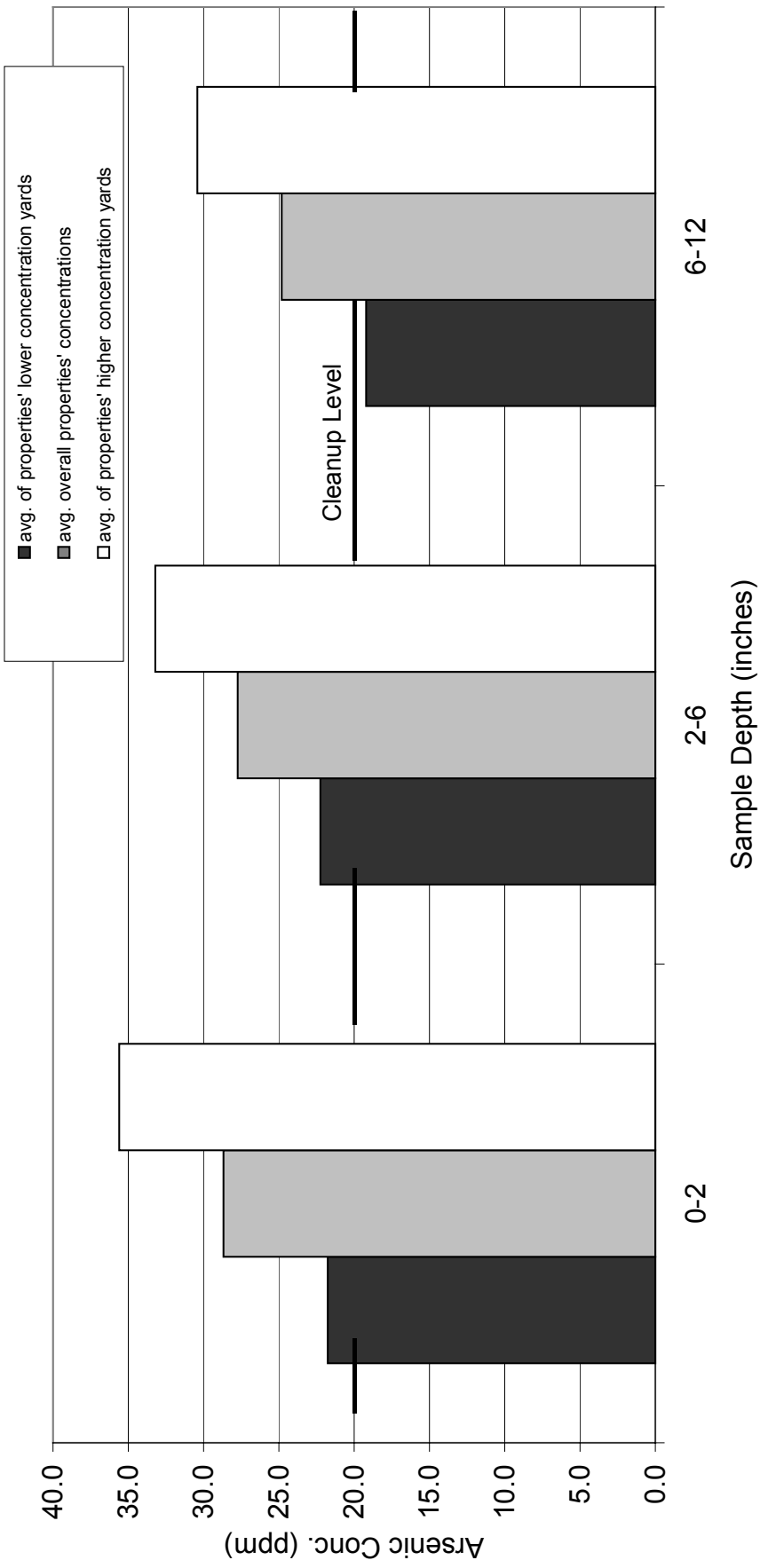


Figure 6. Average Arsenic Concentrations by Depth

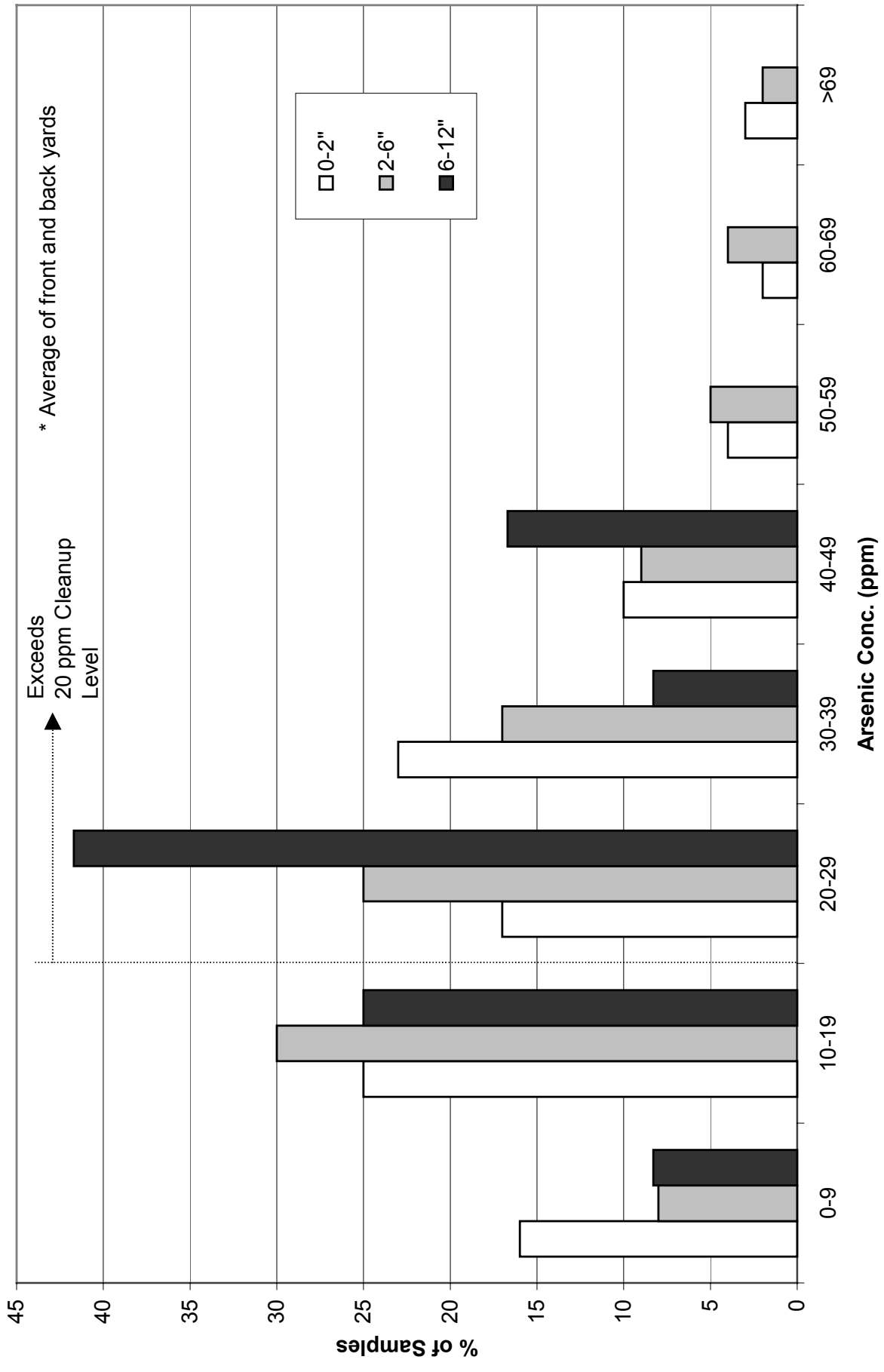


Figure 7. Distribution of Property Arsenic Concentrations

Comparison of Front and Back Yard Concentrations

Front and back yard arsenic concentrations were compared to determine whether there was an overall significant difference between them. The back yards sampled were found to have higher arsenic concentrations than the front yards at all depth intervals (Table 3). The differences were significant at the 95% level of confidence for the 0-2" and 6-12" depth intervals, and at the 90% level of confidence for the 2-6" depth interval.

Table 3. Front Yard vs. Back Yard Mean Arsenic Concentrations (ppm)

Sampling Depth	Front Yard	Back Yard
0-2"	25.0	31.6
2-6"	25.6	29.0
6-12"	19.3	29.0

In general, front yards may be more intensely landscaped than back yards. Front yards may be subject to more excavation, more fill, and more working of the soil in lawn preparation than back yards. Front yards also may be more likely to have topsoil additions. Any of these factors would be expected to decrease the arsenic concentration of soils in front yards compared with back yards.

Age Range of Residential Structures and Soils Arsenic Concentrations

Just as front versus back yard was considered as a correlate to soils arsenic concentrations in the study area, possible differences in arsenic concentrations with the age range of residential structures on the properties were also considered. The age range of the residence for each property was noted at the time of sampling. In this way, it could be determined whether there is a correlation between the age of residential structures and soils arsenic concentration. A frequency distribution of arsenic concentrations for soils of properties with structures having different age ranges is shown in Figure 8.

From the figure it can be seen that arsenic soils concentrations for all three depth intervals varied by age range in a similar manner. Properties with residences ranging from new to 29 years of age averaged less than 18 ppm arsenic. Those ranging from 30 to 89 years averaged greater than 26 ppm arsenic. For all three sampling depth intervals (0-2", 2-6", and 6-12"), properties with younger residences had lower soils arsenic concentrations at a 99% level of confidence. The age range of residential structures, though not a direct indication of the history of land, proved to correlate closely with arsenic concentration.

Although generalities cannot be applied to specific cases, properties with residential structures in the younger group tended to have soils with arsenic concentrations below the MTCA cleanup level. Of the 11 properties with residences in the age range 0-29 years, only one had arsenic concentrations higher than 20 ppm, the MTCA cleanup level, and then only as high as 22 ppm.

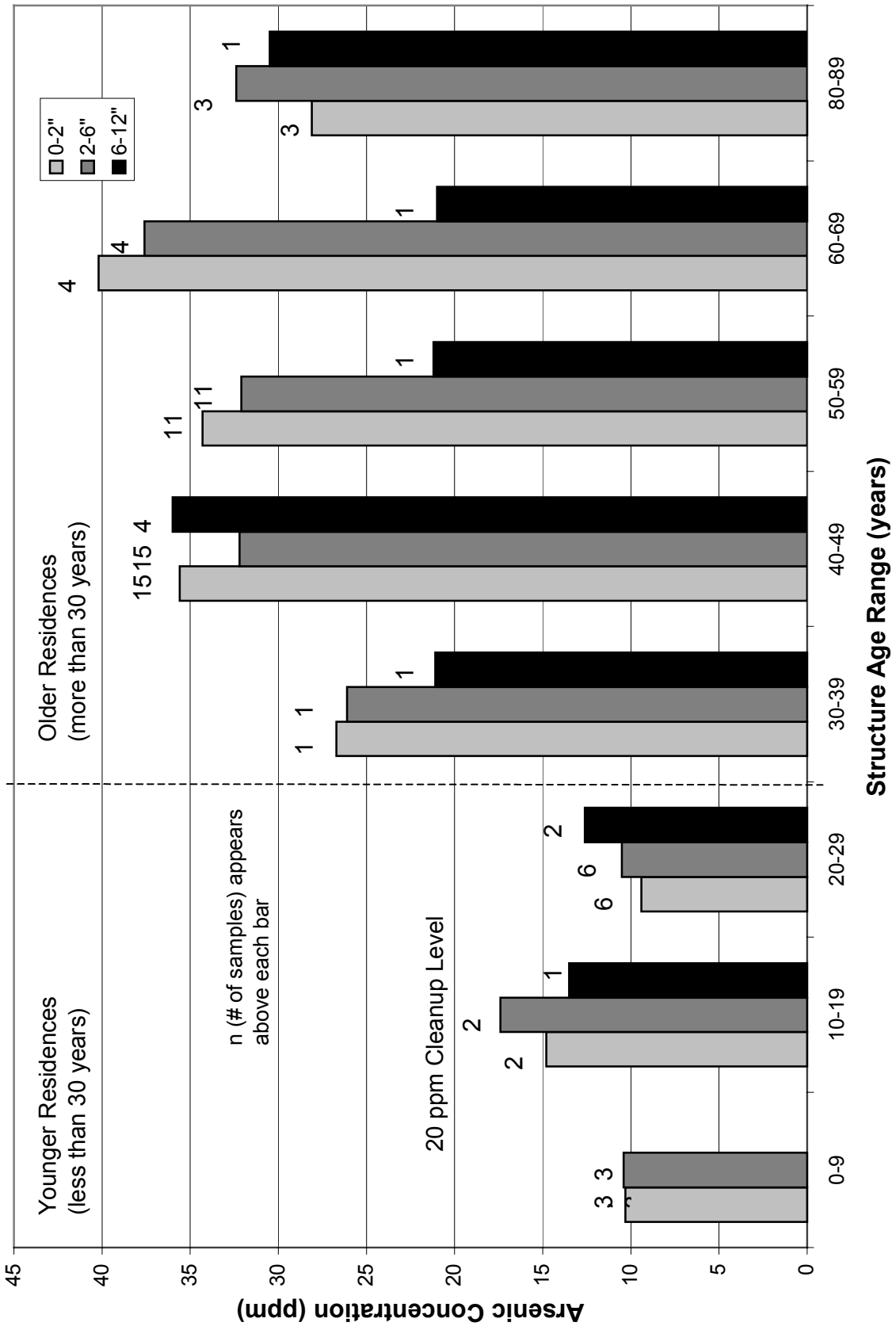


Figure 8. Average Property Arsenic Concentrations by Residence Age Range

Although most of the 43 properties in age range 30-89 years had average arsenic concentrations higher than 20 ppm, ten had arsenic concentrations of both yards lower than 20 ppm and another nine had concentrations of one yard below 20 ppm. It may be that topsoil was brought in or other landscaping performed on these properties in recent years. The extent of initial cut, fill, or placement of topsoil on these properties with older residential structures may also have played a role in determining soils arsenic concentrations. As discussed earlier, landscaping effects can also explain the greater range of arsenic concentrations near the soil surface (0-2") than at greater depths (6-12").

Figure 8 shows not only that there appear to be two groupings of soils arsenic concentrations by age, but also a more general trend of increasing arsenic concentration across age ranges. This is particularly evident for the 0-2" and 2-6" sampling depth intervals. Because there were only 12 data points in the 6-12" data set, trends across this depth interval were less discernable.

The finding of increased soils arsenic concentrations with the age range of residential structures is consistent with the concept that the longer a parcel of land was left undisturbed, the more arsenic was deposited on its surface by aerial deposition. It can be expected that properties with older residential structures tend to have less recent landscaping or other disturbances to the land, allowing for a longer period of undisturbed aerial deposition of arsenic and other pollutants to the land surface. Newer residences (less than 30 years) tend to have not only more recent but also more extensive soil disturbance and alteration, as more intensive landscaping when developing a property has been the trend in recent years.

Because of the small sample size of some age ranges of residential structures, care should be taken not to read too fine a level of detail from the results. For example, the average soils arsenic concentration for age range 20-29 was lower than for age range 10-19. This does not meet Ecology's expectations that properties with newer residences would tend to have lower soils arsenic concentrations. However, the average soils arsenic concentrations for the 10-19 age range were calculated from samples of only two properties at most (n=2). It may be that one or both of the two properties sampled in the 10-19 age group happened to have atypically elevated soils arsenic concentrations for the age range. Similarly, it may be that the average soils arsenic concentration for the 80-89 age range was lower than for the 40-69 age ranges, because there were few properties sampled with residences in the 80-89 age range. There were only three properties in the 80-89 age range, a small sample to represent all properties in the age range. One of the three properties may have had some relatively recent landscaping impacts, lowering the average arsenic concentration for that age range.

It may be that the apparent correlation of residential structure age with arsenic concentration is a reflection of what may be a more direct correlation of landscaping history with arsenic concentration. The age of a residential structure on a property may be only an indication of factors that directly affect soils contaminant concentrations: the type, degree, and timing of alterations to the land. This cannot be directly supported by this study, as no information concerning the use or landscaping of properties was collected.

Implications of Property Selection on the Representativeness of Data

As described in the *Sample Location Selection* section of this report, the central portion of the study area, consisting of relatively smaller lots and older structures, was under represented in the selection of the first 55 sampling sites. It may be that differences in response may have caused older houses to be under represented, not only in the central portion of the study area but in the overall study area. This would mean that properties with newer residences are over represented in this study. Because properties with newer residences tended to have lower arsenic concentrations, the overall results of this study may be influenced by the over representation of properties with relatively low arsenic concentrations. As a consequence, the mean arsenic concentration calculated from the study data (26.4 ppm) may be somewhat understated. A high-end estimate of the true overall mean arsenic concentration is 28.9 ppm, the mean for properties with residences over 30 years old.

Comparison with Other Arsenic Study Data

The soils arsenic concentrations found in the study area are considerably lower than the concentrations of up to 3,000 ppm found near the smelter site in Ruston and north Tacoma. Average soils concentrations were lower than those found in undisturbed soils in the 1998 background study in University Place. While only one of 59 properties sampled in this study had arsenic concentrations higher than 100 ppm, 71% of the University Place background samples were higher than 100 ppm. University Place residential soils were found to have lower arsenic concentrations than the University Place background study of undeveloped land, presumably because landscaping activities in residential areas removed or diluted arsenic in the soil. A study of Vashon and Maury islands background arsenic concentrations in undeveloped areas showed higher background arsenic concentrations (up to 460 ppm) than those found in the University Place background study (up to 281 ppm). Further data from Vashon and Maury islands, that will include some results from residential properties associated with a study of child-use areas, have not yet been published.

Lead in University Place Soils

Because lead and other metals were also emitted from the Asarco smelter stack, elevated lead concentrations were found in the Tacoma Water University Place area background study. As a result, selected samples from the present study were also analyzed for lead. Samples for lead analysis were chosen by rank ordering samples of the higher arsenic concentration of each of a property's two yards and then selecting every third sample for lead analysis. By using this procedure, the range of yards with the highest arsenic concentrations was represented. The results of lead analyses are shown in Figure 9 and Appendix C. All samples analyzed were found to have a lead concentration of 227 ppm or lower. The MTCA lead cleanup level for residential soils is 250 ppm.

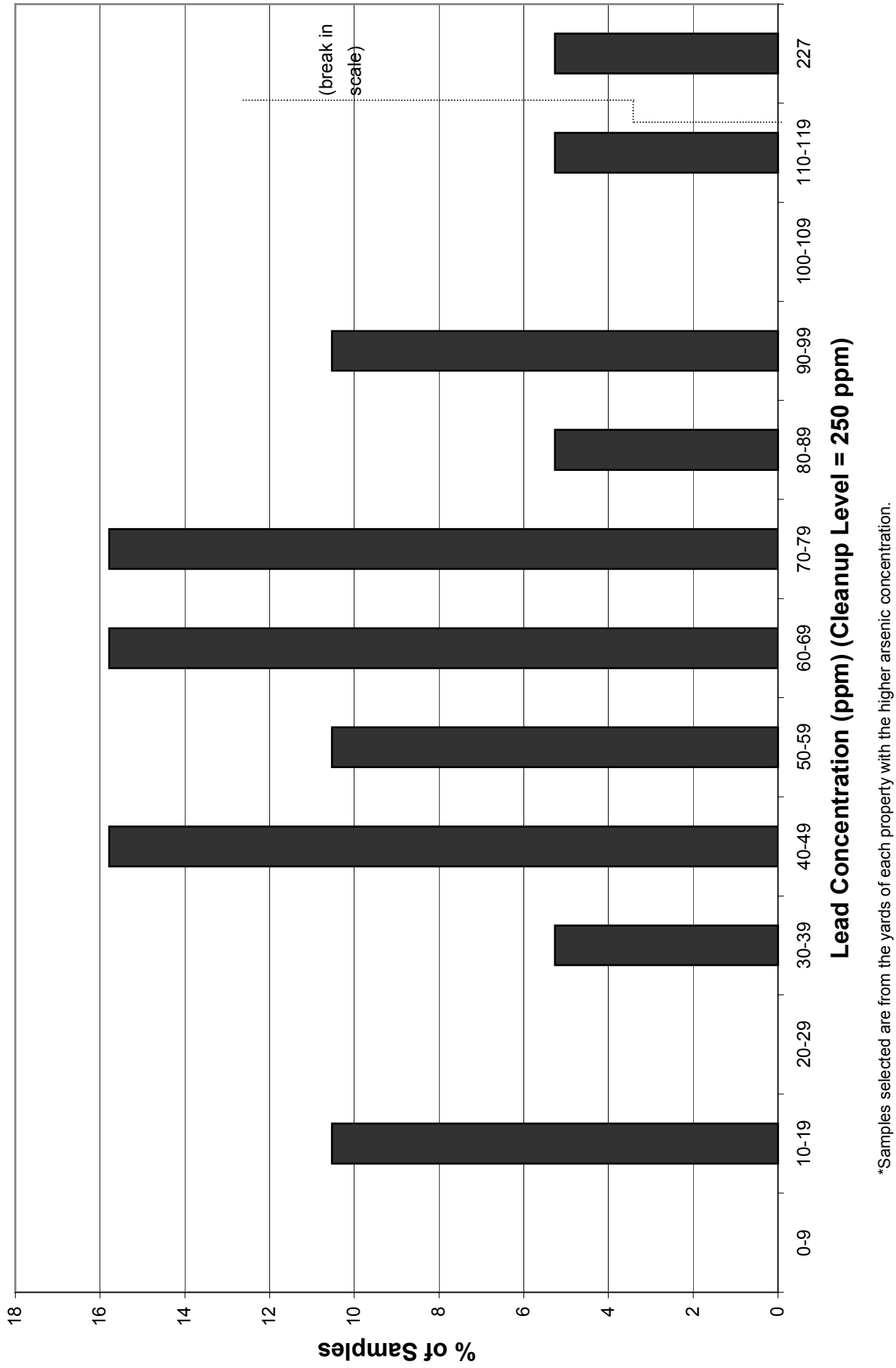


Figure 9. Lead Concentrations for 20 Residences

The relationship between lead and arsenic concentrations in the samples tested is shown in Figure 10. The lines of best fit in Figure 10 intersect the vertical axis at a lead concentration of approximately 25 ppm, a concentration indicative of the urban background of lead in the study area. Urban lead sources include historic auto emissions from the use of leaded fuels and lead paint. Because the best-fit lines do not pass through the origin of the graph, the ratio of lead-to-arsenic varies with arsenic concentration. Figure 10 shows from the best-fit line excluding the highest point, that the lead-to-arsenic ratios at arsenic concentrations of 20 ppm, 50 ppm, and 100 ppm are 2.36, 1.65, and 1.41 respectively. A preliminary evaluation of these ratios suggests they may be consistent with the ratios of other areas impacted by the Asarco smelter (Glass, 2001).

Potential Sources of Arsenic in University Place Soils

The Asarco smelter in Ruston began operating in 1890, well before any of the residential structures were built on the properties in this study. The downward trend in arsenic concentration for properties with newer residential structures and less time for arsenic to accumulate at or near the surface is consistent with the source of arsenic being from aerial deposition from the smelter stack. The pattern in Figure 8 of properties with residential structures newer than 30 years old showing lower arsenic concentrations than the overall trend is consistent with the smelter scaling down operations in the 1970s before ending operations in 1985. The data appear to be consistent with the Asarco smelter being the principal source of arsenic to University Place soils. This is indirect evidence of a link between the Asarco smelter arsenic emissions and the arsenic found in University Place residential soils. If signature metals found in the Asarco emissions were also found in University Place soils, a link between the two would be shown. As described above, the ratio of arsenic-to-lead can be an indicator of the source of soils arsenic. Samples have been archived from this study for potential future analyses of additional signature metals, but these analyses are not part of this study.

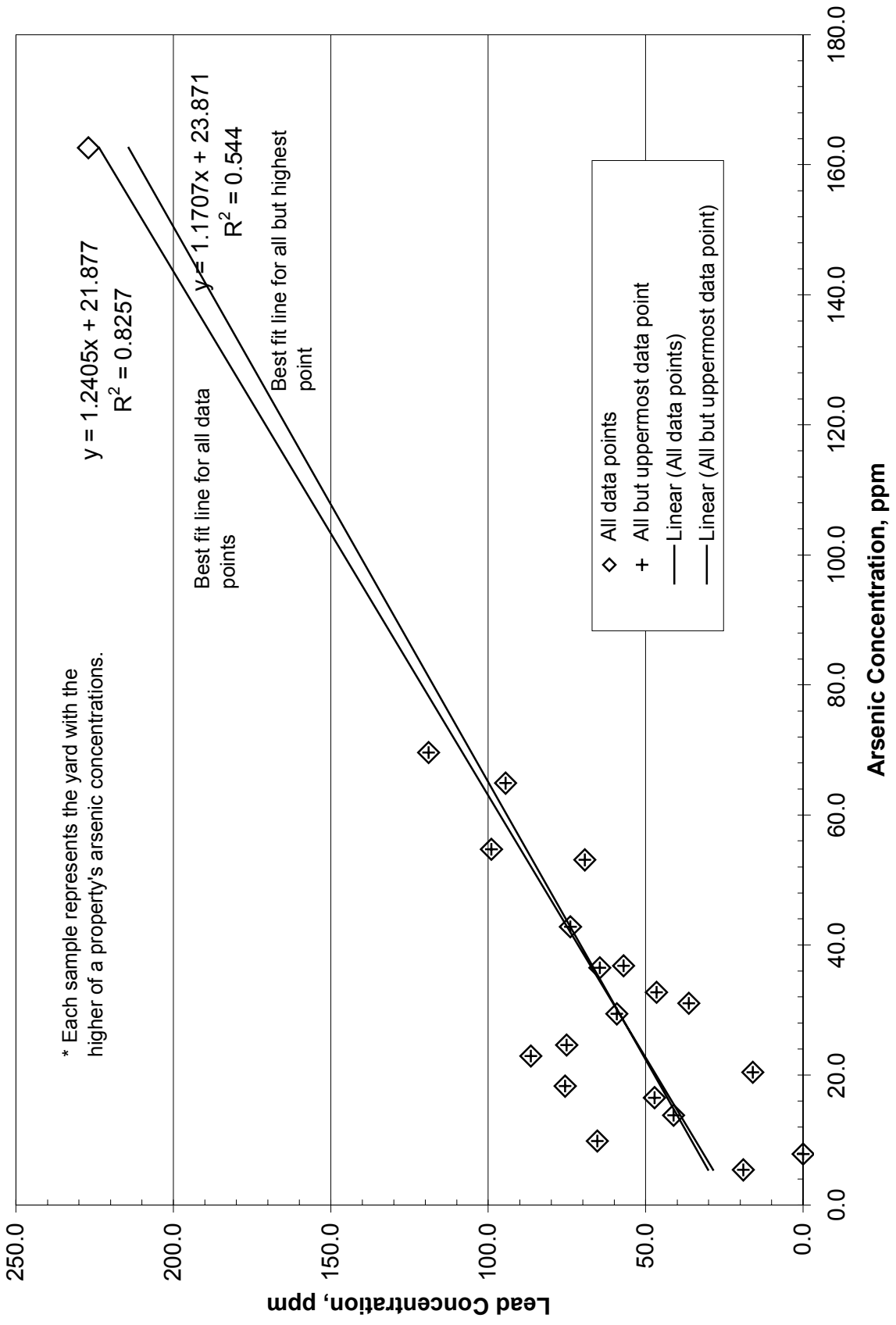


Figure 10. Lead vs. Arsenic Concentrations

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Conclusions

Soil was collected and analyzed from the front and back yards of 59 residential properties in northern University Place.

The mean soils arsenic concentration from the properties sampled was 26.4 ppm. The median soils arsenic concentration was 22.9 ppm. Although approximately 60% of the properties sampled had arsenic concentrations higher than the 20 ppm Model Toxics Control Act (MTCA) cleanup level for arsenic for uncontrolled use in residential areas, 80% of the properties had average arsenic concentrations of 40 ppm or lower. None of the limited number of lead analyses performed were above the MTCA cleanup level of 250 ppm for lead.

The age range of the structure on the properties correlated strongly with arsenic concentration. Properties with younger residential structures tended to have arsenic concentrations below the 20 ppm MTCA cleanup level, while properties with older structures tended to have arsenic concentrations exceeding the cleanup level.

Front yards tended to have lower arsenic concentrations than back yards. The extent and timing of landscaping activities such as cutting, filling, working the soil, or adding topsoil (though not recorded in this study) may be factors in reducing the influence of aerial deposition of arsenic to University Place soils.

There are indications that a higher percentage of property owners with younger residential structures chose to participate in the study than owners with older residences. This may have biased results towards properties with younger residences, causing the mean soils arsenic concentration in the study area (26.4 ppm) to be somewhat under represented. A high-end estimate of the true overall mean arsenic concentration is 28.9 ppm, the mean for properties with residences over 30 years old.

Recommendations

Ecology is working with the Seattle-King County Health Department to begin to address the area-wide contamination problems from the Asarco Tacoma Smelter. Ecology has provided a grant to the Seattle-King County Health Department to conduct additional sampling to identify the extent and magnitude of contamination from the smelter. Ecology will provide a grant to the Pierce County Health Department for the same purpose.

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Appendix A

Responses of Residents for Requests to Sample

First 55 Properties (Random Selection)

Telephone Calls			
Agree to Sample	Not Agree to Sample	Could Not be Reached	
33	15	25	
Letters			
Agree to Sample	Not Agree to Sample	No Response	Mail Undeliverable
22	2	33	8

Final 4 Properties (Selected in Central Portion of Study Area)

Telephone Calls		
Agree to Sample	Not Agree to Sample	Could not be Reached
4	9	5

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Appendix B

Field Sampling Plan

Equipment

We will carry enough equipment so that we will need to clean equipment, other than the actual collection devices, only once after each property. Pipes will be cleaned between front and back yards.

Checklist for sampling

Materials

- Aluminum foil for wrapping cleaned equipment
- Potting soil for filling in holes
- Sampling bottles
- Tags
- Lab sheets
- Field book to note locations, depths sampled
- Compass
- Measuring tape
- Wooden stake

Coring tools

- 2" diameter stainless steel pipe sampling devices: 2", 6", and 12" lengths

Mixing equipment

- Stainless steel mixing bowls (4 bowls for depths to 6"; 6 bowls for depths to 12")
- Stainless steel scoops for removing turf plugs and mixing samples in mixing bowls (4 for depths to 6", 6 for depths to 12")

Cleaning equipment

- Squeeze bottles with 10% nitric acid and DI water
- 2 buckets with lids: 1) Liquinox and water; 2) drip bucket to collect rinse from nitric acid and DI squeeze bottles
- Bottle brushes

Appendix B (cont.)

Sampling procedures

Call all people a day or two before sampling to let them know when you will sample. Almost everyone wanted to be notified before sampling. Go to the house before sampling. Some people will be home and expecting us to stop by before sampling.

Sample separately in front and back yards. Each property should have four samples (separate samples for front and back yards and for each depth interval: 0-2", 2-6") or six samples (with the two additional samples at 6-12", front and back yards). Each sample is prepared by mixing five subsamples of soil from a front or back yard for each depth interval. Dig five holes in front yard, five holes in back yard as follows:

Wear disposable, powder-free nitrile gloves. *Be sure when mixing not to let fines blow away as it is the fines that tend to have the highest arsenic content*. If there is a breeze, keep the sample covered with aluminum soil and mix in the van or other sheltered area.

Locating sampling sites

Stand at the approximate center of the yard. This is the location of the first subsample. Proceed NE, SE, SW, NW from the center a measured distance, halfway to the edge of the yard. These are the locations to obtain four additional subsamples. Mix the five subsamples in a bowl to obtain a composite sample.

Follow the same procedure for *duplicate* subsample sites, but locate the subsamples north, east, south, and west halfway to the edge of the yard.

Sample only on yard areas, not gardens. If the measured site is in a garden, relocate to the nearest spot away from the center point (toward the edge of the lawn) 3' from the edge of the garden. If a tree or utility is in the way, or a potential sampling site is within five feet of a road or within three feet of a building, take the sample from the nearest available yard area.

Coring

After locating sample location, cut a circular plug of turf with a 10% nitric acid-cleaned stainless steel trowel. Shake the soil from the turf roots back into the place where the plug was removed. Take samples with 2" diameter stainless steel pipe samplers. Drive pipes with sledge. Start with 2" pipe sampler for 0-2" depth interval, followed by 6" pipe sampler for 2-6" depth interval. Then at sites sampled to 12", use 12" pipe sampler for 6-12" depth interval. *Prepare separate samples for front and back yards.* Get soil out of pipe sampler by tapping on outside of pipe with sledge. Put five subsamples for each particular depth

Appendix B (cont.)

interval in mixing bowl and mix thoroughly with stainless steel scoop. Keep sample out of wind to prevent fines from blowing away. Spoon out sample and any split sample from bowl into sampling jars with scoop.

Labeling

Pick a label at random. While still at the property, write the age range of the house as the final entry on the summary tag (copying all summary tag information onto a lab sheet at the end of each week).

Age Range Code:

0	0-9 years
1	10-19 years
2	20-29 years
3	30-39 years
4	40-49 years
5	50-59 years
6	60-69 years
7	70-79 years
8	80-89 years
9	90-99 years

Cleaning

Clean all sample augers and pipes *after sampling a front or back yard* (clean between the front and back yard of a house). Clean pipe samplers by swishing in bucket partially filled with Liquinox detergent and water. Then scrub with bottle brush, working over the bucket. Then spray pipe sampler with deionized water from spray bottle. Next, hold the pipe sampler over a second bucket, spraying with 10% nitric acid from squeeze bottle. Follow with deionized water from squeeze bottle, rinsing three times, collecting the rinsate in the second bucket.

Clean mixing bowls and scoops, as above. These items should be cleaned not only after each front or back yard, *but after each depth interval*. The simplest way to do this is to use four to six mixing bowls and scoops (for sampling to 6" or 12" depth respectively) and cleaning them all at once before each property is sampled.

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Appendix C

Laboratory Quality Assurance/Quality Control Case Narrative

The quality of the arsenic and lead data was assessed by evaluating: 1) sample holding times, 2) instrument calibration, 3) procedural blanks, 4) spiked sample analyses, 5) precision data, and 6) laboratory control sample (LCS) analyses. Overall, the results show the arsenic and lead analyses to be accurate.

Sample holding times

All analyses were performed within the recommended holding time (180 days).

Instrument calibration

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run. All initial and continuing calibration verification standards and blanks were within relevant control limits.

Procedural blanks

The procedural blanks associated with these samples showed no analytically significant levels of requested analyte.

Spiked sample analyses

All spiked and duplicate spike recoveries met the acceptance criteria (75-125%) except for sample 259555 (145%). Since the recoveries were within CLP data validation guidelines for soil samples, no qualification was necessary. None of the samples selected for lead analysis were spiked.

Precision data

No duplicate spike analyses for arsenic were performed, as per client request. Replicate analysis of the LCS demonstrated good precision. For lead, precision estimates based on duplicate LCS analysis were all within the acceptance criteria for duplicate analysis (+/- 20%).

LCS analyses

All LCS analyses were within the acceptance criteria for arsenic and lead.

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Appendix D

Split and Field Replicate Soils Arsenic Results

Field ID	Depth	Lawn	Result	Split	Split RPD	Field Replicate	Field Rep RPD
1	2	front	33.9	30.3	11	47.6	34
		back	42.8	45.5	6	58.8	31
	6	front	32.0	33.7	5	37.6	16
		back	28.6	30.6	7	38.6	30
2	2	front	21.8	22.4	3	20.5	6
		back	24.6	23.8	3	26.6	8
	6	front	18.6	19.3	4	17.1	8
		back	15.8	16.8	6	21.1	29
3	2	front	32.2	34.3	6	35.7	10
		back	36.8	39.8	8	58.1	45
	6	front	27.8	31.3	12	25.0	10
		back	38.5	40.2	4	61.9	47
4	2	front	33.8	34.6	2	33.4	1
		back	62.6	59.1	8	31.3	67
	6	front	38.3	35.1	8	35.0	9
		back	49.6	39.9	22	34.2	37
5	2	front	19.6			23.4	18
		back	14.8			15.1	2
	6	front	18.9			21.1	11
		back	15.2			9.71	44
6	2	front	63.4			52.3	19
		back	11.4			17.4	42
	6	front	32.0			32.1	0
		back	33.9			38.5	13

Split - Sample obtained from same mixing bowl with sample

Field Replicate- Independently collected sample from a yard

RPD - Relative percent difference

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Appendix E

Arsenic and Lead Results

Arsenic (ppm)												Lead (ppm)
#	Field ID	Age Range (years)	2" avg	6" avg	12" avg	2"front	6"front	12"front	2" back	6" back	12" back	2"high*
1	19	0-9	4.4	4.9		6.4	6.8		2.5	3.0		
2	14		12.7	9.3		11.4	10.1		14.0	8.4		
3	34		13.7	17.0		5.3	8.8		22.0	25.3		
4	56	10-19	9.2	12.7	13.5	10.4	15.0	15.9	8.0	10.3	11.1	
5	36								20.4	22.0		
6	26	20-29	3.8	9.1		2.1	8.1		5.4	10.0		19 (b)
7	20		7.4	7.6		7.8	7.2		7.0	7.9		8.0 (f)
8	52					8.8	8.4	4.7				
9	25		10.8	9.7		8.7	9.5		12.8	9.9		
10	29		12.3	11.1		8.7	9.9		16.0	12.4		
11	59		13.5	17.4	20.5	8.8	15.9	13.1	18.3	18.9	27.9	75.6 (b)
12	41	30-39	6.5	11.2		8.4	12.3		4.6	10.1		
13	21		14.6	41.7		12.1	32.4		17.1	51.0		
14	5		17.2	17.1		19.6	18.9		14.8	15.2		
15	57		18.8	20.0	21.1	8.2	9.8	13.3	29.4	30.1	28.8	59.2 (b)
16	13		24.5	10.8		25.3	11.8		23.7	9.9		
17	16		24.8	19.0		27.8	19.4		21.8	18.5		
18	11		24.9	27.7		18.7	34.2		31.0	21.1		36.3 (b)
19	10		36.2	25.5		17.3	22.3		55.0	28.6		
20	4		48.2	44.0		33.8	38.3		62.6	49.6		
21	37		51.6	44.7		51.3	50.2		51.9	39.1		
22	30	40-49	8.4	10.8		3.7	8.4		13.1	13.2		
23	31		8.9	9.9		4.0	7.7		13.8	12.1		41.2 (b)
24	18								13.6	16.6		
25	24		14.2	20.2		11.9	14.5		16.5	25.8		47.2 (b)
26	43		17.0	19.1		16.9	20.6		17.0	17.5		
27	15		26.0	24.4		17.4	31.0		34.6	17.8		
28	40		26.8	29.6		27.7	26.3		25.9	32.9		
29	23		32.3	27.3		31.9	24.4		32.7	30.2		46.6 (b)
30	42								33.0	29.3		
31	6		37.4	33.0		63.4	32.0		11.4	33.9		
32	1		38.4	30.3		33.9	32.0		42.8	28.6		73.9 (b)
33	55		38.6	34.7	26.2	48.1	39.4	20.3	29.0	29.9	32.1	
34	8		58.6	50.8		47.5	48.7		69.6	52.8		119 (b)

* Lead analyses for 0-2", yard with higher lead results for each property. Front and back yards are indicated by (f) and (b).

Appendix E - (cont'd)

Arsenic (ppm)												Lead (ppm)
#	Field ID	Age Range (years)	2" avg	6" avg	12" avg	2"front	6"front	12"front	2" back	6" back	12" back	2" high
35	38		68.2	61.8		39.0	46.3		97.4	77.2		
36	51		113	85.7	45.7	63.6	65.4	34.9	163	106	56.4	227 (b)
37	39	50-59	22.4	23.0		22.0	23.3		22.8	22.6		
38	2		23.2	17.2		21.8	18.6		24.6	15.8		75.1 (b)
39	64		29.2	22.2		21.9	17.7		36.5	26.6		64.6 (b)
40	22		29.6	41.7		38.5	62.6		20.6	20.7		
41	9		31.5	36.8		15	16.4		47.9	57.1		
42	63		33.9	37.8		33.9	34.8		33.9	40.7		
43	3		34.5	33.2		32.2	27.8		36.8	38.5		57.0 (b)
44	61		36.7	32.1		54.7	52.3		18.7	11.8		99.0 (f)
45	58		42.9	28.5	21.2	53.1	31.1	22.8	32.7	25.9	19.5	69.4 (f)
46	62		46.9	50.2		37.4	38.8		56.3	61.6		
47	45		47.1	30.7		54.5	35.6		39.6	25.8		
48	49	60-69	8.2	13.4	14.1	7.9	11.3	11.5	8.42	15.5	16.7	
49	54		38.9	31.9	27.8	29	25.3	26.4	48.7	38.4	29.1	
50	7		44.2	38.6		39.9	25.3		48.4	51.9		
51	32		69.6	66.5		58.9	58.1		80.2	74.9		
		70-79	(no sampling sites)									
52	12	80-89	11.2	26.6		12.6	29.4		9.8	23.7		65.4 (f)
53	47								35.7	29.2		
54	53		37.8	41.5	30.5	37.6	48.5	22.6	37.9	34.4	38.4	
55	17	unknown age range	14.4	16.7		10.9	15.2		17.8	18.1		
56	33		16.9	15.7		13.3	12.9		20.4	18.5		16 (b)
57	35		19.4	24.2		18.7	19.7		20.1	28.6		
58	60		20.6	14.3	12.3	22.9	15.8	16.2	18.2	12.8	8.45	86.5 (f)
59	50		47.6	57.6	40.4	30.3	39.0	30.3	64.9	76.1	50.4	94.5 (b)