TACOMA SMELTER PLUME
MAINLAND KING COUNTY, WA
CHILD USE AREA
FINAL REPORT





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EXECUTIVE SUMMARY

The former ASARCO Tacoma copper smelter operated in Ruston, Washington (a small municipality northwest of downtown Tacoma, WA) for almost 100 years before closing permanently in 1986. Concerns over smelter emissions of arsenic and other contaminants, their transport downwind to nearby communities, and possible exposures and health effects from the deposition of contaminants from the smelter plume led to numerous studies starting in the early 1970s.

Several recent studies have focused on levels of arsenic and lead in soils in areas immediately downwind of the smelter. These studies; Vashon Maury Island Soil Study, Vashon Maury Island Child Use Areas Study, and Pierce County Footprint Study; concluded that the smelter emissions had been deposited over a wide area of King and Pierce Counties. Based on the findings of these studies, the Washington State Department of Ecology (Ecology) and Public Health – Seattle and King County (PHSKC) decided it would be prudent to evaluate Child Use Areas (CUAs) in mainland King County to address concerns about possible exposures in developed areas where small children could have frequent contact with soils.

The Tacoma Smelter Plume Child-Use Area study was funded by the Washington State Department of Ecology (Ecology), designed by Ecology and PHSKC, and performed by Science Applications International Corporation (SAIC), under contract to Ecology. The primary goal of the study was to collect enough data to decide whether early cleanup actions, called Interim Actions under Ecology's Model Toxics Control Act regulations, should be taken at any of the sampled child-use areas. Interim Action Trigger Levels (the average concentration of arsenic or lead at a property at which an interim action would be warranted) were established for lead and arsenic for schools, childcare facilities, and parks.

A total of 2,532 soil samples from 97 CUAs were collected and analyzed for arsenic and lead. Child-use areas included public and private schools, public parks, and childcare centers. The sampled CUAs were located on mainland King County in White Center, Burien, Tukwila, Normandy Park, SeaTac, Des Moines, Kent, and Federal Way.

SAIC staff collected soil samples between December 16, 2002 and April 7, 2003. Laboratory analyses were performed by Severn Trent Laboratory in Tacoma, WA (STL – Seattle). Data validation was performed by EcoChem, Inc. in Seattle, WA. Based on the data quality assessments, all results reported by STL - Seattle were acceptable for evaluating the child-use areas.

No property sampled exceeded the Interim Action Trigger Level established for arsenic or lead. Only four properties had individual samples that exceeded the Interim Action Trigger Level for arsenic. No individual samples exceeded the Trigger Level for lead.

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1.0 INTRODUCTION

ASARCO operated a primary copper smelter at Ruston, Washington for almost 100 years. That smelter, referred to as the Tacoma Smelter, specialized in the toll smelting of complex (e.g., high-arsenic) ores. It closed in 1986. For many years, the Tacoma Smelter was the sole domestic source of arsenic for the U.S. market.

The U.S. Environmental Protection Agency is overseeing cleanup of residential properties in Ruston and North Tacoma, within approximately one mile of the former smelter, as part of Commencement Bay Superfund Site cleanup activities. The Washington State Department of Ecology (Ecology), in cooperation with local health departments, is investigating widespread contamination from smelter emissions extending beyond the designated EPA Superfund site. This larger area of contamination has been designated the Tacoma Smelter Plume (TSP) Site under Washington's Model Toxics Control Act (MTCA).

A number of studies of residual soil contamination within the TSP Site have been completed or are in progress. Sampling in relatively undisturbed forested areas has been conducted first, to define the spatial pattern of smelter contamination and its likely maximum magnitude by location. The second phase of studies includes sampling child-use areas in the most heavily impacted areas of the Tacoma Smelter Plume.

Surface soils at Child Use Areas in King County were sampled and analyzed for lead and arsenic during the fall and winter of 2002/2003. This report documents the sampling and analysis activities and provides the results of the studies.

1.1 Purpose and Objectives

Child use areas (CUAs) – those public access or use locations where numbers of children are likely to spend significant time and have opportunities for contact with contaminated soils – were sampled as part of the second phase of studies for the Tacoma Smelter Plume project. Young children are considered a population of special concern because of their propensity for soil contact and ingestion, lower body weight, higher metabolism and greater sensitivity to smelter-related contaminants such as lead. One study of child use areas, on Vashon-Maury Island (King County), was completed in 2001. This study complements the Vashon-Maury Island study by sampling child-use areas on the mainland of south King County. A similar study is underway in Pierce County.

Child-use areas include several different property types and uses where young children are likely to be present with some frequency, and where their activities are likely to put them in contact with potentially contaminated soils. Young children up to 6 years old are the group of primary interest for the sampling of child-use areas. Common types of child-use areas include:

(1) elementary schools
(2) preschools
(3) childcare centers
(4) parks and playfields
(5) camps

Other locations, including informal or undesignated play or activity centers, might also represent potential public child-use areas. For example, community gardens, nature education centers, vacant lots, or play areas associated with apartment complexes, public housing, houses of worship, mobile home parks, or youth clubs could also represent potential exposure locations. Properties were sampled only if owners gave consent to sample.

The primary objective for sampling soils at identified child-use areas in King County within the TSP Site was to identify those locations where smelter-related contamination poses the greatest exposure risks to young children, under current conditions. Several aspects of this primary objective are notable:

- As part of the emphasis on identifying "worst child-use areas first", about 80% of the sampling was limited to the most-affected portions of the total TSP Site based on four factors, including number of children, duration/exposure, prevailing wind direction and distance from the smelter stack. A prioritization system was developed by the Study Design Group and was used to select child-use areas for sampling within that limited area. Due to limited agency resources, only a limited number of child-use areas were sampled during this project phase.
- These investigations focused on characterizing soil contamination resulting from Tacoma Smelter emissions. It was not the objective of sampling to completely characterize impacts from other sources of arsenic or lead, such as treated wood, paint residues, emissions from leaded gasoline use or other non-smelter sources.
- The depth profiles of soil contamination where soils have been disturbed by development activities can be complex, with contamination extending well below depths affected in undisturbed soils. Sampling at child-use areas was not intended to fully characterize soil contamination at selected properties, or to necessarily identify the maximum concentrations occurring at any depth. The emphasis on potential soil exposures under current conditions served to limit sampling to near-surface soils where soil contact is most likely to occur. For this reason, this study is a “health screening level” study rather than a MTCA site characterization study or remedial investigation (RI).
- Results were compared to Interim Action Trigger Level criteria and MTCA cleanup standards to determine what, if any, actions are or will be needed at each decision unit sampled.

The results of child-use area sampling provide additional information on soil contamination levels at developed properties of various types and ages of development, and thereby expand the current understanding of comparative contaminant concentrations at relatively undisturbed, forested properties versus developed properties within the TSP Site in addition to providing short-term risk estimate data.

1.2 Organization

This final report documents the study design and sample results. Chapter 2 provides information on previous studies concerning lead and arsenic emissions from the Tacoma Smelter. Chapter 3 documents the site sampling activities. Chapter 4 discusses the Quality Assurance/Quality Control elements for the sampling and analysis program. Chapter 5 is an analysis of the data Chapter 6 contains references that are cited in the text.

1.3 Personnel

The design of the study components (selecting the child use areas to be sampled, sample locations, sample depths, and analyses performed) was a collaborative effort between Ecology, PHSKC, Tacoma Pierce County Health Department (TPCHD), and Gregory L. Glass. Science Applications International Corporation (SAIC) participated in the planning process as an Ecology contractor. This group is referred to as the Study Design Group.

Figure 1 shows the project organization for the work described in this memorandum. SAIC prepared project plans and conducted the sampling and analysis of Child Use Areas in mainland King County on behalf of Ecology. SAIC subcontracted the analytical chemistry work to Severn Trent Laboratory in Tacoma, Washington (STL – Seattle). EcoChem, Inc. (an SAIC teammate on the Ecology Toxics Cleanup Program contract) performed third-party data validation services and provided technical support on issues pertaining to chemical analysis and data quality.

PHSKC assisted Ecology in identifying the properties where sampling occurred and Ecology secured the agreements providing access to sample.

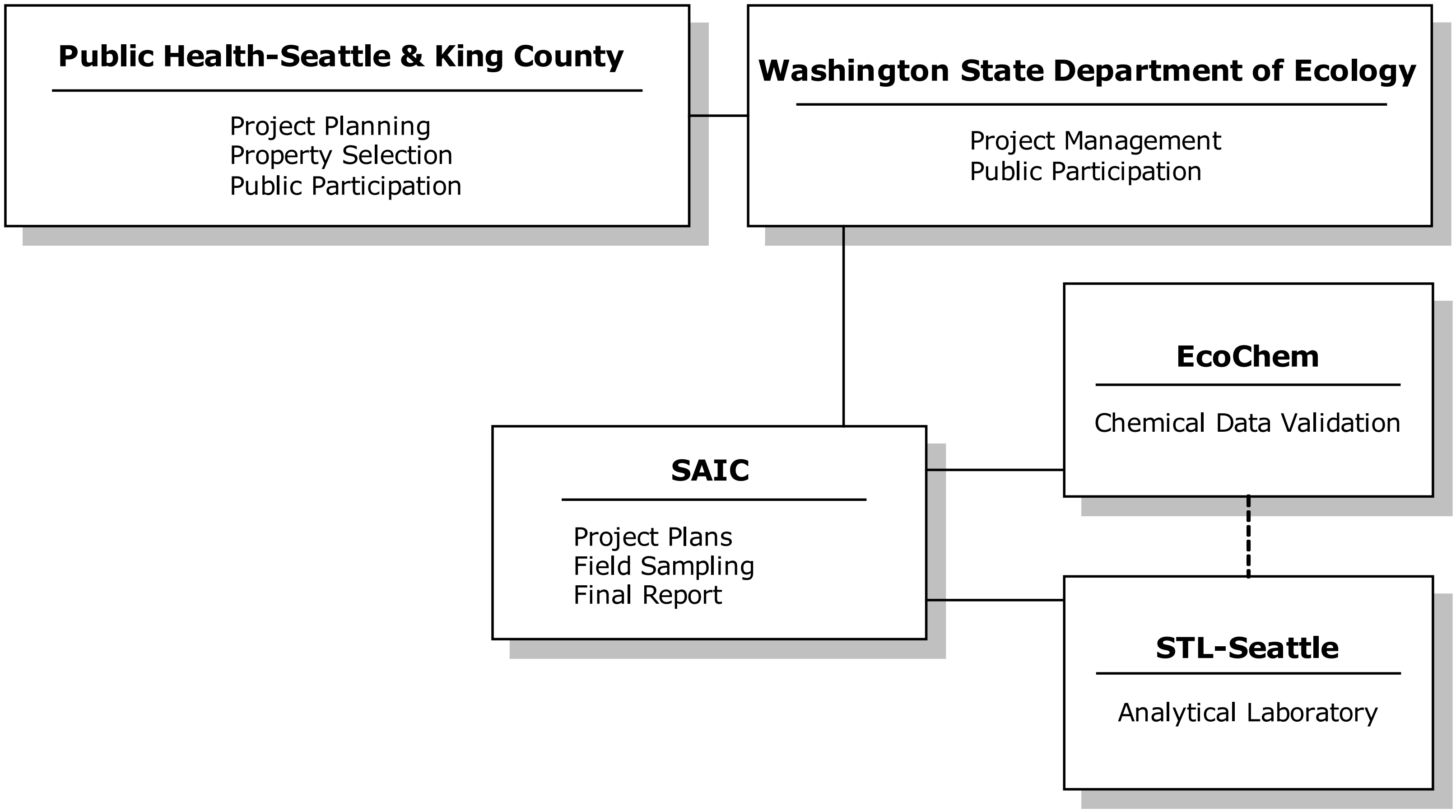
1.3.1 Sample Design Group

During the summer and fall of 2002, a multi-agency work group met to resolve many issues surrounding this program. Issues included what is a child use area; how are the many eligible properties prioritized in order to sample the "worst first"; how many samples should be collected per property; and what should the samples be analyzed for. At this point of the project, the sample design was to include child use areas in both King and Pierce counties, so the planning included agencies from both counties. The Sample Design Group are listed in Table 1.

The Sample Design Group met in August and September 2002 to finalize the sampling program design. In October 2002, Greg Glass published a technical memorandum that documented the Sample Design Group's decision process and conclusions (Glass 2002).

Table 1: Sample Design Group Participants

Agency/Company	Name	Role
Washington Department of Ecology	Marian Abbett	Project Coordinator
	Guy Barrett	Site Manager, King County CUA Study
	Joyce Mercuri	Site manager, Pierce County CUA Study
	Norm Peck	NWRO Representative
	Molly Gibbs	Public Participation Coordinator
Pierce County Health Department	Glenn Rollins	TPCHD Environmental Services Manager
	Jennifer Olson	TPCHD Field Sampler
	Lindsay Knellen	TPCHD Field Sampler
Public Health – Seattle & King County	Nicole Fus/Charles Wu	PHSKC TSP Project Coordinator
	Gary Irvine	PHSKC Env. Health Supervisor
Gregory Glass Environmental Consulting	Greg Glass	Independent Consultant to PHSKC
SAIC	Doug Pearman	Ecology Contractor



Tacoma Smelter Plume
Child Use Area
Sampling Program

Figure 1
Project Organization

1.3.2 King County CUA Soil Sampling Project Implementation

Under Ecology's direction, SAIC:

- Prepared the Health and Safety Plan (SAIC 2002a) and the Field Sampling Plan (SAIC 2002b), which includes the Sampling and Analysis Plan and the Quality Assurance Project Plan;
- Subcontracted the analytical laboratory and the data validation contractor;
- Collected all of the soil samples in the field;
- Coordinated with the lab and validation contractors to answer technical questions and to track progress;
- Managed the data as it was submitted by the laboratory and the validator; and
- Prepared this final report.

SAIC technical staff are listed in Table 2.

Table 2: SAIC Technical Staff for TSP CUA Study

Staff	Role
Doug Pearman	Project Manager
Mark Dagel, RPG	Prepared FSP; QC Coordinator
Michael Johnsen, Ruth Otteman	Field Operations Managers
Brian Baxter, Chris Hunt, Michelle Payne, Don Wyll	Field Samplers

SAIC staff collected soil samples in late December 2002, then again in January – April 2003.

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2.0 BACKGROUND INFORMATION

2.1 Historic Studies

A large number of studies, performed over the period from the early 1970s to the present, have characterized smelter emissions and documented environmental contamination in areas surrounding the former Tacoma Smelter. Historic studies have been compiled and placed in Tacoma Smelter Plume Site project files at Ecology and the local health departments. References for historic studies are available in previous study design documents (Glass 1999, 2000, 2001, 2002; see also the study timeline figures in Bechtel Environmental, Inc. 1992, volume 2).

A basic finding of the studies, taken as a whole, is that the regional-scale pattern of environmental contamination shows a distance/direction versus concentration relationship consistent with airborne smelter emissions and local wind rose patterns. The geographic areas sampled, the types of land uses at sampled properties, the sampling and analysis protocols, and the intensity of sampling have varied greatly among studies. Tacoma Smelter Plume investigations are notable, compared to most earlier studies, for the following: an expanded, regional-scale geographic area of coverage; a systematic approach to selecting land use types being sampled; consistent sampling and analysis protocols for regional sampling coverage; and a large number of samples, with a comparatively high sampling intensity.

The studies preceding Tacoma Smelter Plume investigations can be summarized for convenience as occurring in three periods; studies through smelter closure, Superfund studies, and post-Superfund studies.

2.1.1 Studies Through Smelter Closure

The early studies included sampling of a variety of environmental media to document contamination in areas surrounding the Tacoma Smelter. Sampled media included airborne particulates, precipitation, soils, house dusts, vegetation, sediments, surface water, reservoir sludges, bees, cows, and fish tissue, as well as human urinary and blood samples. Soil sampling included forested properties, roadside soils, residential areas, vacant lots, playfields, and gardens. With the exception of extensive garden soil testing and regional-scale precipitation chemistry monitoring, the early studies were generally small in scale and limited in geographic coverage. Sampling and analytical protocols varied significantly among studies.

Taking advantage of the announced closure date for smelter operations, several studies performed comparative pre- and post-closure sampling at the time of smelter shutdown. A comprehensive multimedia study was also performed at that time by a University of Washington research team to investigate the environmental pathway(s) by which community residents, especially young children, were being exposed to arsenic (Polissar et al. 1987). That Arsenic Exposure Pathways Study, while compiling new sampling information for multiple census tracts on Vashon-Maury Island, Ruston, and North Tacoma, was not designed to define the geographic nature and extent of soil contamination.

2.1.2 Superfund Studies

After completion of the Arsenic Exposure Pathways Study and through 1992, Ecology and USEPA performed a series of studies to define the nature and extent of residual soil contamination in areas near the former smelter (Ruston and North Tacoma, within a distance of approximately one mile). Those studies included a fairly dense grid of sampling locations within the restricted study area. Selected soil samples were also analyzed for an extended list of elements, documenting correlations among elements related to smelter operations and emissions. Once cleanup actions at residential properties began under a Superfund Record of Decision, property-by-property sampling results provided an extremely detailed data set for soil contamination patterns and magnitudes. Cleanup actions at Ruston/North Tacoma properties are continuing under EPA's Superfund program.

2.1.3 Post-Superfund Studies

Starting in about 1998, issues arising at two locations well outside of the EPA's Ruston/North Tacoma Superfund cleanup area resulted in new soil sampling programs. A gravel mine on Maury Island, King County, proposed for expansion, was shown to have elevated metals levels in surface soils (Landau Associates, Inc. 1999; Terra Associates, Inc. 1999). Unexpectedly extensive soil contamination was also found near two water tanks in University Place, Pierce Co., that had been prepared for painting using a slag-blasting matrix. That finding led to an area background soil study that documented elevated metals in surface soils over an area of approximately 5 square miles (City of Tacoma and Glass 1999). In both cases, the soil contamination was judged likely to reflect contamination from Tacoma Smelter emissions. Ecology performed a follow-up study of soils on residential properties in University Place that also documented elevated levels of arsenic; the magnitude of contamination was found to be associated with the age of the homes (Washington State Department of Ecology 2001). These findings, together with other historic data, resulted in Ecology supporting a series of soil investigations over a large geographic area to better define the magnitude and extent of smelter impacts. The area of contamination was designated as the Tacoma Smelter Plume Site under MTCA.

To date, four soils investigations have been or are being performed under the Tacoma Smelter Plume Site program. They are:

- Vashon-Maury Island initial (undisturbed area, or footprint) study. The first study collected and analyzed samples from 177 locations covering all of Vashon-Maury Island and nearshore areas on the King County Mainland east of Vashon-Maury Island. All sampling locations were relatively undisturbed forested areas. All samples were analyzed for arsenic and lead; most were also analyzed for cadmium. This study is completed (Glass 1999 and Public Health - Seattle & King County and Glass 2000).

- Vashon-Maury Island child-use areas study. A survey was performed, after the initial study was completed, of all child-use areas on Vashon-Maury Island whose owners gave permission to sample. A total of 34 child-use areas were sampled. Those child-use areas included beaches, parks, camps, schools, preschools, and childcare centers. A small number of additional forested soil samples were also collected near several of the child-use areas. All soil samples were analyzed for arsenic and lead. Selected samples were also analyzed for additional tracer elements. This study and report are completed (Glass 2000 and Public Health - Seattle & King County and Glass 2001).

- King County Mainland initial (undisturbed area, or footprint) study. The limited nearshore sampling on the King County Mainland, performed as part of the initial Vashon-Maury Island study (see above), included 16 locations. The results confirmed that mainland soils had significantly elevated arsenic and lead concentrations. An expanded sampling program, including 59 sampling locations over an area approaching 200 square miles, was conducted. All samples represented relatively undisturbed forested areas and were analyzed for arsenic and lead. Selected samples were also analyzed for additional tracer elements. The two mainland sampling studies combined provide data at 75 locations. This study and report are completed (Glass 2001 and Washington State Department of Ecology 2002).

- Pierce County initial study ("Footprint" Study). An initial study to evaluate the regional-scale pattern of smelter-related soil contamination in Pierce County was completed in late 2002. It included approximately 200 locations, over an area approaching 200 square miles (those portions of Pierce County west and north of I-5). All samples were analyzed for arsenic and lead. Selected samples were also analyzed for additional tracer elements. Sampling locations included both forested and residential properties. Relatively undisturbed forested areas suitable for sampling are all but absent in the densely developed Pierce County mainland areas from Ruston to University Place and in Northeast Tacoma; therefore, residential sampling is being used in those parts of the study area. Forested properties are being sampled elsewhere.

These four Tacoma Smelter Plume investigations of residual soil contamination include analyses of a total of approximately 4,000 soil samples. The sampling and analysis of soils from selected child-use areas in King County and Pierce County continued the general approach of first determining regional-scale patterns of soil contamination and then evaluating properties where potential exposures of young children are of greatest concern.

2.2 Prioritization Scheme

The primary objective for sampling soils at identified child-use areas in King County and Pierce County within the Tacoma Smelter Plume Site was to identify those locations where smelter-related contamination were deemed most likely to pose the greatest exposure risks to young children, under current conditions. Several aspects of this primary objective are notable:

- As part of the emphasis on identifying "worst child-use areas first", sampling was limited to the most-affected portions of the total Tacoma Smelter Plume Site, and a prioritization system was used to select child-use areas for sampling within that limited area. Within available agency resources, only a limited number of child-use areas were sampled. The results should not be extrapolated to other unsampled child-use areas; or other properties, including residences because local variations in the magnitude of soil contamination are large, being affected in part by property-specific development histories. Sampling at selected child-use areas should also not be used to define the overall Tacoma Smelter Plume Site boundary.

- These investigations focused on characterizing soil contamination resulting from Tacoma Smelter emissions. It is not the objective of sampling to completely characterize impacts from other sources of arsenic or lead, such as treated wood, paint residues, or emissions from leaded gasoline use.

- The depth profiles of soil contamination where soils have been disturbed by development activities can be complex, with contamination extending well below depths affected in undisturbed soils. Sampling at child-use areas is not intended to fully characterize soil contamination at selected properties, or to necessarily identify the maximum concentrations occurring at any depth. The emphasis on potential soil exposures under current conditions serves to limit sampling to near-surface soils where soil contact is most likely to occur and is health-screening level sampling only.

2.2.1 Child Use Study Area Definition

A methodology for defining child-use study areas, equally applicable to King County and Pierce County, was developed by the Sample Design Work Group. Three factors relevant to the issue of defining a study area were identified:

(a) The available agency resources for sampling child-use areas are limited, supporting sampling of only a small percentage of the total number of child-use areas within the large Tacoma Smelter Plume Site.
(b) The initial investigations confirm a regional-scale spatial pattern in the magnitude of smelter-related soil contamination. The maximum observed soil concentrations show an approximately exponential decay with distance from the smelter, with a rate of decay inversely correlated to wind frequency.
(c) The sampling results from relatively undisturbed forested locations are very likely to be an upper bound on soil contaminant concentrations at more developed and disturbed child-use properties.

Given these factors, the Work Group recognized that information from the initial investigations could be used to bound that part of the total Tacoma Smelter Plume Site where maximum soil concentrations at child-use areas could reasonably exceed any chosen criterion level. The initial sampling to identify the most impacted child-use areas could thus be focused within a smaller area reflecting the strong, regional-scale spatial pattern of soil contamination. The Work Group decided to use a criterion value of 100-ppm soil arsenic – equal to the lowest Interim Action

Trigger Level developed by Ecology – as the lower bound for defining the child-use study areas in the two counties.

The general methodology included the following steps:

- Compile a database of maximum soil arsenic concentrations and the distance and direction of each location with respect to the smelter tall stack in Ruston. Review historical study results and as appropriate supplement the data from the initial investigations with earlier data.
- Partition that data set into subsets by wind sectors (using the 16 sectors defined by typical wind roses).
- Plot the data for maximum arsenic concentration versus distance for each wind sector.
- Hand-draw the approximate bounding line for the plotted data. (See Attachment B for a description of how using log-scaled concentration data makes the bounding curve a straight line, which is easier to estimate).
- Use the hand-drawn bounding line to estimate the intercept and slope values, and thereby establish the bounding curve equation.
- Solve the equation for the bounding curve for each wind sector to calculate a distance to the 100 ppm soil arsenic criterion value.
- Use the resulting distances for each wind sector to plot a child-use study area.

The resulting study area is shown in Figure 2.

2.2.2 Selection of Properties to Sample

PHSKC and Ecology identified and listed candidate child-use areas within the defined Study Area. For the common types of child-use areas, such as elementary schools, preschools, parks, and camps, King County databases provided reasonably complete lists. License registries also provided lists of childcare centers. PHSKC and Ecology coordinated with local governments to review and expand these initial inventories of candidate child-use areas. Additional properties within the common child-use area categories were identified through such coordination and by way of public input at meetings. Vacant lots, community gardens, and play areas associated with housing complexes or other facilities are among the types of informal child-use areas that were identified.

Information was compiled for each candidate child-use area and used to derive a numerical score for prioritization purposes. The information used in scoring included four factors related to the potential for exposures:

(a) an estimate for the number of children ages 0 to 6 years present at the child-use area on a frequent basis
(b) the location of the child-use property, expressed as the distance and direction from the tall stack at the Tacoma Smelter, which was used to calculate a bounding estimate for soil arsenic concentrations
(c) information on the property history, specifically the date of property development or major redevelopment that would have established the current soil profiles at the property
(d) the typical frequency and duration of children's activities at the child-use area that could result in soil contact.

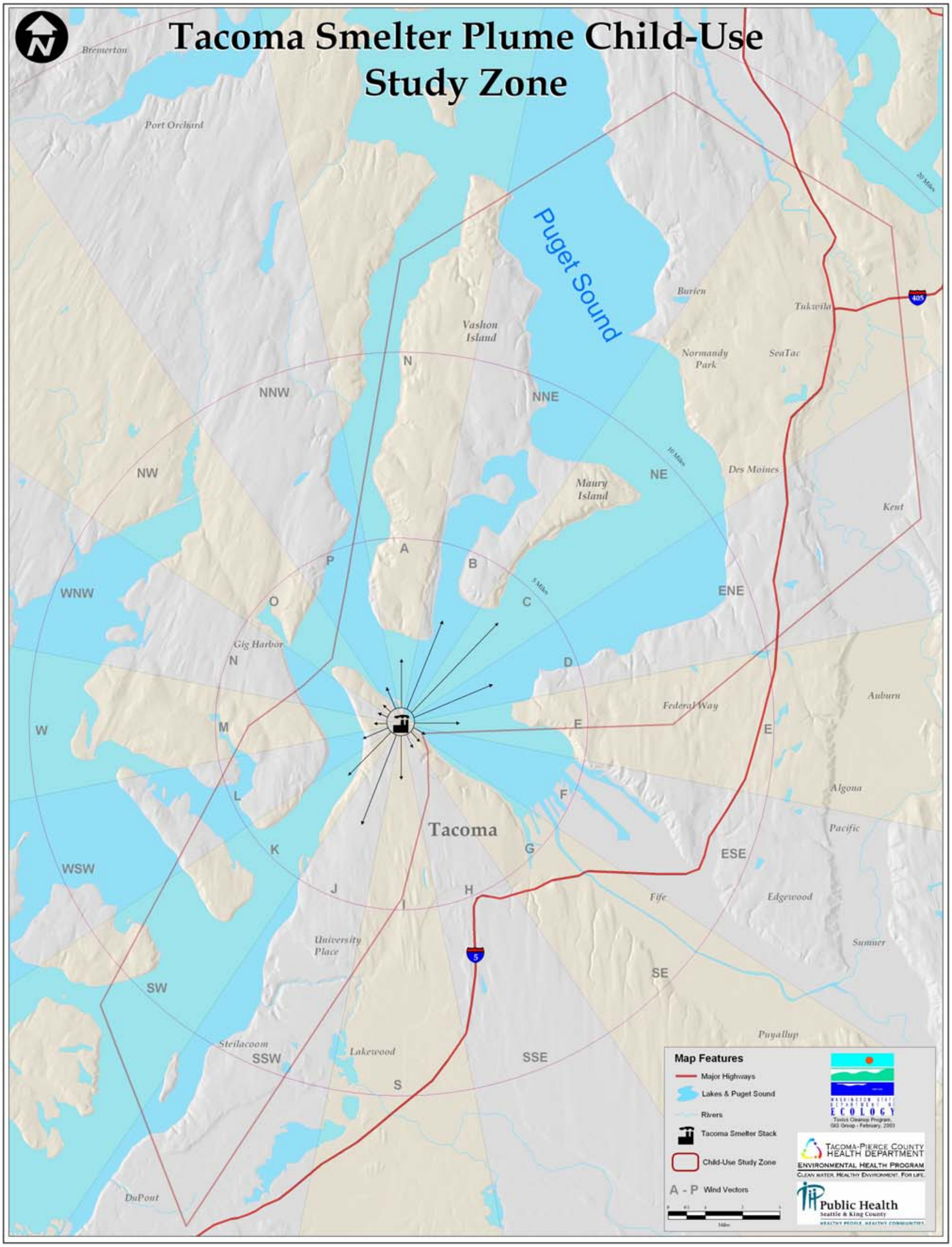

Figure 2: Tacoma Smelter Plume CUA Study Area

The individual scores on these four factors were combined to calculate a single overall score for each candidate child-use area. These scores, with higher scores indicating a higher priority for sampling, prioritized the child-use areas. The specific child-use areas selected reflected the priority rankings as well as the recommendations of local governments and input at public meetings. Ecology selected the highest priority child-use areas while including some lower priority properties recommended by local governments and communities, so the communities would have some information about child-use properties in their area.

Ecology contacted approximately 221 property owners to get agreements for access to sample. After repeated contact, agreements were received for 140 properties. A total of 97 properties were sampled in this study. Some child use areas for which permission to sample was received were not sampled, primarily because conditions at the facility precluded exposure (e.g. thick clean cover with a barrier, facility completely paved, etc.).

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3.0 SITE ACTIVITIES

3.1 Decision Units

Once CUAs were selected for sampling, a consistent design was used to collect soil samples. This section discusses the concept of decision units (DUs) at CUAs.

A child-use property was subdivided into multiple areas - reflecting various child activities, land uses, property histories, or other factors - at which soil was accessible by young children and exposures could occur. Different parts of a child-use property were treated as decision units, since the decisions on appropriate response actions may vary from one portion of the property to another based on the use(s) and contaminant concentrations found.

Small child-use areas often had only a single DU. For example, a childcare center operated out of a private residence may have only a single fenced outdoor play area in the back yard of the property, perhaps 40 feet by 60 feet in size. An elementary school property tens of acres in size, on the other hand, may have a demonstration garden area; several areas with play equipment, various ball fields, and perhaps even a nature exploration area. Such an elementary school was best divided into multiple decision units for sampling and evaluation purposes.

DUs were defined at the selected CUAs by the field sampling teams, based on observations and discussions with property owners or operators. The Sample Design Work Group decided to limit the number of DUs to be sampled at a single CUA to no more than four, to promote sampling at a larger number of CUAs. The set of defined DUs at a CUA was not required to provide complete coverage of the entire property. Well-maintained grass lawns that are not used significantly by young children, for example, were not included in any of the defined DUs. In one instance during the study, a property was large and varied enough that five DUs were identified.

The Sample Design Work Group also decided that eight locations (referred to as "borings" in previous studies) would be sampled in each DU and that two samples would be collected from each location – a sample from the 0-2" or surface soils and a sample representing the 2-6" interval. The sample design also allowed the number of sampling locations to be larger or smaller, if site conditions warranted. In the conduct of the study, one DU was sampled at only four locations and another warranted ten locations.

3.2 Play Area Description

In a broad sense, play areas were defined as any place that young children (up to six years old) were allowed to play on a given property. For elementary schools, this included the pre-schoolers, kindergarteners, and first graders and play areas included playground equipment, soccer or baseball fields, and, in one case, a small outdoor picnic area. In the parks, the sampling teams looked for the playground equipment, picnic areas, and well-worn trails next to creeks or other areas of wonder for small children. Finally, at the childcare facilities, the play areas were defined as the fenced-in backyards or protected areas at the larger facilities – basically wherever children were allowed to play outdoors.

At most of the schools and parks, the playground equipment area had formal borders (timbers, tires, or concrete curbing) and the floor of the play area was covered with play chips, sawdust, pea gravel, or rubber mats. Many of these play area floors were also lined with some type of geo-fabric. If the cover was deeper than six-inches or there was an intact liner, the play area was not sampled. The Sample Design Work Group had decided that greater than six-inches of cover provided sufficient separation from the potentially-contaminated soil beneath.

3.3 Soil Sampling Techniques

Sample locations were marked with wire flags. Actual samples were collected using custom-made coring tools. The two tools were designed to collect samples from the top 2" and then from the 2-6" depth. All loose cover (play chips, tree needles/leaves, etc) was first cleared away. The sampling tool was placed on the ground and then driven with a 2-lb rubber hammer to the full depth. The sampling tool was then withdrawn, and the soil sample placed into an 8-oz glass jar that had been pre-labeled. The sample was then placed in a cooler for further packing and shipment. The 2-6" sample was collected from the same location using the same technique, but using the sampling tool for the deeper sample. Soil was removed from the opening using a stainless steel spoon. After the samples were collected, the opening was refilled with potting soil and, if there was grass covering the sample location, the grass plug was reseated on top of the potting soil. An alternative method was used when X-ray fluoroscopy(XRF) pilot testing was conducted; each such, sample, regardless of depth of origin was initially placed in a pre-cleaned 10" stainless steel bowl, mixed thoroughly with a clean stainless steel spoon and split, one half of the soil going into the glass sample jar, the other half into a new 1-qt. sealable plastic bag. Results of the XRF Pilot Study will be reported separately by Ecology at a later date, and appended to this report.

After each sample was collected, the sampling tools were washed with an Alconox® - deionized distilled water solution and then triple rinsed with deionized distilled water. The tools were placed on aluminum foil and kept clean until they were moved to the next sample location (Figure 3).

Figure 3: Typical Sampling Equipment

Samples were packed in coolers and wrapped with bubble wrap to prevent sample jar breakage. Each sample was logged into a chain-of-custody (COC) form, which was transmitted with the samples to the analytical laboratory. The laboratory acknowledged sample receipt when the coolers were delivered. Copies of the COC forms are included in Appendix A.

In addition to the soil samples collected for analysis, two additional sample types were collected for quality control (QC) purposes. One field duplicate sample (one collected soil sample was split into two jars and labeled as a duplicate) was collected for every 20 field samples. This QC sample is analyzed to verify laboratory precision. An equipment rinse (a sample of laboratory-grade deionized water poured over decontaminated field equipment into a sample jar) was collected every other field sampling day. This QC sample is used to verify that the field decontamination process was adequate to prevent cross contamination between sampling events.

3.4 Facilities Visited and Sampled

Soil samples were collected from child use areas at schools, childcare facilities, and parks. For the entire program, 2,532 soils samples were collected. In addition to these samples, 164 duplicate samples and 19 equipment rinsates were analyzed. The following sections provide additional information on the facilities visited and sampled. Figures 4 and 5 show the actual locations of schools and parks sampled.

3.4.1 Schools

A total of 42 schools were visited, and samples were collected from 38. Four schools were not sampled as the play areas were well covered preventing exposure to potentially contaminated soil. Figure 4 shows the location of each of the schools sampled, including those not sampled. A total of 1,372 samples were collected from schools, representing 54% of the total samples collected. The following school districts were included:

- Seattle School District: Three Seattle School District schools were visited, but none were sampled. Highland Park, Arbor Heights, and Concord elementary schools had play areas but they were all well-covered with wood chips or asphalt and there was no evident areas where children could be exposed to soil. No samples were collected.

- Highline School District. Nineteen elementary schools were sampled. These included North Hill, Marvista, Sunnydale, McMicken Heights, Gregory Heights, Bow Lake, Parkside, Des Moines, Seahurst, White Center Heights, Shorewood, Mt. View, Madrona, Valley View, Hazel Valley, Cedarhurst, Salmon Creek, Hilltop, and Beverly Park/Glendale elementary schools. Of the 2,532 total soil samples collected for the entire program, 736 samples were collected in the Highline School District; almost 30% of the total.

- Kent School District: Only Kent Learning Center/Mt. View Academy was sampled in the Kent School District.

- Tukwila School District: Only Cascade View Elementary was sampled in the Tukwila School District.

- Federal Way School District: Fourteen elementary schools were sampled in the Federal Way School District. These included Adelaide, Lake Grove, Nautilus, Twin Lakes, Star Lake, Woodmont, Green Gables, Sunnycrest, Valhalla, Wildwood, Mark Twain, Mirror Lake, Olympic View, and Brigadoon elementary schools. Of the 2,544 total soil samples collected for the entire program, 496 samples were collected in the Federal Way School District; almost 20% of the total.

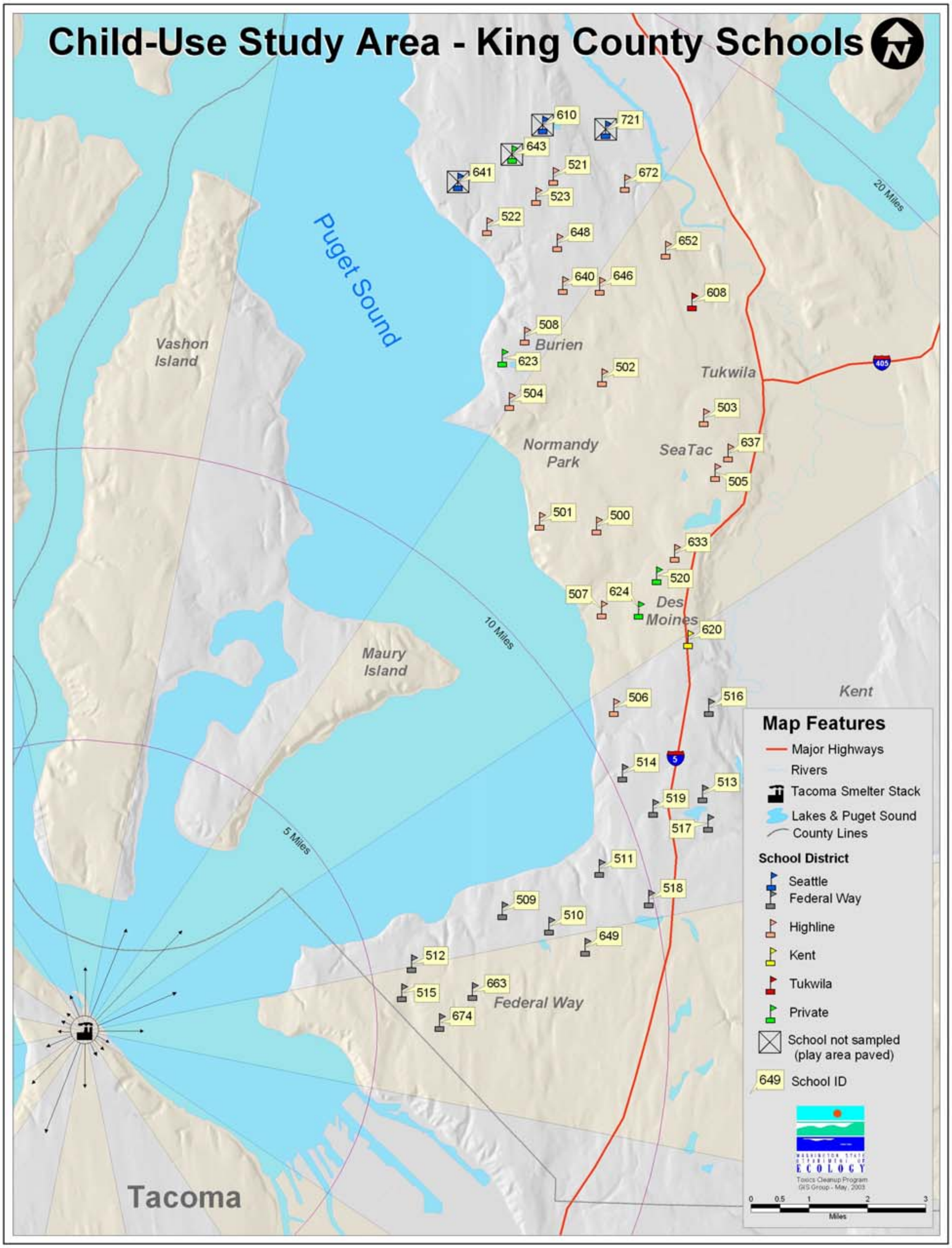

Figure 4: Child Use Study Area - King County Schools

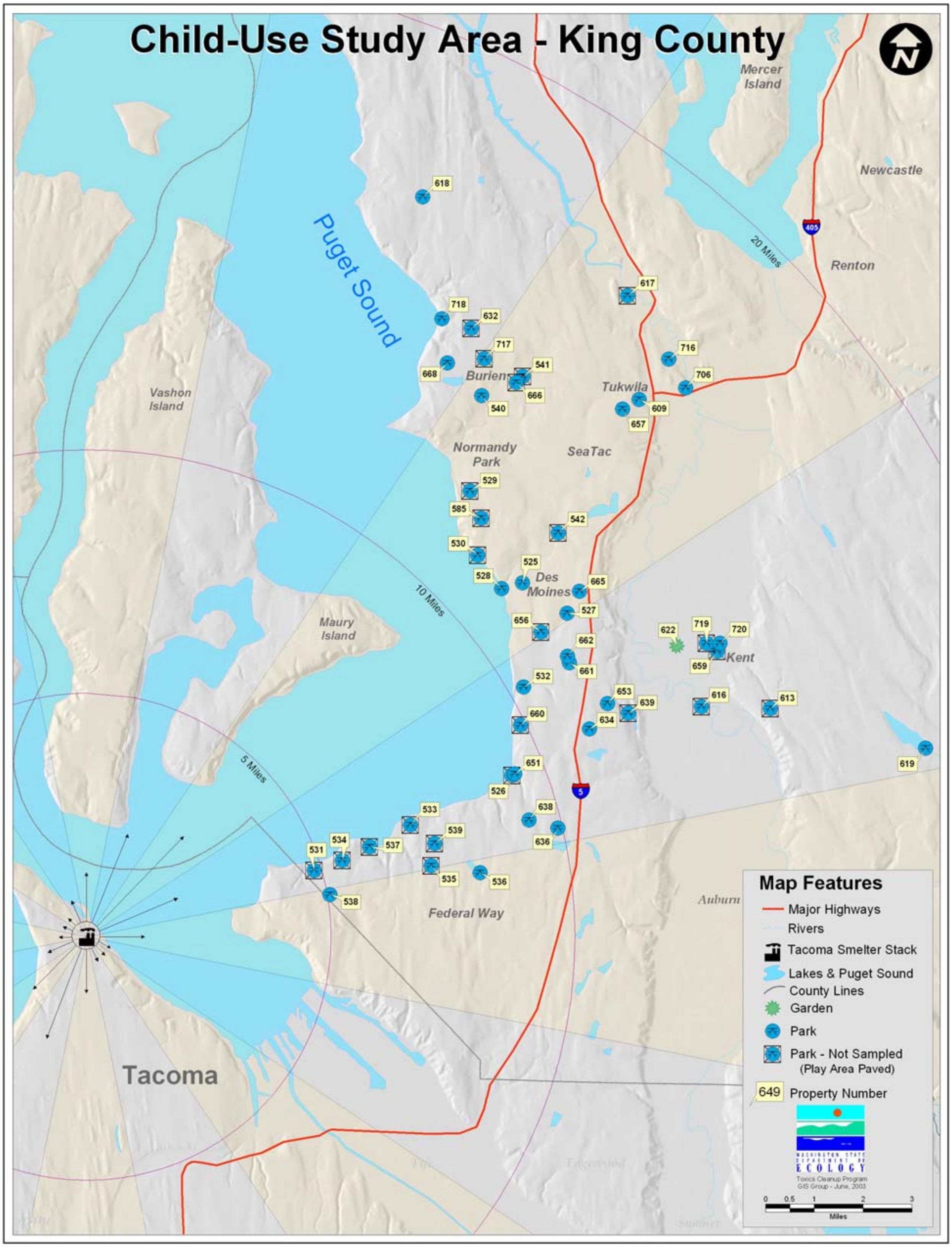

Figure 5: Child Use Study Area - King County Parks

- Private Schools. Three private schools were sampled during the sampling program. These schools included St. Francis of Assisi Primary School in Burien, St. Philomena Primary School in Des Moines, and the Christian Faith Center in SeaTac. One additional private school, Holy Family School in Seattle was visited but no samples were collected because adequate play chips or other cover materials prevented exposure to potentially-contaminated soils.

3.4.2 Parks

A total of 47 parks were visited, and 30 parks were sampled throughout the program. The parks visited are shown on Figure 5. A total of 616 samples were collected from the 30 parks, representing 24% of the sampling program. An additional 17 parks were visited, but no samples were collected. This was primarily due to there being no play areas at the parks. In two instances there were play areas, but there was adequate cover over the potentially-contaminated soils.

3.4.3 Childcare Facilities

Twenty-seven childcare facilities were sampled during the field program. From these facilities, 512 samples were collected, representing 20% of the total soil samples. Access agreements were received from an additional 19 childcare facilities, however, either by telephone conversations or site visits, it became apparent that these properties no longer functioned as childcare facilities and were not sampled. In one instance, a childcare facility was visited for sampling, but no samples were collected due to there being sufficient play chip or asphalt cover over the potentially-contaminated soils.

3.4.4 Other Facility Types

Two additional facilities were sampled that were classified as “other”, i.e., they didn’t match any of the earlier classifications. The Children’s Therapy Center in Kent is a facility that offers physical therapy for injured children and had an outdoor play area. Sixteen samples were collected from this facility. The Church of the Latter Day Saints leases land for a Pea Patch Garden at their Storehouse facility in Kent. Soil from areas surrounding the tilled garden soil was collected in 16 samples with the thought that small children accompanying their parents may be exposed to contamination while playing around the edge of the garden.

3.5 Sample Analyses

All of the collected samples were delivered to Severn Trent Laboratory (STL – Seattle) in Fife, Washington. STL also provided all of the glassware, sample coolers, and custody seals for the sampling program.

Prior to digestion, the entire soil sample was removed from its container, sieved through a 2mm sieve, then homogenized. This procedure was consistent with MTCA protocols [WAC 173-340-740(7)(d)]. The portion of the sieved homogenized material that was not needed for the primary analysis was returned to the original container. The samples were then prepared using a microwave digestion technique (USEPA SW 846 Method 3051A) (USEPA 1998). Total arsenic and lead in the soil samples was analyzed by ICP-mass spectrometry (ICP-MS) (USEPA Method

6020). The reporting limits (RL) for this project were the practical quantitation limits (PQL). The PQL for the ICP-MS method is 1.0 mg/kg for arsenic and 0.5 mg/kg for lead. The laboratory method detection limits (MDL) for ICP-MS are approximately 0.2 mg/Kg for arsenic and 0.02 mg/Kg for lead. Since these limits are lower than the PQL, these methods of analysis were expected to be sufficient for the purposes of this project.

The water samples from the field QC equipment rinses were also analyzed for the same analytes as the soil samples (i.e., arsenic and lead). The waters were digested using either Method 3010A, 3015A, or 3020A of EPA SW 846, as appropriate, and analyzed using the method cited previously.

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4.0 QUALITY ASSURANCE/QUALITY CONTROL

Extreme care was taken throughout the sampling and analysis program to ensure the data that are reported accurately reflect the actual conditions in the field. The Final Quality Assurance Project Plan for the Child Use Area Sampling Program, Tacoma Smelter Plume Investigation, Pierce and King Counties, Washington (SAIC 2002) (QAPP) describes the required field and laboratory QC actions for this sampling program.

4.1 Sample Collection

Sample jar labels were pre-printed prior to the field event. Once the property was evaluated and the number of DUs established, flags were placed at the proposed sampling locations. The sample jars were labeled and placed next to the flags. The sample numbering scheme was as follows:

Example sample numbers: C599A2-09-1A
C755B3-01-2D

Where fields are:

Wind vector Zone, Property #, Property Type, DU – Boring # – Depth Interval, Sample Type

- Wind vector Zone: **A** = North, **B** = North Northeast, **C** = Northeast, **D** = East Northeast, **E** = East

- Property #: Preassigned. Permissible Values **500-999** for King County
- Property Type: Permissible Values are **A** = Childcare/Preschool, **B** = School, **C** = Park, **D** = Other
- Decision Unit (letter): Preassigned. Permissible Values are **1 – 4**. No more than four DUs are normally permitted per property.
- Boring #: Sequential within each Decision Unit. Assign in field. All re-tries get same number as original try in the event of sample tool refusal. Permissible Values are **01 through 10**. No more than ten borings are allowed per property.
- Depth Interval (letter): **1** = 0 – 2 inches, **2** = 2 – 6 inches
- Sample Type: Permissible Values are **A** = Regular Sample, **B** = Blank Sample, **D** = Duplicate Sample, **R** = Rinsate

Samplers wore latex or disposable nitrile gloves while collecting the sample. Gloves were changed for each sampling location.

Field samplers also prepared a field sketch of each property, locating key property features and the actual sample locations. The property sketches are contained in Appendix B. One GPS reading was taken for each property. Photos of the sampling locations were also taken to document actual site conditions; these photos are contained in Appendix C (digital photos on CD-ROM).

4.2 Packing and Shipping

The filled and labeled sample jars were placed back into the cardboard boxes that they were received in and then placed into an insulated plastic cooler. Bubble wrap was placed around and on top of the boxes to protect the samples. The COC form was placed inside the coolers and then the coolers were taped shut and a custody seal was applied to the cooler.

Since STL-Seattle was within driving distance, one of the field samplers routinely delivered the samples to the laboratory. None of the samples were shipped by courier. As a result, no samples were lost during the sampling program. Samples were delivered to the laboratory either at the end of the day they were collected, or the next morning (if sampling activities continued past the time the laboratory receiving door was open for business).

4.3 Chain of Custody

A custom-made chain-of-custody form was created for this sampling program. The form served two purposes; 1) it served as the formal chain-of-custody form, listing the sampling data (property ID, address, DU comment, sample ID, depth, ground cover, date, time, sampler ID, and requested analyses) and having signature blocks for accepting and relinquishing custody, and 2) it served as the field data form, with a place to record the sample location (e.g., "8 feet north of southwestern edge of chain link baseball backstop at home plate")

A copy of the COC was made at the laboratory and the field sampler kept the original. Two copies of the COC were received back from the laboratory. One copy accompanied the laboratory invoice and provided a correlation between the sample ID and the laboratory-assigned Sample Delivery Group (SDG). It also served as an indication that the electronic data deliverable and the hard copy data were shipped from STL-Seattle to EcoChem for data validation. Another copy of the COC accompanied the hard copy data package that was shipped to EcoChem for validation.

Table 3 lists the required quality control elements for the sampling program.

Table 3: Frequency of Quality Control Elements

QC Element	Frequency
Field Duplicates	1 per 20 samples collected (5%)
Laboratory Duplicates	1 per 20 (5%) or 1 per batch (whichever is more frequent)
Equipment Rinsate Samples	1 per two field sampling days
Matrix Spikes[1]	1 per 20 (5%) or 1 per batch (whichever is more frequent)
Reference Materials	1 per 20 (5%) or 1 per batch (whichever is more frequent)
Blank Spikes (rinsates only)	1 per 20 (5%) or 1 per batch (whichever is more frequent)
Method Blanks	1 per 20 (5%) or 1 per batch (whichever is more frequent)

1. Matrix spike duplicates were analyzed for every matrix spike analyzed. These results were not evaluated during the validation process, as the method QC requirements are matrix spike % recovery and relative percent difference between field duplicates.

Two additional field quality assurance checks were also included in the sampling program. As mentioned earlier and as shown in Table 3, field duplicate samples and equipment rinsates were collected for analysis at regular intervals.

4.4 Laboratory QA/QC

The laboratory was required to complete several QC elements; some were required by the EPA analytical method, others were project imposed; in order for the data to be considered valid and accurate. These elements are as follows:

- Chain-of-Custody and Technical Holding Times: The sample chain-of-custody must show that, once the samples were received by the laboratory, they were under constant custody and control of the laboratory. The EPA analytical method requires that samples be digested and analyzed within 180 days of sample collection.
- Initial and Continuing Calibration Verification
- Blanks (Instrument, Method, and Field)
- Laboratory Control Samples (or Standard Reference Materials)
- Matrix Spike and Matrix Spike Duplicate Samples
- Laboratory Duplicate Samples
- ICP Interference Check Samples
- ICP Serial Dilution
- Field Duplicate Samples

The frequency, acceptance criteria, and resulting laboratory action for each of these QC elements are explained in the QAPP (SAIC 2002).

4.5 Validation Results

One hundred percent of the data were validated by EcoChem. The data were reviewed using guidance and quality control criteria documented in the analytical method; the QAPP (SAIC 2002) and National Functional Guidelines for Inorganic Data Review (USEPA 1994). Ten percent of the data packages received a full data review (commonly called a Level IV validation) and the rest received a compliance screening evaluation (commonly called Level III).

Technical validation involves comparison of QC standards and instrument performance results to required control limits. In addition, the laboratory electronic data deliverable (EDD) was loaded into the data quality screening tool (EcoChem DQST). The following QC elements were reviewed for data packages undergoing summary validation:

- Analytical holding times (from summary forms).
- Chain of custody and sample handling
- Preparation Blank contamination (from summary forms)
- Initial and continuing calibration verification (from summary forms).
- Continuing calibration blanks (CCB) (from summary forms and raw data).
- Interference check samples results (from summary forms and raw data).
- Internal standards, ICP/MS only (from summary forms).
- Instrument tuning standards, ICP/MS only (from summary forms).

- Analytical accuracy (matrix spike compounds and standard reference materials [SRM]), expressed as percent recovery (%R) (from summary forms).
- Analytical and field precision (comparison of duplicate sample results) expressed as relative percent difference (RPD) (from summary forms).
- Reported detection limits (from sample result summaries).

Full validation included a review of all the items listed above for summary validation, plus the following QC elements:

- Compound identification (from raw data).
- Compound quantitation, transcription and calculation checks (from raw data).
- Transcription and calculation checks performed at a frequency of 10%. If an error is noted, 100% of the calculations and transcriptions for that data set will be verified.

Full validation was performed on the initial data package and on approximately 10% of randomly selected data packages produced throughout the project. No significant deviations from required protocols and QC criteria were noticed; the remaining data (approximately 90%) received a summary validation.

No sample results were rejected during validation. No sample results were changed from detects or estimated detects to non-detects during the validation process. Approximately 10% of the data were changed from detects to estimated (J-flagged) for various laboratory control limit variations. The Data Quality Assessment Report for the sampling program is contained in Appendix D.

5.0 EVALUATION OF RESULTS

All of the arsenic and lead analytical data results are contained in Appendix E, sorted by property number.

5.1 Magnitude of Soil Arsenic and Lead

Both arsenic and lead results occurred over ranges spanning two orders of magnitude. The highest arsenic and lead concentrations for individual samples were 189-ppm and 699-ppm, respectively. The highest average concentrations for the individual DUs were 41-ppm and 134-ppm for arsenic and lead.

The statistical distributions of both arsenic and lead results are of a type known as "right skewed" - that is, with frequent low values and infrequent high values. A simple way to visualize these skewed distributions is by constructing a bar graph showing the frequency of values in specified concentration ranges. Figures 6 and 7 provide this data summary for the Child-Use Area study. Arsenic and lead concentrations are arrayed across the x-axis. The y-axis is a graphical representation of the percentage of samples per Wind Vector that fell into the concentration range. The graphs show that most of the results are in the lowest concentration range for both arsenic and lead.

Ecology compares the results from the Child Use Area study in two ways. First, the individual results, and DU averages are compared to the state cleanup levels. The State of Washington Model Toxics Control Act (MTCA) is the state law governing cleanup of contaminated soil, water, and air in Washington. MTCA provides the process and standards for studying and cleaning up contamination in our environment. MTCA cleanup levels for arsenic and lead are:

- Arsenic - 20 parts per million
- Lead - 250 parts per million

When individual results or averages are found above the state cleanup levels, Ecology recommends following the soil safety guidelines provided by the health departments, *Soil Safety Guidelines* in King County (PHSKC 2003) and *Healthy Actions* in Pierce County (Tacoma-Pierce County Health Department [TPCHD 2003]). Examples of safety measures include washing hands after playing outside, taking your shoes off when coming inside, and washing toys with which small children play.

Ecology also encourages more physical actions to provide clean play areas for the children. For example, place bark, gravel, or rubber mats conforming to guidelines set by the US Consumer Product Safety Commission underneath playground equipment to keep children from playing directly in the dirt. Some of these actions could take place when opportunities arise, such as development or redevelopment of playground areas.

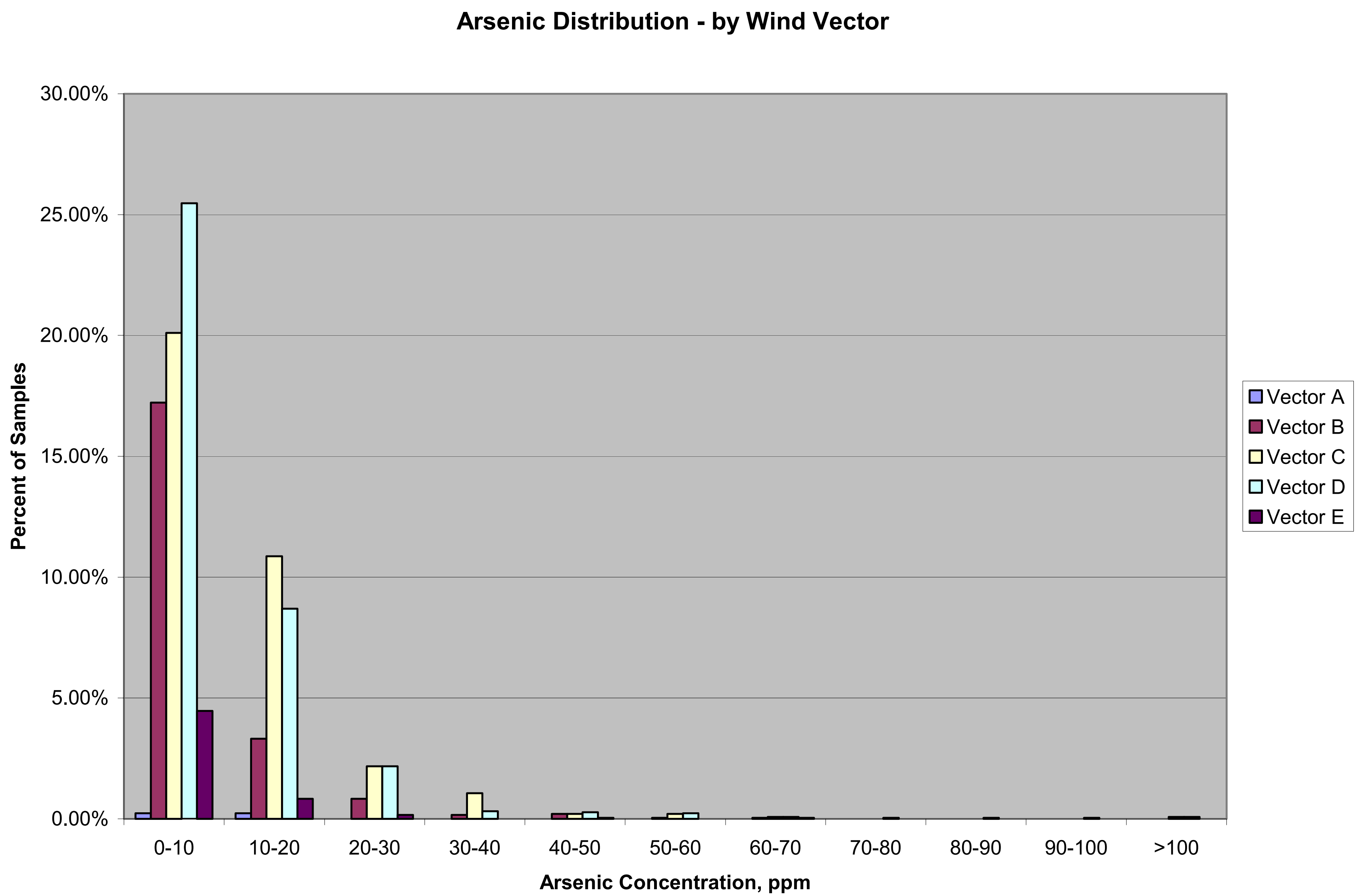


Figure 6: Arsenic Distribution - by Wind Vector

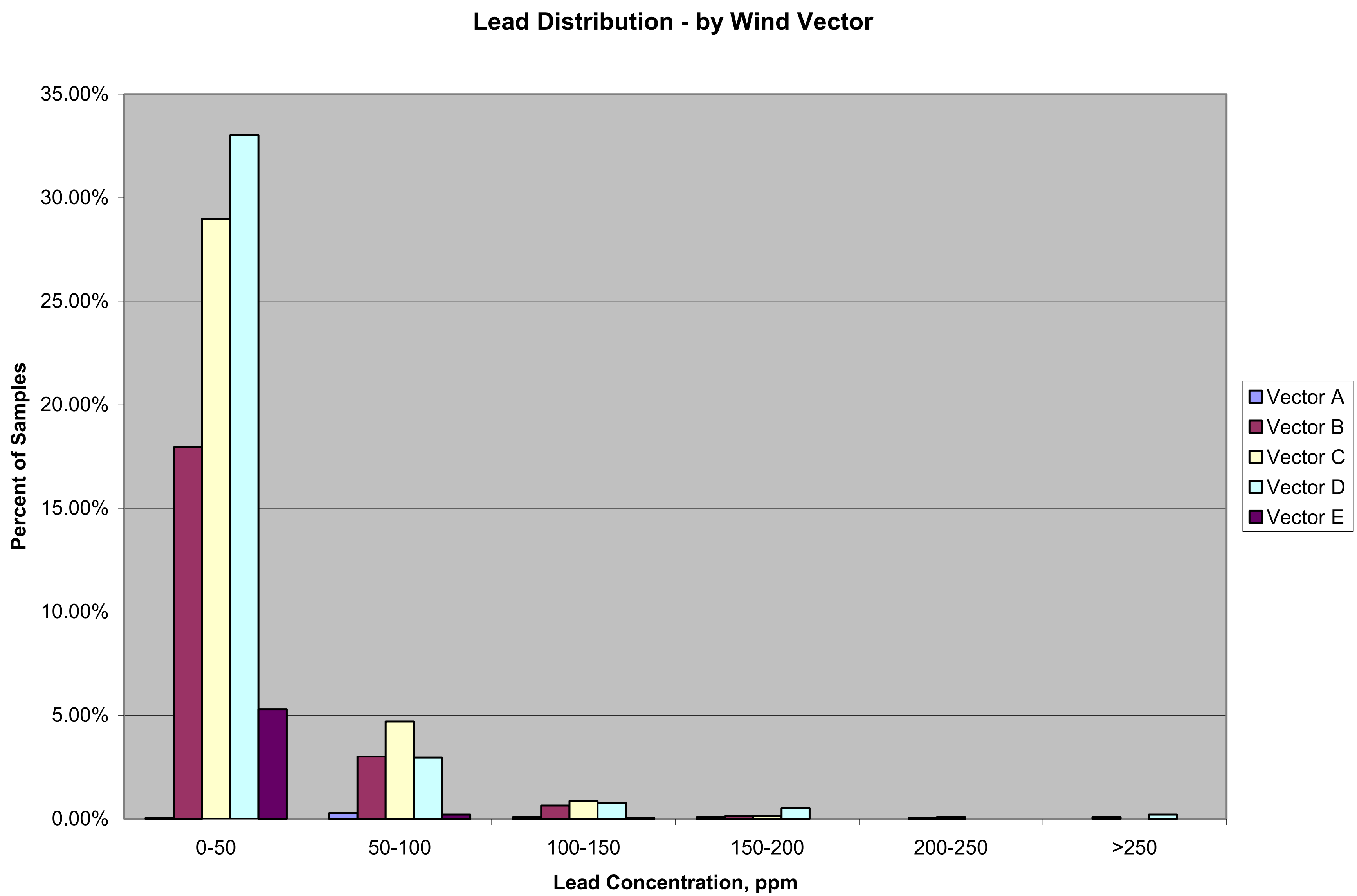


Figure 7: Lead Distribution - by Wind Vector

Ecology also compares results to "interim action trigger levels." If average concentrations of arsenic or lead are high enough, Ecology doesn't want to rely solely on the soil safety guidelines, and recommends more aggressive action to keep children from playing in the contaminated soil. Ecology has defined "high enough" as the Interim Action Trigger Levels which are based on risk assessment methods. A detailed description of the Trigger Levels can be found at http://ecy.wa.gov/programs/tcp/sites/tacoma_smelter/ts_q_and_a.pdf

The Interim Action Trigger Levels are:

- Arsenic: Schools & Childcares, 100 parts per million; Camps and Parks: 200 parts per million
- Lead: Schools & Childcares, 700 parts per million; Parks & camps, 1000 parts per million.

For child-use areas with averages above these levels, or with any one sample above two times the level, Ecology plans to work with the property owner to determine ways to provide clean play areas for children.

5.2 Comparison of Data to MTCA Cleanup Levels

The Model Toxics Control Act (MTCA) has established the cleanup level for arsenic at 20-ppm and for lead at 250-ppm. The arsenic cleanup level reflects the naturally-occurring background concentration for arsenic. This section compares the TSP CUA data with these MTCA cleanup levels.

5.2.1 Average

Decision Unit averages were calculated for each sampled depth at each property. Nine properties had average arsenic concentrations that exceeded the MTCA cleanup level.

- Gregory Heights Elementary: In Wind Vector B, the 0-2" soil samples in DU 1 averaged 22-ppm As.
- Bow Lake Elementary: In Wind Vector C, the 0-2" soil samples in DU 1 averaged 22-ppm As.
- Twin Lakes Elementary: In Wind Vector D, the 0-2" soil samples in DU 2 averaged 27-ppm and the 2-6" samples averaged 21-ppm As.
- Star Lake Elementary: In Wind Vector D, the 0-2" soil samples in DU 2 averaged 39-ppm and the 2-6" samples averaged 33-ppm As.
- Childcare #547: In Wind Vector C, the 0-2" soil samples in DU 1 averaged 23-ppm and the 2-6" samples averaged 26-ppm As.
- High Point Head Start: In Wind Vector B, the 0-2" soil samples in DU 3 averaged 22-ppm As.
- Glen Nelson Park: In Wind Vector D, the 0-2" soil samples in DU 1averaged 26-ppm and the 2-6" samples averaged 22-ppm As.
- Parkside Park: In Wind Vector D, the 0-2" sol samples in DU 1 averaged 35-ppm As and the 2-6" samples averaged 41-ppm As.
- Dottie Harper Park: In Wind Vector C, the DU 1 0-2" soil samples averaged 35-ppm and the 2-6" samples averaged 26-ppm As. In DU 2, the 0-2" samples averaged 34-ppm and the 2-6" samples averaged 20-ppm As.

None of the sampled properties had average soil lead concentrations that exceeded the MTCA cleanup level.

5.2.2 Individual

Of the 2,532 samples analyzed for arsenic, 217 were greater than 20-ppm, or approximately 9%. The maximum arsenic concentration detected was 189-ppm at Parkside Park in Des Moines, in Wind Vector D. Of the 16 samples analyzed at this property, 10 exceeded 20-ppm.

Table 4 lists the properties with a high percentage of samples with concentrations of arsenic greater than 20 ppm.

Table 4: Properties With High Percentage of Arsenic Detects Greater Than 20 ppm

Property	Wind Vector	No. Analyzed	No. > 20 ppm	% > 20 ppm
Marvista Elementary	C	64	11	17%
Gregory Heights Elementary	B	48	7	15%
Bow Lake Elementary	C	48	17	35%
Twin Lakes Elementary	D	32	11	32%
Star Lake Elementary	D	48	20	42%
Childcare #547	C	12	8	67%
Marvista Park	C	64	9	14%
Childcare #612	B	80	14	18%
Glen Nelson Park	D	16	8	50%
Parkside Park	D	16	10	63%
Dottie Harper Park	C	32	22	69%

Only eight lead samples exceeded the MTCA cleanup level of 250-ppm. The maximum lead concentration detected was 699-ppm at Childcare #566 in Des Moines, in Wind Vector C. Table 5 lists the properties where lead concentrations exceeded the MTCA cleanup level of 250-ppm. Each property had only one exceedence.

Table 5: Properties With Lead Concentrations Greater Than 250 ppm

Property	Wind Vector	Lead Concentration, ppm
Star Lake Elementary	D	252
Childcare #566	C	699
Childcare #583	B	396
Childcare #612	B	353
Lake Meridian Park	D	309
Salt Aire Vista Park	D	324
Parkside Park	D	294
Childcare #722	D	255

5.3 Comparison to Interim Action Trigger Levels

Ecology established risk-based concentrations that, if exceeded would trigger an Interim Action at the property. Interim action may be appropriate if the average exceeds the trigger level, or if the maximum is more than two times the trigger level. The trigger levels were set at 100-ppm arsenic for schools and childcare facilities and 200-ppm at parks and camps. For lead, the trigger levels are 700-ppm for schools and childcare facilities and 1000-ppm for parks and camps.

5.3.1 Average

No properties had arsenic or lead average concentrations that exceeded the Interim Action Trigger Levels.

5.3.2 Individual

Four properties (Parkside Park, Cascade View Elementary, Star Lake Elementary, and Dottie Harper Park) had individual samples with arsenic concentrations greater than 100-ppm (one sample each). No properties had individual samples with concentrations of lead that exceeded the Interim Action Trigger Levels.

5.4 Additional Data Evaluation

The intent of the Child Use Area study was to determine if any properties where small children play present any health risks due to arsenic or lead contamination in soil. With this objective in mind, soil samples were collected and analyzed and compared to MTCA Cleanup Levels and Interim Action Trigger Levels (Sections 5.2 and 5.3 above).

In the following sections, an attempt was made to find global, or region-wide, trends in the resulting data. Ecology repeats its earlier caution that soil sampling results should not generally be assumed to be representative of unsampled areas at that property or other properties located nearby. Property-specific sampling is generally recommended for determining the degree of soil contamination at a property or area of interest. The larger spatial patterns are most useful in establishing a range within which property-specific results are expected to occur, rather than predicting actual levels of contamination, which are strongly affected by property development histories and local variations in the deposition of airborne contaminants.

The following results are statistically insignificant. The variability within the data set indicates that there are factors affecting contaminant distribution that Ecology does not understand and cannot draw meaningful conclusions about with the data currently available. These comparisons MAY provide some preliminary clues about potential sources of variability, and/or some preliminary suggestions of trends when viewed in combination with data from previous studies. Do not rely on the results of these results as the basis for any regulatory or planning decisions at any higher level than the property-specific evaluations discussed above.

5.4.1 Contaminant Concentration Versus Prevailing Wind Direction

The properties sampled were located inside an approximate 100-ppm contour as part of the sample design process (see Section 2.2). Mean and standard deviations of arsenic and lead concentrations were calculated for samples in each wind vector to evaluate the potential difference in arsenic and lead concentrations versus wind direction. Tables 6 and 7 present that data.

Table 6: Arsenic Concentration Versus Prevailing Wind Direction

Vector	Mean Concentration 0-2 in	± S.D.	Min	Max	Mean Concentration 2-6 in	± S.D.	Min	Max	n =
B	8.86	8.34	0.84	60.2	7.18	5.70	1.25	45.4	276
C	11.31	10.35	1.52	117.0	10.74	10.57	1.37	149.0	440
D	9.94	10.86	1.22	133.0	10.08	12.19	1.26	189.0	474
E	7.07	8.38	1.52	62.4	6.44	6.65	1.35	41.5	70

Table 7: Lead Concentration Versus Prevailing Wind Direction

Vector	Mean Concentration 0-2 in	± S.D.	Min	Max	Mean Concentration 2-6 in	± S.D.	Min	Max	n =
B	32.0	36.61	0.89	353.0	26.33	36.88	2.0	396.0	276
C	34.36	29.22	2.05	243.0	29.63	40.18	1.58	699.0	440
D	27.29	33.83	2.44	309.0	25.71	33.79	1.97	324.0	474
E	16.26	18.19	2.11	116	12.52	13.52	1.74	81.4	70

1. S.D.= standard deviation of the population
2. n = number of data points in sample population

The standard deviation numbers are, in many cases greater than the mean, indicating the wide variability of the data. The mean and standard deviation numbers are shown graphically on Figures 8 and 9.

In general, the concentrations of lead and arsenic are lowest in Wind Vector E (the southern most sampling area). While closest to the former smelter location, Wind Vector E is not a predominant wind direction. Arsenic concentrations, in general, are highest in Wind Vectors C and D. Lead concentrations are nominally equal in Wind Vectors B, C, and D.

5.5 Depth Profiles

Figures 8 and 9 also present the mean concentrations and standard deviation for arsenic and lead at the two different depths sampled, 0-2" and 2-6". With the exception of arsenic in Wind Vector D, all of the surface samples (0-2") exhibited higher concentrations of arsenic and lead than the near surface samples (2-6"). Again, with the highly variable data set, these differences are not significant.

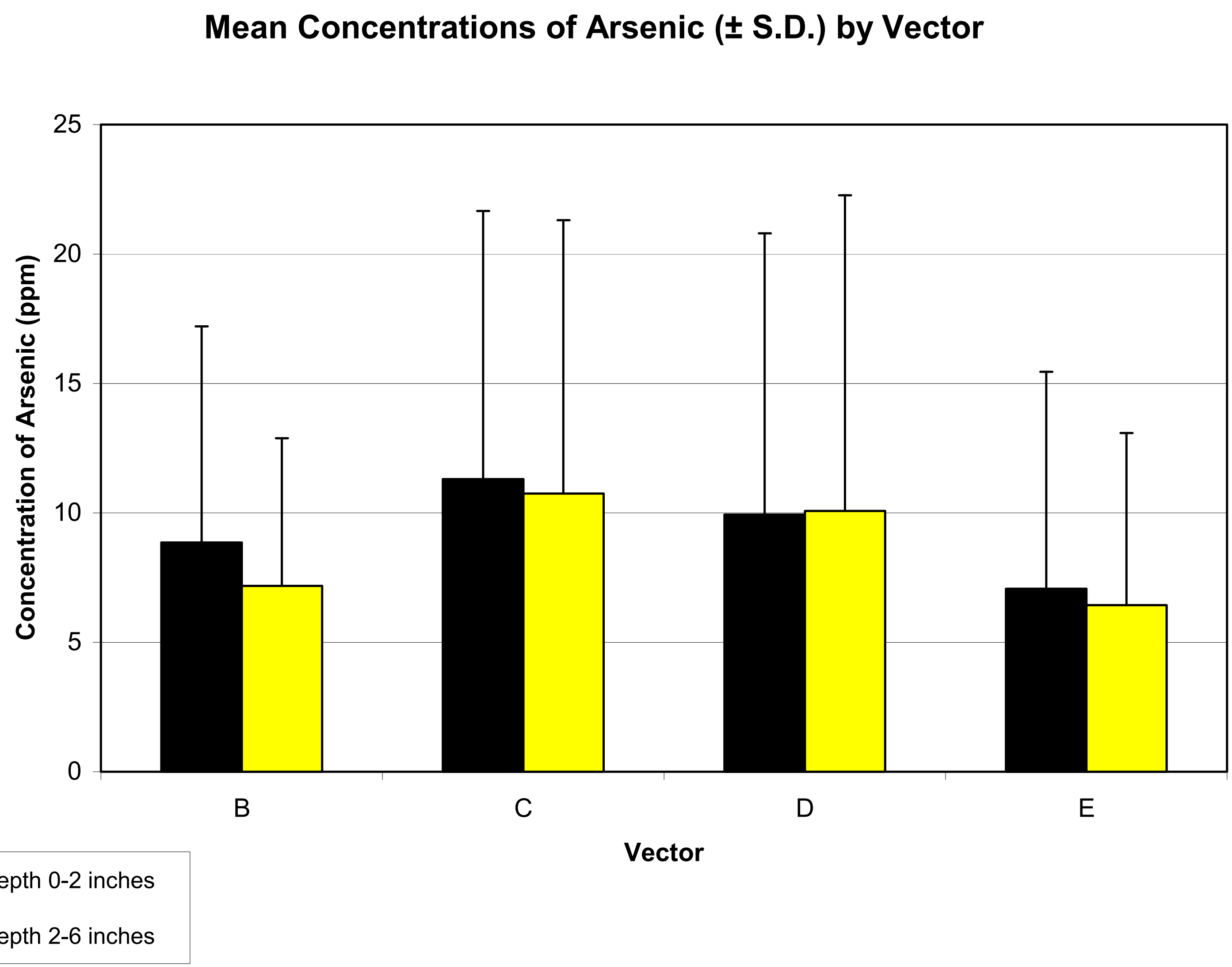


Figure 8: Mean Concentrations and Standard Deviation of Arsenic by Wind Vector

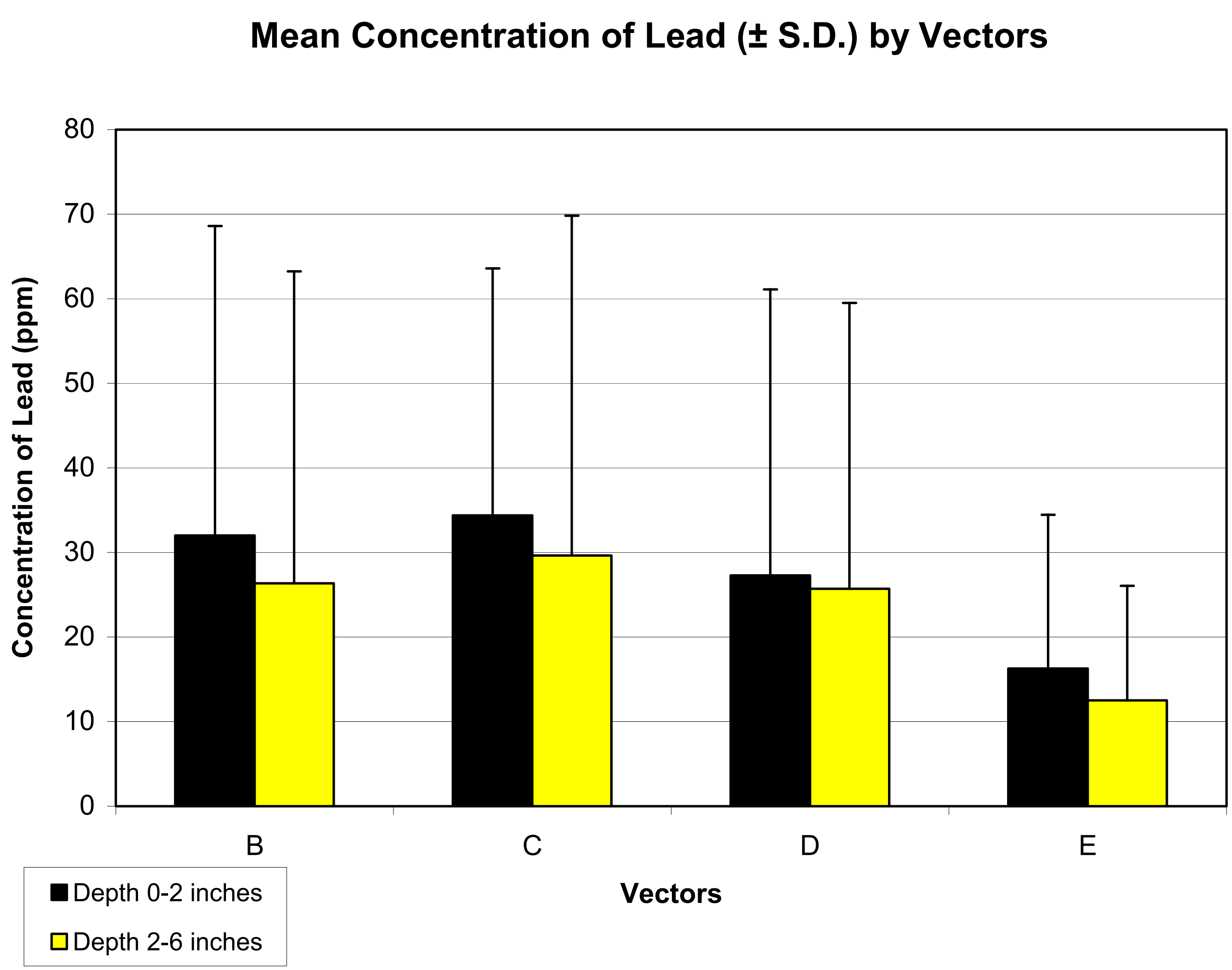


Figure 9: Mean Concentrations and Standard Deviation of Lead by Wind Vector

5.6 As/Pb correlation

A series of correlation/regression analyses was performed to statistically evaluate the relationship between arsenic and lead. Only the linear regression analysis was evaluated, in the form of:

$$y = mx + b$$

A series of scatterplots were prepared. All Wind Vector data were plotted for the 0-2" and 2-6" depths, then only the data for individual Wind Vectors. A $\log_{10}$-$\log_{10}$ plot of the data produced a nominal linear relationship. Table 8 presents the results of the linear regression analysis. The scatterplots are shown in Figures 10 through 14 following this page.

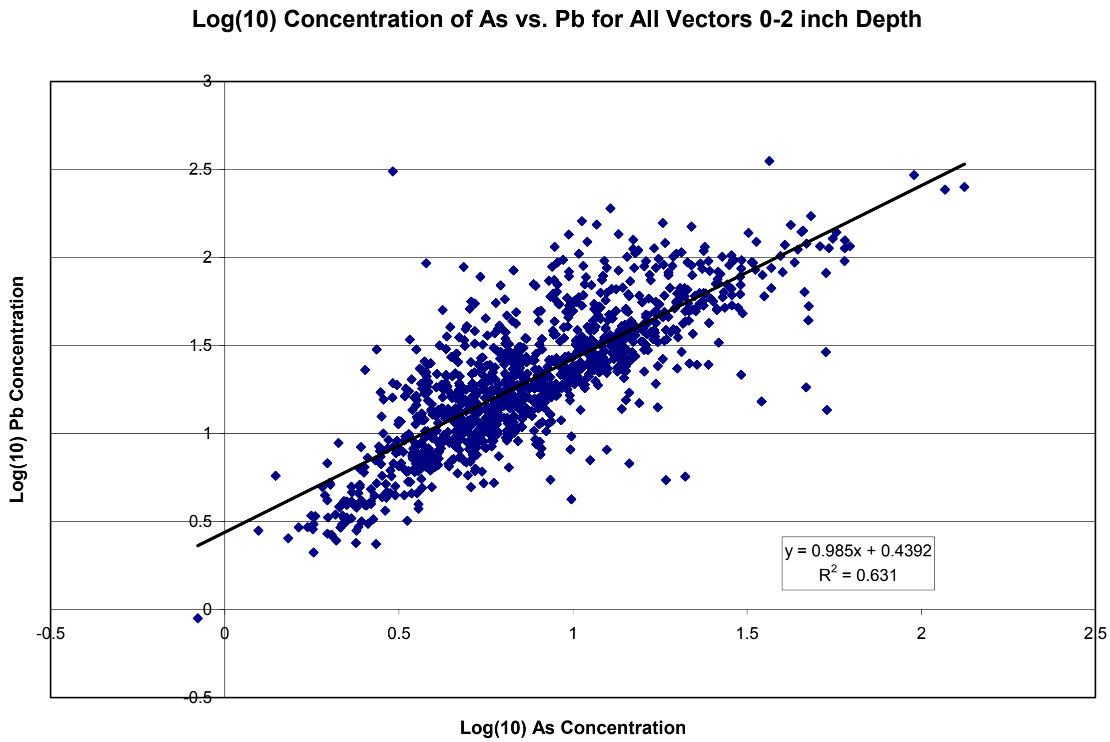
Table 8: Linear Regression Analysis Results

Data Set	Sample Size (n)	R^2 [1]	Model Result
All Vectors 0-2"	1,260	63.1%	Pb = 0.985(As) + 0.4392
All Vectors 2-6"	1,260	63.0%	Pb = 1.055(As) + 0.3237
Vector B, 0-2"	276	67.0%	Pb = 1.164(As) + 0.3273
Vector B, 2-6"	276	63.0%	Pb = 1.2842(As) + 0.204
Vector C, 0-2"	440	52.5%	Pb = 0.787(As) + 0.6726
Vector C, 2-6"	440	58.5%	Pb = 0.9629(As) + 0.4343
Vector D, 0-2"	474	62.5%	Pb = 0.9433(As) + 0.4398
Vector D, 2-6"	474	61.9%	Pb = 0.9955(As) + 0.3434
Vector E, 0-2"	70	86.9%	Pb = 1.169(As) + 0.194
Vector E, 2-6"	70	87.0%	Pb = 1.1377(As) + 0.1517

1. "R-squared", where R is the correlation coefficient between two variables. In statistical regression analyses, R-squared (a value between 0 and 1, but often expressed as a percentage between 0% and 100%) is a measure of the percentage of the total variance in the dependent variable that is explained by its relationship with the independent variable.

5.7 Variability

The primary use of the child-use areas data is to support interim action decisions, where the focus is on evaluating possible exposures in comparison to numerical criteria (i.e., to exposures and risks considered on an absolute rather than a comparative scale). The observed differences across CUAs and CUAs within Wind Vectors reflect the inherent variability in soil contaminant levels. Even areas that are located very close to one another sometimes show substantial differences in maximum or average contamination levels. Property-specific development histories may be contributing to these differences.



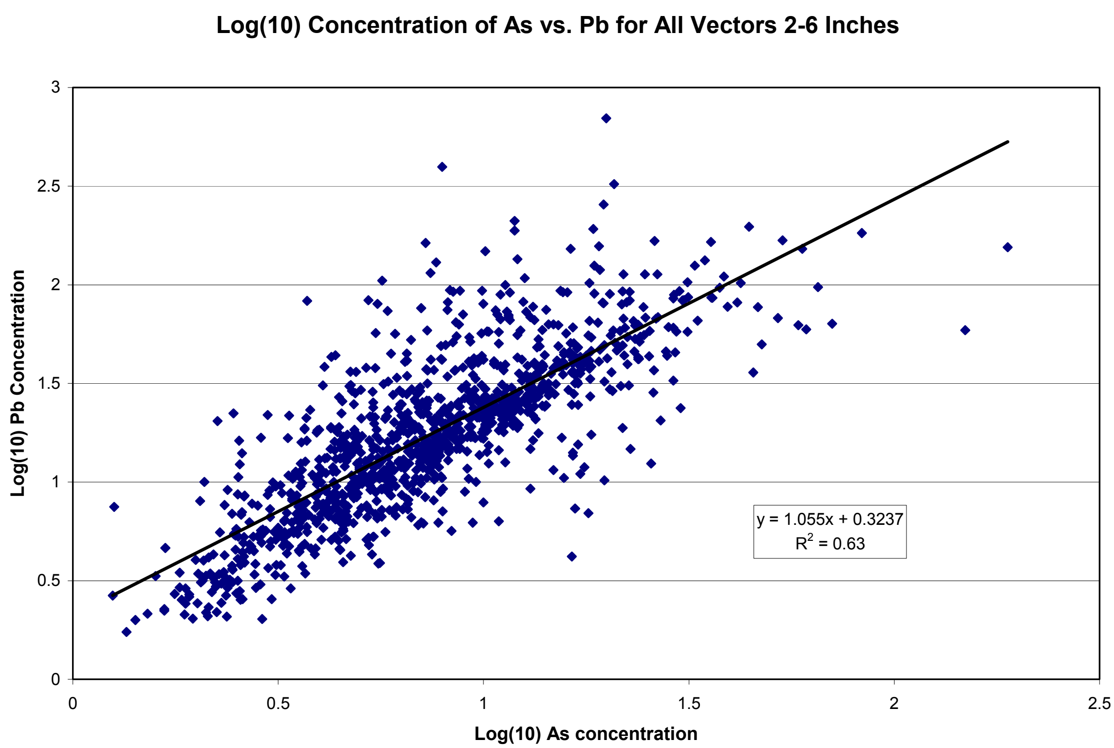
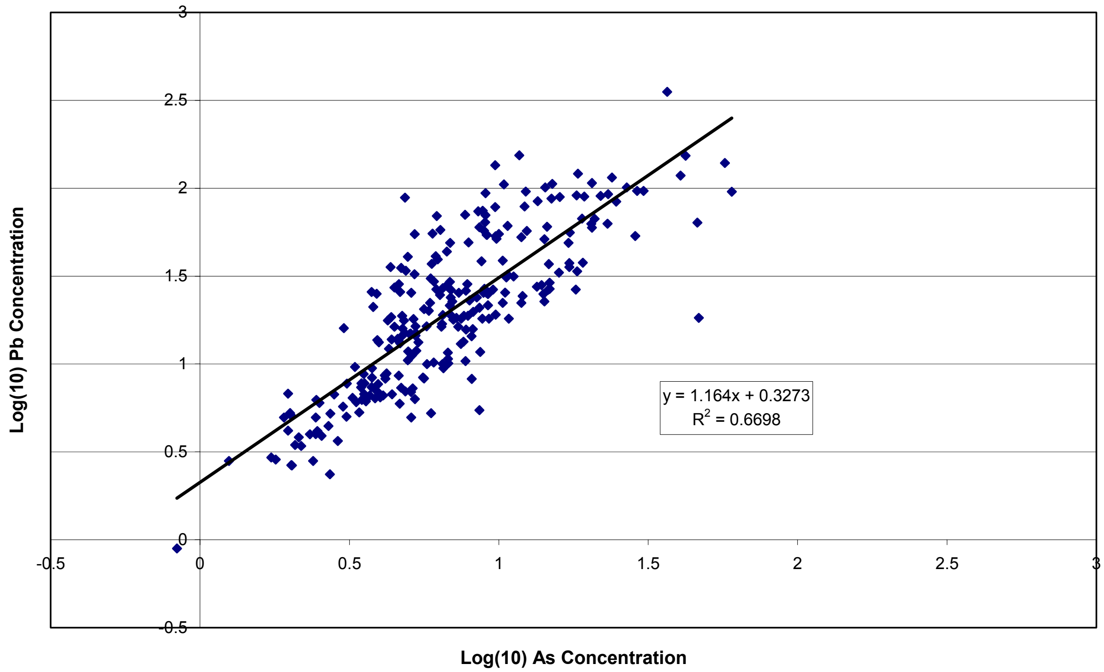


Figure 10: Log_{10} Concentration of As vs. Pb for All Vectors, 0-2 Inches and 2-6 Inches

Log(10) Concentration of As vs. Pb for Vector B (0-2 inch)



Log(10) Concentration of As vs. Pb for Vector B (2-6 inch)

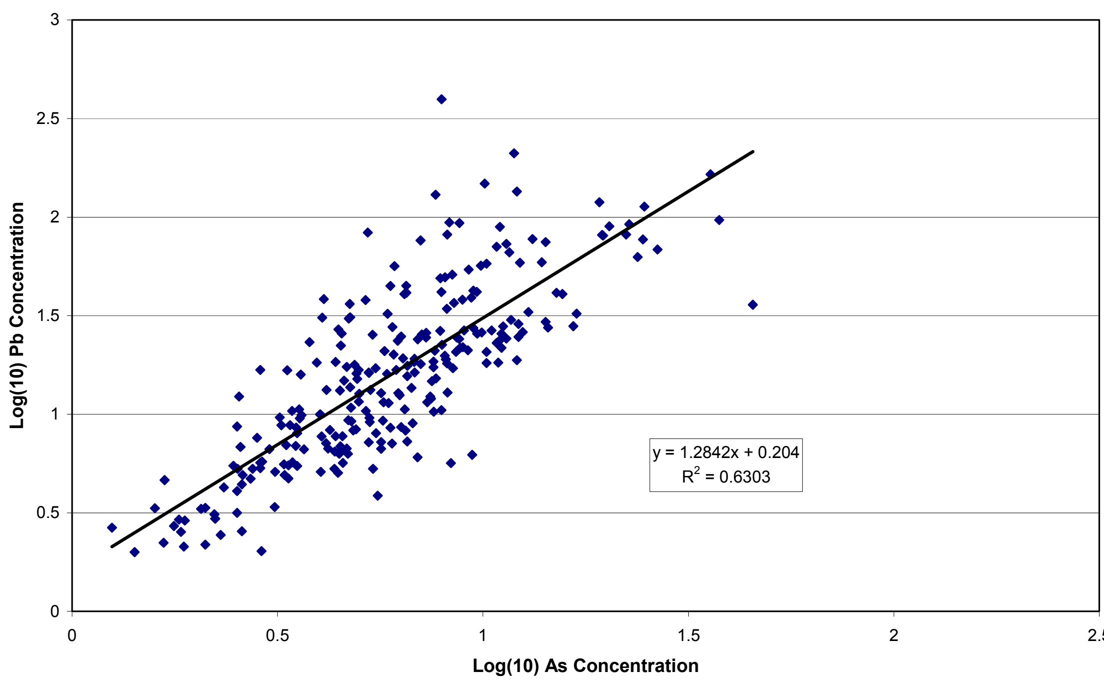
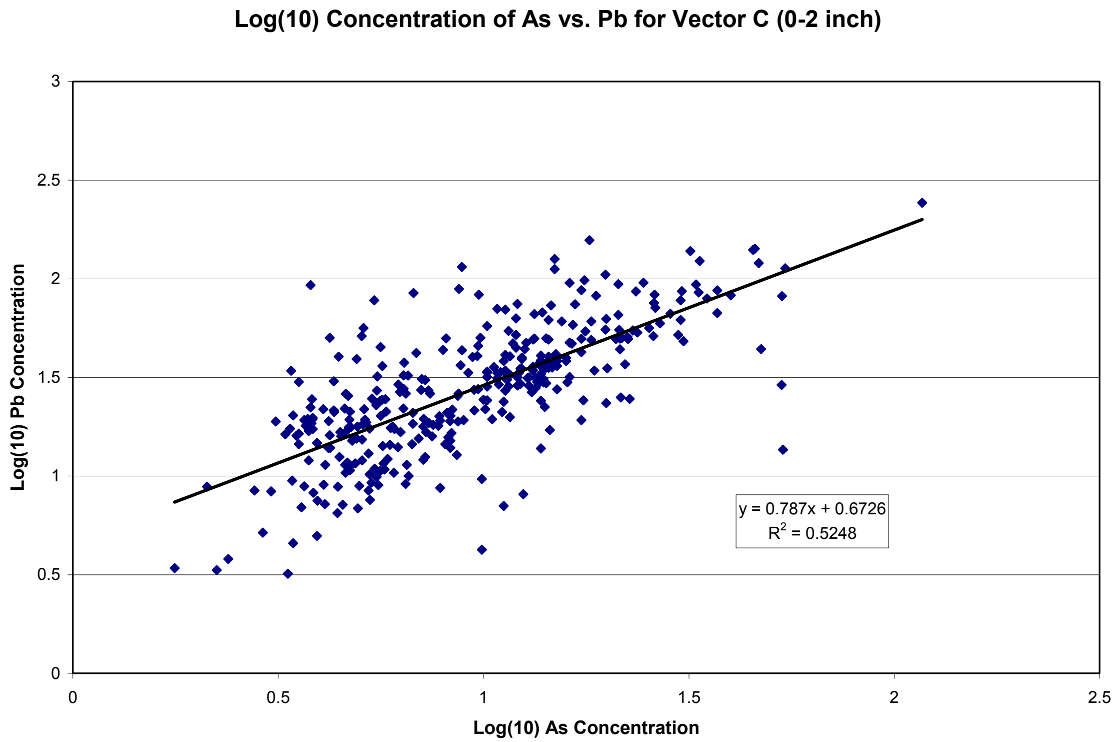


Figure 11: Log_{10} Concentration of As vs. Pb for Vector B



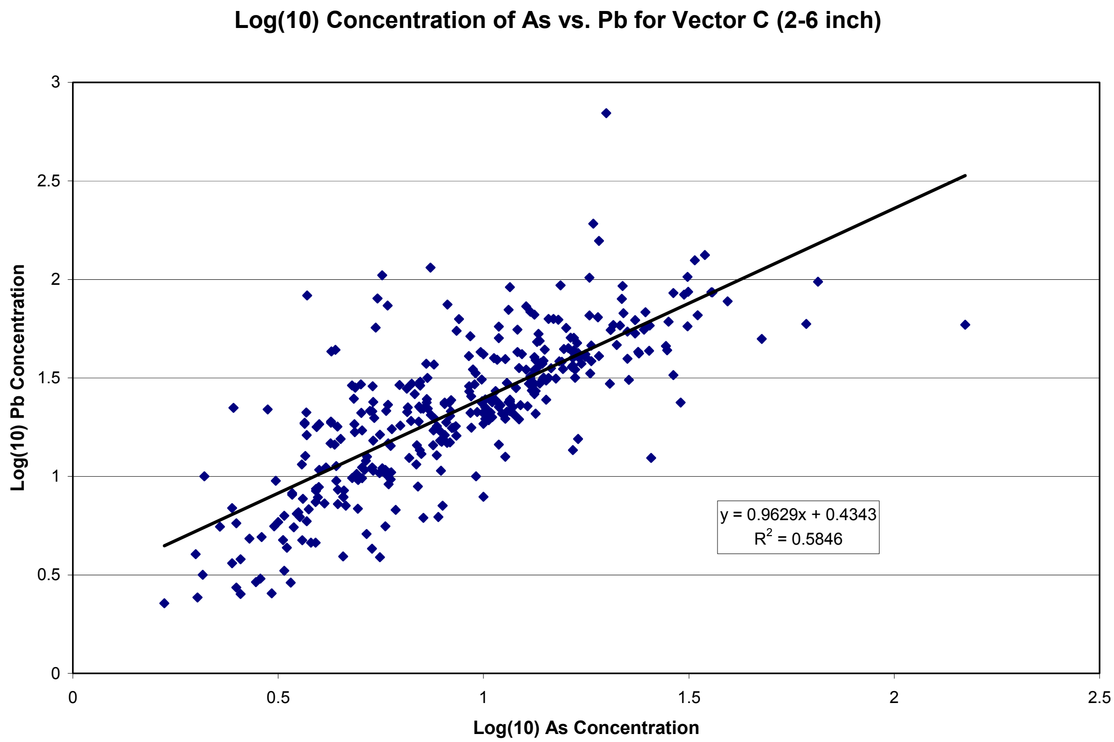
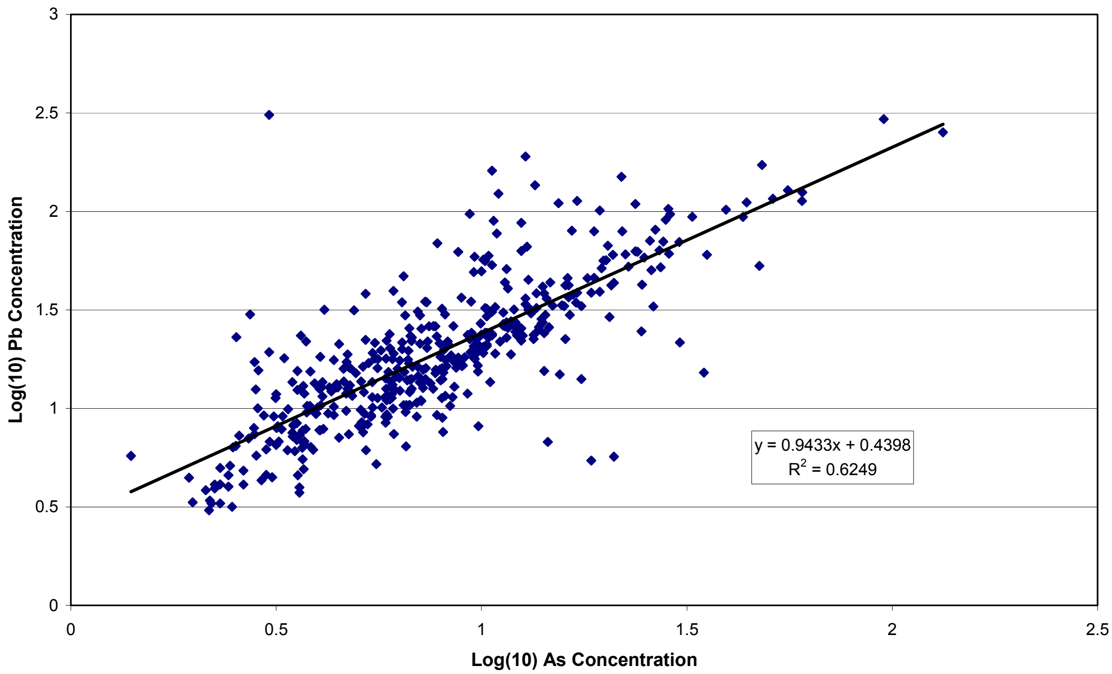


Figure 12: Log_{10} Concentration of As vs. Pb for Vector C

Log(10) Concentration of As vs. Pb for Vector D (0-2 inch)



Log(10) Concentration of As vs. Pb for Vector D (2-6 inch)

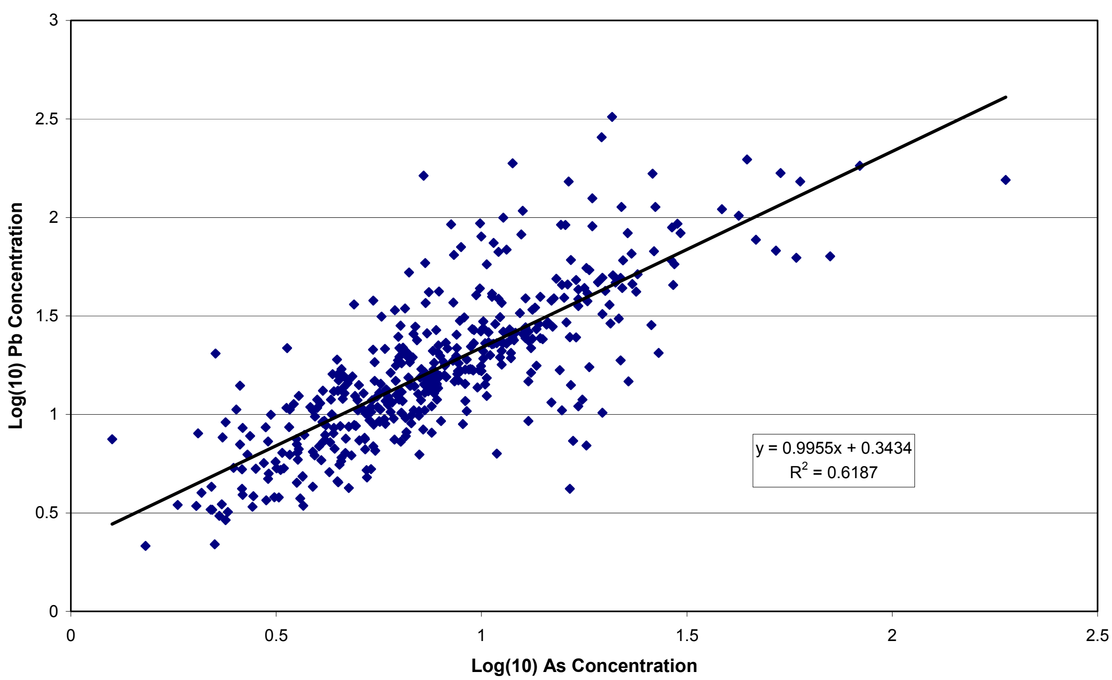
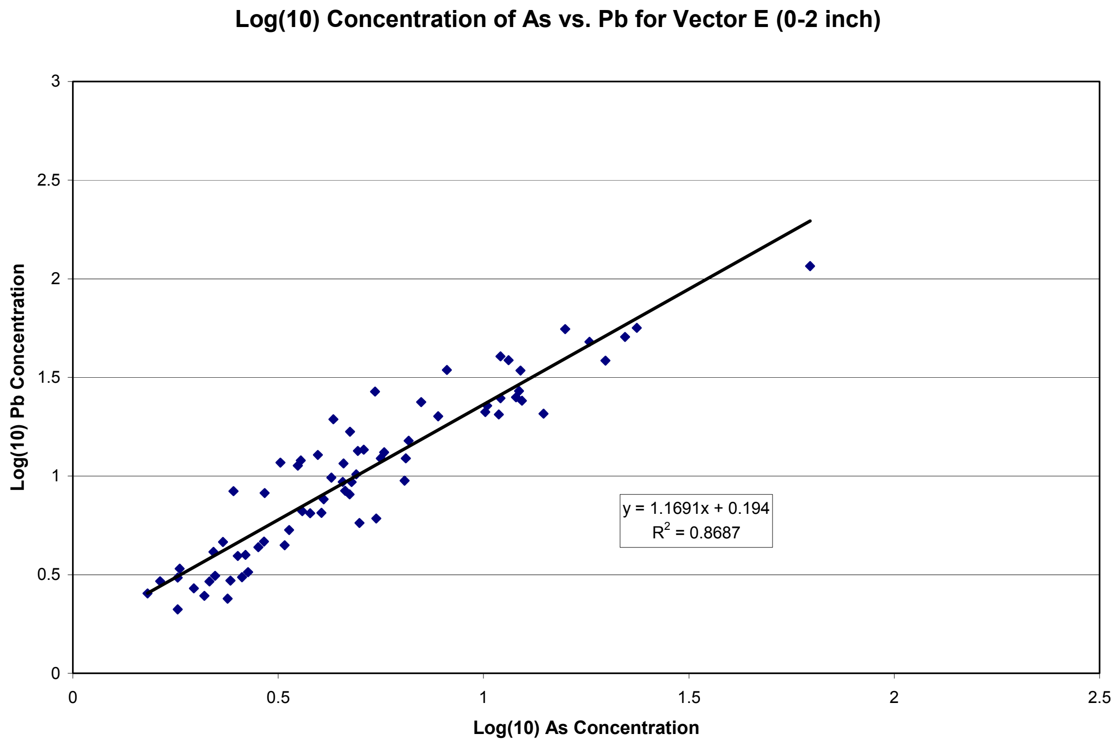


Figure 13: Log_{10} Concentration of As vs. Pb for Vector D



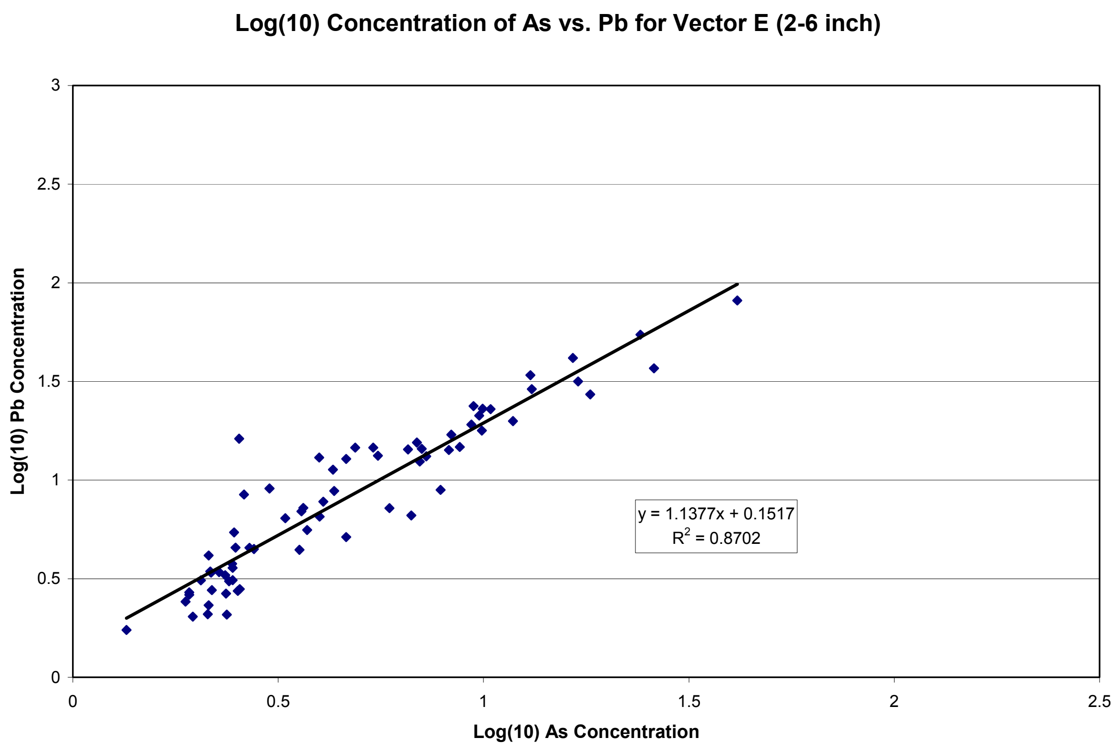


Figure 14: Log_{10} Concentration of As vs. Pb for Vector E

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6.0 CONCLUSIONS AND RECOMMENDATIONS

It is clear from this study that mainland King County properties have elevated concentrations of lead and arsenic in soil. Arsenic and lead in soils at some properties exceed cleanup standards, though not to the point of needing action (e.g. no DU averages exceeded the Interim Action Trigger Levels). Many areas where soils clearly exceed naturally-occurring background concentrations or lead and arsenic are clearly present. The study design, selecting child use areas within a calculated 100-ppm arsenic boundary line for the sampling program, was conservative. Only four samples out of the 2,532 collected and analyzed, exceeded 100-ppm arsenic. That observation made, it must be remembered that this study does NOT address MTCA compliance, and is only intended to serve short-term health screening needs. Use of MTCA statistical methods, because of the very high variability found in many properties would point to the need for action under MTCA for the depth intervals sampled, and exceedances of cleanup standards at greater depths are a distinct likelihood.

No Interim Action Trigger Levels were exceeded for arsenic or lead. Ecology has published a *Dirt Alert - Arsenic and Lead in Soils* (Ecology 2003) that offers property owners practical information about the Tacoma Smelter Plume project and assistance on what to do if the owner wants to know more about contamination on their property. Public Health - Seattle and King County (PHSKC 2002) and Tacoma-Pierce County Health Department have also published excellent information about how to minimize an individual's exposure to arsenic and lead in soils.

Adhering to the following guidelines will help keep houses healthier and cleaner. Dirt has germs, bacteria, chemicals, and other unhealthy things in it. Dirt and dust can be breathed in or eaten, which can be harmful to health.

Inside the home:

- Take off shoes before entering your home.
- Wash hands and face thoroughly after working or playing in the soil, especially before eating.
- Damp mop and wipe surfaces often to control dust.
- Wash toddler toys and pacifiers often.
- Scrub vegetables and fruits with soap and water.
- Wash clothes dirtied by contaminated soil separately from other clothes.
- Repair painted surfaces in homes. Homes built before 1980 may contain lead-based paint. Older paint flakes may be a source of lead.
- Eat a balanced diet. Iron and calcium help keep lead from becoming a problem in the body.
- Use water and soap to wash – avoid "waterless" soaps.

Outside the home:

- Keep children from playing in contaminated dirt.
- Cover bare patches of dirt with bark, sod or other material, or fence off area.
- Dampen dusty soils before gardening.
- Wear gardening gloves.

- Do not eat or drink in contaminated areas.
- Keep vegetable gardens away from old painted structures and treated wood.
- Do not plant food crops under the roof overhang of homes.
- Keep pets off of exposed dirt so they don't track it into the house.

Special Considerations for Adults Doing Construction or Yardwork:

- Avoid all unnecessary exposure to soil or dust.
- Dampen dusty soils before and during the work project.
- Wear full body protective clothing (coveralls, or long sleeve shirt and pants,) shoes, and gloves. For maximum protection wear a dust mask or respiratory protection.
- Avoid eating, drinking or smoking while working in dirt.

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