FINAL
HUMAN HEALTH REMEDIAL EVALUATION REPORT
FOR THE
BUNKER HILL SUPERFUND SITE BOX

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ANOVA	analysis of variance
AOC	Administrative Orders on Consent
ATSDR	Agency for Toxic Substances and Disease Registry
BDL	below detection limit
Box	Bunker Hill Superfund Site
$CaNa_2EDTA$	edentate disodium calcium
CDC	Centers for Disease Control
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CIA	Central Impoundment Area
CR^{-1}	reciprocal clearance rate
CUA	common use area
DOH	Division of Health
EP	erythrocyte protoporphyrin
GIS	Geographic Information System
gsd	geometric standard deviation
HEPA	high efficiency particulate air
ICP	Institutional Controls Program
IDEQ	Idaho Department of Environmental Quality
IDHW	Idaho Department of Health and Welfare
IEUBK	Integrated Exposure Uptake Bio-kinetic Model
LOAEL	lowest-observed-effect level
LHIP	Lead Health Intervention Program
LRRG	Lead Remediation Review Group
MCLs	maximum contaminant levels
mg/kg	milligram per kilogram
NHANES	National Health and Nutrition Examination Survey
NPL	National Priorities List
OAQPS	Office of Air Quality Planning and Standards
O&M	operations and maintenance
OU	Operable Units
OU1	Operable Unit 1 (of the Bunker Hill Mining and Metallurgical Complex Superfund Site, Populated Areas of the Box)
OU2	Operable Unit 2 (of the Bunker Hill Mining and Metallurgical Complex Superfund Site, Non-Populated Areas of the Box)
OU3	Operable Unit 3 (of the Bunker Hill Mining and Metallurgical Complex Superfund Site, the Basin)
PHD	Panhandle Health District
PRP	Potentially Responsible Party
PTM	Principal Threat Materials
RA	remedial action
RAOs	Remedial Action Objectives
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision

ROW	right-of-way
SES	Socioeconomic status
Superfund	Comprehensive Environmental Response, Compensation, and Liability Act, Superfund Amendments and Reauthorization Act
µg	micrograms
USACE	U.S. Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WIC	Woman Infant and Children

SECTION 1.0 INTRODUCTION

1.1 Overview

The Bunker Hill Mining and Metallurgical Complex is a Superfund Site located in the Coeur d'Alene Basin in northern Idaho and includes three Operable Units (OU). An approximate 21 square mile area, commonly referred to as the Bunker Hill Box (the Box), contains the original OUs 1 and 2 (Figure 1.1). The greater Coeur d'Alene River Basin surrounding the Box is OU3. The Box is home to more than 7,000 people in four residential areas or communities, including the cities of Kellogg, Wardner, Smelterville, Pinehurst, and the unincorporated communities of Page, Ross Ranch, Elizabeth Park, and Montgomery Gulch (Figure 1.2). Most of the residential neighborhoods and the former smelter complex are located on the valley floor, side gulches, or adjacent hillside areas.

A century of releases from mining and smelting activities left several thousand acres contaminated with heavy metals. The most significant contaminants are antimony, arsenic, cadmium, copper, lead, mercury, and zinc. The principal sources of unconfined metal contamination were emissions from smelting operations and discharge of mine/mill tailings and waste rock to the South Fork Coeur d'Alene River or its tributaries. Several million tons of tailings were confined in large waste piles on-site or used as aggregate and fill in wide-spread construction activities. Tailings discharged to local streams have heavily contaminated approximately 1,100 acres of the floodplain. These wastes were subsequently transported throughout the area by flooding, erosion, wind, and anthropogenic activities. Decades of sulfur oxide emissions from smelter operations and extensive logging have denuded the adjacent hillsides, resulting in severe erosion. Recently, erosion control and revegetation efforts have reversed some of the damage.

Mining, milling, smelting ores, secondary releases, and subsequent transport have caused ubiquitous heavy metal contamination of soils and dusts (TerraGraphics 2000b). Typical lead concentrations of wastes and soils within the smelter complex were 100,000 mg/kg (10%) or more. Tailings in the river's floodplain averaged greater than 20,000 mg/kg (2%) lead. Soils in residential yards in the smelter communities averaged 2,500 mg/kg in the early 1980s and house dust lead concentrations averaged 2,000 mg/kg to 4,000 mg/kg at that time (TerraGraphics 1990, CH2MHill 1991b, Dames and Moore 1991, USEPA 1991).

Superfund activities were implemented under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) after the Bunker Hill Company mining and smelting complex closed in 1981. The site was added to the National Priorities List (NPL) in 1983 and in the same year the ***1983 Lead Health Study*** was conducted jointly by State, federal, and local health agencies (PHD 1986). This comprehensive survey of lead poisoning and exposures in the community showed elevated levels of lead in blood among area children, including those born since the smelter closure. The data from this study were subsequently analyzed in several reports (PHD 1986, TerraGraphics 1987, JEG et al. 1989, TerraGraphics 1990, TerraGraphics 1999a). Residual contamination in community soils and dusts was identified as the main source of lead exposure to children. The primary route of exposure has been identified as incidental ingestion of soils and dusts by ordinary hand-to-mouth and play activities (Landrigan et al. 1976, PHD 1986, PHD 1999). More than $150M has been expended on investigation, health response and cleanup activities in the last twenty years. The major health response actions undertaken through CERCLA are described in Table 1-1 and printed throughout the text in bold.

1.2 Site Location and History

Biological monitoring and health response activities have been ongoing at this site for nearly thirty years (IDHW 1976, Yankel et al. 1977, PHD 1986, JEG et al. 1989, TerraGraphics 1997, TerraGraphics 2000b, TerraGraphics 2001, von Lindern et al. 2003). These efforts commenced in 1974 in response to epidemic lead poisoning in the community resulting from the Bunker Hill Company lead smelter owners' decision to operate without pollution controls after a fire destroyed the central baghouse filtration unit (Chisolm et al. 1976, IDHW 1976, Yankel et al. 1977). More than a thousand children were lead poisoned, including 99% of the 9-month to 9-year old children residing within 1 mile of the complex (TerraGraphics 1990). In 1974, the criteria for pediatric blood lead poisoning was 40 μg/dl (CDC 1991). Dozens of children exhibited blood lead levels exceeding 80 μg/dl and several were hospitalized and treated. Several homes were purchased and destroyed by smelter owners and families were relocated, many outside the Silver Valley. The smelter closed in 1981 and during the final years of operation more than half the children in the community had blood lead levels exceeding 40 μg/dl (PHD 1986, JEG et al. 1989, TerraGraphics 1990).

Health intervention activities were initiated among those families identified in the 1983 Lead Health Study (PHD 1986). Those efforts were formalized when the ***Lead Health Intervention Program*** (LHIP) was adopted in 1985. The LHIP has served as an interim risk management strategy to minimize lead exposure, through non-engineering means, as the investigation and remedial action phases of the Superfund project continued. Annual blood lead testing of children and follow-up of those with high lead levels have been conducted each year from 1985 through 2003. More than 6,000 blood lead samples have been collected since 1985. It is estimated that more than 50% of all children that have lived on this site since 1985 have been tested (TerraGraphics 2000b).

Emergency response activities undertaken to reduce lead exposure to children commenced at common use areas (CUAs) in 1986. The Community Task Force, founded in 1985, recommended the ***CUA Fast-Track Cleanup*** which provided soil replacement and clean materials to cover public playgrounds, schools, parks and rights-of-way (ROWs). Following the Fast-Track effort, the Box was divided into the ***Populated Areas (OU1) and Non-Populated Areas (OU2)*** to conduct the Remedial Investigation/Feasibility Study (RI/FS) and develop Proposed Plans and Records of Decision (RODs). The State of Idaho had primary responsibility for human health response actions in the Populated Areas, or residential portions of the site. The United States Environmental Protection Agency (USEPA) was the lead agency for the Non-Populated Areas that included the abandoned industrial complex, contaminated riverbed and floodplain, and hillsides areas. The Potentially Responsible Parties (PRPs) conducted the bulk of the RI/FS work in the Non-Populated Areas under a Consent Agreement, and State contractors performed the Populated Areas investigations under a Cooperative Agreement with the USEPA. Several ***Interim Cleanup Actions*** were conducted throughout the late 1980s and early 1990s in both the Populated and Non-Populated Areas. In 1989, the ***High-Risk Yard Cleanup*** of residential properties was initiated at homes of young children and pregnant women living on properties with yard soils in excess of 1,000 mg/kg lead concentration. The ***High-Risk Yard Cleanup*** continued under the ***Populated Areas ROD*** adopted in 1991. The ***Non-Populated Areas ROD*** was adopted in 1992.

High-Risk homes have been remediated on a priority basis each year since 1989, by removing the contaminated soil within the top foot and replacing it with a clean soil barrier. Systematic area-wide cleanup of commercial and residential properties in the Populated Areas of the site began in 1994. This effort, commencing in Smelterville, has continued at a steady pace of about 200 properties per year. The Populated Areas cleanup should be completed by 2005. Remediation of the industrial complex and other Non-Populated Areas of the site was conducted at the same time under the direction of the U.S. Army Corps of Engineers (USACE) as a Fund-lead project following the bankruptcy of the smelter owners in 1995 (USEPA 1992b). The USACE has also been expending CERCLA funds for remediation in the Populated Areas since 2002; the remaining PRPs have bankrupted or sought court relief from their commitments under the Order of Consent to implement Populated Areas cleanup.

The cleanup has reduced lead exposures to children and consequently lowered blood lead levels over the last eighteen years of CERCLA response. In anticipation of the 1991 Centers for Disease Control (CDC) statement on Childhood Lead Poisoning, the 1991 Populated Areas ROD adopted a blood lead Remedial Action Objective (RAO) of no more than 5% of 9-month to 9-year old children exhibiting blood lead levels of 10 μg/dl (micrograms per deciliter) or greater, and no child greater than 15 μg/dl (nominally < 1%) (CDC 1991, USEPA 1991). This was an ambitious goal because in 1991 56% of the children on-site and 8.9% of children nationally had blood lead levels of 10 μg/dl or more (Pirkle et al. 1994).

The strategy adopted in the two RODs for the site was to achieve the required exposure reductions through replacement and/or cover of contaminated soil, dust, and waste piles with clean soils. In addition to blood lead levels, RAOs were established for individual and community-wide yard soil lead concentrations and consequent house dust lead levels (USEPA 1991). The ***Institutional Controls Program (ICP)*** was adopted to ensure the long-term integrity of these clean material barriers, and the LHIP was implemented to minimize exposure through targeted intervention efforts in the interim (PHD 1999). Progress toward this goal and the strategy's remedial effectiveness were evaluated in the 1999 Five Year Review for the Populated Areas (TerraGraphics 2000b).

Several analyses were conducted regarding the blood lead:soil/dust lead relationship in the Five Year Review and the State and USEPA concluded that the blood lead RAOs would likely be achieved under the current strategy (USEPA 2000, TerraGraphics 2001). Those analyses conducted for the Five Year Review used data obtained through the 1998 survey year. Since 1998, the percent of children with blood tested exceeding the 10 μg/dl has continued to decrease from 8% to 2% in 2002. This result is less than those reported in the more recent national surveys where 4.4% of U.S. children aged 1-5 had blood lead levels ≥ 10 μg/dl in the National Health and Nutrition Examination Survey (NHANES) III, Phase 2 (Pirkle et al. 1998).

The 2002 survey tested 368 children and identified 7 with elevated blood lead levels (or 2% site-wide). Follow-up investigations for these individuals suggested exposure from recreating in the Basin or remodeling portions of the home containing lead-based paint. In light of the decreasing trend in blood lead levels, "testing fatigue" in the community, reduced funds from the Agency for Toxic Substances and Disease Registry (ATSDR), and sources of exposure outside of the Box accounting for many of the elevated blood lead level cases, State and federal health officials discontinued the door-to-door surveys in favor of less aggressive solicitations. Beginning in July 2003, voluntary testing without payment (in previous surveys, each child was paid $20) was offered for 2 weeks. Participants were solicited by mail, newspaper, and radio. The Idaho Department of Health and Welfare also began reimbursing local doctors' offices to test Medicaid-eligible children in the area. As a result of these changes, only 8 children were tested in the 2003 walk-in clinic and 2 cases of elevated blood lead levels were reported to the State Health Department.

1.3 Objectives and Scope

The purpose of this remedial effectiveness review is to summarize the environmental monitoring and exposure reduction efforts within the Box; evaluate progress toward the human health related RAOs for soil, house dust, and blood lead; and to provide technical support to adapt the interim risk reduction strategies as cleanup approaches completion.

This report is the first in a series of three reviews and updates of the pertinent findings of the *1999 Five Year Review Report: Bunker Hill Superfund Site* (TerraGraphics 2000b). Those analyses related to the LHIP and achieving the blood lead RAOs are updated in the context of the decision to modify the interim risk reduction strategy. A second report will review the environmental components, focusing on the ROW recontamination and house dust controls; and a third report will evaluate the long-term effectiveness of Institutional Controls and community infrastructure supporting the remedy.

This report is structured as follows:

Section 1 - INTRODUCTION provides an overview of the general lead health situation, the historic and current status of health response efforts, and the objectives of this report. A brief site location and history recaps the site history and the lead health program for less-initiated readers, and the objectives and scope specifies the purpose and intended uses of the document and the report structure.

Section 2 - BLOOD LEAD CONCENTRATIONS updates the tables, figures and discussions of blood lead levels and percentages of children to exceed toxicity criteria in a format similar to the 1999 Five Year Review, adding results for the years 2000-2002. Results and summary statistics are presented for blood lead levels from 1974-2002, distributions of blood lead levels, prevalence of high blood lead levels, and age-specific blood lead and percent to exceed levels of concern. Analysis and interpretation of the results are presented in conjunction with exposure data in Sections 4 and 5.

Section 3 - ENVIRONMENTAL EXPOSURE MEDIA LEAD CONCENTRATIONS updates the tables, figures, and discussions of soil and dust lead levels from the 1999 Five Year Review, adding results for the years 1999-2002. Results and summary statistics are presented for soil lead concentrations from 1988-2002 for residential home yards. House dust lead concentrations for both vacuum bag and dust mat summaries and comparisons are presented. Analysis and interpretation of the house dust and soil data in relation to blood lead levels are provided in Sections 4 and 5.

Section 4 - HEALTH RESPONSE AND RISK MANAGEMENT ACTIVITIES summarizes the exposure and risk reduction strategies that have been employed within the Box. Both pre-CERCLA activities and interim risk management activities conducted prior to the RODs are briefly described. The permanent human health remedy describes the Long-term Risk Management Strategy implemented under the Populated Areas ROD Cleanup Activities, the Non-Populated Areas ROD, and the Institutional Controls Program. The components of the Lead Health Intervention Program are briefly described and Participation Rates and Annual Home Follow-up Summaries are presented and discussed. Soil and dust concentrations summarize exposure reduction progress, and children living on contaminated yards.

Section 5 - RELATIONSHIPS BETWEEN BLOOD LEAD LEVELS AND ENVIRONMENTAL EXPOSURES summarizes observed blood lead concentrations and describes trends in blood lead levels in the context of major remedial activities and subsequent environmental exposures and presents national and State-wide lead absorption databases. Quantitative analysis of blood and environmental exposure lead levels summarizes the paired database and presents correlations of blood lead and environmental exposures and multiple regression models relating blood lead to soil and dust lead levels. Lead intake and uptake biokinetic analysis describes the human health exposure pathways model and development of estimates of soil and dust lead intakes and effective soil/dust bioavailability. These estimates are subsequently used in site-specific IEUBK model applications that are compared to the USEPA default model.

Section 6 - COMPLIANCE WITH THE BOX REMEDIAL ACTION OBJECTIVES presents and evaluates compliance with the Bunker Hill Superfund Site RAOs for OU1 including the blood and soil and dust lead RAOs. Current CDC

Guidelines for preventing lead poisoning, and the Box and LHIP Compliance with Current CDC Guidance are discussed. Modifications to the LHIP implemented in 2003 are discussed in the context of current guidance and the potential CDC reconsideration of the blood lead criteria. A lead health effects review is provided with a summary of the recent lead health finding since 1998. Current USEPA policy regarding children's blood lead levels presents and discusses current USEPA guidance, Box compliance with current USEPA guidance, and the potential for modification of the risk management strategy.

Section 7 – CONCLUSIONS AND RECOMMENDATIONS were developed in coordination with federal and State Agency representatives through the Lead Remediation Review Group (LRRG) process.

Section 8 - REFERENCES includes all references cited in this report.

Appendix A - Contains a technical memorandum documenting the 2001 blood lead survey method changes.

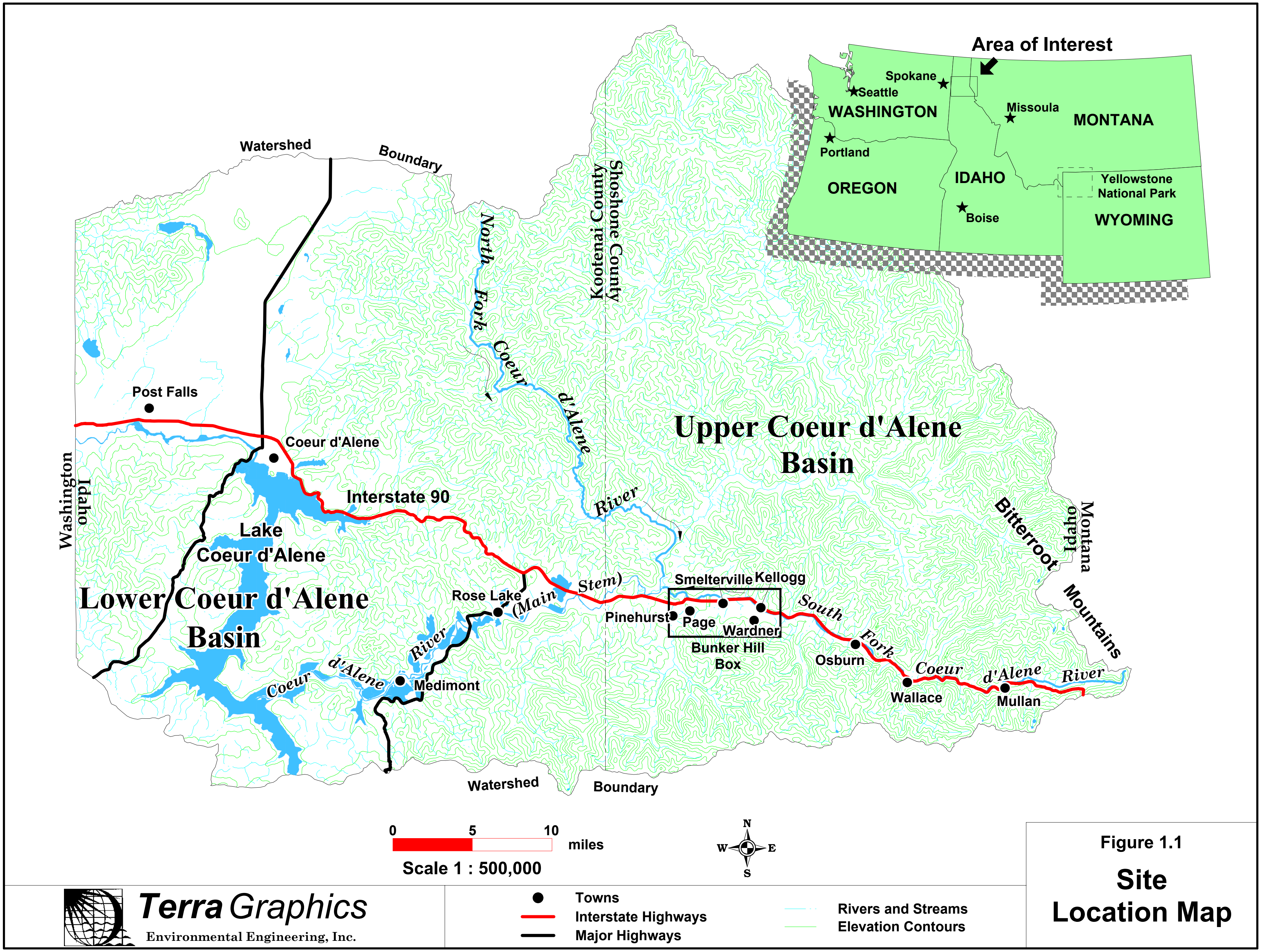
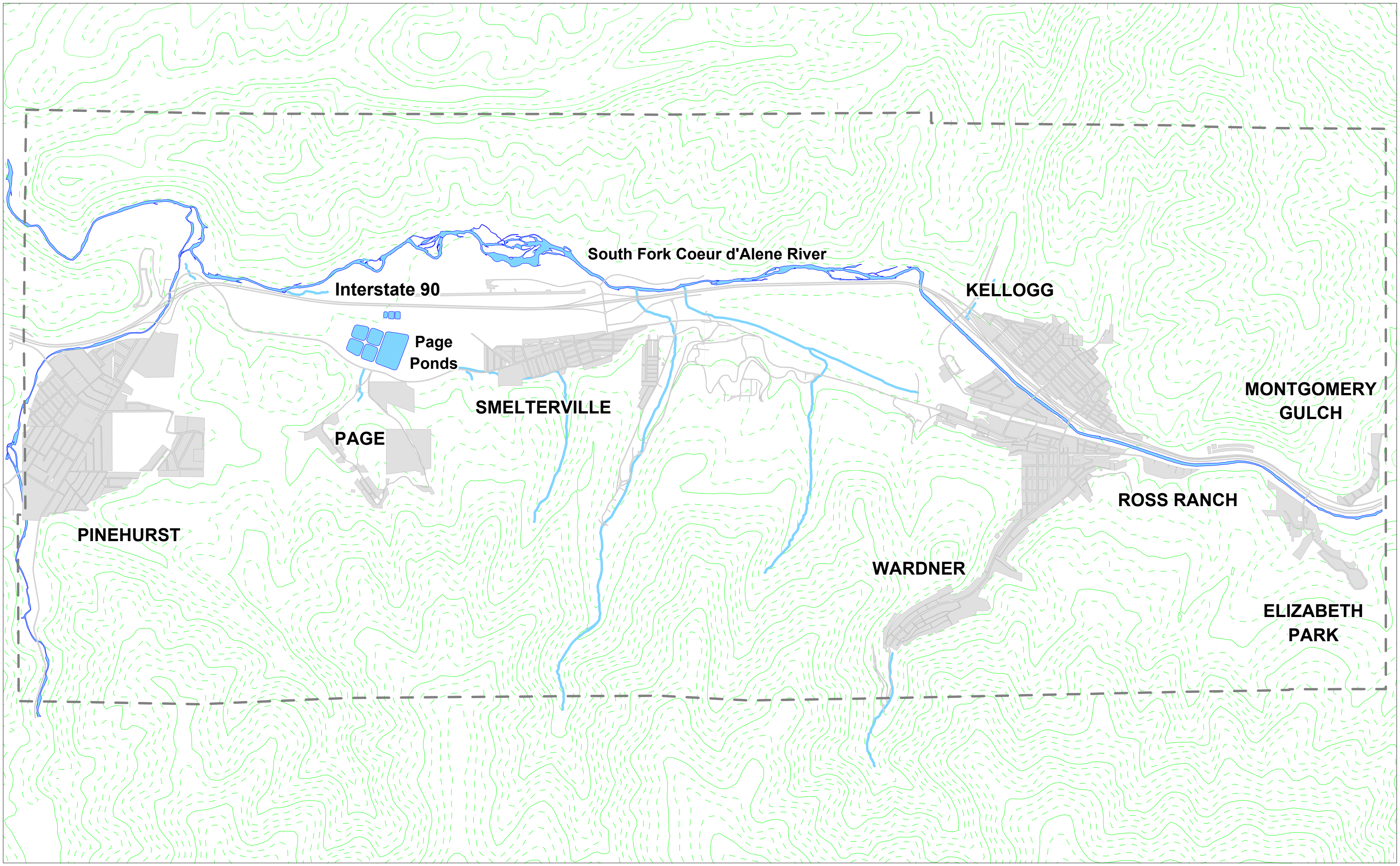


Figure 1.1
Site Location Map



0 0.5 1.0 miles

Scale 1 : 50,000

N W E S

Terra Graphics
Environmental Engineering, Inc.

Main Roads
Topography

Figure 1.2
Bunker Hill
Mining and Metallurgical
Complex (The "Box")

Table 1-1
Summary of Health Response Actions Undertaken Through CERCLA Within the Box (OU1 & OU2)

Health Response Action	Description	Dates
1983 Lead Health Study	A comprehensive exposure study to identify families with elevated blood lead levels, sources and exposure factors related to lead poisoning on site.	1983
Lead Health Intervention Program (LHIP)	The LHIP served as an interim risk management strategy to minimize lead exposure through biological monitoring, nurse follow-ups and parental and child education.	1985 – Present
CUA Fast-Track Cleanup	The Community Task Force founded in 1985 recommended Fast-Track cleanup. The program provided soil replacements and clean materials to cover public playgrounds, schools, parks and rights-of-way.	1986
Site Divided into Populated Areas and Non-Populated Areas	Divisions were undertaken in order to conduct the Remedial Investigation/Feasibility Study and develop Proposed Plans and Records of Decision.	1986 – 1994
Interim Cleanup Actions	Interim cleanup actions undertaken in both the Populated and Non-Populated areas, to control fugitive dusts, stabilize the industrial complex and waste piles on site.	Late 1980s – Early 1990s
High-Risk Yard Cleanup	Cleanup of residential properties was initiated at homes of young children and pregnant women living on properties with yard soils in excess of 1000 mg/kg lead concentration.	1989 – Present
Populated Areas ROD Cleanup	Removal of the top foot of contaminated soil and replacing it with a clean soil barrier at residential, commercial, and public properties throughout the site.	1991 – Present
Non-Populated Areas ROD Cleanup	Systematic area-wide cleanup of commercial and residential properties in the Populated Areas of the site, and cleanup of the Non-Populated areas.	1992 – Present
Institutional Controls Program (ICP)	ICP was adopted to ensure the long-term integrity of these clean material barriers.	1995 – Present & Future

SECTION 2.0 BLOOD LEAD CONCENTRATIONS

2.1 Summary of Blood Lead Levels 1974-2002

Use of the terms lead poisoning, lead intoxication and lead toxicity have been controversial at this site since 1974. Over the last three decades, differing opinions have prevailed as to which of these definitions, if any, should be associated with particular blood lead levels. As a result, a review of the numerous reports generated regarding observed blood lead levels at this site will yield different definitions. For purposes of this report, the ***level of concern*** cited by the CDC of 10 μg/dl (and the earlier value of 25 μg/dl applicable from 1985-1991) refers to a level associated with a risk of lead toxicity, that is currently judged to be unacceptable (or of concern), by public health authorities and lead experts in the United States.

Lead poisoning (levels requiring clinical management) was epidemic in the Silver Valley in the 1970s. In 1973-74 following a fire in the main pollution control facility, the owners continued to operate the smelter despite the absence of emission controls. During the six-month period when the pollution controls were by-passed, lead emissions were equivalent to what would have been released during eleven years of operations with emission controls. Deposition of fine, high-lead particulate in air, soil, and dusts poisoned most of the children in the area. Average blood lead levels for 9-month to 9-year old children ranged from 35 μg/dl to 68 μg/dl in 1974, and 32 μg/dl to 46 μg/dl, in 1975 in various communities on the site. Several children were diagnosed with clinical lead poisoning and many were hospitalized and provided chelation therapy with edentate disodium calcium ($CaNa_2EDTA$). Individual blood lead levels exceeded 160 μg/dl with accompanying erythrocyte protoporphyrin (EP) levels of > 600 μg/dl (red blood cell mass). Emergency response actions taken in 1974-75 reduced emissions to pre-fire levels and overall absorption was substantially decreased by 1976. However, average blood lead levels among children remained near 40 μg/dl until smelter closure in 1981. Figure 2.1 provides perspective for the dramatic changes in childhood blood lead levels accomplished in the last three decades in both the Box and the United States.

Tables 2-1a-c and 2-2 summarize blood lead levels during the years preceding Superfund activities in the area. Little blood lead data were available from the mid-1980s. Venous blood lead levels were measured in a comprehensive survey of lead poisoning and exposures conducted in Box communities in 1983. This survey showed continued excess absorption among area children, including those born since the smelter closure. Mean blood lead levels were 21 μg/dl in Smelterville, 17 μg/dl in Kellogg and 12 μg/dl in Pinehurst. Consistent with CDC recommendations at the time, blood lead surveys were not conducted from 1984 through 1987. EP screening of children's blood was utilized to identify children for intervention services. Table 2-2 summarizes the EP Screening Program results for 1985-87.

In 1988, venous blood lead testing was restored and continued annually through 2001, when capillary blood lead sampling was adopted. Figure 2.2 shows arithmetic mean blood lead levels by town for the years 1988-2002. Table 2-3 contains these data and geometric means and standard deviations (gsd) for the same exposure areas and time periods. Observed blood lead levels were highest in Smelterville in the initial years 1988-89, with arithmetic mean concentrations of 14.2 μg/dl to 14.6 μg/dl (11.6 μg/dl to 13.2 μg/dl geometric mean). Prior to the High-Risk Yard Cleanup, arithmetic mean blood lead levels in Kellogg, Page and Wardner ranged from 8.5 μg/dl to 10.3 μg/dl.

Overall, mean blood lead levels have dropped about 65-80% over the fifteen-year period, with the greatest decreases coinciding with initiation of the High-Risk Yard Cleanup program in 1989-90 and 1990-91. During the first two years of this program, 339 homes to an estimated 600 at-risk children were remediated site-wide. Site-wide blood lead levels decreased by 45% and the percentage of children exceeding 10 μg/dl dropped from 56% in 1989 to 15% by 1991 (Table 2-4).

Comparable arithmetic mean blood lead levels in 2002 were 3.0 μg/dl (2.6 μg/dl geometric mean) in Smelterville and ranged from 2.0 μg/dl to 3.4 μg/dl in Kellogg, Wardner, and Page (1.8 μg/dl to 3.2 μg/dl geometric mean). In 1990, Pinehurst was added to the LHIP and arithmetic mean blood lead levels of 7.4 μg/dl (6.7 μg/dl geometric mean) were observed in the initial survey compared to 2.9 μg/dl (2.4 μg/dl geometric mean) in 2002. In 2002, 2% of children site-wide had blood lead levels of 10 μg/dl or greater.

2.2 Distributions of Blood Lead Levels

The distribution of blood lead levels among the tested population also changed over the years. From 1988 to 1992, geometric standard deviations (gsds) for blood lead levels among the tested population were in the 1.41-1.80 range for towns with large numbers of observations (i.e., Kellogg, Pinehurst, Smelterville) (Table 2-3). In 1993, gsds increased to values of 1.79-2.23. The abrupt change in gsd in 1993 is likely caused by the bimodal distribution of home yard soil exposures and improved analytical methods that lowered the reporting limit for blood lead. The High-Risk Yard Cleanup decreased exposures and lowered blood lead concentrations for the bulk of the population. From 1988 to 1992, the blood lead reporting limit was 5.0 μg/dl and values below detection limit (bdl) were reported as 4.0 μg/dl. In 1993 the detection limit was reduced to 1.0 μg/dl and values below the detection limit were reported as 1.0 μg/dl. In 2001, the introduction of capillary blood testing increased the detection limit to 1.4 μg/dl (See Appendix A). This analytical and reporting methodology may have overestimated blood lead means and underestimated gsds in 1991-92 when a significant percentage of children were reported as below 5.0 μg/dl. The detection limit reporting methodology, however, has no effect on the percentage of children to exceed 10 μg/dl. From 1994 to 2000, gsd values stabilized and then decreased in 2002 to 1.64-1.68, as the cleanup neared completion.

Figures 2.3 a-o show histograms of the blood lead distributions in 5 μg/dl increments. These plots show that marked differences in the distribution of blood lead levels, especially near the 10 μg/dl criteria, were achieved at particular intervals of the cleanup. Obvious changes in the fraction of children at risk were achieved in 1989-91 with the advent of the High-Risk Yard Cleanup. Not only were there decreases in the percentage of children with elevated levels as high-risk exposures were mitigated, the percentage of children reporting the lowest levels increased significantly as overall soil/dust lead concentrations in the site were reduced. The percent of children in the <5µg/dl category changed from about 25% to greater than 60% from 1988 to 1991. The percentage of children in this lower category held nearly constant around 50-60% until 1997. From 1998-2002, the percentage of children <5 µg/dl has remained high at 70-90%. These results are discussed in more detail in Section 5.1.

2.3 Prevalence of High Blood Lead Levels

The incidence of blood lead levels greater than or equal to the 10 µg Pb/dl whole blood level of concern largely parallels the pattern observed in mean blood lead levels (Table 2-4 and Figure 2.4a-b). However from 1985 to 1991, the operational level of concern was 25 µg/dl (CDC 1985, CDC 1991). In 1988, 46% of the tested population (105 children) in the interior towns (Smelterville, Kellogg, Page, Wardner) exhibited lead levels greater than 10 µg/dl. The percent to exceed the 10 µg/dl level of concern in these areas increased in 1989 to 56% of children, with most of the additional poisoning (49 children) occurring among children new to Kellogg. The greatest percentage of children exceeding this health criteria were observed in Smelterville with 72% and 78% of children lead poisoned in 1988 and 1989, respectively. Marked decreases in the percent greater than or equal to 10 µg/dl occurred in Smelterville in 1990, with exceedance levels dropping to 31%. In 1990, Kellogg dropped to 40% exceedance, while the smaller towns did not markedly change. Pinehurst children were tested for the first time in 1990, with 29% of children exceeding the 10 µg/dl criteria.

By 1991, the percent exceeding the level of concern had decreased site-wide by more than half, with 15% of all children exhibiting levels greater than or equal to 10 µg/dl, as opposed to 37% a year earlier. Kellogg, Page and Smelterville showed exceedances of about 20%, and Wardner and Pinehurst showed exceedances of 11% and 5%, respectively. Conversely, the higher blood lead levels observed in 1992 resulted in significant increases in the number and percentage of children exhibiting levels of concern. The incidence in Kellogg and Smelterville respectively increased to 32% and 31%, while Wardner and Pinehurst increased to 22% and 18%, respectively.

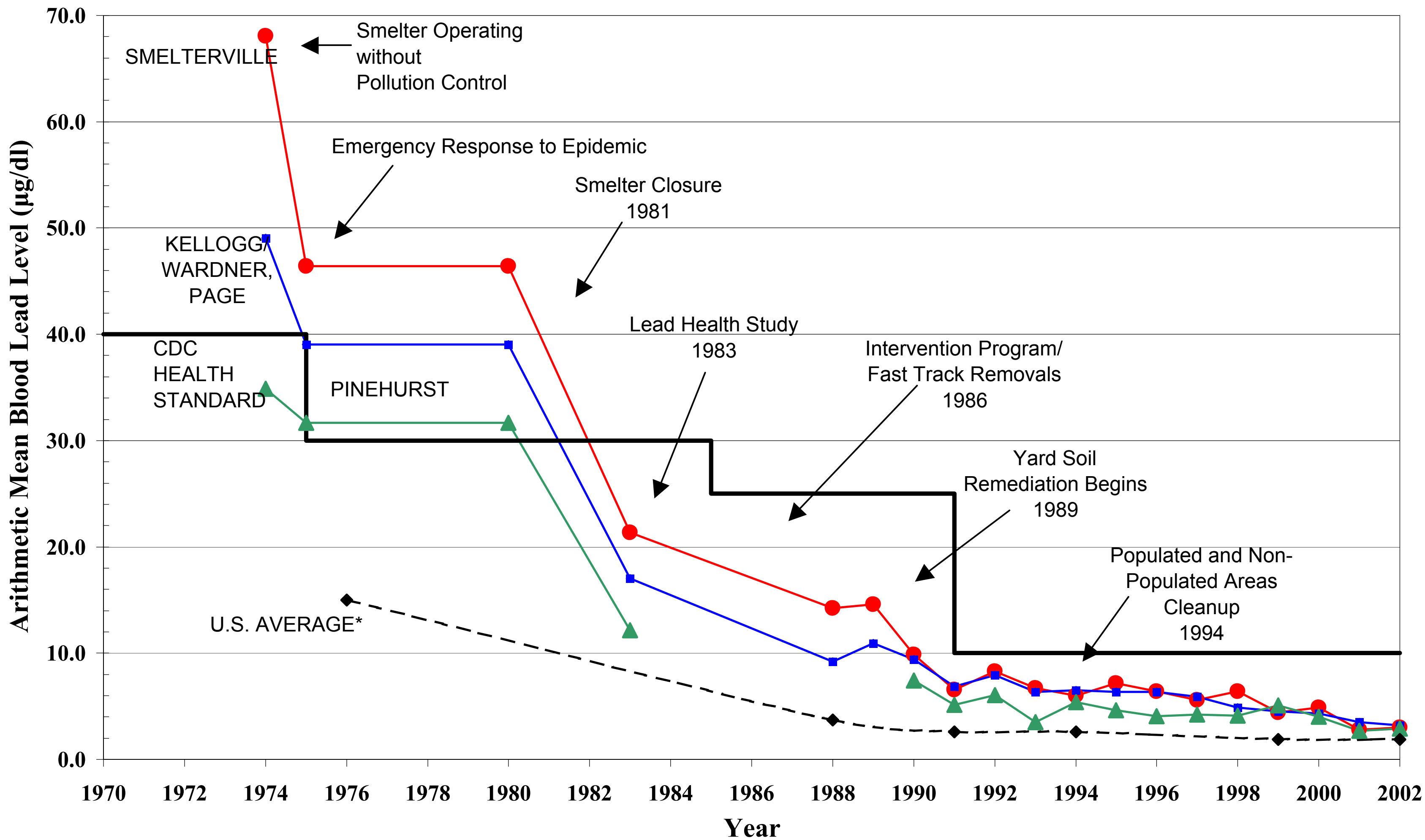
Site-wide exceedance levels returned to about 15% in 1993 and stabilized near that level (62 to 71 children annually among the tested population) for the next three years. In 1995, Kellogg showed 17% greater than or equal to 10 µg/dl with Smelterville increasing to 28%. From 1996 to 1998, site-wide exceedance decreased from 12% to 8%. Since the 1998 survey, the incidence of high blood lead levels has continued to decline, dropping to 6% in 1999 and 5% in 2000. In the last two years, a 33% reduction in blood lead levels and associated decrease in the gsd was observed. This has resulted in only 3% and 2% of children tested site-wide to have observed blood lead levels exceeding the 10 µg/dl criteria in 2001 and 2002, respectively. For individual communities in 2002, 2% of Kellogg and 3% of Pinehurst children had high blood lead levels. No children had levels

≥ 10 μg/dl in Smelterville, Page, or Wardner in 2002. Two children in Kellogg and one child in Pinehurst had blood lead levels exceeding 15 μg/dl. These results are discussed in relation to declining soil/dust exposures in Section 5.

2.4 Age-specific Blood Lead and Percent to Exceed the Level of Concern

Table 2-5 shows mean blood lead levels and toxicity incidence by age group. These results show that higher blood lead levels and the percentage of children exceeding the 10 μg/dl criteria are evident in the younger age groups. The same age-dependence of blood lead levels is seen nationally in the NHANES surveys (Pirkle et al. 1998). One and two year old children typically show higher blood lead levels than older age groups, with about 20% of the younger children exceeding 10 μg/dl in 1998. Three, four and five-year-old children had an approximate 10% exceedance rate in 1998. The percentage to exceed the 10 μg/dl criteria for all pre-schoolers dropped to about 8% by 2000 and 3% by 2002. Prior to 1995, from 2 to 16 children in the 8-9 year old age category showed high blood lead levels each year. Since 1995, few children older than age 6 years reported blood lead levels above 10 μg/dl. Excess absorption for most of the older children was associated with exposures from outside the home environment. Follow-up results for all children with high blood lead levels are discussed in detail in Section 4.3.5.

Figure 2.1
Children's Blood Lead Levels by Year, 1974-2002



*Ref.=(Mahaffey et al. 1982; Pirkle et al. 1994; Pirkle et al. 1998 ; Lofgren et al. 2000)

Figure 2.2
Blood Lead Level by City, 1988-2002

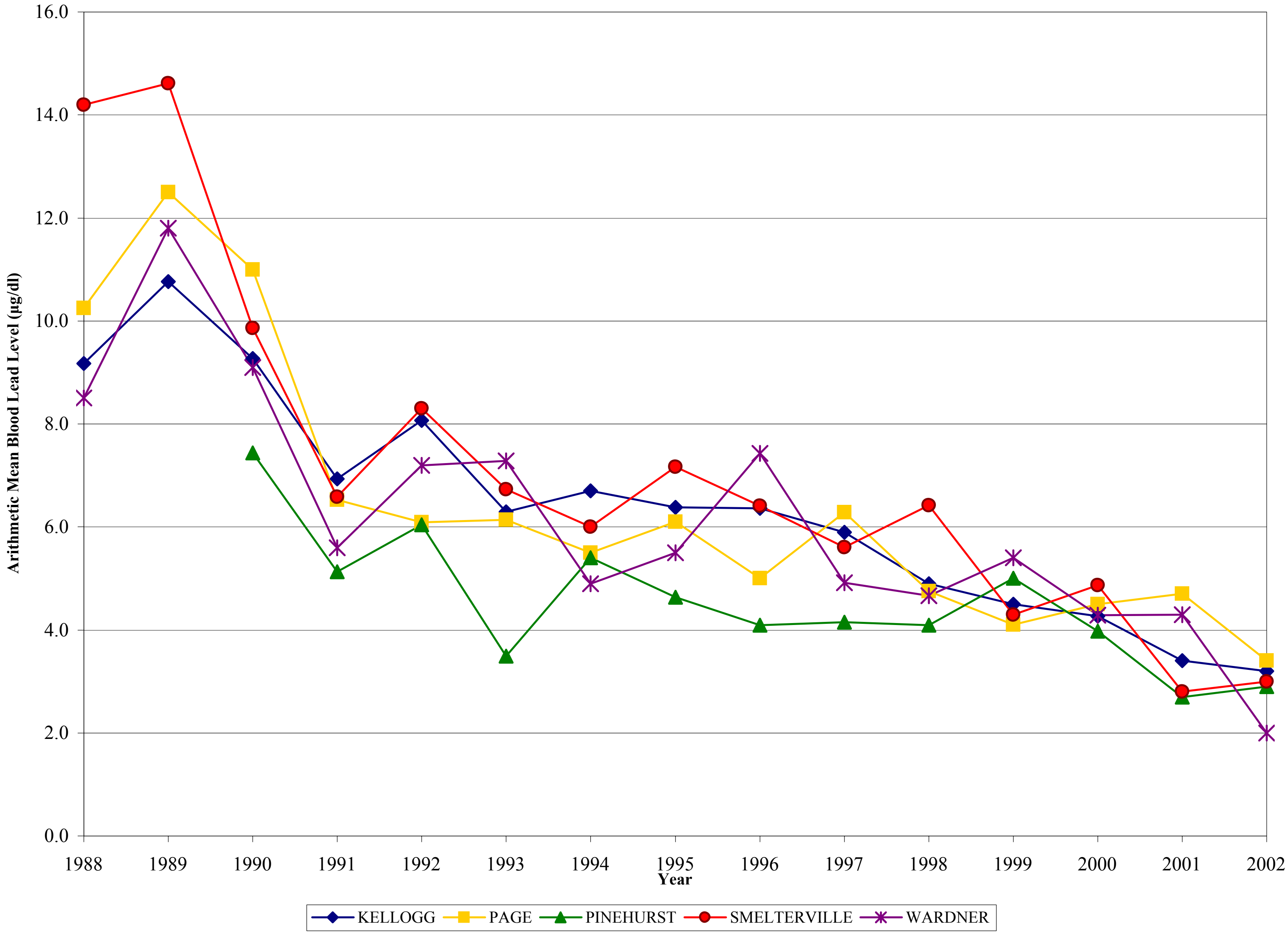


Figure 2.3
Blood Lead Distribution Histograms - Site-wide, 1988-2002

Figure 2.3a
Blood Lead Histogram - 1988[1]

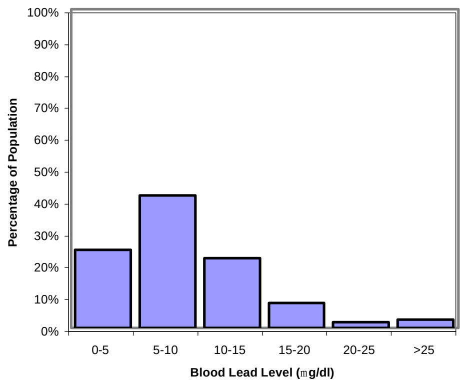


Figure 2.3b
Blood Lead Histogram - 1989[1]

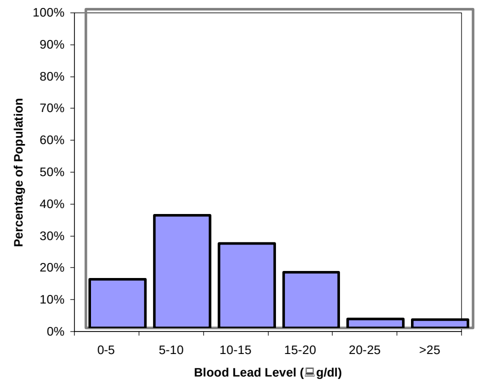


Figure 2.3c
Blood Lead Histogram - 1990

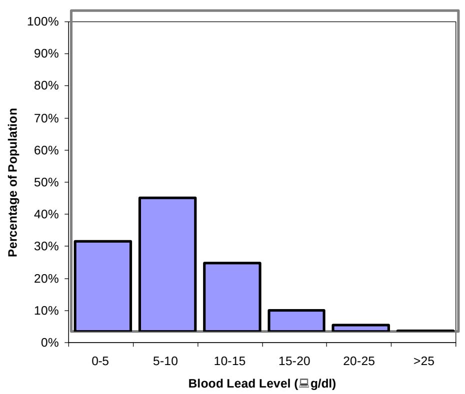


Figure 2.3d
Blood Lead Histogram - 1991

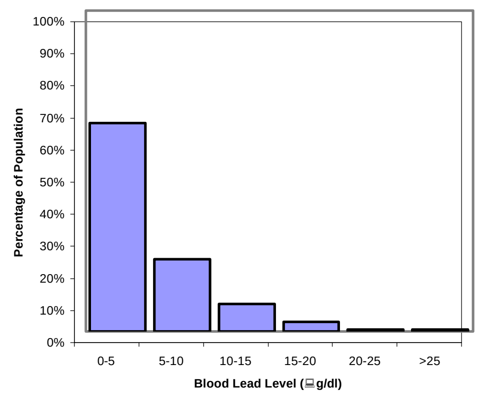


Figure 2.3e
Blood Lead Histogram - 1992

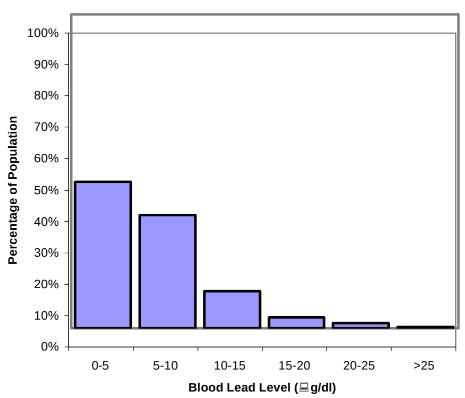


Figure 2.3f
Blood Lead Histogram - 1993

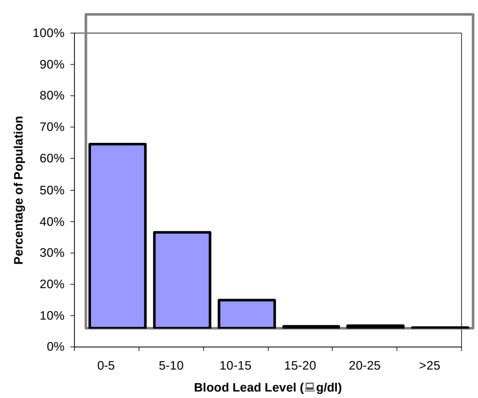
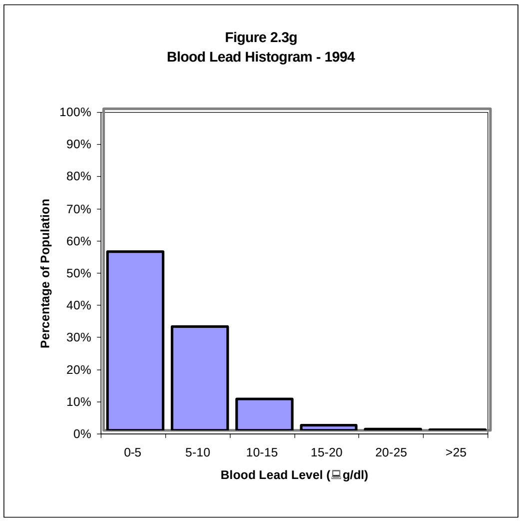
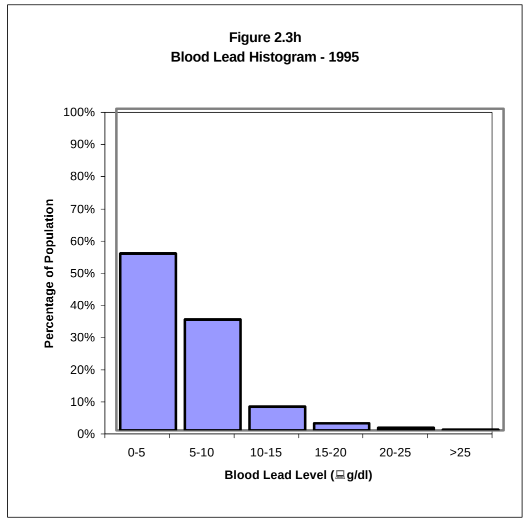
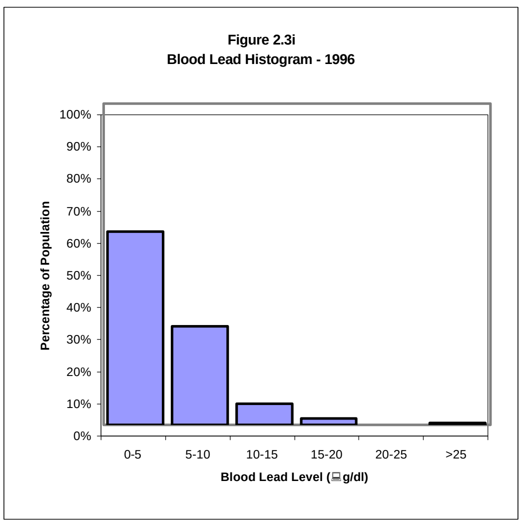
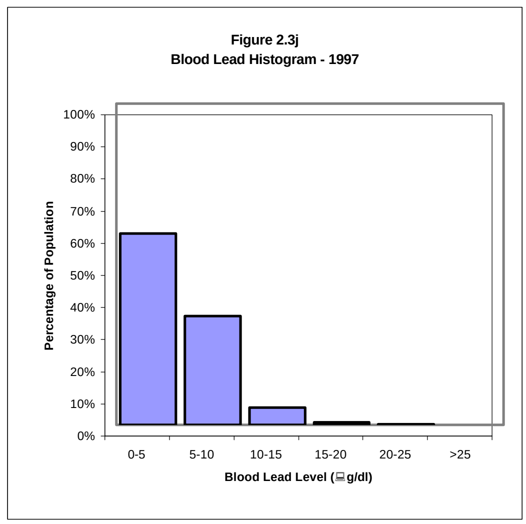


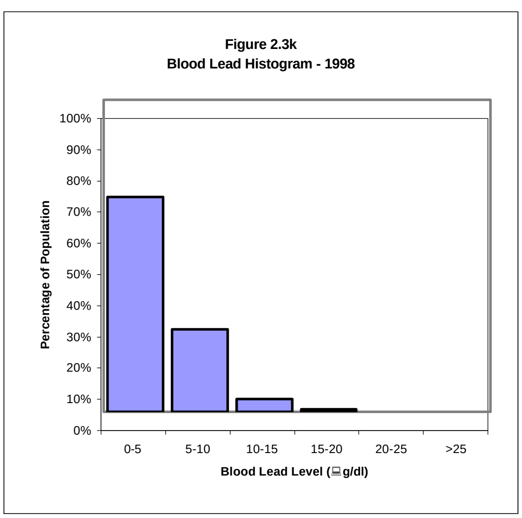
Figure 2.3 (continued)
Blood Lead Distribution Histograms - Site-wide, 1988-2002











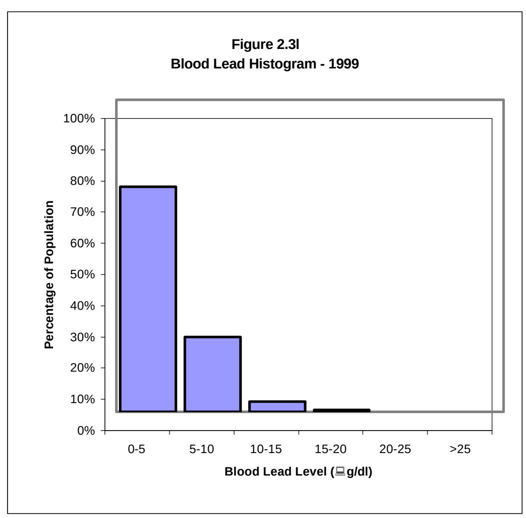


Figure 2.3 (continued)
Blood Lead Distribution Histograms - Site-wide, 1988-2002

Figure 2.3m
Blood Lead Histogram - 2000

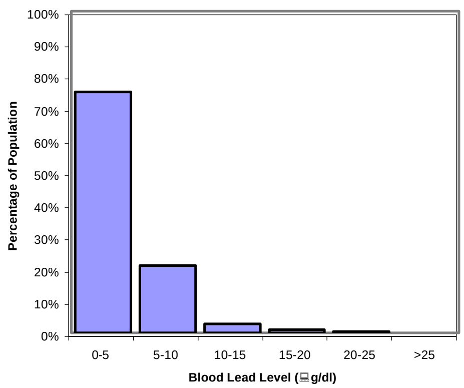


Figure 2.3n
Blood Lead Histogram - 2001

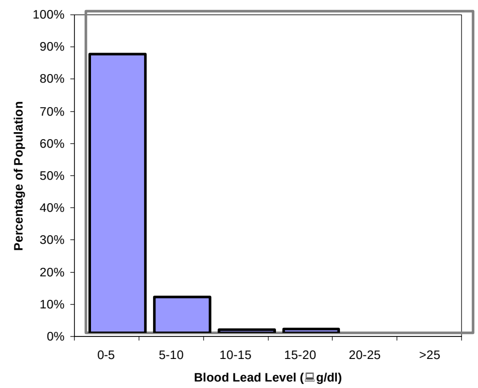
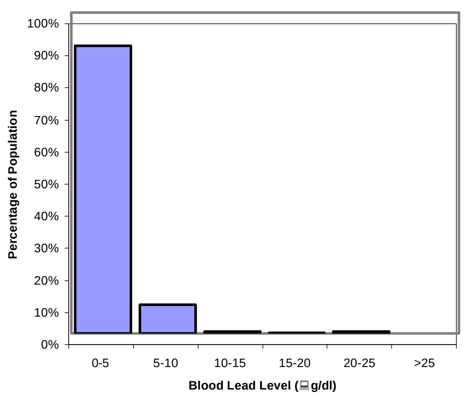


Figure 2.3o
Blood Lead Histogram - 2002



[1] No data collected in Pinehurst.

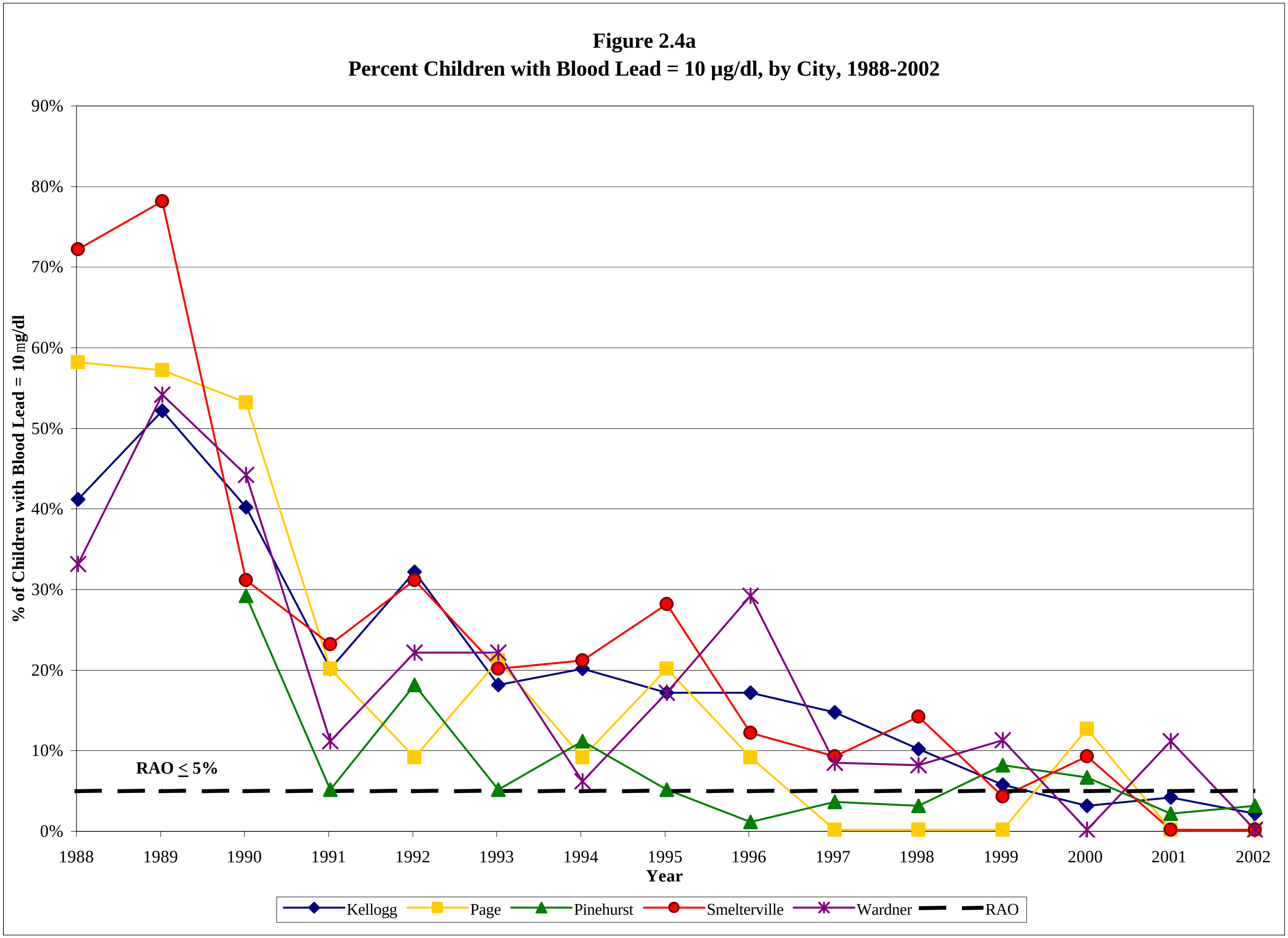


Figure 2.4a
Percent Children with Blood Lead = 10 µg/dl, by City, 1988-2002
% of Children with Blood Lead = 10 mg/dl
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAO ≤ 5%
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Kellogg
Page
Pinehurst
Smelterville
Wardner
RAO

Figure 2.4b
Percent Children with Blood Lead Levels = 15 µg/dl, by City, 1988-2002

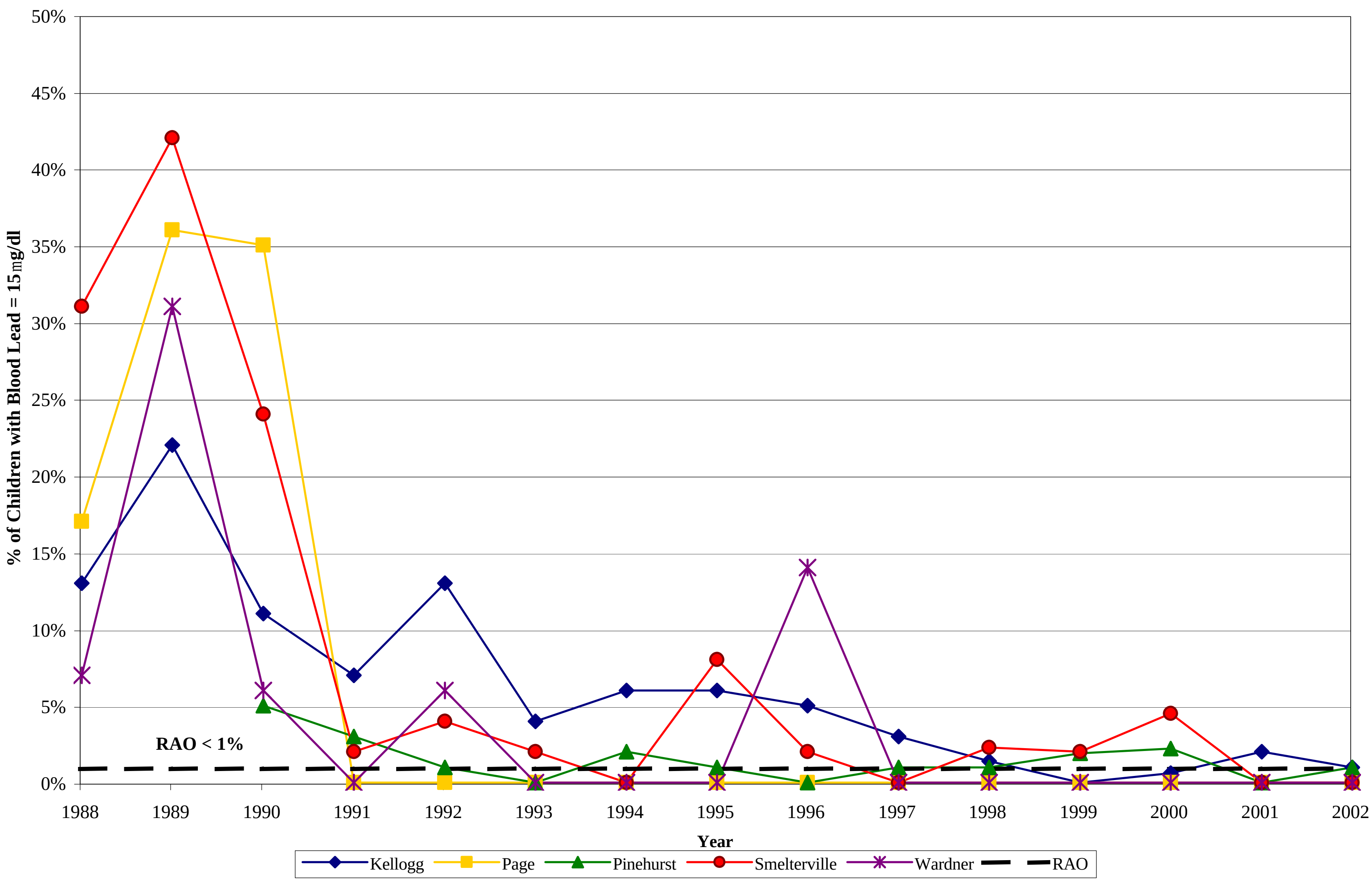


Table 2-1a
Blood Lead Levels Box Area Children Ages 1-10, 1974-1982

	Aug-74		Aug-75		Aug-76		Aug-77		Aug-78		Aug-79		Apr-80		Oct-80		Aug-81		Aug-82	
Blood Lead (mg/dl)	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Area I - Smelterville																				
80	38	22	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60-79	73	42	25	16	4	6	2	3	6	8	5	18	0	0	0	0	0	0	0	0
40-59	59	34	79	52	34	53	28	36	34	44	16	57	18	22	14	17	8	14	0	0
0-39	2	1	45	30	26	41	47	61	37	48	7	25	64	78	71	84	51	86	50	100
Total	172		153		64		77		77		28		82		85		59		50	
Area II - Kellogg, Wardner and Page																				
80	3	2	2	0	0	0	0	0	No Data Available				0	0	0	0	0	0	0	0
60-79	39	20	48	10	4	3	0	0	No Data Available				1	0	0	0	0	0	0	0
40-59	109	55	160	34	44	34	10	32	No Data Available				23	8	9	21	12	10	4	3
0-39	48	24	261	55	81	63	21	68	No Data Available				274	92	33	79	112	90	154	98
Total	199		471		129		31						298		42*		124**		158**	

29 Children were tested in 1979 (1 was 11 years old).

450 Children were tested in April 1980 (70 were 11 and 12 years old).

146 Children were tested in October 1980 (19 were 11 and 12 years old).

259 Children were tested in August 1981 (76 were 11 and 12 years old).

264 Children were tested in August 1982 (56 were 11 and 12 years old).

* Area II children were tested because of previous blood lead levels of 40 ug/dl or over in selves or siblings.
** Area II children were tested because of previous blood lead levels of 30 ug/dl or over in selves or siblings.

Note: Number of Area I and Area II children, age 1-10, with blood lead levels 30-39 ug/dl in August 1981 were 21 and 38, respectively.
Number of Area I and Area II children, age 1-10, with blood lead levels 30-39 ug/dl in August 1982 were 12 and 15, respectively.

Source: IDHW (1983)

Table 2-1b
Mean Blood Lead and Erythrocyte Protoporphyrin (EP) Levels of 1983 Survey Participants by Age and Year

	Age in Years								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Smelterville (Area 1)									
Number	6	5	4	1	8	5	3	5	6
Blood Lead (mg/dl)	23	21	24	22	23	24	13	17	21
EP (mg/dl)	37	43	30	38	35	45	17	26	34
Kellogg, Wardner and Page (Area 2)									
Number	13	15	30	28	17	28	16	29	23
Blood Lead (mg/dl)	14	18	19	21	16	18	18	15	12
EP (mg/dl)	30	25	30	29	24	33	30	22	20
Pinehurst (Area 3)									
Number	12	14	11	17	18	15	14	12	9
Blood Lead (mg/dl)	12	12	12	12	11	15	10	10	15
EP (mg/dl)	34	20	20	20	23	21	19	21	23

Source: PHD (1986)

Table 2-1c
Percent and Number of Children Found to be Lead Toxic*, August 1983

Smelterville (Area 1)	
1-2 Years (N)	45.5% (5)
3-9 Years (N)	18.8% (6)
All Ages Combined (N)	25.6% (11)
Kellogg, Wardner and Page (Area 2)	
1-2 Years (N)	10.7% (3)
3-9 Years (N)	8.8% (15)
All Ages Combined (N)	9.1% (18)
Pinehurst (Area 3)	
1-2 Years (N)	3.9% (1)
3-9 Years (N)	1.1% (1)
All Ages Combined (N)	1.7% (2)

*Defined as Blood Lead 25 µg/dl or greater and EP 35 µg/dl or greater.

Source: PHD (1986)

Table 2-2
EP Screening Progress Results, 1985-1987

Survey by community & site wide		Number screened via EP	Children with blood lead ≥25 mg/dl		Children receiving follow-ups
			Number	Percent	Number
1985		331	9	2.7%	26
1986	winter	107	4	3.7%	23
	summer	211	3	1.4%	
1987	winter	102	0	0.0%	7
	summer	160	3	1.9%	
Total		911	19	2.1%	56

Source: PHD (1986)

Table 2-3
Blood Lead Levels (mg/dl) by Year, 1988-2002

			Blood Lead Level Range (ug/dl)		Mean Blood Lead Level (mg/dl)			
					Arithmetic		Geometric	
Year	City	Number of Observations	Minimum	Maximum	Mean	S. D.	Mean	S. D.
1988	KELLOGG	171	4	39	9.2	5.14	8.0	1.66
	PAGE	12	4	26	10.3	6.63	8.5	1.92
	SMELTERVILLE	32	4	55	14.2	11.10	11.6	1.80
	WARDNER	15	4	18	8.5	3.68	7.8	1.52
1989	KELLOGG	212	3	40	10.8	6.01	9.3	1.72
	PAGE	14	6	22	12.5	5.61	11.4	1.57
	SMELTERVILLE	36	5	41	14.6	7.11	13.2	1.60
	WARDNER	13	6	20	11.8	4.50	11.0	1.50
1990	KELLOGG	193	4	25	9.3	4.58	8.3	1.61
	PAGE	17	4	21	11.0	5.98	9.4	1.83
	PINEHURST	107	4	20	7.4	3.70	6.7	1.59
	SMELTERVILLE	29	4	30	9.9	5.64	8.8	1.60
	WARDNER	16	4	15	9.1	3.30	8.5	1.50
1991	KELLOGG	177	4	31	6.9	4.55	6.0	1.60
	PAGE	15	4	14	6.5	3.44	5.9	1.58
	PINEHURST	116	4	26	5.1	2.98	4.7	1.41
	SMELTERVILLE	48	4	16	6.6	3.30	5.9	1.56
	WARDNER	9	4	11	5.6	2.40	5.2	1.40
1992	KELLOGG	211	4	26	8.1	4.86	6.9	1.71
	PAGE	11	4	10	6.1	1.92	5.8	1.36
	PINEHURST	120	4	15	6.0	2.81	5.5	1.51
	SMELTERVILLE	55	4	30	8.3	4.76	7.4	1.61
	WARDNER	18	4	15	7.2	2.80	6.8	1.40
1993	KELLOGG	228	1	24	6.3	4.02	5.2	1.88
	PAGE	14	3	12	6.1	2.80	5.6	1.54
	PINEHURST	119	1	13	3.5	2.76	2.6	2.23
	SMELTERVILLE	66	1	26	6.7	3.89	5.8	1.79
	WARDNER	18	3	14	7.3	3.10	6.7	1.50
1994	KELLOGG	232	1	41	6.7	4.60	5.5	1.89
	PAGE	11	2	12	5.5	2.80	4.9	1.63
	PINEHURST	109	1	19	5.4	3.30	4.6	1.81
	SMELTERVILLE	48	2	13	6.0	3.30	5.3	1.67
	WARDNER	16	2	11	4.9	2.50	4.3	1.70
1995	KELLOGG	252	1	30	6.4	4.31	5.2	1.91
	PAGE	10	2	12	6.1	3.38	5.3	1.79
	PINEHURST	97	1	15	4.6	2.54	4.0	1.75
	SMELTERVILLE	40	2	17	7.2	3.91	6.2	1.72
	WARDNER	6	3	10	5.5	2.58	5.1	1.50
1996	KELLOGG	225	1	54	6.4	5.19	5.1	1.90
	PAGE	11	2	13	5.0	3.38	4.2	1.88
	PINEHURST	103	1	12	4.1	1.96	3.7	1.61
	SMELTERVILLE	51	2	15	6.4	2.97	5.8	1.60
	WARDNER	7	3	15	7.4	4.31	6.4	1.83

Table 2-3 (continued)
Blood Lead Levels (mg/dl) by Year, 1988-2002

Year	City	Number of Observations	Blood Lead Level Range (ug/dl)		Mean Blood Lead Level (mg/dl)			
					Arithmetic		Geometric	
			Minimum	Maximum	Mean	S. D.	Mean	S. D.
1997	KELLOGG	199	1	22	5.9	3.42	5.0	1.84
	PAGE	7	2	9	6.3	2.36	5.7	1.66
	PINEHURST	86	1	17	4.2	3.02	3.5	1.79
	SMELTERVILLE	33	2	10	5.6	2.30	5.2	1.52
	WARDNER	12	1	10	4.9	3.06	3.9	2.20
	SITE-WIDE	**337**	**1**	**22**	**5.4**	**3.19**	**4.5**	**1.84**
1998	KELLOGG	212	1	19	4.9	3.11	4.0	1.94
	PAGE	8	3	6	4.8	1.28	4.6	1.34
	PINEHURST	100	1	17	4.1	2.56	3.5	1.73
	SMELTERVILLE	43	3	20	6.4	3.25	5.8	1.54
	WARDNER	12	1	13	4.7	3.39	3.7	2.07
	SITE-WIDE	**375**	**1**	**20**	**4.8**	**3.03**	**4.0**	**1.86**
1999	KELLOGG	198	1	14	4.5	2.70	3.7	1.90
	PAGE	8	1	8	4.1	2.20	3.5	1.90
	PINEHURST	106	1	17	5.0	3.10	4.2	1.80
	SMELTERVILLE	49	1	17	4.3	2.90	3.6	1.90
	WARDNER	9	1	12	5.4	3.20	4.5	2.00
	SITE-WIDE	**370**	**1**	**17**	**4.7**	**2.90**	**3.9**	**1.90**
2000	KELLOGG	170	1	16	4.3	2.31	3.7	1.71
	PAGE	8	1	11	4.5	2.98	3.7	1.97
	PINEHURST	91	1	19	4.0	3.31	3.1	2.04
	SMELTERVILLE	44	1	22	4.9	4.32	3.7	2.09
	WARDNER	7	1	8	4.3	2.69	3.3	2.37
	SITE-WIDE	**320**	**1**	**22**	**4.3**	**2.98**	**3.5**	**1.88**
2001	KELLOGG	182	1.4	18.0	3.4	2.70	2.8	1.79
	PAGE	7	1.4	9.4	4.7	3.30	3.7	2.08
	PINEHURST	101	1.0	11.0	2.7	1.80	2.4	1.70
	SMELTERVILLE	23	1.4	7.7	2.8	1.80	2.4	1.72
	WARDNER	9	1.4	11.5	4.3	3.40	3.3	2.22
	SITE-WIDE	**322**	**1.0**	**18.0**	**3.2**	**2.40**	**2.7**	**1.79**
2002	KELLOGG	195	1.4	21.3	3.2	2.30	2.8	1.64
	PAGE	8	1.8	5.1	3.4	1.24	3.2	1.40
	PINEHURST	115	1.4	21.0	2.9	2.49	2.4	1.68
	SMELTERVILLE	45	1.4	7.7	3.0	1.59	2.6	1.66
	WARDNER	5	1.4	3.8	2.0	1.03	1.8	1.53
	SITE-WIDE	**368**	**1.4**	**21.3**	**3.1**	**2.30**	**2.6**	**1.65**

Note: Site-wide blood lead levels presented only for 1997-2002.

Table 2-4
Summary of Children with Elevated Blood Lead Levels, 1988-2002

Year	City	Number of Observations	Blood Lead Level Range (μg/dl) Minimum	Maximum	Number and Percent of Children with Elevated Blood Lead Levels: Blood Lead ≥ 15 μg/dl Number	Percent	Blood Lead ≥ 10 μg/dl Number	Percent
1988	KELLOGG	171	4	39	22	13%	70	41%
	PAGE	12	4	26	2	17%	7	58%
	SMELTERVILLE	32	4	55	10	31%	23	72%
	WARDNER	15	4	18	1	7%	5	33%
	SITE-WIDE	**230**	**4**	**55**	**35**	**15%**	**105**	**46%**
1989	KELLOGG	212	3	40	47	22%	111	52%
	PAGE	14	6	22	5	36%	8	57%
	SMELTERVILLE	36	5	41	15	42%	28	78%
	WARDNER	13	6	20	4	31%	7	54%
	SITE-WIDE	**275**	**3**	**41**	**71**	**26%**	**154**	**56%**
1990	KELLOGG	193	4	25	22	11%	78	40%
	PAGE	17	4	21	6	35%	9	53%
	PINEHURST	107	4	20	5	5%	31	29%
	SMELTERVILLE	29	4	30	7	24%	9	31%
	WARDNER	16	4	15	1	6%	7	44%
	SITE-WIDE	**362**	**4**	**30**	**41**	**11%**	**134**	**37%**
1991	KELLOGG	177	4	31	12	7%	35	20%
	PAGE	15	4	14	0	0%	3	20%
	PINEHURST	116	4	26	4	3%	6	5%
	SMELTERVILLE	48	4	16	1	2%	11	23%
	WARDNER	9	4	11	0	0%	1	11%
	SITE-WIDE	**365**	**4**	**31**	**17**	**5%**	**56**	**15%**
1992	KELLOGG	211	4	26	27	13%	67	32%
	PAGE	11	4	10	0	0%	1	9%
	PINEHURST	120	4	15	1	1%	21	18%
	SMELTERVILLE	55	4	30	2	4%	17	31%
	WARDNER	18	4	15	1	6%	4	22%
	SITE-WIDE	**415**	**4**	**30**	**31**	**7%**	**110**	**27%**
1993	KELLOGG	228	1	24	9	4%	40	18%
	PAGE	14	3	12	0	0%	3	21%
	PINEHURST	119	1	13	0	0%	6	5%
	SMELTERVILLE	66	1	26	1	2%	13	20%
	WARDNER	18	3	14	0	0%	4	22%
	SITE-WIDE	**445**	**1**	**26**	**10**	**2%**	**66**	**15%**
1994	KELLOGG	232	1	41	13	6%	47	20%
	PAGE	11	2	12	0	0%	1	9%
	PINEHURST	109	1	19	2	2%	12	11%
	SMELTERVILLE	48	2	13	0	0%	10	21%
	WARDNER	16	2	11	0	0%	1	6%
	SITE-WIDE	**416**	**1**	**41**	**15**	**4%**	**71**	**17%**
1995	KELLOGG	252	1	30	16	6%	43	17%
	PAGE	10	2	12	0	0%	2	20%
	PINEHURST	97	1	15	1	1%	5	5%
	SMELTERVILLE	40	2	17	3	8%	11	28%
	WARDNER	6	3	10	0	0%	1	17%
	SITE-WIDE	**405**	**1**	**30**	**20**	**5%**	**62**	**15%**
1996	KELLOGG	225	1	54	11	5%	39	17%
	PAGE	11	2	13	0	0%	1	9%
	PINEHURST	103	1	12	0	0%	1	1%
	SMELTERVILLE	51	2	15	1	2%	6	12%
	WARDNER	7	3	15	1	14%	2	29%
	SITE-WIDE	**397**	**1**	**54**	**13**	**3%**	**49**	**12%**

Table 2-4 (continued)
Summary of Children with Elevated Blood Lead Levels, 1988-2002

			Blood Lead Level Range (mg/dl)		Number and Percent of Children with Elevated Blood Lead Levels			
					Blood Lead 3 15 mg/dl		Blood Lead 3 10 mg/dl	
Year	**City**	**Number of Observations**	**Minimum**	**Maximum**	**Number**	**Percent**	**Number**	**Percent**
1997	KELLOGG	199	1	22	5	3%	29	15%
	PAGE	7	2	9	0	0%	0	0%
	PINEHURST	86	1	17	1	1%	3	3%
	SMELTERVILLE	33	2	10	0	0%	3	9%
	WARDNER	12	1	10	0	0%	1	8%
	SITE-WIDE	**337**	**1**	**22**	**6**	**2%**	**36**	**11%**
1998	KELLOGG	212	1	19	3	1%	21	10%
	PAGE	8	3	6	0	0%	0	0%
	PINEHURST	100	1	17	1	1%	3	3%
	SMELTERVILLE	43	3	20	1	2%	6	14%
	WARDNER	12	1	13	0	0%	1	8%
	SITE-WIDE	**375**	**1**	**20**	**5**	**1%**	**31**	**8%**
1999	KELLOGG	198	1	14	0	0%	11	6%
	PAGE	8	1	8	0	0%	0	0%
	PINEHURST	106	1	17	2	2%	9	8%
	SMELTERVILLE	49	1	17	1	2%	2	4%
	WARDNER	9	1	12	0	0%	1	11%
	SITE-WIDE	**370**	**1**	**17**	**3**	**1%**	**23**	**6%**
2000	KELLOGG	170	1	16	1	1%	6	3%
	PAGE	8	1	11	0	0%	1	13%
	PINEHURST	91	1	19	2	2%	6	7%
	SMELTERVILLE	44	1	22	2	5%	4	9%
	WARDNER	7	1	8	0	0%	0	0%
	SITE-WIDE	**320**	**1**	**22**	**5**	**2%**	**17**	**5%**
2001	KELLOGG	182	1.4	18.0	4	2%	7	4%
	PAGE	7	1.4	9.4	0	0%	0	0%
	PINEHURST	101	1.0	11.0	0	0%	2	2%
	SMELTERVILLE	23	1.4	7.7	0	0%	0	0%
	WARDNER	9	1.4	11.5	0	0%	1	11%
	SITE-WIDE	**322**	**1.0**	**18.0**	**4**	**1%**	**10**	**3%**
2002	KELLOGG	195	1.4	21.3	2	1%	4	2%
	PAGE	8	1.8	5.1	0	0%	0	0%
	PINEHURST	115	1.4	21	1	1%	3	3%
	SMELTERVILLE	45	1.4	7.7	0	0%	0	0%
	WARDNER	5	1.4	3.8	0	0%	0	0%
	SITE-WIDE	**368**	**1.4**	**21.3**	**3**	**1%**	**7**	**2%**

Table 2-5
Mean Blood Lead Levels and Percentage of Children Exceeding the Level of Concern by Age Group and Year, 1988-2002

								1 Year Olds							
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	21.0	33.0	19.0	37.0	46.0	50.0	41.0	50.0	35.0	36.0	40.0	49.0	44.0	45.0	51.0
Minimum	4.0	6.0	4.0	4.0	4.0	1.0	2.0	2.0	2.0	1.0	2.0	2.0	1.0	1.4	1.4
Maximum	41.0	38.0	23.0	23.0	30.0	22.0	20.0	23.0	18.0	17.0	17.0	15.0	14.0	18.0	16.0
Arithmetic Mean	12.1	13.0	10.5	7.2	8.5	6.4	8.0	8.0	7.0	6.4	7.1	5.7	5.3	3.7	3.6
Standard Deviation	10.2	6.5	4.6	5.1	5.9	4.2	4.2	4.5	4.7	3.5	3.6	3.0	3.3	2.9	2.6
Geometric Mean	9.3	11.8	9.6	6.1	7.0	5.0	7.0	6.8	5.7	5.6	6.2	5.0	4.4	3.1	3.0
Geometric St. Dev.	2.1	1.5	1.6	1.7	1.8	2.1	1.7	1.8	1.9	1.7	1.6	1.7	1.9	1.8	1.7
# =10 mg/dl	12.0	22.0	10.0	9.0	16.0	9.0	11.0	15.0	8.0	6.0	9.0	7.0	6.0	2.0	3.0
% = 10 mg/dl	57.1	66.7	52.6	24.3	34.8	18.0	26.8	30.0	22.9	16.7	22.5	14.3	13.6	4.4	5.9
# = 15 mg/dl	5.0	9.0	2.0	4.0	8.0	2.0	3.0	5.0	5.0	2.0	3.0	1.0	0.0	1.0	1.0
% = 15 mg/dl	23.8	27.3	10.5	10.8	17.4	4.0	7.3	10.0	14.3	5.6	7.5	2.0	0.0	2.2	2.0
# = 25 mg/dl	2.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	9.5	6.1	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
								2 Year Olds							
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	23.0	29.0	35.0	24.0	51.0	48.0	57.0	32.0	46.0	40.0	39.0	33.0	35.0	41.0	32.0
Minimum	5.0	4.0	4.0	4.0	4.0	2.0	2.0	2.0	3.0	2.0	1.0	1.0	1.0	1.4	1.4
Maximum	28.0	40.0	30.0	24.0	23.0	26.0	21.0	17.0	31.0	18.0	19.0	17.0	16.0	16.0	11.0
Arithmetic Mean	11.7	13.6	11.1	7.3	8.2	7.9	7.7	6.9	8.1	6.2	6.2	6.5	5.1	4.6	3.6
Standard Deviation	6.2	7.2	6.4	5.3	4.4	4.7	4.2	3.9	5.2	3.4	3.7	3.9	3.1	3.1	2.2
Geometric Mean	10.3	12.0	9.5	6.1	7.3	6.8	6.6	6.0	6.9	5.4	5.2	5.5	4.3	3.8	3.1
Geometric St. Dev.	1.7	1.7	1.8	1.8	1.6	1.7	1.8	1.7	1.8	1.7	1.9	1.9	1.9	1.8	1.7
# =10 mg/dl	14.0	21.0	19.0	6.0	16.0	11.0	16.0	7.0	12.0	6.0	8.0	5.0	2.0	4.0	1.0
% = 10 mg/dl	60.9	72.4	54.3	25.0	31.4	22.9	28.1	21.9	26.1	15.0	20.5	15.2	5.7	9.8	3.1
# = 15 mg/dl	7.0	9.0	8.0	3.0	5.0	4.0	4.0	3.0	4.0	1.0	1.0	1.0	1.0	1.0	0.0
% = 15 mg/dl	30.4	31.0	22.9	12.5	9.8	8.3	7.0	9.4	8.7	2.5	2.6	3.0	2.9	2.4	0.0
# = 25 mg/dl	1.0	2.0	2.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	4.3	6.9	5.7	0.0	0.0	2.1	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
								3 Year Olds							
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	29.0	32.0	32.0	37.0	40.0	60.0	41.0	54.0	28.0	42.0	34.0	35.0	22.0	40.0	46.0
Minimum	4.0	4.0	4.0	4.0	4.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	2.0	1.4	1.4
Maximum	55.0	23.0	23.0	31.0	25.0	22.0	21.0	30.0	17.0	13.0	20.0	10.0	19.0	10.0	6.7
Arithmetic Mean	12.5	13.8	9.9	8.1	8.1	6.2	6.6	7.7	6.3	6.2	5.9	4.5	6.0	3.3	3.3
Standard Deviation	10.8	5.3	5.2	6.6	4.4	3.8	3.9	5.4	3.6	2.9	3.9	2.3	4.1	1.8	1.4
Geometric Mean	10.0	12.5	8.6	6.6	7.2	5.1	5.6	6.4	5.3	5.5	4.9	4.0	5.1	2.9	3.0
Geometric St. Dev.	1.9	1.6	1.7	1.8	1.6	1.9	1.8	1.9	1.9	1.7	1.9	1.7	1.8	1.6	1.6
# =10 mg/dl	18.0	27.0	14.0	10.0	13.0	9.0	7.0	14.0	6.0	7.0	4.0	1.0	3.0	1.0	0.0
% = 10 mg/dl	62.1	84.4	43.8	27.0	32.5	15.0	17.1	25.9	21.4	16.7	11.8	2.9	14.0	2.5	0.0
# = 15 mg/dl	5.0	14.0	6.0	5.0	3.0	1.0	2.0	7.0	1.0	0.0	1.0	0.0	2.0	0.0	0.0
% = 15 mg/dl	17.2	43.8	18.8	13.5	7.5	1.7	4.9	13.0	3.6	0.0	2.9	0.0	9.0	0.0	0.0
# = 25 mg/dl	3.0	0.0	0.0	2.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	10.3	0.0	0.0	5.4	2.5	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2-5 (continued)
Mean Blood Lead Levels and Percentage of Children Exceeding the Level of Concern by Age Group and Year, 1988-2002

	4 Year Olds														
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	19.0	32.0	36.0	33.0	50.0	43.0	48.0	43.0	58.0	30.0	43.0	34.0	31.0	23.0	49.0
Minimum	4.0	4.0	4.0	4.0	4.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.4	1.4
Maximum	18.0	29.0	21.0	17.0	20.0	14.0	15.0	25.0	54.0	22.0	14.0	12.0	22.0	16.0	14.0
Arithmetic Mean	8.6	11.3	10.2	6.6	8.1	6.7	6.0	7.4	7.3	5.5	5.3	4.9	4.5	3.9	3.1
Standard Deviation	4.4	5.7	4.7	3.4	3.9	4.0	3.1	4.6	7.2	4.3	2.9	3.0	3.7	3.4	2.3
Geometric Mean	7.6	10.0	9.2	5.9	7.2	5.1	5.2	6.3	5.6	4.3	4.5	4.0	3.6	3.0	2.6
Geometric St. Dev.	1.7	1.7	1.6	1.6	1.6	2.3	1.7	1.8	2.0	2.1	1.9	1.9	1.9	2.0	1.7
# =10 mg/dl	7.0	17.0	16.0	7.0	16.0	13.0	7.0	11.0	12.0	3.0	4.0	3.0	1.0	1.0	1.0
% = 10 mg/dl	36.8	53.1	44.4	21.2	32.0	30.2	14.6	25.6	20.7	10.0	9.3	8.8	3.0	4.3	2.0
# = 15 mg/dl	3.0	8.0	7.0	1.0	4.0	0.0	1.0	4.0	2.0	1.0	0.0	0.0	1.0	1.0	0.0
% = 15 mg/dl	15.8	25.0	19.4	3.0	8.0	0.0	2.1	9.3	3.4	3.3	0.0	0.0	3.0	4.3	0.0
# = 25 mg/dl	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	0.0	3.1	0.0	0.0	0.0	0.0	0.0	2.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0

	5 Year Olds														
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	30.0	20.0	43.0	32.0	43.0	46.0	46.0	46.0	37.0	40.0	37.0	50.0	29.0	35.0	38.0
Minimum	4.0	5.0	4.0	4.0	4.0	1.0	2.0	1.0	1.0	2.0	1.0	1.0	1.0	1.4	1.4
Maximum	25.0	21.0	22.0	16.0	21.0	21.0	17.0	16.0	17.0	15.0	11.0	14.0	10.0	7.0	21.0
Arithmetic Mean	11.7	11.5	9.4	7.1	7.3	5.6	6.3	5.7	5.7	5.9	4.7	4.6	3.8	2.5	3.5
Standard Deviation	4.7	4.5	4.3	3.7	4.1	4.0	3.1	3.1	3.0	3.1	2.8	2.5	2.3	1.5	3.2
Geometric Mean	10.7	10.6	8.4	6.3	6.4	4.5	5.6	4.9	5.0	5.1	4.0	4.0	3.3	2.2	2.9
Geometric St. Dev.	1.5	1.5	1.6	1.6	1.6	2.0	1.7	1.8	1.8	1.7	1.8	1.7	1.7	1.7	1.7
# =10 mg/dl	17.0	12.0	17.0	9.0	10.0	5.0	8.0	5.0	3.0	5.0	4.0	2.0	1.0	0.0	1.0
% = 10 mg/dl	56.7	60.0	39.5	28.1	23.3	10.9	17.4	10.9	8.1	12.5	10.8	4.0	3.0	0.0	2.6
# = 15 mg/dl	7.0	5.0	5.0	1.0	4.0	2.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0
% = 15 mg/dl	23.3	25.0	11.6	3.1	9.3	4.3	2.2	2.2	2.7	2.5	0.0	0.0	0.0	0.0	2.6
# = 25 mg/dl	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	6 Year Olds														
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	24.0	29.0	48.0	42.0	38.0	54.0	51.0	37.0	52.0	33.0	40.0	40.0	44.0	33.0	43.0
Minimum	4.0	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.4
Maximum	18.0	41.0	16.0	18.0	21.0	14.0	41.0	13.0	13.0	12.0	11.0	10.0	10.0	17.0	6.0
Arithmetic Mean	10.0	13.9	8.0	6.2	7.3	4.5	5.5	5.7	5.3	5.7	4.4	4.0	3.8	3.4	2.5
Standard Deviation	4.9	7.8	3.5	3.5	4.2	3.4	5.8	2.8	3.2	2.9	2.3	2.4	2.0	2.9	1.1
Geometric Mean	8.8	12.1	7.2	5.6	6.4	3.4	4.3	5.0	4.4	4.9	3.8	3.3	3.2	2.7	2.3
Geometric St. Dev.	1.7	1.7	1.6	1.6	1.7	2.2	1.9	1.7	1.9	1.9	1.8	1.9	1.8	1.9	1.5
# =10 mg/dl	13.0	20.0	16.0	7.0	12.0	6.0	6.0	5.0	6.0	4.0	1.0	1.0	1.0	1.0	0.0
% = 10 mg/dl	54.2	69.0	33.3	16.7	31.6	11.1	11.8	13.5	11.5	12.1	2.5	2.5	2.3	3.0	0.0
# = 15 mg/dl	5.0	13.0	3.0	2.0	3.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
% = 15 mg/dl	20.8	44.8	6.3	4.8	7.9	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0
# = 25 mg/dl	0.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	0.0	6.9	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2-5 (continued)
Mean Blood Lead Levels and Percentage of Children Exceeding the Level of Concern by Age Group and Year, 1988-2002

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
7 Year Olds															
N	23.0	36.0	45.0	47.0	45.0	44.0	37.0	55.0	49.0	44.0	40.0	51.0	28.0	35.0	43.0
Minimum	4.0	3.0	4.0	4.0	4.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	1.0	1.0	1.4
Maximum	15.0	21.0	22.0	14.0	26.0	11.0	19.0	9.0	11.0	17.0	8.0	13.0	19.0	4.8	21.3
Arithmetic Mean	8.3	8.7	9.2	5.2	7.5	5.0	5.8	4.1	4.7	4.5	4.2	4.3	3.9	2.5	2.8
Standard Deviation	3.1	4.9	4.7	2.1	5.1	3.3	4.3	1.9	2.1	3.1	2.0	2.6	3.6	1.0	3.1
Geometric Mean	7.8	7.5	8.1	4.9	6.4	3.9	4.7	3.6	4.3	3.8	3.8	3.5	2.9	2.3	2.3
Geometric St. Dev.	1.5	1.7	1.7	1.4	1.7	2.2	1.9	1.7	1.5	1.8	1.6	1.9	2.2	1.5	1.7
# =10 mg/dl	9.0	13.0	20.0	1.0	12.0	7.0	8.0	0.0	1.0	4.0	0.0	2.0	1.0	0.0	1.0
% = 10 mg/dl	39.1	36.1	44.4	2.1	26.7	15.9	21.6	0.0	2.0	9.1	0.0	3.9	3.6	0.0	2.3
# = 15 mg/dl	1.0	5.0	6.0	0.0	3.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0
% = 15 mg/dl	4.3	13.9	13.3	0.0	6.7	0.0	5.4	0.0	0.0	2.3	0.0	0.0	3.6	0.0	2.3
# = 25 mg/dl	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 Year Olds															
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	22.0	33.0	55.0	55.0	53.0	48.0	49.0	45.0	47.0	36.0	51.0	35.0	51.0	25.0	36.0
Minimum	4.0	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.4
Maximum	11.0	30.0	17.0	16.0	14.0	16.0	13.0	11.0	10.0	10.0	8.0	17.0	11.0	12.0	7.8
Arithmetic Mean	6.6	9.2	7.6	5.6	5.9	4.7	5.0	4.5	4.1	4.1	3.6	4.4	3.5	2.4	2.6
Standard Deviation	2.4	5.8	3.8	2.9	2.6	3.3	3.0	2.8	2.0	2.2	2.0	3.0	2.1	2.2	1.4
Geometric Mean	6.2	8.0	6.9	5.1	5.4	3.7	4.2	3.7	3.6	3.5	3.1	3.6	3.0	2.0	2.3
Geometric St. Dev.	1.4	1.7	1.6	1.5	1.5	2.1	1.8	1.9	1.6	1.8	1.8	2.0	1.7	1.7	1.5
# =10 mg/dl	4.0	11.0	16.0	5.0	7.0	4.0	4.0	4.0	1.0	1.0	0.0	1.0	1.0	1.0	0.0
% = 10 mg/dl	18.2	33.3	29.1	9.1	13.2	8.3	8.2	8.9	2.1	2.8	0.0	2.9	2.0	4.0	0.0
# = 15 mg/dl	0.0	6.0	4.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
% = 15 mg/dl	0.0	18.2	7.3	1.8	0.0	2.1	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0
# = 25 mg/dl	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 Year Olds															
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
N	38.0	31.0	49.0	58.0	48.0	52.0	46.0	42.0	45.0	36.0	51.0	43.0	36.0	45.0	30.0
Minimum	4.0	4.0	4.0	4.0	4.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4
Maximum	24.0	20.0	12.0	11.0	16.0	13.0	16.0	10.0	8.0	9.0	10.0	10.0	11.0	6.6	7.1
Arithmetic Mean	7.6	8.4	6.4	4.9	6.3	4.1	4.7	4.2	3.6	3.9	3.2	3.3	3.3	2.5	2.4
Standard Deviation	4.2	4.2	2.3	1.7	3.0	2.3	3.2	2.2	1.8	1.9	1.9	2.0	2.1	1.5	1.4
Geometric Mean	6.8	7.5	6.1	4.7	5.7	3.4	4.0	3.6	3.2	3.4	2.8	2.8	2.8	2.2	2.2
Geometric St. Dev.	1.6	1.6	1.4	1.3	1.5	1.9	1.8	1.8	1.7	1.7	1.7	1.9	1.8	1.7	1.5
# =10 mg/dl	11.0	11.0	6.0	2.0	8.0	2.0	4.0	1.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0
% = 10 mg/dl	28.9	35.5	12.2	3.4	16.7	3.8	8.7	2.4	0.0	0.0	2.0	2.3	2.8	0.0	0.0
# = 15 mg/dl	2.0	2.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 15 mg/dl	5.3	6.5	0.0	0.0	2.1	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
# = 25 mg/dl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% = 25 mg/dl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SECTION 3.0 ENVIRONMENTAL EXPOSURE MEDIA LEAD CONCENTRATIONS

3.1 Soil Lead Concentrations 1988-2002

3.1.1 Community-wide Soil Lead Levels

Table 3-1 summarizes home yard remediation progress and consequent soil lead concentration data for each community in the Box from 1989 to 2002. These data represent all home yards in each city. Figure 3.1a shows the mean community wide yard soil concentrations and the 350 mg/kg RAO by year since initiation of the yard soil cleanup activities in 1989. Figure 3.1b shows the percent of estimated total yard remediations that have been completed by year since 1989. Community-wide soil concentration refers to the geometric mean soil lead concentration for all yards (with or without children) that have been sampled or remediated in the community. Because additional yards are sampled and remediated each year, this value is updated annually for all previous years. Remediated yards are assumed to have a nominal soil lead concentration of 100 mg/kg, the maximum allowable concentration for replacement soils. Actual replacement soils have averaged about 55 mg/kg throughout the cleanup. Newly sampled yard soil lead concentrations are assumed to have applied in earlier years prior to remediation.

The concentrations reported in Figure 3.1 and Table 3-1 come from the database of properties maintained by the PRPs. As each property is sampled and remediated, those results are added to the database and the resultant mean community concentration is an indicator of progress of the cleanup effort. It is important to understand the nature of the cleanup in assessing these data. The residential soil cleanup was prioritized differently from year to year. In the early years, soil was remediated at homes occupied by the youngest children, pregnant women, or those children with high blood lead levels. In later years, neighborhood-wide cleanups were accomplished for all homes in prescribed geographic areas as well as High-Risk homes.

This strategy affected the mean and distribution of soil lead concentrations for each community in different ways. Figure 3.2 shows histograms of the distribution of soil lead levels. These results show that at the beginning of the remedial effort, soil concentrations were log-normally distributed and the geometric mean reflected the central tendency or typical yard soil lead level with gsd values generally ranging from 2.0-3.0. As the remediation effort progressed, a more skewed distribution of soil lead concentrations developed, with progressively more homes reporting <100 mg/kg as yards with soils greater than 1,000 mg/kg were replaced. As a result, the gsd for the yard soil lead distribution increased to values ranging from 4.0 to 5.0 as homes were remediated in the High-Risk program. Following completion of area-wide cleanups, individual yard soil lead concentrations ranged from <100 mg/kg to <1,000 mg/kg, means were <350 mg/kg, and associated gsds returned to the 1.8 to 2.5 range.

Because the cleanup altered the distribution of lead in soil, the relationship between geometric and arithmetic mean soil concentrations changed throughout the cleanup. As a result, the usefulness of these statistics in representing the central tendency of the distribution varied. Between 1989 and 2002, lead concentrations in the top-inch of yard soils (as measured by the arithmetic mean) was reduced by 96% in Smelterville, 76% in Kellogg, 36% in Page, 37% in Wardner, and 35% in Pinehurst (from Table 3-1).

From 1989 to 1998, with the exception of 1993, an average of 100-200 yards (and other residential discrete areas) were remediated each year, mostly in the cities of Kellogg and Smelterville. Significant reductions in site-wide means occurred in all years except 1993-1994. In that year, protracted negotiations between the governments and the site PRPs delayed the remediation program and only 39 home yards were remediated site-wide through the High-Risk Yard Cleanup. From 1999-2001, approximately 55 yards were remediated annually in specific geographic areas as well as other residential discrete areas (driveways, gardens, etc.).

Generally, community mean yard soil concentrations decreased by about 70-120 mg/kg annually, with larger reductions associated with area-wide removal efforts. No significant change occurred in Kellogg in 1993-1996 when remedial efforts were focused in Smelterville. Conversely, large reductions were noted in Smelterville in those years, with the geometric mean for the community dropping from 1,280 mg/kg in 1993 to 547 mg/kg in 1995 to 142 mg/kg in 1996 (Table 3-1). Large decreases were similarly noted in Kellogg during area-wide removals in 1997-1999. No significant changes in year-to-year geometric mean soil concentrations were observed in Pinehurst until the area-wide remediation efforts in 2000-2002.

3.1.2 Neighborhood Soil Lead Levels

Geographic Information System (GIS) techniques were employed to estimate arithmetic and geometric mean soil concentrations at various radii around each home in the Box for the years 1988-2002. The number of homes, ranges in concentrations, geometric and arithmetic means and standard deviations were determined for 200, 500, and 1,000 foot radii, for each home and year. Peripheral site areas, (e.g., ROWs and hillsides) were not included in this analysis, only residential yard soil data were accessed. This procedure was repeated for every house and for 200, 500, and 1,000 foot radii. The relationships between these variables and blood lead levels were examined in the 1999 Five Year Review. The variables for all three radii in both arithmetic and logarithmic forms were significantly correlated with blood lead levels. The geometric mean 200-foot radius was adopted as the most representative exposure variable in those analyses. Only the 200-foot neighborhood variable has been updated for this review.

Figures 3.3a-e, 3.4a-e and 3.5a-e show geometric mean (200-foot radius) top-inch soil lead concentrations for typical homes in Smelterville, Kellogg, and Pinehurst. These figures demonstrate the progression in the cleanup from the neighborhood perspective by interpolating the neighborhood lead concentration values and assigning a color scheme representing ranges of lead concentration levels within each town. The resulting means were divided into the following categories: 0 mg/kg to 349 mg/kg, 350 mg/kg to 499 mg/kg, 500 mg/kg to 999 mg/kg, 1,000-2,499 mg/kg, 2,500-4,999 mg/kg, and 5,000 mg/kg or greater.

The 1989 map of Smelterville demonstrates that prior to remediation, the eastern portion of town, nearest to the smelter, was the most contaminated neighborhood (Figure 3.3a). The western side of town had considerably lower neighborhood lead concentrations. Initially, only homes with children under 12 years old or pregnant women were targeted (i.e., High-Risk yards). Geometric mean soil lead concentrations gradually decreased from 1989 to 1994. In 1994, the program was changed to include remediation of large tracts or geographical areas in addition to the High-Risk yards. This resulted in remarkable changes in soil lead concentrations in Smelterville. By 1995, desired concentrations (<350 mg/kg) were reached in the eastern portion of the town, which was initially one of the most contaminated. By 1996, remediation was largely complete and concentrations were below the 350 mg/kg RAO throughout Smelterville (Table 3-1).

Initially, Kellogg was contaminated to levels similar to Smelterville (Figure 3.3a-e), although it was more remote from the smelter. Similar to the pattern in Smelterville, neighborhood soil lead concentration gradually decreased from 1989 through 1996 when remediation targeted only High-Risk properties. Significant progress in reducing neighborhood concentrations has been observed since 1996, when more yards were remediated. By 1997, the soil RAO of 350 mg/kg was achieved in the northeastern part of the town, initially one of the most contaminated. The entire north side of town was completed in 1998. However in 1999, remedial activities in the remainder of Kellogg were suspended to minimize conflicts with infrastructure improvements in that area. Since then, the area-wide yard program focused on Pinehurst, returning to Kellogg in 2002.

Neighborhood yard soil means in Pinehurst were initially lower than the other communities in the Box (Figure 3.5a), with an estimated 22% of the yards above 1,000 mg/kg (Table 3-1). In 1989-1998, relatively few yards were remediated each year, and geometric mean neighborhood soil lead levels gradually decreased (Figures 3.5a-e). A larger percentage of yards were remediated in Pinehurst in 1999-2001, and by 2002, neighborhood means were mostly below the action level (Figure 3.5g). A larger proportion of discrete areas in Pinehurst (i.e., ROWs and driveways) were above action levels, but followed the same trend in remediation as yards.

3.1.3 Sub-surface Soil Lead Levels

Because yard soil remediation is limited to the top one-foot of contaminated soils, contamination at-depth remains a potential problem within the Box. Figures 3.6a-c show current soil concentrations below barriers (anywhere from 6-18 inches) for Smelterville, Kellogg, and Pinehurst. Most of the soil contained under the barriers have high lead concentrations above 1,000 mg/kg, with a large portion greater than 5,000 mg/kg in Smelterville and Kellogg.

3.1.4 Other Soil Sources

Other soils that could not be remediated such as hillsides, or gravel ROWs and driveways recontaminated due to vehicular tracking also pose potential problems to remediated residential properties. The status of the Populated Areas Cleanup with respect to Commercial Properties, ROWs, and CUAs will be provided in a subsequent report.

3.2 House Dust Lead Concentrations 1988-2002

3.2.1 Vacuum Bag Dust Levels

Geometric mean house dust concentrations since 1988 are shown by town in Table 3-2 and Figure 3.7. House dust samples have been obtained from residents' vacuum cleaners from homes of children that participated in LHIP blood lead testing. Concentrations from LHIP participant homes may not be representative of the community at-large. Homes with older children, or no children, or those families that elected not to participate in the LHIP might have different habits and exposure factors. Since 1997 however, house dust samples have also been collected from the communities in site-wide surveys conducted by the Idaho Department of Environmental Quality (IDEQ). Mean house dust lead concentrations in Smelterville and Kellogg have decreased by more than 70% from a range of about 1,200 to 1,600 mg/kg in 1988-1990, to a range of 350-435 mg/kg in 2002. House dust lead concentrations tend to correlate with mean community soil concentrations and decrease as the residential yard, ROWs, and commercial property soil cleanup progresses. This decrease paralleled the reductions in community-wide soil concentrations through 1994.

Notable decreases were observed in Kellogg from 1988-1994. The percentage of houses with dust lead above 1,000 mg/kg dropped from 77% in 1988 to 41% in 1994 (Table 3-2). Geometric mean house dust lead levels in Kellogg decreased at an average rate of about 170 mg/kg per year from 1991-1994 and then stabilized at around 600 mg/kg through 1999. Concentrations then decreased to 529 mg/kg in 2000, and were observed at about 430 mg/kg for 2001 and 2002. However, the percentage of homes above 1,000 mg/kg remained at 12% in 2001 and 14% 2002.

In 1990, 86% of the homes with vacuum cleaners sampled in Smelterville, exceeded the 1,000 mg/kg RAO for house dust. Significant decreases in lead concentration were noted in the early years of the High-Risk Yard Cleanup in 1990-1992. An increase in dust lead levels was observed in 1993 in Smelterville. Mean lead levels of about 1,000 mg/kg were observed in 1993 and 1994, and averaged around 600 mg/kg in 1995-1997. From 1993-1996, mean concentrations decreased at a rate of about 200 mg/kg per year. Mean lead concentrations fluctuated around the RAO of 500 mg/kg in 1998-2001, then decreased in 2002 to 350 mg/kg. However, in the past two years approximately 10% of Smelterville houses had vacuum cleaner dust above 1,000 mg/kg.

Geometric means in Pinehurst ranged from 600 mg/kg to 700 mg/kg in the early 1990s, fluctuated from 300 mg/kg to 500 mg/kg through 2000, and have been less than 300 mg/kg since. Too few samples were available for Page and Wardner to quantitatively assess trends. Each community provided fewer than 15 samples each in 2002, with Page averaging 285 mg/kg and Wardner 469 mg/kg.

Figure 3.8 shows histograms of house vacuum dust lead concentrations from 1988-2002. In 1988, nearly 70% of homes site-wide had house dust vacuum bag lead concentrations exceeding 1,000 mg/kg. With the addition of Pinehurst in 1990, more than 50% of site-wide homes remained above that level. The percentage of homes greater than 1,000 mg/kg lead dropped to near 30% by 1993 and remained at that level through 1997, fell below 20% in 2000, and was less than 10% in 2000-2001. The percentage of homes with dust lead levels below 400 mg/kg increased from around 30% prior to 1999 to more than 50% in the last two years.

3.2.2 Mat Dust Lead Levels

The house dust lead samples discussed in the preceding Section were collected from vacuum cleaners provided by local residents during the annual blood lead surveys. This presents potential bias with respect to both the methodology and the population sampled. The vacuum bag method provides a dust lead sample directly from the home, contemporaneous with the blood lead observations for children. The vacuum bag sample represents the actual media being managed by the resident. This method also has the advantage of being quick, easy, and relatively inexpensive to collect and has been used at this site in dose-response analysis using bio-kinetic models for many years. However, there are certain drawbacks to the technique. It is uncontrolled as residents' habits, frequency of cleaning, and efficiencies of vacuum methods and machinery may vary. The technique only measures lead concentration and provides no measure of dustiness or lead loading. Finally, samples are collected primarily from homes that have young children whose families have been counseled on the importance of home hygiene and house dusts in childhood lead poisoning.

To address limitations associated with the vacuum bag samples, Panhandle Health District (PHD) and IDEQ, in cooperation with the ATSDR and the USEPA, developed a complementary sampling technique that measured both lead concentration and lead loading rate at homes in the site and in the greater Coeur d'Alene River Basin. This method uses carpeted floor mats that are placed in the home for some number of weeks, with instructions that the mats not be disturbed or cleaned (TerraGraphics 1999b, IDHW 2000, Farfel et al. 2001, TerraGraphics 2002). The mats are then collected and vacuumed in a controlled dust laboratory at the University of Idaho. Dust collected from the mats is analyzed for lead, then total dust, total lead, and dust and lead loading rates are calculated. This technique was initially used in the 1996 Coeur d'Alene River Basin Environmental Health Exposure Assessment, and has since been applied in the Box as well as other sites in the United States (IDHW 2000).

In 1997-2002, PHD continued this method of sampling as part of the LHIP. LHIP participants are generally characterized as families with young children. Additionally, Idaho DEQ sampling was initiated in Smelterville in 1997, and homes in both Smelterville and Kellogg in 1998-2002. These homes are generally characterized as families with either no children or older children, and are typically not involved in the LHIP. The population sampled by DEQ is considered to be representative of the community at-large as opposed to the LHIP population that includes only homes with young children who have had their blood sampled.

Tables 3-3a-b present mat dust lead concentrations and dust and lead loading rates for 1996-2002. As observed in Figure 3.9, the trend in geometric mean mat concentrations throughout the years has gradually decreased and in 2002 means were below the established RAO for house dust. However, the larger decrease observed in 2002 may be artifactual due to a change in the mats used. The manufacturer of the mat used from 1996-2001 discontinued the model and a new mat was researched and tested for 2002. According to the lead concentration and loading data, the mat model used in 2002 showed the most similar results to the previous model. A new laboratory was contracted to analyze the 2002 mats, and lower results than the previous model were observed. An in-depth analysis of this change in mats will be discussed in a subsequent report discussing house dust trends and remedial measures. Trends discussed in Section 3.2 exclude 2002 because of concern regarding the effect of changing mats.

Dust loading rate measures the mass of dust entering the home per square meter per day while the lead loading rate measures the mass of lead entering the home (in the same units). Lead loading rates in Kellogg and Smelterville decreased markedly between 1996 and 1997, and from 1998-2001 fluctuated around 0.2-0.3 mg/m^2/day (Table 3-3b). The mean lead loading rate decrease observed in Smelterville in 1996-1998 is possibly attributable to the completion of the soil remediation program or aftereffects of the flood in 1996. Smelterville was near completion in 1996 and completed in 1997. The mean dust loading rate in 1996 was 571 mg/m^2/day and 509 mg/m^2/day in 1997, but the mean lead loading rates decreased by more than half in those years, and decreased again in 1998 to a level that has remained low (Table 3-3b). Pinehurst's lead loading rates also decreased by more than half from 1996 to 1997, however, mean dust loading rates also markedly decreased in those years. In 1997-1999, Pinehurst's lead loading rates remained around 0.3 mg/m^2/day although mean dust loading rates increased (Table 3-3b). By 2000 and 2001, mean lead loading rates decreased to levels near 0.2 mg/m^2/day, while dust loading rates also decreased. By 2002, lead loading rates were at an all-time low for the larger communities. Page and Wardner have too few samples to assess trends.

3.2.3 Mat/Vacuum Paired Data

Direct comparison of vacuum bag and dust mat results was accomplished by merging results on a house-by-house basis. Paired vacuum bag and dust mat lead concentrations are available for a subset of the total houses sampled from 1996-2002. A summary of the paired data is presented in Table 3-4. A paired analysis of this type provides insight into the similarities and differences in the sampling techniques employed on site. A statistical analysis of the paired data for all 1996-1998 dust data is included in the 1999 Five Year Review Report (TerraGraphics 2000b). This report concluded that the two sampling techniques are correlated but yield significantly different results. These same analyses were updated for this report.

Paired dust concentrations show that the mat dust lead concentrations were generally higher than the vacuum bag concentrations until the year 2002. The opposite effect was observed in the 2002 paired results where vacuum bag concentrations were higher than the mat concentrations. This may be affected by the change in mats as described in the previous section. A study on background house dust levels outside the Box in communities unaffected by mining revealed that mat and vacuum bag lead concentrations showed no significant difference between the two techniques, using the old mats prior to the change (Spalinger 2000). As remediation is completed at the site, a trend toward converging mat and vacuum bag lead concentrations is expected and was probably near in 2002, but due to the discrepancy in mat models, is difficult to observe.

In Kellogg, significant differences between the mat and vacuum concentrations have been observed for all years mats have been collected (Table 3-4). Significant differences have been observed in Pinehurst for 1996-2001, except in 2000. Examining the paired data in Table 3-4, this difference caused discrepancies with respect to achieving the RAO in 1996 and 1997 only. Since 1997, differences between the two techniques have been between geometric means < 500 mg/kg. In 1996, 1998, and 1999, significant differences were observed in Smelterville. However, by 2000 and 2001, differences were not significant and mean concentrations were converging. Page and Wardner typically have too few paired observations to draw conclusion.

Site-wide correlations range from about 0.3 to 0.6 (Table 3-4) and generally show there is a linear relationship among vacuum bag and mat dust lead concentrations. These analyses reveal that the mat and vacuum techniques show similar trends in lowered concentrations and that as remediation nears completion, mean lead concentrations between the two techniques should converge as observed in Smelterville.

These analyses will be developed in greater detail in a later report addressing house dust issues in the Box.

Figure 3.1a
Community Geometric Mean Soil Lead Concentrations and Progress Toward Remedial Action Objective (RAO), 1989-2002

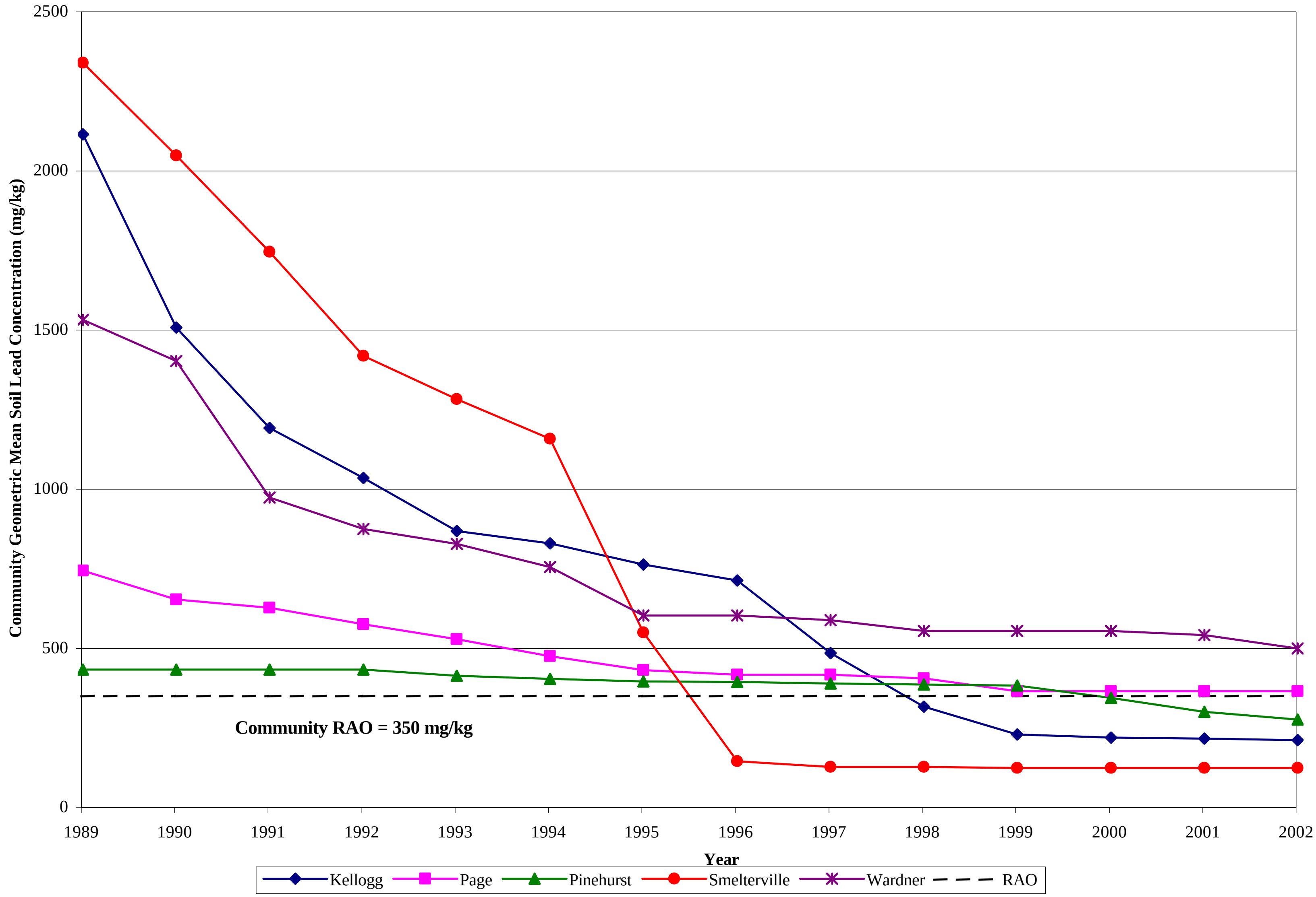
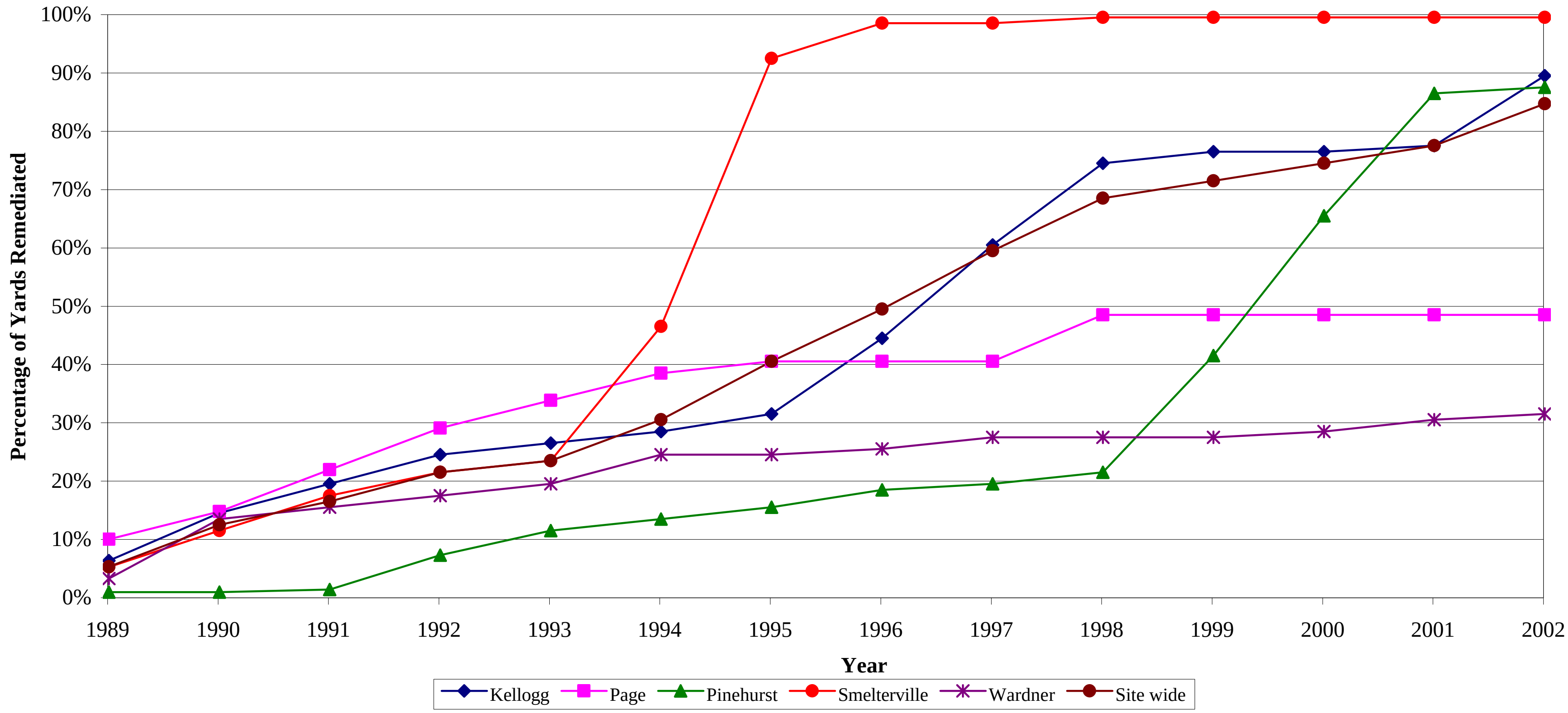


Figure 3.1b

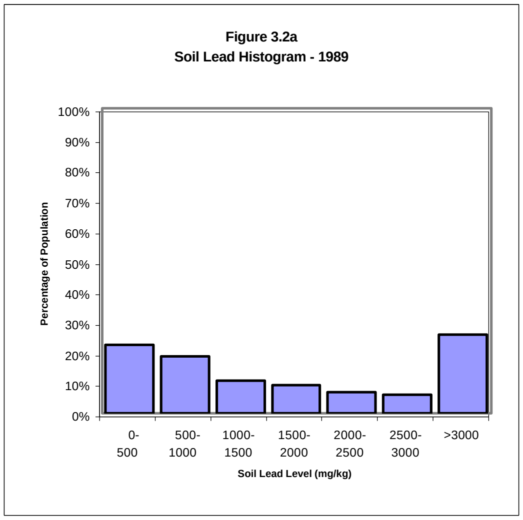
Percentage of Yard Remediations Completed by City, 1989-2002[a]

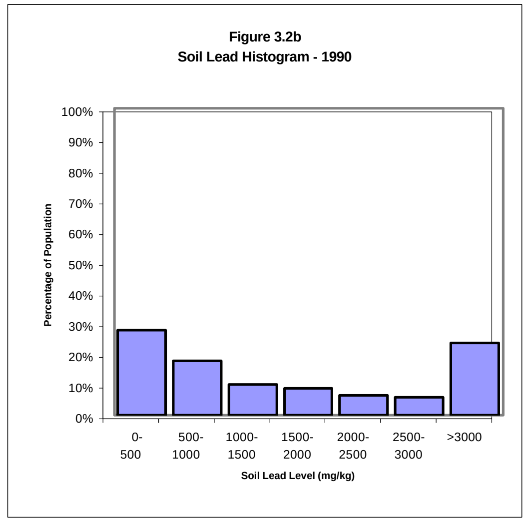


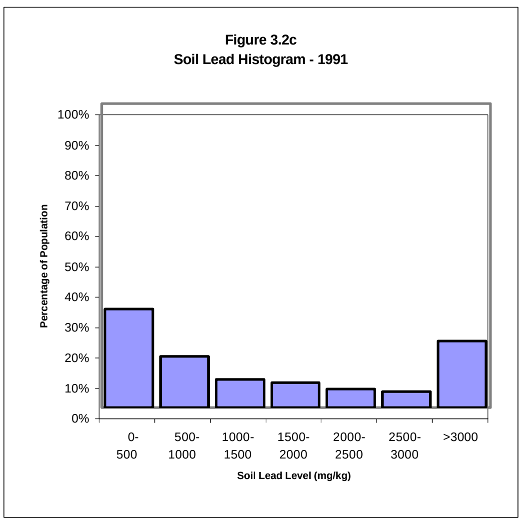
[a]The number of residential properties was originally estimated from tax assessor parcel maps. The number of remediated residential yards is based on the PRP soil database, which is not based on tax assessor parcel maps. Therefore, 100% agreement between counts is not expected.

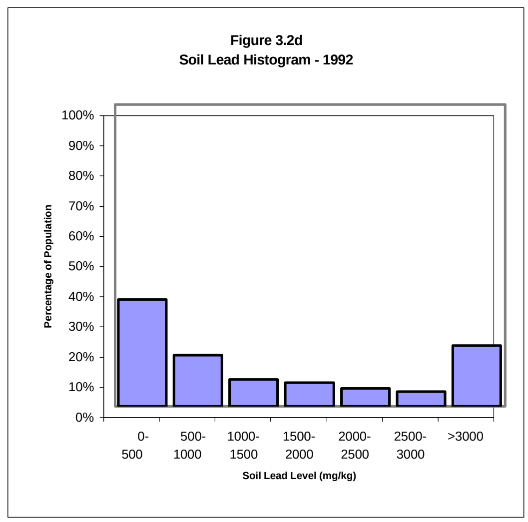
Note: Kellogg includes outlying communities such as Elizabeth Park and Montgomery Gulch.

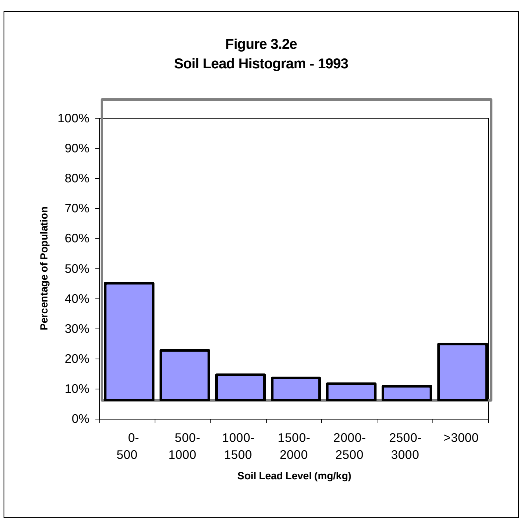
Figure 3.2
Soil Lead Distribution Histograms - Site-wide, 1989-2002











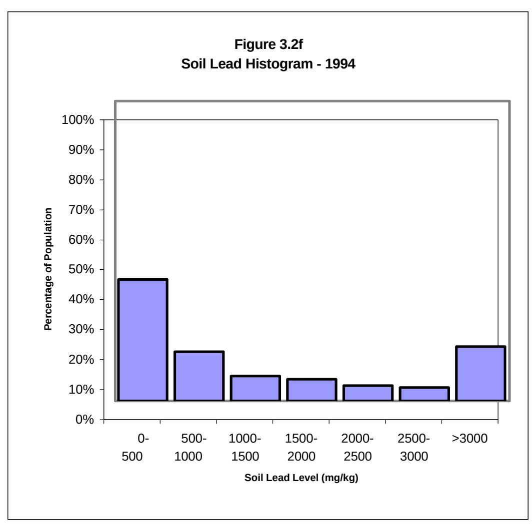


Figure 3.2 (continued)
Soil Lead Distribution Histograms - Site-wide, 1989-2002

Figure 3.2g
Soil Lead Histogram - 1995

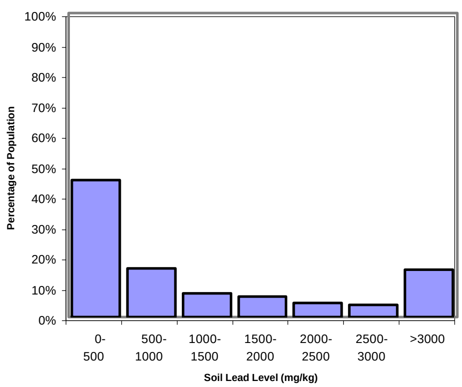


Figure 3.2h
Soil Lead Histogram - 1996

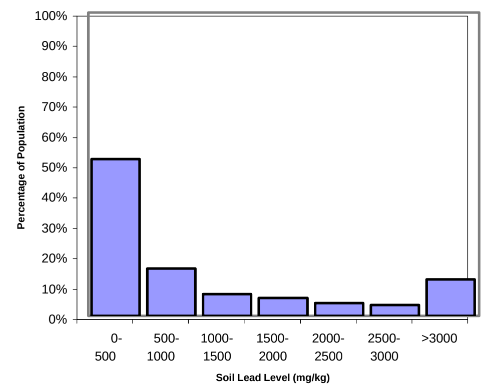


Figure 3.2i
Soil Lead Histogram - 1997

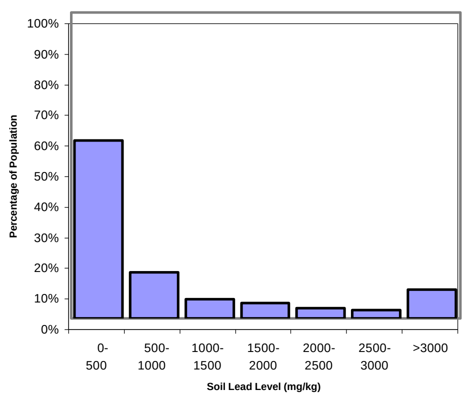


Figure 3.2j
Soil Lead Histogram - 1998

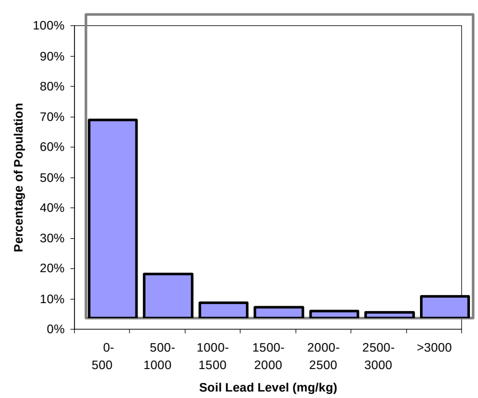


Figure 3.2k
Soil Lead Histogram - 1999

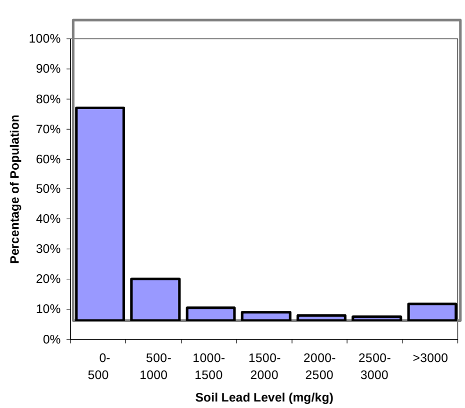


Figure 3.2l
Soil Lead Histogram - 2000

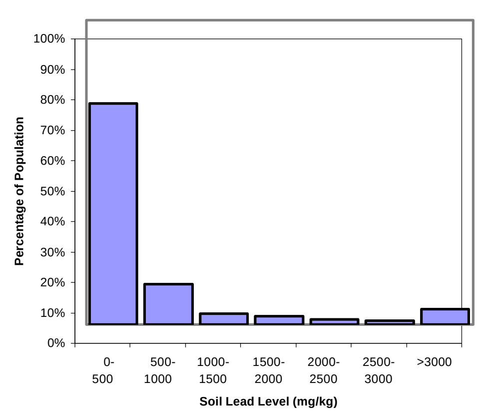
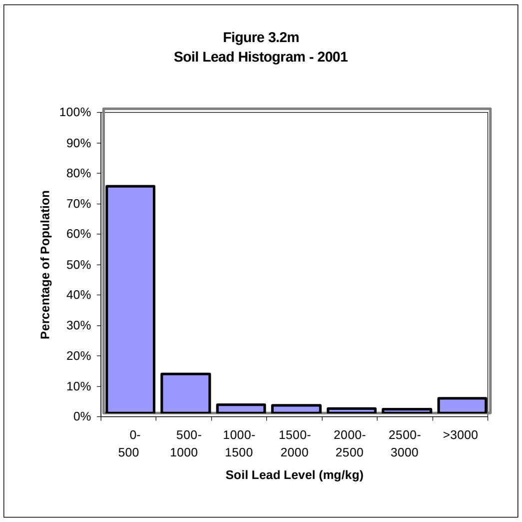
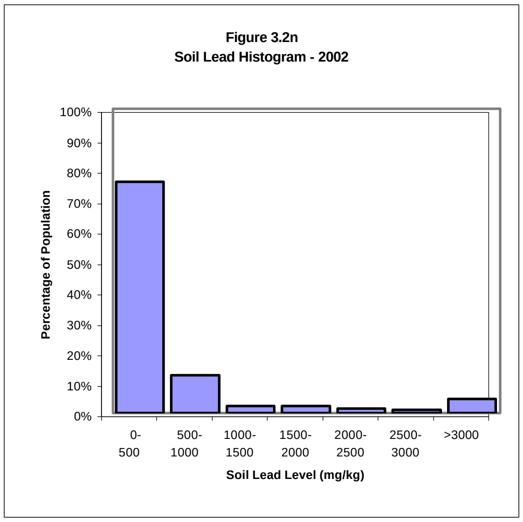
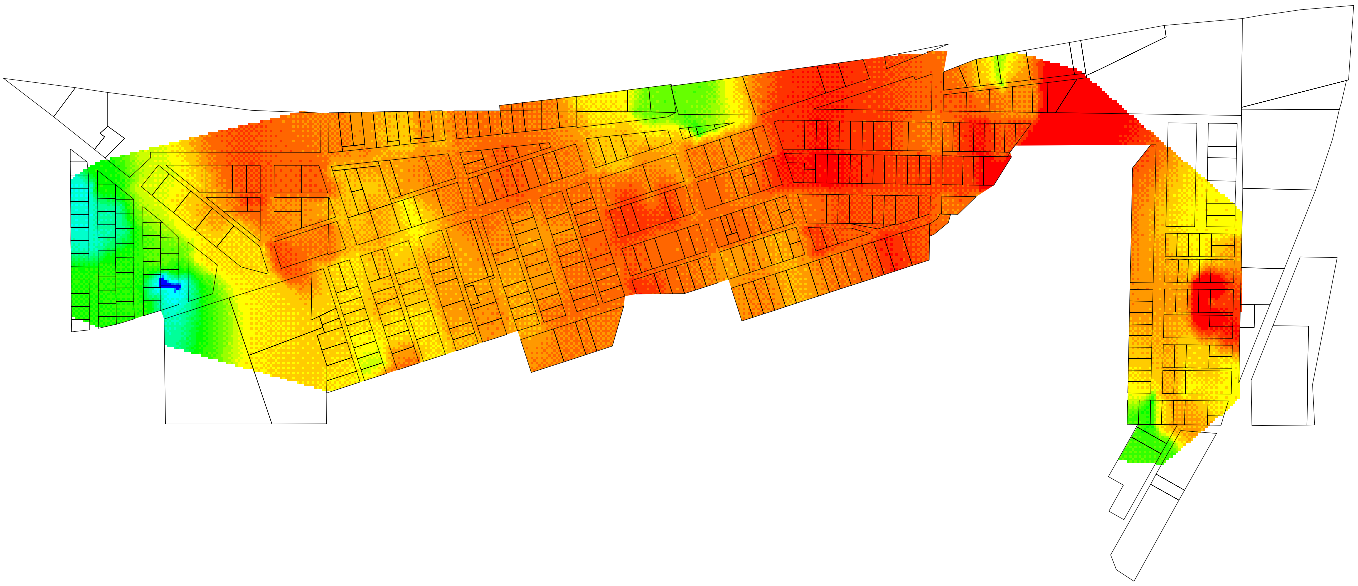


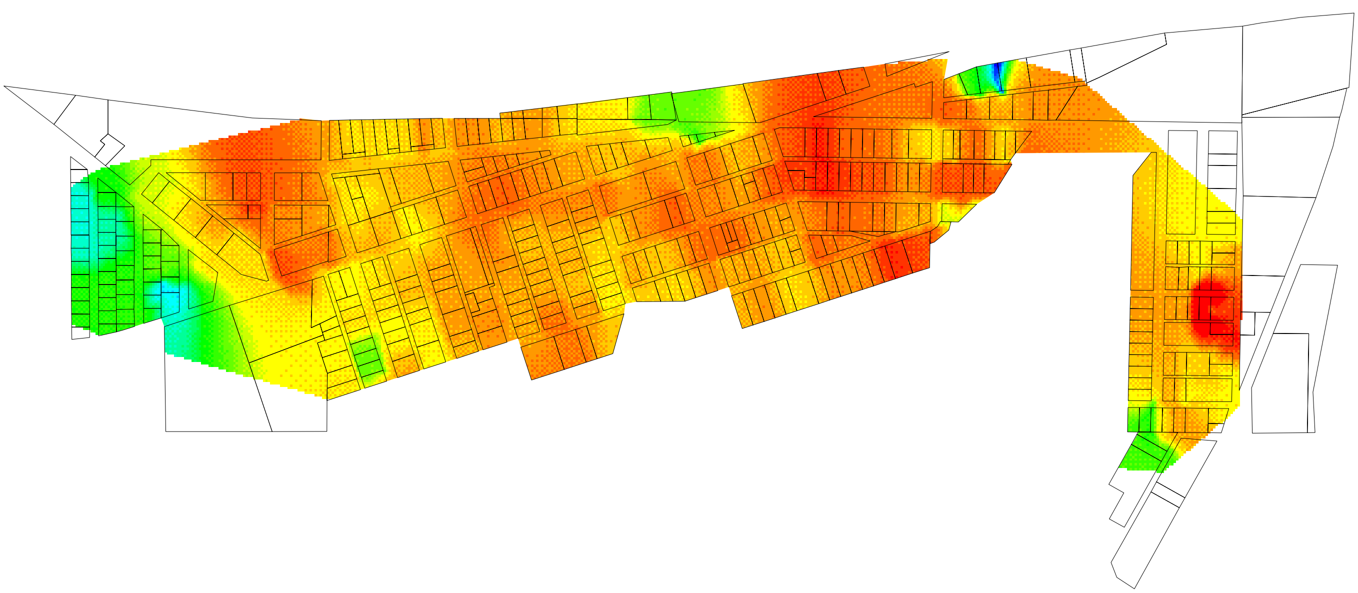
Figure 3.2 (continued)
Soil Lead Distribution Histograms - Site-wide, 1989-2002







1989



1990

Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Light orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

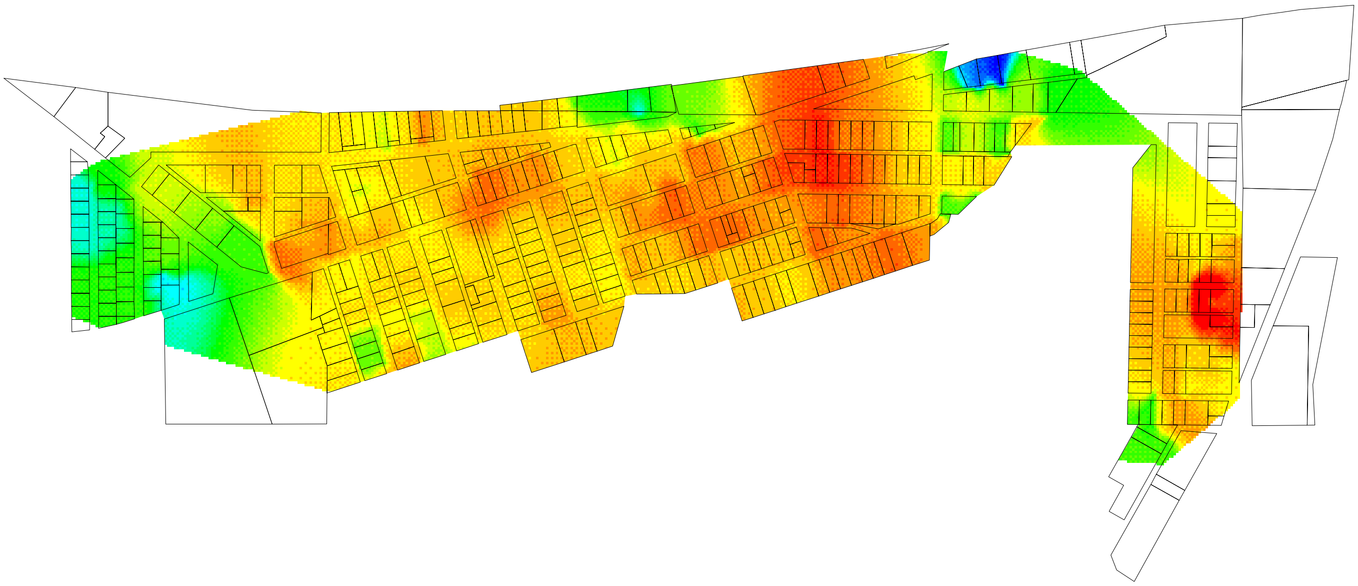
Terra Graphics
Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Smelterville/G20089-90	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

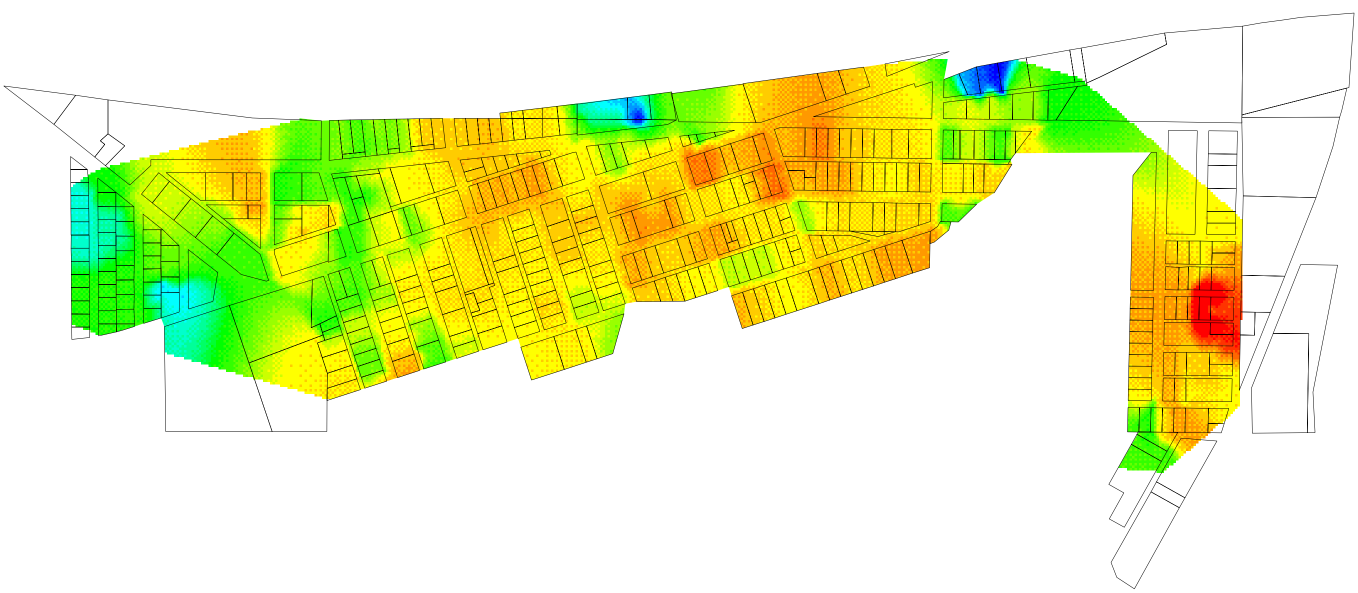
Figure 3.3a

1989 and 1990 Yard Lead Concentration Zones for Smelterville, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



1991



1992

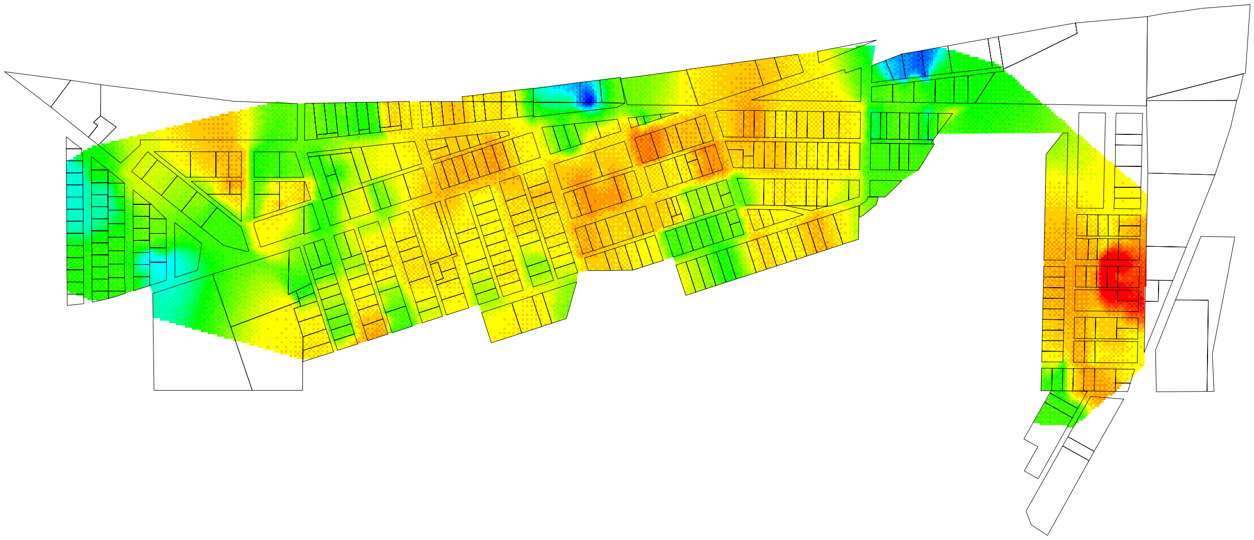
0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

Terra Graphics
Environmental Engineering, Inc.

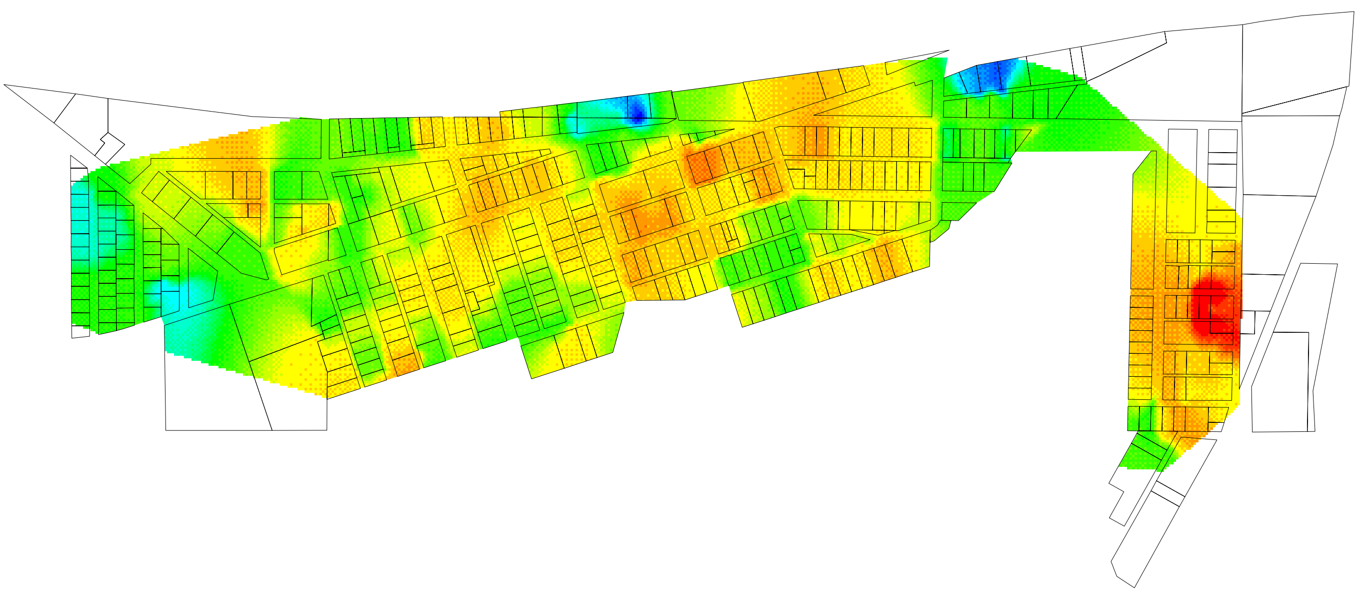
FILE	1998-10-10 LRRG/Smelterville/G20091-92	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.3b
1991 and 1992 Yard Lead Concentration Zones for Smelterville, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



1993



1994

0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

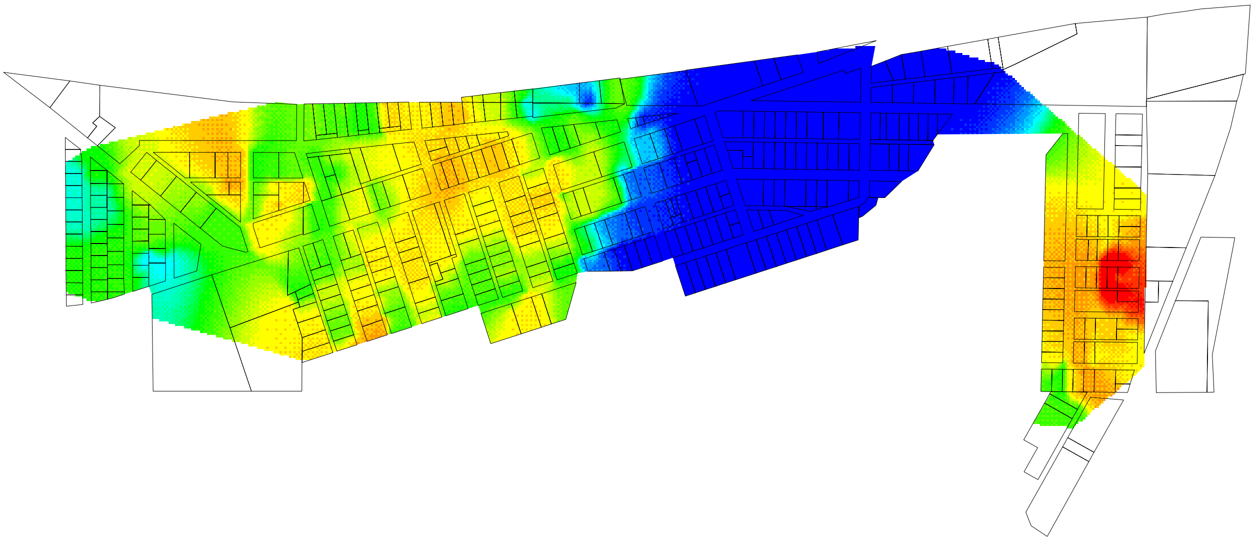
Terra Graphics
Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Smelterville/G20093-94	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

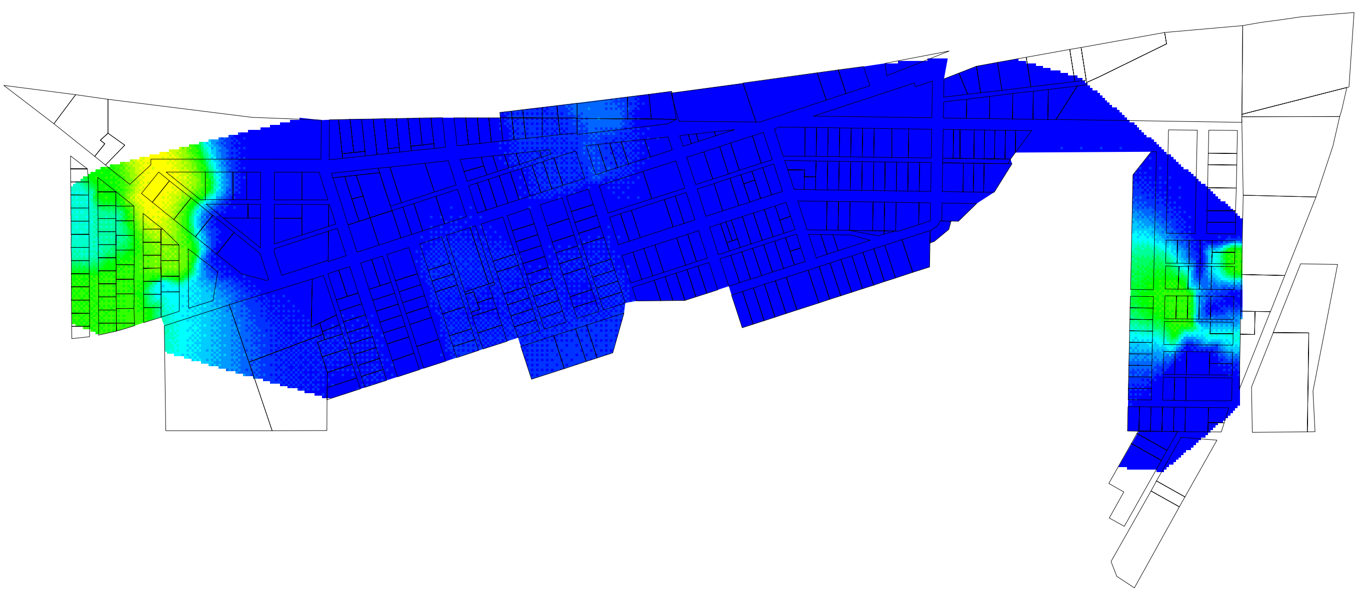
Figure 3.3c

1993 and 1994 Yard Lead Concentration Zones for Smelterville, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



1995



1996

0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

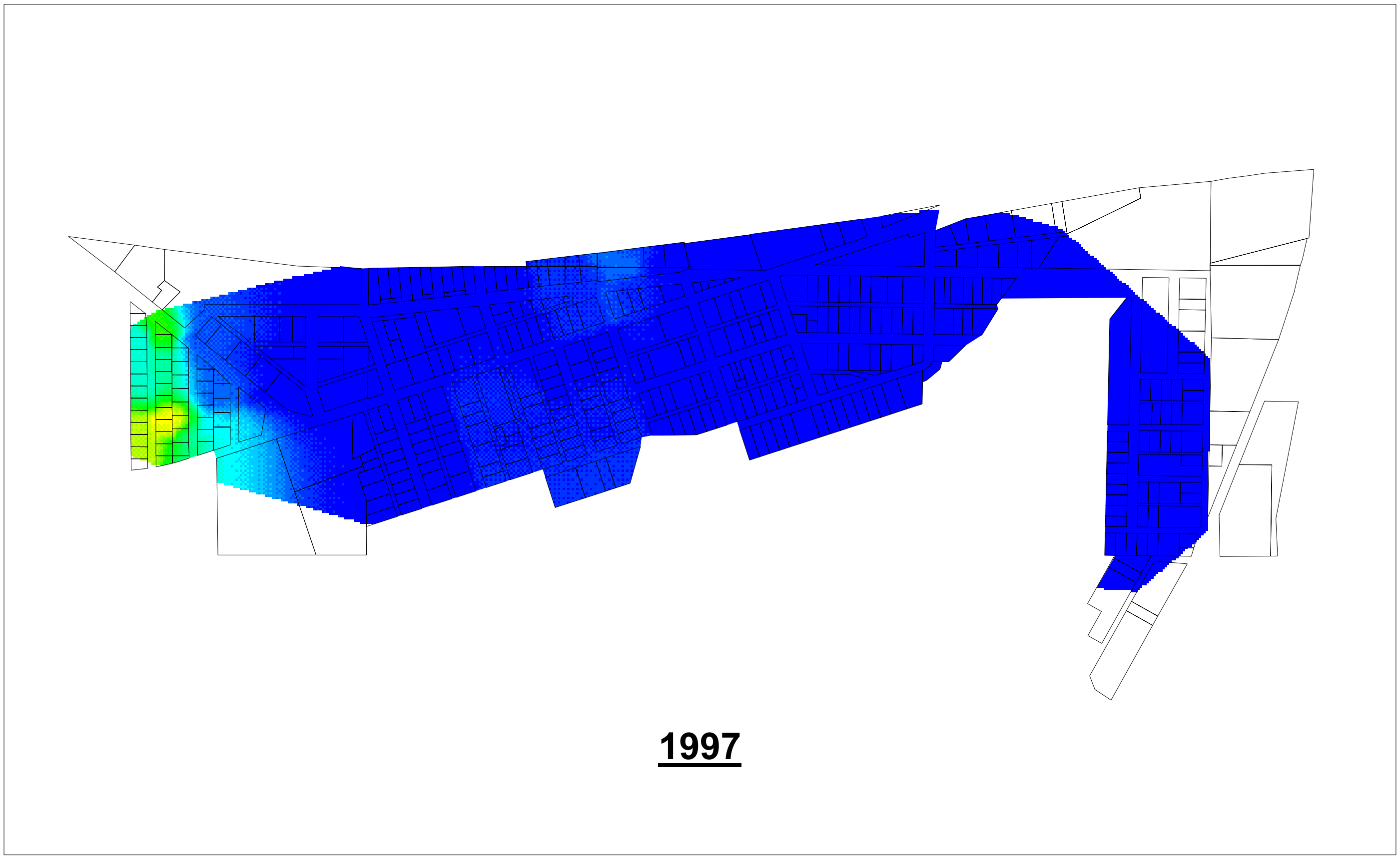
Terra Graphics
Environmental Engineering, Inc.

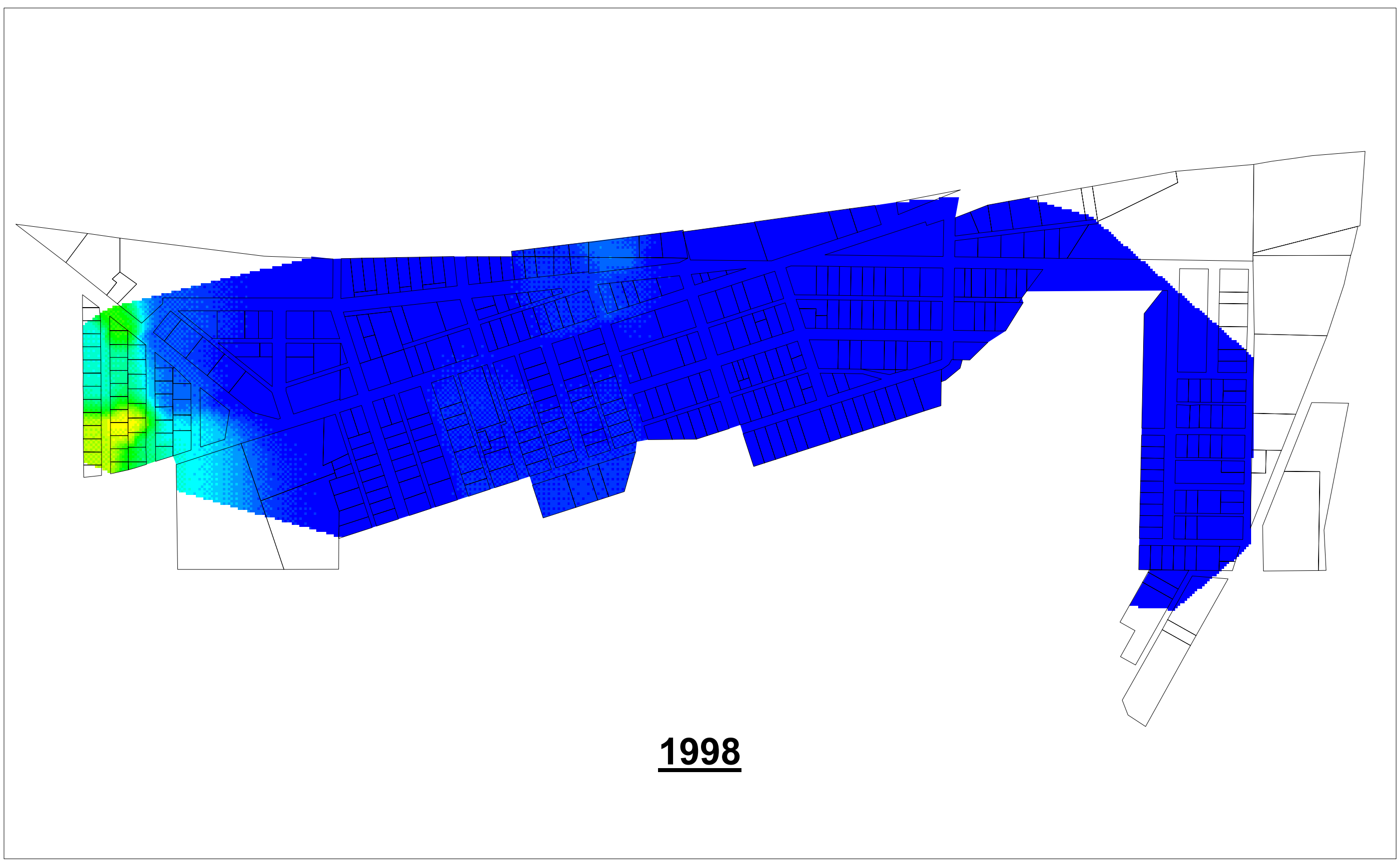
FILE	1998-10-10 LRRG/Smelterville/G20095-96	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.3d

1995 and 1996 Yard Lead Concentration Zones for Smelterville, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.





Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

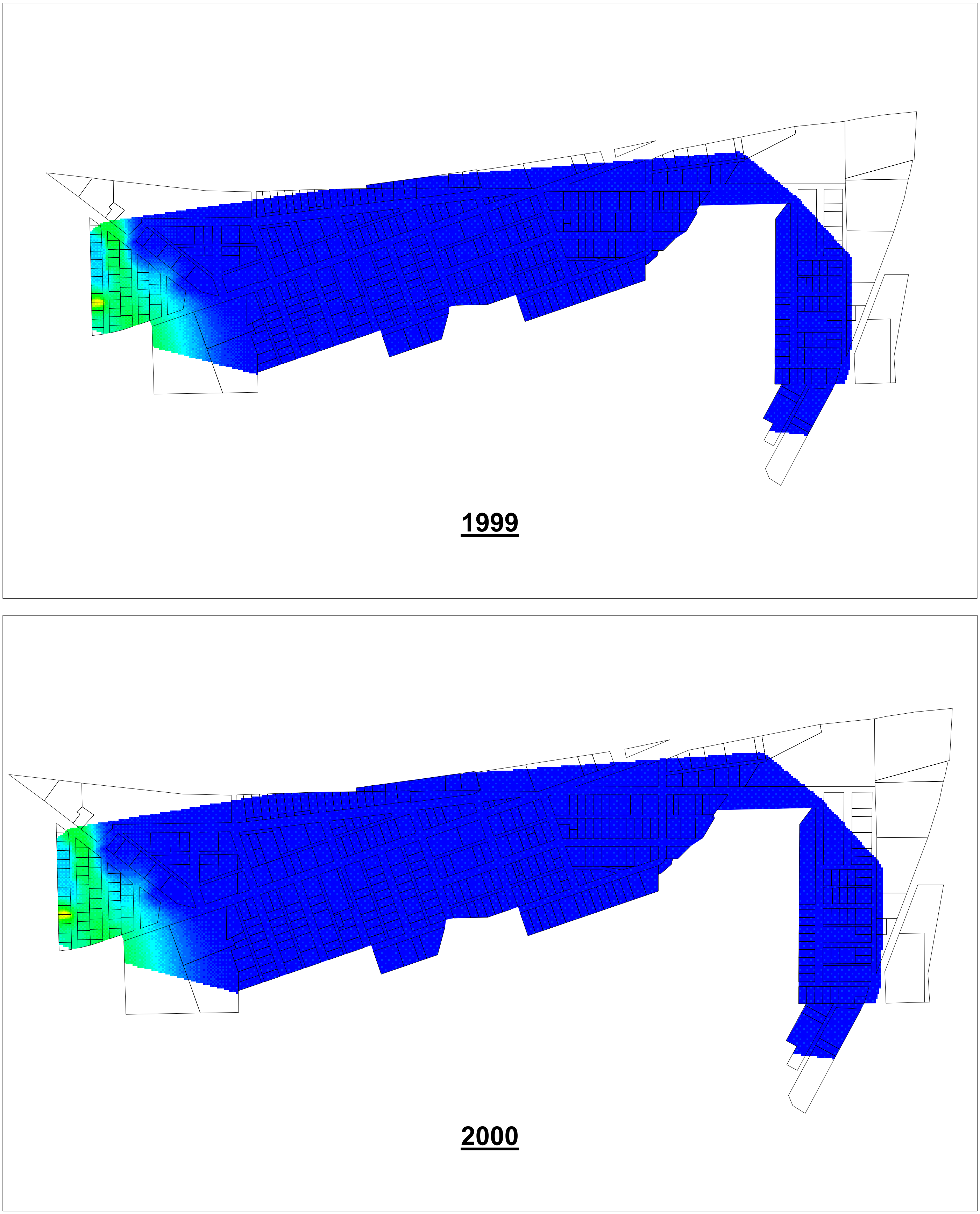
Terra Graphics
Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Smelterville/G20097-98	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.3e

1997 and 1998 Yard Lead Concentration Zones for Smelterville, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

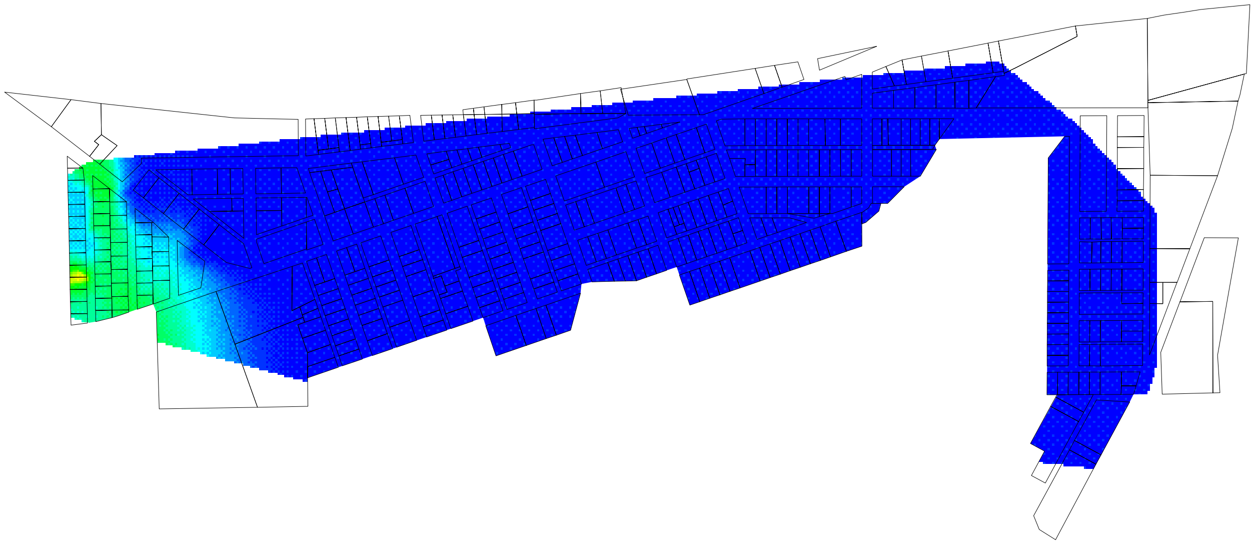
Terra Graphics
Environmental Engineering, Inc.

FILE	1998-10-10LRRG/Smelterville/G20099-2000	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

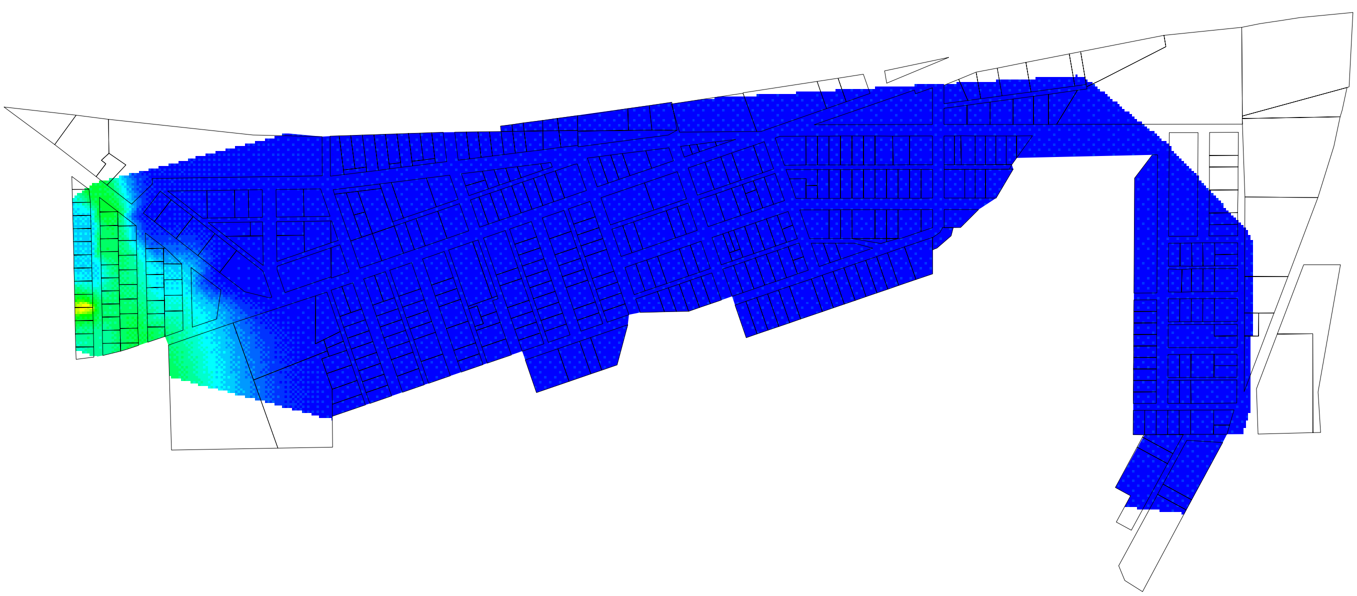
Figure 3.3f

1999 and 2000 Yard Lead Concentration Zones for Smelterville, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



2001



2002

0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

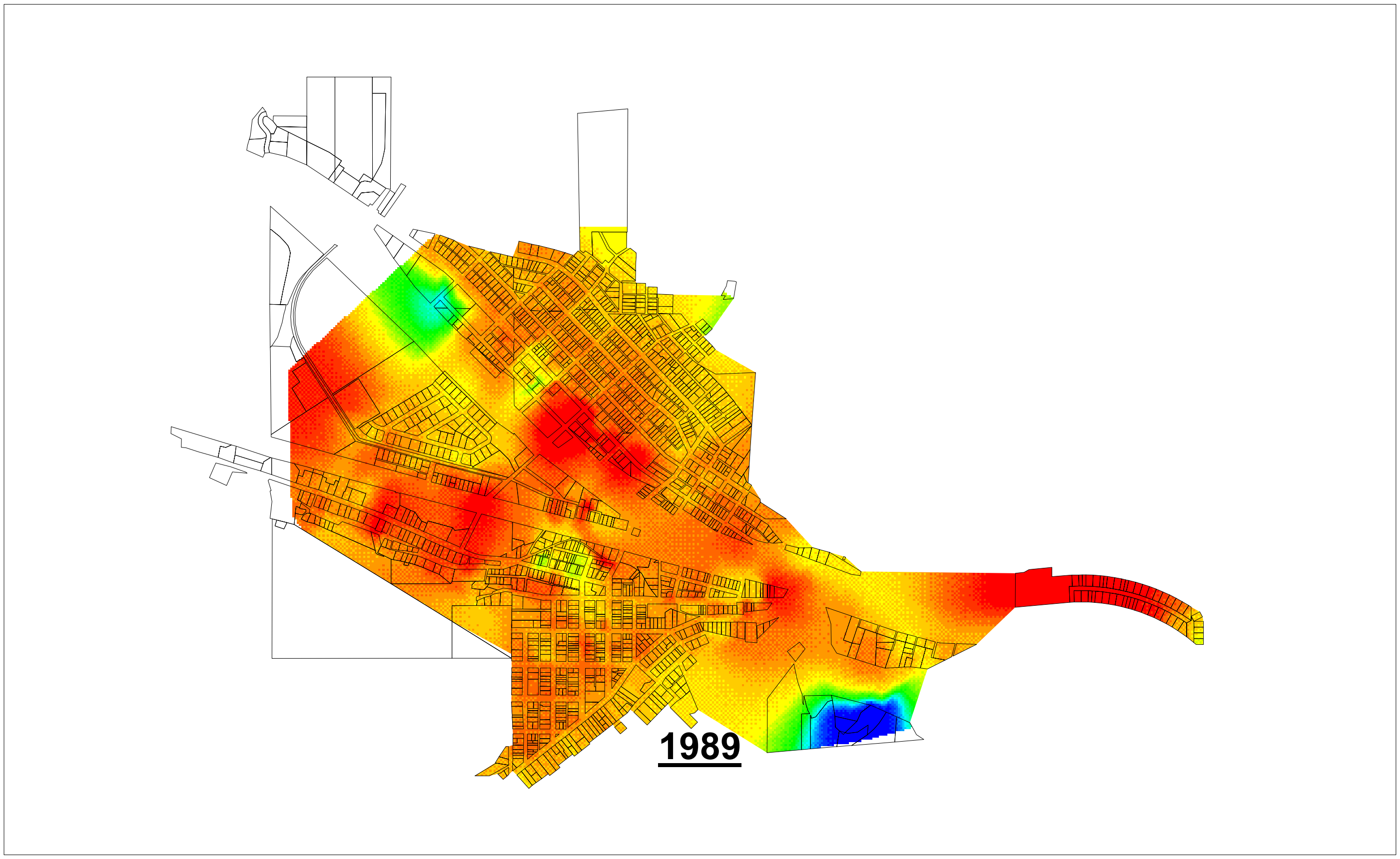
Terra Graphics
Environmental Engineering, Inc.

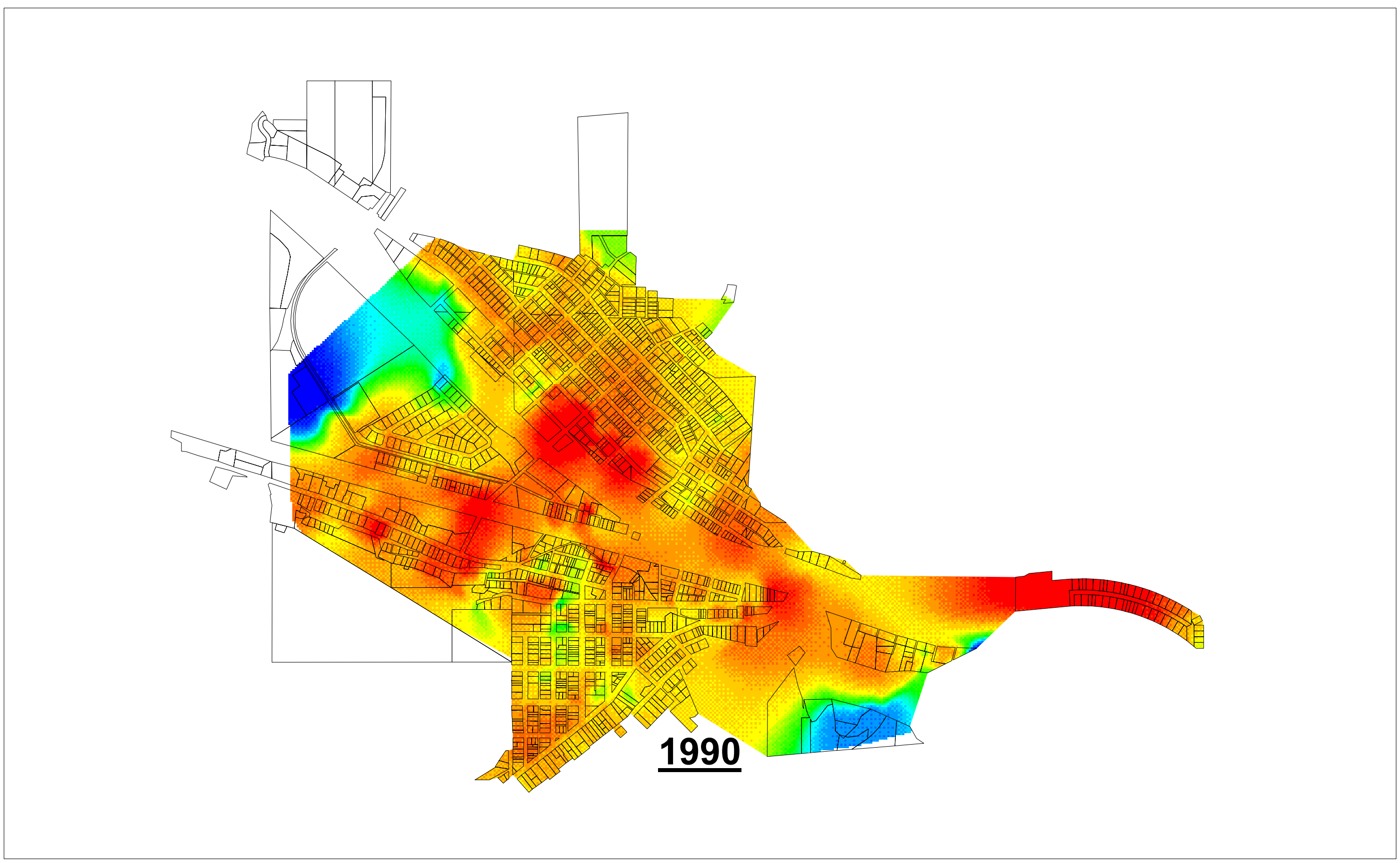
FILE	1998-10-10LRRG/Smelterville/G2002001-2002	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.3g

2001 and 2002 Yard Lead Concentration Zones for Smelterville, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.





Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

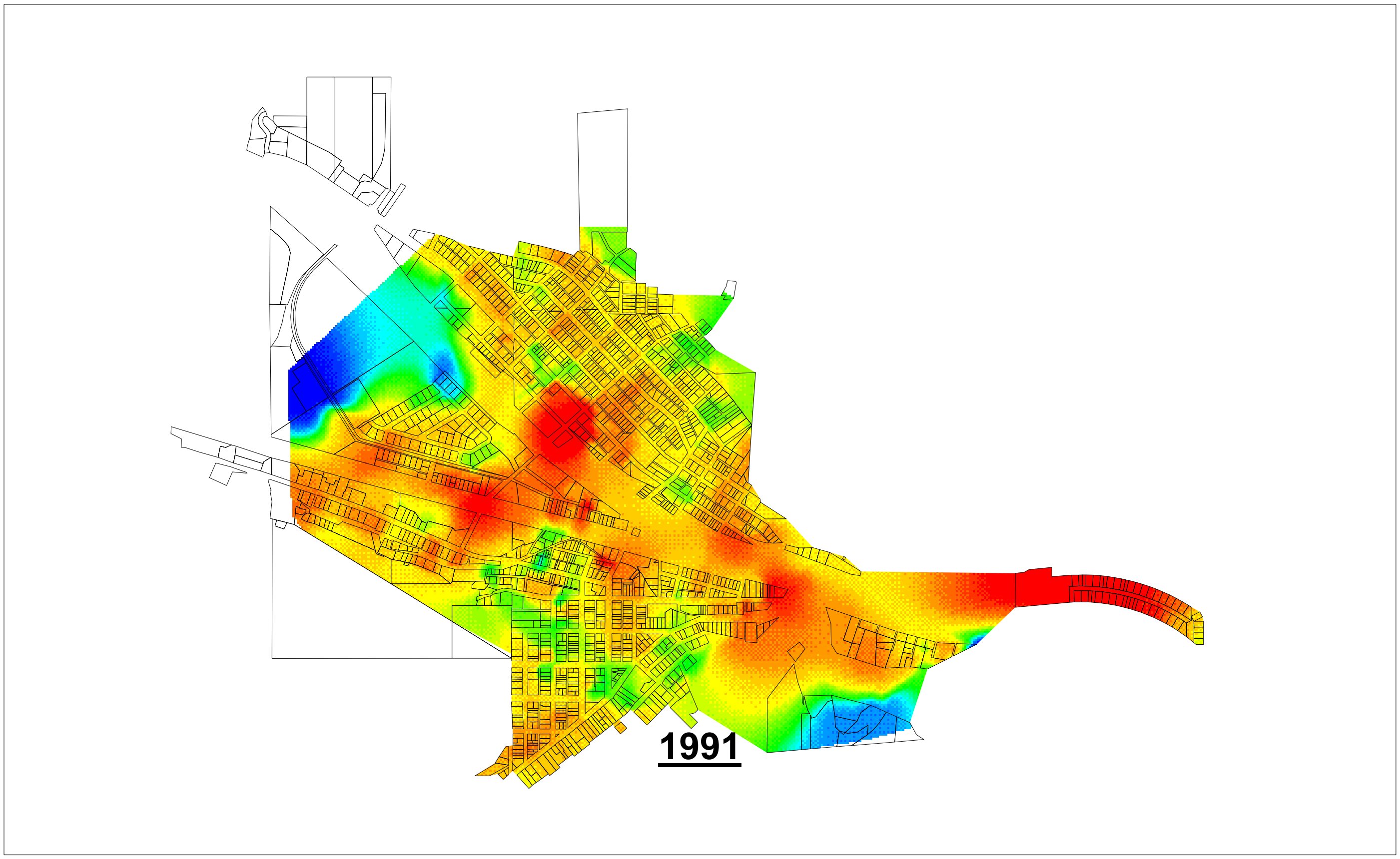
Figure 3.4a

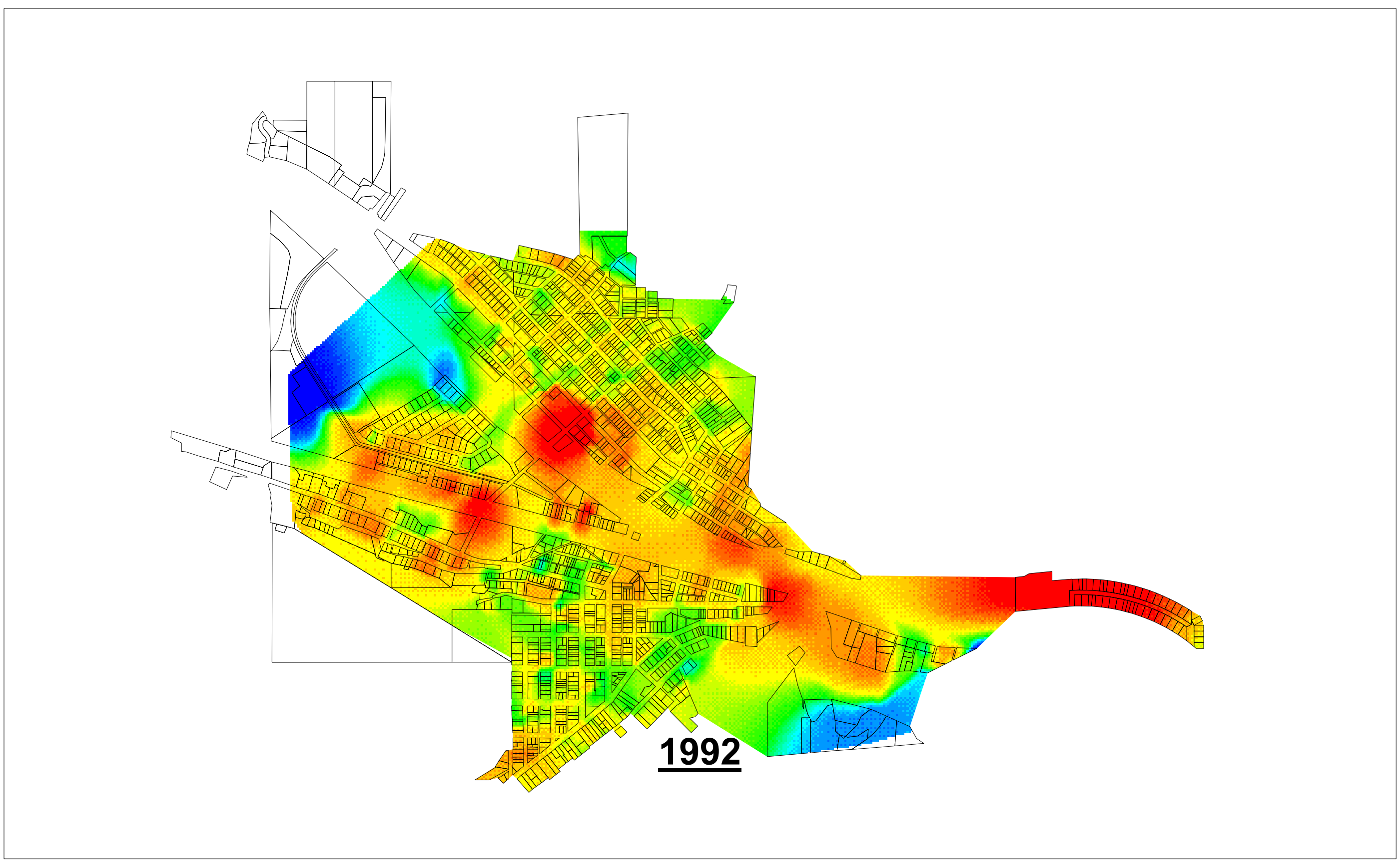
1989 and 1990 Yard Lead Concentration Zones for Kellogg, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.

Terra Graphics Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Kellogg/G20089-90	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	





Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

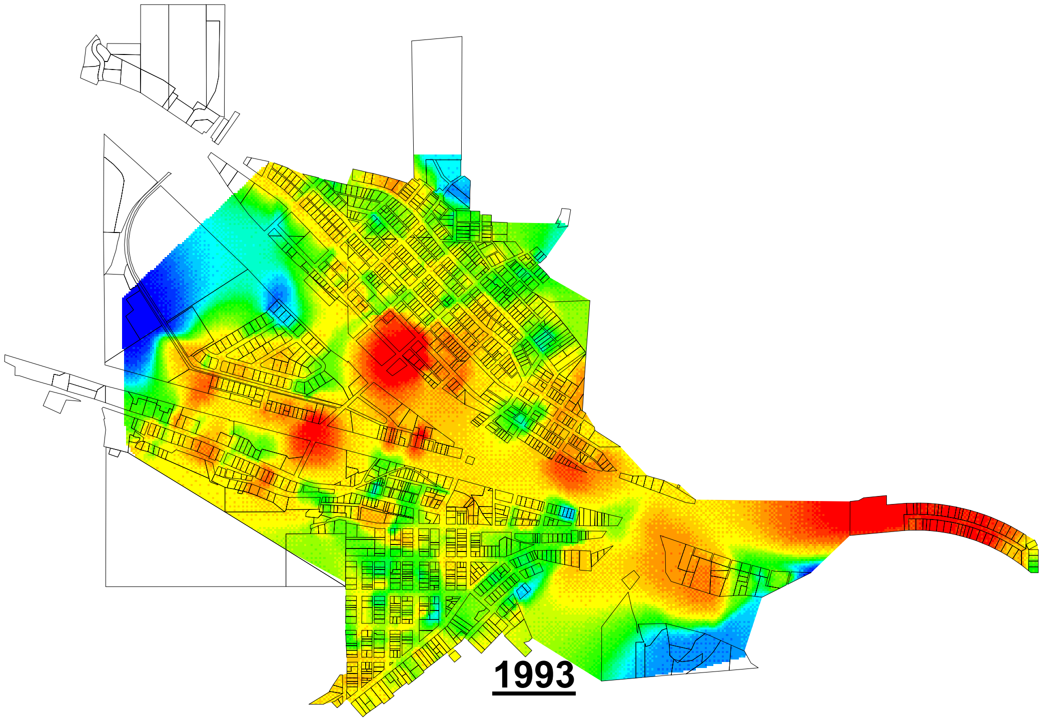
Figure 3.4b

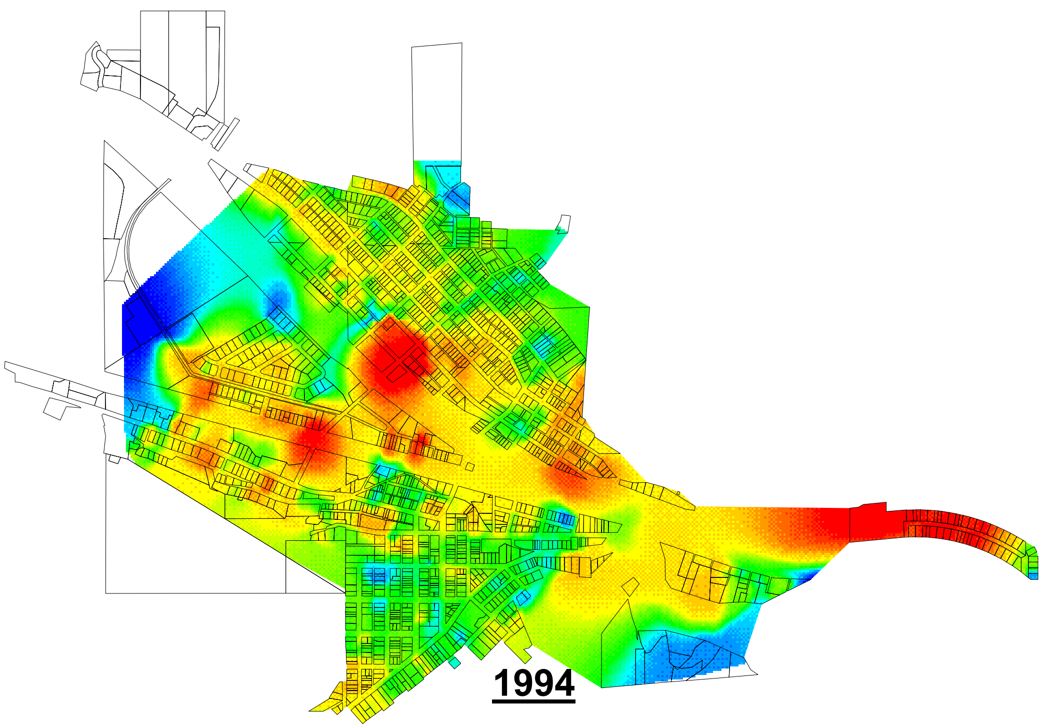
1991 and 1992 Yard Lead Concentration Zones for Kellogg, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.

Terra Graphics
Environmental Engineering, Inc.

File	1998-10-10 LRRG/Kellogg/G20091-92	Requestor	S. Spalinger
Date	August 2003	Designer	B. Bailey
Project No.		Cartographer	B. Bailey
		Approved	





0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

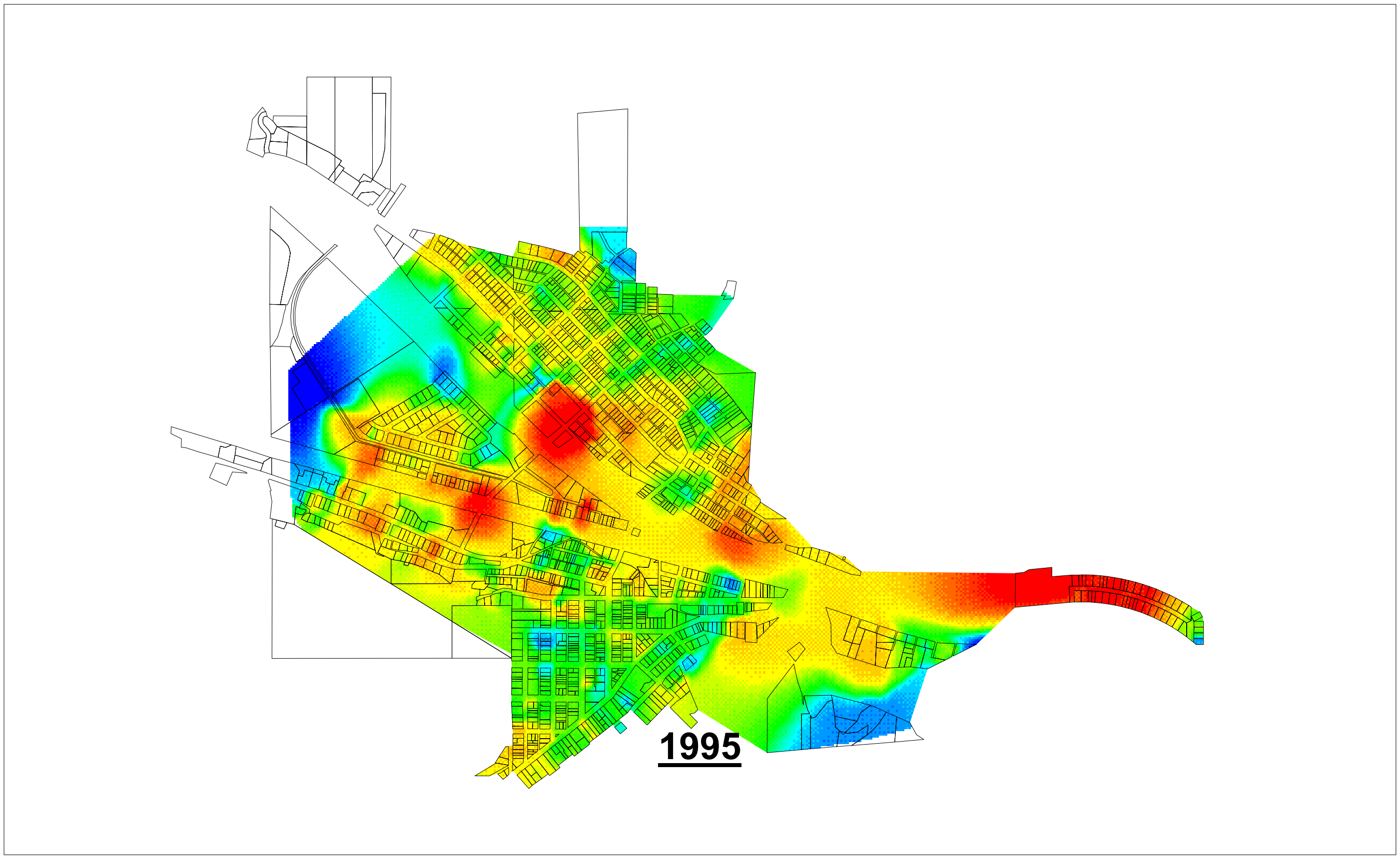
Terra Graphics
Environmental Engineering, Inc.

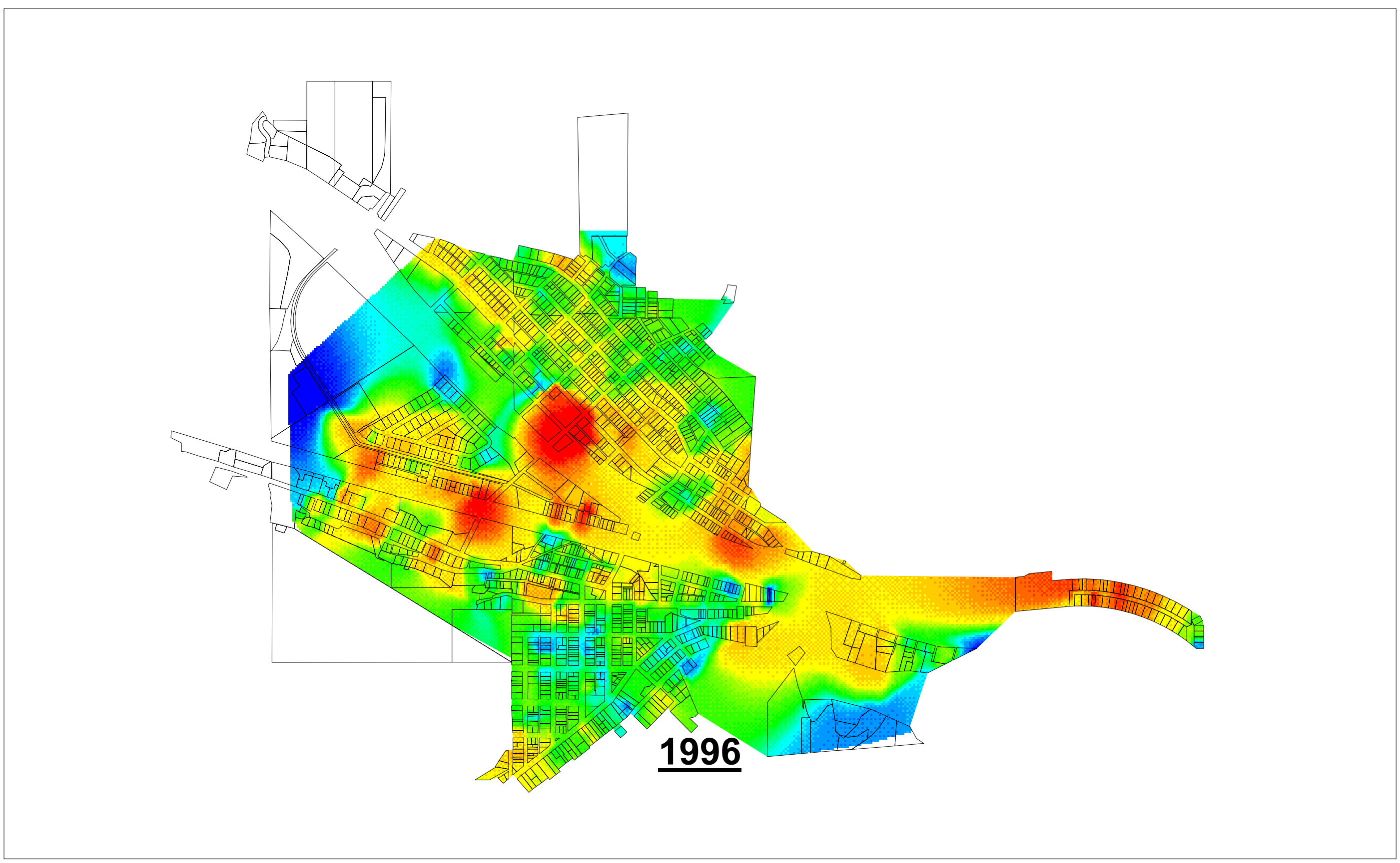
FILE	1998-10-10 LRRG/Kellogg/G20093-94	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.4c

1993 and 1994 Yard Lead Concentration Zones for Kellogg, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.





0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

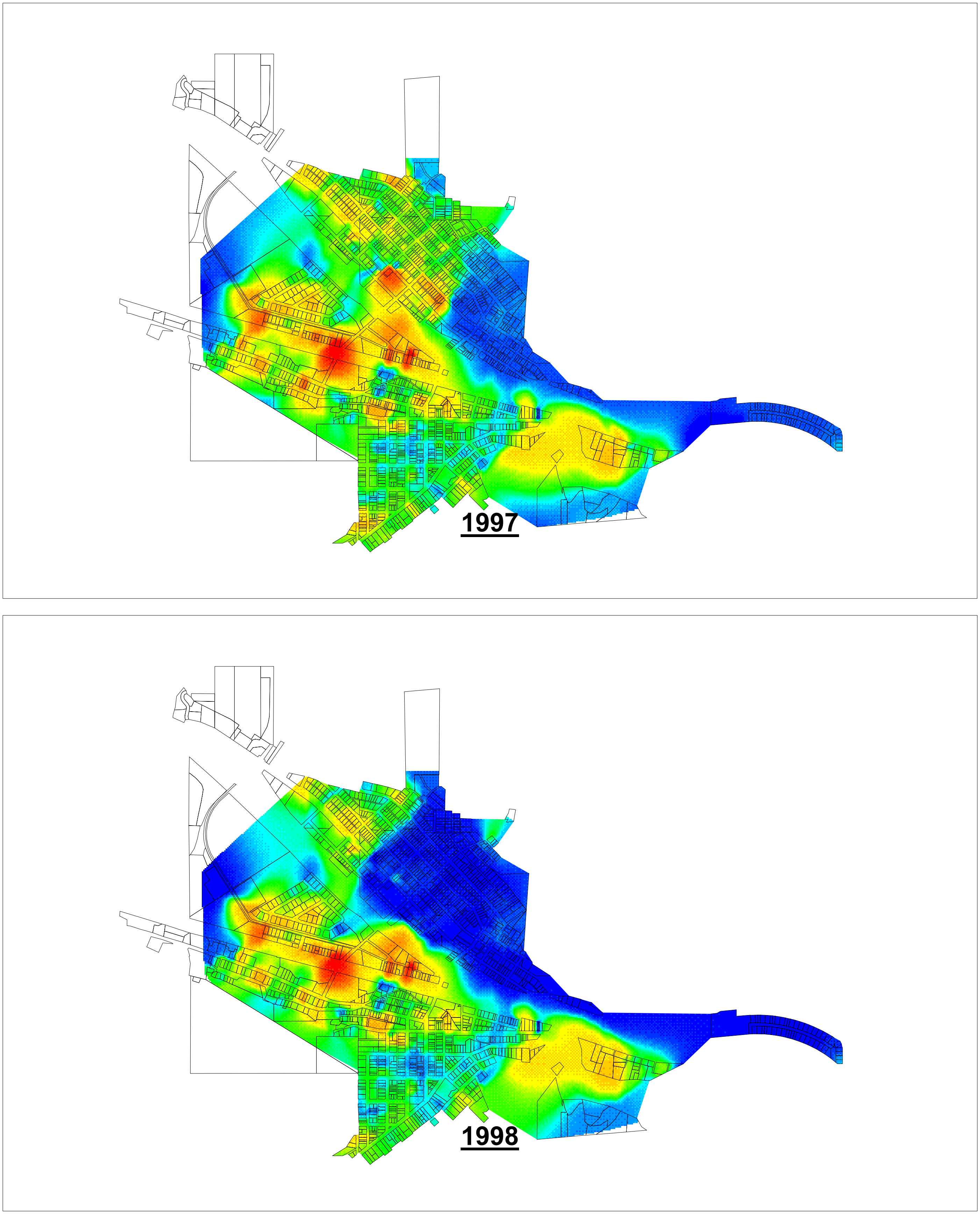
Figure 3.4d

1995 and 1996 Yard Lead Concentration Zones for Kellogg, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.

Terra Graphics
Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Kellogg/G20095-96	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	



0 - 349.9 mg/kg
350 - 499.9 mg/kg
500 - 999.9 mg/kg
1,000 - 2499.9 mg/kg
2500 - 4999.9 mg/kg
5,000 and greater mg/kg

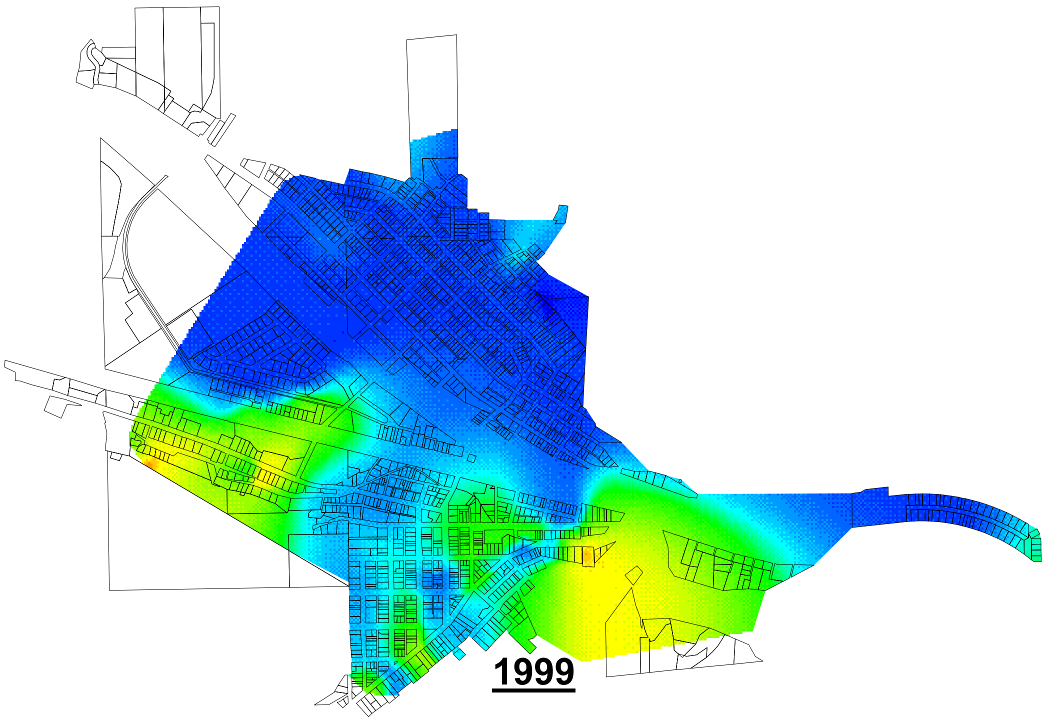
Terra Graphics
Environmental Engineering, Inc.

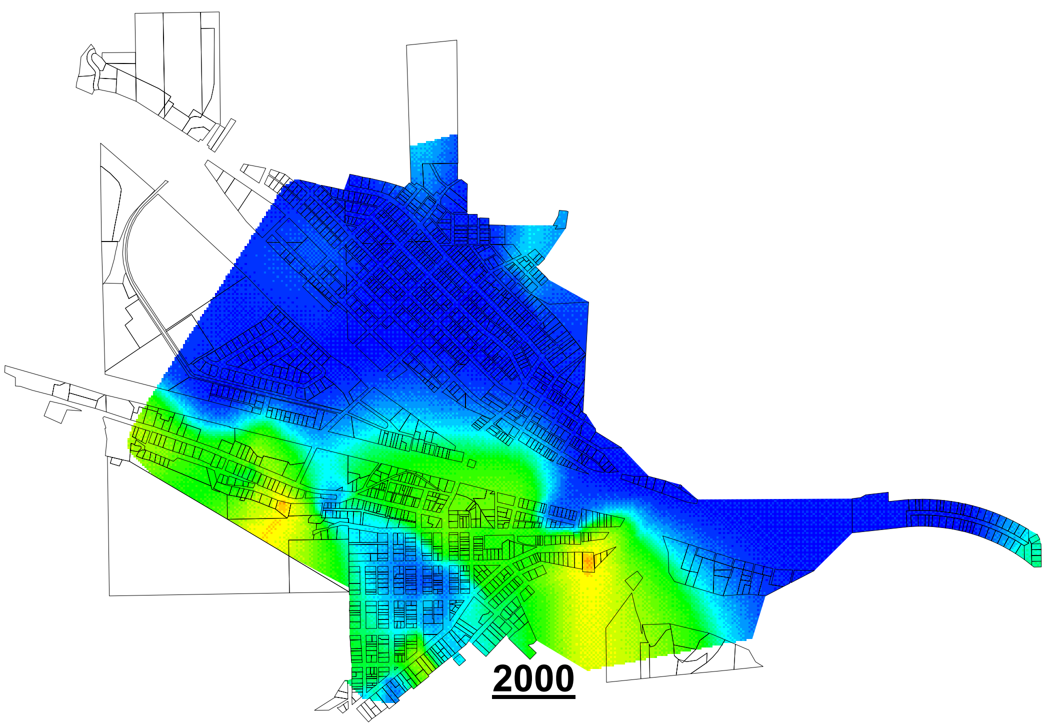
FILE	1998-10-10 LRRG/Kellogg/G20097-98	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.4e

1997 and 1998 Yard Lead Concentration Zones for Kellogg, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.





Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

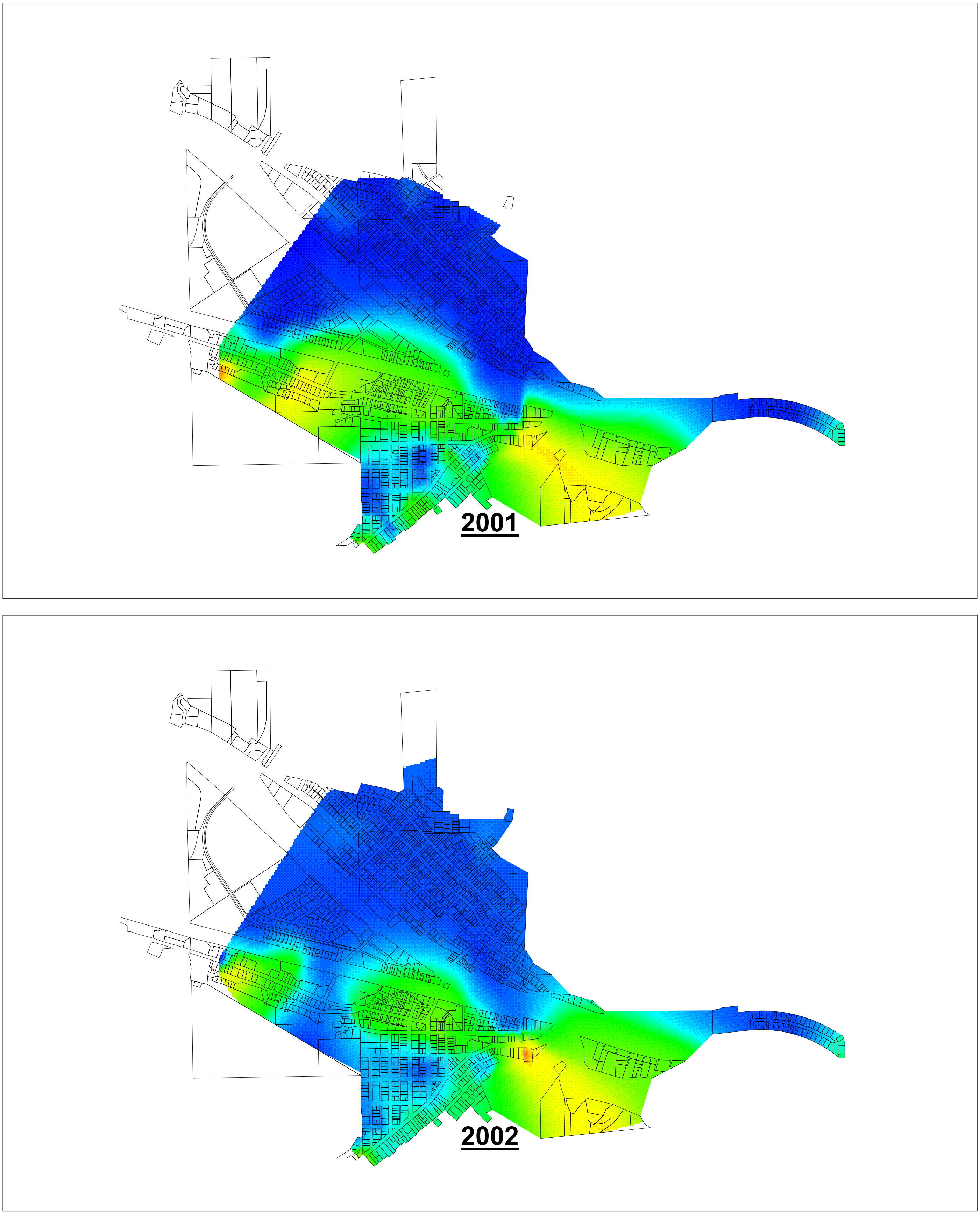
Terra Graphics
Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Kellogg/G20099-2000	REQUESTOR	S. Spalinger
DATE	August 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.4f

1999 and 2000 Yard Lead Concentration Zones for Kellogg, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

Terra Graphics
Environmental Engineering, Inc.

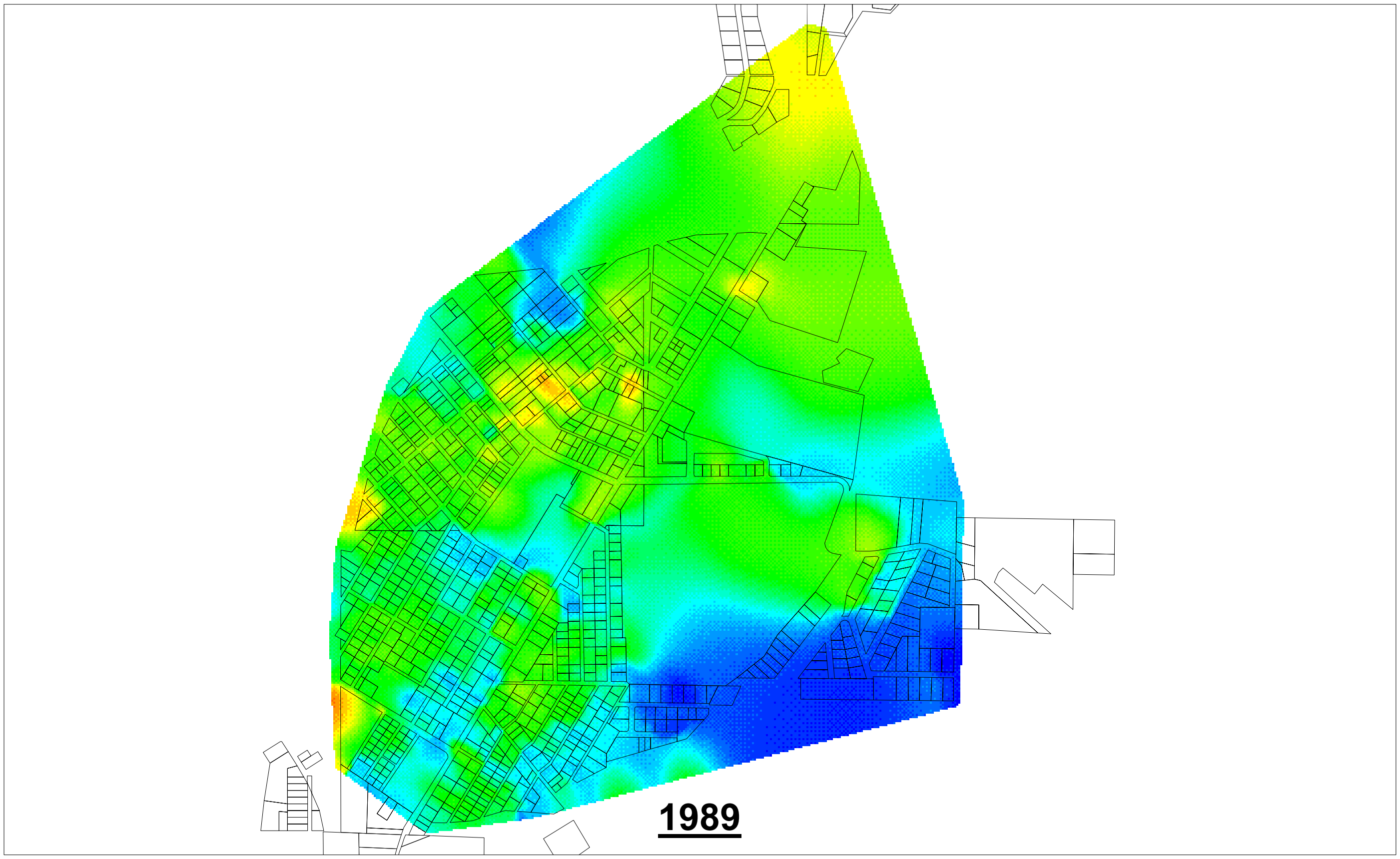
FILE 1998-10-10 LRRG/Kellogg/G2002001-2002
DATE August 2003
PROJECT NO.

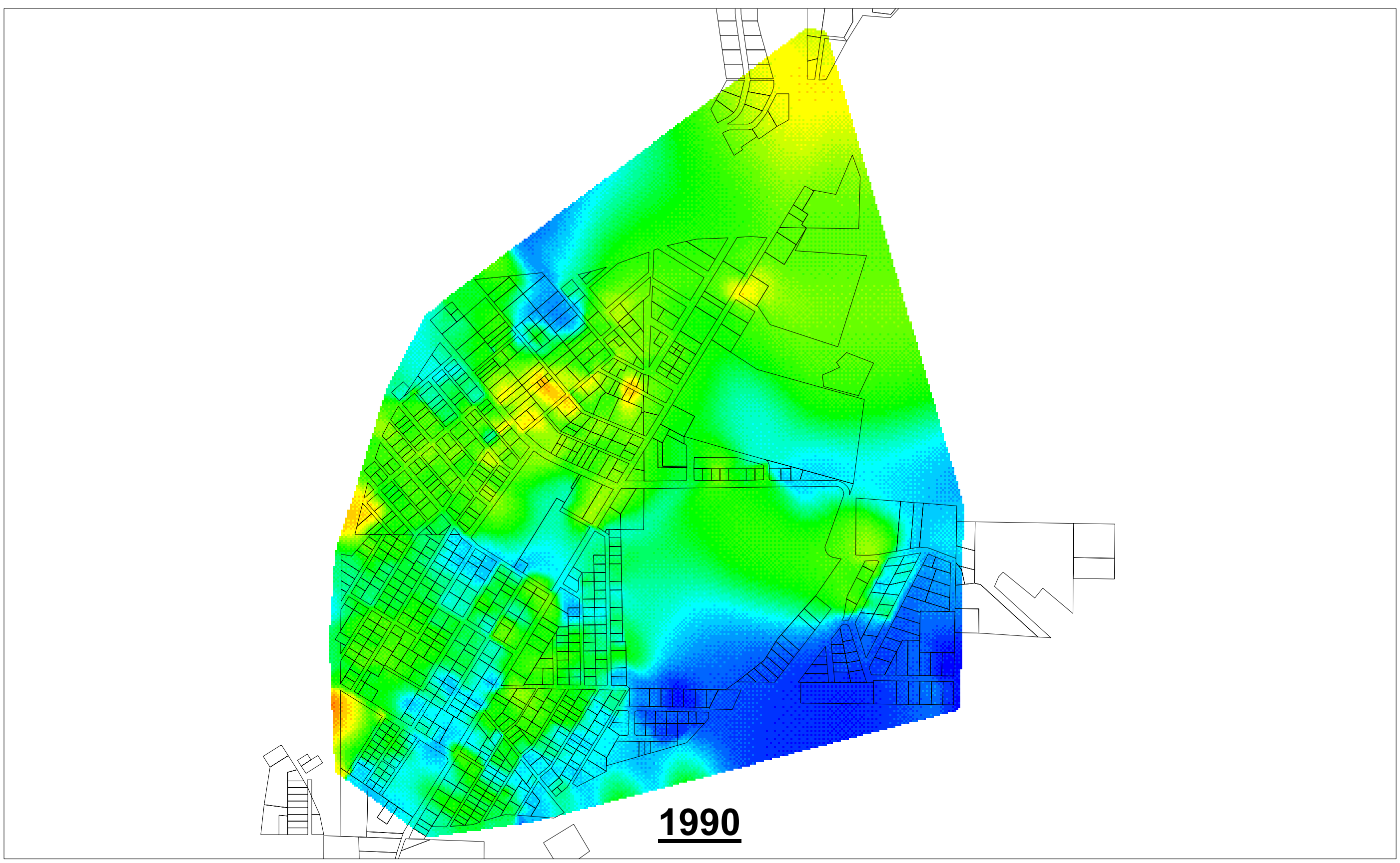
REQUESTOR S. Spalinger
DESIGNER B. Bailey
CARTOGRAPHER B. Bailey
APPROVED

Figure 3.4g

2001 and 2002 Yard Lead Concentration Zones for Kellogg, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.





0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

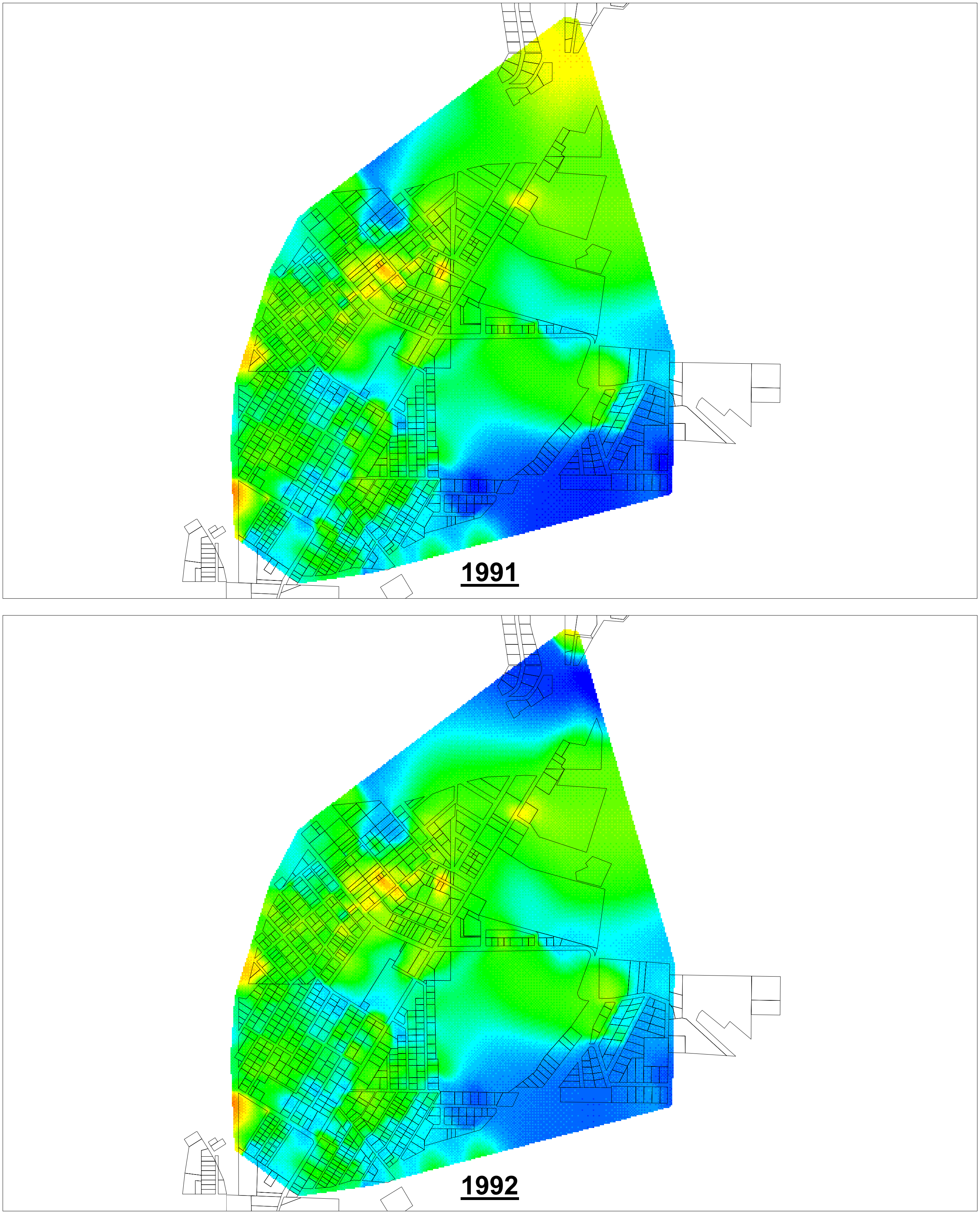
Figure 3.5a

1989 and 1990 Yard Lead Concentration Zones for Pinehurst, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.

Terra Graphics
Environmental Engineering, Inc.

FILE	2004 HHRE/Pinehurst/G20089-90	REQUESTOR	S. Spalinger
DATE	March 2004	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	



Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

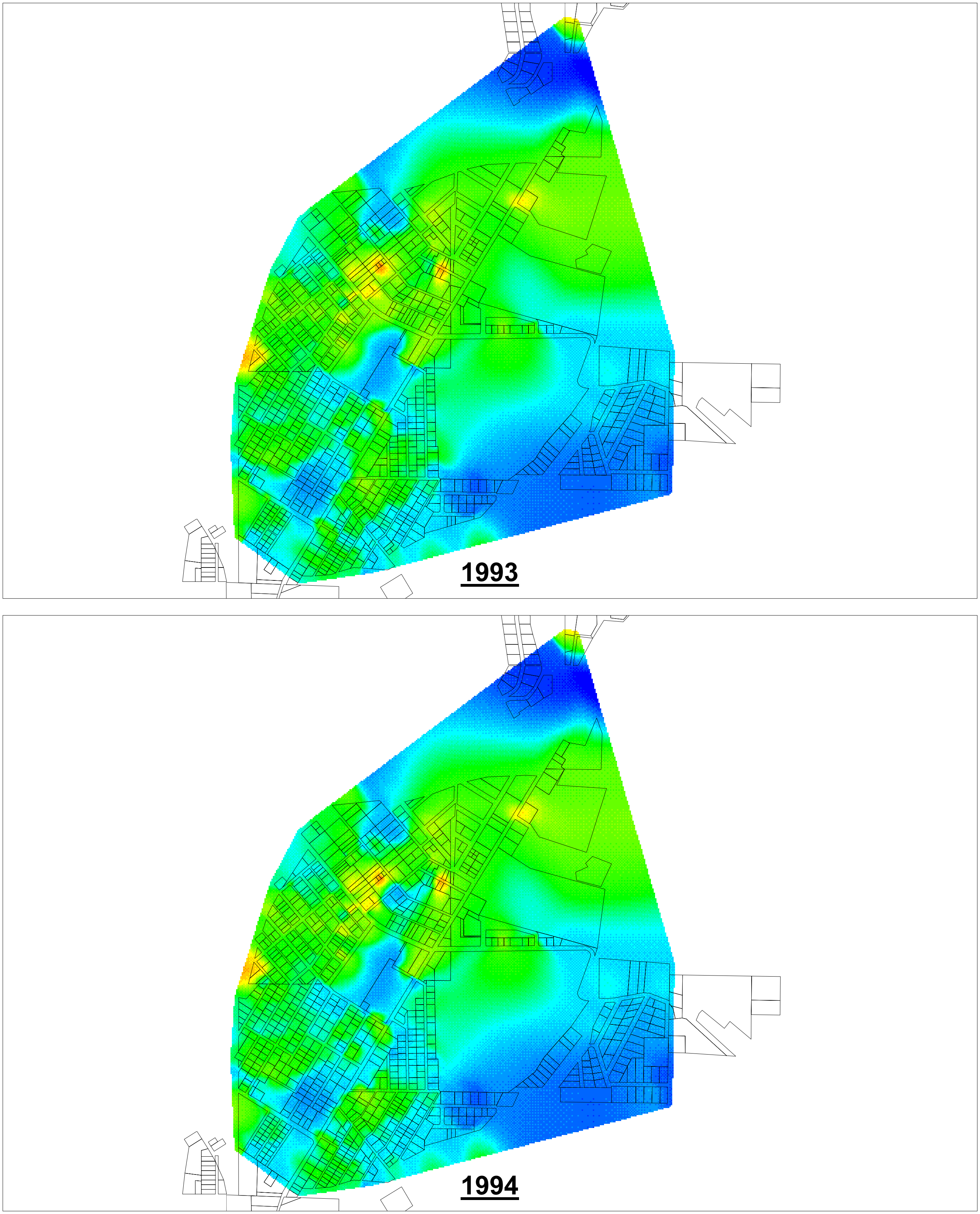
Figure 3.5b

1991 and 1992 Yard Lead Concentration Zones for Pinehurst, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.

Terra Graphics
Environmental Engineering, Inc.

FILE	2004 HHRE/Pinehurst/G20091-92	REQUESTOR	S. Spalinger
DATE	March 2004	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	



Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

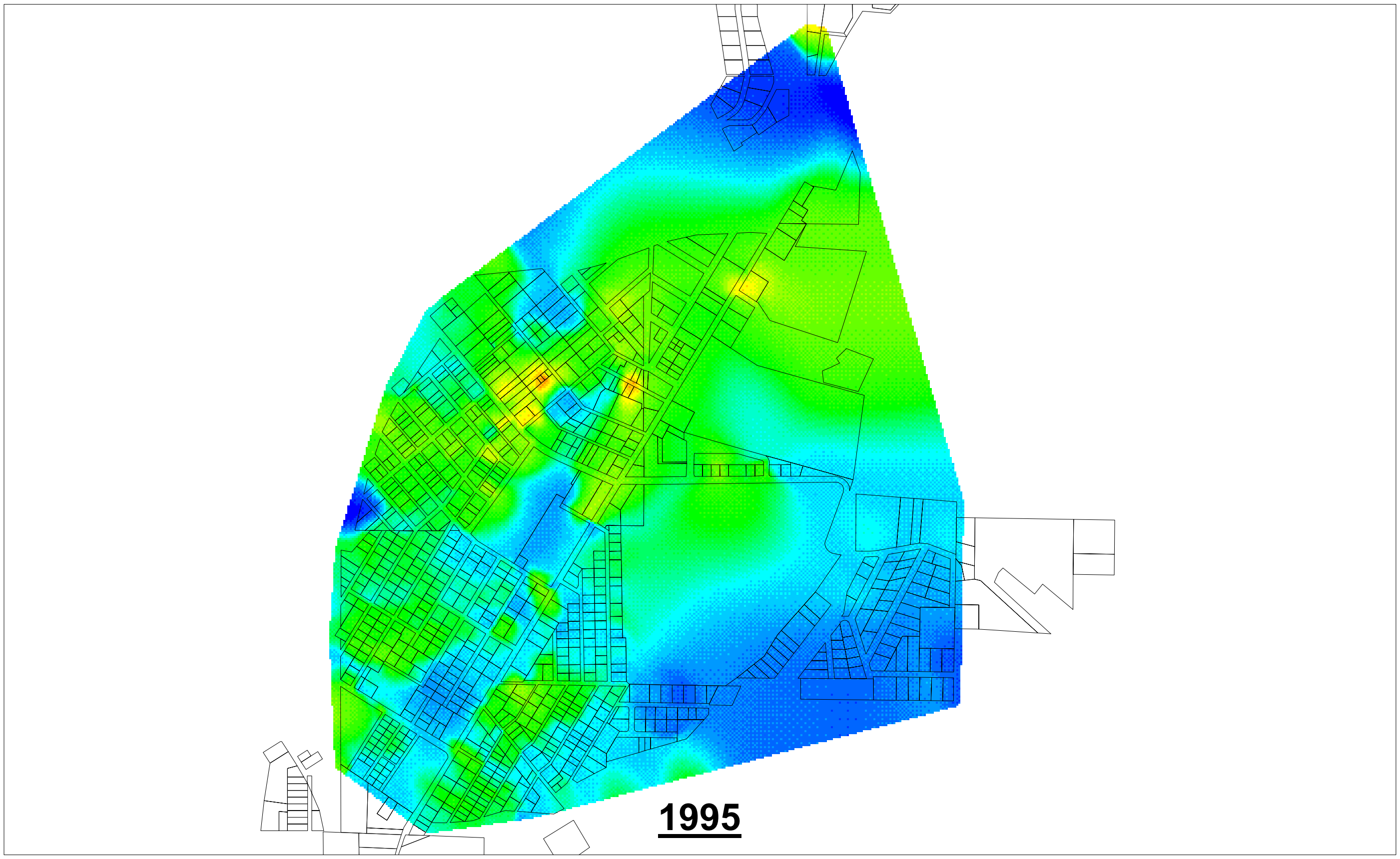
Terra Graphics
Environmental Engineering, Inc.

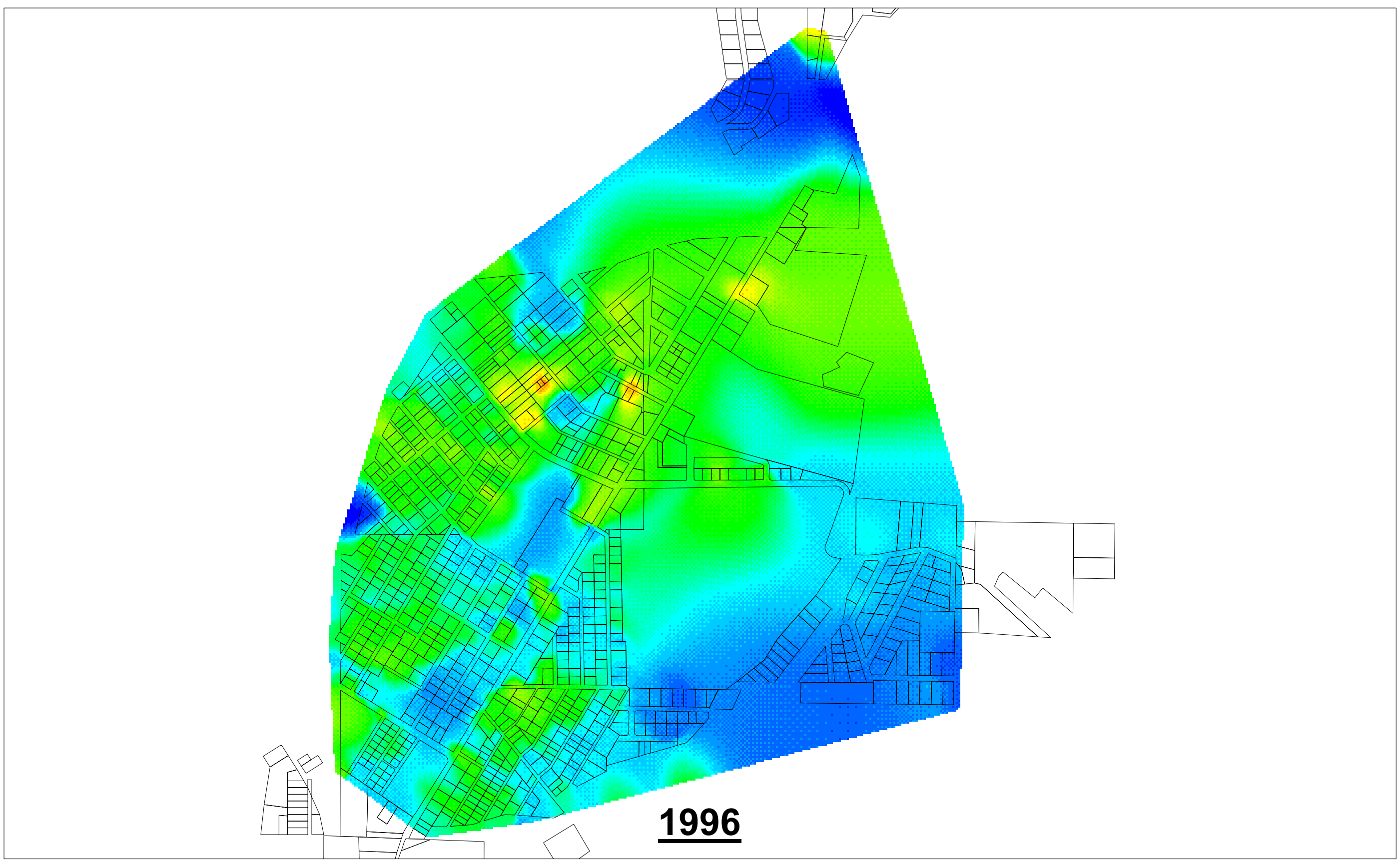
FILE	2004 HHRE/Pinehurst/G20093-94	REQUESTOR	S. Spalinger
DATE	March 2004	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.5c

1993 and 1994 Yard Lead Concentration Zones for Pinehurst, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.





Blue	0 - 349.9 mg/kg	
Cyan	350 - 499.9 mg/kg	
Green	500 - 999.9 mg/kg	
Yellow	1,000 - 2499.9 mg/kg	
Orange	2500 - 4999.9 mg/kg	
Red	5,000 and greater mg/kg	

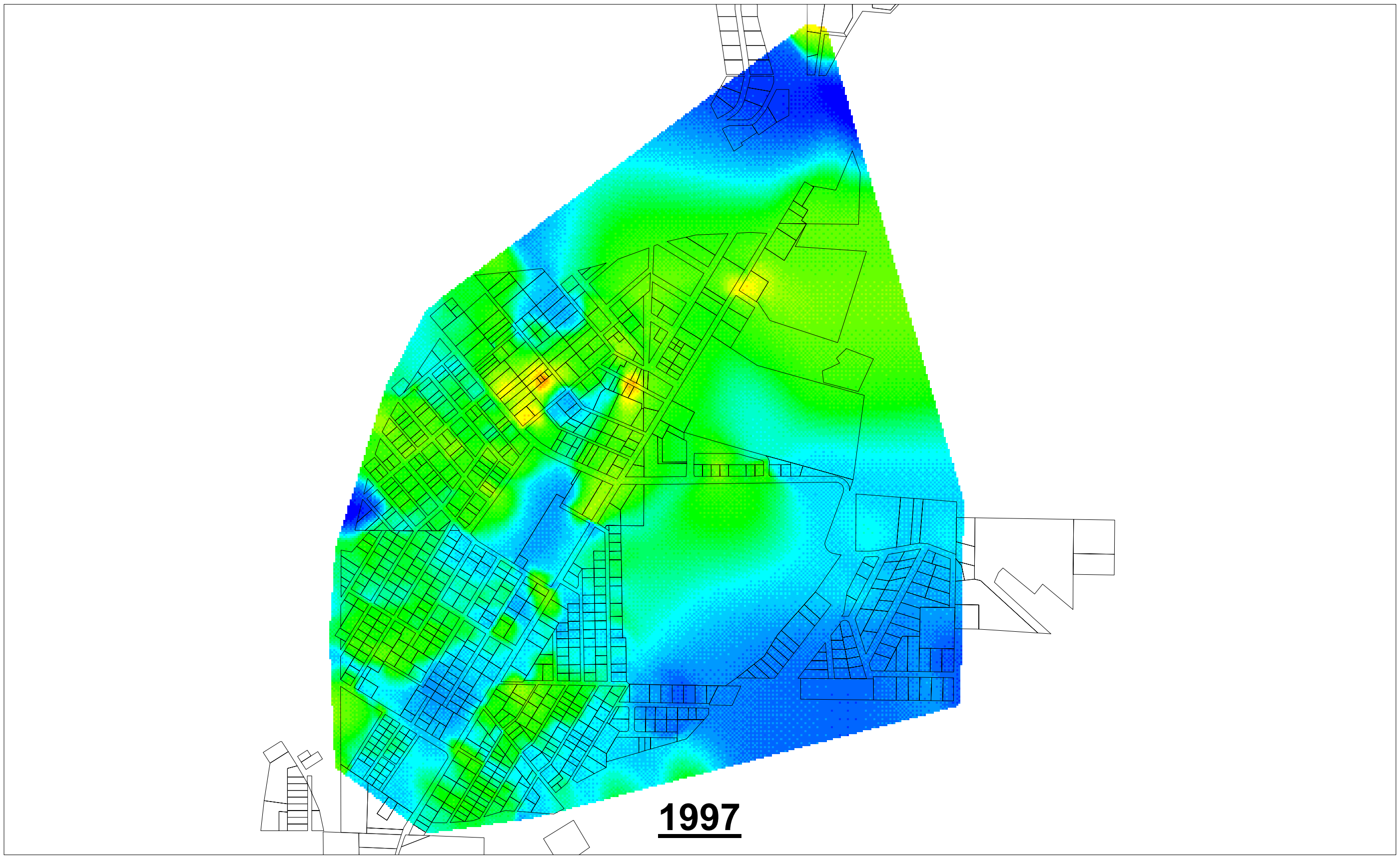
Figure 3.5d

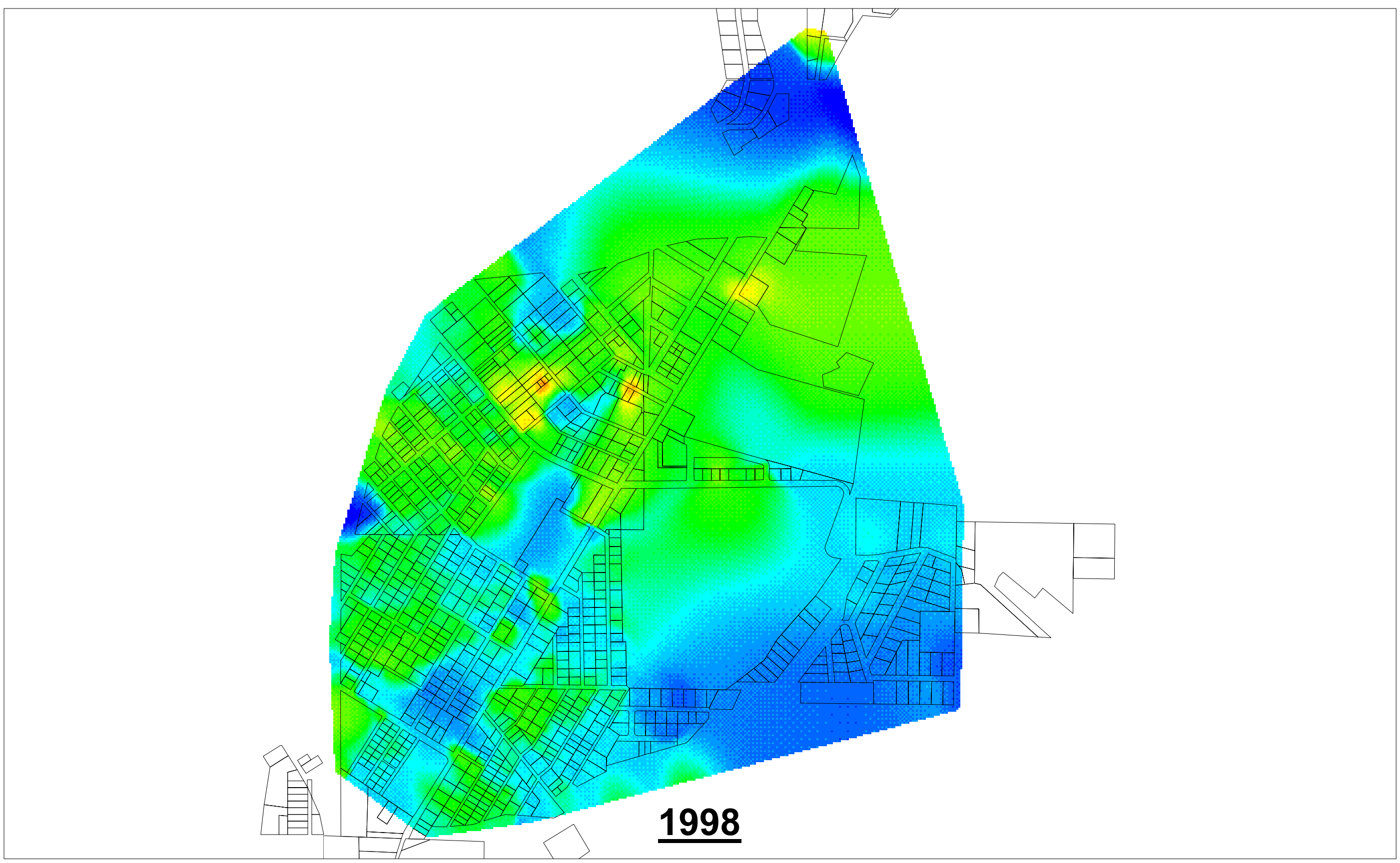
1995 and 1996 Yard Lead Concentration Zones for Pinehurst, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.

TerraGraphics
Environmental Engineering, Inc.

FILE	2004 HHRE/Pinehurst/G20095-96	REQUESTOR	S. Spalinger
DATE	March 2004	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	





0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

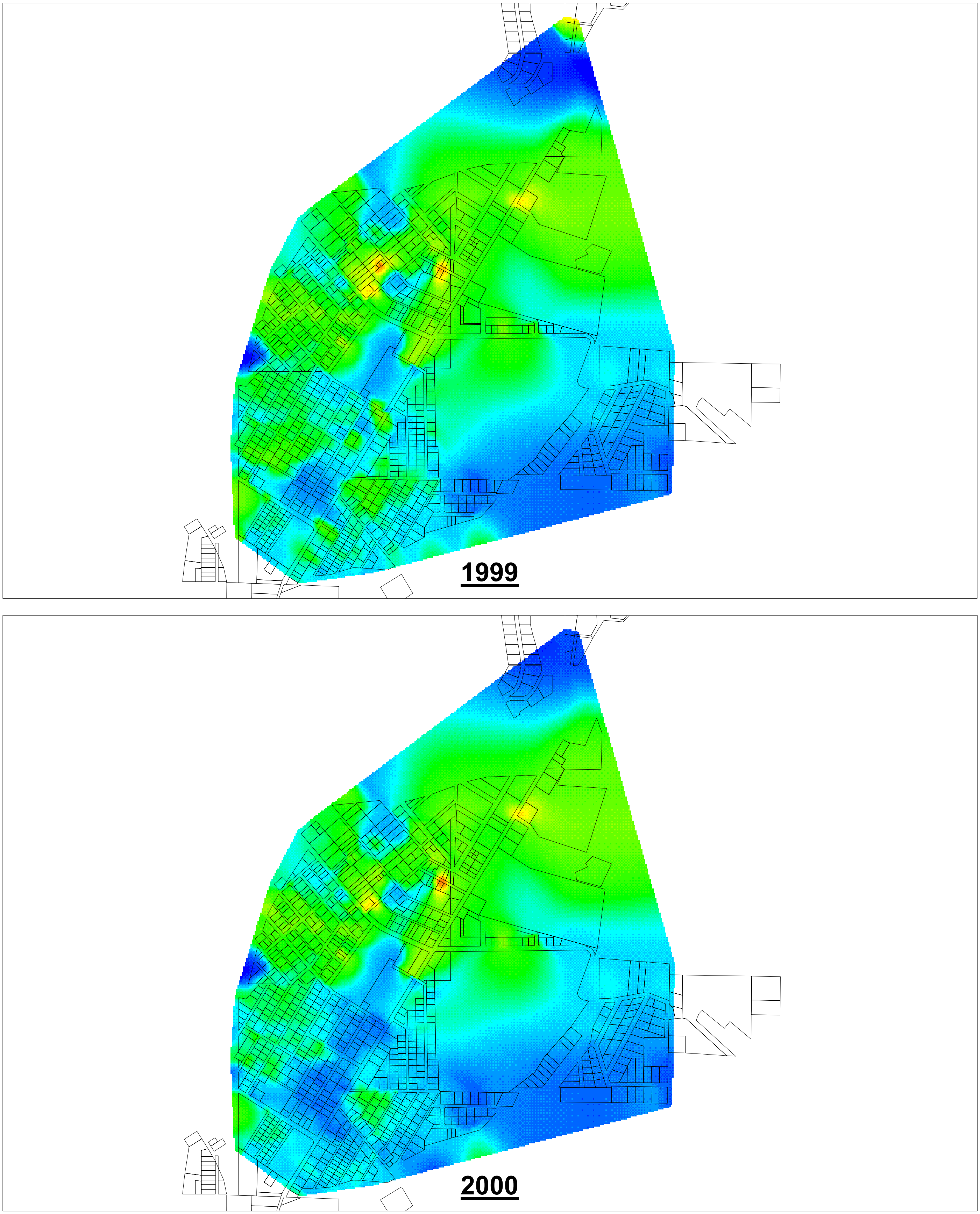
Terra Graphics
Environmental Engineering, Inc.

FILE	2004 HHRE/Pinehurst/G20097-98	REQUESTOR	S. Spalinger
DATE	March 2004	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.5e

1997 and 1998 Yard Lead Concentration Zones for Pinehurst, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

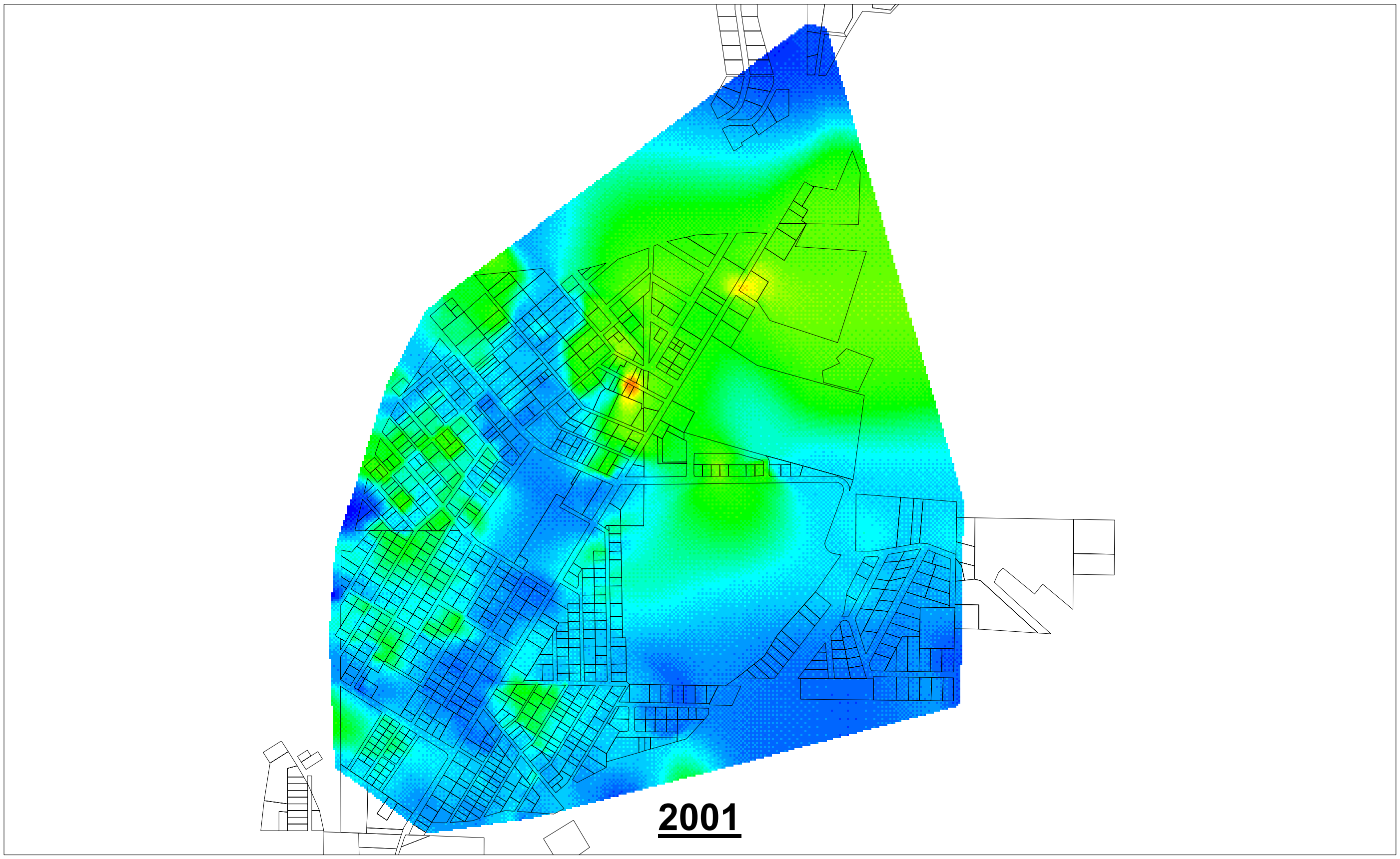
Terra Graphics
Environmental Engineering, Inc.

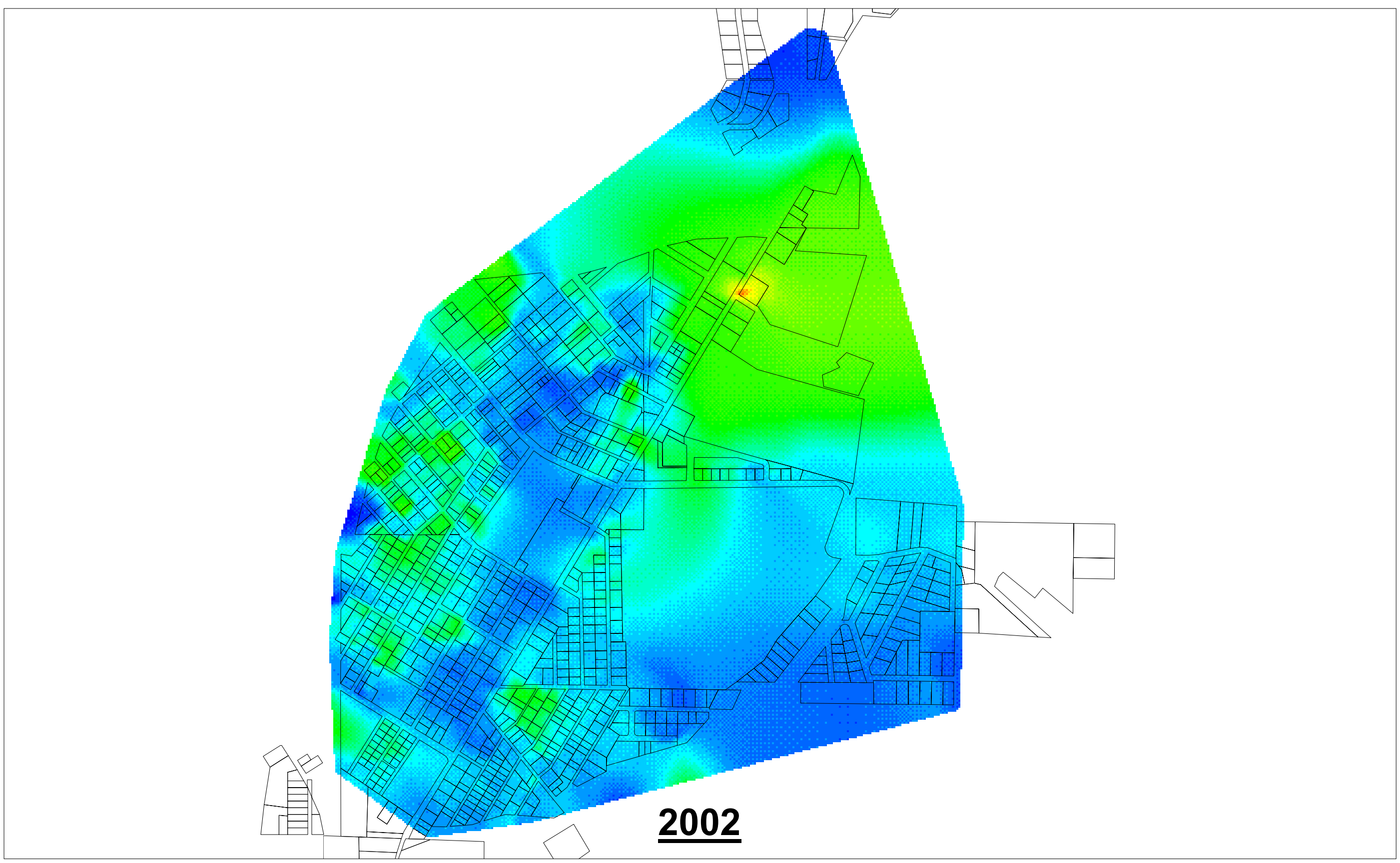
File	2004 HHRE/Pinehurst/G20099-00	Requestor	S. Spalinger
Date	March 2004	Designer	B. Bailey
Project No.		Cartographer	B. Bailey
		Approved	

Figure 3.5f

1999 and 2000 Yard Lead Concentration Zones for Pinehurst, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.





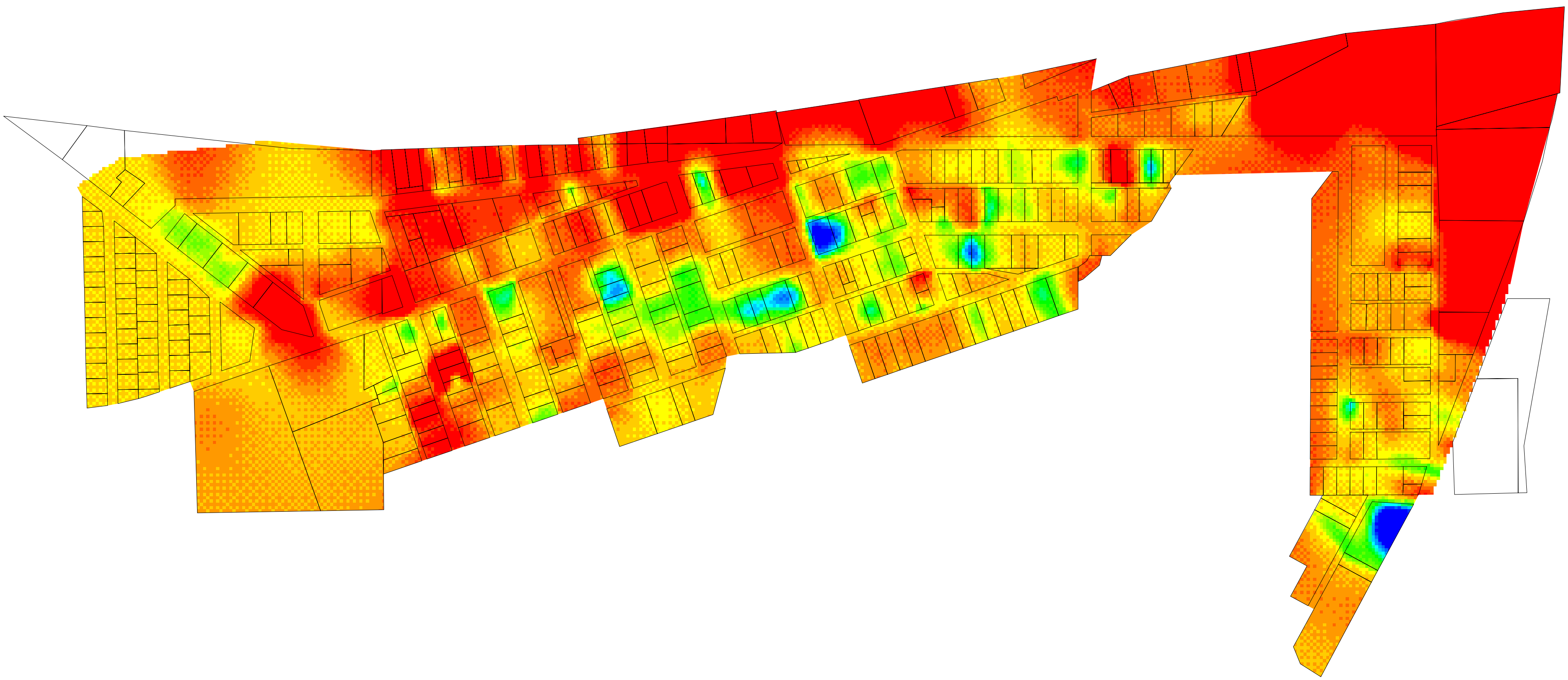
Blue	0 - 349.9 mg/kg	Yellow	1,000 - 2499.9 mg/kg
Cyan	350 - 499.9 mg/kg	Orange	2500 - 4999.9 mg/kg
Green	500 - 999.9 mg/kg	Red	5,000 and greater mg/kg

Terra Graphics
Environmental Engineering, Inc.

File	2004 HHRE/Pinehurst/G20001-02	Requestor	S. Spalinger
Date	March 2004	Designer	B. Bailey
Project No.		Cartographer	B. Bailey
		Approved	

Figure 3.5g
2001 and 2002 Yard Lead Concentration Zones for Pinehurst, Idaho

Data based on geometric means of soil lead concentrations.
Soil samples taken within a 200 foot vicinity of properties.



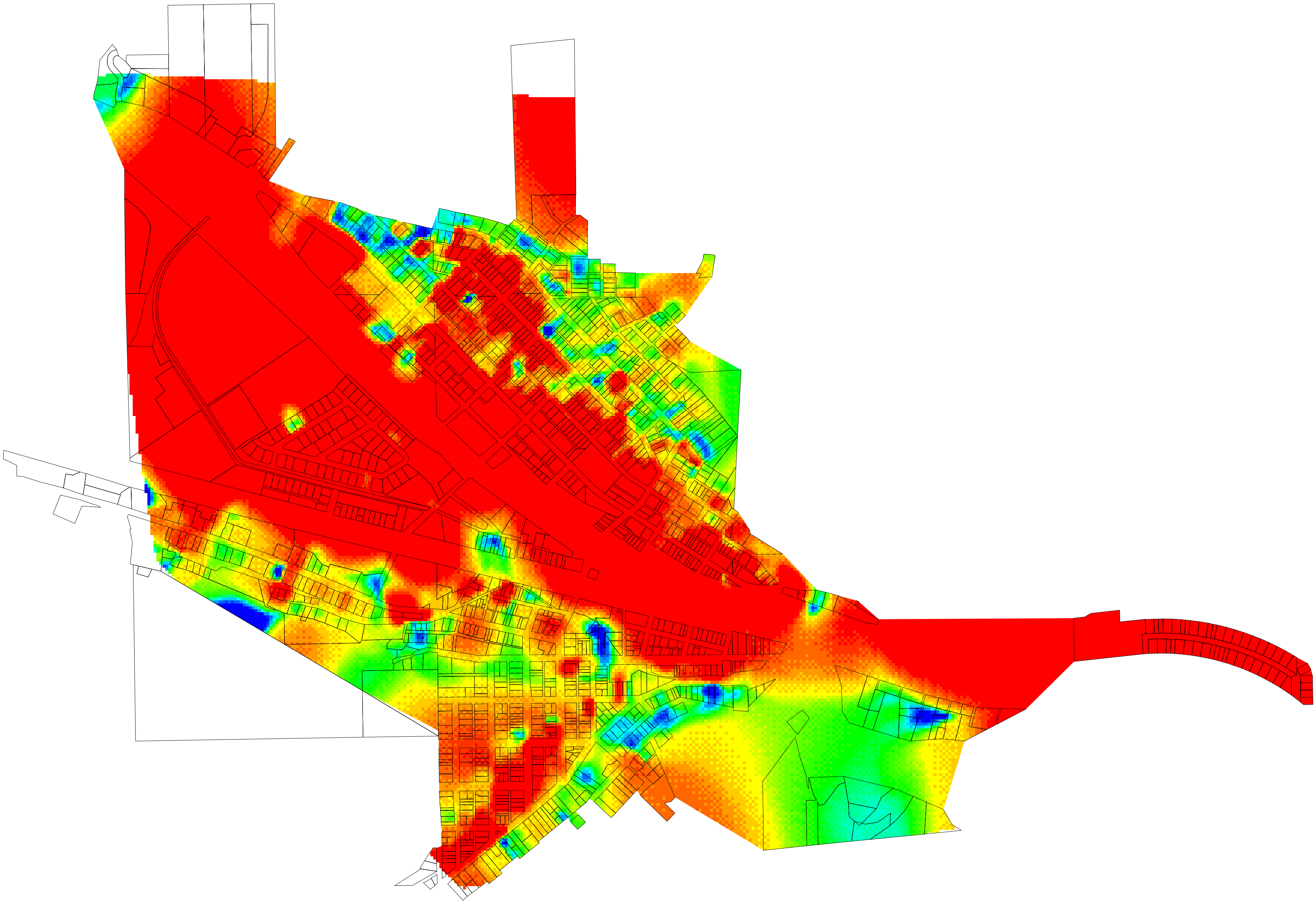
0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

Figure 3.6a

Current Subsurface Soil (Below Barrier) Lead Concentrations for Smelterville, Idaho

TerraGraphics
Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Smelterville/smeltbarrier	REQUESTOR	S. Spalinger
DATE	October 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	



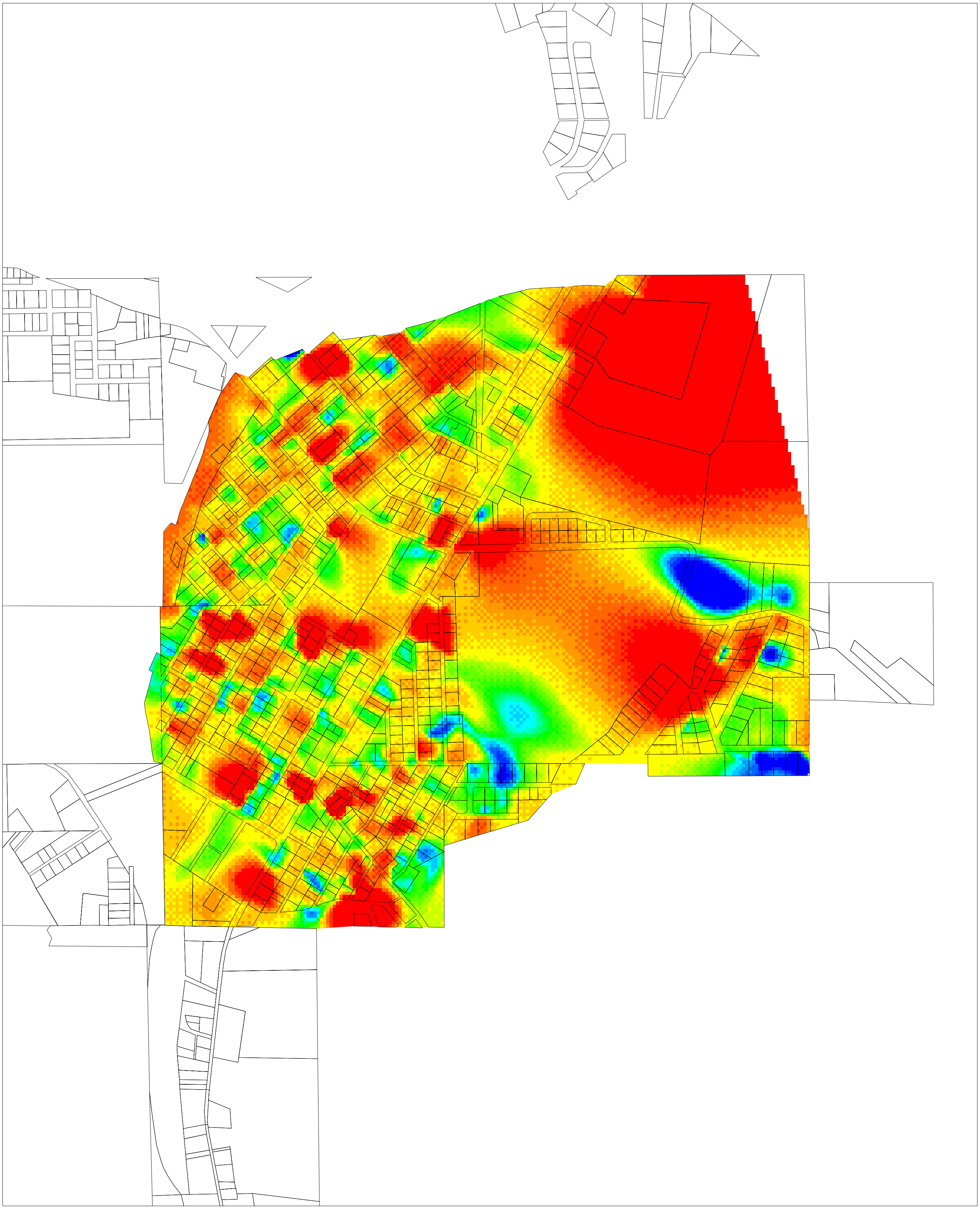
0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

Figure 3.6b

Current Subsurface Soil (Below Barriers) Lead Concentrations for Kellogg, Idaho

Terra Graphics
Environmental Engineering, Inc.

FILE	1998-10-10 LRRG/Kellogg/kell_barrier
DATE	October 2003
PROJECT NO.	
REQUESTOR	S. Spalinger
DESIGNER	B. Bailey
CARTOGRAPHER	B. Bailey
APPROVED	



0 - 349.9 mg/kg	1,000 - 2499.9 mg/kg
350 - 499.9 mg/kg	2500 - 4999.9 mg/kg
500 - 999.9 mg/kg	5,000 and greater mg/kg

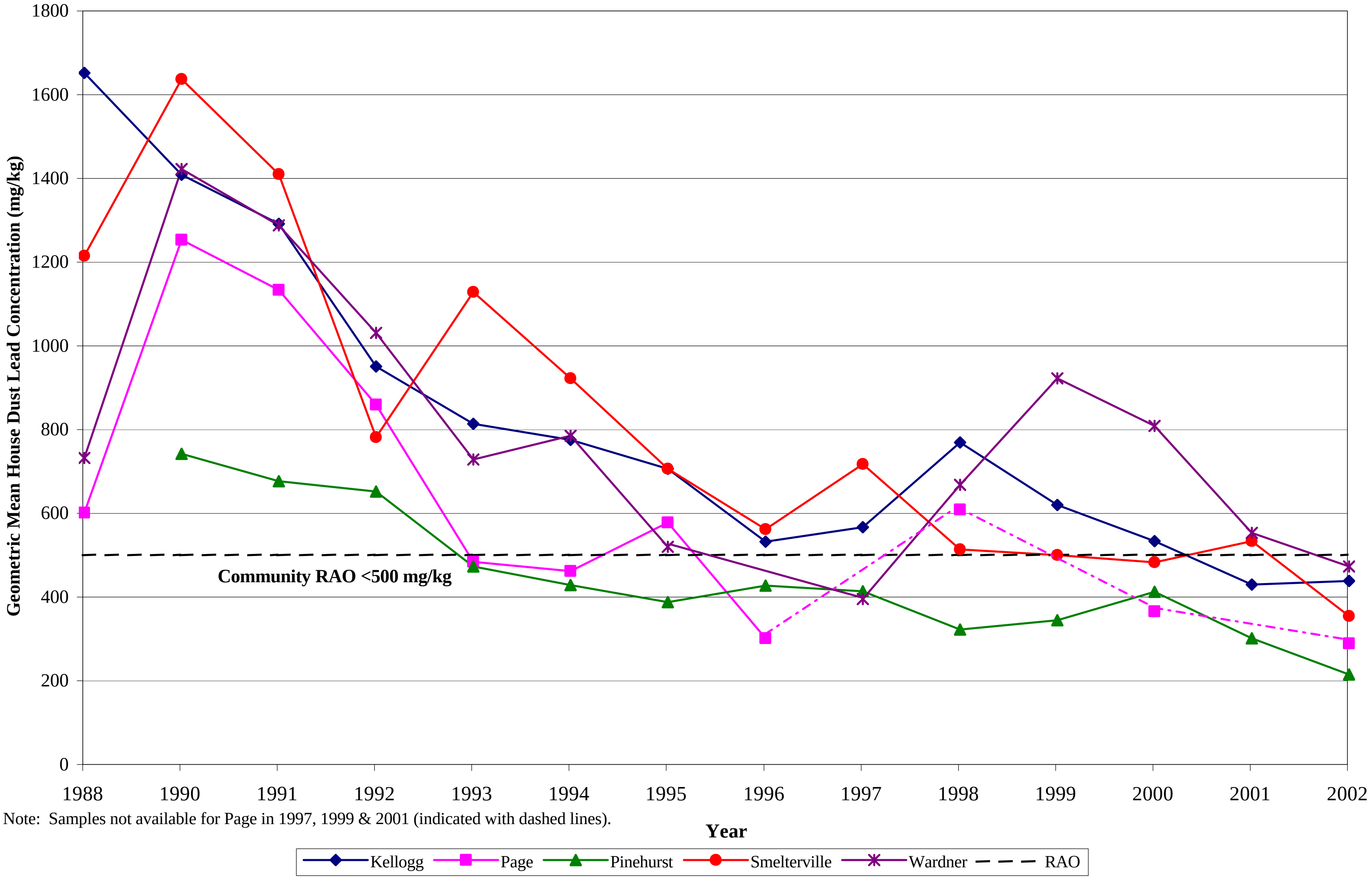
Terra Graphics
Environmental Engineering, Inc.

FILE 1998-10-10 LRRG/Pinehurst/pinebarrier		REQUESTOR	S. Spalinger
DATE	October 2003	DESIGNER	B. Bailey
PROJECT NO.		CARTOGRAPHER	B. Bailey
		APPROVED	

Figure 3.6c

Current Subsurface Soil (Below Barriers) Lead Concentrations for Pinehurst, Idaho

Figure 3.7
House Dust Vacuum Bag Lead Concentration by City, 1988-2002



Note: Samples not available for Page in 1997, 1999 & 2001 (indicated with dashed lines).

Figure 3.8
House Dust Vacuum Bag Concentration Histograms - Site-wide, 1988-2002

Figure 3.8a
House Dust Vacuum Bag Lead Concentration Histogram - 1988

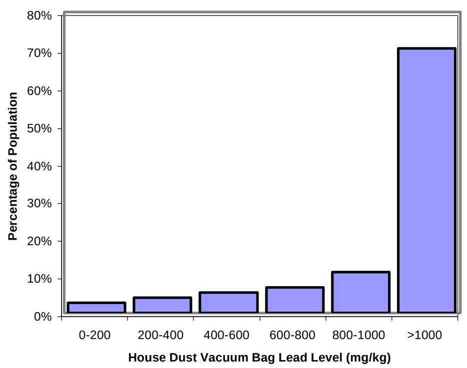


Figure 3.8b
House Dust Vacuum Bag Lead Concentration Histogram - 1990

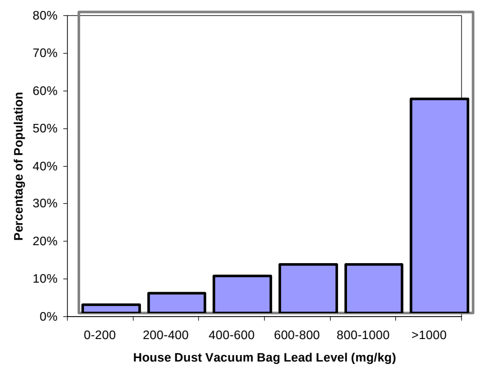


Figure 3.8c
House Dust Vacuum Bag Lead Concentration Histogram - 1991

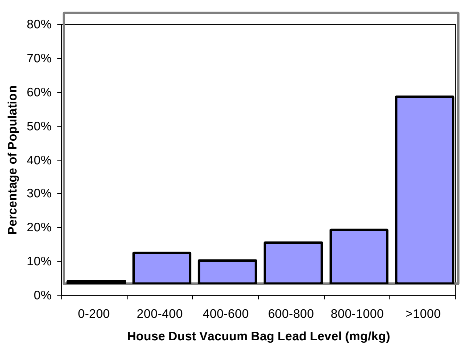


Figure 3.8d
House Dust Vacuum Bag Lead Concentration Histogram - 1992

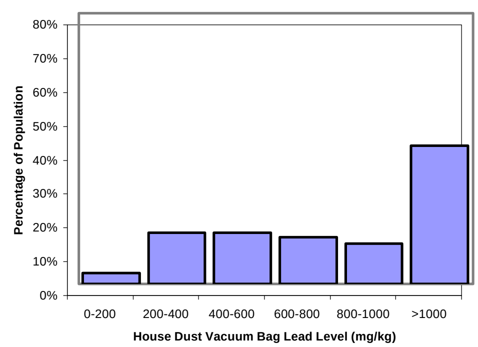


Figure 3.8e
House Dust Vacuum Bag Lead Concentration Histogram - 1993

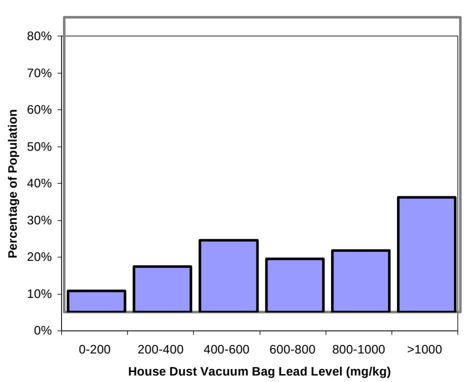


Figure 3.8f
House Dust Vacuum Bag Lead Concentration Histogram - 1994

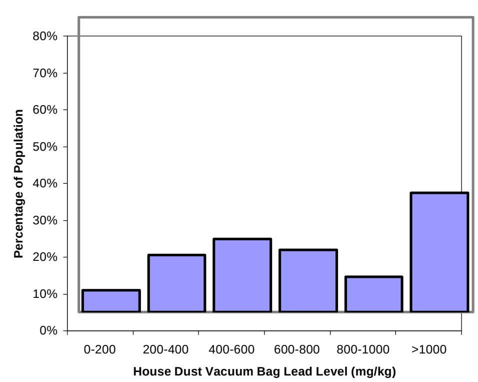
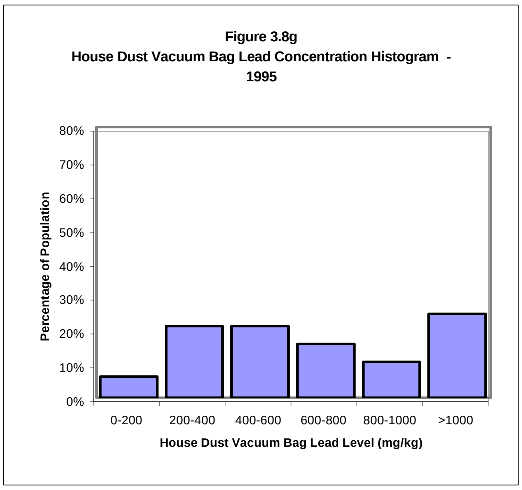
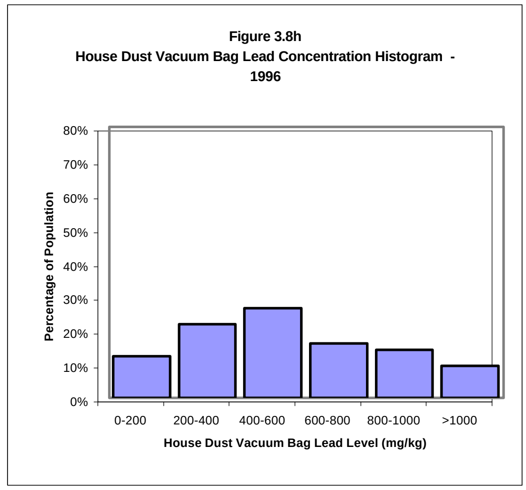
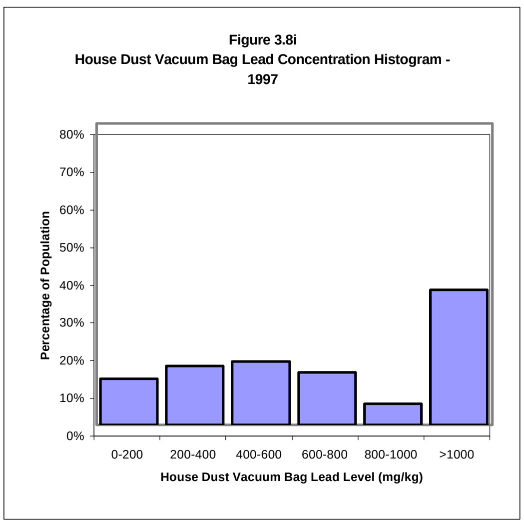
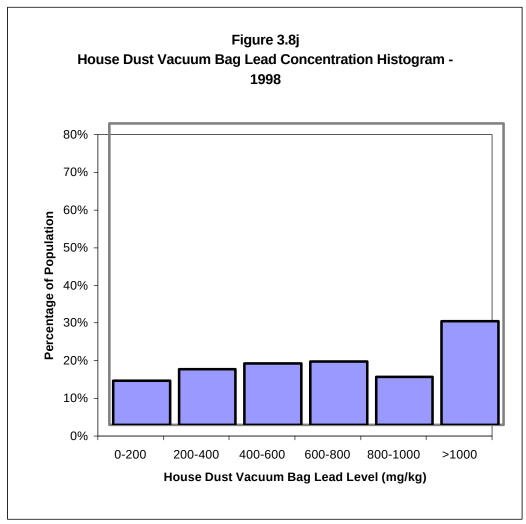


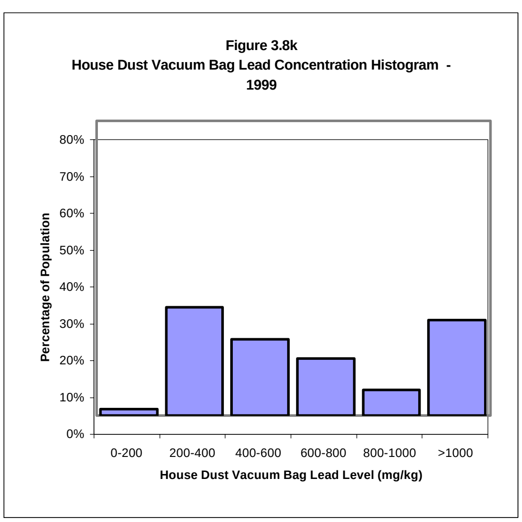
Figure 3.8 (continued)
House Dust Vacuum Bag Concentration Histograms - Site wide, 1988-2002











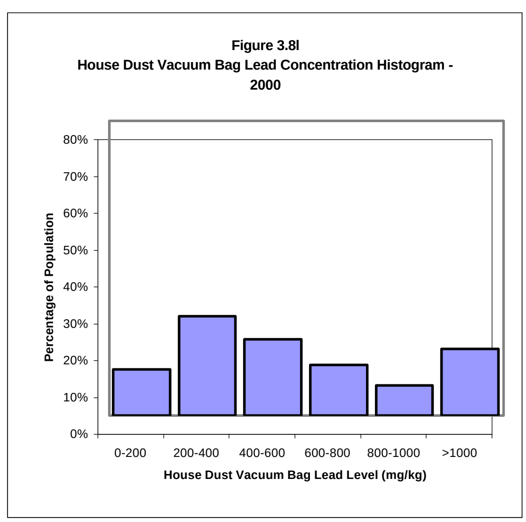
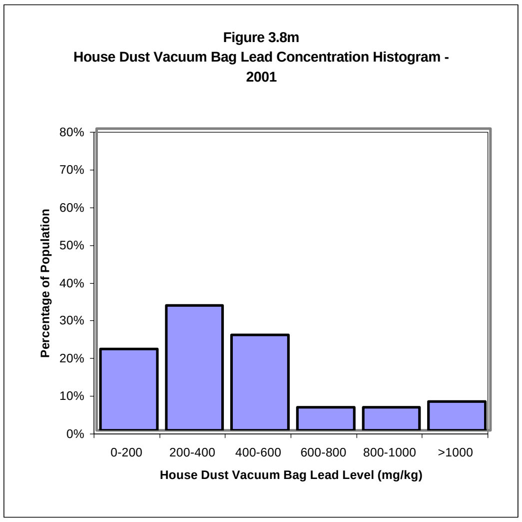
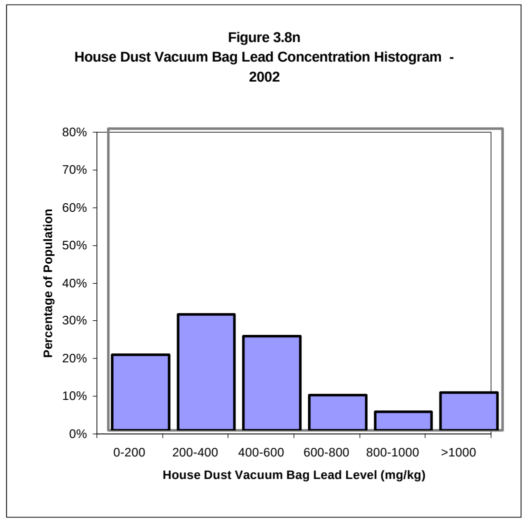


Figure 3.8 (continued)
House Dust Vacuum Bag Concentration Histograms - Site wide, 1988-2002





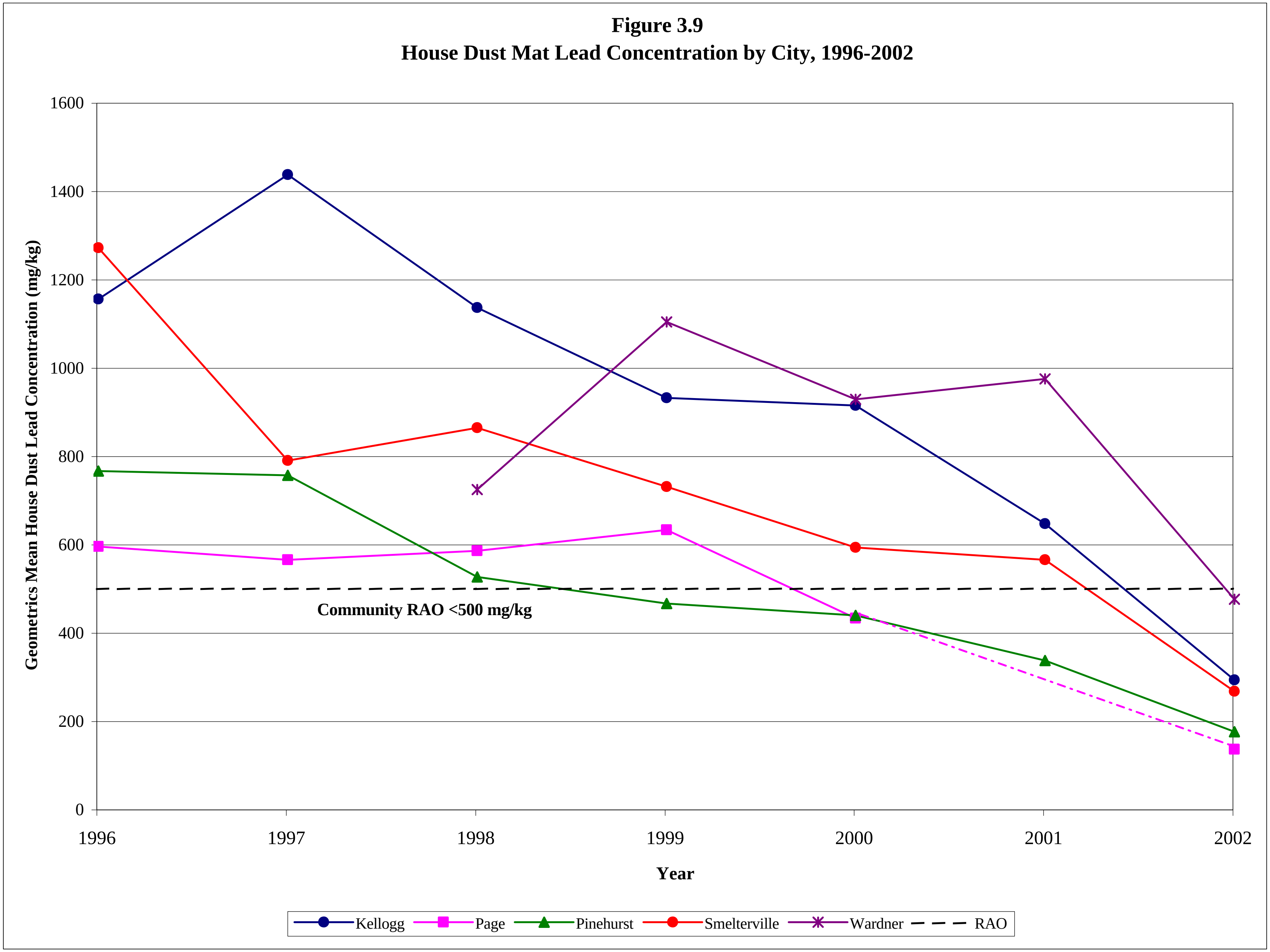


Figure 3.9
House Dust Mat Lead Concentration by City, 1996-2002
Geometrics Mean House Dust Lead Concentration (mg/kg)
1600
1400
1200
1000
800
600
400
200
0
Community RAO <500 mg/kg
1996
1997
1998
1999
2000
2001
2002
Year
Kellogg
Page
Pinehurst
Smelterville
Wardner
RAO

Table 3-1
Yard Soil Remediation Progress, 1989-2002

Year	City	Number of Residential Units[a]	Number (%) Yards Above Action Level This Year[b]		Number (%) Remediated This Year[b]		Number (%) Remediated Total		Mean Soil Lead Concentration Prior To Remediation (mg/kg)[c] Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1989	Kellogg	1513	1113	74%	63	6%	63	6%	2837	2233	2112	2.30
	Page	75	42	56%	4	10%	4	10%	1015	784	741	2.39
	Pinehurst	950	208	22%	1	0%	1	0%	582	546	431	2.22
	Smelterville	409	333	81%	17	5%	17	5%	3399	2817	2336	2.64
	Wardner	148	181	122%	5	3%	5	3%	2592	4041	1529	2.62
	Total	3095	1877	61%	90	5%	90	5%	---	---	---	---
1990	Kellogg	1513	1050	69%	94	9%	157	14%	2525	2277	1505	3.42
	Page	75	38	51%	2	5%	6	14%	964	805	651	2.69
	Pinehurst	950	207	22%	0	0%	1	0%	582	546	431	2.22
	Smelterville	409	316	77%	19	6%	36	11%	3254	2841	2045	3.13
	Wardner	148	176	119%	19	11%	24	13%	2530	4047	1399	2.92
	Total	3095	1787	58%	134	7%	224	12%	---	---	---	---
1991	Kellogg	1513	956	63%	57	6%	214	19%	2323	2306	1189	4.07
	Page	75	36	48%	3	8%	9	21%	934	794	624	2.72
	Pinehurst	950	207	22%	1	0%	2	1%	582	546	431	2.22
	Smelterville	409	297	73%	20	7%	56	17%	3104	2888	1743	3.69
	Wardner	148	157	106%	3	2%	27	15%	2243	3957	971	3.98
	Total	3095	1653	53%	84	5%	308	16%	---	---	---	---
1992	Kellogg	1513	899	59%	54	6%	268	24%	2181	2302	1032	4.34
	Page	75	33	44%	3	9%	12	29%	867	740	573	2.76
	Pinehurst	950	206	22%	13	6%	15	7%	581	546	430	2.22
	Smelterville	409	277	68%	13	5%	69	21%	2825	2781	1416	4.19
	Wardner	148	154	104%	3	2%	30	17%	2171	3971	872	4.22
	Total	3095	1569	51%	86	5%	394	21%	---	---	---	---
1993	Kellogg	1513	845	56%	18	2%	286	26%	1973	2187	866	4.56
	Page	75	30	40%	2	7%	14	33%	836	754	525	2.91
	Pinehurst	950	193	20%	8	4%	23	11%	560	525	411	2.25
	Smelterville	409	264	65%	7	3%	76	23%	2719	2781	1280	4.45
	Wardner	148	151	102%	4	3%	34	19%	2145	3980	825	4.36
	Total	3095	1483	48%	39	3%	433	23%	---	---	---	---
1994	Kellogg	1513	827	55%	30	4%	316	28%	1930	2184	828	4.62
	Page	75	28	37%	2	7%	16	38%	779	749	472	2.98
	Pinehurst	950	185	19%	4	2%	27	13%	547	514	401	2.26
	Smelterville	409	257	63%	77	30%	153	46%	2603	2785	1155	4.65
	Wardner	148	147	99%	10	7%	44	24%	2063	3973	753	4.49
	Total	3095	1444	47%	123	9%	556	30%	---	---	---	---
1995	Kellogg	1513	797	53%	32	4%	348	31%	1838	2142	761	4.69
	Page	75	26	35%	1	4%	17	40%	740	757	430	3.06
	Pinehurst	950	181	19%	5	3%	32	15%	541	515	394	2.28
	Smelterville	409	180	44%	153	85%	306	92%	1739	2581	547	5.19
	Wardner	148	137	93%	0	0%	44	24%	1797	3867	601	4.57
	Total	3095	1321	43%	191	14%	747	40%	---	---	---	---
1996	Kellogg	1513	765	51%	144	19%	492	44%	1774	2121	711	4.76
	Page	75	25	33%	0	0%	17	40%	719	753	414	3.07
	Pinehurst	950	176	19%	5	3%	37	18%	539	514	391	2.28
	Smelterville	409	27	7%	21	78%	327	98%	354	1323	142	2.40
	Wardner	148	137	93%	2	1%	46	25%	1797	3867	601	4.57
	Total	3095	1130	37%	172	15%	919	49%	---	---	---	---

Table 3-1 (continued)
Yard Soil Remediation Progress, 1988-2002

Year	City	Number of Residential Units[a]	Number (%) Above Action Level This Year [b]		Number (%) Remediated This Year [b]		Number (%) Remediated Total		Mean Soil Lead Concentration Prior To Remediation (mg/kg)			
									Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1997	Kellogg	1513	621	41%	177	29%	669	60%	1393	1865	483	4.86
	Page	75	25	33%	0	0%	17	40%	719	753	414	3.07
	Pinehurst	950	171	18%	3	2%	40	19%	535	513	388	2.29
	Smelterville	409	6	1%	0	0%	327	98%	171	287	125	1.81
	Wardner	148	135	91%	3	2%	49	27%	1779	3869	586	4.59
	Total	3095	958	31%	183	19%	1102	59%	---	---	---	---
1998	Kellogg	1513	444	29%	159	36%	828	74%	1045	1749	314	4.53
	Page	75	25	33%	3	12%	20	48%	712	756	403	3.10
	Pinehurst	950	168	18%	4	2%	44	21%	529	505	384	2.29
	Smelterville	409	6	1%	4	67%	331	99%	171	287	125	1.81
	Wardner	148	132	89%	0	0%	49	27%	1741	3874	552	4.65
	Total	3095	775	25%	170	22%	1272	68%	---	---	---	---
1999	Kellogg	1513	285	19%	15	5%	843	76%	782	1584	226	3.96
	Page	75	22	29%	0	0%	20	48%	649	717	363	3.09
	Pinehurst	950	164	17%	42	26%	86	41%	524	503	380	2.29
	Smelterville	409	2	0%	0	0%	331	99%	149	137	122	1.68
	Wardner	148	132	89%	0	0%	49	27%	1741	3874	552	4.65
	Total	3095	605	20%	57	9%	1329	71%	---	---	---	---
2000	Kellogg	1513	270	18%	7	3%	850	76%	731	1477	217	3.84
	Page	75	22	29%	0	0%	20	48%	649	717	363	3.09
	Pinehurst	950	122	13%	50	41%	136	65%	477	478	341	2.32
	Smelterville	409	2	0%	0	0%	331	99%	149	137	122	1.68
	Wardner	148	132	89%	1	1%	50	28%	1741	3874	552	4.65
	Total	3095	548	18%	58	11%	1387	74%	---	---	---	---
2001	Kellogg	1513	263	17%	7	3%	857	77%	708	1447	213	3.78
	Page	75	22	29%	0	0%	20	48%	649	717	363	3.09
	Pinehurst	950	72	8%	42	58%	178	86%	417	440	298	2.30
	Smelterville	409	2	0%	0	0%	331	99%	149	137	122	1.68
	Wardner	148	131	89%	4	3%	54	30%	1723	3876	538	4.65
	Total	3095	490	16%	53	11%	1440	77%	---	---	---	---
2002	Kellogg	1513	256	17%	139	54%	996	89%	694	1441	209	3.73
	Page	75	22	29%	0	0%	20	48%	649	717	363	3.09
	Pinehurst	950	30	3%	2	7%	180	87%	376	385	274	2.25
	Smelterville	409	2	0%	0	0%	331	99%	149	137	122	1.68
	Wardner	148	127	86%	3	2%	57	31%	1628	3837	497	4.61
	Total	3095	437	14%	144	33%	1584	84%	---	---	---	---

[a]Estimated from tax assessor parcel maps

[b] Based on PRP soil database, residential yards only. Numbers will vary from PRP summaries because discrete areas were not counted here. 100% agreement between the tax assessor and the PRP soil database is not expected.

[c]Means are based on other soil data in addition to the PRP soil database.
Note: Kellogg includes outlying communities such as Elizabeth Park and Montgomery Gulch
mg/kg: milligrams per kilogram
---: Not applicable

Table 3-2
House Dust Vacuum Bag Lead Concentration by Year, 1988-2002

Year[a]	City	Number of Houses	Number (%) Above Action Level	Concentration Range (mg/kg) Minimum	Concentration Range (mg/kg) Maximum	Mean House Dust Lead Concentration (mg/kg) Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1988[b]	Kellogg	48	37 (77%)	94	52700	3618	8421.9	1648	2.80
	Page	6	4 (67%)	69	1160	813	439.8	597	3.02
	Smelterville	17	10 (59%)	209	4640	1657	1293.3	1212	2.39
	Wardner	3	1 (33%)	427	1480	839	562.6	728	1.90
1990[b]	Kellogg	68	49 (72%)	117	16800	1920	2180.3	1405	2.20
	Page	4	3 (75%)	898	2070	1315	517.4	1249	1.43
	Pinehurst	43	10 (23%)	119	7990	1022	1272.4	739	2.05
	Smelterville	14	12 (86%)	777	4210	1858	1006.3	1634	1.69
	Wardner	3	2 (67%)	691	2220	1590	799.4	1418	1.88
1991[b]	Kellogg	64	44 (69%)	274	3960	1490	815.1	1288	1.75
	Page	5	4 (80%)	545	1680	1209	434.2	1130	1.55
	Pinehurst	40	9 (23%)	65	13500	1076	2078.6	673	2.27
	Smelterville	17	14 (82%)	790	2700	1496	551.7	1406	1.44
	Wardner	6	3 (50%)	307	4800	1786	1596.4	1284	2.52
1992[b]	Kellogg	82	43 (52%)	65	5860	1250	1003.5	947	2.21
	Page	4	2 (50%)	473	1500	932	435.5	856	1.62
	Pinehurst	50	12 (24%)	139	6670	906	1041.7	648	2.14
	Smelterville	18	6 (33%)	140	3790	978	799.1	778	2.01
	Wardner	5	3 (60%)	322	5240	1724	2029.6	1028	3.10
1993[b]	Kellogg	73	25 (34%)	111	3210	966	566.2	810	1.89
	Page	5	0 (0%)	139	794	557	253.3	480	2.03
	Pinehurst	38	5 (13%)	60	3460	626	597.7	469	2.14
	Smelterville	16	11 (69%)	201	3350	1347	843.3	1125	1.93
	Wardner	6	2 (33%)	382	1290	785	343.8	724	1.56
1994[b]	Kellogg	61	25 (41%)	88	3770	940	591.0	772	2.00
	Page	6	2 (33%)	90	1340	655	521.2	458	2.78
	Pinehurst	36	1 (3%)	76	1490	510	284.3	424	1.97
	Smelterville	21	11 (52%)	228	3060	1149	742.2	919	2.06
	Wardner	12	5 (42%)	211	2270	997	671.4	782	2.17
1995[b]	Kellogg	66	21 (32%)	62	4400	918	775	703	2.12
	Page	4	1 (25%)	239	1430	706	519	574	2.12
	Pinehurst	28	3 (11%)	22	1720	501	371	383	2.29
	Smelterville	11	3 (27%)	297	3470	923	895	702	2.05
	Wardner	4	0 (0%)	245	892	570	265	517	1.72
1996[b]	Kellogg	64	7 (11%)	85	2300	633	387	528	1.90
	Page	2	0 (0%)	140	630	385	346	297	2.90
	Pinehurst	27	2 (7%)	100	2100	525	429	423	1.90
	Smelterville	11	2 (18%)	99	11300	1565	3258	558	3.92
	Wardner	2	0 (0%)	--	--	--	--	--	--

Table 3-2 (continued)
House Dust Vacuum Bag Lead Concentration by Year, 1988-2002

Year	City	Number of Houses	Number (%) Above Action Level	Concentration Range (mg/kg)		Mean House Dust Lead Concentration (mg/kg)			
				Minimum	Maximum	Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1997[c]	Kellogg	38	10 (26%)	43	6800	859	1104	563	2.54
	Page	2	0 (0%)	--	--	--	--	--	--
	Pinehurst	14	2 (14%)	130	15000	1410	3919	410	3.22
	Smelterville	121	51 (42%)	50	9570	1098	1253	714	2.67
	Wardner	4	1 (25%)	220	1100	488	412	392	2.05
1998[c]	Kellogg	124	46 (37%)	68	7470	1066	1076	765	2.29
	Page	5	1 (20%)	220	1500	722	474	605	1.99
	Pinehurst	27	2 (7%)	71	2000	428	396	318	2.17
	Smelterville	35	5 (14%)	65	1590	639	368	510	2.20
	Wardner	5	1 (20%)	270	6000	1538	2503	664	3.67
1999[c]	Kellogg	138	31 (22%)	99	15300	862	1466	616	1.99
	Page	2	0 (0%)	--	--	--	--	--	--
	Pinehurst	38	2 (5%)	45	4010	490	635	341	2.26
	Smelterville	41	10 (24%)	14	6680	803	1072	497	2.79
	Wardner	11	5 (45%)	254	2760	1196	823	919	2.26
2000[c]	Kellogg	156	33 (21%)	37	11200	771	1028	529	2.34
	Page	5	0 (0%)	86	941	495	362	362	2.67
	Pinehurst	54	5 (9%)	40	2640	541	506	408	2.08
	Smelterville	79	14 (18%)	38	30900	1027	3451	479	2.67
	Wardner	11	3 (27%)	330	2700	985	708	804	1.92
2001[c]	Kellogg	67	8 (12%)	64	4520	586	647	426	2.16
	Page	1	0 (0%)	--	--	--	--	--	--
	Pinehurst	88	5 (6%)	30	2010	387	319	298	2.10
	Smelterville	30	3 (10%)	93	1570	624	350	530	1.85
	Wardner	16	3 (19%)	180	1460	660	396	549	1.91
2002[c]	Kellogg	78	11 (14%)	32	7090	659	922	435	2.38
	Page	4	0 (0%)	250	376	289	59	285	1.21
	Pinehurst	22	1 (5%)	51	1200	287	269	211	2.17
	Smelterville	23	2 (9%)	54	2400	524	519	350	2.65
	Wardner	13	0 (0%)	188	746	494	148	469	1.43

[a]No data collected in 1989

[b]1988-1996 vacuum bags collected as part of LHIP

[c]1997-2002 vacuum bags collected as part of LHIP & DEQ sampling program

-- When the number of observation is ≤2, then data are not shown for confidentiality purposes.

Table 3-3a
House Dust Mat Lead Concentration by Year, 1996-2002

Year	City	Number of Houses	Number (%) Above Action Level	Concentration Range (mg/kg)		Mean House Dust Lead Concentration (mg/kg)			
				Minimum	Maximum	Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1996	Kellogg	41	24 (59%)	247.7	7019	1526	1306	1154	2.12
	Page	3	1 (33%)	180.2	1444	809	632	593	2.92
	Pinehurst	21	6 (29%)	365.2	2729	887	566	764	1.70
	Smelterville	8	5 (63%)	360.3	3477	1677	1204	1270	2.33
	Wardner	2	1 (50%)	--	--	--	--	--	--
1997	Kellogg	83	55 (66%)	200	8200	1941	1539	1436	2.25
	Page	6	0 (0%)	326	959	609	266	563	1.54
	Pinehurst	10	3 (30%)	300	2800	974	806	755	2.06
	Smelterville	199	69 (35%)	11	4800	979	698	788	2.02
	Wardner	0	--	--	--	--	--	--	--
1998	Kellogg	312	174 (56%)	43	35600	1768	3243	1134	2.22
	Page	8	2 (25%)	270	1560	681	442	584	1.77
	Pinehurst	54	6 (11%)	120	4040	651	577	525	1.87
	Smelterville	106	47 (44%)	224	2680	1000	551	862	1.75
	Wardner	7	3 (43%)	270	1840	866	532	723	1.97
1999	Kellogg	205	88 (43%)	90	7750	1170	908	930	1.96
	Page	7	1 (14%)	170	8930	1677	3206	632	3.66
	Pinehurst	53	6 (11%)	146	32100	1132	4358	465	2.38
	Smelterville	74	24 (32%)	97	57600	1896	7121	729	2.57
	Wardner	15	7 (47%)	305	18400	2232	4520	1102	2.69
2000	Kellogg	177	74 (42%)	174	15500	1288	1668	913	2.13
	Page	8	1 (13%)	180	1400	533	400	431	1.97
	Pinehurst	67	9 (13%)	70	7830	625	981	437	2.05
	Smelterville	68	14 (21%)	162	4110	769	675	592	2.01
	Wardner	9	3 (33%)	486	2780	1149	853	926	1.95
2001	Kellogg	103	24 (23%)	7	15100	996	1746	645	2.42
	Page	2	0 (0%)	--	--	--	--	--	--
	Pinehurst	38	2 (5%)	2690	2010	427	431	336	1.91
	Smelterville	34	6 (18%)	3590	1570	753	666	564	2.23
	Wardner	8	3 (38%)	4980	1460	1528	1607	973	2.76
2002	Kellogg	167	11 (7%)	43	4210	425	551	291	2.20
	Page	8	0 (0%)	15	546	192	160	135	2.84
	Pinehurst	81	0 (0%)	36	611	209	135	174	1.85
	Smelterville	64	3 (5%)	46	4690	379	588	265	2.09
	Wardner	25	5 (20%)	108	79700	3758	15834	474	3.99

-- When the number of observation is ≤ 2, then data are not shown for confidentiality purposes.

Table 3-3b
House Dust Mat Loading Rates by Year, 1996-2002

Year	City	Number of Mats	Dust Loading Rate ($mg/m^2/day$)				Number of Mats	Lead Loading Rate ($mg/m^2/day$)			
			Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation		Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1996	Kellogg	65	1029	1250	576	3.08	41	1.94	2.00	1.32	2.50
	Page	3	2332	1344	2052	1.90	3	1.63	1.31	1.22	2.78
	Pinehurst	27	1079	1101	682	3.09	21	1.08	0.83	0.79	2.32
	Smelterville	10	838	620	571	3.10	8	2.00	2.26	1.11	3.67
	Wardner	2	--	--	--	--	2	--	--	--	--
1997	Kellogg	83	661	684	441	2.42	83	1.28	1.59	0.63	3.39
	Page	6	1517	1346	1128	2.29	6	0.94	0.80	0.63	2.78
	Pinehurst	10	679	1024	371	2.78	10	0.64	0.74	0.28	4.35
	Smelterville	196	898	1576	509	2.67	196	0.97	2.48	0.41	3.56
	Wardner	0	--	--	--	--	0	--	--	--	--
1998	Kellogg	311	508	834	298	2.69	311	1.12	4.25	0.34	3.67
	Page	8	927	988	647	2.35	8	0.58	0.52	0.38	2.83
	Pinehurst	53	1074	1157	638	2.98	53	0.67	0.98	0.34	3.29
	Smelterville	106	620	641	404	2.56	106	0.53	0.56	0.35	2.60
	Wardner	7	1050	884	753	2.47	7	1.13	1.66	0.54	3.60
1999	Kellogg	204	703	1387	321	3.51	204	0.72	1.03	0.30	4.46
	Page	7	2127	1440	1803	1.81	7	6.86	16.19	1.14	5.68
	Pinehurst	53	1145	969	769	2.67	53	1.90	9.70	0.36	3.77
	Smelterville	75	723	1006	386	3.17	75	0.60	0.92	0.28	3.72
	Wardner	15	855	1684	339	3.91	15	8.67	32.10	0.37	6.92
2000	Kellogg	177	562	645	390	2.29	177	0.62	0.92	0.35	3.02
	Page	8	1323	645	1211	1.60	8	0.56	0.38	0.45	2.59
	Pinehurst	67	950	1236	538	3.28	67	0.50	0.75	0.23	3.88
	Smelterville	68	654	540	493	2.15	68	0.55	1.07	0.29	2.83
	Wardner	9	265	87	251	1.45	9	0.37	0.41	0.25	2.82
2001	Kellogg	120	525	895	268	3.04	103	0.46	0.62	0.22	3.81
	Page	3	1293	1021	1051	2.18	2	0.44	0.02	0.43	1.05
	Pinehurst	41	679	708	395	3.26	38	0.29	0.41	0.16	3.34
	Smelterville	37	829	1885	370	3.10	34	0.54	1.14	0.24	3.42
	Wardner	8	948	1578	482	2.89	8	1.09	1.44	0.47	4.08
2002	Kellogg	167	567	692	412	2.11	167	0.26	0.43	0.12	3.36
	Page	8	620	656	441	2.31	8	0.10	0.08	0.06	4.66
	Pinehurst	79	847	1161	542	2.39	79	0.22	0.55	0.09	3.28
	Smelterville	64	875	1116	551	2.54	64	0.43	1.18	0.15	3.84
	Wardner	25	740	480	593	2.04	25	1.12	2.79	0.28	4.87

-- When the number of observation is $\leq$ 2, then data are not shown for confidentiality purposes.

Table 3-4
Paired House Dust Data, 1996-2002

Year	City	Number of Pairs	Geometric Mean Mat Lead Conc. (mg/kg)	Geometric Mean Vacuum Lead Conc. (mg/kg)	Correlation Coefficient (R)	Paired T-Test P-Value
1996	Kellogg	33	1105	658	0.22	0.0010
	Page	2	510	297	--	--
	Pinehurst	20	768	464	0.32	0.0053
	Smelterville	7	1414	1052	--	--
	Wardner	2	1231	340	--	--
	Site-wide	64	992	594	0.26	<.0001
1997	Kellogg	38	1214	563	0.41	<.0001
	Page	2	549	398	--	--
	Pinehurst	12	763	420	0.76	0.0392
	Smelterville	120	819	712	0.20	0.1654
	Wardner	4	886	392	--	--
	Site-wide	176	885	640	0.28	<.0001
1998	Kellogg	121	1142	771	0.39	<.0001
	Page	5	559	605	--	--
	Pinehurst	26	471	315	0.43	0.0116
	Smelterville	40	734	547	0.33	0.0230
	Wardner	5	616	664	--	--
	Site-wide	197	898	633	0.48	<.0001
1999	Kellogg	130	982	611	0.53	<.0001
	Page	2	191	197	--	--
	Pinehurst	34	491	358	0.63	0.0303
	Smelterville	41	711	519	0.66	0.0141
	Wardner	10	1331	844	0.16	0.2852
	Site-wide	217	828	547	0.60	<.0001
2000	Kellogg	125	939	521	0.34	<.0001
	Page	5	418	362	--	--
	Pinehurst	43	415	373	0.14	0.4097
	Smelterville	63	587	494	0.61	0.0548
	Wardner	8	958	814	0.91	0.1883
	Site-wide	244	709	488	0.42	<.0001
2001	Kellogg	55	596	412	0.33	0.0058
	Page	1	--	--	--	--
	Pinehurst	13	315	196	0.11	0.0115
	Smelterville	22	563	596	0.36	0.7495
	Wardner	3	1483	532	--	--
	Site-wide	94	547	403	0.41	0.0011
2002	Kellogg	72	287	449	0.20	0.0007
	Page	3	128	290	--	--
	Pinehurst	15	208	285	0.26	0.0983
	Smelterville	21	263	376	0.51	0.0550
	Wardner	12	312	463	0.16	0.1764
	Site-wide	123	269	409	0.27	<.0001

-- Sample size too small for analyses.

SECTION 4.0 HEALTH RESPONSE AND RISK MANAGEMENT ACTIVITIES

4.1 Interim Risk Management Activities Conducted Prior to the RODs

4.1.1 Pre-CERCLA Activities

The pathways and human health effects associated with exposure to heavy metals have been studied extensively since the early 1970s (Chisolm et al. 1976, Landrigan et al. 1976, Yankel et al. 1977). Over the past 16 years, more than 5,000 blood lead samples have been obtained from children living within the Box. Analyses of these data in conjunction with the RI/FS effort resulted in an integrated risk management and Box cleanup strategy designed to monitor and minimize children's exposures as remediation occurred over several years. This same database was used extensively to design, implement and monitor the progress of the permanent cleanup and health response actions at the site (TerraGraphics 2000b).

Public health response actions have continued at the site since the lead poisoning epidemic of 1973-74 (Chisolm et al. 1976, PHD 1999). Early interventions and source controls in the 1970s included emissions reductions at the smelter, relocation of families with susceptible children, home yard and community dust control, revegetation and greening efforts, biological (blood lead) monitoring, nursing follow-up, parental awareness, and public/school education programs (Chisolm et al. 1976, IDHW 1976, JEG et al. 1989). During the 1970s, these activities were successful in preventing and mitigating clinical lead poisoning (>60 μg/dl) among area children (Chisolm et al. 1976). However, mean childhood blood lead levels were near 40 μg/dl throughout the 1970s and several hundred children were severely poisoned, according to current criteria (CDC 1991, TerraGraphics 2000b). The program ceased in 1981 following smelter closure and discontinued funding from the owners (PHD 1986, TerraGraphics 1987).

4.1.2 The 1983 Lead Health Study

The 1983 Lead Health Study, a comprehensive survey of lead poisoning and exposures in the community, showed continued excess absorption among area children. Residual contamination in community soils and dusts was identified as the primary source of lead exposure to children. Incidental ingestion of these soils and dusts via ordinary hand-to-mouth behavior and play activities was considered the primary route of exposure. Several factors were found to influence the soil/dust pathway and were related to excess absorption. Significant risk factors included parental income and socioeconomic status, parental education level, home hygiene practices, smokers in the home, nutritional status of the child, use of locally grown produce, play area cover (grass vs. exposed surfaces), number of hours spent outside, pica behavior, and child's age.

Analysis of the ***1983 Lead Health Study*** also suggested that approximately 80% of a typical child's lead intake was from incidental ingestion of soil and dust. Roughly 40% of the intake was estimated to come from indoor house dusts, 30% from home yard soils, and 30% from neighborhood or community wide sources (PHD 1986, TerraGraphics

1987). Based on this observation, a strategy of incremental removal of sources (Fast-Track) was developed in the summer of 1985. The ***Fast-Track Cleanup*** effort was classified as an expedited response (or emergency removal) at that time. The initial plan was to remediate the broadest source groups first (i.e., common use areas and fugitive dust lead sources), followed by addressing residential yards as resources became available, and finally home interior sources. Meanwhile, the LHIP addressed specific yards and home interiors presenting problems to individual children identified through screening.

4.1.3 Lead Health Intervention Program

The ***Lead Health Intervention Program (LHIP)*** was introduced in 1985 based on this information. The LHIP is a comprehensive plan of intervention and risk reduction designed to minimize lead absorption during the Superfund project. A combination of biological monitoring, in-home intervention, public awareness efforts, and targeted remediation activities has continued since 1985 throughout the RI/FS and Remedial Design/Remedial Action phases of the project. The LHIP, sponsored by the CDC and the ATSDR, is implemented by the local PHD under the auspices of the Idaho Department of Health and Welfare (IDHW). During the entire LHIP and Superfund effort, a comprehensive confidential database has been maintained that relates children's blood lead levels, media contaminant concentrations, environmental exposures, health intervention, and remedial activities on an individual basis. LHIP activities from 1985 to 2003 are summarized in Section 4.3 (PHD 1986, TerraGraphics 1987, JEG et al. 1989, TerraGraphics 1997, TerraGraphics 1998, PHD 1999, TerraGraphics 2000b, TerraGraphics 2000a, TerraGraphics 2001).

4.1.4 Fast-Track Cleanup Activities

Fast-Track Cleanup Activities 1986-87: The Fast-Track strategy was based both on exposure and institutional considerations. From an exposure standpoint, the CUA sources (parks, playgrounds, fugitive dusts from roadsides and bare areas, etc.) affected all children to some degree. Eliminating these sources would benefit children across the entire population. Individual High-Risk exposures could be addressed in the LHIP. From an institutional perspective, logistics and site access were facilitated by initiating cleanup activities on publicly-owned properties.

In 1985, the Bunker Hill Project Team (State, local, and federal agency personnel and contractors) enrolled volunteer Task Force members (a local citizen advisory group) and local elected officials in identifying public access areas and properties that contributed to soil and fugitive dust exposures in each community. The recommendation of the Fast-Track cleanups was the first major involvement of the Task Force in assisting in remedial actions on the site. The ***Bunker Hill Site Task Force*** has continued to be an integral part of the overall Superfund effort. This advisory group of nine volunteer residents has served as a sounding board, as advocates of local interests, and as liaisons between the Project team and the community. Three current members have served since 1985. More than 84 Task Force meetings have been held during the course of the project. Task Force members have been involved in determining project priorities and schedules and have significantly influenced the course of the project and its general acceptance among local citizens.

As part of the Fast-Track effort, about thirty properties were identified as significantly contributing to exposures across the site. These properties were divided into two groups based on ownership (i.e., publicly-owned and privately-owned parcels). Sufficient CERCLA funds were available to remediate the public parcels in 1986. About four parks and playgrounds and thirteen ROWs identified by the Task Force were cleaned up during the summer and fall of 1986. Approximately 12,000 cubic yards of contaminated soils were removed and staged on-site (TerraGraphics 1986, JEG et al. 1989).

The interim risk management strategy called for completion of the remaining privately-owned Fast-Track sites the following summer, and interim (1987) removal plans were developed in late 1986 for several of the sites. It was originally anticipated that individual home yard removals would begin in the 1988 construction season. However, project delays resulted in an 18-month hiatus in removal activities. The High-Risk Yard Cleanup commenced in 1989, and private site remediation did not occur until 1994 in conjunction with the geographic areas cleanups. Fugitive dust control measures were instituted in 1987 and 1990-93, and smelter complex stabilization has continued since 1990 under Administrative Orders on Consent (AOC) issued by the USEPA and as a Fund-lead Remedial Action (RA) since 1994.

4.1.5 High-Risk Yard Cleanup

The High-Risk Yard Cleanup was implemented in 1989 with emergency response funds and was initially targeted at the homes of pregnant women and children up to 3 years of age. Cleanup of all identified homes of pregnant women and children up to 7 years of age was accomplished in 1990 and was extended to 12 year old children in 1991. The emergency response program continued to fund this effort until the Populated Areas ROD was adopted in 1991. The Site PRPs implemented the High-Risk Yard Cleanup from 1991 to 1993 under an Order on Consent. After 1994, the High-Risk Yard Cleanup was implemented by the Site PRPs under the Populated Areas ROD (TerraGraphics 2000b, TerraGraphics 2001).

4.1.6 Other Interim Source Control Measures

Other Interim Source Control Measures were also accomplished prior to the RODs within the Box. Stabilization of barren areas contributing to fugitive dusts in the towns also commenced in 1986 and continued intermittently through 1993. Critical response activities were undertaken in the industrial complex at various intervals to protect against fire and catastrophic releases. These were conducted pursuant to a Public Health Advisory issued by the ATSDR in 1989 (ATSDR 1989). Emergency response funds and Unilateral Orders to site PRPs were used to effect critical stabilization efforts in the industrial complex until the Non-Populated Areas ROD was implemented in 1994. Since that time all remedial actions have been pursuant to the RODs. These have been accomplished with both PRP and Remedial Action Fund monies in the Populated Areas and bankruptcy proceeds and Remedial Action Fund monies in the Non-Populated Areas.

4.2 Permanent Human Health Remedy

4.2.1 Long-term Risk Management Strategy

The interim health response strategies developed and employed throughout the 1980s were formalized and enhanced in the two RODs adopted in 1991 and 1992 (USEPA 1991, USEPA 1992b). The LHIP was to continue as an interim risk management tool during the cleanup. The High-Risk Yard Cleanup was modified to a 6-year old age limit in deference to the PRPs and has continued throughout the cleanup. Cleanup criteria were established for various environmental exposure media in both the Populated and Non-Populated Areas. Soil remediation became the key component of the Populated Areas cleanup. This was accomplished through partial contaminated soil removals with clean soil replacement, caps and covers acting as barriers to exposure and as sources of clean soil to children. Commercial properties and ROWs were added to residential yards and CUAs as integral parts of the Populated Areas effort.

In the Non-Populated Areas, massive demolition, soils removals, waste repository, and re-vegetation efforts were undertaken to reduce on-site soil and waste material exposures and to prevent migration of contaminants into the Populated Areas through fugitive dust, mechanical tracking, flood, fire and other potentially catastrophic events. From the start, the cleanup strategy recognized that exposure to house dust could only be controlled by reducing the sources of lead in soil adjacent to the homes of children as well as in the larger, outlying areas of the community.

An Institutional Controls Program (ICP) was established as a permanent Remedial Action to ensure that:

- barriers will be installed and maintained into perpetuity,
- clean materials and appropriate disposal options for the local communities are provided, and
- the impact of residual subsurface contamination on community development and the conduct of commerce is minimized.

The cleanup strategy adopted in the 1991 Populated Areas ROD was based on site-specific relationships observed between blood lead levels among children and environmental media lead concentrations at the site. The initial version of what was later to become the USEPA Integrated Exposure Uptake Bio-kinetic Model (IEUBK) for lead was applied in the Box to develop the target cleanup criteria for lead in soil and dust.

Site-wide RAOs were defined in the two RODs (See Section 6). The blood lead RAOs seek to reduce the incidence of elevated blood lead levels such that no more than 5% of children in the community would have a blood lead level of 10 micrograms per deciliter (μg/dl) or greater with no individual child exceeding 15 μg/dl (nominally, <1% of population).

The strategy to achieve the blood lead goals was to undertake soil and waste removals and capping and stabilization efforts throughout the site that, in turn, would effect sufficient reductions in house dust lead levels. In combination, these efforts would reduce children's lead intake from soils and dusts to sufficiently low levels to meet the blood lead objectives. In the Populated Areas, the soil and dust RAOs included remediation of all yards, commercial properties, and ROWs that have lead concentrations greater than 1,000 mg/kg; achieving a geometric mean yard soil lead concentration of less than 350 mg/kg for each community in the site; controlling fugitive dust and stabilizing and covering contaminated soils throughout the site; and achieving geometric mean interior house dust lead levels for each community of 500 mg/kg or less, with no individual house dust level exceeding 1,000 mg/kg.

House dust has long been recognized as a primary source of lead intake and subsequent absorption among children in numerous populations (PHD 1986). House dusts are the predominant source of exposure for young children within the Box. Previous analyses have suggested that the success of the cleanup depends on reduction of interior house dust lead levels. The Populated Areas ROD requires that should house dust lead levels remain elevated, homes with lead concentrations greater than 1,000 mg/kg will be evaluated for interior remediation (USEPA 1991).

This cleanup strategy was developed in response to studies suggesting that interior dust remediation was not effective in permanently reducing dust lead concentrations prior to controlling exterior sources (CH2MHill 1991a). Interiors of homes that were completely remediated in 1989 were re-contaminated by outdoor sources within one year. Remediation efforts were directed towards elevated lead levels in soil on residential and commercial properties and on ROWs. As the soil cleanup progressed and lead concentrations in interior dusts began to decrease, monitoring of blood lead levels and interior dust concentrations continued through the LHIP. Parents were counseled regarding home and personal hygiene and were encouraged to clean frequently. Access to high efficiency particulate air (HEPA) vacuums was provided for families not having access to vacuum cleaners.

4.2.2 Cleanup Activities under the Populated Areas ROD

The largest Populated Areas source control effort was the block-by-block residential soil removal and replacement and the continuing of the High-Risk Yard Cleanup implemented in 1989. Until 1993, only homes resident to this population (children and pregnant women) with soils greater than 1,000 mg/kg were remediated. In 1993, agreements were reached with several site PRPs to undertake the Populated Areas cleanups pursuant to both the 1991 and 1992 RODs. In 1994, the High-Risk priority schedule was changed to pregnant women and children under 7 years located on yards with soil levels greater than 1,000 mg/kg lead anywhere in the Box. At the same time, the PRP group began cleaning up specified geographic areas of towns including all residential and commercial properties and ROWs that exceed 1,000 mg/kg lead. Residential soils receive a 12 inch removal and clean soil replacement, with garden locations receiving 24 inch removal and clean soil replacement.

Commercial properties throughout the Populated Areas include all non-residential property parcels and have been divided into two types: Type 1 includes properties with unrestricted access by members of the sensitive population, and Type 2 includes all other commercial properties. Type 1 properties with lead concentrations exceeding 1,000 mg/kg receive a 12-inch clean material barrier. Type 2 properties receive a 6-inch barrier. Barrier types may include rock, clean soil, or asphalt/concrete. The barrier type is based on ICP guidelines to ensure that application is sensitive to a property's projected land use and traffic patterns.

ROWs that are candidates for remediation include primary highways, roads, city streets, alleys, electrical utility substations, and buried utility corridors that are not addressed by the residential yards or commercial properties cleanup. In general, ROWs are remediated similar to adjacent properties. For example, an alley adjacent to a residence receiving a 12-inch soil barrier receives the same treatment if lead soil concentrations exceed 1,000 mg/kg at depth. In some locations, access controls such as fencing or modifications in barrier thickness or re-vegetation in lieu of removal is allowed.

For contaminated aquifers, areas of drilling concern have been established. Closure of domestic, industrial, and unused monitoring/test wells is required throughout the site. These closures are required to reduce the potential for human ingestion and/or contact with contaminated groundwater, and to prevent groundwater pollution from surface sources or interconnected aquifers. Owners of wells identified for future closure have been informed about the potential risks associated with using water from these wells and have been advised to use an alternate drinking water source, if necessary. A trust fund has been established to finance future well closures.

From 1994 through present, yard cleanup activities were undertaken by site PRPs. Since 2002, federal contractors have assumed a substantial portion of the remedial responsibility. The USACE has remediated 260 properties (including ROWs and commercial properties) due to the inability of PRPs to meet their obligation.

4.2.3 Cleanup Activities under the Non-Populated Areas ROD

Remedial actions in the Non-Populated Areas became a Fund-lead Project in 1994 when the PRP responsible for the Non-Populated Areas cleanup declared bankruptcy. Following the PRP bankruptcy and initiation of a Fund-lead Project, the USEPA and the State of Idaho negotiated a *Comprehensive Cleanup Plan* (IDEQ 1995) assigning lead and support agency responsibilities and outlining the implementation strategy of the 1992 Non-Populated Areas ROD. During these negotiations, the primary focus of the Non-Populated Areas cleanup shifted from *in situ* containment and management of contaminants to large-scale source removals from the river floodplain, Industrial Complex, and side drainages.

Fund-lead activities have included the final demolition of the Industrial Complex and removal of contaminated soils in the adjacent gulches. Non-populated Areas remedial activities are not addressed by this report. Excavated materials and wastes were disposed of at the Smelter landfill and the mine's Central Impoundment Area (CIA). Both landfills were capped with low permeability geosynthetic covers, clean soil, and vegetation.

The demolition at the Lead Smelter began in March of 1994 and continued through mid-1995. To address the fire hazards at the Lead Smelter and Zinc Plant, general demolition of the complex began in the summer of 1995 and was essentially completed in 1996. All industrial complex debris, Principal Threat Materials (PTM) (i.e., the most severely contaminated materials requiring special treatment), and contaminated soils from adjacent gulches were placed in the Lead Smelter landfill. Following source removals, the adjacent gulches and drainages were stabilized.

The Smelterville Flats area cleanup removed approximately 2 million cubic yards of tailings from the South Fork Coeur d'Alene River floodplain and other adjacent properties. Following the removal, approximately 120 acres of the floodplain was restored to a functional natural system. This removal effort was completed in 2000 and the excavated materials were placed in the 140 acre CIA. After material placement, the CIA was closed with a geosynthetic liner and vegetated soil cap closure system in 2001.

Other remedial actions have included hillsides re-vegetation, stabilization of the major side drainages, and general surface water/water quality management. These efforts began in 1995 and are scheduled to continue until 2005. A site-wide ICP was also adopted in 1995 and is a permanent piece of the remedy.

Future development considerations in each of the major cleanup areas are a key component to assuring long-term remedial action performance. Commercial and light industrial uses are anticipated at all locations within designated areas, except the smelter cap.

4.2.4 Institutional Controls Program

The ICP is responsible for integrating remedial action required to facilitate current and future daily activities with local government and residents as they interact with clean barriers. The ROD for the Populated Areas (USEPA 1991) calls for a one-time installation of barriers on residential and commercial properties. Following remediation, operations and maintenance (O&M) and cleanup or re-remediation of properties recontaminated by events such as flooding, erosion, or redeposition of contaminated soils, become the responsibility of the property owner.

The ROD also requires that an ICP be established to regulate the long-term stability of these barriers in perpetuity and enforce the property owners' obligations. The ICP is a locally adopted set of land use rules and regulations (developed and adopted by PHD in 1995) designed to ensure barrier integrity throughout the site. The ICP is intended to protect the public health and assist local land transactions within the Box realizing that contamination at depth will not be removed. The ICP has been established to oversee the tracking of property cleanup status, permitting contractors to complete work within the Box, to enforce rules and regulations, and to aid residents in interpreting these rules and regulations. The ICP also covers all the day-to-day activities by homeowners, local governments, and contractors who do excavation, grading, landscaping, etc.

The ICP regulates construction and use-changes on all properties where barriers and caps have been applied. The program provides for:

- education,
- sampling assistance,
- clean soils for small projects (less than one cubic yard of material),
- pickup of soil removed from small projects,
- and a permanent disposal site for contaminated soils generated site-wide.

The ICP issues permits and assists with construction and renovation projects on building interiors that include ceiling and/or insulation removal, and work in dirt basements and crawl spaces. The ICP's main enforcement mechanisms are through PHD's environmental health code, which is linked to existing local building departments and land use planning activities, and includes:

- PHD's contaminant management rules, and
- barrier design/permitting criteria.

Ordinances supporting the ICP were also adopted by affected cities and Shoshone County, which require PHD's concurrence prior to issuance of building permits, as well as amendments to comprehensive plans and zoning regulations. Support documents that identify and explain the ICP include a model subdivision ordinance, storm water management requirements, and road standards and design criteria.

4.3 Lead Health Intervention Program

Lead health intervention activities for this project refer to efforts designed to intervene in lead absorption pathways through biological monitoring, follow-up, parental awareness and counseling, education, and behavior modification. The LHIP has been conducted by the local PHD and funded primarily through federal grants to the Idaho Department Health and Welfare, Division of Health (DOH).

The basic elements of the LHIP are:

- voluntary blood lead screening,
- environmental and nursing follow-up,
- education and awareness, and
- targeted source remediation.

4.3.1 Annual Voluntary Blood Lead Screening Program and Community Census

Communities in the Box were surveyed each year from 1985-2002 in July through August. Door-to-door screening in each town was accomplished using local residents trained and hired part-time to canvas neighborhoods. These individuals contacted each household in the study area and identified homes with children through 9 years old and pregnant women. Basic data were collected; residents were solicited to have their children's blood lead levels tested; and an appointment at the local hospital was scheduled. Each eligible child that participated was paid $20. Since 1988, the contents of the home's vacuum cleaner have been collected. Since 1996, dust mats have been placed in homes to assess both lead concentration and dust loading. These results were used to identify candidate homes for the High-Risk Yard Cleanup.

From 1985 to 1987, the screening program drew capillary blood (finger-stick) and analyzed EP levels based on the CDC trigger criteria of 25 μg/dl blood lead and 35 μg/dl EP established in 1985 (CDC 1985). In 1988, the finger-stick EP method was abandoned in favor of venous blood lead draws that continued through 2000. In 2001, a new machine was purchased to analyze capillary blood lead samples by finger puncture. The LeadCare System uses an electrochemical test method with disposable sensors to provide immediate results. A comparison study was conducted relating the results of the side-by-side venous and capillary data in 2001 (See Appendix A). In 2002, the LHIP relied on the capillary results, with confirmation of all results 8 μg/dl or greater by duplicate venous samples (one analyzed by LeadCare and one sent to ESA Laboratories, MA).

In the summer of 2003, the LHIP surveillance protocol was modified in response to consecutive years of low blood lead levels to eliminate the door-to-door survey and incentive payments in favor of a voluntary testing program. Solicitations were made through local newspapers and radio stations. A mass mailing went to all homes on site. Separate from the LHIP, local physicians are encouraged to test children under the Medicaid program.

4.3.2 Environmental and Nursing Follow-up

Follow-up services are provided to the parents of all children exhibiting an elevated blood lead level. From 1985 to 1987, the capillary sample was analyzed for EP and any child with an EP level of 35 µg/dl or greater was scheduled for a venous blood lead level test. A public health nurse provided follow-up for all children with EP levels greater than 35 µg/dl with nutritional counseling as a minimum. Lead health counseling and an environmental survey were conducted for all children with blood lead levels greater than 25 µg/dl. In 1991, the follow-up criterion was reduced to 20 µg/dl in anticipation of the CDC review of the lead health advisory standards that were announced in October 1991 (CDC 1991). In 1992, follow-up was conducted on all children with blood lead levels greater than 15 µg/dl. In 1993, the LHIP follow-up criterion was lowered to 10 µg/dl.

Follow-up consists of a home visit by a public health nurse that provides parents counseling and written information on how to identify sources of lead and reduce their child's exposure. A home survey and questionnaire is completed and educational materials are provided to the parents, as well as nutritional counseling. Multi-vitamins were also provided until 2002. A follow-up blood screen is offered 3-4 months later, and it is recommended that the child's blood lead information be shared with the family physician and that the child participate in the following Summer Screening Program.

The environmental survey includes:

- A records search of environmental data collected from the residence.
- Sampling of soil, dust, paint, water, etc., as appropriate.
- Counseling regarding the avoidance of locally grown produce.
- Education regarding play activities, including those not associated with the primary residence.
- Evaluation of sources of exposure associated with parental occupations, hobbies, and other household activities.
- Evaluation of past or planned home remodeling activities.
- Recommendation for those without vacuum cleaners to use one of the high efficiency vacuums available, free of charge, from the Panhandle Health District since 1991.

4.3.3 Education and Awareness

Each year, a public health nurse visits area public schools, Headstart Programs, and a privately run academy. Presentations are conducted for students in kindergarten through the third grade and differ for each grade (e.g., puppet show, doll house, and glow germs). Presentations to other grades are conducted by request only. The presentations cover the students' role in identification and management of exposure pathways that may affect them or their siblings. The program is presented in May so children are reminded of the hazards of lead in soil and dust prior to summer vacation, when they are at the greatest risk of exposure (Yiin et al. 2000).

A public health nurse and a senior environmental health specialist are available for consultations regarding sources of exposure to lead and the management of exposure pathways. A variety of locally developed fact sheets, brochures, coloring books, and two videos are available regarding lead and children and exposure to lead during pregnancy. Lead health information has been integrated into existing programs offered by the local health district. This information has been added to the Well Child Program, Immunization Clinics, Woman Infant and Children (WIC) Clinics, and pregnancy screening and prenatal clinics offered by the PHD. Prenatal blood level screening is available for all pregnant women in the area through the LHIP. Pregnant women are offered blood lead testing and nutritional counseling during the first and third trimesters and are advised to provide their blood lead and exposure history to their private physicians.

A physician awareness program has been developed to keep local physicians apprized of program activities and the services that are available. Reference materials and a resource manual regarding lead and other heavy metals have been provided to area physicians and the local hospital. Upon request, additional follow-up activities and sampling can be conducted on behalf of physicians attending patients with an elevated blood lead level.

4.3.4 Participation Rates

In 1984, a voluntary fixed site blood lead screening program was met with low participation. Under the LHIP from 1985 to the present, a more aggressive door-to-door solicitation approach was adopted. Beginning in 1988 to encourage participation, each child was paid $20 at the time of blood draw. Eligible participants for this program are defined as children between the ages of 9 months and 9 years.

Annual door-to-door solicitation occurred in July or August. The health district trained and hired local residents to contact each home in the site. Participating families were administered a questionnaire and appointments for blood drawing were scheduled at the local hospital. At residences where no one was at home, a minimum of two call backs were made during the survey period. If residents were still not contacted, a written notice was left informing residents of the survey. During the door-to-door survey, neighbors were questioned regarding homes where no contact was made to determine if children were present. These homes were then contacted at other than working hours. Information from neighbors was also used to calculate an approximate number of eligible children whose parents did not participate.

Participation rates were assessed in the 1999 Five Year Review for the Populated Areas (TerraGraphics 2000b). Additional sources of information regarding the total population of eligible children in the Box were investigated and the notes from the door-to-door survey crews were compiled to determine why individuals elected not to participate in the surveys. With assistance from the Superintendent of School District #391, enrollment and bus chart data were reviewed and the number of children living within the Box in the spring of 1999 was determined. A total of 1,422 students in grades K-12 were enrolled in the school district in the spring of 1999. Of these, 970 or 68% resided within the Box. Using the known total district enrollment for past years, and assuming a constant proportion of the students living within the site, the number of students residing on the site each year for the period 1990-98 was estimated. Because the LHIP focuses on children between the ages of 9-months and 9-years, the estimated Box school enrollment was adjusted, assuming even distribution for each age group to yield an estimate of the total number of eligible children.

Table 4-1 summarizes the participation information from 1988-1998. The estimated number of 9-month to 9-year old children on the site is shown in the first column of Table 4-1 as "Estimated Eligible Population." The second column contains the total number of individual children contacted or otherwise identified in the annual census and survey. This number is the total number of individual children whose parents agreed to participate, whose parents refused to participate, or children identified as resident by neighbors or relatives whose parents were never contacted or did not respond. Those sub-categories of response are included in the next three columns. The percentage of the estimated total eligible population identified in the survey is also found in the second column in parentheses. These data suggest that through 1998, the door-to-door survey was successful in identifying from 61% to 88% of the estimated total eligible population. The latter percentage is from 1998, the only year with bus route records available. The group of children unaccounted for according to comparative school records are referred to as "potentially unidentified" in Figures 4.1 and 4.2a.

In summary through 1998, about 73% of the total estimated population was identified by the door-to-door census. About 75% of those identified agreed to participate and a sample was obtained from about 91% of those participants. Samples were obtained from approximately 50% of the total estimated eligible population, or about 70% from the identified population, of which approximately 50% were repeats from the preceding year.

From 1999 to 2002, between 320 and 370 children provided blood samples each year. This is compared to an average of about 380 children in the previous four years. Records obtained from the local school district indicate that K-5 enrollments are down about 6% for the same period indicating that LHIP participation rate has remained about the same since 1999. This suggests that an estimated 685 children, age 9-month to 9-years, live in the Box in the most recent years. Approximately 54% of these children were tested and 2% of those tested had elevated blood lead levels. Follow-up visits were conducted at the homes of these children and the results indicated that their excess absorption was likely associated with exposures outside of the home environment.

The LHIP is a voluntary program. Compelling participation would require new legislation or application of child neglect laws. In 1998, when complete school records were available, approximately 12% or 88 children were not reconciled with the

Superintendent's estimate. Typically, 4% or about 20 children fail to respond to repeated solicitations, and 20% or 110 children refuse to participate.

Table 4-2 shows a compilation of the reasons included in column five of Table 4-1 provided for refusing to participate. The surveyors' notes were reviewed and the parent's reasons for refusal categorized into common responses. In total from 1990 to 1998, about 21% (Table 4-1) refused to participate at the door. This refusal rate was highest in the most recent years, with 18% and 26% of the eligible population refusing to participate, respectively in 1997 and 1998. Parents are increasingly reporting that their children have tested "safe" in past years; did not want their child subjected to the trauma; believe that the LHIP is no longer, or never was necessary; or were short-term residents of the area.

There had been divergent speculation regarding the direction of selection bias in the voluntary blood lead screening program. Because families whose children tested low during a previous survey may no longer feel in need of the services are declining to participate, participants may be self-selecting toward those with higher blood lead levels. Conversely, those most attentive to lead health issues may be continuing to participate even though their children's blood lead levels are lower. Figure 4.2b illustrates the various reasons children's parents have declined to participate over the years.

Figure 4.1 summarizes the total estimated eligible population for 1998, the only year with available bussing records. Figure 4.2a shows composite estimates for the 1990 to 1998 time period for all children that did not provide blood lead samples. This figure included those potentially unidentified children estimated from school enrollment records. Figure 4.2b shows the same data eliminating the latter group and those that agreed to participate but could not secure a sample. Figure 4.2b shows the aggregate 1990-1998 estimate for all the children specifically identified that elected not to participate.

The high mobility of the target population complicates recruitment of volunteers and matching blood lead levels to environmental samples. Table 4-3 shows the percentage of participating children from Kellogg that resided at their current address for less than six months and less than one year for each survey year. The data in Table 4-3 suggest a mobile population at this site, particularly in Kellogg and in Smelterville (not shown). For the past decade, 30% to 51% of all children in Kellogg resided at their current address less than one year. Immigration was particularly high in 1989, and from 1992-1995, when nearly 50% of the population was new to their homes each year. During those years, a significant portion of these children moved onto contaminated yards, substantially increasing the total number of children at-risk in the community. For example, in 1995 fifty-nine children (or 50% of the newcomers) moved onto contaminated yards in Kellogg, more than in any year since 1991. Similar statistics for families not participating in the survey are not available. With the progress in the yard remediation program, the number of newcomers to contaminated yards was reduced to 15 children (or 19%) in 1997 and to 6 children (or 4%) in 1998. Since 1998, that percentage has remained at around 10%. Prior to the area-wide cleanups, from 30% to 50% of newcomers moved onto contaminated properties.

The substantial number of families that report living at their current address for less than six months or one year confound participation rates and any exposure or toxicity prevalence analysis. There are questions regarding the appropriate characterization of longer term exposures and the representativeness of surveys conducted in summer months when families are more likely to be moving. The LHIP is conducted during the summer months because the highest blood lead levels are expected at this time (Yiin et al. 2000).

4.3.5 Annual Home Follow-up Summaries

Table 4-4 summarizes the home intervention activities undertaken from 1988 to 2002. The number of children provided in-home intervention services increased markedly in the mid-1990s in response to lower blood lead levels recognized as lead poisoning by State and federal health officials. From 1988 to 1990, all children with blood lead levels of 25 μg/dl or greater were eligible for a home visit and follow-up. That level was reduced to 20 μg/dl in 1991, 15 μg/dl in 1992, and 10 μg/dl in 1993. As a result, only a few children received intervention through 1992. Beginning in 1993, substantially more children received these services with more than 30-70 children targeted through 1996, about 30 from 1997 to 1998, 17 in 2000, 12 in 2001, and 8 in 2002.

The effects of health intervention, and particularly home follow-up activities, are difficult to quantify. During intervention, public health professionals visit the homes to observe the home environment and the child's behavior and to counsel parents. Two basic interventions are attempted in this Program:

- Identification and mitigation of a particular source in the child's environment, and
- Accomplishing modification of the child's behavior through parental education.

The latter requires professional and personal communication skills and experience. The level of detail and the apparent effectiveness of these techniques depends on the individual counselor and the receptiveness of the parent. Examination of nursing notes over the eighteen years the LHIP has been active shows considerable differences in the style, level of detail, and approach to the program among various health care personnel. Many of these differences were related to the trigger level used to initiate intervention and the Surgeon General's recommendations for following up high blood lead levels. In the late 1980s, few children exceeded the CDC's 25 μg/dl standard. Lowering this standard in the 1990s substantially increased the number of children included and the intensity of follow-up activities.

The activities and effectiveness of the LHIP efforts were analyzed and evaluated in the 1999 Five Year Review for the Populated Areas. That review included data obtained through 1998. A brief summary of that review is included below. Additional data collected from 1999-2001 is presented below in more detail. More detailed discussion of the earlier results can be found in the 1999 Five Year Review (TerraGraphics 2000b).

1985-1987: The first three years of intervention effort were based on capillary EP screening and a venous whole blood lead level of 25 μg/dl to initiate intervention services. Prior to 1988, parents of children with elevated EP levels, but blood lead concentrations below 25 μg/dl, were provided nutritional information and counseling on iron deficiency anemia. Ten children were provided follow-up after exhibiting elevated blood lead levels in 1985-87. Health department personnel found the following factors contributing to these children's excess exposure: elevated soil and dust lead concentrations in all cases, poor personal hygiene of the child in two cases, poor household hygiene in four cases, pica behavior (the tendency to ingest non-food items) in three cases, poor nutrition in two cases, poor soil cover in two cases, and extreme exposure situations in five cases. Of the latter, two children were exposed to extremely high soil/dust lead concentrations associated with the yard or home remodeling, and two children were exposed to occupational dusts brought into the home by the parent. Exposures for three of these children were likely exacerbated by family pets bringing soil and dust into the home.

Intervention efforts were believed to have had immediate success in reducing exposures for five of the nine children whose families were accessible and cooperative. Blood lead levels were reduced by 14% to 60% in one to two years for these children. The most important interventions noted were improved personal and home hygiene due to the parental education counseling program and the elimination of extremely high lead sources in the home. All of the remaining children showed marked declines in blood lead levels three or more years later, but these declines may have been associated with age, moving, or a yard remediation.

1988-1990: A total of 230 children were screened in Kellogg, Smelterville, Page and Wardner in 1988. Screening in Pinehurst did not commence until lowering of the blood lead level of concern was anticipated in 1990. Geometric mean blood lead levels in these communities were about 7 μg/dl to 13 μg/dl in these years with 29% to 78% of children exceeding 10 μg/dl blood lead. Individual blood lead levels exceeding 40 μg/dl and 55 μg/dl were reported during this time.

During this period, follow-up efforts were based on venous blood lead levels of 25 μg/dl or greater. Nine children were reported with elevated blood lead levels and seven children received follow-up attention in 1988. Substantial immigration to the site occurred in 1989 with a total of 275 children surveyed in the same area, a 20% increase over 1988. Two children had levels exceeding 40 μg/dl. Eight children were identified with blood lead levels greater than 25 μg/dl and eight children received follow-up. However, one of these was a sibling with a blood lead level <25 μg/dl. The six month follow-up protocol (winter screening) conducted the previous year was dropped because it was believed to be discouraging participation rates, particularly among lower socioeconomic groups. In 1990, a total of 362 children provided blood lead samples and only three children were presented for follow-up in 1990. The maximum blood lead level reported was 30 μg/dl.

Risk profiles developed for children during this time period showed extreme exposure situations. Risk co-factors included a home with no electric power or heat, houses and yards in poor condition, highly contaminated yards and children's play areas with little vegetative cover present, poor home and/or personal hygiene, and poor nutritional status. Some were extremely active children that exhibited pica-like tendencies. One child's father had been severely lead poisoned in salvage operations at the smelter complex and was believed to be bringing lead dust home on his clothes, exposing the child. Another home visit revealed that the parents practiced a lead-related hobby and recent remodeling activities had deposited contaminated dusts into the child's bedroom.

Subsequent blood lead levels were notably lower for 13 of the 20 individuals receiving intervention services. No decrease was observed for two children and follow-up results were unavailable for the remaining five children. The High-Risk Yard Cleanup began in 1989 as a new source control measure in the intervention program. All children that had follow-up also received home yard soil replacement, if appropriate. This program had positive effects in reducing exposures as ten of the thirteen children showed lower follow-up blood lead levels. More detailed descriptions of these children's risk profiles can be found in the 1999 Five Year Review (TerraGraphics 2000b).

1991-1992: These years marked the transition of the follow-up criteria in response to the CDC's review of lead poisoning in children (CDC 1991). The criterion was lowered to 20 μg/dl in 1991, 15 μg/dl in 1992, and 10 μg/dl in 1993. By 1991, the effects of the yard removal program on site-wide exposures and blood lead levels were evident. More than 75% of children were on yards with soil concentration less than 1,000 mg/kg as compared to 17% in 1989. Site-wide mean blood lead levels had dropped by approximately 35% since 1989 to around 6.0 μg/dl. Six (6) children were presented for follow-up in 1991.

In 1992, substantial immigration to the site occurred and increased participation by 15% in Smelterville, 19% in Kellogg, and 4% in Pinehurst. Site-wide, 14% more children were screened in 1992 than in the previous year. Despite the fact that more than 100 additional high-risk homes resident to children were remediated in 1991, nine more children (92 versus 83) were observed living on contaminated yards than the previous year. Mean site-wide blood lead levels increased by about 1 μg/dl to 6.5 μg/dl, and the percentage of blood lead levels exceeding 10 μg/dl increased from 15% in 1991 to 27% in 1992.

This combination of factors greatly increased the follow-up demand and 30 children were provided intervention services in 1992. Ten of these children had been in the program previously, but had not been identified for follow-up under the old criteria. Modest decreases in blood lead levels were noted for most of these children following intervention and yard remediation efforts.

Fifteen of the children with blood lead levels greater than 15 µg/dl were in the program for the first time in 1992. Only two of these children reported living at their current address for more than one year. The remaining thirteen children with blood lead levels greater than 15 µg/dl were new to their homes in 1992. Parents for seven of these children were positively identified as new to the area and had moved in unaware of the potential lead problems. In each of these cases, health department personnel felt confident that intervention through educating the parent was the primary factor in reducing blood lead levels. No behavioral, nutritional, or hygiene problems were identified with these families. Unlike other members of this community, they were unaware of the hazards. Working with the parents of these children and remediating the yards achieved an average 60%, or approximately 12 µg/dl drop in blood lead levels in 6 to 12 months for these children.

Of the remaining six children provided follow-up in 1992, it is unknown if the parents were previously aware of site hazards. Their participation in the 1992 blood lead survey was their first formal contact with the program. Four of these children reported blood lead levels less than 10 µg/dl by 1993. No follow-up blood lead levels were obtained for the other two children.

1993-1995: The number of children requiring follow-up increased markedly in 1993 as the intervention criteria was reduced to 10 µg/dl. Sixty-six children were targeted for follow-up and 56 were completed in 1993. The number of children demonstrating toxicity peaked from 1993 through 1995 with 71 (17%) children exhibiting blood lead levels exceeding 10 µg/dl in 1994 and 62 (15%) children in 1995. Follow-ups were completed on 53 children in 1994 and 58 children in 1995. During this period the high-risk yard remediation program was significantly curtailed as cleanup negotiations with the Site's PRPs stalled. Only 39 homes were remediated in 1993 and the number of children living on contaminated yards increased through these years from 19% in 1993 to 29% in 1995. Mean blood lead levels remained constant near 5 µg/dl to 6 µg/dl and the percentage of children with greater than 10 µg/dl blood lead was from 15% to 17% site-wide.

Five children in 1993, six children in 1994, and four children in 1995 had blood lead levels exceeding the 20 µg/dl medical intervention level. These children represent the upper 1-2% of the blood lead distribution for the population tested. This group is similar to those provided intervention services in the earlier years of the program. Their risk profile also showed extreme exposures and behaviors that left them susceptible to lead poisoning. Several of these children were noted to exhibit pica-like tendencies, had poor nutrition and hygiene status, and tended to spend a great deal of time outdoors, playing in contaminated areas, and engaging in vigorous activities. Health response personnel noted that many of these children spent time in extended family day care situations at homes that had not been remediated. Several siblings, and cousins and relatives were noted to have exhibited elevated blood lead levels and the LHIP had limited success in achieving significant reductions among these families. Recontamination associated with flooding and remodeling was observed and sub-standard housing and lead paint exposures were noted. One parent was found to be bringing lead dust home from the workplace on his clothing.

One three-year-old child, with a blood lead level of >30 μg/dl in 1995, lived with an extended family with several children that had previously displayed excess absorption problems. Children in this neighborhood played on a number of contaminated unremediated properties and the railroad corridor. This child was reportedly outdoors 10 to 12 hours per day. Home and personal hygiene was rated as fair and the child exhibited frequent hand to mouth activity. This child had a 10-15 μg/dl blood lead level in 1994. In 1995, the family camped for the entire summer in a tent along the river at Cataldo. PHD officials felt that exposure to high concentrations of lead (>20,000 mg/kg) in river sands and floodplain deposits in this area was a significant contributor to this child's poisoning.

The LHIP was now conducting home visits, investigating exposure situations, developing risk profiles and providing intervention services to as much 17% of the population with the highest blood lead levels. Subsequent analysis of these data conducted in the 1999 Five Year Review suggests that the intervention effort showed detectible effects in reducing blood lead levels for the upper 5^{th} percentile of the distribution. It was suggested that these children were exposed to the most severe environmental conditions; highest lead concentrations in environmental media; exhibited extreme behaviors; and/or experienced disadvantaged nutritional, hygiene and family co-factors. These factors could be most readily identified in follow-up investigations and remedied through parental cooperation. In 1993-95 these were children with blood lead levels greater than 13 μg/dl to14 μg/dl.

However, these techniques are apparently less effective for children with less severe blood lead levels. The behavior and pre-disposition of these children are more typical and less prone to modification. For these children, the causes are likely more attributable to typical lead levels in their environment rather than extreme conditions or unsafe behaviors. Although intervention may be successful in reducing the extreme responses in a population, these results suggest that effectively reducing blood lead levels for the bulk of the population requires source control.

Children in the 10 μg/dl to 14 μg/dl range may not have benefited directly by a detectible blood lead reduction due to intervention efforts. However, the LHIP learned some valuable lessons in developing these risk profiles that served to reduce blood lead levels throughout the community in the following years. Investigation of children with blood lead levels in the 85^{th} -95^{th} percentiles of the distribution showed that many of these children were associates, playmates and companions of each other and children showing higher absorption rates. Many of these children experienced common exposures in their neighborhoods as they engaged in group-play activities. The significance of neighborhood soil and dust exposures became more apparent as more of these investigations were conducted and area-wide cleanup activities commenced in the next few years.

1996-1998: Marked reductions in mean blood lead levels and the number and percentage of children exhibiting excessive absorption corresponded with significant reductions in the percentage of children living on contaminated yards and neighborhood soil contamination levels in the next three years. Mean blood lead levels decreased by about 20% from greater than 5 µg/dl in 1996 to about 4 µg/dl in 1998. The percentage of children living on contaminated properties was reduced from 19% to 4%. Children with blood lead levels greater than 10 µg/dl decreased from 12% to 8% at this time.

Much of the improvement was attributable to the cleanup of particular geographic areas. Cleanup in Smelterville was completed in 1997. In addition to the Kellogg housing complex discussed below, the railroad corridor noted in several children's exposure profiles was remediated in 1998. In 1997, several children were exposed to silt and sediment (as contaminated as 10,000 mg/kg lead) deposited during the Milo Creek flood in May of that year. More than 50 properties and 5 miles of public ROWs were contaminated, or recontaminated, in the flood. The area was re-remediated in 1997 and the corridor through Wardner and Kellogg was reconstructed with clean materials during the 1998-2000 Milo Creek Flood Control Project.

In 1996, 49 children exceeded the 10 µg/dl blood lead criteria. Two siblings, 2 and 4 years old, had extremely high levels with one exceeding 30 µg/dl and one exceeding 50 µg/dl. The latter child was hospitalized for chelation therapy. Risk profiles for these children indicated a difficult home environment, deficient housing, poor hygiene, outdoor play up to 14 hours per day, positive pica tendencies, and unsupervised access to highly contaminated soils. No paint problems were indicated.

These children resided on contaminated property in a newly constructed multiple-family dwelling complex. The area was located in the former river floodplain and was highly contaminated. Several homes were tested showing soils contaminated in the 5,000 mg/kg to 10,000 mg/kg lead range. The area had an unpaved road, little ground cover, and was surrounded by contaminated hillsides. Seven of fourteen children tested in 1995 in this complex were identified with excess absorption. PHD and State officials requested that the entire area be remediated in the fall of 1995, but the request was rejected by the PRPs. Thirteen children were tested in this housing complex in 1996. Seven children had levels exceeding 10 µg/dl; 3 exceeded 15 µg/dl, and 2 exceeded 30 µg/dl. The area was fully remediated in 1996, except for the adjacent hillsides. No children from this complex exceeded 10 µg/dl in 1997.

In 1997, 36 children exceeded 10 µg/dl, and 32 received follow-up services from PHD. One five year-old child had a blood lead exceeding 20 µg/dl. This child also had an older sibling with an elevated blood lead level. These children's yard was remediated and household hygiene was reported as good. The children did not exhibit pica-like behavior, but personal hygiene was reported as poor and hand-to-mouth activity was observed. Both children also spent 8 to 10 hours outdoors in the summer and reportedly played in contaminated areas.

Five children had blood lead levels between 15 µg/dl and 20 µg/dl in 1997. All but one of the children lived in Kellogg. Generally, these children played in areas with high lead concentrations. Two children played in areas affected by the Milo Creek flood and one reported playing in a neighborhood mine dump. Three of the children exhibited pica behavior. Thirty children in the 1997 blood screening had blood lead levels between 10 and 14 µg/dl. Fourteen of these children played in areas affected by the Milo Creek flood and nine resided in a single apartment complex that was impacted by the flood. Two children were reported to have camped for an extended period at a contaminated public campground in the Lower Basin in the months prior to the blood draw. Two children moved from homes in Wallace with unremediated yards four months before the blood draw. Three children played on contaminated hillsides in Smelterville; three additional children from Smelterville reportedly played in various areas around town. Sixteen of the thirty children showed pica-like behavior.

In 1998, 31 children had blood lead levels exceeding 10 µg/dl with one blood lead level equal to 20 µg/dl. Four children did not receive follow up because they moved out of the area. Five children in 1998 had lead levels between 15 µg/dl and 20 µg/dl. Two of the children had reportedly played under the bleachers of the Pinehurst Elementary playfield, where soil lead concentrations ranged from 1,500 to 4,100 mg/kg. Two children had repeated exposure to recreational areas in the Lower Basin. Hand-to-mouth behavior for toys, rocks and dirt, and/or thumb sucking was reported as frequent for four of the five children. One child lived in a home with an interior mat dust lead concentration above 1,100 mg/kg and one lived in a home with chipping paint in the children's bedroom.

Twenty-six children had blood lead levels between 10 µg/dl and 14 µg/dl in 1998, with approximately half equal to 10 µg/dl. Six of these children played on contaminated hillsides and their ages ranged from 4 to 9 years old. Eight children were reported as having camped at contaminated Lower Basin campgrounds for extended periods. Eleven of the children lived in homes with interior dust lead concentrations exceeding 1,200 mg/kg. Chipping paint was reported as a possible exposure source for two of the children. Six children were reported as exhibiting poor personal hygiene or household hygiene. Eleven children exhibited pica-like hand-to-mouth behavior.

1999-2002: During this period the number of children with blood lead levels exceeding 10 µg/dl decreased markedly from 23 to 7 children. This corresponded to 6% and 2% of the sampled population, respectively. Site-wide mean blood lead levels decreased from 3.9 to 2.6 µg/dl. Follow-up efforts are again targeted to the highest 1-2% of the population, as few children exceed the 10 µg/dl blood lead criterion. Year-by-year summaries of follow-up findings are presented below.

1999: A total of 49 children provided samples in Smelterville and two (or 4%) had blood lead levels exceeding 10 µg/dl in 1999, down from six (or 14%) in 1998. One child's level exceeded 15 µg/dl and one had a blood lead equal to 10 µg/dl. The 1999 geometric mean blood lead level in Smelterville was 3.6 µg/dl, down from 5.8 µg/dl in 1998 and 5.2 µg/dl in 1997. Follow-up surveys were conducted on the two children with blood lead levels exceeding 10 µg/dl. Risk profiles showed both children had potentially significant exposures in contaminated play areas; the child exceeding 15 µg/dl had stayed at a contaminated Lower Basin campground for one month during the summer. This child also exhibited significant hand-to-mouth activities or pica-like tendencies and lived in a home with chipping exterior paint with a high lead content. The child with a blood lead level equal to 10 µg/dl reportedly played outdoors for at least ten hours a day in the yard and at a relative's home in Page. Unlike previous years, no children targeted for follow-up in 1999 reported playing on unremediated hillsides in Smelterville.

Children in Kellogg continued to have a significant frequency of high blood lead levels. In 1999, 6% of children tested, or eleven of 198 children in Kellogg have blood lead levels equal to or exceeding 10 µg/dl. This result was down from 10% (21 children) in 1998 and 15% (29 children) in 1997. Follow-up was completed on all eleven children. Ten children's profiles indicated exposure to contaminated soils in play areas or day care situations, four of those in non-remediated areas in Kellogg and five children reported playing in areas outside of the Box in the Lower Basin or in nearby gulches. None of the children reportedly lived in homes with potential exposure to lead-based paints. Ten children showed significant hand-to-mouth activities, including sucking fingers and thumbs. Personal or home hygiene problems were indicated for two children. Six of the eleven children lived in a home with dust lead levels greater than 1,000 mg/kg. Three children living in the flood-exposed area near Milo Creek exhibited blood lead levels greater than 10 µg/dl; as opposed to six reported in 1998 and thirteen in 1997.

As in 1998, little or no exceedance of critical toxicity levels was observed in Wardner and Page. In 1999, one child out of nine (11%) tested in Wardner had a blood lead level exceeding 10 µg/dl and none in Page. Seven children of 106 (7%) tested in Pinehurst had blood lead levels between 10 and 15 µg/dl and two had blood lead levels above 15 µg/dl (for a total of 8% greater than or equal to 10 µg/dl and 2% greater than or equal to 15 µg/dl). This was the highest proportion of children exhibiting excessive blood lead levels in Pinehurst since testing began in 1990. All ten children were provided follow-up in these communities. Five children were indicated as having possibly significant exposure to contaminated and unremediated play areas in Pinehurst; three children also camped for extended periods of time in areas of the Lower Coeur d'Alene River Basin prior to blood being drawn. Three children were indicated as recently moving from other Coeur d'Alene Basin communities. Three children were noted as having poor household or personal hygiene. Six children exhibited pica behavior and one child resided in a home with interior and exterior peeling paint. Six children lived in a home with dust lead levels exceeding 1,000 mg/kg.

2000: A total of 44 children provided samples in Smelterville and four (9%) had blood lead levels exceeding 10 µg/dl in 2000, up from two (4%) in 1999 and six (14%) in 1998. Two children had levels that exceeded 15 µg/dl. The 2000 geometric mean blood lead level in Smelterville was 3.7 µg/dl, 3.6 µg/dl in 1999, 5.8 µg/dl in 1998 and 5.2 µg/dl in 1997. Follow-up surveys were conducted on the four children with blood lead levels exceeding 10 µg/dl. Two siblings lived in poor housing conditions with possible exterior lead paint exposure. Two children exhibited excessive hand-to-mouth activities. High house dust lead concentrations and playing on contaminated hillsides was indicated for one child. In 2000, 3% of children tested, or 6 of 170 children in Kellogg had blood lead levels greater or equal to 10 µg/dl. This result is down from eleven children (6%) in 1999, 21 children (10%) in 1998 and 29 children (15%) in 1997. Follow-up was completed on all six children. Three children were indicated to exhibit pica-like behavior. Two homes showed high dust lead concentrations, but no source was identified. No remarkable risk factors were found for three children and one parent refused to cooperate with the follow-up.

Consistent with preceding two years, few exceedances of critical toxicity levels were observed in Wardner and Page. In 2000, one child out of eight (13%) tested in Page had a blood lead level exceeding 10 µg/dl and none in Wardner. Playing on contaminated hillsides was also indicated for the 9 year-old child in Page. Six children out of 91 (7%) tested in Pinehurst had blood lead levels between 10 and 15 µg/dl and two (2%) had blood lead levels above 15 µg/dl. One child had pica-like behavior. One had no remarkable risk indices and four lived in homes with yard soil concentrations between 850 mg/kg and 1,000 mg/kg.

2001: In 2001, 322 children were tested using the capillary finger-stick method. All capillary results 8 µg/dl or greater were confirmed by venous/laboratory samples. Ten children were confirmed with high blood lead levels, or 3%, of the tested population. Seven of 182 children, or 4% exceeded 10 µg/dl blood lead in Kellogg and one child was from Wardner. Follow-up investigations were reported for seven of the eight children. Potential paint and remodeling exposures were indicated for four children. Extended recreation in the Lower Basin lakes and river was indicated for five of the children. Playing on contaminated hillsides or at unremediated properties belonging to extended family members was indicated for four children. Pica-like behavior occurred for two of the children. Both children exhibiting high blood lead levels in Pinehurst received follow-up. Both indicated extended recreation in the lower Basin. One lived on an unremediated property. Paint was a potential source for one child and one child had pica-like behavior.

2002: In 2002, 368 children provided samples and seven were confirmed with blood lead levels of 10 µg/dl or greater. Four of five children from Kellogg were provided follow-up. One child's blood lead was not confirmed as elevated on venous redraw. Two children had suspected exposure to high concentrations of exterior peeling paint. One child lived in a non-remediated home with a yard soil concentration of 3,500 mg/kg lead and one recreated in the lower Basin. All three children followed in Pinehurst reported extended recreational activity in lower Basin campgrounds. One also had paint noted as a possible source.

4.4 Soil Remediation and Environmental Exposures

4.4.1 Remedial Progress

Table 3-1 and Figures 3.1a-b summarize the residential yard soil remediation progress. More than 1,800 home yards were estimated as being above the action level of 1,000 mg/kg lead on the site in 1989. Most of these homes were located in Kellogg, Smelterville, and Wardner, where over 70% of yards exceeded action levels. The remaining contaminated homes are in the communities of Pinehurst, Page, and other unincorporated residential areas. Subsequent sampling conducted since the ROD has shown additional contaminated properties, particularly outside PRP boundary areas.

By the end of the 2002 removal season, more than 1,500 yards, or about 84% of all of the homes on-site had been remediated. By city, 89% of Kellogg, 48% of Page, 31% of Wardner, and 87% of Pinehurst's yards had been remediated by 2002. The Smelterville remediation was completed in 1997.

4.4.2 Children Living on Contaminated Yards

The strategy of the High-Risk Yard Soil Removal Program was to remediate as many homes with young children and pregnant women as soon as possible. Table 4-5 and Figure 4.3 show the annual percentages of children living on clean yards (remediated or yards not requiring cleanup) versus children on contaminated yards (those above the action level at the time of each survey). Remediation status for each year is updated after the blood lead survey. These values reflect the numbers, and percentages, of children whose exposures were reduced by living on yards remediated at least one year earlier.

Table 4-5 shows that this program resulted in reducing the percentage of children on high-risk yards site-wide from 83% in 1989 to 25% in 1991. However, that percentage varied from 18% to 29% through 1996. Substantial progress has been achieved since 1996. Site-wide, this percentage decreased from 19% in 1996, to 9% in 1997 to 4% in 1998. Only Kellogg has showed a significant percentage of children on yards exceeding 1,000 mg/kg lead since 1996 (27% in 1996, 13% in 1997) and has remained at 6% since 1998.

Figure 4.3 shows that prior to the yard remediation program (1988-1989), more than 80% of children in Smelterville and Kellogg, and about 60% of Wardner and Page children were living on yards above the 1,000 mg/kg action level. With the onset of remediation, progressively more children transferred from the high soil to the low soil group. By 1990, that number had decreased to about 55% for Kellogg and Smelterville, and about 35% for Page and Wardner. Pinehurst was sampled in 1990 and approximately 12% of children were living on yards above the 1,000 mg/kg action level. With the addition of

Pinehurst to the database, the site-wide split was almost even with 43% on high soils, 57% on low soils.

By 1991, the majority of children had progressed to the low soil category with 25% of children remaining on high soils. In 1991, about 33% of Kellogg and Smelterville children, and 11% of Pinehurst children were on contaminated yards. In 1991, no children were on contaminated yards in Page and Wardner. Steady decreases of about 10% per year in the number of children at risk have been observed in Smelterville since 1993, with nearly all children on yards of less than 1,000 mg/kg achieved in 1996.

The same result was achieved again for Page in 1995. Little progress was evident in reducing the percentage of children on contaminated yards in Kellogg between 1991 and 1996, with levels fluctuating between 20% and 40% of the population. The site-wide percentage of children on contaminated yards was nearly constant from 1991 to 1996 and, in fact, increased to 29% in 1995 due to a large number of new children moving onto contaminated yards in Kellogg. Similarly, about 5% of Pinehurst children lived at homes with contaminated yards since 1994. The percentage of Wardner children on contaminated yards increased to more than 60% in 1996. This percentage, however, is due to a small number of families moving to homes with unremediated yards. Since 1998, the percentage of tested children on contaminated yards has ranged from 3% to 6% site-wide in the Box.

Corresponding drops in blood lead levels and the number of children exhibiting toxicity were also noted. Figure 4.4 shows percent of children tested with blood lead levels exceeding the 10 μg/dl and 15 μg/dl since 1988, plotted with the percentage of children residing on contaminated yards in the corresponding year. The annual data points show that considerable progress was made in transferring children from contaminated to clean yards from 1989 to 1991, and corresponding decreases in blood lead levels were achieved. However, progress stalled from 1992 to 1996, with increases in the number of children living on contaminated yards occurring in 1992 and 1995. Progress was again made in 1996 through 1998, when all-time lows in both toxicity and the percentage of children on contaminated yards were achieved. Few children have been on contaminated yards since 1999 and the percent of children with elevated blood lead levels has been less than 5% since 2001. The relationships between soil remediation, reduced soil and dust exposures, and declining blood lead levels is discussed in detail in Section 5.0.

4.4.3 Characterization of Soil and House Dust Lead Exposures

Site-wide soil and dust lead concentrations were presented in Section 3. In this section these concentration measurements are converted to exposure variables. Exposure variables refer to those media concentrations that were experienced by individual children that provided blood results. Due to the complicated nature of the cleanup and a highly mobile population, four different soil and dust exposure variables are tracked and used in assessing remedial effectiveness. Figures 4.5a-e illustrate three of these metrics for each community in the Box. The geometric mean *community-wide soil lead concentration* for all home yards represents the overall soils in each town, the child-based mean *yard soil lead exposure* and *house dust exposure* represent individual homes occupied by children 9 years of age or less that participated in the LHIP. *Neighborhood soil exposures* are estimated by GIS techniques aggregating all yard soil lead observations within various radii around each child's home. These different concentration measures over time demonstrate direct and indirect benefits of the systematic, block-by-block residential soil cleanup on individual soil and dust exposures.

The residential soil cleanup was prioritized differently as the cleanup progressed. Initially, soil remediation was targeted at those yards with the highest lead levels at homes occupied by the youngest children, pregnant women, or those children with high-blood lead levels. In later years, neighborhood-wide cleanups were accomplished for all homes in an area. As a result, exposures to home yard soils changed abruptly for most individuals in the early years, neighborhood-exposures to soils declined slowly until the area-wide strategy reached that location and then were markedly reduced, and community-wide exposures declined steadily for a decade until completion of the program. Because the area-wide remedial strategy was accomplished in different communities in different years, soil exposure reductions also vary by community.

To assess the significance of the remedial actions in reducing soil exposures, changes year-by-year and community-by-community for the home, neighborhood and community-wide environment were examined. Tables 4-6a-d through 4-8a-d show analysis of variance results by year for mean *individual yard soil exposures* and *neighborhood soil exposures* for resident children site-wide and for each city, and *community soil concentrations*. These tables show that significant changes in geometric soil lead levels were noted for a number of years ($p \leq 0.05$).

4.4.3.1 Yard Soils Lead Exposures

Table 4-9 shows arithmetic and geometric mean *yard soil exposure* levels by town and site-wide for the years 1974-2002. Because the yard remediation effort was focused on high-risk children (i.e., young children on high lead soils), these soil exposure measurements represent only homes where children reside, and differ from the community-wide means that represent all yards in a city. The community-wide arithmetic and geometric mean lead concentrations for all yards in a community are shown in Table 3-1. These mean values decrease each year proportionately to the number of yards remediated.

Extremely high standard deviations in *yard soil exposure* levels are noted in Table 4-9 after 1990. This is because the remediation effort results in a bi-modal distribution of yard soil lead levels. As a High-Risk yard is cleaned up, that observation moves from the high end of the soil distribution to an imputed post-remediation value of 100 mg/kg lead at the lower extreme. The pre-remedial distribution in 1988 had a number of children exposed to extremely high concentrations in the tail of the distribution. Remediation activities resulted in a bimodal distribution through 1996 that will become log-normal and truncated with no yard exceeding 1,000 mg/kg lead at completion of remedial activities. For example the gsd for Smelterville was 2.33 prior to remediation, peaked at 5.88 at the beginning of the geographic areas cleanup and decreased to 1.83 after certification of completion of remedial actions.

Tables 4-6a-d show analysis of variance results for mean individual yard soil exposures when each year's data were compared to the previous. These tables show that site-wide geometric mean yard soil exposures at homes where children resided decreased from more than 2,000 mg/kg in 1988 to 581 mg/kg in 1990 and 312 mg/kg in 1991. This reduction corresponds with the first two years of the high-risk yard soil removal program and the effect was significant in both Kellogg and Smelterville. Yard soil exposure from 1991 to 1996 was largely unchanged. Since 1996, significant decreases in yard soil lead levels were again noted with area-wide cleanup activity in Smelterville (1995-1996) and Kellogg (1996-1997). In 2000-2001, a significant difference was observed associated with geographic areas cleanup in Pinehurst. These trends are consistent with the number and percentage of children residing on contaminated yards throughout the cleanup.

Examination of the analysis of variance tables for the individual cities shows that this pattern of significant ($p<0.05$) decrease was most consistent in Kellogg where large numbers of children reside. Results from Smelterville are more difficult to interpret due to smaller numbers of observation and Wardner and Page results are omitted for the same reason. The change in mean yard soil exposure was significant in 1989-1991 and 1996-1997 in Kellogg, for 1989-1990 and 1995-1996 in Smelterville, and 2000-2001 in Pinehurst. However, in 1993-1994 in the initial years of the High-Risk Yard Cleanup, a marginally significant ($p=0.051$) decrease was observed in Pinehurst. Other than those particular years, significant year-to-year decreases in individual yard soil lead exposures were not observed in any city.

4.4.3.2 Community-wide Soil Lead Exposures

Community-wide soil lead exposures are represented by the geometric mean concentration variable presented in Section 3.1.1. This variable is community-specific, as opposed to the other soil/dust exposure variables that are child or home-specific. Figures 4.5a-e show the community-wide geometric mean soil concentration variable along with the yard soil exposure geometric means for the years 1988-2002. These figures show the progress in reducing soil lead exposures for children in these communities as remediation progressed. Over the fifteen-year period, soil exposures were a combination of the individual yard and the aggregate of all other soils, and dusts in the community and individual homes. The RAO with respect to these soils is to eliminate the high soil exposure category by removing all soils greater than 1,000 mg/kg and reducing the community-wide geometric mean to less than 350 mg/kg. That goal was reached in Smelterville in 1996 when the remediation of all remaining yards exceeding 1,000 mg/kg lead was completed. In 2002, geometric mean soil lead concentrations were 209 mg/kg in Kellogg, 363 mg/kg in Page, 274 mg/kg in Pinehurst, 122 mg/kg in Smelterville and 497 mg/kg in Wardner.

Tables 4-7a-d show analysis of variance results for the community mean soil concentrations for all homes in the Box. Significant reductions were noted site-wide from 1989 to 1999, with the exception of 1993-1994. In 1993, protracted negotiations between the governments and the site PRPs delayed the remediation program and only 39 homes were remediated site-wide. Generally, large reductions were associated with area-wide removal efforts. No significant change occurred in Kellogg in 1993-1996 when remedial efforts were focused in Smelterville and after 2000 when area-wide efforts switched to Pinehurst. Conversely, large reductions were noted in Smelterville in those years, with the geometric mean for the community dropping from 1,155 mg/kg in 1994 to 547 mg/kg in 1995 to 142 mg/kg in 1996. No significant change in year-to-year geometric mean soil concentrations was observed in Pinehurst until area-wide cleanups were accomplished from 2000 to 2002.

4.4.3.3 Neighborhood Soil Lead Exposures

Tables 4-8a-d show analysis of variance results for the 200 ft. radius neighborhood soil lead concentration variable specific to each child's home. In contrast to the individual yard soil exposure variable, significant changes in mean neighborhood soil concentrations are noted throughout the last decade. Site-wide, significant differences in neighborhood concentrations occurred in every year through 1998 except 1994-1995. In 1994-1996 remedial efforts concentrated in Smelterville where a significant reduction from a geometric mean of 1,073 mg/kg to 132 mg/kg was achieved (p=0.0001). A significant increase occurred in Kellogg in this period as children moved into contaminated neighborhoods. The site-wide reduction seems isolated to Kellogg and Smelterville, as no significant change from year to year was observed in Pinehurst until 1999-2001. The difference over all the years was also insignificant in Pinehurst (p=0.1112). No changes have been observed in Smelterville since the majority of yard remediations were completed in 1996.

4.4.3.4 House Dust Lead Exposures

Table 4-10 shows both arithmetic and geometric mean house dust lead exposures by town for 1974-2002. The values in this Table differ from those in Table 3-2, in that these are means by child rather than by home. That is, exposure means are weighted according to the number of children providing blood lead samples from any home. Concentrations in Section 3 apply only to individual homes. House dust was not sampled in 1989 and concentrations for that year were substituted from 1988 values from the same house.

Tables 4-11a-d show year-to-year analysis of variance results for each community. Geometric mean dust lead exposures have decreased by about 50% between 1988 and 1995. The largest reductions were observed in Kellogg, where geometric means dropped from near 1,600 mg/kg in 1988-89 to approximately 1,250 mg/kg in 1990-91 to about 670 mg/kg by 1994-95 to almost 360 mg/kg in 2001-2002. Smelterville house dust lead exposures ranged from 1,200 to 1,850 mg/kg through 1991, dropped to 880 mg/kg in 1992, increased slightly in 1993, dropped to 700 mg/kg by 1995, ranged from 350 mg/kg to 600 mg/kg from 1996 to 2000 and then dropped to less than 300 mg/kg in 2001. Pinehurst house dust exposures have gradually decreased from a geometric mean of 747 mg/kg in 1990 to 299 mg/kg in 1995, and ranged from 300 mg/kg to 400 mg/kg through 2000. In 2001-2002 , as PRP yard remediation activities focused in Pinehurst, mean house dust lead exposures decreased by more than half to 222 mg/kg in 2001 and 157 mg/kg in 2002. Both were significant year-to-year decreases.

The vacuum bag results reported in Table 4-10 come from homes of children participating in the LHIP for the years 1988-2002. In recent years, almost all of these children have lived in homes with clean yards. Major remedial activities were completed in 2000-2001 in both the Populated and Non-Populated Areas. Both the PRPs and the USACE were completing geographic areas cleanups in Pinehurst and Kellogg, respectively. The CIA was capped and closed, the Smelterville Flats and Hillsides re-vegetation programs were showing success and the Milo Flood Control Project had capped large portions of Kellogg and Wardner properties and gravel ROWs. These efforts eliminated or curtailed significant fugitive dust sources, and any construction related dusts terminated with completion of the remedial activities.

Figure 4.1
Total Population Participation Summary, 1998

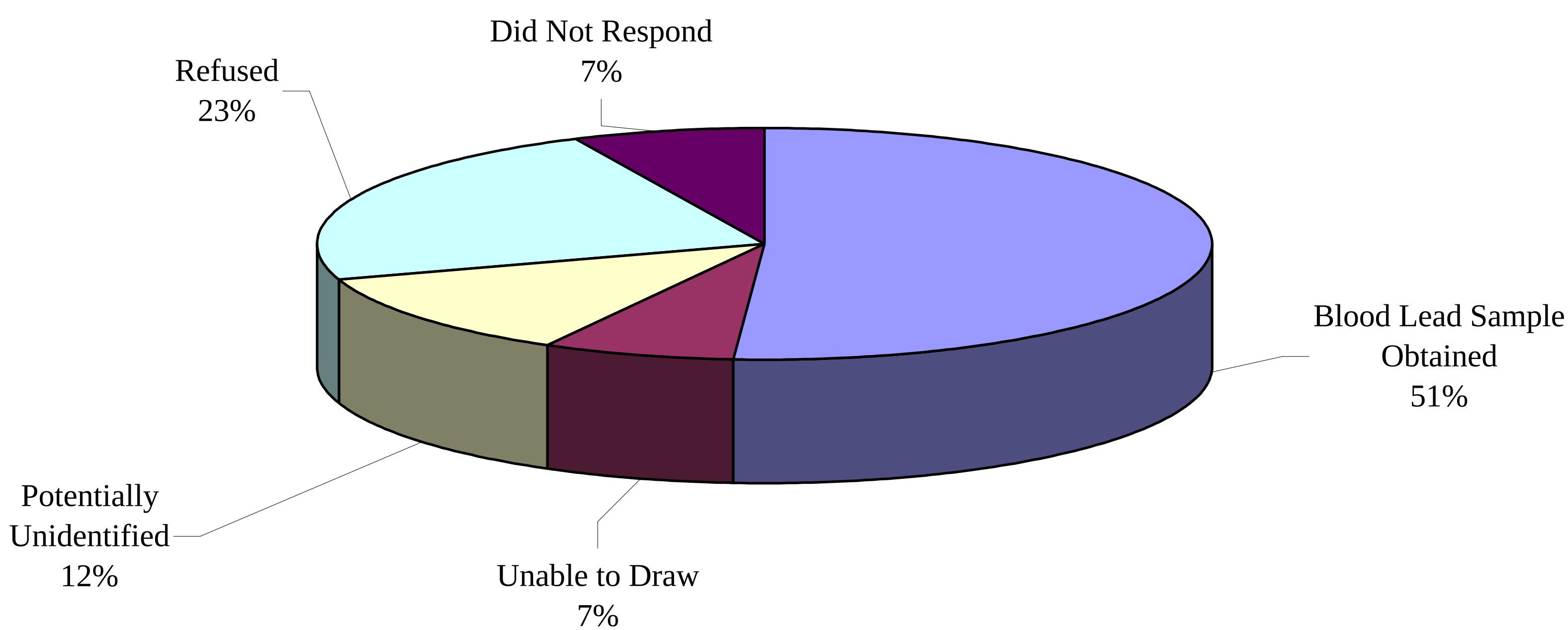


Figure 4.2a
Summary Status of Individuals Not Providing Blood Lead Samples, 1990-1998

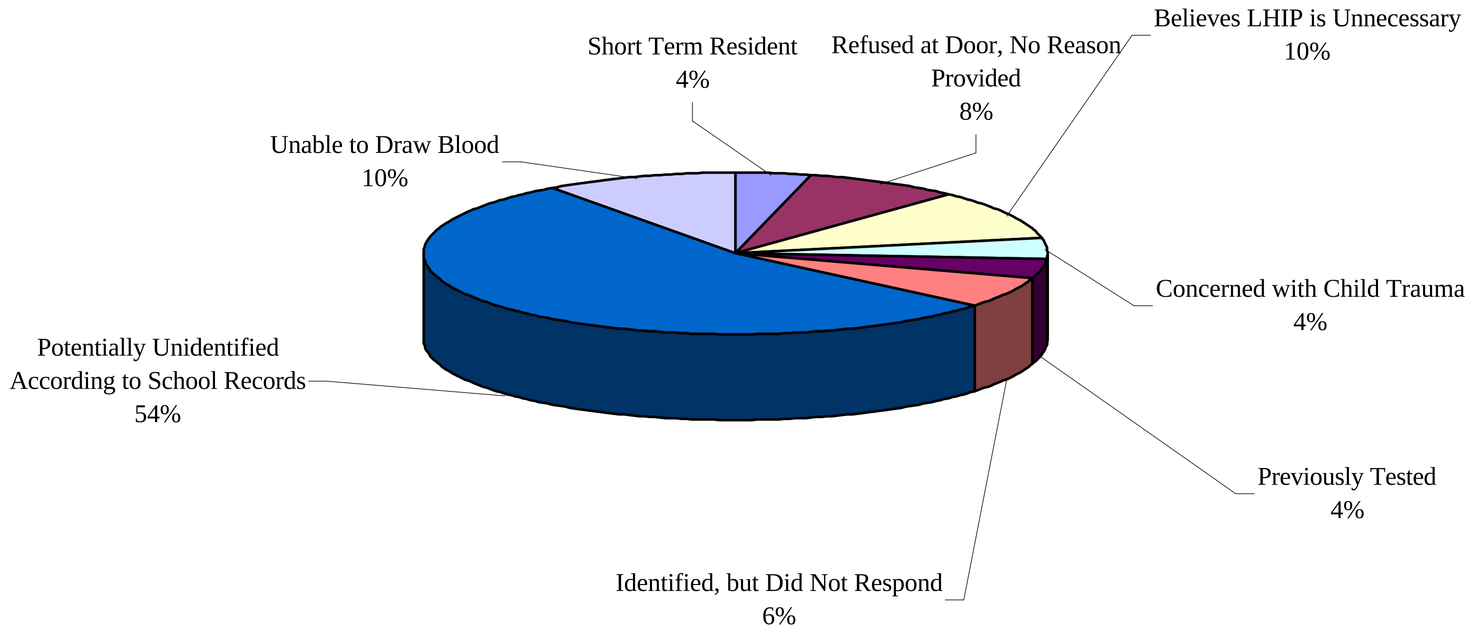
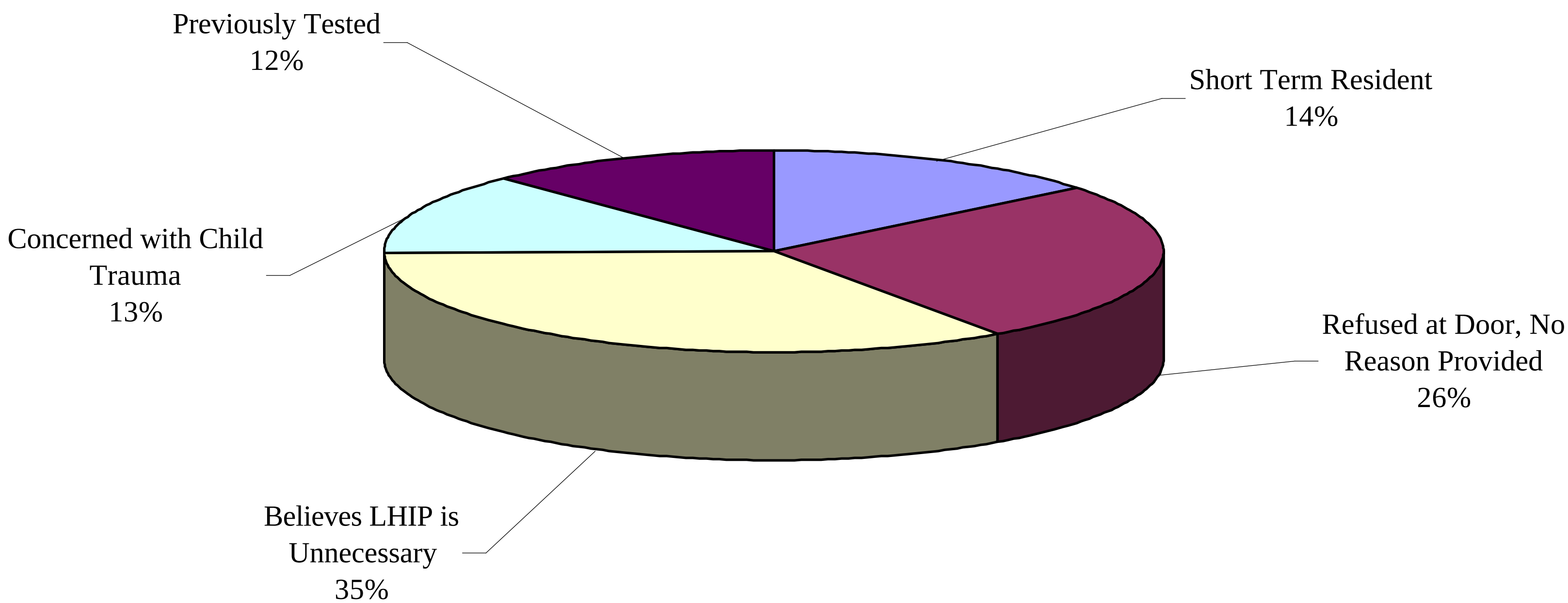


Figure 4.2b
Reasons Provided by Those Declining Participation in the LHIP, 1990-1999[1]



[1]This figure does not include the potentially unidentified and unable to draw groups from Figure 4-2a

Figure 4.3
Percent of Children Residing in Homes with Contaminated Yards, 1988-2002

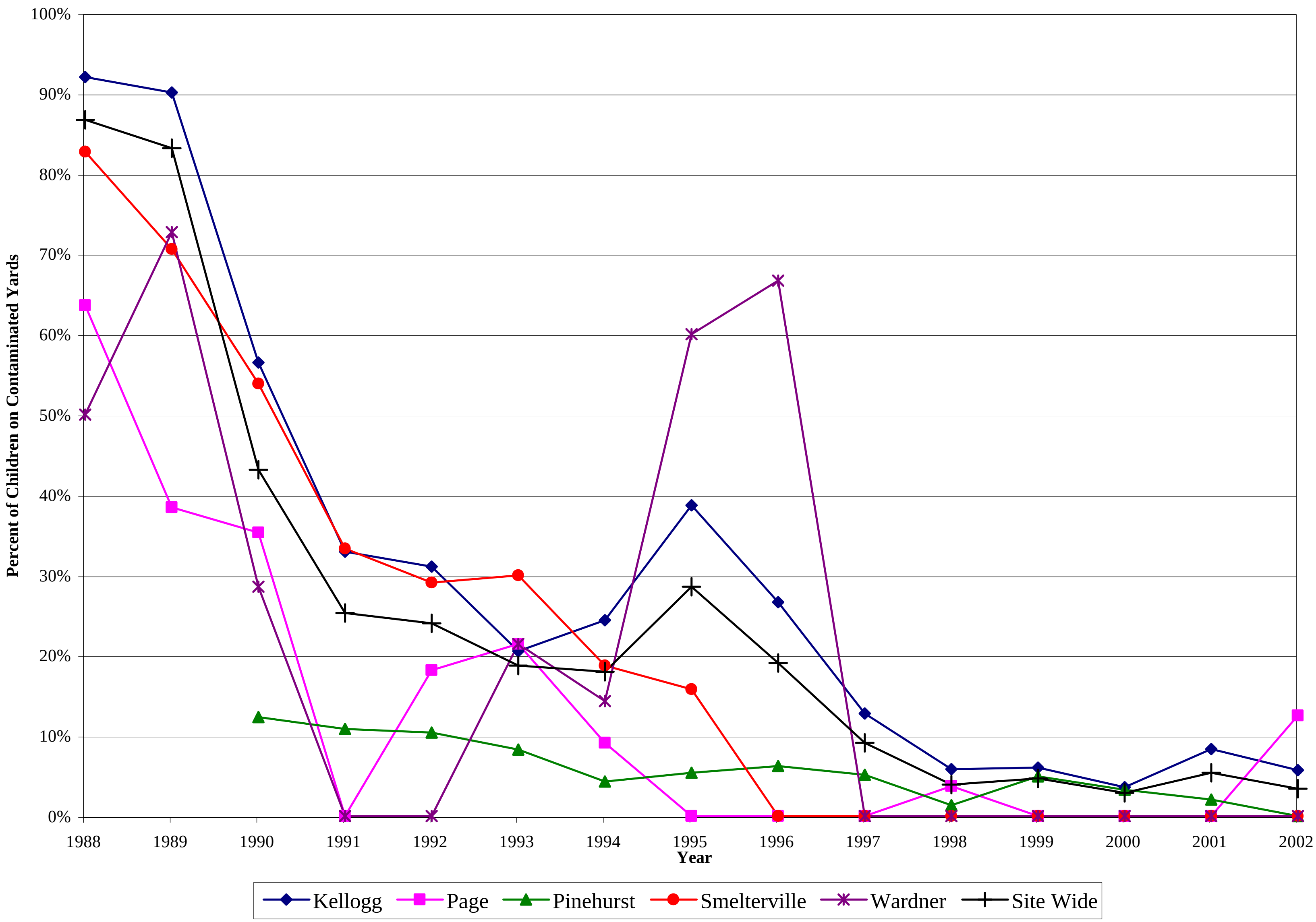
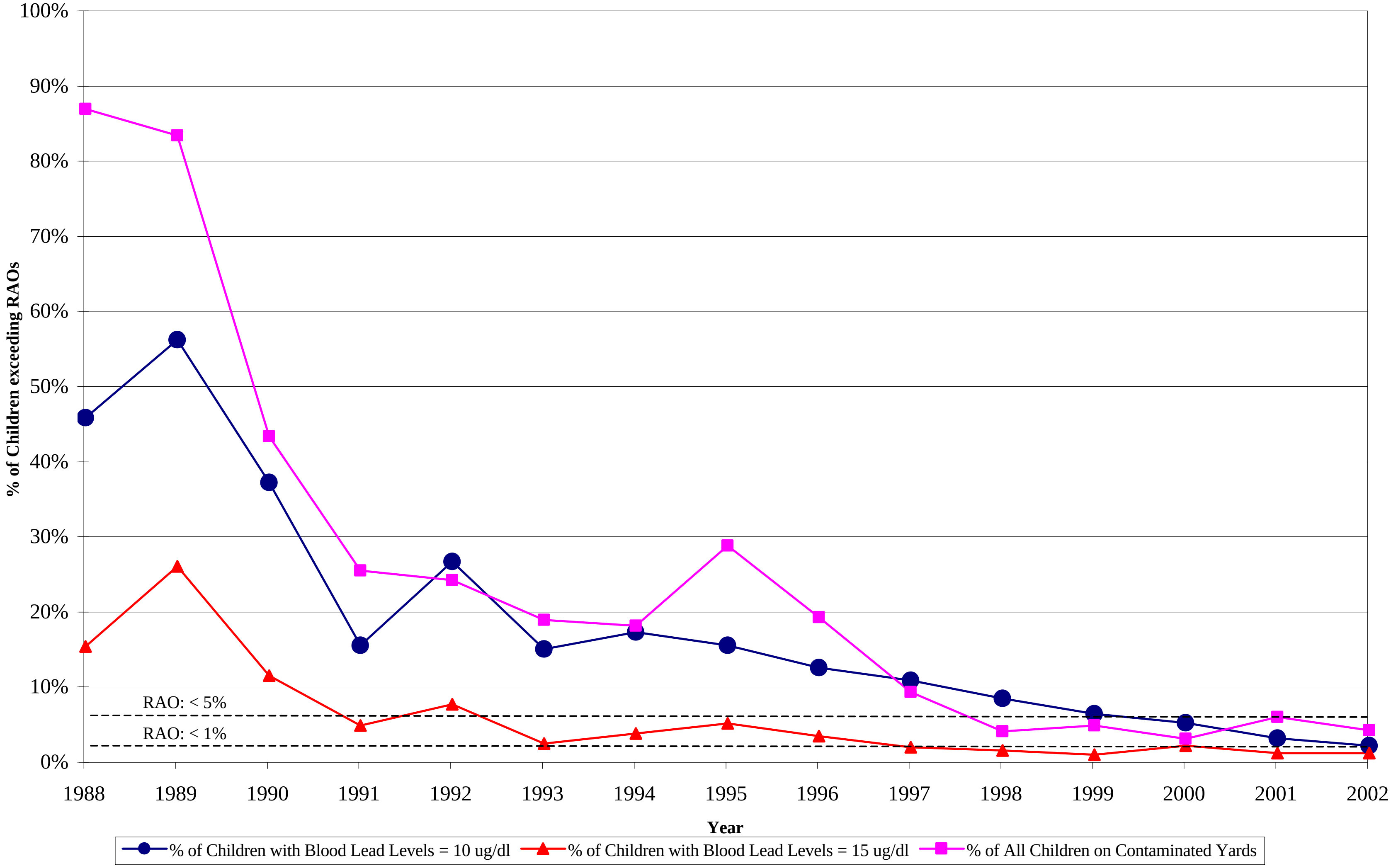


Figure 4.4

Percent of Children with Blood Lead Levels = 10 mg/dl, Blood Levels = 15mg/dl and the Percent of All Children Tested Residing on Contaminated Yards, Site-Wide, 1988-2002



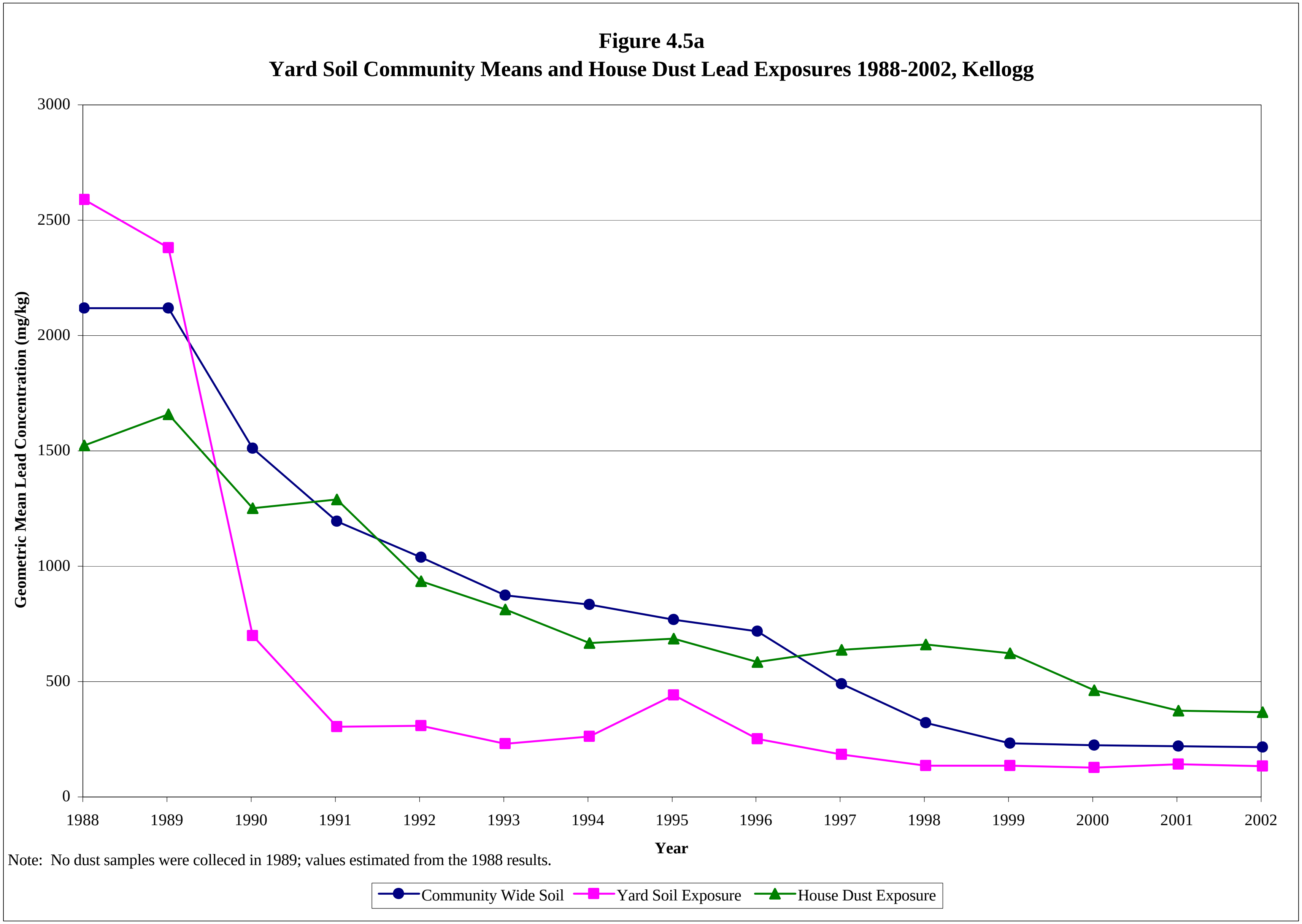
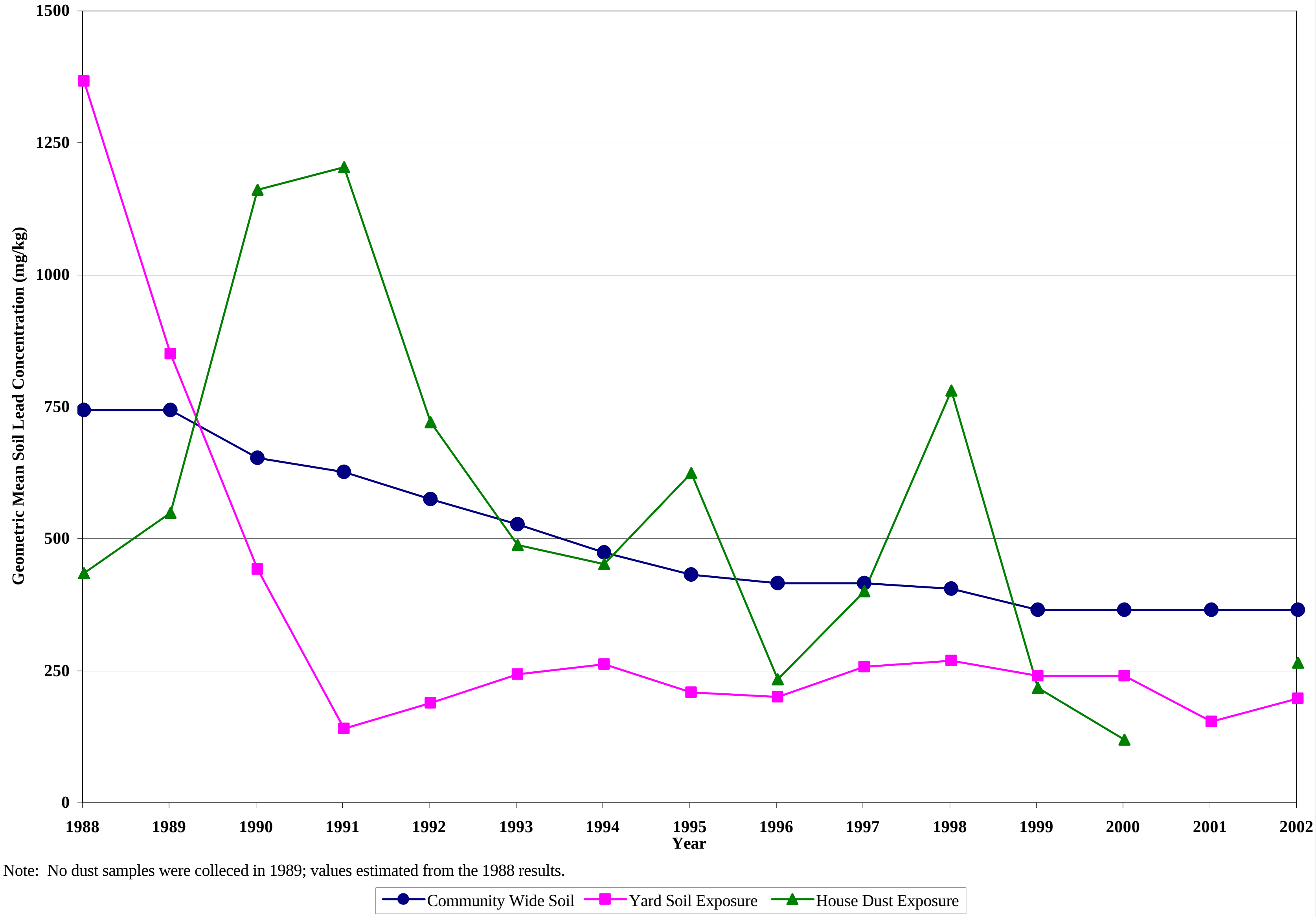


Figure 4.5a
Yard Soil Community Means and House Dust Lead Exposures 1988-2002, Kellogg
Geometric Mean Lead Concentration (mg/kg)
3000
2500
2000
1500
1000
500
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Note: No dust samples were colleced in 1989; values estimated from the 1988 results.
Community Wide Soil
Yard Soil Exposure
House Dust Exposure

Figure 4.5b
Yard Soil Community Means and House Dust Lead Exposures 1988-2002, Page



Note: No dust samples were colleced in 1989; values estimated from the 1988 results.

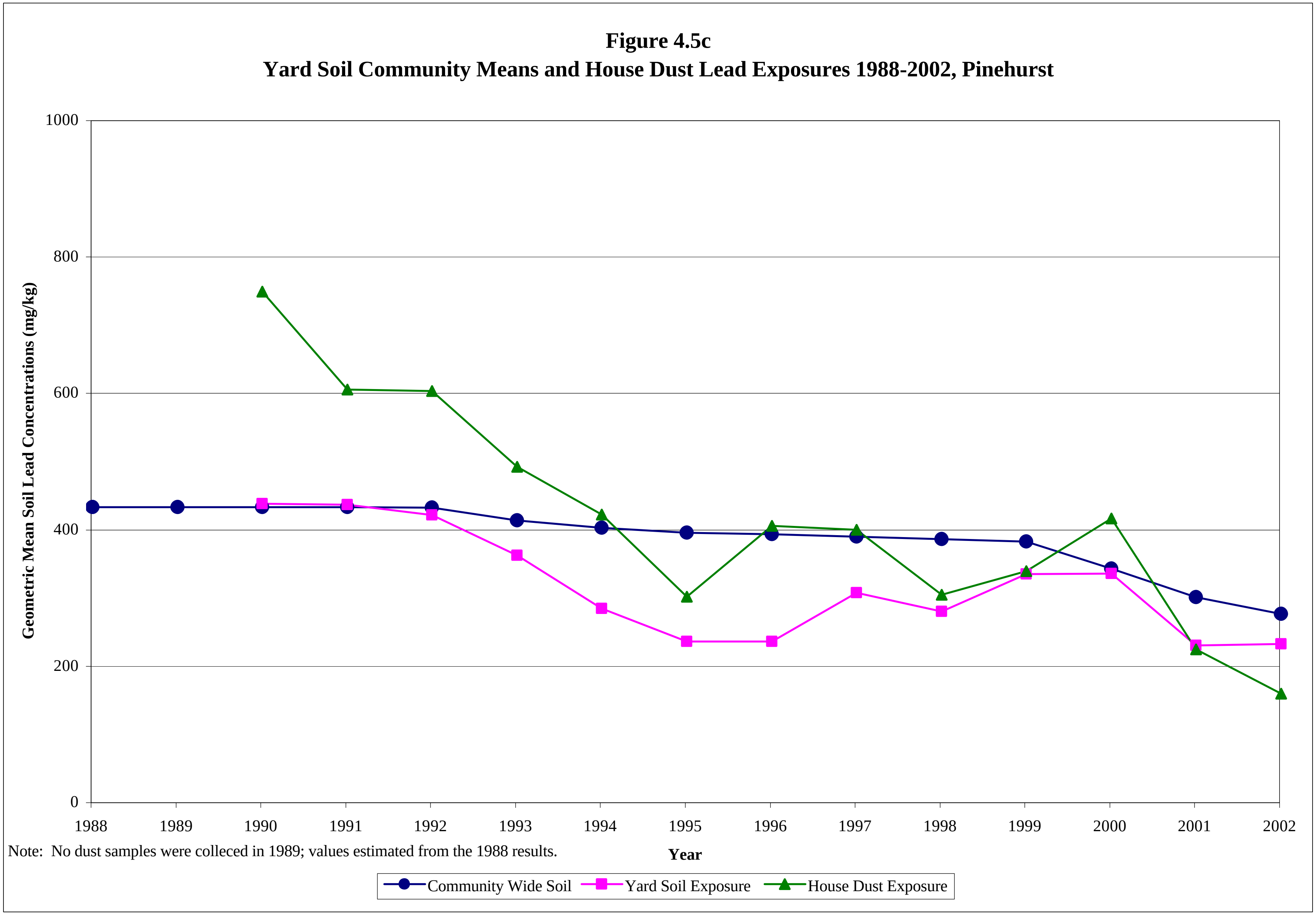


Figure 4.5c
Yard Soil Community Means and House Dust Lead Exposures 1988-2002, Pinehurst
Geometric Mean Soil Lead Concentrations (mg/kg)
1000
800
600
400
200
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Note: No dust samples were colleced in 1989; values estimated from the 1988 results.
Community Wide Soil
Yard Soil Exposure
House Dust Exposure

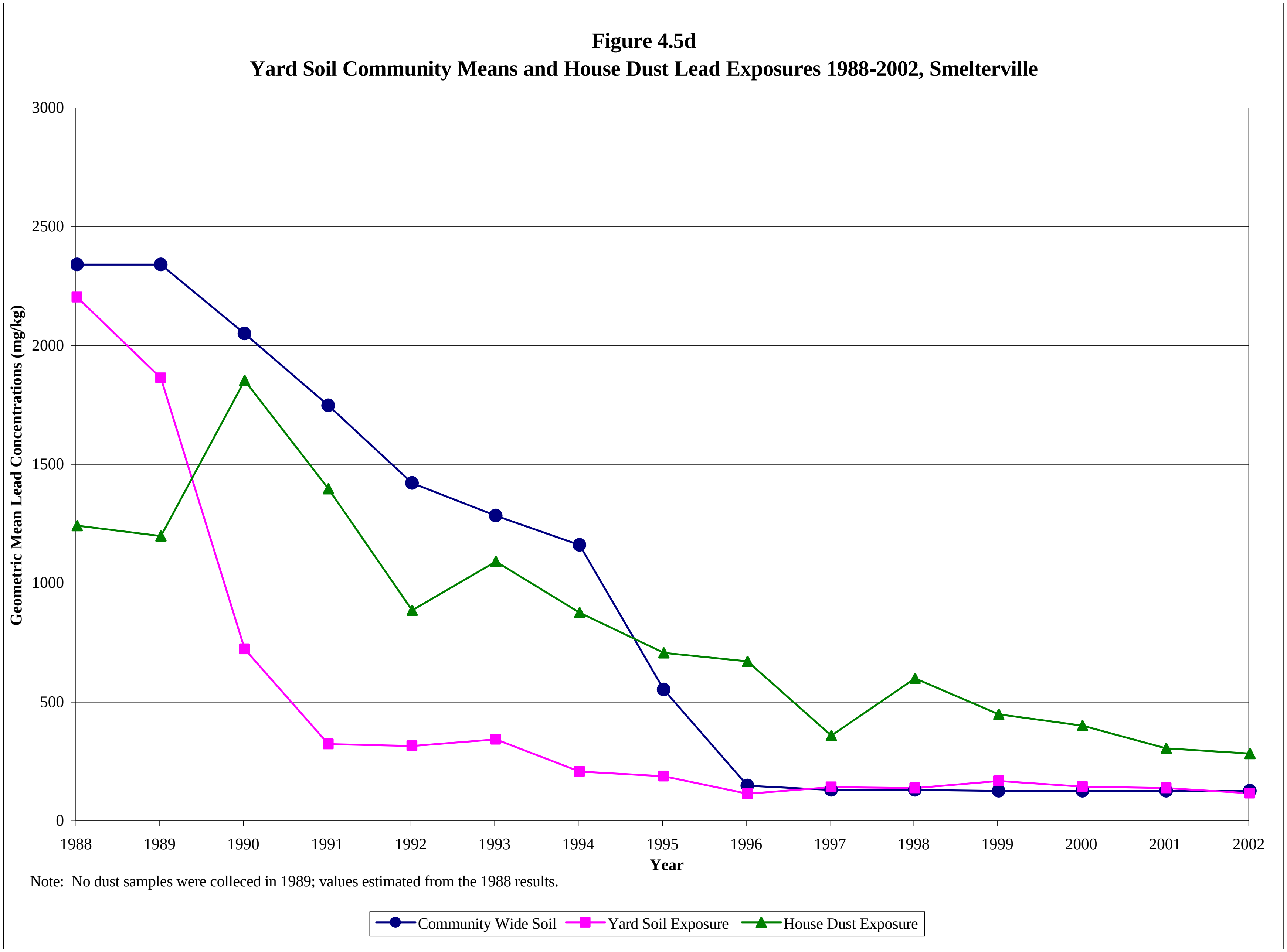
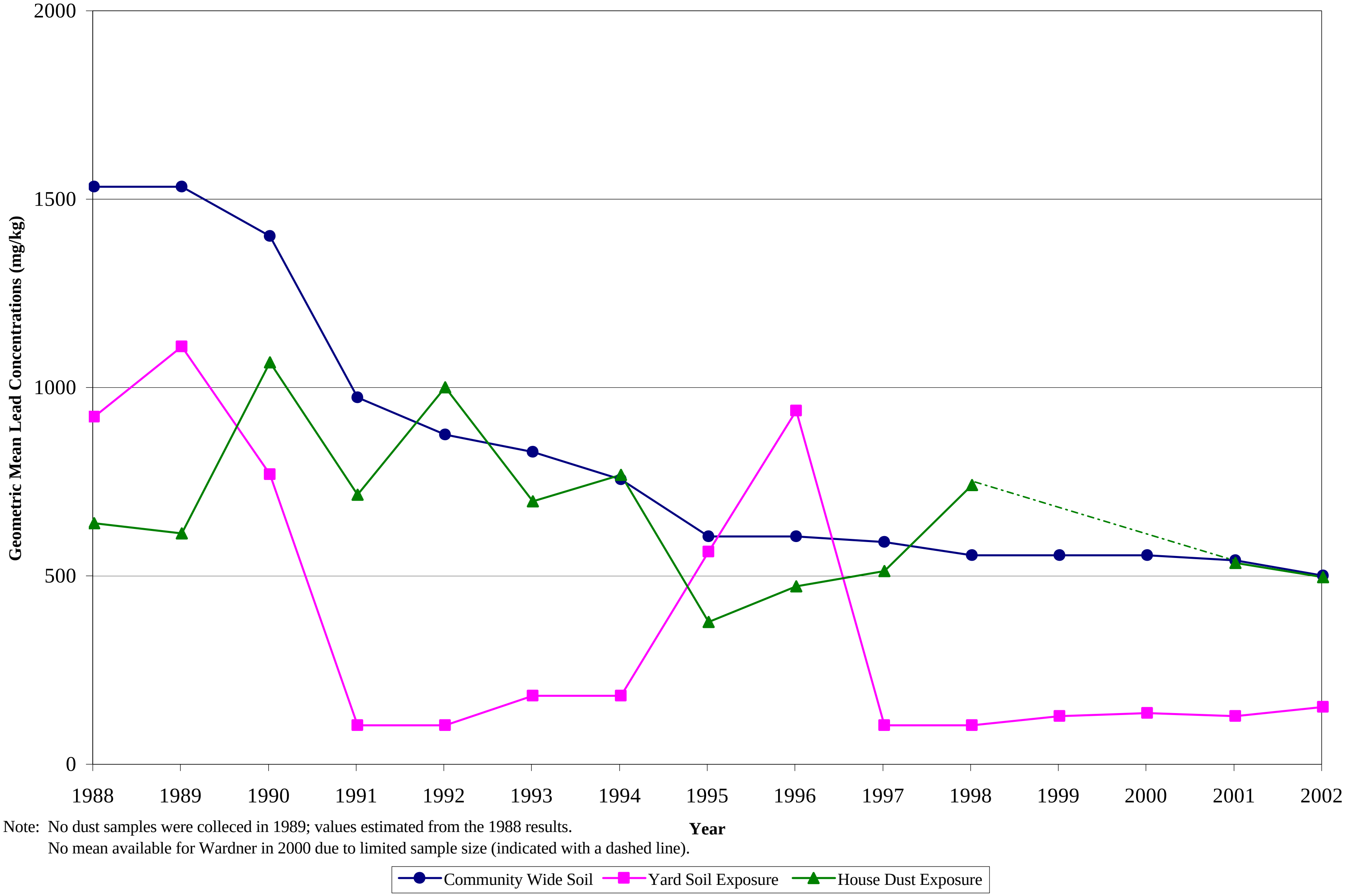


Figure 4.5d
Yard Soil Community Means and House Dust Lead Exposures 1988-2002, Smelterville
Geometric Mean Lead Concentrations (mg/kg)
3000
2500
2000
1500
1000
500
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Note: No dust samples were colleced in 1989; values estimated from the 1988 results.
Community Wide Soil
Yard Soil Exposure
House Dust Exposure

Figure 4.5e
Yard Soil Community Means and House Dust Lead Exposures 1988-2002, Wardner



Note: No dust samples were colleced in 1989; values estimated from the 1988 results.
No mean available for Wardner in 2000 due to limited sample size (indicated with a dashed line).

Table 4-1
Summary of Participation Rates for the Annual Blood Lead Survey, 1988-1998

Year	Estimated Eligible Population	Total # of Children Identified (% of Pop.)	Total # of Participants (% of Pop.)	Total # of Survey Refusals (% of Pop.)	Total # of "Other" Children Identified (% of Pop.)	Total # Blood Samples (Yield)	Number of Children Repeating Participation from the Previous Year	Percent of Eligible Population Providing Samples	Percent of Identified Population Providing Samples
1988	-	344	263 (77%)	63 (18%)	18 (5%)	230 (88%)	-	-	67%
1989	-	373	292 (78%)	58 (16%)	23 (6%)	275 (94%)	105 (38%)	-	74%
1990	871	556 (64%)	418 (75%)	111 (20%)	27 (5%)	362 (87%)	139 (37%)	42%	65%
1991	833	536 (64%)	399 (74%)	121 (23%)	16 (3%)	365 (92%)	197 (54%)	44%	68%
1992	807	595 (74%)	443 (75%)	127 (21%)	25 (4%)	415 (94%)	201 (48%)	51%	70%
1993	771	633 (82%)	475 (75%)	144 (23%)	14 (2%)	445 (94%)	224 (50%)	58%	70%
1994	767	550 (72%)	460 (84%)	81 (15%)	9 (2%)	416 (90%)	216 (52%)	54%	76%
1995	762	617 (81%)	444 (72%)	148 (24%)	25 (4%)	405 (91%)	206 (51%)	53%	66%
1996	769	571 (74%)	437 (77%)	116 (20%)	18 (3%)	397 (91%)	205 (52%)	52%	70%
1997	770	470 (61%)	371 (79%)	85 (18%)	14 (3%)	337 (91%)	162 (48%)	44%	72%
1998	729	641 (88%)	427 (67%)	165 (26%)	49 (8%)	375 (88%)	172 (46%)	51%	59%
1990-1998 avg.		73%	75%	21%	4%	91%	49%	50%	68%

Pop. = Population
# = Number
% = Percent

Table 4-2
Number and Percentage of Identified Children in the Box Eligible Population that Refuse Participation, 1985-1999

Year	Total Refusals	Reasons					Total
		PREVTESTED	TRAUMA	UNNECESS	REFUSAL	SHRTABSNT	
1985	Family	2	2	5	59	7	75
	% of Total	3%	3%	7%	79%	9%	
	Children	2	4	10	73	10	99
	% of Total	2%	4%	10%	74%	10%	
1986	Family	4	0	1	66	3	74
	% of Total	5%	0%	1%	89%	4%	
	Children	5	0	2	103	5	115
	% of Total	4%	0%	2%	90%	4%	
1987	Family	39	5	10	21	7	82
	% of Total	48%	6%	12%	26%	9%	
	Children	44	6	13	26	11	100
	% of Total	44%	6%	13%	26%	11%	
1989	Family	2	2	11	23	6	44
	% of Total	5%	5%	25%	52%	14%	
	Children	3	2	11	34	8	58
	% of Total	5%	3%	19%	59%	14%	
1990	Family	5	14	28	21	11	79
	% of Total	6%	18%	35%	27%	14%	
	Children	8	16	39	33	15	111
	% of Total	7%	14%	35%	30%	14%	
1991	Family	5	18	24	23	10	80
	% of Total	6%	23%	30%	29%	13%	
	Children	8	22	36	36	19	121
	% of Total	7%	18%	30%	30%	16%	
1992	Family	9	7	49	9	14	88
	% of Total	10%	8%	56%	10%	16%	
	Children	11	11	69	12	24	127
	% of Total	9%	9%	54%	9%	19%	
1993	Family	3	15	21	40	18	97
	% of Total	3%	15%	21%	41%	18%	
	Children	5	24	27	58	30	144
	% of Total	3%	17%	19%	40%	21%	
1994	Family	8	12	17	7	11	55
	% of Total	15%	22%	31%	13%	20%	
	Children	10	18	26	10	17	81
	% of Total	12%	22%	32%	12%	21%	
1995	Family	7	6	13	64	10	100
	% of Total	7%	6%	13%	64%	10%	
	Children	8	7	22	96	15	148
	% of Total	5%	5%	15%	65%	10%	

Table 4-2 (continued)
Number and Percentage of Identified Children in the Box Eligible Population that Refuse Participation, 1985-1999

Year	Total Refusals	Reasons					Total
		PREVTESTED	TRAUMA	UNNECESS	REFUSAL	SHRTABSNT	
1996	Family	15	9	37	15	6	82
	% of Total	18%	11%	45%	18%	7%	
	Children	20	14	49	21	10	114
	% of Total	18%	12%	43%	18%	9%	
1997	Family	14	10	15	23	4	66
	% of Total	21%	15%	23%	35%	6%	
	Children	20	13	19	27	6	85
	% of Total	24%	15%	22%	32%	7%	
1998	Family	14	12	57	15	11	109
	% of Total	13%	11%	52%	14%	10%	
	Children	26	17	81	26	15	165
	% of Total	16%	10%	49%	16%	9%	
1999	Family	26	18	54	18	20	136
	% of Total	19%	13%	40%	13%	15%	
	Children	45	23	77	21	28	194
	% of Total	23%	12%	40%	11%	14%	
1990-1999 Total	Family	106	121	315	235	115	892
	% of Total	12%	14%	35%	26%	13%	
	Children	161	165	445	340	179	1290
	% of Total	12%	13%	34%	26%	14%	

PREVTESTED= child was previously tested, and parents did not feel it was necessary again
TRAUMA= child had a bad experience with needles/doctors/etc., and parents did not want to subject child to testing
UNNECESS= parent did not feel program was necessary
REFUSAL= parent did not express specific reason
SHRTABSNT= family had only been in area a short time, or were moving out of area soon

Table 4-3
Children Living at Residence Less than Six Months or One Year
Kellogg, 1988-2002

Year	Percentage of Children at Address		Number of Children Living Less Than One Year at the Reported Address		
	< 6 months	<1 year	Total Newcomers	Number of Newcomers in Homes with Contaminated Yards	Percent of Newcomers in Homes with Contaminated Yards
1988	20%	30%	51	36	71%
1989	28%	51%	108	73	68%
1990	27%	45%	86	44	51%
1991	28%	37%	66	37	56%
1992	26%	48%	101	44	44%
1993	23%	41%	94	30	32%
1994	37%	51%	119	36	30%
1995	28%	46%	117	59	50%
1996	22%	43%	97	30	31%
1997	24%	41%	81	15	19%
1998	23%	38%	141	6	4%
1999	33%	49%	97	12	12%
2000	18%	32%	55	5	9%
2001	30%	49%	89	7	8%
2002	23%	43%	84	8	10%

Table 4-4
Lead Health Intervention Summary Statistics, 1988-2002

Year	Number of Children Supplying Blood Lead Samples	Geometric Mean Blood Lead Level (mg/dl)	Number (%) = 25 mg/dl		Number (%) = 15 mg/dl		Number (%) = 10 mg/dl		Followup Criteria = mg/dl	Number Targeted for Followup	Number (%) of Followups Completed	
1988	230	8.5	9	4%	35	15%	105	46%	25	9	7	78%
1989	275	9.9	8	3%	71	26%	154	56%	25	8	8	100%
1990[a]	362	7.9	2	1%	41	11%	134	37%	25	3	2	67%
1991[a]	365	5.5	2	1%	17	5%	56	15%	20	6	6	100%
1992[a]	415	6.5	3	1%	31	7%	110	27%	15	31	30	97%
1993[a]	445	4.4	1	0.2%	10	2%	66	15%	10	66	56	85%
1994[a]	416	5.2	1	0.2%	15	4%	71	17%	10	71	53	75%
1995[a]	405	5.0	2	0.5%	20	5%	62	15%	10	62	58	94%
1996[a]	397	4.7	2	0.5%	13	3%	49	12%	10	49	38	78%
1997[a]	337	4.5	0	0.0%	6	2%	36	11%	10	36	32	89%
1998[a]	375	4.0	0	0.0%	5	1%	31	8%	10	31	27	87%
1999[a]	370	3.9	0	0.0%	3	1%	23	6%	10	23	13	57%
2000[a]	320	3.5	0	0.0%	5	2%	17	5%	10	17	15	88%
2001[a]	322	2.7	0	0.0%	4	1%	10	3%	10	12	12	100%
2002[a]	368	2.6	0	0.0%	3	1%	7	2%	10	8	7	88%

[a]Includes Pinehurst

μg/dl: micrograms per deciliter

Table 4-5
Number of Children on Remediated and Non-Remediated Yards, 1988-2002[b]

Year	City	Number and Percent of Children on Yards Below the Action Level			Number and Percent of Children on Contaminated Yards	
		Remediated Yards	Yards < 1000 mg/kg Lead	Percent of Children	Yards ≥ 1000 mg/kg Lead	Percent of Children
1988	Kellogg	-	11	8%	127	92%
	Page	-	4	36%	7	64%
	Smelterville	-	5	17%	24	83%
	Wardner	-	5	50%	5	50%
	Site-wide[a]	-	25	13%	163	87%
1989	Kellogg	-	16	10%	146	90%
	Page	-	8	62%	5	38%
	Smelterville	-	10	29%	24	71%
	Wardner	-	3	27%	8	73%
	Site-wide[a]	-	37	17%	183	83%
1990	Kellogg	60	7	44%	87	56%
	Page	6	5	65%	6	35%
	Pinehurst	0	57	88%	8	12%
	Smelterville	9	3	46%	14	54%
	Wardner	2	8	71%	4	29%
	Site-wide	77	80	57%	119	43%
1991	Kellogg	117	1	67%	58	33%
	Page	10	2	100%	0	0%
	Pinehurst	0	74	89%	9	11%
	Smelterville	31	1	67%	16	33%
	Wardner	9	0	100%	0	0%
	Site-wide	167	78	75%	83	25%
1992	Kellogg	135	7	69%	64	31%
	Page	8	1	82%	2	18%
	Pinehurst	0	86	90%	10	10%
	Smelterville	35	4	71%	16	29%
	Wardner	15	0	100%	0	0%
	Site-wide	193	98	76%	92	24%
1993	Kellogg	153	17	79%	44	21%
	Page	9	2	79%	3	21%
	Pinehurst	11	89	92%	9	8%
	Smelterville	39	3	70%	18	30%
	Wardner	11	0	79%	3	21%
	Site-wide	223	111	81%	77	19%
1994	Kellogg	145	16	76%	52	24%
	Page	6	4	91%	1	9%
	Pinehurst	19	70	96%	4	4%
	Smelterville	39	0	81%	9	19%
	Wardner	11	1	86%	2	14%
	Site-wide	220	91	82%	68	18%
1995	Kellogg	126	15	61%	89	39%
	Page	6	4	100%	0	0%
	Pinehurst	27	43	95%	4	5%
	Smelterville	32	0	84%	6	16%
	Wardner	2	0	40%	3	60%
	Site-wide	193	62	71%	102	29%

Table 4-5 (continued)

Number of Children on Remediated and Non-Remediated Yards, 1988-2002[b]

Year	City	Number and Percent of Children on Yards Below the Action Level			Number and Percent of Children on Contaminated Yards	
		Remediated Yards	Yards < 1000 mg/kg Lead	Percent of Children	Yards ≥ 1000 mg/kg Lead	Percent of Children
1996	Kellogg	139	4	73%	52	27%
	Page	7	4	100%	0	0%
	Pinehurst	29	31	94%	4	6%
	Smelterville	39	0	100%	0	0%
	Wardner	2	0	33%	4	67%
	Site-wide	216	39	81%	60	19%
1997	Kellogg	169	15	87%	27	13%
	Page	3	4	100%	0	0%
	Pinehurst	18	56	95%	4	5%
	Smelterville	26	7	100%	0	0%
	Wardner	12	0	100%	0	0%
	Site-wide	228	82	91%	31	9%
1998	Kellogg	180	13	94%	12	6%
	Page	13	13	96%	1	4%
	Pinehurst	16	57	99%	1	1%
	Smelterville	34	8	100%	0	0%
	Wardner	12	0	100%	0	0%
	Site-wide	255	91	96%	14	4%
1999	Kellogg	177	9	94%	12	6%
	Page	4	4	100%	0	0%
	Pinehurst	18	78	95%	5	5%
	Smelterville	28	19	100%	0	0%
	Wardner	8	1	100%	0	0%
	Site-wide	235	111	95%	17	5%
2000	Kellogg	151	9	96%	6	4%
	Page	4	4	100%	0	0%
	Pinehurst	19	65	97%	3	3%
	Smelterville	34	9	100%	0	0%
	Wardner	6	1	100%	0	0%
	Site-wide	214	88	97%	9	3%
2001	Kellogg	159	6	92%	14	8%
	Page	5	2	100%	0	0%
	Pinehurst	33	57	96%	4	4%
	Smelterville	19	4	100%	0	0%
	Wardner	8	1	100%	0	0%
	Site-wide	224	70	94%	18	6%
2002	Kellogg	170	10	94%	11	6%
	Page	5	2	88%	1	13%
	Pinehurst	21	74	98%	2	2%
	Smelterville	41	3	100%	0	0%
	Wardner	4	1	100%	0	0%
	Site-wide	241	90	96%	14	4%

[a]Does not include Pinehurst

[b]Only homes where children's blood samples were obtained

mg/kg: milligrams per kilogram

-: Not applicable

Tables 4-6a-d
ANOVA Results-Yard Soil Exposure, 1988-2002

Table 4-6a ANOVA Results-Yard Soil Exposure, Site-wide

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	192	3042	2299	-
1989	222	2686	2069	0.1771
1990	295	1357	581	0.0001
1991	340	907	312	0.0001
1992	391	883	300	0.7028
1993	422	805	268	0.2297
1994	398	799	250	0.4376
1995	381	818	254	0.8408
1996	386	614	234	0.3771
1997	329	413	193	0.0224
1998	357	377	182	0.4843
1999	363	305	175	0.5595
2000	315	280	168	0.5503
2001	316	298	158	0.3577
2002	355	253	151	0.4639
Overall				0.0001

Table 4-6b ANOVA Results-Yard Soil Exposure, Kellogg

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	138	3138	2578	-
1989	165	2846	2374	0.2866
1990	154	1741	693	0.0001
1991	176	1088	298	0.0001
1992	207	1064	303	0.9133
1993	220	786	233	0.0668
1994	222	969	252	0.5612
1995	242	970	269	0.6421
1996	221	808	257	0.7342
1997	195	454	173	0.0016
1998	204	408	151	0.2047
1999	198	265	129	0.0938
2000	166	218	121	0.4140
2001	180	309	135	0.2182
2002	192	247	127	0.4786
Overall				0.0001

Table 4-6c ANOVA Results-Yard Soil Exposure, Smelterville

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	29	2932	2198	-
1989	33	2954	1820	0.4543
1990	26	1886	650	0.0071
1991	46	1284	335	0.1136
1992	54	1221	280	0.5861
1993	59	1624	319	0.6886
1994	48	1074	202	0.1630
1995	40	983	212	0.8898
1996	51	124	112	0.0050
1997	33	176	137	0.0718
1998	43	167	132	0.8182
1999	47	209	162	0.1333
2000	43	183	139	0.2665
2001	23	174	133	0.7894
2002	44	125	111	0.1648
Overall				0.0001

Table 4-6d ANOVA Results-Yard Soil Exposure, Pinehurst

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1990	84	517	410	-
1991	94	575	425	0.7396
1992	101	551	413	0.7907
1993	111	522	357	0.1848
1994	101	393	286	0.0507
1995	84	373	247	0.2275
1996	97	382	263	0.6402
1997	82	461	308	0.2333
1998	90	409	315	0.8739
1999	101	437	333	0.6131
2000	91	443	334	0.9855
2001	97	325	228	0.0018
2002	106	313	230	0.9332
Overall				0.0001

mg/kg: milligram per kilogram

N: number of samples used in the analysis

Table 4-7a-d
ANOVA Results-Community Soil Concentrations, 1988-2002

Table 4-7a ANOVA Results-Community Soil Concentrations, Site-wide

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	2735	2154	1251	-
1989	2735	2154	1251	1.0000
1990	2841	2002	1052	0.0001
1991	2908	1880	907	0.0001
1992	2909	1766	815	0.0026
1993	2909	1639	724	0.001
1994	2910	1593	687	0.1582
1995	2911	1416	585	0.0001
1996	2913	1194	470	0.0001
1997	2915	977	379	0.0001
1998	2915	799	304	0.0001
1999	2915	661	255	0.0001
2000	2916	622	242	0.0981
2001	2916	592	230	0.1074
2002	2916	568	222	0.2061
Overall				**0.0001**

Table 4-7b ANOVA Results-Community Soil Concentrations, Kellogg

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	1297	2837	2112	-
1989	1297	2837	2112	1.0000
1990	1400	2525	1505	0.0001
1991	1458	2323	1189	0.0001
1992	1459	2181	1032	0.0080
1993	1459	1973	866	0.0016
1994	1459	1930	828	0.4148
1995	1460	1838	761	0.1423
1996	1460	1774	711	0.2339
1997	1461	1393	483	0.0001
1998	1461	1045	314	0.0001
1999	1461	782	226	0.0001
2000	1461	731	217	0.4132
2001	1461	708	213	0.6870
2002	1461	694	209	0.6861
Overall				**0.0001**

Table 4-7c ANOVA Results-Community Soil Concentrations, Smelterville

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	385	3399	2336	-
1989	385	3399	2336	1.0000
1990	387	3254	2045	0.0813
1991	393	3104	1743	0.0684
1992	393	2825	1416	0.0342
1993	393	2719	1280	0.3320
1994	393	2603	1155	0.3449
1995	393	1739	547	0.0001
1996	395	354	142	0.0001
1997	395	171	125	0.0165
1998	395	171	125	1.0000
1999	395	149	122	0.5137
2000	395	149	122	1.0000
2001	395	149	122	1.0000
2002	395	149	122	1.0000
Overall				**0.0001**

Table 4-7d ANOVA Results-Community Soil Concentrations, Pinehurst

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1990	850	582	431	-
1991	850	582	431	1.0000
1992	850	581	430	0.9436
1993	850	560	411	0.2620
1994	851	547	401	0.5093
1995	851	541	394	0.6496
1996	851	539	391	0.8833
1997	852	535	388	0.8120
1998	852	529	384	0.8228
1999	852	524	380	0.7865
2000	853	477	341	0.0074
2001	853	417	298	0.0011
2002	853	376	274	0.0320
Overall				**0.0001**

mg/kg: milligram per kilogram

N: number of samples used in the analysis

Table 4-8a-d
ANOVA Results-Neighborhood (200) Soil Exposure, 1988-2002

Table 4-8a ANOVA Results-Neighborhood (200) Soil Exposure, Site-wide

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	227	2705	2157	-
1989	275	2775	2235	0.3146
1990	357	1779	1287	0.0001
1991	362	1762	1075	0.0022
1992	405	1692	935	0.0098
1993	443	1566	830	0.0187
1994	406	1477	715	0.0041
1995	394	1457	775	0.2626
1996	391	1225	636	0.024
1997	332	1065	521	0.021
1998	368	775	374	0.0001
1999	306	647	330	0.0763
2000	268	613	311	0.3406
2001	263	651	302	0.6718
2002	294	542	267	0.0911
Overall				**0.0001**

Table 4-8b ANOVA Results-Neighborhood (200) Soil Exposure, Kellogg

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	168	2635	2159	-
1989	212	2637	2176	0.8212
1990	191	2382	1788	0.0001
1991	177	2264	1404	0.0001
1992	211	2088	1176	0.0009
1993	228	1950	1033	0.0202
1994	232	1748	819	0.0001
1995	251	1952	1025	0.0078
1996	224	1870	933	0.3166
1997	199	1446	679	0.0007
1998	211	1036	466	0.0001
1999	171	776	300	0.0001
2000	144	788	302	0.9264
2001	161	797	297	0.8742
2002	174	683	277	0.5046
Overall				**0.0001**

Table 4-8c ANOVA Results-Neighborhood (200) Soil Exposure, Smelterville

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	32	3876	2951	-
1989	36	3968	3146	0.3971
1990	28	3359	2216	0.0001
1991	47	3435	1948	0.1363
1992	54	2842	1377	0.0001
1993	66	2423	1098	0.0032
1994	46	2443	1073	0.8061
1995	40	957	435	0.0001
1996	51	163	132	0.0001
1997	33	209	179	0.0651
1998	43	195	174	0.8827
1999	37	191	185	0.7388
2000	35	133	131	0.0645
2001	19	114	112	0.4481
2002	39	100	100	0.1621
Overall				**0.0001**

Table 4-8d ANOVA Results-Neighborhood (200) Soil Exposure, Pinehurst

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1990	105	320	216	-
1991	114	358	247	0.0555
1992	111	394	264	0.3170
1993	117	383	278	0.4940
1994	101	384	286	0.7393
1995	88	353	260	0.2525
1996	98	346	249	0.5413
1997	81	360	258	0.6149
1998	94	319	229	0.0909
1999	83	528	442	0.0001
2000	76	498	404	0.0972
2001	70	419	338	0.0077
2002	71	376	308	0.1279
Overall				**0.1112**

mg/kg: milligram per kilogram
N: number of samples used in the analysis

Table 4-9

Yard Soil Lead Exposure by Year, 1974-2002[b]

Year	City	Number of Children	Concentration Range (mg/kg)		Mean Soil Lead Concentration (mg/kg)			
			Minimum	Maximum	Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1974	Kellogg	171	35	14000	3073	2199	2255	2.62
	Page	7	730	6800	3609	2477	2652	2.58
	Pinehurst	184	84	10400	1169	1434	768	2.41
	Smelterville	174	120	24600	7386	5157	5770	2.19
	Wardner	16	1000	23200	4863	5365	3405	2.29
1975	Kellogg	328	144	25800	3918	3652	2658	2.60
	Pinehurst	88	108	4020	676	617	497	2.18
	Smelterville	104	268	31800	5581	4721	3907	2.52
	Wardner	9	316	4800	2372	2311	1186	3.92
1983	Smelterville	43	83	17550	6231	3945	4188	3.60
	Area 2[a]	185	108	41200	3201	3722	2334	2.28
	Pinehurst	117	97	4375	814	842	534	2.54
1988	Kellogg	138	136	10400	3140	1796	2582	2.00
	Page	11	589	2720	1591	817	1365	1.86
	Smelterville	29	356	10700	2932	2180	2198	2.33
	Wardner	10	271	1930	1047	514	919	1.78
1989	Kellogg	162	136	9230	2846	1600	2374	1.92
	Page	13	53	2720	1156	775	848	2.72
	Smelterville	34	356	8740	2975	2594	1858	2.94
	Wardner	11	271	2250	1304	632	1106	1.98
1990	Kellogg	154	100	10600	1741	1815	693	5.03
	Page	17	53	3480	953	1019	440	4.21
	Pinehurst	65	169	3060	561	474	436	2.00
	Smelterville	26	100	8170	1906	2190	719	5.21
	Wardner	14	100	13200	1675	3340	766	3.28
1991	Kellogg	176	100	7380	1088	1741	298	4.83
	Page	12	100	811	200	238	138	2.13
	Pinehurst	83	117	3060	597	597	434	2.13
	Smelterville	48	100	10700	1235	2063	319	5.16
	Wardner	9	100	100	100	0	100	1.00
1992	Kellogg	206	100	6930	1068	1639	302	4.80
	Page	11	100	1190	353	452	187	2.96
	Pinehurst	96	79	3060	571	530	419	2.15
	Smelterville	55	100	8800	1254	2329	311	4.99
	Wardner	15	100	100	100	0	100	1.00
1993	Kellogg	214	100	10600	772	1531	223	3.96
	Page	14	100	1670	493	570	241	3.43
	Pinehurst	109	79	3060	525	575	360	2.31
	Smelterville	60	100	7650	1639	2644	339	5.88
	Wardner	14	100	1850	409	623	179	3.20
1994	Kellogg	213	100	13400	952	1901	256	4.37
	Page	11	100	1670	463	512	260	3.12
	Pinehurst	93	79	2860	407	412	282	2.32
	Smelterville	48	100	8740	1074	2374	202	4.56
	Wardner	14	100	2568	453	801	179	3.28

Table 4-9 (continued)

Yard Soil Lead Exposure by Year, 1974-2002[b]

Year	City	Number of Children	Concentration Range (mg/kg) Minimum	Concentration Range (mg/kg) Maximum	Mean Soil Lead Concentration (mg/kg) Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1995	Kellogg	231	100	10500	1663	2486	435	5.60
	Page	10	100	664	309	274	207	2.57
	Pinehurst	74	100	2670	373	483	234	2.44
	Smelterville	38	100	7370	873	1932	184	4.19
	Wardner	5	100	2568	1142	1051	561	4.91
1996	Kellogg	195	100	6880	855	1487	245	4.28
	Page	11	100	664	301	278	198	2.57
	Pinehurst	64	37	1380	377	360	234	2.72
	Smelterville	40	100	3900	195	601	110	1.78
	Wardner	6	100	3180	1949	1458	935	5.66
1997	Kellogg	178	100	4770	472	942	176	3.12
	Page	7	100	664	341	236	255	2.42
	Pinehurst	74	37	2860	470	561	305	2.50
	Smelterville	31	100	766	176	165	137	1.87
	Wardner	11	100	100	100	0	100	1.00
1998	Kellogg	205	100	4957	322	827	128	2.46
	Page	27	100	1322	412	355	267	2.70
	Pinehurst	73	37	1850	368	280	277	2.23
	Smelterville	42	100	616	169	150	133	1.83
	Wardner	12	100	100	100	0	100	1.00
1999	Kellogg	198	100	5363	265	691	129	2.22
	Page	8	100	651	336	258	238	2.54
	Pinehurst	101	100	1820	437	351	333	2.12
	Smelterville	47	100	588	209	163	162	1.97
	Wardner	9	100	727	170	209	125	1.94
2000	Kellogg	166	100	5320	218	590	121	1.98
	Page	8	100	651	336	258	238	2.54
	Pinehurst	91	66	1820	443	342	334	2.22
	Smelterville	43	100	766	183	173	139	1.93
	Wardner	7	100	727	190	237	133	2.12
2001	Kellogg	180	100	3889	309	730	135	2.45
	Page	7	100	425	193	159	151	2.03
	Pinehurst	97	34	1540	325	292	228	2.35
	Smelterville	23	100	766	174	175	133	1.89
	Wardner	9	100	727	170	209	125	1.94
2002	Kellogg	192	100	5363	247	619	127	2.16
	Page	8	100	1160	314	372	195	2.65
	Pinehurst	106	31	874	313	237	230	2.28
	Smelterville	44	100	467	125	94	111	1.48
	Wardner	5	100	727	225	280	149	2.43

[a] Kellogg, Wardner, and Page Combined

[b]Only homes where children's blood samples were obtained

Yards are assigned a lead concentration of 100 mg/kg once remediated

mg/kg: milligram per kilogram

Table 4-10
House Dust Lead Exposure by Year, 1974-2002[b]

Year	City	Number of Children	Concentration Range (mg/kg)		Mean House Dust Lead Concentration (mg/kg)			
			Minimum	Maximum	Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1974	Kellogg	68	1945	24500	8316	5722.5	6765	1.91
	Page	0	-	-	-	-	-	-
	Pinehurst	49	940	4790	2317	1097.9	2087	1.59
	Smelterville	86	1940	26700	11997	5277.5	10789	1.65
	Wardner	11	2060	6800	5318	1547.3	5033	1.47
1975	Kellogg	243	325	9850	5094	2038.6	4552	1.73
	Pinehurst	65	465	6000	2042	1186.3	1707	1.87
	Smelterville	60	200	9350	4736	2852.2	3492	2.54
	Wardner	5	2550	3350	2710	357.8	2693	1.13
1983	Smelterville	42	322	18400	4734	4207.0	2922	3.07
	Area 2[a]	194	53	20700	3621	3520.1	2585	2.35
	Pinehurst	121	151	2915	590	459.0	471	1.92
1988	Kellogg	58	94	52700	3336	7790.4	1516	2.85
	Page	3	69	1160	746	591.4	432	4.91
	Smelterville	23	209	4640	1746	1376.7	1237	2.51
	Wardner	4	427	1480	736	503.5	637	1.80
1989[c]	Kellogg	47	228	52700	4568	9721.2	1652	3.31
	Page	5	69	1160	794	496.4	547	3.38
	Smelterville	14	209	4640	1628	1352.9	1193	2.42
	Wardner	2	--	--	--	--	--	--
1990	Kellogg	89	117	6230	1610	1164.9	1245	2.22
	Page	5	898	2070	1221	487.3	1159	1.41
	Pinehurst	57	119	7990	1140	1491.2	747	2.37
	Smelterville	15	777	4210	2117	1128.8	1849	1.72
	Wardner	5	691	2220	1231	749.8	1064	1.81
1991	Kellogg	75	274	3960	1460	761.0	1283	1.69
	Page	5	545	1680	1285	432.6	1202	1.57
	Pinehurst	59	65	13500	912	1732.0	603	2.16
	Smelterville	27	790	2700	1468	496.0	1393	1.39
	Wardner	4	307	964	784	319.5	712	1.75
1992	Kellogg	125	104	5530	1183	838.8	928	2.08
	Page	5	473	1500	792	420.5	719	1.61
	Pinehurst	78	165	3470	769	645.0	601	1.96
	Smelterville	26	140	3790	1175	1033.3	881	2.15
	Wardner	9	322	5240	1458	1508.9	997	2.51
1993	Kellogg	115	111	3210	966	563.7	806	1.91
	Page	6	139	794	550	227.1	486	1.89
	Pinehurst	55	111	3460	707	763.7	490	2.29
	Smelterville	26	201	3350	1307	818.6	1086	1.94
	Wardner	8	382	1290	766	353.4	695	1.61
1994	Kellogg	106	88	3770	835	551.7	660	2.13
	Page	7	90	1340	619	485.2	450	2.55
	Pinehurst	48	88	1490	491	283.7	420	1.82
	Smelterville	35	228	3060	1146	785.9	872	2.21
	Wardner	13	211	2270	1025	764.3	764	2.31
1995	Kellogg	98	62	4400	906	809	679	2.15
	Page	3	239	1430	791	600	622	2.46
	Pinehurst	38	22	1720	458	381	299	3.02
	Smelterville	20	297	3470	1020	1087	703	2.24
	Wardner	4	245	601	408	190	374	1.63

Table 4-10 (continued)
House Dust Lead Exposure by Year, 1974-2002[b]

Year	City	Number of Children	Concentration Range (mg/kg) Minimum	Concentration Range (mg/kg) Maximum	Mean House Dust Lead Concentration (mg/kg) Arithmetic Mean	Standard Deviation	Geometric Mean	Standard Deviation
1996	Kellogg	108	85	2300	684	399	577	1.86
	Page	3	140	630	303	283	231	2.38
	Pinehurst	38	100	2100	519	459	403	2.00
	Smelterville	12	99	11300	2299	4213	667	4.69
	Wardner	3	130	890	637	439	469	3.04
1997	Kellogg	59	43	6800	1047	1445	631	2.63
	Page	2	--	--	--	--	--	--
	Pinehurst	19	140	15000	1155	3363	397	2.83
	Smelterville	15	110	1070	453	323	354	2.09
	Wardner	6	220	1100	668	473	509	2.33
1998	Kellogg	84	140	4000	856	764	654	2.04
	Page	4	550	1500	848	441	779	1.57
	Pinehurst	36	71	2000	399	367	302	2.08
	Smelterville	26	340	1100	621	201	595	1.34
	Wardner	10	270	6000	1589	2335	738	3.27
1999	Kellogg	99	199	15300	1107	2560	617	2.23
	Page	3	151	258	222	62	216	1.36
	Pinehurst	64	45	4010	435	492	337	1.98
	Smelterville	16	248	2150	575	517	444	1.97
	Wardner	2	--	--	--	--	--	--
2000	Kellogg	74	49	11200	841	1806	457	2.52
	Page	3	86	220	131	77	118	1.72
	Pinehurst	40	150	2300	590	594	414	2.21
	Smelterville	23	150	1100	433	207	396	1.53
	Wardner	1	--	--	--	--	--	--
2001	Kellogg	71	64	1900	449	335	368	1.87
	Page	2	--	--	--	--	--	--
	Pinehurst	36	57	1200	291	268	222	2.01
	Smelterville	5	220	420	308	82	299	1.31
	Wardner	3	180	960	670	427	532	2.56
2002	Kellogg	65	32	3500	548	636	362	2.52
	Page	3	250	270	263	12	263	1.05
	Pinehurst	31	51	1200	204	213	157	1.94
	Smelterville	17	54	2400	448	536	278	2.87
	Wardner	2	--	--	--	--	--	--

-- When the number of observations is < 3, then data are not shown for confidentiality purposes.

[a]Kellogg, Wardner, and Page Combined

[b]Vacuum bags collected only from homes where children's blood samples were obtained.

[c]1989 exposures are projected from 1988 samples of the same homes.

mg/kg: milligram per kilogram

Table 4-11a-d
ANOVA Results-Vacuum Dust Lead Exposure, 1988-2002

Table 4-11a ANOVA Results-Vacuum Dust Lead Exposure, Site-wide

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	88	2714	1324	-
1989*	68	3569	1383	0.8043
1990	171	1475	1080	0.0658
1991	170	1250	984	0.2679
1992	243	1051	801	0.0046
1993	210	921	720	0.1273
1994	209	813	621	0.0465
1995	163	801	554	0.1980
1996	164	756	526	0.5754
1997	101	945	519	0.9058
1998	160	760	547	0.6231
1999	190	813	487	0.1669
2000	141	693	425	0.1336
2001	117	394	309	0.0011
2002	118	436	279	0.3472
Overall				**0.0001**

Table 4-11b ANOVA Results-Vacuum Dust Lead Exposure, Kellogg

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	58	3336	1516	-
1989*	47	4568	1652	0.6957
1990	89	1610	1245	0.1020
1991	75	1460	1283	0.7788
1992	125	1183	928	0.001
1993	115	966	806	0.1180
1994	106	835	660	0.0352
1995	98	906	679	0.7915
1996	108	684	577	0.0957
1997	59	1047	631	0.4727
1998	84	856	654	0.8012
1999	99	1107	617	0.7158
2000	74	841	457	0.0139
2001	71	449	368	0.1033
2002	65	548	362	0.9036
Overall				**0.0001**

Table 4-11c ANOVA Results-Vacuum Dust Lead Exposure, Smelterville

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1988	23	1746	1237	-
1989*	14	1628	1193	0.9074
1990	15	2117	1849	0.1170
1991	27	1468	1393	0.0419
1992	26	1175	881	0.0062
1993	26	1307	1086	0.2947
1994	35	1146	872	0.2557
1995	20	1020	703	0.3409
1996	12	2299	667	0.8997
1997	15	453	354	0.1728
1998	26	621	595	0.0028
1999	16	575	444	0.0608
2000	23	433	396	0.5172
2001	5	308	299	0.1735
2002	17	448	278	0.8783
Overall				**0.0001**

Table 4-11d ANOVA Results-Vacuum Dust Lead Exposure, Pinehurst

Year	N	Mean (mg/kg)	Geomean (mg/kg)	P-value
1990	57	1140	747	-
1991	59	912	603	0.1613
1992	78	769	601	0.9827
1993	55	707	490	0.1197
1994	48	491	420	0.2839
1995	38	458	299	0.0743
1996	38	519	403	0.1646
1997	19	1155	397	0.9491
1998	36	399	302	0.2597
1999	64	435	337	0.4513
2000	40	590	414	0.1657
2001	36	291	222	0.0005
2002	31	204	157	0.0433
Overall				**0.0001**

mg/kg: milligram per kilogram
N: number of samples used in the analysis
* The data for 1989 was substituted with the data for 1988.

SECTION 5.0 RELATIONSHIPS BETWEEN BLOOD LEAD LEVELS AND ENVIRONMENTAL EXPOSURES

5.1 Observed Blood Lead Concentrations

5.1.1 Trends in Blood Lead Levels

Blood lead has declined over the years in response to the soil cleanup and LHIP activities. A substantial drop in the number and percent of children showing EP levels greater than 35 μg/dl and/or blood lead levels exceeding 25 μg/dl was associated with the introduction of the LHIP, CUA Fast-Track Cleanup, and fugitive dust control efforts instituted in the mid-1980s. Tables 2-1a-c and 2-2 summarized lead health monitoring results during 1983-87. The 1983 Lead Health Study showed that 26% of children tested in Smelterville exhibited EP levels greater than 35 μg/dl and blood lead levels exceeding 25 μg/dl on follow-up testing. By 1987, that percentage had decreased to 1.9% or 3 children, site-wide.

Blood lead levels have been compared between years for 1988-2002. Tables 5-1a-d show comparisons among geometric mean blood lead levels for successive years for the larger cities and site-wide for the period 1988-2002. The results were obtained by conducting analysis of variance and multiple comparisons to identify like-groups among successive years. A significance criteria of $p < 0.05$ was used. In general, these results reflect the changes in the blood lead histograms shown in Section 2.0, and are associated with the significant changes in soil/dust exposures noted in Section 4.4. Relatively large and significant decreases in blood lead levels were observed in the initial years of the High-Risk Yard Cleanup, as the number of children in high-risk situations was reduced and yard soil and house dust exposures decreased. The increase noted in 1988-89 prior to the High-Risk Yard Cleanup was limited to Kellogg and likely associated with immigration of new families and a 25% increase in the number of children tested (See Tables 4-3 and 2-3). Mean blood lead levels were not significantly different between 1988 and 1989 in Smelterville.

However, decreases in mean blood lead levels associated with initial High-Risk Yard Cleanup the following year were more pronounced in Smelterville. In 1989-90, geometric mean blood lead levels in Smelterville decreased by 4.5 μg/dl, or about 33%. Kellogg experienced a respective 1.0 μg/dl, or 11%, decrease in the same year. In 1990-91, the effect was site-wide with a 2.9 μg/dl geometric mean decrease noted in Smelterville, compared to 2.3 μg/dl geometric mean decrease in Kellogg and a 2.0 μg/dl geometric mean decrease in Pinehurst. In the first two years of the High-Risk Yard Cleanup Program in 1989-91, blood lead levels decreased 55% in Smelterville, 35% in Kellogg, and 30% in Pinehurst. During this period the estimated number of children living on contaminated yards was reduced from 87% in 1988 to 25% in 1991.

A significant increase in blood lead levels, again likely associated with new families moving to contaminated properties on the site, occurred in 1991-92 site-wide. Many of these families were inexperienced with living in high-risk homes and their children exhibited high blood lead levels (See Section 4.3.5). The increase in immigration limited the success of risk-reduction efforts over the next four years, as many socioeconomically disadvantaged families moved to the Box to avoid high rents in neighboring areas experiencing a real estate boom. Unfortunately, prior to the initiation of the ***Geographic Area Cleanups*** in 1995-96, few clean homes were available for these children (See Section 4.4.2).

In 1992, significant geometric mean blood lead increases of 1.5 µg/dl in Smelterville, 0.9 µg/dl in Kellogg and 0.8 µg/dl in Pinehurst were observed. Since 1992, significant increases in blood lead levels were noted in Pinehurst in 1993-94 and 1998-99. No other significant increases in blood lead levels were observed since 1992.

In 1993, blood lead levels again decreased, returning to near 1991 mean concentrations in Kellogg and Smelterville. Blood lead levels in Pinehurst decreased by more than 50% to mean concentrations less than 3 µg/dl. Interpretation of changes in mean blood lead levels in the 1991-93 time period requires some caution as the analytical methodology and detection limit was changed in 1993. In 1991 and 1992, the detection limit was 5 µg/dl and below detection limit (BDL) values were reported as 4 µg/dl in developing summary statistics. In 1993, the detection limit was lowered to 1.0 µg/dl and BDL values were reported as 1.0 µg/dl. This change in accuracy and reporting could affect calculated group statistics in those years, as more members of the population approached the blood lead detection limit.

Little change, and occasional increases in mean blood lead levels occurred from 1993 to 1996, as little change in exposure profiles was achieved in these years. This was despite the intervention and yard remediation efforts, as new children continued to move into high-risk situations on the site. In 1994, Pinehurst blood lead levels increased again to an arithmetic mean concentration of 5.4 µg/dl (4.6 µg/dl geometric). From 1994 to 1997, arithmetic mean blood lead levels stabilized at 6.0 to 7.0 µg/dl in Kellogg and Smelterville (5.0 to 6.0 µg/dl, geometric) and 4.0 to 5.0 µg/dl in Pinehurst (3.5 to 4.5 µg/dl geometric). During this time little progress was made in reducing the percentage of children living on contaminated yards as new families continued to move into contaminated homes. Immigration offset the gains in overall exposure reduction as few homes were remediated in 1993-94 due to stalled negotiations with the PRPs. The percentage of children living on contaminated yards actually increased from 18% in 1994 to 29% in 1995, peaking at an estimated 220 children on contaminated yards in 1995.

In 1994-95, the PRPs began cleaning up geographic areas of the community in addition to the High-Risk program aimed at homes of children. This provided more homes with clean yards for children migrating to the site. The result was large reductions in both the percentage of children living in contaminated homes, and in community and neighborhood soil lead exposures in 1996-97 (Table 4-5). By 1998, only 4% of children tested site-wide were in homes with soil lead levels exceeding 1,000 mg/kg lead. In 1997-98, a significant decrease of 1.0 µg/dl in mean blood lead levels was observed in

Kellogg following the initiation of area-wide cleanups in the previous year. That cleanup resulted in three consecutive years of significant decreases in neighborhood soil exposures that reduced the geometric mean by 68% from 933 mg/kg to 300 mg/kg lead. A significant decrease in blood leads of 2.2 µg/dl geometric mean was observed for Smelterville in 1998-99, the largest reduction observed since 1991. This corresponded with a 25%, marginally significant (p=0.06), decrease in dust lead exposure from 595 mg/kg to 444 mg/kg.

The 1999 Five Year Review concluded that blood lead RAOs would likely be achieved at the end of cleanup activities, provided house dust lead concentrations continued to decrease to below 500 mg/kg lead. From 1999 to 2002, site-wide blood lead levels decreased by 33% from 3.9 to 2.6 µg/dl geometric mean (4.7 to 3.1 µg/dl arithmetic) with significant drops in both blood lead and house dust lead in 1999-2001. Significant changes in all soil lead and house dust exposure variables were also achieved in Pinehurst in 1999-2002, as the geographic areas cleanup focused on that community. By 2002, community mean geometric mean blood lead levels ranged from 2.4 µg/dl in Pinehurst to 2.8 µg/dl in Kellogg, where the majority of properties awaiting cleanup are located.

5.1.2 Comparison to National and State Lead Absorption Databases

Throughout the history of lead health programs in the Silver Valley and the Box, the question as to how these data compare to national blood lead levels is continuously asked by a variety of stakeholders. Table 5-2 shows blood lead levels from the various national and State-wide studies. There is a divergence of opinions regarding the appropriate comparisons among various health professionals. An explicit warning on technical grounds against making comparison between national and local blood lead levels is in the Executive Summary of ATSDR's 1988 report to Congress on childhood lead poisoning in America (ATSDR 1988).

Such large data sets, for various technical reasons, should not be used to compare and draw conclusions about the relative degree of health hazard existing for children in individual communities. Scientific designs of the NHANES surveys, are stratified in a way that does not allow simple comparisons with results of blood lead distributions for a single community. NHANES data provide a current snapshot for numerous *national* subsets, or strata of numerous communities, that may not be appropriate for any single community. Additionally, the Box surveys were conducted in a manner that does not match the organization of the various demographic and socioeconomic strata in the NHANES III survey reports (e.g., race/ethnicity, income, housing age). The LHIP blood lead results are observational data collected from children participating in voluntary health intervention efforts. The objective of the LHIP was to encourage maximum participation to identify children at-risk that could benefit from follow-up services. This was not a survey or experiment designed to obtain a representative sampling of the population. The data represent approximately half of the target population of children residing in the Bunker Hill Box between the ages of nine months and nine years who elected to participate. There are age biases and repeat children included in the data.

Caution should be executed in comparing LHIP results with elevated blood lead prevalence rates from Idaho or nation-wide surveys. Nevertheless, to answer questions posed by various stakeholders, the data are presented in Table 5-2. In the Box, 2.3% of 1-6 year old children tested in 2002 showed blood lead levels greater than or equal to 10 μg/dl. A state-wide survey conducted in 1997 found that 4.2% of pre-school children living in pre-1970 housing exceeded the 10 μg/dl criteria (IDHW 1998). Nationally, the 1991-1994 National Health and Nutrition Evaluation Survey (NHANES III) reported that 5.6% and 1.4% of 1-5 year old children living in pre-1946 and 1946-1973 aged housing, respectively, exceeded the 10 μg/dl blood lead criteria among similarly aged white non-Hispanic children (Pirkle et al. 1998).

The 2002 geometric mean blood lead for 1-6 year old children in the Box was 2.8 μg/dl and the arithmetic average was 3.3 μg/dl. State-wide, the average blood lead level for 1-6 year old children in 1997 was 3.7 μg/dl in older housing. The majority of housing in the Box is in the pre-1970 category. Nationally, 1991-1994 levels for the non-Hispanic population were 3.3 μg/dl and 2.4 μg/dl in pre-1946 and 1946-1973 housing, respectively (Pirkle et al. 1998).

5.2.1 Quantitative Analysis of Blood and Environmental Exposure Lead Levels

5.2.1.1 The Quantitative Analysis Database

Several quantitative analyses were presented in the 1999 Five Year Review. The approaches and methods used were suggested by a number of contributors and several collaborators provided input, advice and direction. This effort was possible because of the unique nature of this database. The database for the Box is a large and comprehensive assembly of information from several sources that, in combination, provide more than 5,000 observations of children's blood lead levels and environmental exposure indices over a fifteen year period of massive cleanup and exposure reductions that have effected 60% to 80% reduction in blood lead levels. However, there are some drawbacks. Many of these techniques were data intensive and sensitive to experimental design and variable distribution assumptions underlying the models. Some techniques were more useful than others in evaluating remedial effectiveness. All were presented and critiqued in the 1999 Five Year Review (TerraGraphics 2000b, TerraGraphics 2001).

Only the initial techniques typically applied in these types of investigations have been updated for this report. Simple correlation and multiple regression models that have been applied to similar studies for many years are examined. More sophisticated mixed model, repeat measures and structural equations or pathways techniques that are relatively new to the analysis of dose-response or remedial effectiveness lead health issues were not updated. Nevertheless, it is important to reiterate the disclaimers provided in the 1999 Five Year Review regarding quantitative analysis of this observational database.

The surveys providing the data were not experiments and were not specifically designed to accommodate the analysis techniques applied. The biological data were obtained from the annual blood lead surveys of the LHIP using appropriate technical methods with rigid quality control procedures. These blood lead samples are solicited for the expressed purpose of identifying individual children with high blood lead levels. The objective of the LHIP is to obtain a sample from as many at-risk children as possible, identify these children in a confidential manner, and provide follow-up services designed to effect blood lead reductions. Over the years, the LHIP has been successful in recruiting approximately half of the eligible target population. It is neither a random sample nor a controlled solicitation. It is also voluntary and some bias is introduced each year through self-selection of the population. Non-participants are questioned regarding reasons for refusal and these were summarized and discussed in Section 4.2.2.

Environmental data include house dust samples that are collected concurrent with the blood lead and only from the homes of participating children that have a vacuum cleaner with residue present. Soil data were collected to support RI/FS and Remedial Action activities using enforcement quality procedures. Environmental exposures have changed extensively since 1988. With regard to soil exposures, initial remediations were purposefully targeted at High-Risk children by age, environmental media concentrations and blood lead data. Subsequent soil cleanup was accomplished by geographic areas, which resulted in soil exposure variables that varied in magnitude and in the characteristics of the distribution from year to year.

With regard to other sources of lead, little locally obtained foodstuffs are used by this population and market basket intakes are likely representative. In contrast to soil and dust exposures, little change in dietary intake has occurred in the past decade since lead was eliminated from food packaging during the 1980s (NRC 1993). Drinking water has been consistently observed to meet maximum contaminant levels (MCLs) and has likely not changed in the 1990s. No efforts to reduce paint lead exposures have been implemented other than advisories during follow-up. Paint lead exposure may have increased over the past two decades as socioeconomic conditions have failed to improve and much of the housing stock is old and used for low-cost rentals.

Finally, the mobility of the population must be considered. The majority of families with young children in the Box move annually, both within and beyond the site boundaries. About half the children in each annual blood lead survey are repeats from the previous year. The majority of the remainder was either new to the program or returning from another address outside the Box. As a result, children's long-term exposures are complex, reflecting both changing home location, decreasing exposures related to the general cleanup, and specific remediation or intervention follow-up efforts. As a result, many of the effects of the various risk reduction efforts converged on the highest risk-children simultaneously, with risk profiles changing markedly in some years, but not others.

In summary, the quantitative techniques applied use observational data. The distribution of variable values and the number of observations in various categories varies over the years in both magnitude and character. There are difficult questions regarding appropriate variable transformations to accommodate the underlying assumptions of normality in particular analyses. Generally, log transforms of environmental data have been applied where univariate analysis and scatter plots indicate skewed distributions. Appropriate caution should be exercised in interpreting and using the results. However, this is a unique database providing serial blood lead data linked to comprehensive data for lead in air, soil, and dust during the course of intensive soil remediation and intervention programs.

5.2.1.2 Correlations of Blood Lead and Environmental Exposures

The data presented and analyzed in this report were acquired and combined from various sources including the LHIP, remedial investigation, and remedial action monitoring efforts. As such, this study is not a designed and controlled experiment, but is observational and subject to limitations of the underlying programs supplying the data. The resulting distributions and variability in the data are controlled by the nature of the cleanup effort, health response activities, and the behavior of the population. Prior to applying inferential analyses, descriptive statistical techniques have been used (e.g., histograms, residuals plots, normal probability plots, box plots, and scatter plots) to assess variable distributions and variability. Transformations have been incorporated to meet the basic assumptions underlying the analyses. Typically, the log transformation of the variables improved data normality, ensuring minimal violation of the statistical assumptions, and inferences developed in the following analyses generally rely on geometric means and associated probability indices.

Over the last fifteen years, the yard soil remediation program (over 1,500 yards remediated) has reduced direct and indirect lead soil exposures to children by replacing high lead soils (yards ≥1,000 mg/kg) with clean soil, the majority of which are less than 100 mg/kg lead. Concurrently, this remediation, combined with other source control efforts has reduced the soil and dust lead exposures throughout each community. The LHIP has supplemented the remedial efforts by serving the families of children with elevated blood levels through intervention, education, and source control.

During this time period blood lead levels have been reduced by more than 75% in the most contaminated areas. However, quantitatively evaluating the effectiveness of these remedial and intervention efforts requires analysis of a complex and dynamic relationship between children and lead in their environment. Analysis of variance and regression techniques have shown important relationships between blood lead levels and several environmental and child-specific variables at this site. Previous studies have shown significant relationships between blood, house dust and soil lead levels (both at the home and in the community in general), age of the child, home hygiene practices, nutrition, and socioeconomic co-factors.

A general correlation matrix was developed and examined for the combined data (all cities, all years) to assess the association between variable pairs and to identify the best potential predictors of blood lead concentrations for multiple regression model analysis. Table 5-3 shows the most significant correlates for blood lead both untransformed and log transformed. Examination of the correlation matrix shows that blood lead concentration is significantly correlated with the child age (negative association), house dust lead levels, yard soils, neighborhood soils, community soils and air lead levels. All correlations are significant ($p<0.001$). Correlation coefficients are generally greater for the log transformed blood lead levels and significantly higher for the log transformed dust concentration. The highest correlation coefficients for untransformed blood lead are with the geometric community-wide soil lead mean ($r=0.438$), followed by the neighborhood (200 ft. radius) geometric soil lead variable ($r=0.392$), log transformed house dust lead ($r=0.283$), and untransformed individual yard soil ($r=0.270$).

The imputed dust lead concentration and log transformed imputed dust lead concentration are also included in the correlation analysis. These variables were created to address missing house dust observations. Many homes included in the annual blood lead survey do not provide vacuum bag dust samples, either because the vacuum bag has been recently disposed of, the vacuum is used outside or in the car, or the home has no vacuum cleaner. Previous studies and health intervention activities have noted that children in the homes that do not provide a vacuum bag sample tend to have higher blood lead levels and the absence of a vacuum is an important risk factor in childhood lead poisoning within the Box.

It was important to include these children in dose-response analyses conducted for this population. This was accomplished with the imputed dust lead variables MISSDUST and DUSTIMP. If a dust sample was present, MISSDUST=0 and DUSTIMP assumes that concentration value. If the sample was missing MISSDUST=1 and DUSTIMP has the value of the mean house dust concentration for the community and year that the blood lead was drawn. This imputed value procedure more than doubles the number of observations included in the quantitative analyses. Both model forms, raw and imputed dust lead concentration, are presented and discussed in the following analyses.

5.2.1.3 Multiple Regression Models

Linear regression models relating blood lead levels to environmental lead concentrations were developed in the 1999 Five Year Review. Stepwise multiple regression techniques were applied to assess various combinations of selected variables. Age, log transformed house dust, individual yard soil, neighborhood (within 200 ft. radius) and community soil lead concentrations all remained significant in multiple regression against both log transformed and untransformed blood lead levels. Both raw dust lead and imputed dust lead concentrations show much greater significance and added to the strength of the regressions as log transformed variables. Transformation of the yard soil lead variables added little to model or parameter significance. However, the log transform was used in the final selected models to normalize the distribution.

The final models selected to represent variations in blood lead levels were for the raw dust lead format (Table 5-4c):

$$BLPB = \beta_0 + \beta_1 * AGE + \beta_2 * LNDUSTPB + \beta_3 * LNSOILPB + \beta_4 * GSOIL200 + \beta_5 * GCITSOMN + \varepsilon$$

and for the imputed dust lead model (Table 5-4b):

$$BLPB = \beta_0 + \beta_1 * AGE + \beta_2 * LNDUSTIM + \beta_3 * MISSDUST + \beta_4 * LNSOILPB + \beta_5 * GSOIL200 + \beta_6 * GCITSOMN + \varepsilon$$

where:

BLPB	=	observed blood lead level,
AGE	=	child's age,
LNDUSTPB	=	log transformed house dust lead concentration,
LNDUSTIM	=	log transformed imputed dust lead concentration,
MISSDUST	=	indicator of missing vacuum bag sample,
LNSOILPB	=	log transformed soil lead concentration of individual home yards (homes where children's blood lead levels were tested),
GSOIL200	=	geometric mean soil lead concentration within 200 feet,
GCITSOMN	=	geometric mean community soil lead concentration
β_0	=	intercept,
β_1, β_2, β_3, β_4, β_5 and β_6	=	corresponding regression coefficients, and
ε	=	error term

The observations from 1999-2002 were added to the original database and these models were rerun from 1988-2002. Statistical summaries for these multiple regression models are presented in Tables 5-4a-c. The significance, coefficients, r-square and error statistics and general findings of these models are similar to the earlier report. Each of these models suggests significant effects associated with all of the soil and dust variables that decrease with age. Because of potential covariance effects among the soil variables, it is difficult to quantify the relative contributions of these sources to children's blood lead levels. Alternative models that successively delete the individual soil variables are shown in Tables 5-4d-f, as well. The relative strengths of the soil variables seems to be consistent with the community variable (R^2=0.25) showing the greatest effect followed by neighborhood (R^2=0.23) and yard soils (R^2=0.18).

Analyses conducted for the ***1983 Lead Health Study*** suggested that 40% of lead exposure to children came from house dust, and 60% from soils about evenly split between the home yard and the greater community (PHD 1986). This 40-30-30 (dust-community-yard) partition was used in the original analysis developing the cleanup criteria for the site in 1990 (USEPA 1991). Structural equations analyses were also conducted in the 1999 Five Year Review, and a subsequent model was developed indicating that about 42% of soil/dust lead exposure to children came from house dust, 27% from community soils, 19% from neighborhood soils near the home, and 12% directly from the home yard. This finding was consistent with the original 40-30-30 model and was employed as the selected site-specific model in the 1999 Five Year Review (TerraGraphics 2000b). Although the structural equations analysis was not repeated, addition of the most recent year's data to these simple regression models continues to indicate that results have remained consistent.

5.2.2 Lead Intake and Uptake Biokinetic Analysis

5.2.2.1 Human Health Exposure Pathways

Several variations of environmental exposure models have been proposed for children within the Box. Figure 5.1 shows the model evaluated in formulating the cleanup strategy and in subsequent IEUBK analyses of blood lead response for the Box. This model assumes that children are exposed to multiple sources of lead including diet, drinking water, air, soils and dusts, and other consumer products including lead paint in the home. Consistent with other studies, the major source of exposure to young children in the Box is contaminated soils and dusts that manifest lead derived from other sources (Succop et al. 1998, Manton et al. 2000, TerraGraphics 2001).

Dietary and Drinking Water Lead Sources: Gardening and consumption of locally grown produce has been discouraged in the Box by State and PHD health authorities since the epidemic lead poisoning associated with smelter operations in the 1970s. Garden produce and fish consumption were reevaluated by the State Health Department in the early 1980s, following smelter closure, and the advisory against local gardening was continued. These surveys and advisories were summarized in the *Human Health Risk Assessment: Protocol for the Populated Areas of the Bunker Hill Superfund Site* (JEG et al. 1989). As a result, the diet for this population is appropriately represented by the market basket. Dietary default intake rates recommended in the USEPA IEUBK and Adult models for lead are used to characterize this exposure route. Residents of the Box are served by public water systems that have consistently met the MCL for both source and tap delivery requirements.

Lead in Paint and Consumer Goods: Paint lead was sampled in the large epidemiological surveys conducted in 1974-75 and 1983 in the Box. Because the housing stock is predominantly older than 1960, lead paint is prevalent and has been investigated on a case-by-case basis in the follow-up of children with high lead levels. Occasional problems with lead paint have been noted in individual situations, but health officials do not believe this problem to be widespread. The majority of interior paint lead impact is believed to manifest through house dust. Similarly, exterior paint and gasoline sources of lead are predominantly manifested through soils.

As a result, lead originating from paint and gasoline sources was accounted for in the soil and dust pathways. No systematic remediation of lead paint has occurred in the Box. It is possible that risks due to paint lead have exacerbated over the last two decades as socioeconomic conditions have deteriorated, more housing has moved to the lower income rental markets, and more disadvantaged families have been attracted to the area. Presently, more than 30% of children in this county live at or below the poverty level, more than double the state-wide rate (Idaho Kids Count 2000). The risk of lead paint exposure will remain following the soil remediation effort and is likely reflected in the residual house dust lead concentrations observed site-wide. Although to date, observed reductions in blood and house dust lead levels have been a result of decreased soil lead concentrations. As of 2002, house dust lead levels in Smelterville averaged 350 mg/kg, with 9% of homes exceeding 1,000 mg/kg. This mean is comparable to about 200 mg/kg average in homes of similar age and socioeconomic strata outside the mining district in northern Idaho (TerraGraphics 2000b). The latter concentration is likely reflective of the typical paint lead contribution to overall exposure in older homes (TerraGraphics 2000b).

Lead in Soils and Dusts: Lead in soils and house dust has long been recognized as a principal source of excess lead absorption among children within the Box. The cleanup strategy adopted in the Populated Areas ROD was based on partial removal of contaminated surface soils, capping of sub-surface contaminants and waste piles throughout the site with a permanent ICP. Constructing barriers over contaminated sources prevented direct contact and isolated contaminants in place. This strategy requires that house dust lead levels progressively decline to acceptable concentrations as the soil and waste pile sources are contained. These factors suggest that children on the site are primarily exposed by direct contact with contaminated soils or house dusts that generally represent an indirect exposure to lead from outdoor soils, paint, and possibly, residual smelter particulates remaining in structures.

Lead in house dust originates from numerous sources and concentrations depend on the relative contribution of those sources as well as the habits of the residents (Succop et al. 1998, IDHW 2000, TerraGraphics 2000b, TerraGraphics 2001, TerraGraphics 2001). Soil sources can affect house dust through a number of routes. Home yard, neighborhood and community-wide soils all contribute to varying degrees through tracking by residents, pets or visitors; or as a deposited aerosol from airborne dusts. Potential interior sources of lead in the Box include lead-based paints, residual contaminants in structures and soft surfaces (i.e., carpets and furniture) from smelter operation years, or residents bringing lead into the home from occupational or hobby activities. Reductions in house dust levels over the last decade depend on all of these factors. Specific efforts have reduced lead in house dust through the soil remediation, fugitive dust control, and the LHIP.

The role of house dust in environmental lead exposure within the Box was extensively reviewed in the 1999 Five Year Review. That document summarized the accumulated environmental media data and identified the trends in house dust lead levels for each community and population. Factors contributing to elevated house dust lead concentrations and loading rates were identified and quantified. Previous analysis of available soil and dust data suggests that house dust contains a complex combination of lead from several sources modified by a variety of social, cultural, and environmental factors. Soils from home yards, neighborhoods, and throughout a community all seem to contribute significantly to house dust. Except children that eat paint chips, lead paint exposure predominantly comes from peeling and chalking paints incorporated into house dusts or outdoor soils. Local produce can be contaminated by soils or dusts adhering to plant tissue despite washing. Airborne contamination presents its greatest hazard as it settles and contaminates surface dusts that are ingested by children (USEPA 1986).

Understanding the soil and dust pathways is critical to developing effective risk reduction and remediation strategies for the Box. Figure 5.2 summarizes the results of extensive pathway analyses conducted in the 1999 Five Year Review. These analyses suggest that about 40% of lead in a typical child's blood comes from the house dust and about 60% from exterior soils. However, examination of the relationship between house dust and soil lead levels suggest that most of the lead in house dust originates from those same soil sources (TerraGraphics 2000b). In turn, the soil contribution comes from different sources, as well. Approximately half of the soil lead in house dust is attributable to the greater community, with the remainder coming from the home yard and the immediate neighborhood of the home (i.e., within 200 feet). Although this relationship seems to apply to the overall community, dust lead concentrations demonstrate large variation. Soil lead levels significantly correlate with, but explain 20% of the variability in house dust lead concentration.

Analysis of dust collected from mats placed in Box homes and associated questionnaire data shows that much of the variation in house dust lead levels is associated with housing, socioeconomic, behavioral, family, occupational, and recreational factors. Although several of these factors do not affect dust lead concentration, as much as 26% to 31% of the variability in dust and lead loading rates (the amount of dust and lead accumulating in a home) is explained by these factors. Socioeconomic status (SES) plays a complex role in how much dust collects in a home (dust loading rate). Home or housing related factors (home age, yard cover, inside and outside paint condition); socioeconomic factors (own/rent, occupancy time, number of residents); personal habits (use of mats, children's outside play frequency, general household hygiene, pets), and occupational/hobby related factors (mill worker, carpenter, landscaper, sanding within the home) influence dust loading rate.

These SES factors are indicative of complex social structure with many inter-related factors that influence both dust and lead loading in this community. In the presence of active sources of lead (i.e., contaminated soils or paint), this can result in higher *lead loading* rates. Many of the factors relate to both lead sources and dust loading. Paint condition can influence both dust and lead loading rates as a contaminant source and as an indicator of household hygiene and socioeconomic status. Grass cover of the yard and general household hygiene are significant factors influencing lead and dust loading rates.

Because of the complexity and uncertainty of the soil/dust relationship it is difficult to quantify how much lead children intake directly from the various sources, or indirectly through the soil to house dust pathway. This uncertainty was recognized early in the project. The methodologies for assessing risk in the Populated Areas of the site were established in the *Human Health Risk Assessment Protocol for the Populated Areas of the Bunker Hill Superfund Site* (JEG et al. 1989). It was determined to include three different dust:soil partition scenarios in estimating intake rates. These intake partition scenarios represent different relative contributions from soil and dust sources. The USEPA default (55% house dust:45% yard soil) represented the current scientific consensus, with the 40:30:30 (40% house dust:30% yard soil:30% community soil) weighted toward soils and the 75:18:7 (75% house dust:18% yard soil:7% community soil) toward house dust. Results of intake and biokinetic analysis were reported in ranges to accommodate the uncertainty associated with the relative soil/dust ingestion rates. Each has been tracked throughout the cleanup and evaluated annually and was applied to the Integrated Exposure Uptake Biokinetic Model (IEUBK). All three scenarios were included in pre-1990 ROD risk assessment analyses conducted for the Box .

The three original partition scenarios developed were (JEG et al. 1989, TerraGraphics 1990):

- 55:45 (IEUBK default) house dust:yard soil partition assumes 55% of a child's intake derives from household dust and 45% from residential yard soils. The USEPA developed this partition based on consensus from literature and time-weighted analysis of children's behavior.

- 40:30:30 house dust:yard soil:community soil partition assumes 40% of children's soil/dust ingestion derives from house dust and 60% from soil divided equally, 30% from home yard soil and 30% from community-wide soils (Figure 5.2). These site-specific ingestion rates were developed using the results of earlier dose-response analyses of the 1983 Lead Health Study database and the biokinetic model of Harley and Kneip (Harley et al. 1985, TerraGraphics 1987). Those results (based on a typical bioavailability of 30%) suggested that a high-risk child ingested about 60 mg/day of yard soil and house dust from the home environment and 25 mg/day from other soil and dusts in the community. The 60 mg/day was partitioned 60% house dust:40% yard soil, based on parental interviews indicating a 60:40 indoor/outdoor orientation for 2-6 year-old children. This resulted in a 36:24:25 mg/day (42:28:29%) ratio that was rounded to 40:30:30 in relative percentage terms.

- 75:18:7 house dust:yard soil:community soil partition assumes 75% of child's soil and dust ingestion derives from house dust, with 18% from yard soils, and 7% from community soils. This partition was based on time-weighted estimates of young children's indoor-outdoor exposures and was developed subsequent to analysis of the 1988-89 LHIP survey data.

A fourth partition scenario was derived through structural equations pathways analysis conducted in the 1999 Five Year Review: 42% house dust, 27% community-wide soil, 19% from neighborhood soil (within a 200 ft. radius), and 12% yard soil.

5.2.2.2 Estimation of Soil and Dust Lead Intakes

Typical lead intake from soil and dust sources can be estimated by multiplying soil and dust ingestion rates by the respective lead concentrations in each media. This was accomplished for each child for each year assuming a typical combined soil/dust consumption rate of 100 mg/day. Tables were developed for each of the four soil and dust partition scenarios described in the last section.

The different partitions result in similar patterns of decline in total soil and dust intake estimates over the past decade. Tables 5-5a-d through 5-8a-d show multiple comparisons and year-to-year analysis of variance results for each of the partition scenarios, respectively. These tables summarize the results and trends in estimated daily lead intake (μg/day) for resident children from soil and dust sources for each year by community and site-wide. The largest decreases in estimated site-wide intake rates were achieved from 1989-1991, 1993-1994 and 2000-2001. The earlier changes were most evident in Kellogg and Smelterville and the latter in Pinehurst. Pre-remediation arithmetic mean intake rates were estimated at 250 to 270 μg/day site-wide under the various scenarios. During the first year of remediation 1989-90, intakes decreased by 40-50% to 140 to 155 μg/day lead. Another 20-30% reduction was achieved in 1990-1991 to typical levels of 105-120 μg/day depending on the scenario. The greatest decreases were associated with reductions in yard soil exposure (80%), followed by neighborhood soils (50%), house dust (35%), and community mean soils (27%).

From 1991 to 1992 those partition scenarios dominated by house dust showed a 5-15% decrease that was marginally significant. Under the 40:30:30 and default scenarios the 1991-1992 change was not significant in Kellogg. Intake estimates for 1991-1992 were in the 100-125 μg/day range for Kellogg and Smelterville. From 1992 to 1993 another 15-20% reduction was achieved associated primarily with soil exposures in all partition scenarios that was highly significant. By 1993, site-wide estimated intake rates were around 80 μg/day or decreased by more than 70% since 1988-89. In 1993-94, a 5 to 10% significant reduction occurred ($p=0.003$-0.02) with site-wide intake rates decreasing to 70-80 μg/day. Geometric mean intake rate estimates show a similar pattern with means reaching 60 μg/day by 1994.

No significant change in site-wide intake rates has been noted between 1994 and 2000, except a slight increase in Smelterville in 1998 associated with high dust lead concentrations in a small number of dust samples in 1997. Gradual decreases, however, have occurred as the area-wide cleanups have progressed and site-wide lead intake estimates were 55 to 70 μg/day by 1998. In 2000, the site-wide arithmetic mean had decreased to 44 μg/day and by 2001-2002 the level was near 30 μg/day. The most significant change occurred in Pinehurst where intake levels decreased by half from 2000 to 2002. Geometric mean intakes in 2002 ranged from 22 μg/day in Pinehurst to 34 μg/day in Kellogg, depending on the community and partition scenario. This represents a 65% decrease in Pinehurst and an 85% decrease in Kellogg, from 63 μg/day and 228 μg/day, respectively in 1988-89.

The lead intakes under the various IEUBK scenarios are predictive of the blood lead trends in Table 4-6a-d. All dust/soil partitions examined show significant site-wide reductions in estimated lead intake from soil and dust were achieved in 1989-1990, 1990-1991 and 1992-1993. These are the same years in which significant decreases in blood lead levels were also noted site-wide. No significant change in estimated intake rates was evident under any partition scenario for 1994-97 (except Pinehurst in 1994). Similarly, there was little change in mean blood lead levels during those same years. Increases in site-wide blood lead levels were noted in 1991-1992 and 1993-1994. Changes in intake rates were not significant in those years for those partitions with higher portions of soil and were marginally significant ($p=0.02$-0.03) for those dominated by house dust. Gradual decreases in both blood lead levels and estimated intake rates were evident from 1996 to 1998 as area-wide remediation continued. Kellogg showed a significant blood lead drop in 1998, as remediation was completed in the north side of the city, and in 2001, as dust lead levels decreased site-wide. Significant decreases were noted in Smelterville in 1999 and 2001, and in Pinehurst from 1999 through 2001 as yard remediation was focused there and significant decreases in house dust lead concentration were observed.

5.2.2.3 Estimation of Effective Soil/Dust Bioavailability

Figure 5.3 depicts site-wide intake rates and blood lead levels for 1988-2002 and shows that blood lead levels have paralleled intake rates throughout the cleanup. This Figure and the preceding discussion illustrate the efficacy of the cleanup strategy. Soil cleanup was undertaken to both decrease direct soil exposure and reduce the soil lead contribution to house dust. Consequently, as soil and house dust lead levels decreased, the combination effected 65% to 85% reductions in children's lead intake by 2002. The reduced lead intake, in turn, resulted in a corresponding reduction in blood lead levels. The magnitude of the blood lead decrease depended on how much of the lead intake is absorbed, or the uptake. In this case, the percent of lead intake that is absorbed is referred to as absolute bioavailability. Whether sufficient reductions in intakes have been achieved to meet blood lead health criteria depends on the effective bioavailability, or how much of the lead in soils/dust is absorbed by children.

The relationship illustrated in Figure 5.3 was used to estimate the aggregate bioavailability of soils and house dust in the 1999 Five Year Review. This analysis is similar to the methodology used to estimate the soil/dust dose coefficient for lead in earlier IEUBK applications at this site (JEG et al. 1989, TerraGraphics 1990). Total lead uptake was estimated by dividing observed blood lead levels by the Harley and Kneip age-specific blood lead response coefficient or reciprocal clearance rate (CR^{-1}) shown below (Kneip et al. 1983, Harley et al. 1985).

Age (yrs)	1	2	3	4	5	6	7	8	9
CR^{-1}	0.297	0.404	0.366	0.350	0.363	0.345	0.325	0.248	0.232

The uptake estimate was then adjusted to reflect only that portion of blood lead related to the soil and dust intake by subtracting dietary, air and drinking water component uptakes estimated from the IEUBK default criteria. The default dietary/water/air uptake was about 3.4 µg/day during the 1990s. This compared to 3.7-4.5 µg/day for 1988-89, 10.4-10.9 µg/day for 1983, 29-30 µg/day in 1980, and 40-55 µg/day in 1974-75 estimated in the dose-response analysis for the site in 1989-90 (JEG et al. 1989, TerraGraphics 1990). The higher rates in earlier years reflected a substantial airborne contribution during smelter operations and national dietary lead levels that decreased nearly an order of magnitude through the 1980s.

In the original 1988-89 analysis, it was noted that neither the soil/dust ingestion rate, nor the GI absorption rate (bioavailability) for soil and dust lead, could be independently determined from the site-specific data. However, the product of these two terms could be calculated, and was expressed as the *Soil/Dust Lead Dose Coefficient*. The Soil/Dust Lead Dose Coefficient averaged about 14 mg/day in the post-smelter years and an ingestion rate of 70 mg/day combined with a bioavailability of 20% (70 mg/day x 20% = 14 mg/day) was used in the original site-specific IEUBK analysis developing the site cleanup criteria (CH2MHill 1991b). It was noted that any number of combinations of these two variables could explain the 14 mg/day value and would result in identical blood lead predictions by the IEUBK model. For a typical childhood ingestion rate of 100 mg/day soil/dust, a 14% bioavailability would apply. This resulted in the site-specific dose-response rate being slightly less than half the 100 mg/day ingestion rate times 30% bioavailability recommended in the default IEUBK model application. The outcome was a 1,000 mg/kg soil cleanup limit as opposed to the 400 mg/kg predicted by default parameters.

In subsequent analyses, the IEUBK was utilized to re-assess the dose-response relationship and track progress as the cleanup proceeded. Default ingestion rates from the IEUBK were assumed in these applications. This has the effect of expressing the reduced site-specific response rate in terms of the effective bioavailability. However, it was continuously acknowledged that some portion of the observed decrease from default assumptions could be due to reduced ingestion rates, especially any potentially related to the ongoing intervention program.

Age-specific soil and dust intake rates were calculated using default soil and dust ingestion rates from the IEUBK and the same soil/dust partitions used in the preceeding Section 5.2.2.2 Estimation of Soil and Dust Lead Intakes. Aggregate bioavailability of soils and dust was then determined by dividing the uptake by the intake. Because the default ingestion rates used in the IEUBK model are protective (i.e., not under-estimated), the calculated effective bioavailability is likely conservative (not over-estimated).

This was accomplished for the site-wide database and Table 5-9 and Figure 5.4 summarize estimated arithmetic and geometric mean bioavailability for the years 1988 to 2002 for the 40:30:30 partition. Effective bioavailability results are similar for the alternate soil/dust partitions, as total soil/dust intakes show little difference. Since 1988, the geometric mean bioavailability has ranged from 12% to 23% and has averaged 18%. This is opposed to a 25% arithmetic mean with a range of 16% to 35%. The marked difference in arithmetic and geometric mean estimates could be due to the continuing change in the soil and dust exposure distributions effected by the cleanup.

Another possible explanation is that a small number of children responded at much higher rates. These higher response rates could be real and due to any number of physiological, nutritional, socioeconomic, or behavioral causes; or possibly, due to other sources of lead, unaccounted for in the analyses. As a result, it is likely more appropriate to use the geometric mean bioavailability estimate as the central tendency in evaluating the historic effects of soil and dust exposure in site-specific applications of the IEUBK. Using the arithmetic mean could result in over-prediction of mean blood lead levels and the percent of children to exceed critical toxicity levels due to the sources in the model.

The analyses show that the pre-remediation geometric mean bioavailability was comparable to the estimated 14% (at a nominal 100 mg/day ingestion rate) in 1988-89 (JEG et al. 1989). That result (actually expressed as 20%, 70 mg/day) was used to develop the RAOs (TerraGraphics 1990, CH2MHill 1991b, USEPA 1991). Bioavailability remained in the 15% to 20% range through 1996 and then increased to the 20% to 23% range from 1997 to 2000, and then returned to 15% in 2001-2002. Figure 5.4 and Table 5-9 also show the mean percent contribution of house dust to total soil dust lead intake (age-adjusted-arithmetic mean dust lead intake/total soil and dust lead intake) for the same time period (for the 40:30:30 partition). The period of higher calculated aggregate bioavailability from 1997 to 2000 corresponds with greater contributions of dust to total intake.

From 1990 to 1996, dust made up 40% to 45% of lead intake (according to the 40:30:30 partition) and bioavailability averaged about 17%. From 1997 to 2000 dust made up about 60% to 65% of intake and bioavailability averaged about 22%. In 2001-2002, the dust contribution was near 50% and bioavailability about 15%. There is some concern that the later bioavailabilities may be underestimated, as remediated soils were assumed at 100 mg/kg concentration for these calculations. Follow-up testing of these properties has not been conducted since 1998 when actual values were closer to 50 mg/kg. Substitution of 55 mg/kg for the 100 mg/kg post-remedial assumption results in 0.5 to 0.8% increases in the bioavailabilty estimates for the later years. These results suggest an aggregate bioavailability of 18% is appropriate for risk evaluations, recognizing the various assumptions used in deriving the ingestion estimates.

In addition, these results suggest that pathway-specific bioavailabilities may apply to soil and house dust, even though soils are likely the main source of lead in house dust. As the area-wide cleanup progressed, community and neighborhood soil lead concentrations decreased and the predominant source of lead intake changed from soils to house dust in 1997. Dust continued to dominate intake through 2000. In 2001, dust lead concentrations dropped significantly across the Box and the dust contribution and overall bioavailability decreased toward earlier levels.

It is not unexpected that house dusts could be more bioavailable to children than outdoor soils. House dust particles are smaller and more accessible to young children than soils. House dusts are available to children year-round, more readily adhere to hands, toys and personal items, and are more prone to absorption by the gut. In addition, as soil concentrations decrease, other sources of lead to dust become greater relative contributors. These sources may include paint or residual smelter contaminants that are more available, increasing the overall bioavailability of dust-derived lead.

5.2.3 IEUBK Model Applications

5.2.3.1 Overview

The intakes calculated above were used in the IEUBK model in the 1999 Five Year Review. The IEUBK results suggest that the dose/response rate for blood lead due to soil and dust lead is less than what would be expected using the default bioavailability parameter. The observed decrease in blood lead per 1,000 mg/kg soil and dust was about 60% of default values. This finding was similar to the assumptions used in developing the cleanup strategy and establishing the RAOs for the site, and seems to continue to apply for the last four years. The 1999 Five Year Review concluded that when complete, the cleanup strategy, devised in 1990, should be successful in reducing blood lead levels to acceptable criteria. However, based on USEPA default parameters, the soil RAO may not be adequate to achieve the blood RAO. Those analyses and some additional site-specific evaluations based on more recent observations are updated and discussed in this Section.

The IEUBK Model for lead has been applied to the Box repeatedly in past analyses. Cleanup criteria for the site were developed using the initial version of the IEUBK for lead developed by the USEPA Office of Air Quality Planning and Standards (OAQPS) in 1986. The analysis conducted during the Populated Areas RI/FS simulated different cleanup scenarios for yard soils. The IEUBK Model was used to estimate resultant blood lead levels, and those were compared to the blood RAOs to select cleanup action levels. The analysis concluded that, to meet the RAOs of 95% of the childhood population below 10 µg/dl blood lead, with no (nominally <1%) children exceeding 15 µg/dl the following RAOs for soil and dust must be met:

- all yards with soil concentrations greater than 1,000 mg/kg lead must be replaced with soils containing less than 100 mg/kg lead;

- the geometric mean lead concentration of all yards in any community must be less than 350 mg/kg; and

- house dust lead levels must decrease to concentrations similar to those in post remediation yard soils.

In the 1990 RI/FS analysis, the default soil and dust ingestion/absorption parameters of the IEUBK Model were substantially decreased to conform with observed site blood lead levels (CH2MHill 1991b). The 1988-89 data available at that time suggested that the IEUBK default parameters overestimated absorption of soil/dust lead by a factor of about two. The original OAQPS IEUBK Model's default parameters were adjusted from a general assumption of about 100 mg/day soil ingestion with 30% absorption to 70 mg/day and 20% absorption for the 1989 analyses (TerraGraphics 1990). This adjustment had the effect of predicting an acceptable action level of 1,000 mg/kg rather than a value less than 500 mg/kg that would have been predicted under the default parameters. Since 1990, several revisions to the IEUBK Model have been released by the USEPA, and thirteen years of additional site data have accumulated. These data were periodically analyzed using both default and adjusted intake and absorption parameters and alternate dust:soil partitions to assess any changes in model performance or site dose-response relationship (USEPA 1994b, USEPA 1994a, USEPA 1994c, USEPA 1998, USEPA 1999a, USEPA 1999b, TerraGraphics 2000b).

The following three dust:soil partition scenarios were applied in the IEUBK analyses (See Section 5.2.2.1):

- The IEUBK default 55:45 house dust:yard soil partition that assumes that 55% of a child's intake derives from household dust and 45% from residential yard soils,

- 40:30:30 house dust:yard soil:community soil partition that assumes that 40% of children's soil/dust ingestion derives from house dust and 30% equally from both home yard and community-wide soils, and

- 75:18:7 partition that assumes the child's soil and dust ingestion derives predominantly from house dust, with the remainder proportionately from yard soils and community soils, respectively.

The community-wide geometric mean soil lead concentrations are used to represent the community soil component in these analyses.

Each of these partitions has been evaluated in previous dose-response analyses in the Box. It was clear in initial pathways and dose-response analyses, that achieving sufficient reductions in house dust lead levels was the key to meeting the blood lead RAOs. It was also clear that the relationship between outdoor soils and indoor dusts was complex and dynamic. As a result, determining the appropriate soil and dust partition rate to apply in IEUBK analysis was, and continues to be, one of the greatest challenges in assessing exposure and dose-response relationships. To accommodate the range of potential relative contributions and the uncertainty in the partition selection, these three scenarios were developed and tracked throughout the cleanup. The USEPA default represents national consensus, the 40:30:30 is a soils driven model incorporating a community component, and the 75:18:7 is a dust dominated scenario. As the cleanup proceeded, it became evident that the dependence of dust lead on the outdoor soils resulted in similar lead intakes from each of the different partition assumptions (Figure 5.3). Moreover, blood lead levels paralleled these intakes. It became more important to assess ingestion rates and bioavailability in evaluating remedial progress in achieving the blood lead RAO.

5.2.3.2 Applying the IEUBK Default Parameters

Several community and batch-mode applications were run using the existing blood lead environmental exposure database matching children's observed blood, soil, and house dust lead concentrations in the 1999 Five Year Review. Only the batch mode applications were updated for this report. The batch mode has the advantage of simulating each child's exposure situation using observed soil and dust concentrations for that specific residence and comparing predicted to observed blood lead levels. IEUBK model default parameters were used in each case, with the exception of soil and dust lead concentrations associated with the three original soil/dust partitions. Observed house dust and yard soil lead values were used when available. If the house dust value was missing, the geometric mean house dust lead concentration for that community and year was substituted. Missing yard soil lead values were replaced with the geometric mean pre-remediation community-wide yard soil lead concentration. If both house dust and yard soil lead values were missing, the observation was not included in the analyses. Data available for 8- and 9-year-old children were included by assigning an age of 84 months (i.e., the maximum age in the IEUBK Model) to maximize the number of observations in the analysis.

Predicted blood lead levels: Table 5-10a and Figures 5.5a-c show blood lead level predictions for 9-84 month-old children. These model runs vary only in soil and house dust lead concentrations as observed in the annual blood lead surveys and the dust:soil partition. Model default values for air, diet, drinking water, and maternal contribution were used. Several of the communities have small numbers of observations and assessment of the effectiveness of model predictions is limited. Additionally, the summary statistics reported in these tables may not agree with those presented in earlier sections of this report due to the deletion of incomplete observations from the IEUBK analyses.

The model results show little difference in predicted blood lead levels among the three dust:soil partition scenarios. This similarity is likely due to the predominance of house dust in each scenario and the association between community-wide soils and house dust lead concentrations. All three scenarios predict blood lead concentrations from 12% to 88% greater than the observed levels over the fifteen year period.

Figures 5.5a-c show that, prior to the yard remediation program, the default mode of the IEUBK model predicted blood lead levels significantly higher than were observed. This was noted in 1990 and was the basis for adopting the reduced soil ingestion and 20% absorption parameters used in the Feasibility Study (CH2MHill 1991b). However, as the Yard Remediation Program progressed, the difference between predicted and observed levels decreased. In 1988-89 the effect was nearly 2-fold (i.e., 60-90% greater). At that time, estimated intake rates for lead from soil and dust were near 250 μg/day. From 1990 to 1993, exposure profiles and estimated intake rates were in transition to 70-80 μg/day. By 1993, the predicted blood lead levels were 25-55% greater than observed. From 1994 through 1998, the difference ranged from 7% in 1997 to 57% in 1995. In other years, predictions were about 20% high. The difference increased in the most recent years, consistent with the apparent reduction of dust lead levels, the relative contribution of dust to total intake, and effective bioavailability.

Variance in blood lead level estimates: There are differences in predicted geometric standard deviations (gsd) among the three dust:soil partitions that also vary for different cities. The variation among cities may be due to the fewer number of observations in Smelterville. Table 5-10b and Figures 5.6a-c show predicted and observed gsd for Kellogg, Smelterville, and site-wide scenarios, respectively. The *overall* gsd refers to the distribution of blood lead levels across each community. The batch mode application of the IEUBK model estimates a mean blood lead level for each individual child's specific exposure situation. The variability in those estimates reflects variation in exposure among individual situations and age within each community. However, there is also potential variation in the individual response. That is accounted for by applying an individual gsd of 1.6 to each predicted mean, aggregating the results, and calculating an overall gsd for each community.

The overall gsd is compared to the observed gsd for the population in Figures 5.6a-c. Observed gsds were near 1.6 from 1989 to 1992. In 1993 observed gsds increased to more than 2.0 (site-wide, and 1.9 in Kellogg), stabilized near 1.8 through 2000, and decreased to near pre-remediation levels in the last two years. As there is little reason for the individual gsd to change, most of these temporal differences are likely attributable to change in exposure variable distributions. The high mobility of the population and the manner in which the cleanup was accomplished significantly influenced the distribution of individual soil exposures.

Mobility in the childhood population has had an important effect on exposure profiles for the community. Between 1989 and 1991, overall blood lead levels in young children were reduced by nearly 40% as the percentage of children on contaminated yards was reduced from more than 80% to 25%. However, from 1991 to 1996 the number of children on contaminated yards was unchanged, even increasing in some years. Despite the efforts of the High-Risk Yard Cleanup, there was little gain in reducing the number of children at risk from 1991, until area-wide remedial activities were completed in Smelterville in 1995-96. As a result, the only significant exposure reductions achieved from 1991 to 1996, from a population-wide perspective, were overall decreases in community-wide soils and house dust lead concentrations through the general cleanup.

The increase in population gsd observed in this period is likely in response to the bimodal distribution of yard soil exposures created by cleanup. Since 1991, the majority of children across all age groups have been in homes with less than 100 mg/kg soil lead. The remaining children, usually families new to the home in the preceeding year, were on contaminated yards. As the cleanup nears completion, the distribution of exposures has become more uniform, and the gsd is likely returning to pre-remediation levels more reflective of the individual variation in the population. Site-wide, the three scenarios produce reasonably consistent predicted gsds, with the default scenario showing the largest variation in blood lead levels. The default mode IEUBK model tended to predict higher than observed overall gsds during the early years and the most recent years when observed gsds were near the 1.6 value.

Percent Predicted to Exceed 10 μg/dl: Table 5-10c and Figures 5.7a-c show predicted and observed percent equal to or exceeding 10 μg/dl. Percent to excced predictions from the USEPA Default Model are consistently greater than observed values. This is expected as mean blood lead levels are overestimated for most years. However, since the completion of remedial actions in Smelterville, the USEPA default model has more closely predicted observed values.

Default Model Discussion: The default application of the IEUBK model has predicted higher than observed blood lead levels and percent of children exceeding 10 μg/dl since the beginning of cleanup activities. However, the difference decreased as the cleanup progressed and intake rates and blood lead levels were reduced. These results suggest that the slope of the dose-response relationship between blood lead and soil and dust lead may have changed, increasing during the cleanup, and subsequently decreased as the RAOs were achieved.

There are several possibilities that could explain the apparent change in dose-response rates as the cleanup proceeded, including:

- demographic changes in the population (e.g., increased soil and dust ingestion rates reflective of demographic and behavioral changes, or bias introduced by self-selection with respect to blood lead levels or exposure profiles),

- changing bio-kinetic relationships at lower blood lead levels (i.e., lead bio-kinetics are not linear and ingested lead is more efficiently absorbed at lower concentrations), and

- changes in source characteristics (i.e., as the cleanup proceeds the dominant sources change and differing chemical or physical characteristics affect ingestion or uptake rates).

The analysis of the most recent information suggests the last factor may account for the apparent changes. The relative lead intake from house dusts increased as the increase in the dose-response relationship was observed during the 1990s. A corresponding decrease in both the relative dust lead intake and the dose-response relationship was noted in 2000-2001. It is plausible that differing bioavailabilities for dust and soil may explain the apparent differences in the dose-response noted throughout the cleanup (See Section 5.2.2.3).

5.2.3.3 Site-specific Applications of the IEUBK

Two site-specific applications of the IEUBK model have been used in developing, implementing, and evaluating the human health risk management strategy in the Box. The 40:30:30 partition model with a reduced bioavailability was used in the original development of the site cleanup criteria. The IEUBK software has been modified since that time and various adjustments in bioavailability and age-specific ingestion rates have been incorporated to maintain consistency with the original parameters. The initial model scenario used in the Box evolved into the ***40:30:30 – 18% Bioavailability Box Model*** that was used in the adjacent Coeur d'Alene Basin communities in the *Human Health Risk Assessment for the Coeur d'Alene Basin* in 2001-2002 (TerraGraphics et al. 2001).

A second site-specific application was developed from structural equations pathways analysis of the eleven year period preceding the 1999 Five Year Review. That investigation suggested the 42% house dust: 27% community soil: 19% neighborhood soil: 12% yard soil partition and 18% bioavailability parameters used in Section 5.2.2.2. This partition was consistent with the earlier Box Model, differing mainly in that soils within a 200-foot radius of the home were included with the yard and community soils in the home-specific soil exposure.

Both of these site-specific models were run for the period 1988-2002 and the results are shown in Table 5-11 and Figures 5.8a-c through 5.11a-c. It should be noted in reviewing the following results that similar results could be obtained by reducing the soil and dust ingestion rate by 40% or several combinations of reduced bioavailability and ingestion rate.

Predicted blood lead levels: Table 5-11 and Figure 5.8a-c show predicted and observed results for 9-84 month-old (or 0-7 year old) children for Kellogg, Smelterville, and site-wide, respectively, for all years. Both of these models produce better agreement between predicted and observed geometric mean blood lead levels than the USEPA Default model. The 40:30:30 partition predicts slightly lower values site-wide than the pathways derived model as the cleanup progresses. Predicted and observed blood lead levels have decreased consistently with estimated soil and dust intake rates for both models. Both models switched from slightly over-predicting observed levels, to slight under prediction, and back to slight over prediction in the last two years. This result may be effected by the possible over-estimation of yard soils lead intake due to the 100 mg/kg assumption for remediated yards discussed in Section 5.2.2.3.

Table 5-12 and Figures 5.9a-c show similar results for two year-old children only. These figures indicate good correspondence between modeled and observed blood lead levels for this critical segment of the population. Other age groups show similar results. Smelterville results are confounded in these figures by few numbers of observations in several years.

Variance in blood lead level estimates: Table 5-11 and Figures 5.10a-c show observed and the predicted overall gsds for all ages for all years and communities. The results are similar to those noted in the USEPA Default model applications. Predicted overall gsds exceeded observed levels prior to 1993 and have been near or slightly less than observed levels since.

Predicted Toxicity Levels: Table 5-11, 5-12 and Figures 5.11a-c show these results for the batch mode reduced bioavailability models. These results show good correspondence between predicted and observed percentage of children to exceed 10 μg/dl. Percent to exceed values are well predicted site-wide for all years prior to 1994. From 1994 to 2000, percent to exceed values were slightly under-predicted. The low percentage to exceed the 10 μg/dl criteria (2-3%) observed in the last two years was predicted by both models. These results are not unexpected. It was anticipated that the IEUBK Model would somewhat under-predict lead toxicity as the cleanup proceeded. This is because follow-up investigations of high blood lead levels have indicated that some are due to exposures from remote sources that are not unaccounted for in the model.

The children whose apparent greater response rates confound these analyses are, not coincidentally, the same children served by the LHIP. Review of these children's histories since 1996, when suggested increases in effective bioavailability were noted, provides some insight regarding the potential sources of variation. These histories show that PHD investigators found the majority of these children are socioeconomically disadvantaged, highly mobile, with care often provided in multiple locations among extended family or cooperative situations. These children tend to exhibit frequent hand to mouth activity and poor to fair personal and home hygiene. Most were also exposed to high concentration soil and dust sources in play areas or away from their home. Generally, those soil sources identified within the Box were areas away from the child's home at locations that had not yet been remediated. These included relatives' and day care yards in unremediated portions of Kellogg, hillsides, and common use areas surrounding particular housing complexes and Milo Creek flood debris. Extended recreational activities at contaminated locations and moving from contaminated homes outside of the Box has also been noted more frequently in recent years. Several children were noted to be in homes with relatively high dust concentrations. Some were indicated to be in homes with poor interior paint condition.

These observations suggest that the high response rates are due to a number of factors. Frequent hand to mouth activities, poor personal and home hygiene, high house dust concentrations, and any paint lead reflected in those dusts are all factors accounted for in the model analysis. These factors should be accommodated for in the individual gsd applied to account for variance in exposures. However, sources outside the home environment (i.e., flood debris, hillsides, campgrounds, un-remediated areas in Kellogg, and contaminated soils in the greater Coeur d'Alene Basin) are not accounted for by the model predictions.

These batch mode results indicate that the IEUBK, utilizing site-specific reduced absorption rate and soil partition factors suggested by the structural equations analyses, is an effective predictor of mean blood lead levels throughout the cleanup process. This methodology is useful in reassessing the cleanup criteria and likelihood that blood lead RAOs will be achieved. However, there are exposure factors unaccounted for in the model constructs. These include other sources of exposure and peculiar conditions that affect individual children leaving them at greater risk. With respect to residential soils and dust, these analyses suggest that the cleanup has been effective in reducing risk to acceptable levels (i.e., those reflected in the RAO) for the vast majority of the population. There are, however, individual situations and additional sources of lead remaining in and around the Box putting some children at-risk. Some of these sources will be addressed in upcoming remedial activities. Those problems identified outside the scope of the remediation strategy will need to be resolved on a case-by-case basis to determine the potential sources of this variation.

Figure 5.1

ENVIRONMENTAL PATHWAYS FOR LEAD EXPOSURE FOR THE BUNKER HILL SITE

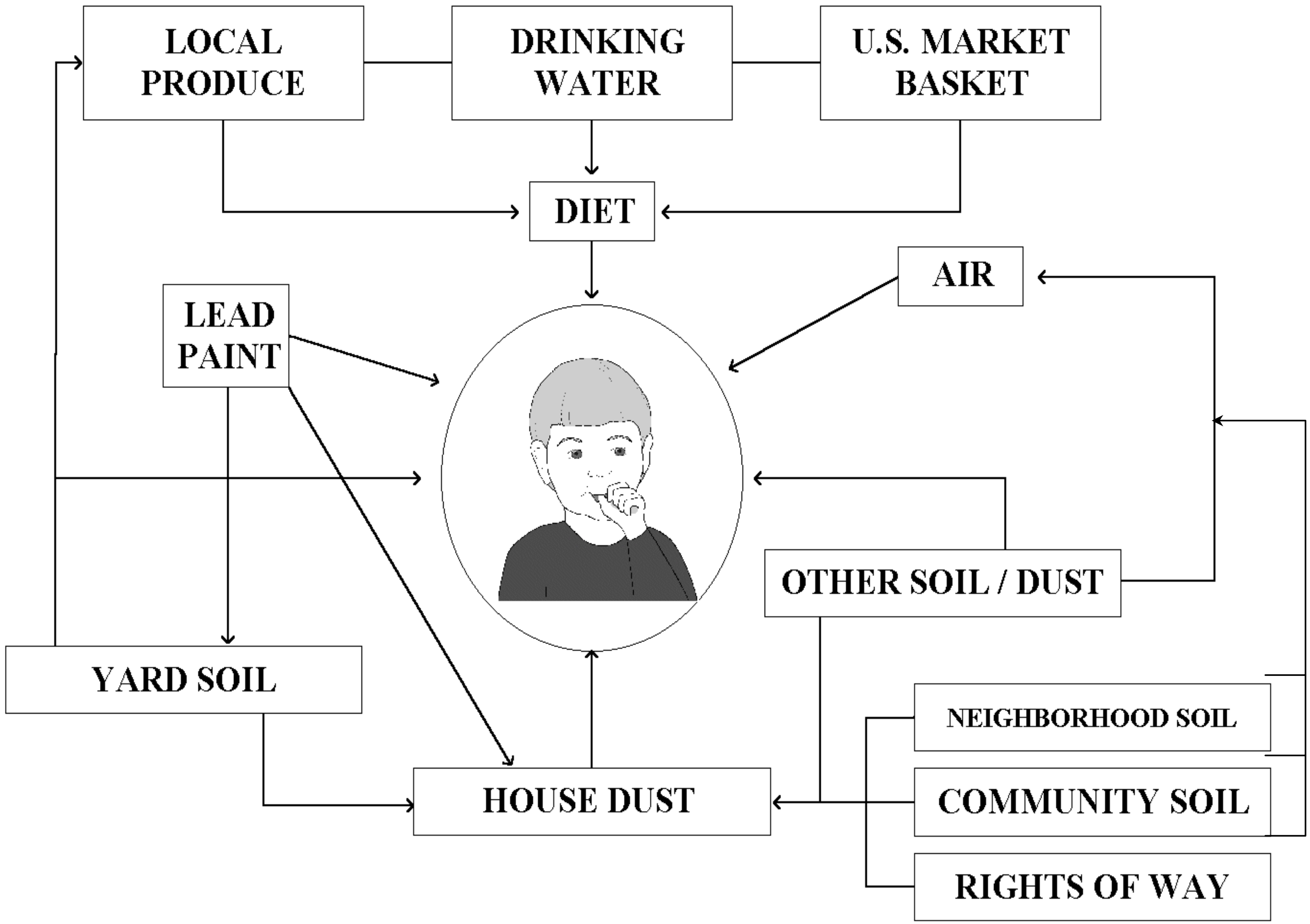


Figure 5.2
Soil and Dust Lead to Blood Pathways

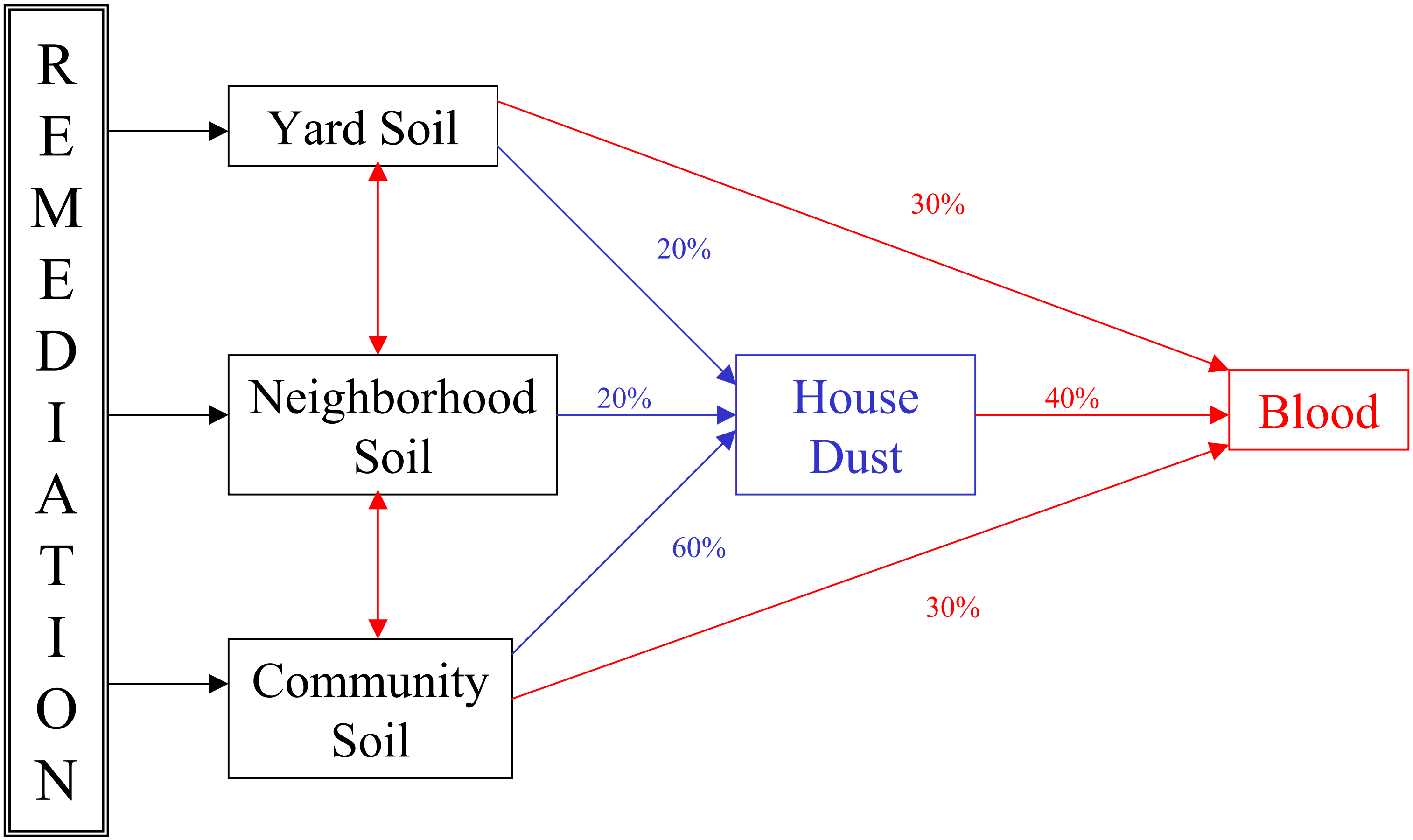
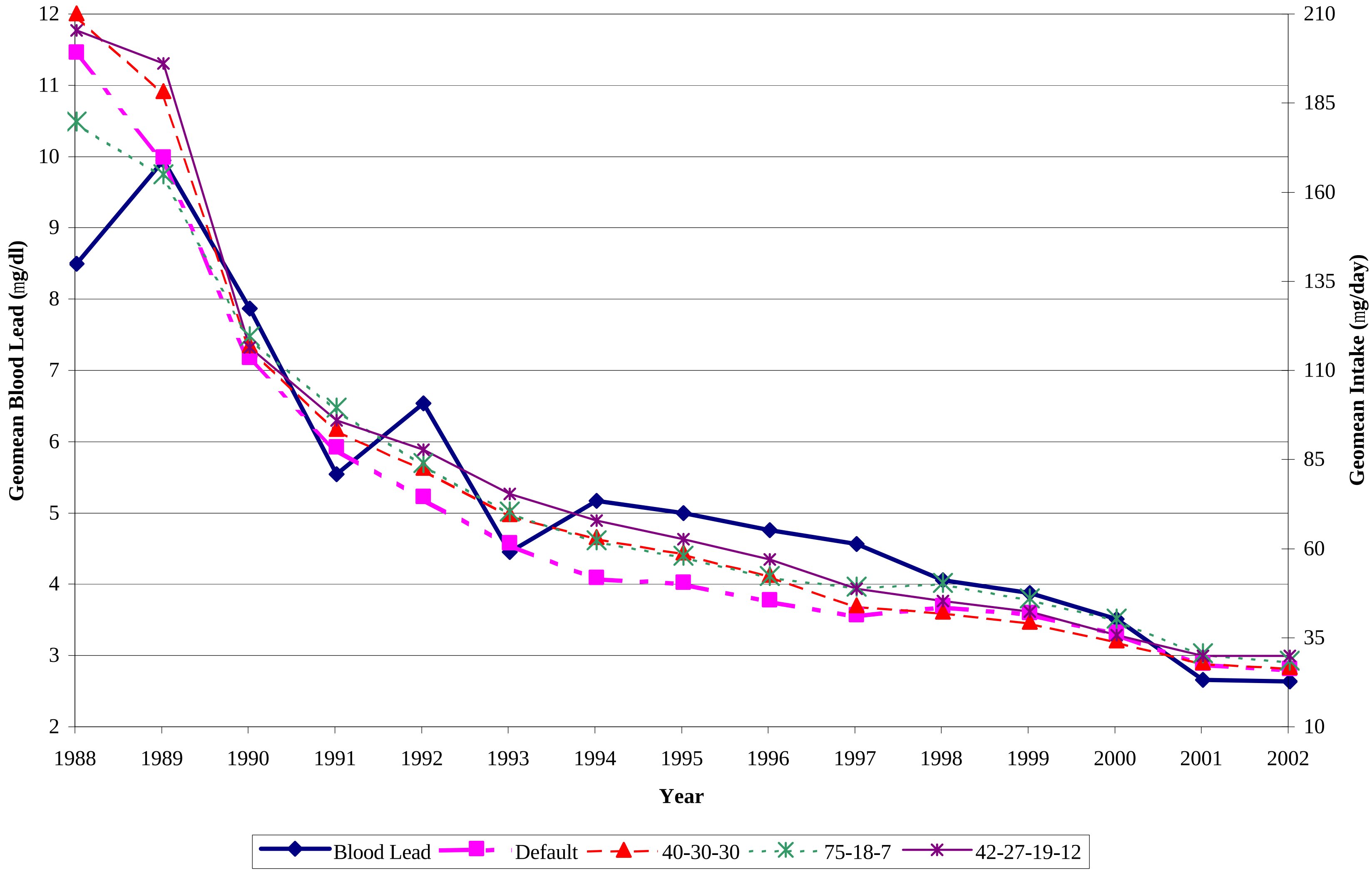


Figure 5.3
Site-wide Intake Rates and Geometric Mean Blood Lead Levels



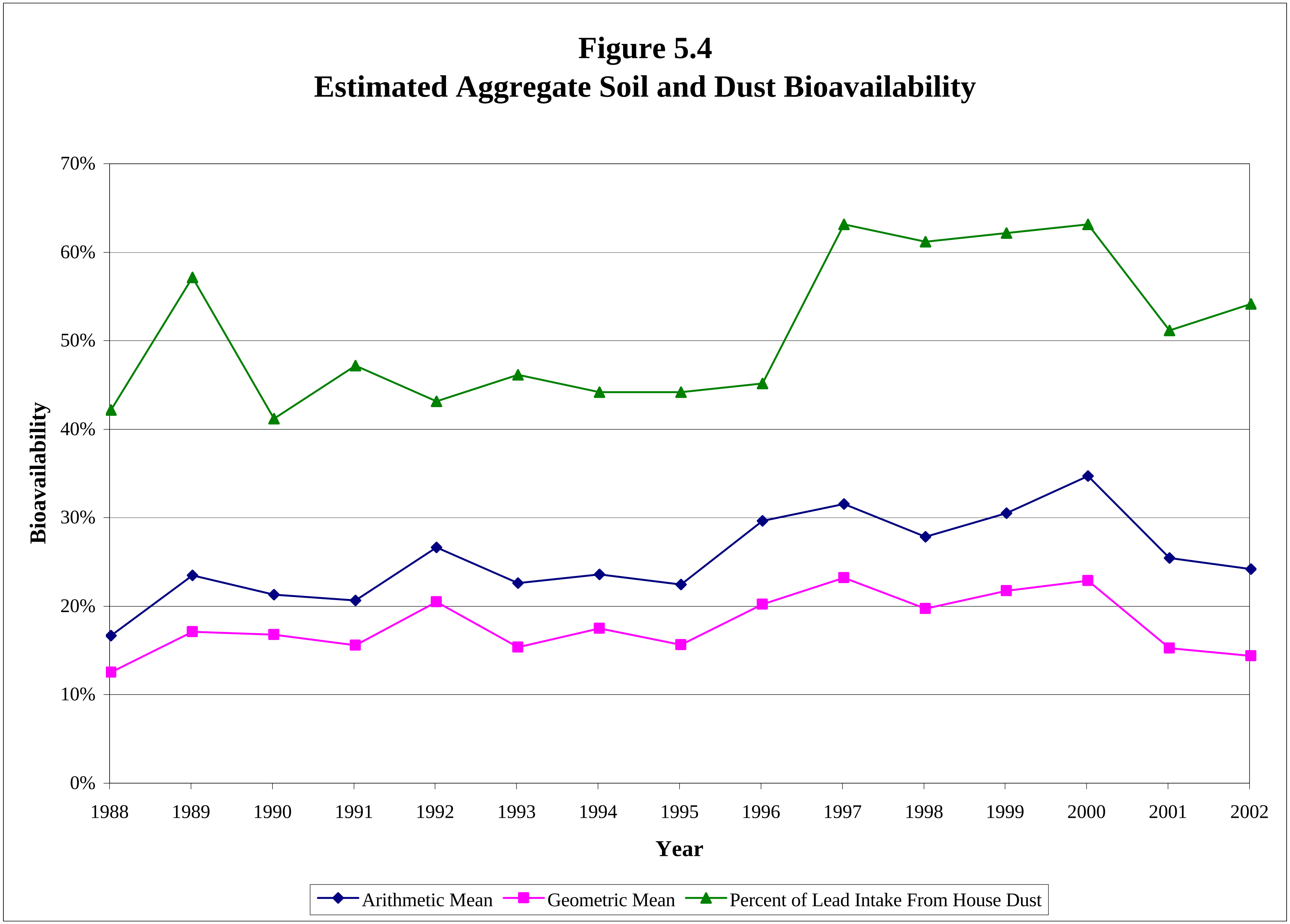


Figure 5.4
Estimated Aggregate Soil and Dust Bioavailability
70%
60%
50%
40%
30%
20%
10%
0%
Bioavailability
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Arithmetic Mean
Geometric Mean
Percent of Lead Intake From House Dust

Figure 5.5a
Predicted and Observed Geometric Mean Blood Lead Levels in 0-9 Year Old Children
Default Parameters - Three Dust:Soil Partition Scenarios
Kellogg, 1988-2002

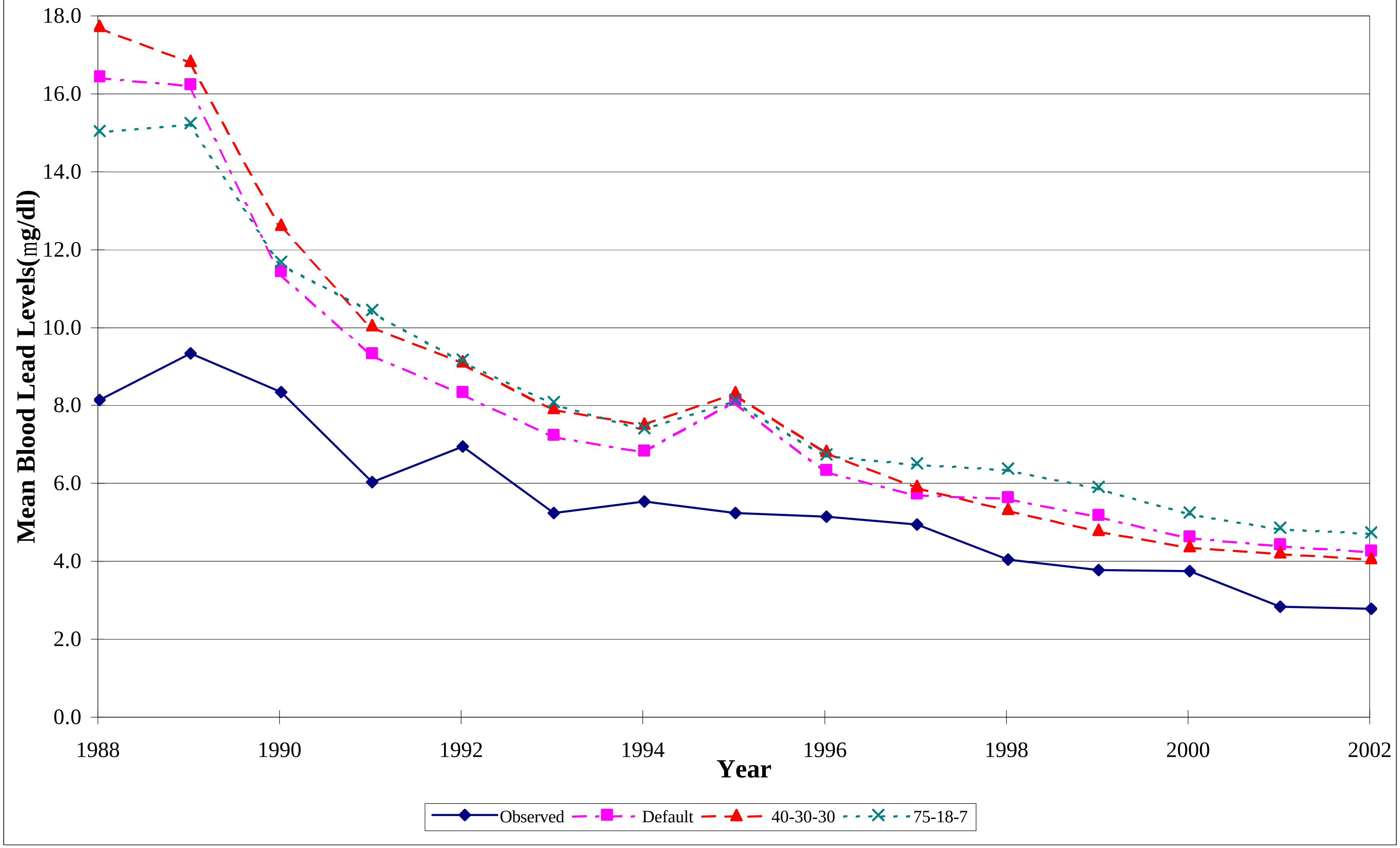


Figure 5.5b
Predicted and Observed Geometric Mean Blood Lead Levels in 0-9 Year Old Children
Default Parameters - Three Dust:Soil Partition Scenarios
Smelterville, 1988-2002

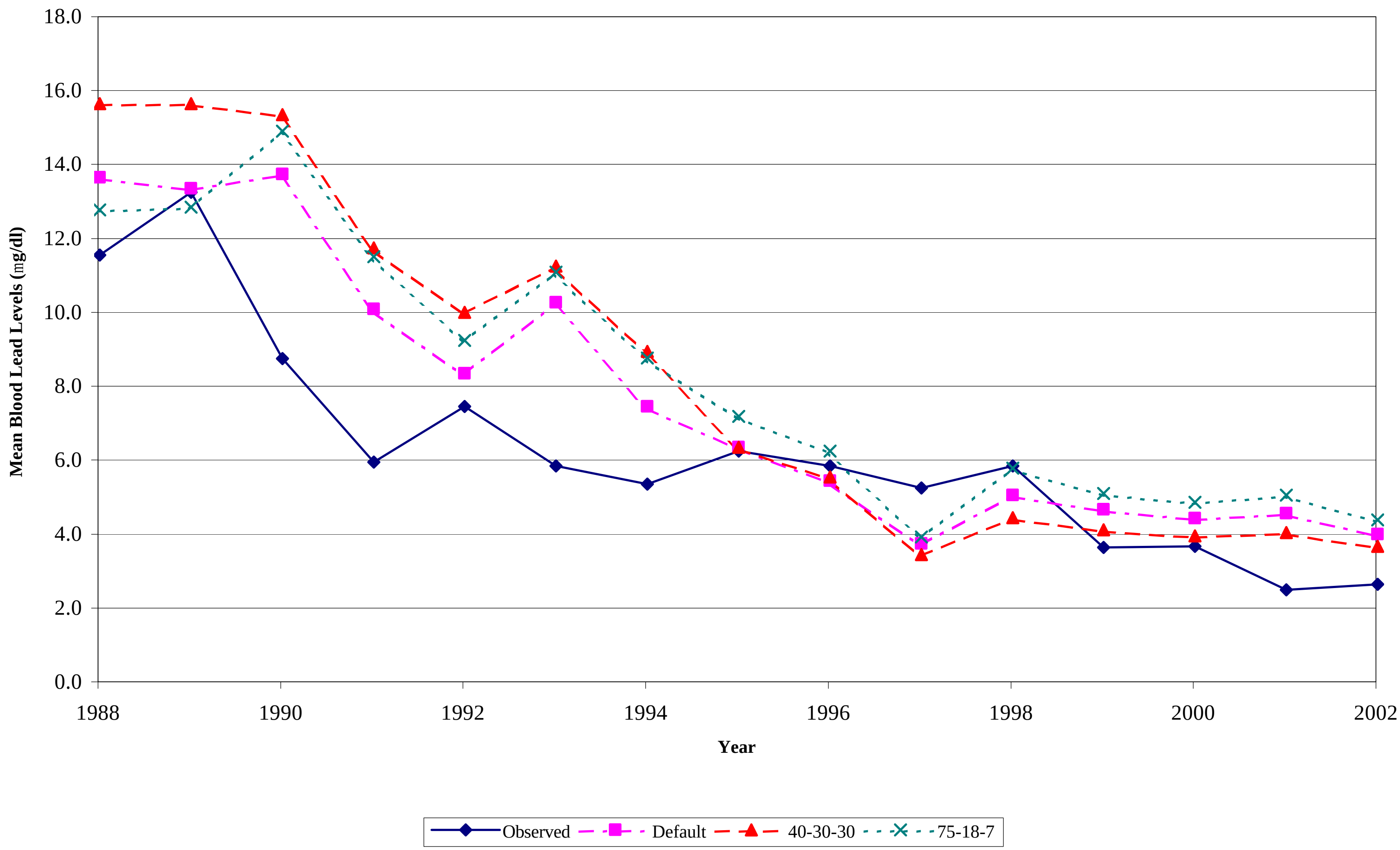
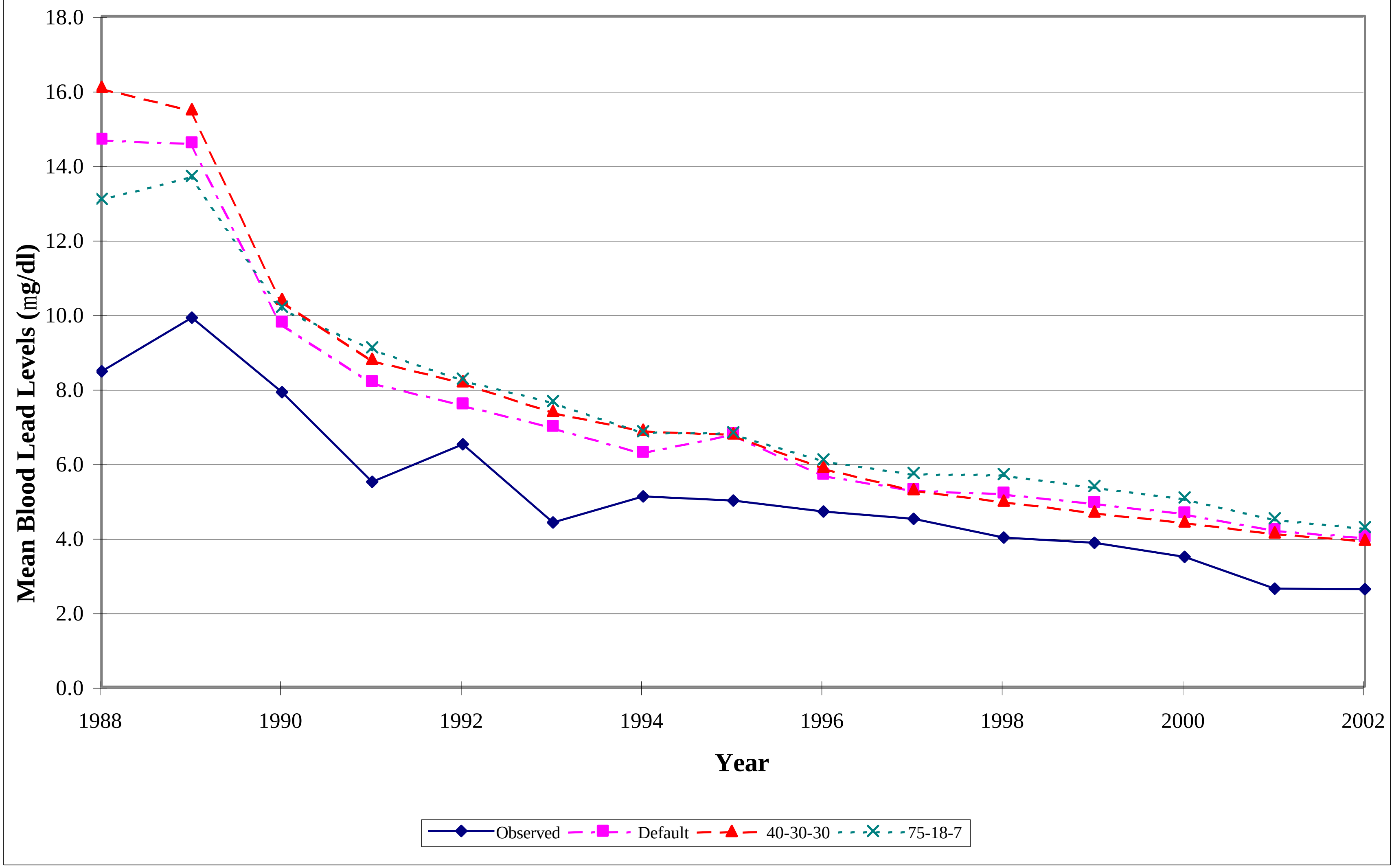


Figure 5.5c
Predicted and Observed Geometric Mean Blood Lead Levels in 0-9 Year Old Children
Default Parameters - Three Dust:Soil Partition Scenarios
Site-wide, 1988-2002



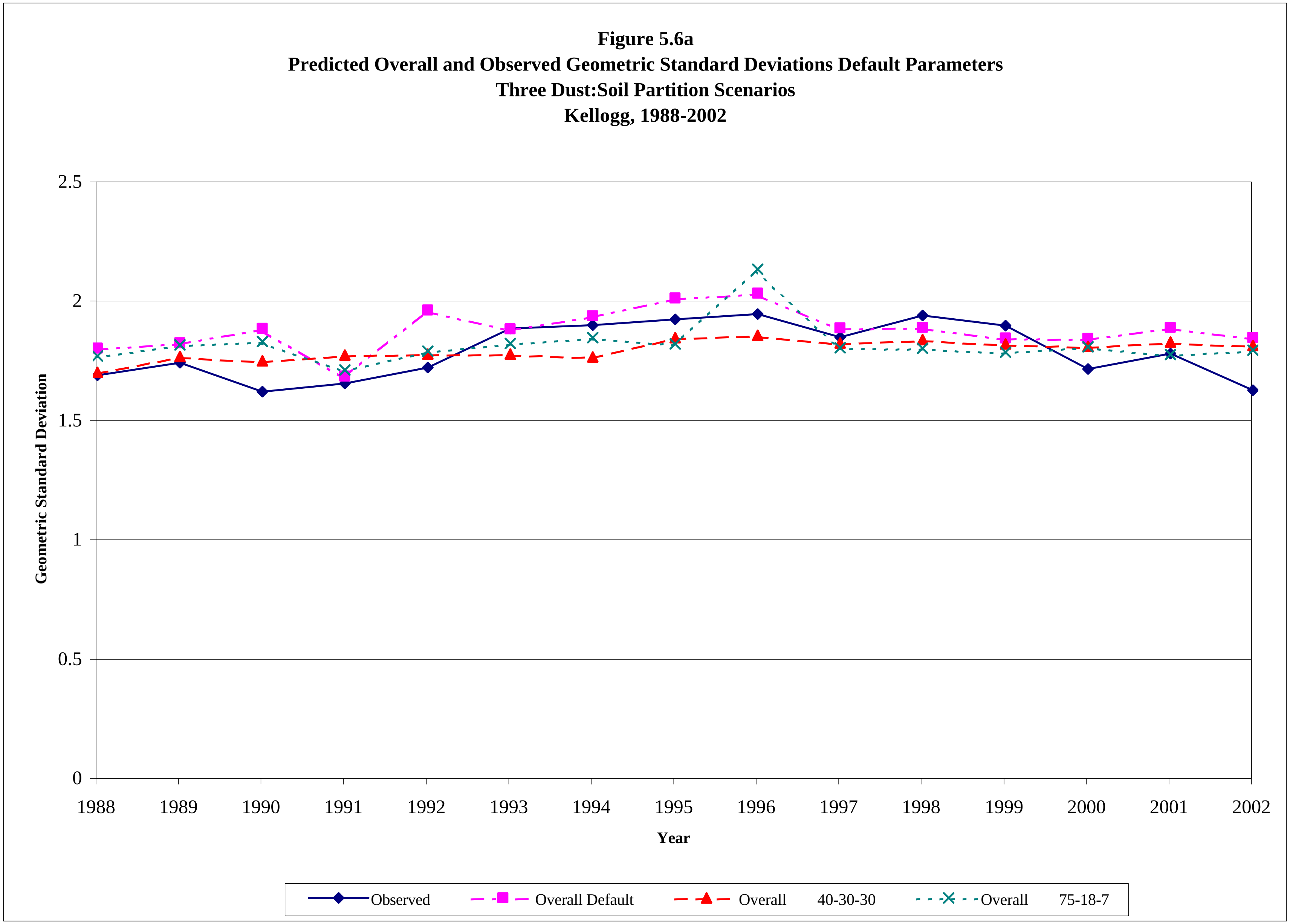


Figure 5.6a
Predicted Overall and Observed Geometric Standard Deviations Default Parameters
Three Dust:Soil Partition Scenarios
Kellogg, 1988-2002
Geometric Standard Deviation
2.5
2
1.5
1
0.5
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Overall Default
Overall 40-30-30
Overall 75-18-7

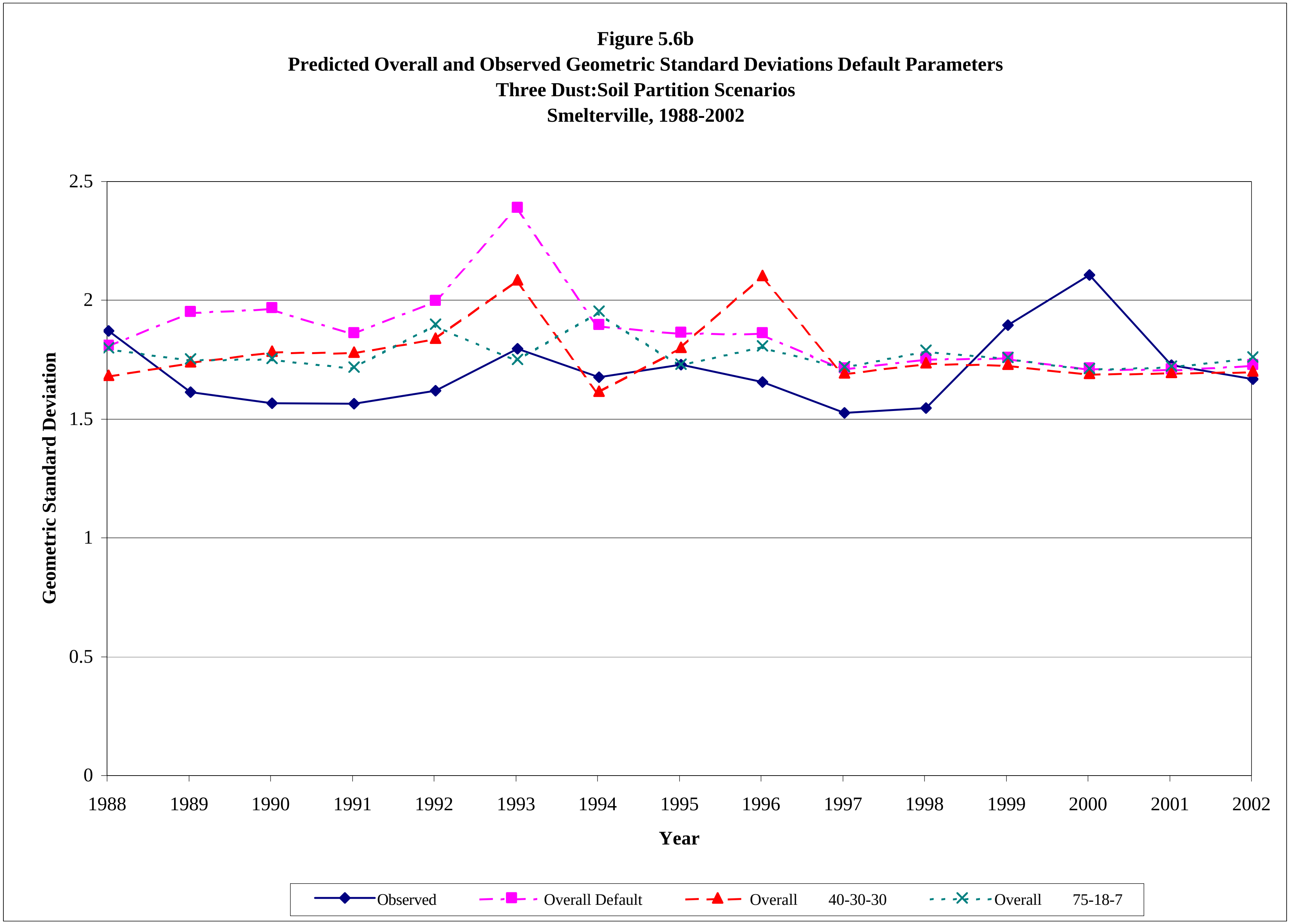


Figure 5.6b
Predicted Overall and Observed Geometric Standard Deviations Default Parameters
Three Dust:Soil Partition Scenarios
Smelterville, 1988-2002
Geometric Standard Deviation
2.5
2
1.5
1
0.5
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Overall Default
Overall 40-30-30
Overall 75-18-7

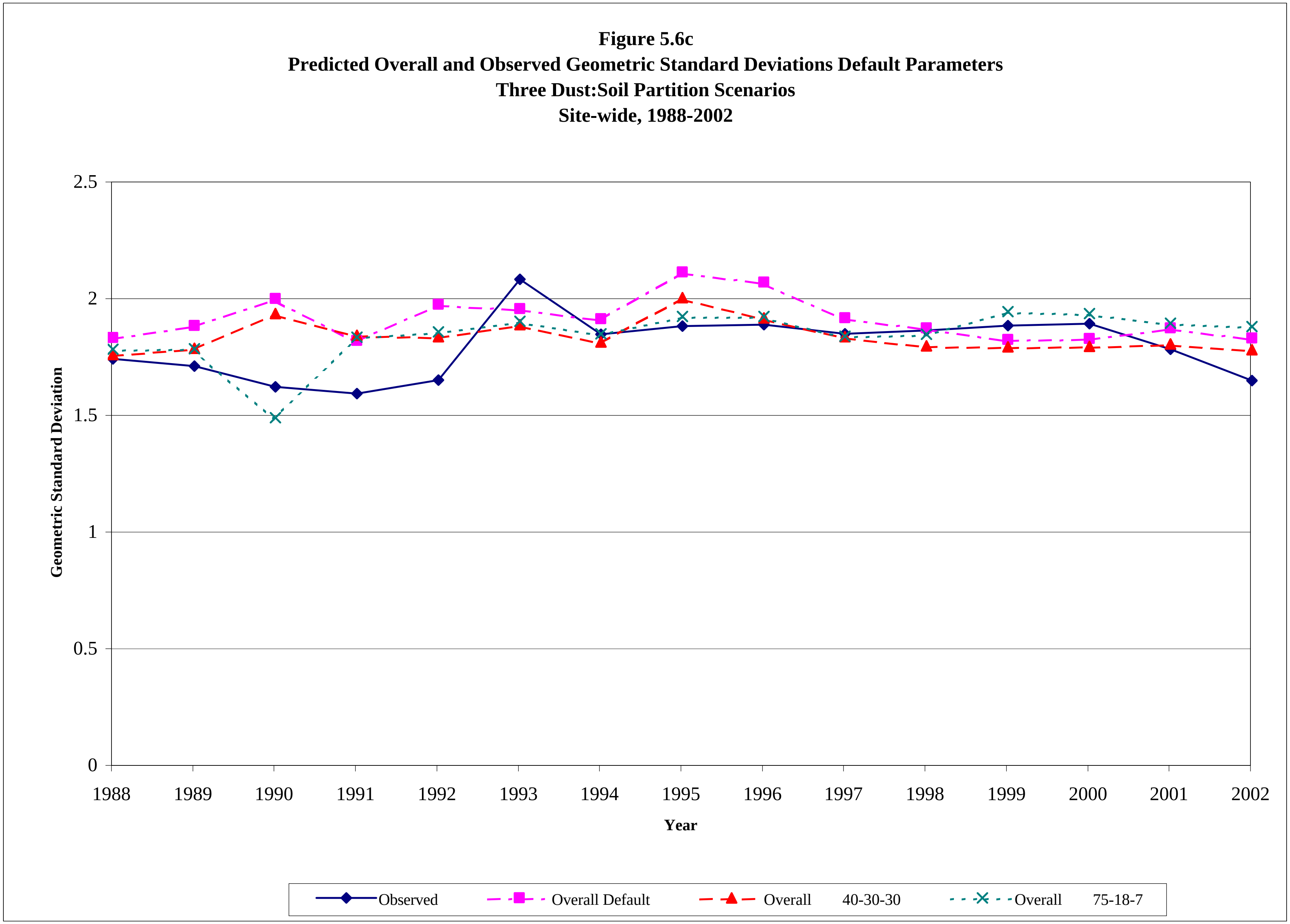


Figure 5.6c
Predicted Overall and Observed Geometric Standard Deviations Default Parameters
Three Dust:Soil Partition Scenarios
Site-wide, 1988-2002
Geometric Standard Deviation
2.5
2
1.5
1
0.5
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Overall Default
Overall 40-30-30
Overall 75-18-7

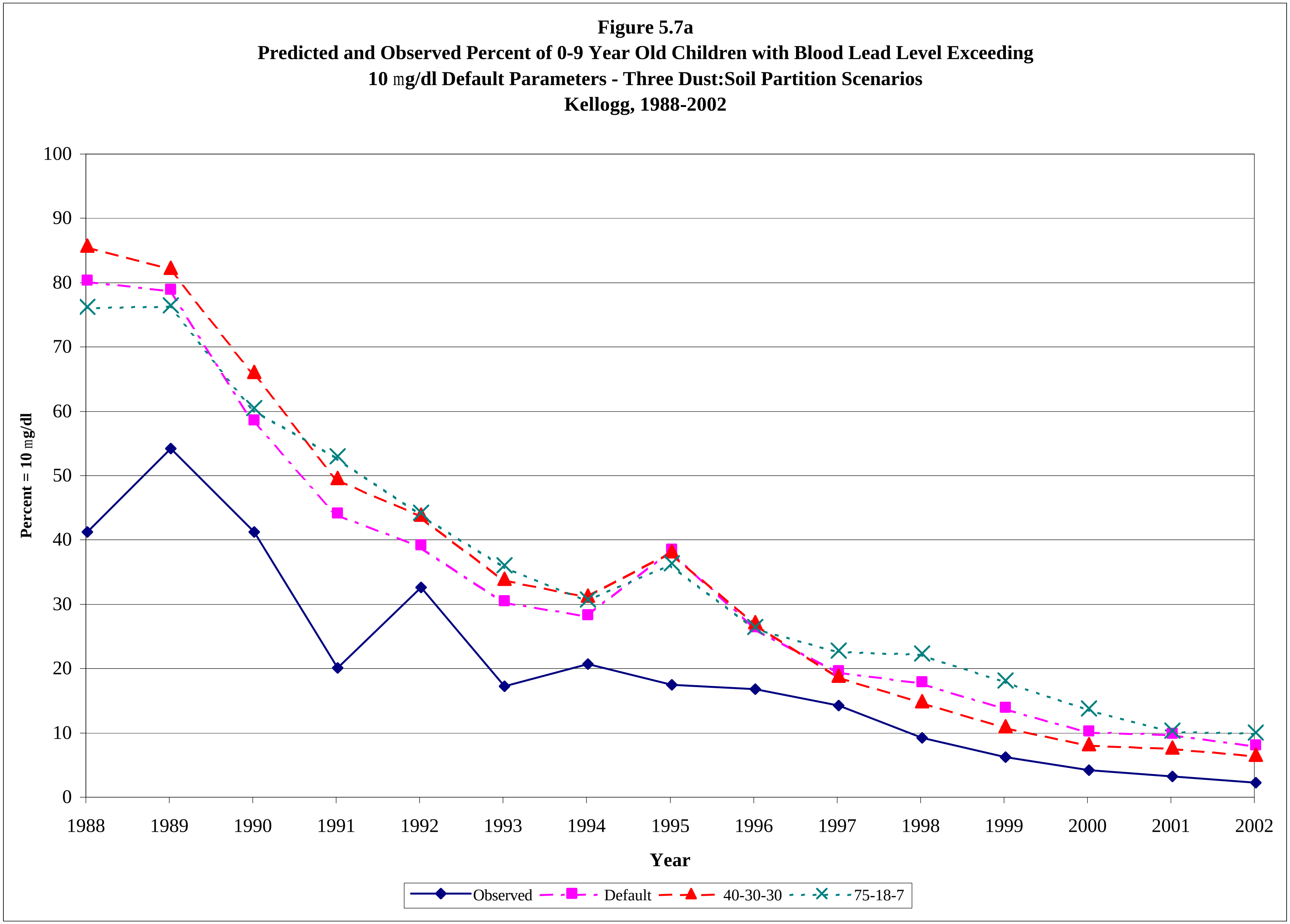


Figure 5.7a
Predicted and Observed Percent of 0-9 Year Old Children with Blood Lead Level Exceeding
10 mg/dl Default Parameters - Three Dust:Soil Partition Scenarios
Kellogg, 1988-2002
Percent = 10 mg/dl
100
90
80
70
60
50
40
30
20
10
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Default
40-30-30
75-18-7

Figure 5.7b
Predicted and Observed Percent of 0-9 Year Old Children with Blood Lead Level Exceeding 10 mg/dl Default Parameters - Three Dust:Soil Partition Scenarios
Smelterville, 1988-2002

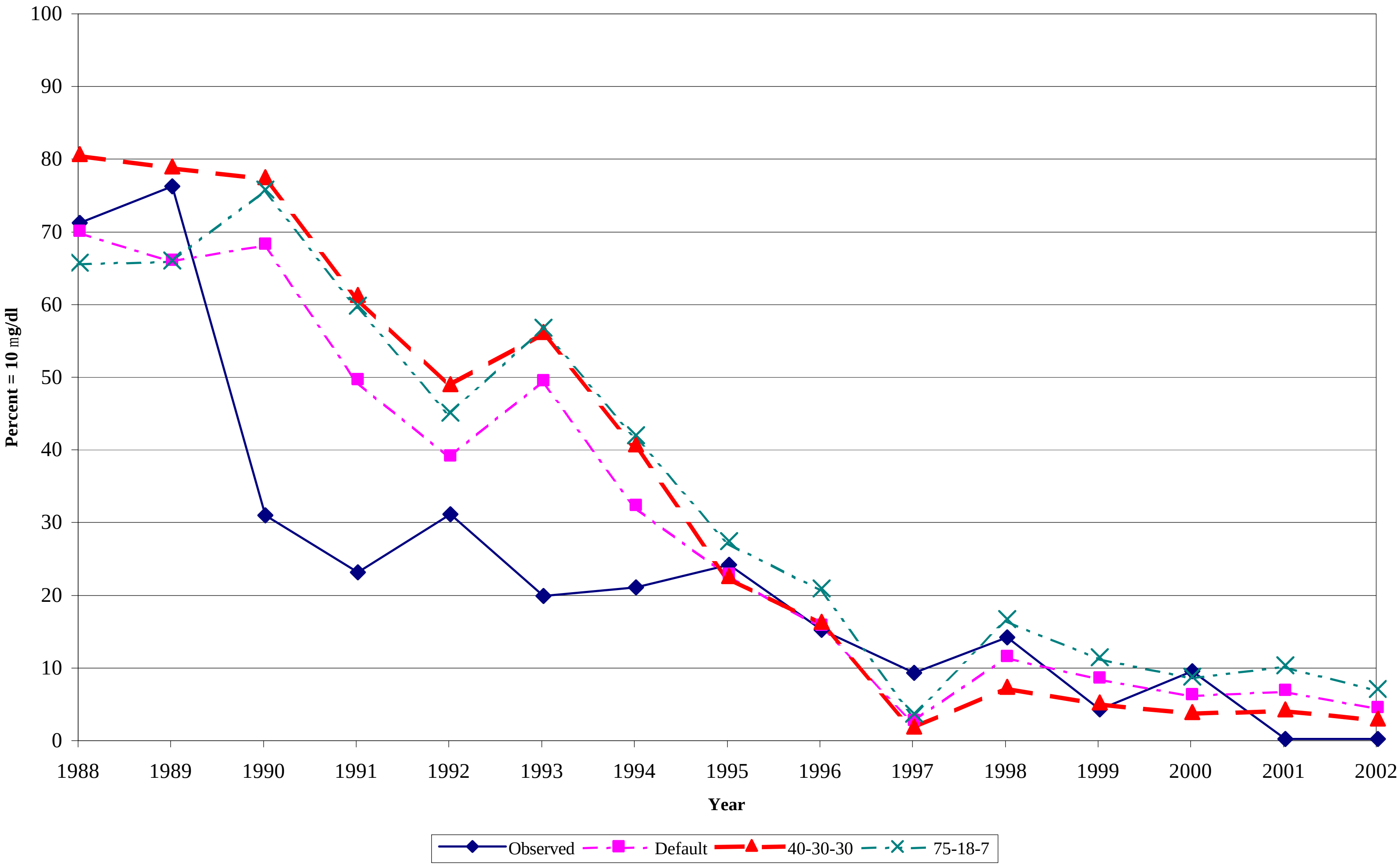
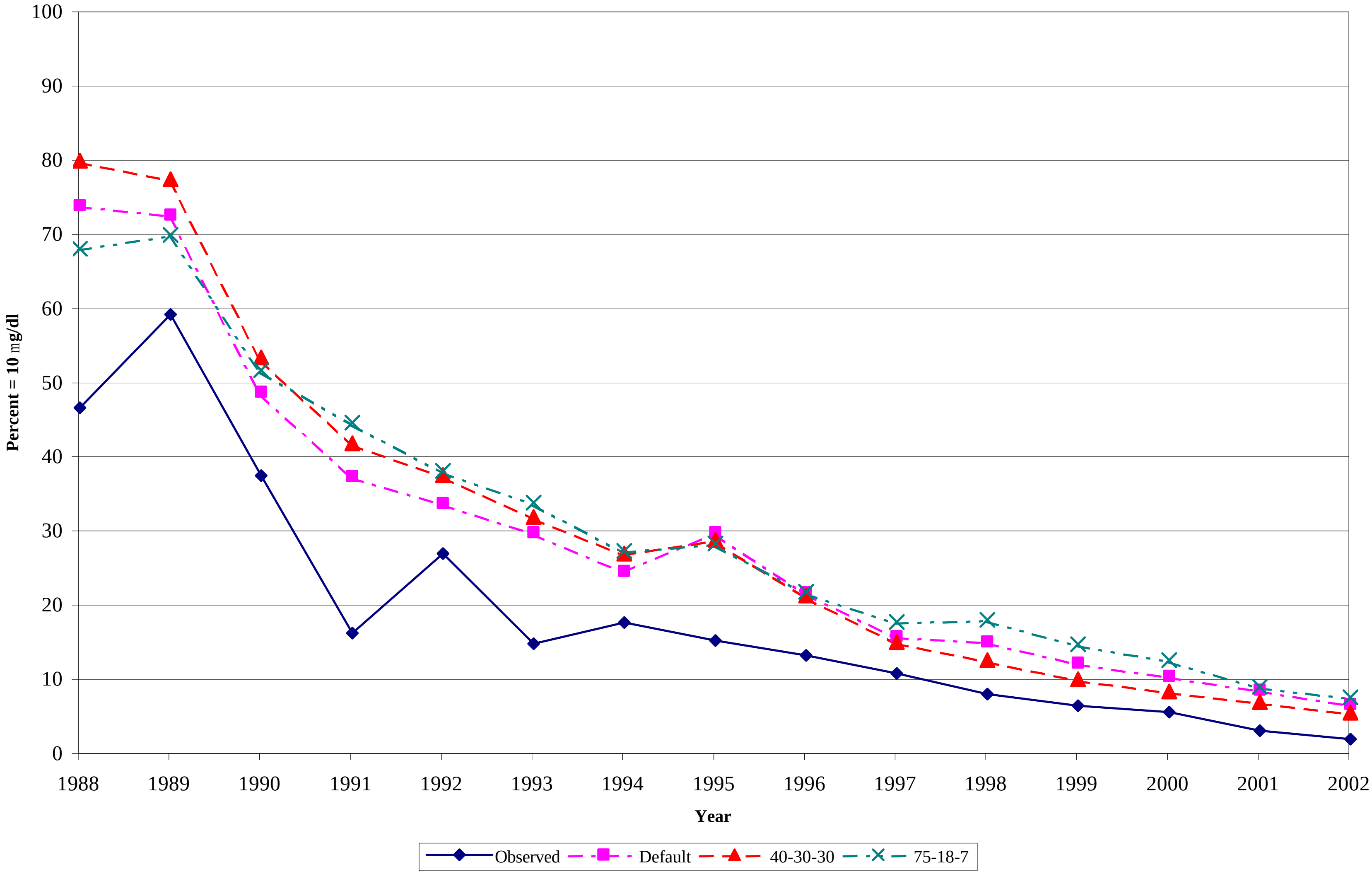


Figure 5.7c
Predicted and Observed Percent of 0-9 Year Old Children with Blood Lead Level Exceeding 10 mg/dl Default Parameters - Three Dust:Soil Partition Scenarios
Site-wide, 1988-2002



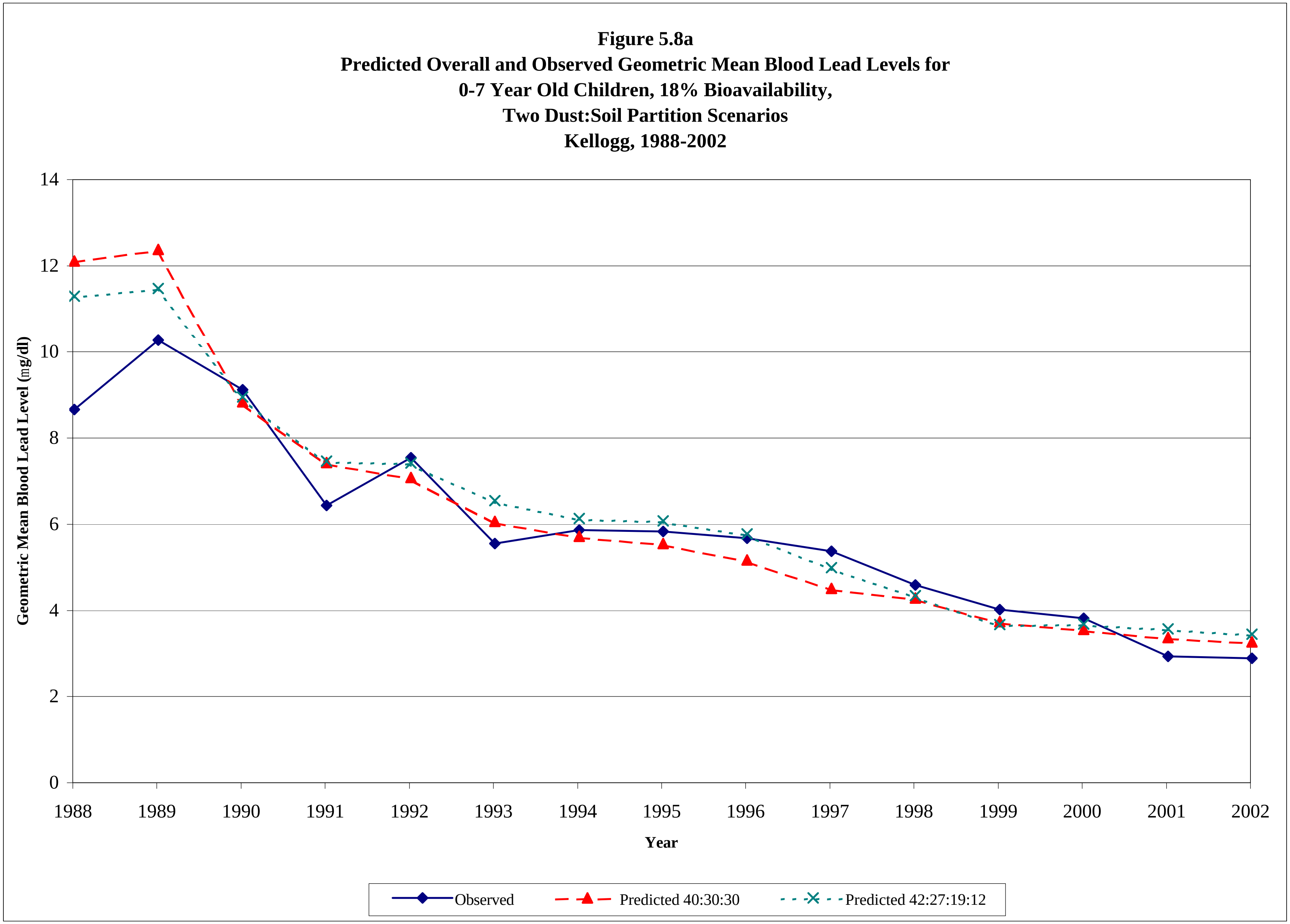


Figure 5.8a
Predicted Overall and Observed Geometric Mean Blood Lead Levels for
0-7 Year Old Children, 18% Bioavailability,
Two Dust:Soil Partition Scenarios
Kellogg, 1988-2002
Geometric Mean Blood Lead Level (mg/dl)
0
2
4
6
8
10
12
14
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Predicted 40:30:30
Predicted 42:27:19:12

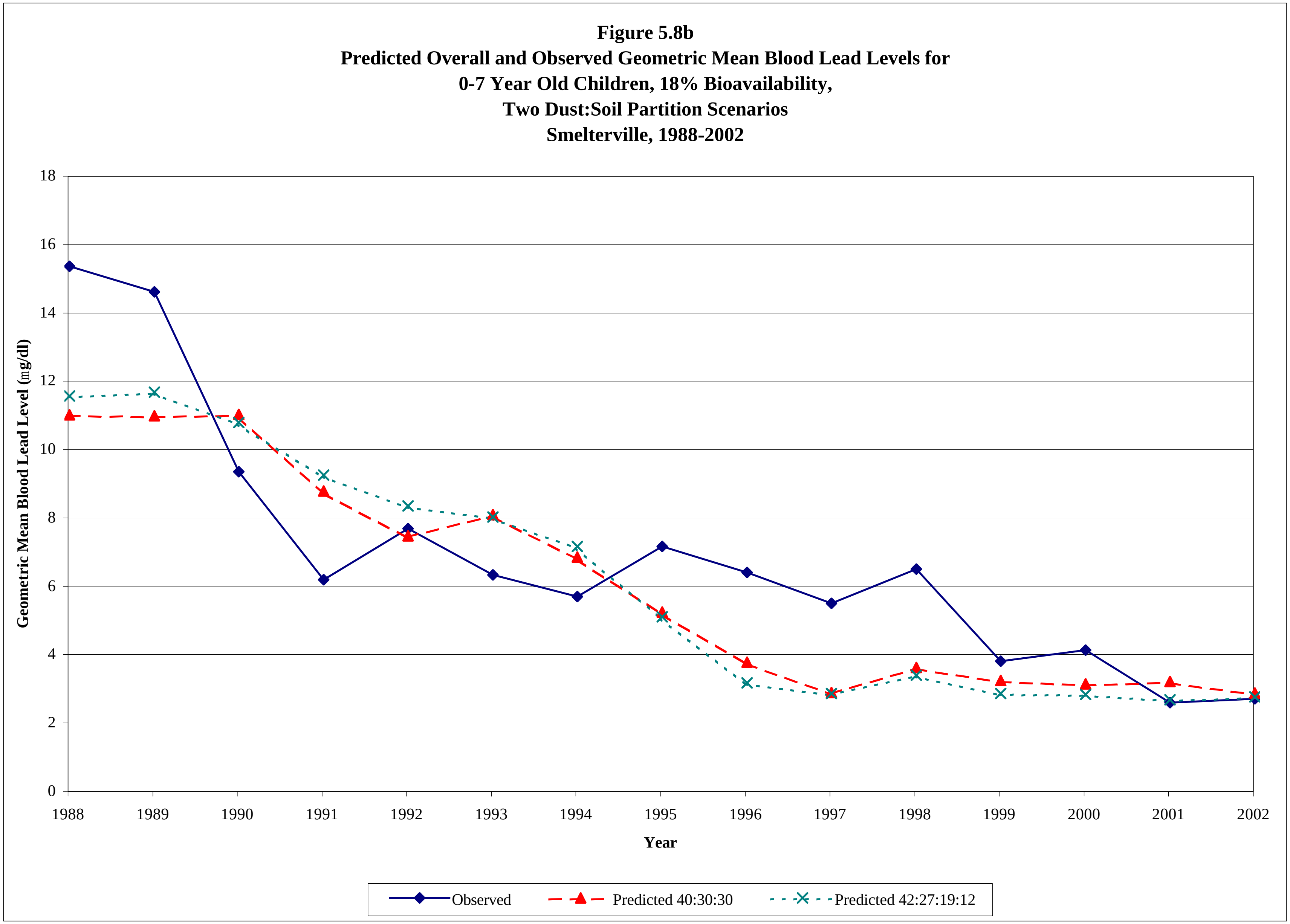


Figure 5.8b
Predicted Overall and Observed Geometric Mean Blood Lead Levels for
0-7 Year Old Children, 18% Bioavailability,
Two Dust:Soil Partition Scenarios
Smelterville, 1988-2002
Geometric Mean Blood Lead Level (mg/dl)
0
2
4
6
8
10
12
14
16
18
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Predicted 40:30:30
Predicted 42:27:19:12

Figure 5.8c
Predicted Overall and Observed Geometric Mean Blood Lead Levels for 0-7 Year Old Children, 18% Bioavailability, Two Dust:Soil Partition Scenarios Site-wide, 1988-2002

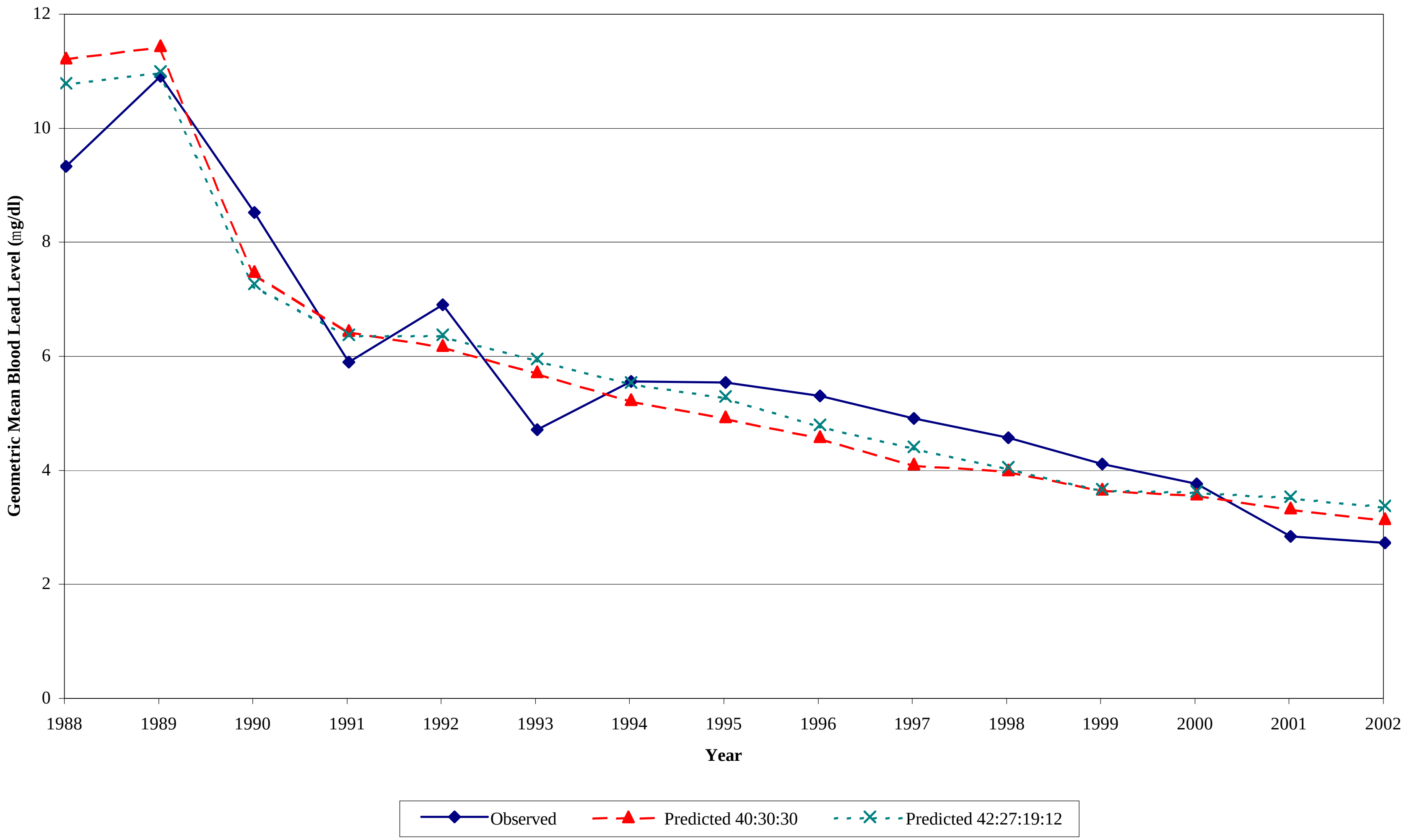


Figure 5.9a
Predicted and Observed Geometric Mean Blood Lead Levels in Two Year Old Children
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Kellogg, 1988-2002

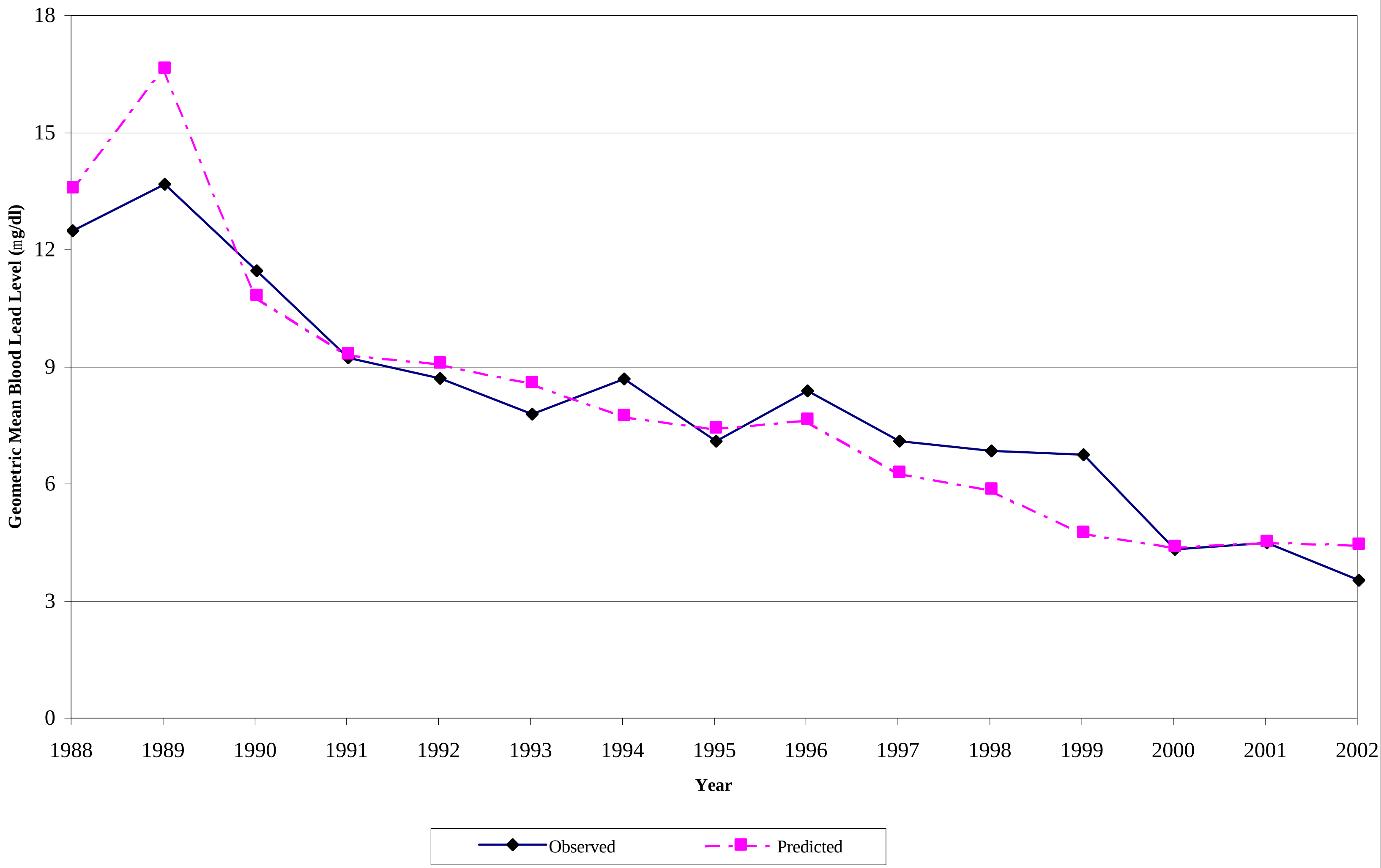


Figure 5.9b
Predicted and Observed Geometric Mean Blood Lead Levels in Two Year Old Children
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Smelterville, 1988-2002

Figure 5.9c
Predicted and Observed Geometric Mean Blood Lead Levels in Two Year Old Children
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Site-wide, 1988-2002

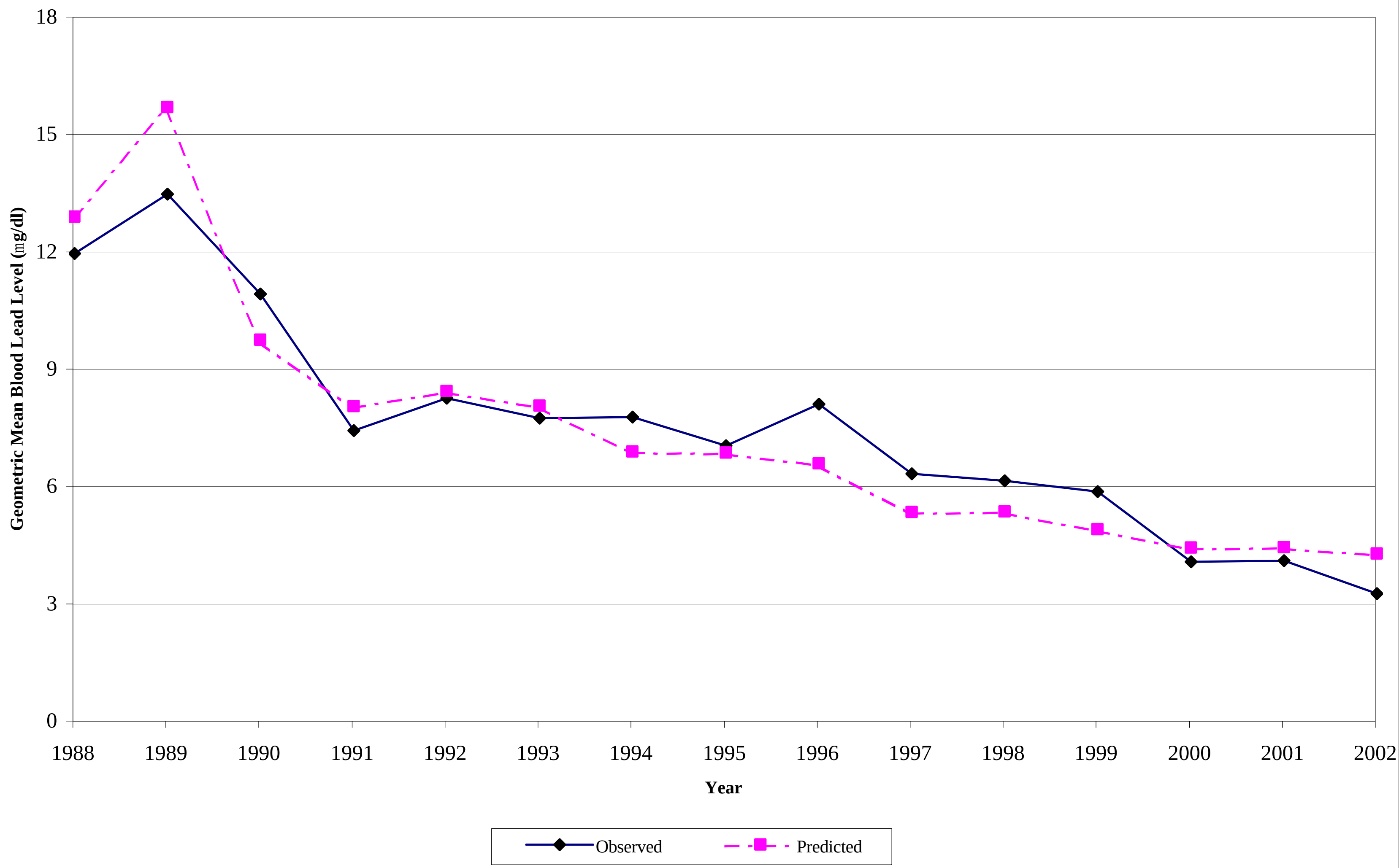


Figure 5.10a
Predicted Overall and Observed Geometric Standard Deviations for
0-7 Year Old Children, 18% Bioavailability,
Two Dust:Soil Partition Scenarios
Kellogg, 1988-2002

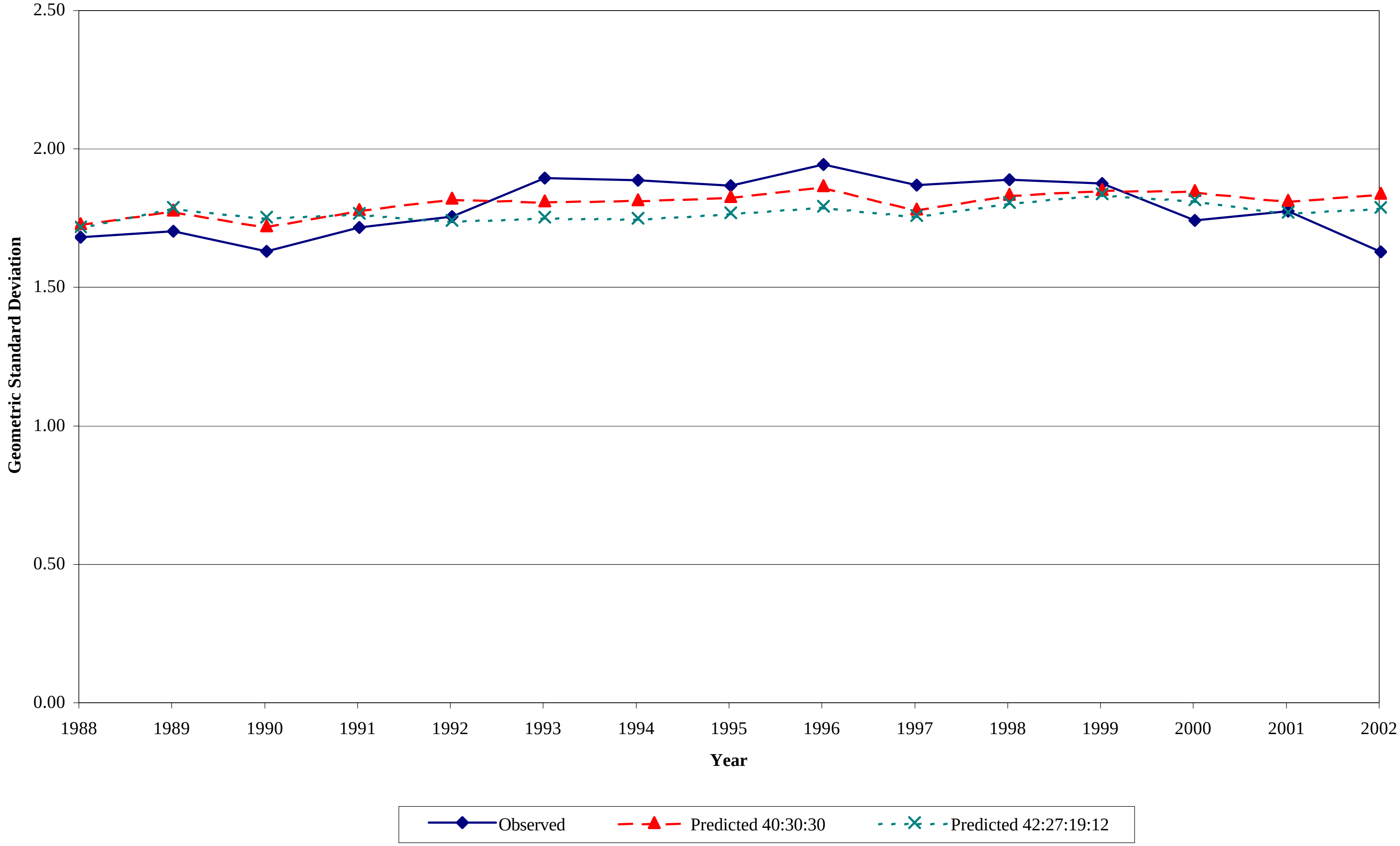
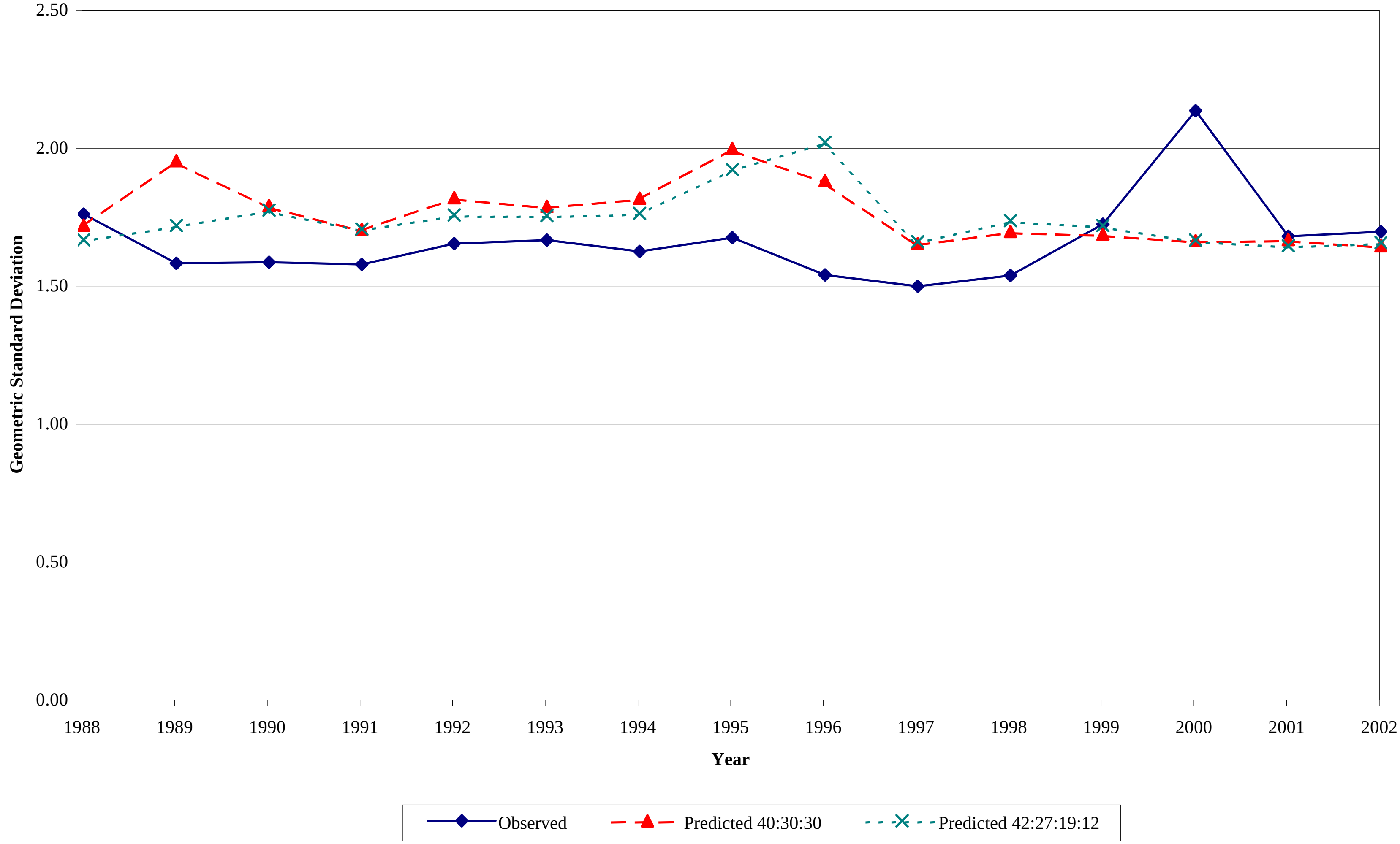


Figure 5.10b
Predicted Overall and Observed Geometric Standard Deviations for
0-7 Year Old Children, 18% Bioavailability,
Two Dust:Soil Partition Scenarios
Smelterville, 1988-2002



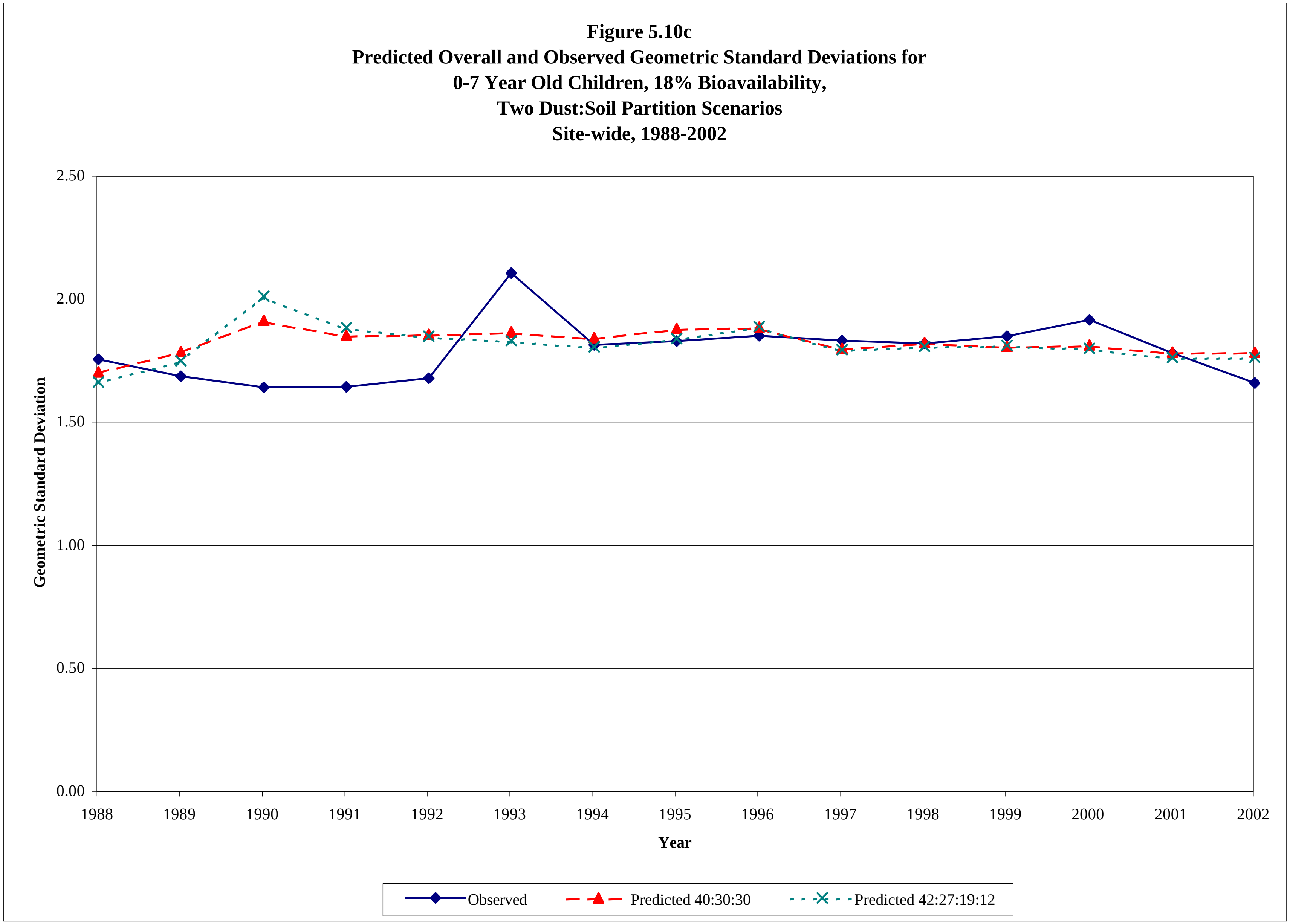


Figure 5.10c
Predicted Overall and Observed Geometric Standard Deviations for
0-7 Year Old Children, 18% Bioavailability,
Two Dust:Soil Partition Scenarios
Site-wide, 1988-2002
Geometric Standard Deviation
2.50
2.00
1.50
1.00
0.50
0.00
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Predicted 40:30:30
Predicted 42:27:19:12

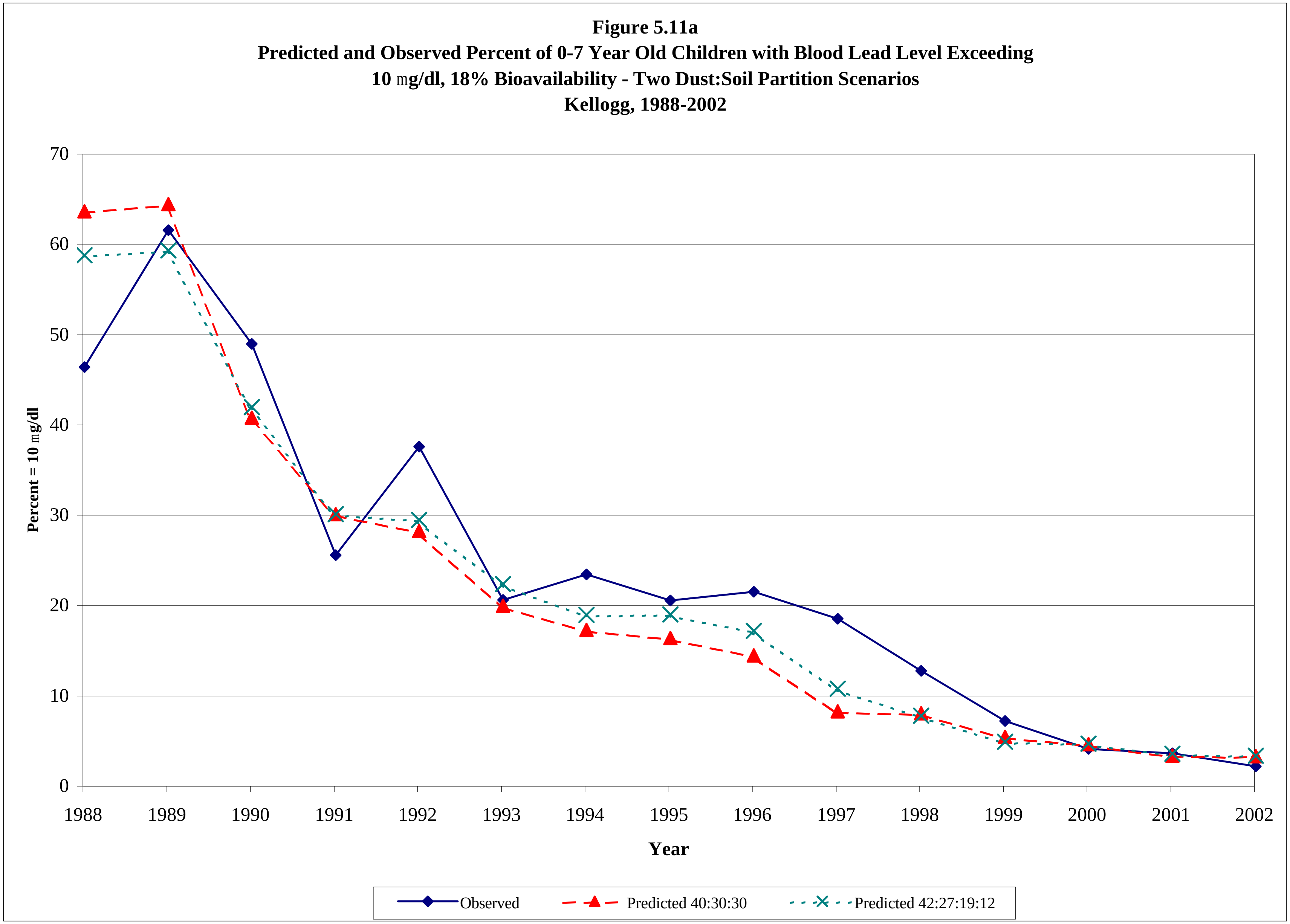
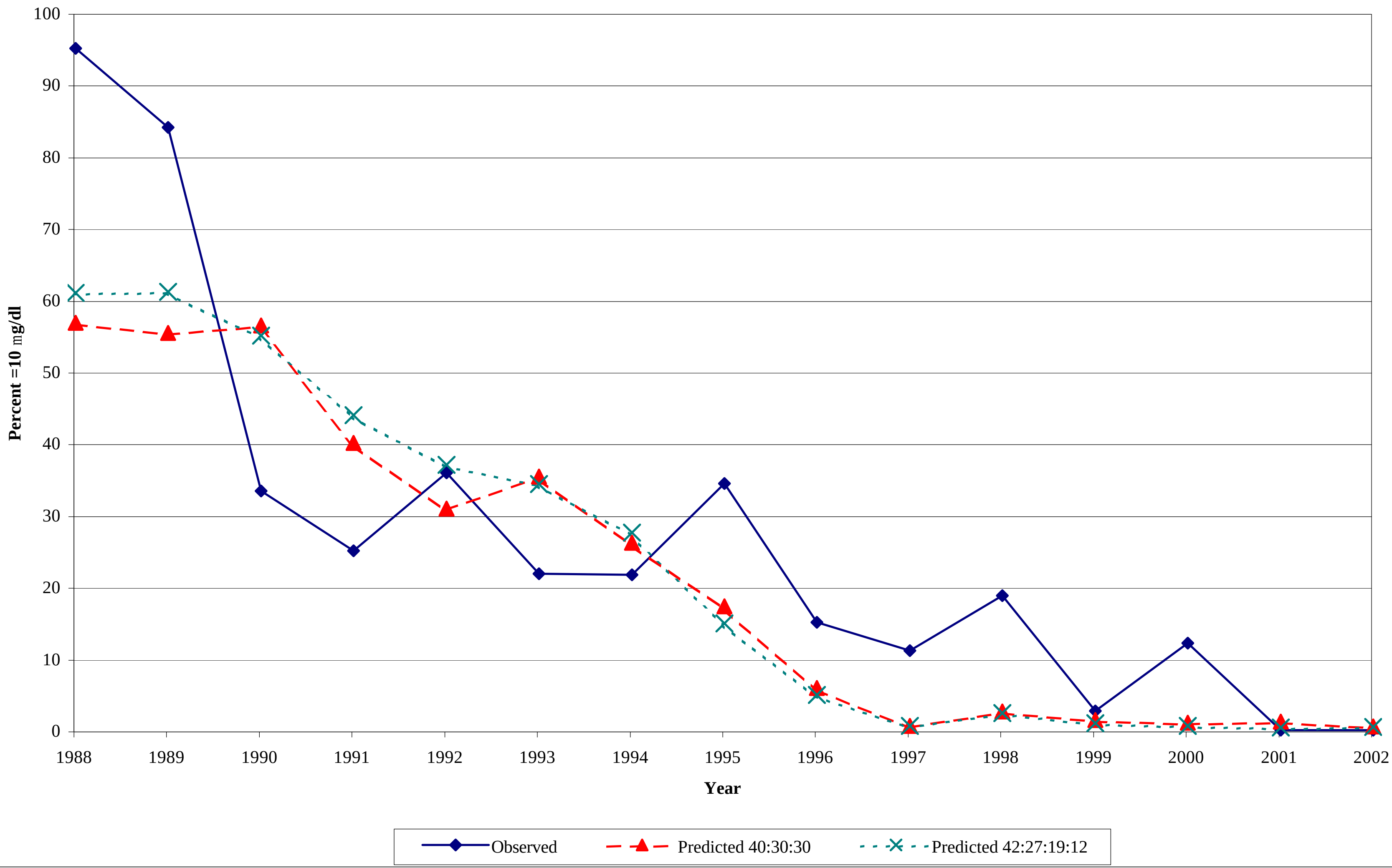


Figure 5.11a
Predicted and Observed Percent of 0-7 Year Old Children with Blood Lead Level Exceeding
10 mg/dl, 18% Bioavailability - Two Dust:Soil Partition Scenarios
Kellogg, 1988-2002
Percent = 10 mg/dl
Year
0
10
20
30
40
50
60
70
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Observed
Predicted 40:30:30
Predicted 42:27:19:12

Figure 5.11b
Predicted and Observed Percent of 0-7 Year Old Children with Blood Lead Level Exceeding 10 mg/dl, 18% Bioavailability - Two Dust:Soil Partition Scenarios
Smelterville, 1988-2002



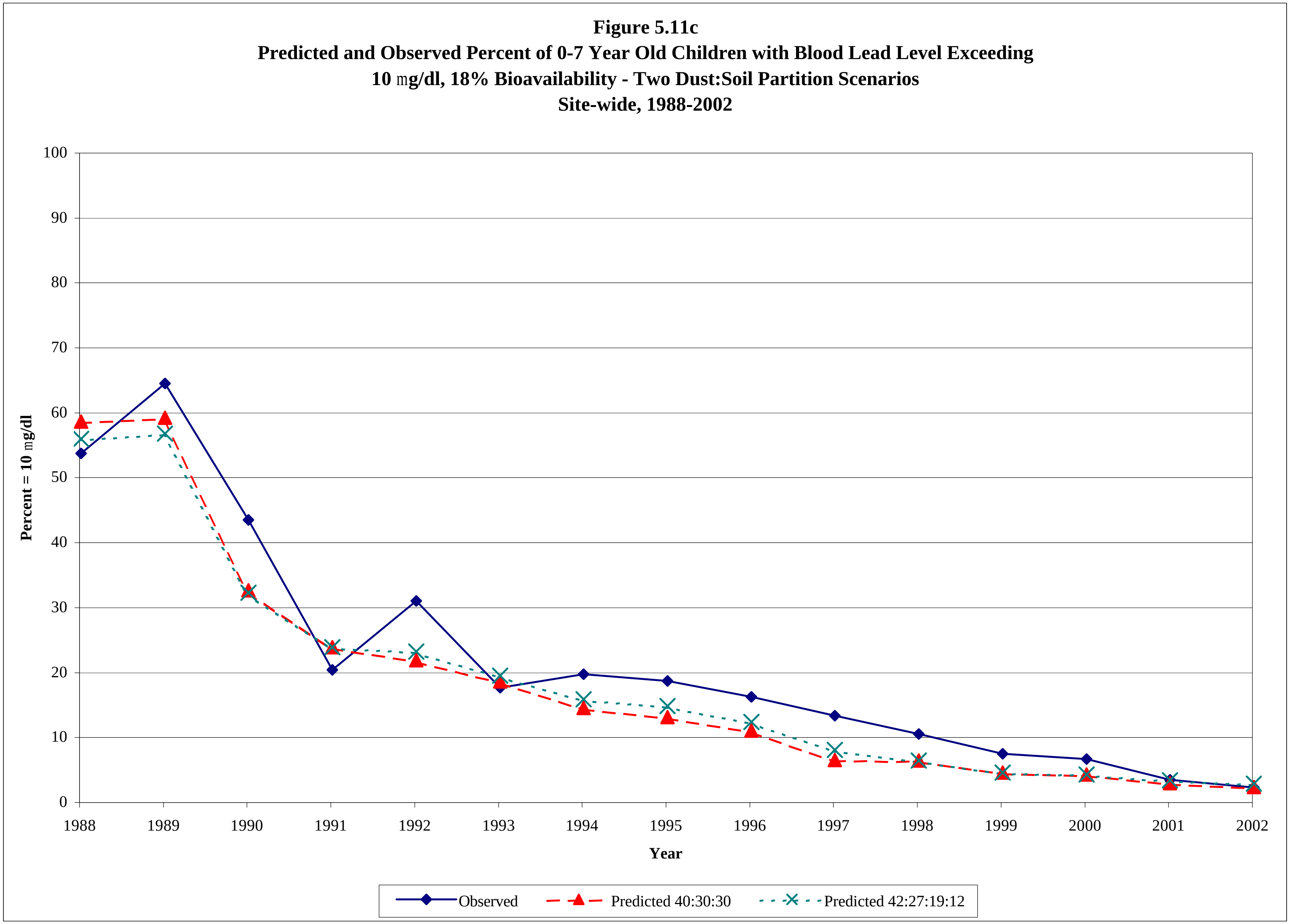


Figure 5.11c
Predicted and Observed Percent of 0-7 Year Old Children with Blood Lead Level Exceeding
10 mg/dl, 18% Bioavailability - Two Dust:Soil Partition Scenarios
Site-wide, 1988-2002
Percent = 10 mg/dl
100
90
80
70
60
50
40
30
20
10
0
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Observed
Predicted 40:30:30
Predicted 42:27:19:12

Tables 5-1a-d
Analysis of Variance for Blood Lead Levels

Table 5-1 a Blood Lead by Year, Site-wide

Year	N	Mean (mg/dl)	GeoMean (mg/dl)	P-value
1988	229	9.9	8.5	-
1989	275	11.4	9.9	0.0011
1990	362	8.9	7.8	0.0001
1991	365	6.3	5.5	0.0001
1992	414	7.4	6.5	0.0001
1993	445	5.6	4.4	0.0001
1994	416	6.2	5.1	0.0012
1995	404	6.0	5.0	0.4264
1996	397	5.8	4.7	0.2646
1997	337	5.4	4.5	0.3631
1998	375	4.8	4.0	0.0105
1999	370	4.7	3.9	0.3532
2000	320	4.3	3.5	0.0386
2001	322	3.2	2.7	0.0001
2002	368	3.1	2.6	0.7275
Overall				0.0001

Table 5-1 b Blood Lead by Year, Kellogg

Year	N	Mean (mg/dl)	GeoMean (mg/dl)	P-value
1988	169	9.2	8.1	-
1989	212	10.8	9.3	0.0089
1990	193	9.3	8.3	0.0212
1991	177	6.9	6.0	0.0001
1992	211	8.1	6.9	0.0062
1993	228	6.3	5.2	0.0001
1994	232	6.7	5.5	0.3794
1995	251	6.4	5.2	0.3541
1996	225	6.4	5.1	0.6954
1997	199	5.9	5.0	0.7499
1998	212	4.9	4.0	0.0006
1999	198	4.5	3.7	0.2760
2000	170	4.3	3.7	0.9438
2001	182	3.4	2.8	0.0001
2002	195	3.2	2.8	0.6541
Overall				0.0001

Table 5-1 c Blood Lead by Year, Smelterville

Year	N	Mean (mg/dl)	GeoMean (mg/dl)	P-value
1988	32	14.2	11.6	-
1989	36	14.6	13.2	0.3374
1990	29	9.9	8.7	0.0009
1991	48	6.6	5.9	0.0005
1992	55	8.3	7.4	0.0178
1993	66	6.7	5.8	0.0130
1994	48	6.0	5.3	0.3967
1995	40	7.2	6.2	0.1444
1996	51	6.4	5.8	0.4748
1997	33	5.6	5.2	0.2708
1998	43	6.4	5.8	0.2268
1999	49	4.3	3.6	0.0001
2000	44	4.9	3.7	0.8753
2001	23	2.8	2.4	0.0227
2002	45	3.0	2.6	0.6466
Overall				0.0001

Table 5-1 d Blood Lead by Year, Pinehurst

Year	N	Mean (mg/dl)	GeoMean (mg/dl)	P-value
1988	-	-	-	-
1989	-	-	-	-
1990	107	7.4	6.7	-
1991	116	5.1	4.7	0.0001
1992	119	6.1	5.5	0.0017
1993	119	3.5	2.6	0.0001
1994	109	5.4	4.6	0.0001
1995	97	4.6	4.0	0.1015
1996	103	4.1	3.7	0.2169
1997	86	4.2	3.5	0.5884
1998	100	4.1	3.5	0.9791
1999	106	5.0	4.2	0.018
2000	91	4.0	3.1	0.0005
2001	101	2.7	2.4	0.0045
2002	115	2.9	2.4	0.584
Overall				0.0001

Table 5-2

Comparison of Bunker Hill Box Results to National and State-wide Blood Lead Levels*

		Blood Lead Concentrations		Percent
		Arithmetic Mean (mg/dl)	**Geometric Mean (mg/dl)**	**= 10 mg/dl**
Box - 2002	**(1-6 year olds)**	3.3	2.8	2.3%
State-wide (1997)	**(1-6 year olds in high risk housing)**	3.7	NR	4.2%
National (1991-1994)				
Low Income	**Pre-1946 Housing**	NR	5.5	16.4%
	1946-1973 Housing	NR	3.6	7.3%
	Post 1973 Housing	NR	3.0	4.3%
Middle Income	**Pre-1946 Housing**	NR	2.9	4.1%
	1946-1973 Housing	NR	2.4	2.0%
	Post 1973 Housing	NR	1.9	0.4%
White (Non-Hispanic)	**Pre-1946 Housing**	NR	3.3	5.6%
	1946-1973 Housing	NR	2.4	1.4%
	Post 1973 Housing	NR	1.8	1.5%

*Source: Morbidity and Mortality, *Weekly Reports*, February 21, 1999; Pirkle et al. 1998; IDHW 1998

NR = not reported

Table 5-3
Correlation Matrix for Blood Lead Levels,
All Cities, All Years[1]

	Blood Lead Levels (mg/dl)	Log of Blood Lead Levels (mg/dl)
Blood Lead Levels	1	0.895
Log of Blood Lead Levels	0.895	1
Age	-0.213	-0.224
Vacuum Dust Lead Concentration	0.088	0.100
Log of Vacuum Dust Lead Concentration	0.283	0.306
Imputed Dust Concentration	0.112	0.126
Log of Imputed Dust Concentration	0.324	0.358
Geometric Mean City Soil Lead Concentration	0.438	0.452
Arithmetic Mean City Soil Lead Concentration	0.403	0.433
Arithmetic Mean Neighborhood Soil Lead Concentration (200' Radius)	0.357	0.367
Geometric Mean Neighborhood Soil Lead Concentration (200' Radius)	0.392	0.388
Yard Soil Lead Concentration	0.270	0.259
Log of Yard Soil Lead Concentration	0.263	0.253

[1] All results were significant with $p<0.0001$

Tables 5-4a-f
Multiple Regression Models Relating Blood Lead Levels to Environmental Sources

Table 5-4a Blood Lead Model with Imputed Dust

Dependent Variable	Pr > F	R-Square
BLPB	<0.0001	0.2572

Variables	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Value
Intercept	1	-0.3706	0.6461	-0.57	0.5663	0
AGE	1	-0.3970	0.0217	-18.29	<.0001	-0.2281
LNDUSTIM	1	0.8098	0.0999	8.11	<.0001	0.1236
LNSOILPB	1	0.2347	0.0477	4.92	<.0001	0.0700
GSOIL200	1	0.0007	0.0001	7	<.0001	0.1302
GCITSOMN	1	0.0019	0.0002	11.09	<.0001	0.2334

Table 5-4b Blood Lead Model with Imputed Dust and Missing Dust Dummy Variable

Dependent Variable	Pr > F	R-Square
BLPB	<0.0001	0.2595

Variables	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Value
Intercept	1	-0.6414	0.6485	-0.99	0.3227	0
AGE	1	-0.3972	0.0217	-18.33	<.0001	-0.2282
LNDUSTIM	1	0.8158	0.0997	8.18	<.0001	0.1245
MISSDUST	1	0.4584	0.1139	4.02	<.0001	0.0500
LNSOILPB	1	0.2300	0.0476	4.83	<.0001	0.0686
GSOIL200	1	0.0007	0.0001	6.99	<.0001	0.1297
GCITSOMN	1	0.0019	0.0002	11.11	<.0001	0.2334

Table 5-4c Blood Lead Model with Raw Dust

Variable	Pr > F	R-Square
BLPB	<0.0001	0.2641

Variables	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Value
Intercept	1	-0.1801	0.6813	-0.26	0.7916	0
AGE	1	-0.4075	0.0310	-13.15	<.0001	-0.2497
LNDUSTPB	1	0.7288	0.1012	7.20	<.0001	0.1515
LNSOILPB	1	0.2555	0.0679	3.76	0.0002	0.0777
GSOIL200	1	0.0008	0.0002	4.95	<.0001	0.1380
GCITSOMN	1	0.0018	0.0002	7.57	<.0001	0.2250

Tables 5-4a-f (continued)
Multiple Regression Models Relating Blood Lead Levels to Environmental Sources

Table 5-4d Blood Lead Model with Dust and Yard Soil

Dependent Variable	Pr > F	R-Square
BLPB	<0.0001	0.1827

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	-3.9039	0.6362	-6.14	<.0001
AGE	-0.4038	0.0314	-12.87	<.0001
LNDUSTPB	1.3060	0.0932	14.01	<.0001
LNSOILPB	0.5835	0.0650	8.97	<.0001

Table 5-4e Blood Lead Model with Dust and Geometric Neighborhood Means (200 ft.)

Dependent Variable	Pr > F	R-Square
BLPB	<0.0001	0.2289

Parameter	Estimate	Error	t Value	Pr > |t|
Intercept	0.7966	0.6107	1.3	0.1923
AGE	-0.4032	0.0310	-13.01	<.0001
LNDUSTPB	0.8914	0.0966	9.23	<.0001
GSOIL200	0.0017	0.0001	15.78	<.0001

Table 5-4f Blood Lead Model with Dust and Geometric Community Means

Dependent Variable	Pr > F	R-Square
BLPB	<0.0001	0.2536

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	1.3729	0.5705	2.41	0.0162
AGE	-0.3907	0.0292	-13.37	<.0001
LNDUSTPB	0.6717	0.0934	7.19	<.0001
GCITSOMN	0.0029	0.0002	18.51	<.0001

BLPB	Blood lead levels (ug/dl)
AGE	Child age (years)
LNDUSTPB	Log transformed vacuum dust lead concentration (mg/kg)
LNDUSTIM	Log Imputed Dust Concentration (mg/kg)
MISSDUST	Missing Vacuum Sample Indicator (unitless)
LNSOILPB	Log transformed yard soil lead concentration (mg/kg)
GSOIL200	Geometric mean yard soil lead concentration within a 200 foot radius (mg/kg)
GCITSOMN	Geometric mean city soil lead concentration (mg/kg)

Table 5-5a-d

Estimated Soil and Dust Lead Intake (Default 55:45 Dust/Soil)[1]

Table 5-5a Site-wide

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	70	272	199	-
1989	49	263	169	0.2428
1990	139	154	113	0.0025
1991	162	109	88	0.0028
1992	230	101	74	0.0233
1993	199	81	61	0.0096
1994	203	71	51	0.0248
1995	153	78	50	0.7802
1996	162	68	45	0.2857
1997	100	65	41	0.3536
1998	157	57	43	0.5272
1999	179	62	42	0.5606
2000	139	52	36	0.0810
2001	117	34	27	0.0016
2002	117	37	26	0.5525
Overall				0.0001

Table 5-5b Kellogg

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	44	314	224	-
1989	31	330	205	0.6045
1990	68	176	133	0.0154
1991	75	126	108	0.0757
1992	124	125	91	0.1216
1993	111	84	64	0.0006
1994	105	75	54	0.1210
1995	97	84	57	0.6229
1996	107	69	50	0.2119
1997	59	73	48	0.8206
1998	82	63	47	0.8661
1999	99	77	45	0.6956
2000	72	57	33	0.0241
2001	71	36	29	0.2820
2002	65	45	30	0.8380
Overall				0.0001

Table 5-5c Smelterville

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	21	226	184	-
1989	14	162	138	0.2170
1990	15	218	186	0.1962
1991	27	125	109	0.0045
1992	26	76	58	0.0006
1993	19	118	85	0.1212
1994	35	97	65	0.2899
1995	20	118	64	0.9896
1996	12	132	46	0.4596
1997	15	31	27	0.1671
1998	26	41	40	0.0026
1999	14	38	33	0.1270
2000	23	34	31	0.7780
2001	5	30	28	0.5630
2002	16	32	25	0.7085
Overall				0.0001

Table 5-5d Pinehurst

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1990	46	97	75	-
1991	51	82	62	0.1612
1992	66	70	58	0.6608
1993	55	67	54	0.5079
1994	43	41	37	0.0022
1995	30	40	31	0.1914
1996	37	44	36	0.3450
1997	18	80	36	0.9986
1998	35	40	34	0.8364
1999	61	46	39	0.2482
2000	40	54	45	0.2598
2001	36	29	23	0.0001
2002	31	23	18	0.1633
Overall				0.0001

[1] assumes dust/soil intake is 55% housedust, 45% yard soil

Table 5-6a-d

Estimated Soil and Dust Lead Intake (40:30:30)[1]

Table 5-6a Site-wide

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	70	254	210	-
1989	49	248	188	0.2934
1990	139	143	117	0.0001
1991	162	107	93	0.0011
1992	230	97	82	0.0271
1993	199	80	69	0.0012
1994	203	74	63	0.0677
1995	153	74	58	0.2606
1996	162	66	52	0.1103
1997	100	59	44	0.0298
1998	157	50	42	0.5612
1999	179	53	39	0.2728
2000	139	44	34	0.0401
2001	117	31	28	0.0038
2002	117	33	26	0.4447
Overall				0.0001

Table 5-6b Kellogg

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	44	284	228	-
1989	31	297	217	0.7192
1990	68	169	149	0.0019
1991	75	125	117	0.0009
1992	124	118	102	0.0591
1993	111	86	77	0.0001
1994	105	78	69	0.0910
1995	97	82	69	0.9931
1996	107	70	60	0.0848
1997	59	67	53	0.1556
1998	82	54	45	0.1242
1999	99	62	40	0.2715
2000	72	47	32	3.6988
2001	71	32	28	0.1821
2002	65	38	29	0.6956
Overall				0.0001

Table 5-6c Smelterville

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	21	226	207	-
1989	14	183	173	0.2061
1990	15	212	198	0.3451
1991	27	139	132	0.0007
1992	26	93	85	0.0001
1993	19	118	103	0.1833
1994	35	102	87	0.2801
1995	20	97	66	0.1398
1996	12	100	41	0.1998
1997	15	26	24	0.1270
1998	26	33	33	0.0034
1999	14	31	27	0.1000
2000	23	27	26	0.7646
2001	5	25	24	0.5236
2002	16	26	22	0.7855
Overall				0.0001

Table 5-6d Pinehurst

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1990	46	82	68	-
1991	51	71	58	0.1782
1992	66	63	56	0.6552
1993	55	59	52	0.3825
1994	43	41	39	0.0011
1995	30	39	35	0.2365
1996	37	42	38	0.4113
1997	18	68	39	0.9124
1998	35	39	36	0.641
1999	61	43	40	0.1837
2000	40	48	43	0.3854
2001	36	29	27	0.0001
2002	31	24	22	0.0705
Overall				0.0001

[1] assumes dust/soil intake is 40% housedust, 30% yard soil, 30% community soil

Table 5-7a-d

Estimated Soil and Dust Lead Intake (75:18:7)[1]

Table 5-7a Site-wide

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	70	270	179	-
1989	49	283	165	0.5387
1990	139	152	119	0.0073
1991	162	118	99	0.0137
1992	230	104	84	0.0087
1993	199	86	70	0.0052
1994	203	77	62	0.0639
1995	153	79	57	0.3347
1996	162	71	52	0.2297
1997	100	79	49	0.5352
1998	157	65	50	0.8253
1999	179	70	46	0.2269
2000	139	60	40	0.1103
2001	117	36	30	0.0011
2002	117	39	28	0.4017
Overall				0.0001

Table 5-7b Kellogg

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	44	324	201	-
1989	31	359	191	0.7731
1990	68	169	140	0.0427
1991	75	136	124	0.1914
1992	124	120	100	0.0094
1993	111	91	77	0.0013
1994	105	80	66	0.0729
1995	97	87	67	0.8666
1996	107	69	58	0.0973
1997	59	88	59	0.8359
1998	82	73	57	0.7383
1999	99	91	54	0.5916
2000	72	70	40	0.0263
2001	71	40	34	0.1510
2002	65	48	34	0.9357
Overall				0.0001

Table 5-7c Smelterville

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1988	21	199	165	-
1989	14	167	142	0.4956
1990	15	213	193	0.1368
1991	27	140	134	0.0037
1992	26	101	82	0.0008
1993	19	125	101	0.2948
1994	35	107	84	0.3846
1995	20	105	73	0.4995
1996	12	176	56	0.5175
1997	15	37	31	0.1631
1998	26	50	49	0.0025
1999	14	42	35	0.0157
2000	23	37	35	0.9615
2001	5	29	29	0.2587
2002	16	38	27	0.8784
Overall				0.0001

Table 5-7d Pinehurst

Year	N	Mean (mg/day)	GeoMean (mg/day)	P-value
1990	46	110	81	-
1991	51	86	63	0.0711
1992	66	75	62	0.8233
1993	55	67	54	0.2361
1994	43	45	41	0.0172
1995	30	40	31	0.0719
1996	37	47	39	0.1940
1997	18	98	39	0.9831
1998	35	39	33	0.4279
1999	61	38	38	0.2255
2000	40	55	44	0.2145
2001	36	29	24	0.0001
2002	31	22	18	0.0573
Overall				0.0001

[1] assumes dust/soil intake is 75% housedust, 18% yard soil, 7% community soil

Table 5-8a-d

Estimated Soil and Dust Lead Intake (42:27:19:12)[1]

Table 5-8a Site-wide

Year	N	Mean (mg/day)	GeoMean (mg/day)	GeoP-value
1988	70	248	205	-
1989	49	255	196	0.6421
1990	139	139	116	0.0001
1991	162	110	96	0.0046
1992	226	99	87	0.0979
1993	197	83	75	0.0013
1994	201	76	67	0.0290
1995	151	74	62	0.1624
1996	160	68	57	0.1365
1997	100	65	48	0.0437
1998	153	53	45	0.3334
1999	152	56	42	0.2807
2000	118	45	35	0.0160
2001	87	32	29	0.0101
2002	94	36	29	0.9792
Overall				0.0001

Table 5-8b Kellogg

Year	N	Mean (mg/day)	GeoMean (mg/day)	GeoP-value
1988	44	275	216	-
1989	31	294	212	0.8828
1990	68	167	156	0.0029
1991	75	130	125	0.0001
1992	124	117	109	0.0057
1993	111	93	88	0.0001
1994	105	82	76	0.0021
1995	97	86	77	0.8641
1996	107	74	68	0.0373
1997	59	74	60	0.0896
1998	82	60	51	0.0913
1999	87	66	44	0.0996
2000	63	49	35	0.0443
2001	61	33	30	0.1194
2002	58	39	32	0.4590
Overall				0.0001

Table 5-8c Smelterville

Year	N	Mean (mg/day)	GeoMean (mg/day)	GeoP-value
1988	21	226	214	-
1989	14	213	203	0.6609
1990	15	212	204	0.9766
1991	27	149	147	0.0001
1992	26	115	110	0.0001
1993	19	119	111	0.9000
1994	33	103	96	0.1913
1995	20	79	60	0.0038
1996	12	105	42	0.2992
1997	15	27	25	0.1391
1998	26	35	34	0.0041
1999	10	34	29	0.2483
2000	17	29	27	0.6962
2001	3	23	23	0.3105
2002	13	29	23	0.9602
Overall				0.0001

Table 5-8d Pinehurst

Year	N	Mean (mg/day)	GeoMean (mg/day)	GeoP-value
1990	46	77	63	-
1991	51	64	53	0.1229
1992	62	57	52	0.7879
1993	53	54	48	0.3338
1994	43	39	37	0.0029
1995	28	35	32	0.0875
1996	35	39	36	0.2661
1997	18	69	38	0.7214
1998	31	36	33	0.4254
1999	51	44	42	0.0072
2000	35	45	41	0.7750
2001	21	27	26	0.0001
2002	21	27	25	0.6413
Overall				0.0001

[1] assumes dust/soil intake is 42% housedust, 27% community soil, 19% neighborhood soil, 12% yard soil

Table 5-9
Estimated Aggregate Soil and Dust Effective Bioavailability 1988-2002

Year	Bioavailability Arithmetic Mean	Bioavailability Geometric Mean	Percent of Lead Intake From House Dust
1988	16%	12%	42%
1989	23%	17%	57%
1990	21%	17%	41%
1991	20%	15%	47%
1992	26%	20%	43%
1993	22%	15%	46%
1994	23%	17%	44%
1995	22%	15%	44%
1996	29%	20%	45%
1997	31%	23%	63%
1998	28%	20%	61%
1999	30%	22%	62%
2000	35%	23%	63%
2001	25%	15%	51%
2002	24%	14%	54%

Table 5-10a
Predicted and Observed Geometric Mean Blood Lead Levels in
0-9 Year Old Children, Default Parameters - Three Dust:Soil Partition Scenarios

Observed and Predicted Blood Lead Levels (mg/dl)				
Year	**Observed**	**Default**	**40-30-30**	**75-18-7**
Kellogg				
1988	8.1	16.4	17.7	15.0
1989	9.3	16.2	16.8	15.2
1990	8.3	11.4	12.6	11.7
1991	6.0	9.3	10.0	10.4
1992	6.9	8.3	9.1	9.1
1993	5.2	7.2	7.9	8.1
1994	5.5	6.8	7.5	7.4
1995	5.2	8.1	8.3	8.1
1996	5.1	6.3	6.8	6.7
1997	4.9	5.7	5.9	6.5
1998	4.0	5.6	5.3	6.3
1999	3.7	5.1	4.8	5.9
2000	3.7	4.6	4.4	5.2
2001	2.8	4.4	4.2	4.8
2002	2.7	4.2	4.0	4.7
Smelterville				
1988	11.5	13.6	15.6	12.7
1989	13.2	13.3	15.6	12.8
1990	8.7	13.7	15.3	14.9
1991	5.9	10.1	11.7	11.5
1992	7.4	8.3	10.0	9.2
1993	5.8	10.2	11.2	11.0
1994	5.3	7.4	8.9	8.7
1995	6.2	6.3	6.3	7.1
1996	5.8	5.4	5.5	6.2
1997	5.2	3.7	3.4	3.9
1998	5.8	5.0	4.4	5.7
1999	3.6	4.6	4.1	5.0
2000	3.6	4.4	3.9	4.8
2001	2.4	4.5	4.0	5.0
2002	2.6	3.9	3.6	4.3
Site-wide				
1988	8.5	14.7	16.1	13.1
1989	9.9	14.6	15.5	13.7
1990	7.9	9.8	10.4	10.2
1991	5.5	8.2	8.8	9.1
1992	6.5	7.6	8.2	8.3
1993	4.4	7.0	7.4	7.7
1994	5.1	6.3	6.9	6.9
1995	5.0	6.8	6.8	6.8
1996	4.7	5.7	5.9	6.1
1997	4.5	5.3	5.3	5.7
1998	4.0	5.2	5.0	5.7
1999	3.9	5.0	4.7	5.4
2000	3.5	4.7	4.4	5.1
2001	2.6	4.2	4.1	4.5
2002	2.6	4.0	3.9	4.3

Table 5-10b
Predicted and Observed Geometric Standard Deviation, 1988-2002, Default Parameters - Three Dust:Soil Partition Scenarios

Observed and Predicted Geometric Standard Deviations				
Year	**Observed**	**Overall Default**	**Overall 40-30-30**	**Overall 75-18-7**
Kellogg				
1988	1.68	1.80	1.70	1.76
1989	1.74	1.82	1.76	1.81
1990	1.61	1.88	1.74	1.83
1991	1.65	1.68	1.77	1.71
1992	1.72	1.96	1.77	1.78
1993	1.88	1.88	1.77	1.82
1994	1.89	1.93	1.76	1.84
1995	1.92	2.01	1.84	1.82
1996	1.94	2.03	1.85	2.13
1997	1.84	1.88	1.82	1.80
1998	1.93	1.88	1.83	1.80
1999	1.89	1.84	1.82	1.78
2000	1.71	1.84	1.80	1.80
2001	1.78	1.88	1.82	1.77
2002	1.62	1.84	1.81	1.79
Smelterville				
1988	1.87	1.80	1.68	1.79
1989	1.61	1.95	1.74	1.75
1990	1.56	1.96	1.78	1.75
1991	1.56	1.86	1.78	1.71
1992	1.61	1.99	1.83	1.89
1993	1.79	2.38	2.08	1.74
1994	1.67	1.89	1.61	1.95
1995	1.72	1.86	1.80	1.72
1996	1.65	1.86	2.10	1.80
1997	1.52	1.71	1.69	1.72
1998	1.54	1.75	1.73	1.78
1999	1.89	1.75	1.72	1.75
2000	2.10	1.71	1.69	1.71
2001	1.72	1.70	1.69	1.72
2002	1.66	1.72	1.70	1.76
Site-wide				
1988	1.74	1.83	1.75	1.78
1989	1.71	1.88	1.78	1.78
1990	1.62	1.99	1.93	1.48
1991	1.59	1.81	1.84	1.83
1992	1.65	1.97	1.83	1.85
1993	2.08	1.95	1.88	1.90
1994	1.84	1.91	1.81	1.84
1995	1.88	2.11	2.00	1.92
1996	1.88	2.06	1.91	1.92
1997	1.84	1.91	1.83	1.83
1998	1.86	1.87	1.79	1.84
1999	1.88	1.82	1.79	1.94
2000	1.89	1.82	1.79	1.93
2001	1.78	1.87	1.80	1.89
2002	1.64	1.82	1.78	1.87

Table 5-10c
Predicted and Observed Lead Toxicity
Percent of 0-9 Year Old Children With Blood Lead ≥ 10 μg/dl

Default Parameters - Three Dust:Soil Partition Scenarios

Observed and Predicted Lead Toxicity				
Year	**Observed**	**Default**	**40-30-30**	**75-18-7**
Kellogg				
1988	41	80	86	76
1989	54 (52)[1]	79	82	76
1990	41 (40)	58	66	60
1991	20	44	49	53
1992	32	39	44	44
1993	17 (18)	30	34	36
1994	20	28	31	31
1995	17	38	38	36
1996	17	26	27	26
1997	14 (15)	19	19	23
1998	9 (10)	18	15	22
1999	6	14	11	18
2000	4 (3)	10	8	14
2001	3 (4)	10	7	10
2002	2	8	6	10
Smelterville				
1988	71 (72)	70	81	66
1989	76 (78)	66	79	66
1990	31	68	77	76
1991	23	50	61	60
1992	31	39	49	45
1993	20	49	56	57
1994	21	32	41	42
1995	24 (28)	23	22	27
1996	15 (12)	16	16	21
1997	9	3	2	4
1998	14	11	7	17
1999	4	8	5	11
2000	9	6	4	9
2001	0	7	4	10
2002	0	4	3	7
Site-wide				
1988	46	74	80	68
1989	59 (56)	72	77	70
1990	37	49	53	52
1991	16 (15)	37	42	44
1992	27	34	37	38
1993	15	30	32	34
1994	17	24	27	27
1995	15	30	29	28
1996	13 (12)	22	21	22
1997	11	16	15	18
1998	8	15	12	18
1999	6	12	10	14
2000	5	10	8	12
2001	3	8	7	9
2002	2	6	5	7

Notes:

1 - Values in parentheses indicate total population values, and the full number of observations were not included in the model runs due to missing environmental media concentrations.

Table 5-11
Predicted and Observed Geometric Mean Blood Lead Levels,
Geometric Standard Deviations, and Toxicity for 0-7 Year Old Children
For the 42:27:19:12 and 40:30:30 Models at 18% Bioavailability

Geometric Mean Blood Lead Levels 0-7 Year Old Children (mg/dl)				Geometric Standard Deviations (0-7 yr. olds)			Percent of Children (0-7) with Blood Lead ≥ 10 mg/dl		
Year	**Observed**	**Predicted 40:30:30**	**Predicted 42:27:19:12**	**Observed**	**Predicted 40:30:30**	**Predicted 42:27:19:12**	**Observed**	**Predicted 40:30:30**	**Predicted 42:27:19:12**
Kellogg									
1988	8.6	12.1	11.3	1.67	1.72	1.71	46	64	59
1989	10.2	12.3	11.4	1.70	1.77	1.78	61	64	59
1990	9.1	8.8	8.9	1.62	1.72	1.75	49	41	42
1991	6.4	7.4	7.4	1.71	1.77	1.76	25	30	30
1992	7.5	7.1	7.4	1.75	1.82	1.74	37	28	29
1993	5.5	6.0	6.5	1.89	1.81	1.75	20	20	22
1994	5.8	5.7	6.1	1.88	1.81	1.74	23	17	19
1995	5.8	5.5	6.0	1.86	1.82	1.76	20	16	19
1996	5.6	5.1	5.7	1.94	1.86	1.79	21	14	17
1997	5.3	4.5	5.0	1.86	1.78	1.75	18	8	11
1998	4.6	4.3	4.3	1.88	1.83	1.80	13	8	8
1999	4.0	3.7	3.6	1.87	1.85	1.83	7	5	5
2000	3.8	3.5	3.7	1.74	1.84	1.81	4	4	5
2001	2.9	3.3	3.5	1.77	1.81	1.76	3	3	3
2002	2.9	3.2	3.4	1.62	1.83	1.78	2	3	3
Smelterville									
1988	15.3	11.0	11.5	1.76	1.71	1.66	95	57	61
1989	14.6	10.9	11.6	1.58	1.95	1.71	84	55	61
1990	9.3	11.0	10.8	1.58	1.79	1.77	33	56	55
1991	6.2	8.7	9.2	1.57	1.70	1.70	25	40	44
1992	7.6	7.4	8.3	1.65	1.81	1.75	36	31	37
1993	6.3	8.1	8.0	1.66	1.78	1.75	22	35	34
1994	5.7	6.8	7.1	1.62	1.81	1.76	22	26	27
1995	7.1	5.2	5.1	1.67	1.99	1.92	34	17	15
1996	6.4	3.7	3.1	1.53	1.88	2.02	15	6	5
1997	5.5	2.9	2.8	1.49	1.65	1.66	11	1	1
1998	6.5	3.6	3.4	1.53	1.69	1.73	19	3	2
1999	3.8	3.2	2.8	1.72	1.68	1.71	3	1	1
2000	4.1	3.1	2.8	2.13	1.66	1.66	12	1	1
2001	2.5	3.2	2.6	1.67	1.66	1.64	0	1	0
2002	2.7	2.8	2.7	1.69	1.64	1.65	0	1	0
Site-wide									
1988	9.3	11.2	10.8	1.75	1.70	1.66	54	58	56
1989	10.9	11.4	11.0	1.68	1.78	1.74	64	59	57
1990	8.5	7.5	7.2	1.64	1.91	2.01	43	32	32
1991	5.9	6.4	6.4	1.64	1.85	1.88	20	24	24
1992	6.9	6.2	6.3	1.67	1.85	1.84	31	22	23
1993	4.7	5.7	5.9	2.10	1.86	1.83	17	18	19
1994	5.5	5.2	5.5	1.81	1.84	1.80	20	14	16
1995	5.5	4.9	5.3	1.82	1.87	1.83	19	13	15
1996	5.3	4.6	4.8	1.84	1.88	1.88	16	11	12
1997	4.9	4.1	4.4	1.83	1.80	1.79	13	6	8
1998	4.5	4.0	4.0	1.81	1.82	1.80	10	6	6
1999	4.1	3.6	3.6	1.84	1.80	1.81	7	4	4
2000	3.7	3.6	3.6	1.91	1.81	1.79	6	4	4
2001	2.8	3.3	3.5	1.78	1.78	1.76	3	3	3
2002	2.7	3.1	3.3	1.65	1.78	1.76	2	2	3

Table 5-12

Predicted and Observed Mean Blood Lead Levels for Two Year Old Children
42:27:19:12 Dust:Soil Partition at 18% Bioavailability

	Mean Blood Lead Levels 2 Year Old Children (mg/dl)	
Year	**Observed**	**Predicted**
Kellogg		
1988	12.4	13.5
1989	13.6	16.6
1990	11.4	10.8
1991	9.2	9.3
1992	8.7	9.1
1993	7.7	8.6
1994	8.6	7.7
1995	7.1	7.4
1996	8.3	7.6
1997	7.1	6.3
1998	6.8	5.8
1999	6.7	4.7
2000	4.3	4.4
2001	4.4	4.5
2002	3.5	4.4
Smelterville		
1988	5.0	12.3
1989	13.7	13.4
1990	13.3	15.1
1991	4.0	10.3
1992	9.6	9.7
1993	8.9	9.0
1994	8.4	9.5
1995	11.7	6.2
1996	10.4	3.4
1997	7.2	3.4
1998	7.0	4.6
1999	3.0	3.8
2000	3.4	3.2
2001	2.1	3.1
2002	3.6	3.3
Site-wide		
1988	11.9	12.9
1989	13.4	15.6
1990	10.9	9.7
1991	7.4	8.0
1992	8.2	8.4
1993	7.7	8.0
1994	7.7	6.8
1995	7.0	6.8
1996	8.1	6.5
1997	6.3	5.3
1998	6.1	5.3
1999	5.8	4.9
2000	4.0	4.4
2001	4.1	4.4
2002	3.2	4.2

SECTION 6.0 COMPLIANCE WITH THE BOX REMEDIAL ACTION OBJECTIVES

This Section assesses the Box compliance with the Remedial Action Objectives (RAOs) by direct comparison of observed blood lead and soil and dust concentrations to Box criteria and discussion of the underlying dose-response relationships. The potential for modifying the Blood Lead RAOs, or the underlying strategy to achieve those goals within the Box is also discussed generally in the following three categories:

- Potential changes in State and Federal Health Policy that modify the health criteria or strategies to prevent childhood lead poisoning,
- Changes in the population base, prevalence of high lead levels, and/or the environmental exposure situation, or
- Identification of more efficient and effective public health protection measures.

6.1 Bunker Hill Superfund Site Remedial Action Objectives

Site-wide RAOs were defined in the Populated and Non-Populated Records of Decision (RODs) for the Bunker Hill Superfund Site (Box) (USEPA 1991, USEPA 1992a). The blood lead RAOs were defined in the 1991 Populated Areas ROD and were based on site-specific blood lead levels among children and environmental media lead concentrations. The RAOs defined for the Box were developed prior to publication of the 1994 USEPA and 1991 CDC guidance and updates that outline the current blood lead criteria (CDC 1991, USEPA 1994b, CDC 1997, USEPA 1998). The blood lead RAOs within the Box seek to reduce the incidence of lead poisoning in the community to the following levels:

- less than 5% of children with blood lead levels of 10 μg/dl or greater, and
- less than 1% of children exceeding 15 μg/dl.

These objectives are to be achieved by a strategy of soil and house dust RAOs that includes:

- Remediating all residential yards, commercial properties, and ROWs that have soil lead concentrations greater than 1,000 mg/kg;
- Achieving a geometric mean yard soil concentration of less than 350 mg/kg for each community in the site;
- Controlling fugitive dust and stabilizing and covering contaminated soils throughout the site;

- Achieving a geometric mean interior house dust lead concentrations of less than 500 mg/kg for each community in the site; and

- If house dust lead levels remain elevated, homes with concentrations greater than 1,000 mg/kg will be considered for a one-time interior remediation after completion of remedial actions that address fugitive dust.

The success of the Box strategy depends on reduction of interior house dust lead levels to concentrations comparable to post-remedial area soils.

6.1.1 Blood Lead RAOs

Less than 5% of children with blood lead levels of 10 µg/dl or greater: The blood lead RAOs apply to each community in the Box. Table 6-1a shows that for those children tested, all communities have achieved compliance with the 10 µg/dl blood lead RAOs as of 2002. Two percent (2%) of children tested in Kellogg (4 children) and 3% of Pinehurst children (3 children) had levels greater than or equal to 10 µg/dl in 2002. Blood lead levels of children in other Box communities were all below 10 µg/dl. No children in the communities of Wardner and Page showed blood lead levels exceeding 10 µg/dl in 2002; however, these towns have so few children that it is difficult to evaluate an RAO based on the percentage of children.

As a result, the dose-response relationship underlying the development of the compliance strategy was also examined for appropriateness and consistency with the larger communities. The analysis discussed in Section 5, concludes that sufficient reductions in lead from residential soil and dust sources have been accomplished throughout the site to achieve the blood lead RAO, although the cleanup is not yet complete. Nevertheless, there remain individual homes in some communities that do not meet soil and dust RAOs. About 5% of children tested in 2001-2002 lived in these homes. These children, and others that might move to similar residences, and have a greater risk of experiencing an elevated blood lead level. It is unlikely that a sufficient number of these situations exist to result in exceeding the 10 µg/dl RAO for the community.

Less than 1% of children exceeding 15 µg/dl: Table 6-1b shows that two children (or 1% of Kellogg) and one child (also 1%) in Pinehurst exceeded the individual 15 µg/dl criteria. Compliance with this objective is difficult to access in all communities, as one or two children exceeding 15 µg/dl equates to more than 1% of the population (e.g., 1 child ≥ 15 µg/dl divided by 90 children tested equals 1.1% greater than 15 µg/dl). Additionally, these distribution-based standards assume that the population in any community is similarly exposed to typical soil and dust lead levels. It is unlikely, with the post-remedial gsds expected, that 1% of individuals would exceed the 15 µg/dl level if the population continues to meet the 95% below 10 µg/dl criteria. As indicated in recent LHIP follow-up investigations, children exhibiting these levels are exposed to sources of lead beyond the reach of cleanup activities. However, with respect to those homes that have not met soil and dust RAOs there remains a significant probability that elevated blood lead levels, possibly exceeding the 15 μg/dl RAO, may be observed until the cleanup is completed for all residences.

6.1.2 Soil and Dust RAOs

Remediating all residential yards, commercial properties, and ROWs that have lead concentrations greater than 1,000 mg/kg lead: Table 6-2 summarizes the number of residential yards in the Box that have been remediated. Estimates for the number of homes remaining that require cleanup are also provided. About 300 properties remain to be cleaned up, mostly in the outlying communities of Ross Ranch and Elizabeth Park (included as part of Kellogg in Table 6-2), and others in Page, Wardner, and Pinehurst.

Achieving a geometric mean yard soil concentration of less than 350 mg/kg for each community in the site and no yards ≥ 1,000 mg/kg: Table 6-3a shows geometric mean soil concentrations by community as of 2002 and the associated percent decrease achieved since the High-Risk Yard program was initiated in 1989. The 350 mg/kg RAO has been achieved in all communities except Page and Wardner where the largest percentage of community properties remain to be cleaned up (Table 6-3b).

Controlling fugitive dust and stabilizing and covering contaminated soils throughout the site: Numerous efforts have been undertaken to control fugitive dust sources throughout the Box. The remaining major efforts include the hillsides re-vegetation effort, covering additional areas of the former PRP properties through development initiatives, and addressing gravel ROWs in the smaller communities. These efforts will be examined in more detail in a subsequent report.

Achieving a geometric mean interior house dust lead concentration of less than 500 mg/kg for each community in the site: Table 6-4a shows the 1988 and 2002 geometric mean house dust lead concentrations for vacuum bag samples in comparison to the 500 mg/kg RAO. Table 6-4a also indicates the percent reduction in house dust lead concentration, as measured in vacuum cleaners, achieved since 1988 for each community.

If house dust lead levels remain elevated after soil remediation is complete, homes with concentrations greater than 1,000 mg/kg will be considered for interior remediation: Table 6-4b shows the number and percent of homes tested in which concentrations exceeding 1,000 mg/kg were observed for vacuum bags. Kellogg has the largest number of homes that remain above 1,000 mg/kg. Evaluation of these data as well as the dust mat data will be accomplished in a later report that will also address the efficacy of interior cleanup protocols.

6.2 Current Centers for Disease Control (CDC) Guidelines

The strategy outlined by the Surgeon General in CDC's *Prevention of Childhood Lead Poisoning* was last updated in 1997. In that document, the CDC reiterated the 10 μg/dl criteria and issued recommendations for public health response based on blood lead levels. The Surgeon General has outlined three major areas for development of policies and activities related to childhood lead poisoning prevention. These areas are primary prevention activities, secondary prevention activities, and monitoring (surveillance). Primary prevention activities are aimed at preventing children from being exposed to lead. Recommendations include evaluation and control of residential lead-based paint hazards, public lead education, professional lead education and training, anticipatory guidance by child health-care providers, and identification, stabilization, control and remediation of sources of lead exposure other than lead-based paint (CDC 1997).

The following secondary prevention guidelines regarding child blood lead levels were also issued (adapted from CDC 1997, Table 4-3):

blood lead concentration <10 μg/dl	Re-assess or re-screen in one year. No additional action is necessary unless exposure sources change.
blood lead concentration 10-14 μg/dl	Provide family lead education. Provide follow-up testing. Refer for social services, if necessary.
blood lead concentration 15-19 μg/dl	Provide family lead education. Provide follow-up testing. Refer for social services, if necessary. If blood lead levels persist or worsen (i.e., 2 venous blood lead levels in this range at least three months apart), proceed according to actions for blood lead concentrations in the 20-44 μg/dl range.
blood lead concentration 20-44 μg/dl	Provide coordination of care (case management), clinical management, environmental investigation, and lead-hazard control.
blood lead concentration 45-69 μg/dl	Within 48 hours, begin coordination of care (case management), clinical management, environmental investigation, and lead-hazard control.
blood lead concentration ≥70 μg/dl	Hospitalize child and begin medical treatment immediately. Begin coordination of care (case management), clinical management,

environmental investigation, and lead-hazard control immediately.

6.2.1 Box and LHIP Compliance with Current CDC Guidance

Both the long-term cleanup and interim health response strategies for the Box have met or exceeded current CDC recommendations. The blood lead RAOs have been achieved through a preventative program of permanently reducing key environmental media lead concentrations. Maintenance of these criteria will sufficiently limit children's lead intake from soils/dusts to prevent excess absorption from these sources in the future. These environmental criteria were developed through site-specific analysis of dose-response relationships relating observed blood lead levels to soil/dust exposures. Blood lead levels have decreased consistently with the underlying dose-response relationships throughout the cleanup.

The LHIP response protocols are consistent with and exceed the CDC's secondary response and surveillance recommendations. School, community, and health care provider education and awareness programs have been conducted routinely throughout the cleanup. Home visits were provided as follow-up to all children with levels of 10 μg/dl, or greater, exceeding the CDC recommendation. Through 2002, monitoring and surveillance was solicited community-wide through door-to-door contact. Comparisons of the survey participants with school records indicated that more than 80% of all parents were contacted each year. More than 50% of all children in the Box were tested annually and about half of those were new to the program each year.

6.2.2 Modifications to the LHIP

In the summer of 2003, the LHIP surveillance protocol was modified. No door-to-door survey was conducted and payment for children's participation was no longer offered. The rationale for this decision was six-fold:

i. The incidence of excess absorption was sufficiently low ($<3\%$) that more efficient targeting strategies for at-risk children could be developed.

ii. The blood lead RAOs had been achieved and concentrations and percent of children above the 10 μg/dl criteria were consistent with typical levels in similar national socioeconomic strata.

iii. The blood lead absorption response of the population to declining environmental media concentrations was consistent with the dose-response relationships underlying the cleanup strategy throughout the remedial action phase.

iv. Most of the Box has achieved the environmental cleanup criteria and the population most at-risk could alternatively be identified through other risk-based indices.

v. Community concern and participation has waned as blood lead levels continue to meet RAOs and community expectations.

vi. Blood lead screening has been historically funded by ATSDR, which currently is reducing the funds allocated for the site.

The incidence of elevated blood lead levels among children tested had been below the RAO for two consecutive years. Blood lead levels were consistent with the intake estimates and dose-response relationships used to determine the Box cleanup criteria. Most of the homes and communities in the Box meet those criteria. As a result, the incidence of blood lead levels exceeding health criteria estimated by biokinetic modeling (Box Model) indicates compliance with RAOs for those areas of the site at or near completion of remedial activities. About 4% of children site-wide remain on contaminated yards, mostly in the smaller residential communities yet to be remediated. The ***High-Risk Yard Cleanup*** remains in place to address these homes as identified. Additionally the Non-Populated Areas cleanup was largely completed in 2001 and dust lead exposures have decreased significantly. In 2002, house dust geometric means decreased to below the RAO.

Screening of the population in 2001-2002 demonstrated the prevalence of lead poisoning among the population was near the national rate of 2-3% exceeding the 10 μg/dl health criteria. The 1999 Five Year Review concluded that the participation rate among families in the Box was sufficient to assess compliance with the blood lead RAO. Approximately three-fourths of children residing in the Box were identified in door-to-door screening and 50% overall were providing blood samples.

Although a substantial portion of the overall population continued to participate in the survey, refusal rates increased in recent years as blood lead levels decreased. The majority of parents that were not participating believed their children had low blood lead levels, most because of previous testing or they thought the program was no longer necessary. Additionally, private physicians throughout the State are now being reimbursed through Medicaid for blood lead testing for socioeconomically disadvantaged children and are required to report high levels to the Health Department. These factors suggest that few children with potentially high blood lead levels were missed in the surveys and that the prevalence rates were representative or biased high.

In 2001 and 2002, 322 and 368 children, respectively, provided blood samples. This is compared to an average 351 children in the previous four years. Records obtained from the local school district indicate that K-5 enrollments are down about 6% for the same period indicating that LHIP participation remained at about the same level in 2001-2002. This suggests that an estimated 685 children, age 9-month to 9-years, living in the Box at the time. Approximately, 54% of these children were tested and 2% of those tested were found with elevated blood lead levels. Follow-up visits were conducted at the homes of these children and the results indicated that their excess absorption was likely associated with exposures outside of the home environment (See Section 4).

In 2003, following cessation of the door-to-door solicitation and incentive payments, only eight children opted for testing in the Box. All were tested by capillary finger-stick. Two of these children were confirmed by venous follow-up that had blood lead levels of 10 μg/dl or greater. The highest level reported was 11 μg/dl.

6.3 U.S. Environmental Protection Agency Policy Regarding Children's Blood Lead Levels

6.3.1 Current USEPA Guidance

At lead contaminated residential sites, USEPA seeks assurance that the health of the most susceptible population (children and women of child bearing age) is protected and promotes a program that proactively assesses and prevents unacceptable exposures to lead. USEPA believes that predictive tools should be used to evaluate the risk of lead exposure, and that cleanup actions should be designed to address both current and potential future risk. For this reason, cleanup decisions can be made on IEUBK predicted blood lead levels alone. Blood lead monitoring provides useful and complementary data to Model results. Blood lead monitoring data is invaluable to initiate treatment and intervention for children with elevated lead levels, but is of limited use in developing remedial action criteria (USEPA 1994b, USEPA 1998). USEPA policy is available online at the following locations.

- http://www.epa.gov/superfund/programs/lead/products/oswer98.pdf
- http://www.epa.gov/superfund/programs/lead/products/oswerdir.pdf

To meet these objectives, USEPA seeks actions that limit exposure to soil lead levels such that a typical child or group of similarly exposed children would have an estimated risk of no more than 5% exceeding a blood lead level of 10 μg/dl. USEPA emphasizes the use of the IEUBK Model for estimating risks for childhood lead exposure from a number of media, such as soils, dust, air, water, and other sources to predict blood lead levels in children 6 months through 84 months old. USEPA recommends that the IEUBK Model be used as the primary tool to generate risk-based soil cleanup levels at lead sites for current or future residential land use. Response actions can be taken using IEUBK Model predictions alone; blood lead studies are not required.

Blood lead studies and surveys are useful tools at lead sites and can be used to identify key site-specific exposure pathways and to direct health professionals to individuals needing immediate assistance in minimizing lead exposure; however, USEPA recommends that blood lead studies not be used for establishing long-term remedial or non-time-critical removal cleanup levels at lead sites.

It is recommended that risk assessments conducted at lead-contaminated residential sites use the individual residence as the primary exposure unit of concern. This does not mean that a risk assessment should be conducted for every home yard, rather that the soil lead concentration data from yards and other residential media (for example, interior dust and drinking water) should be input into the IEUBK Model to provide a preliminary remediation goal (PRG) for the residential setting. When applicable, potential exposure to accessible site-related lead sources outside the residential setting should also be evaluated to understand how these other potential exposures contribute to the overall risk to children, and to suggest appropriate cleanup measures for those areas (USEPA 1998).

6.3.2 Box Compliance with Current USEPA Guidance

The selected remedy in the 1991 ROD includes a community blood lead RAO of no more than 5% of children in each community exhibiting a blood lead level greater than 10 μg/dl and less than 1% exhibiting a blood lead of 15 μg/dl or greater. This approach was consistent with USEPA national policy at that time (USEPA 1989). That policy was replaced by the 1994 and 1998 USEPA lead directives discussed above (USEPA 1994b, USEPA 1998). In the clarification, USEPA recommends that the individual residence be used as the primary unit of concern for evaluating potential risk at lead contaminated residential sites. The directives state that cleanup actions should be designed to address both current and potential future risk, and that actions should be taken to limit exposure to soil lead levels such that a typical child or group of similarly exposed children would have an estimated risk of no more than 5% of exceeding a 10 μg/dl blood lead level.

Key distinctions between the Box RAOs and current USEPA lead policies are:

- Protection against the risk of an elevated blood lead to an individual at the 10 μg/dl level (instead of 15 μg/dl in the Box);
- Focus prevention efforts and risk criteria on younger children (6 to 84 months of age instead of up to 9 years);
- The percentage of children exceeding 10 μg/dl can be estimated from blood lead surveys in the Box, as participation rates exceed 50% and reasons for failure to participate are known for the majority of the remaining resident children (TerraGraphics 2000b).

These differences were discussed in the 1999 Five Year Review for the site and it was concluded that the selected remedy was sufficiently protective and did not require modification to meet the new criteria (USEPA 2000). The 2001-2002 LHIP results confirm that conclusion. These results show that 2-3% of tested children have blood lead levels exceeding the 10 μg/dl criteria. Mean blood lead levels are 2-3 μg/dl, with more than 80% of children tested now showing blood lead levels of <5 μg/dl. Analysis of the distribution of both blood lead levels and soil and dust exposures suggest that post-remedial gsds are stabilizing at levels that suggest the new policy criteria may be achieved. Follow-up results on those children that have been observed to have high blood lead levels in recent years show exposure to sources other than residential soils and house dust.

As a result, it is unlikely that exposure to residential soils in the post-remedial environment will result in excessive risk levels under either the 1991 or 1998 policies.

However, there may be other sources such as lead paint in particular households or in recreational activities in contaminated areas that could result in higher absorption rates for individual children.

These results are based on review and analysis of the LHIP blood lead screening database. The 1994 and 1998 National USEPA guidance recommends evaluation of blood lead data in assessing health risks at a site. However, USEPA is specific in not recommending that these data be used alone when quantifying risk or developing soil lead cleanup levels. The guidance recognizes that blood lead levels below 10 μg/dl are not necessarily evidence that a potential for significant lead exposure does not exist or that such potential could not occur in the future. The guidance recommends using the IEUBK model to project risk probabilities. The IEUBK Box model suggests that the 1991 community-wide criteria will be met. The risk of exceeding the 1994 guidance (5% probability at any home), however, will not be achieved at homes where both soil and house dust lead levels exceed 500 mg/kg lead. The number of homes that will exceed these levels in the post-remedial environment is unknown.

Different opinions have been expressed regarding potential selection bias in the annual screening results. One argument suggests the incidence of elevated blood lead levels is biased low because families who participated were more likely to be attentive to lead health concerns and were more likely to have benefited from the LHIP's assistance in helping parents reduce exposures in the home. A counter argument suggests the incidence of elevated blood lead levels is biased high because the financial incentives for participation favored economically-disadvantaged families, and poverty is generally associated with higher than average blood lead levels.

Analysis presented in the 1999 Five Year Review and updated in Section 4, indicates that about 50% of the population participated each year and that about half of those children were tested for the first time. Interviews of those that chose not to participate suggested that many parents felt their children's blood lead levels would be low. Reasons for this belief included previous testing of the child or siblings, confidence that the exposures were low for their children, knowledge of the status of the cleanup, belief that the testing was unnecessary, or that they were new to the area or would soon be moving. As a result, it was concluded in the 1999 Five Year Review that observed blood lead levels are more likely biased high and the database was sufficient to assess compliance with the RAO.

However, the surveys were not designed to make statistical inferences. As a result, IEUBK modeling was also used to estimate the prevalence of blood lead levels exceeding RAO criteria. That analysis, accomplished in Section 5, shows that the Box Model, utilizing reduced bioavailablity estimates for soil and dust sources, showed agreement with observed blood lead levels for the tested population. The Bunker Hill Box data spanned 15 years, included more than 5,000 paired blood and environmental results, and have represented more than 50% of all children residing in the Box during every year, since 1988. It is important to note that this relationship has held for more than a decade throughout the evolving cleanup for this highly mobile population.

As a result, the Box Model has continued to be applicable through a range of exposures, blood lead levels, and any temporal or geographic selection bias introduced by the participants. Examination of the soil and dust exposure database shows little difference among exposure profiles for the community-wide database and participant residences. The Bunker Hill Box database is large enough and sufficiently representative of environmental conditions and characteristics of the exposed population to provide a sound basis for assessing compliance with the RAOs. Both observed blood lead levels and projected risk probabilities using the Box Model support these findings.

6.3.3 Potential for Modification of the Risk Management Strategy

A follow-up report will review the environmental components, focusing on the ROW recontamination and house dust controls. That report will also address the need for additional remediation associated with interior house dust lead concentrations and loadings. A separate follow-up report will evaluate the long-term effectiveness and the prognosis for sustained compliance as related to the Institutional Controls Program (ICP), future economic development, and infrastructure needs in the Box Communities.

Table 6-1a
Percent of Children Exceeding the 10 µg/dl Blood Lead Level
Remedial Action Objective (RAO) by City
(number of children)

City	1988	2002	RAO
Kellogg[a]	41% (70)	2% (4)	<5%
Page	58% (7)	0% (0)	<5%
Pinehurst	29% (31)[b]	3% (3)	<5%
Smelterville	72% (23)	0% (0)	<5%
Wardner	33% (5)	0% (0)	<5%

[a] Kellogg includes outlying communities such as Elizabeth Park, Montgomery Gulch, and Ross Ranch.

[b] 1990 data used because 1988 data were not collected for Pinehurst.

Table 6-1b
Percent of Children Exceeding the 15 µg/dl Blood Lead Level
Remedial Action Objective (RAO) by City
(number of children)

City	1988	2002	RAO
Kellogg[a]	13% (22)	1% (2)	<1%
Page	17% (2)	0% (0)	<1%
Pinehurst	5% (5)[b]	1% (1)	<1%
Smelterville	31% (10)	0% (0)	<1%
Wardner	7% (1)	0% (0)	<1%

[a] Kellogg includes outlying communities such as Elizabeth Park, Montgomery Gulch, and Ross Ranch.

[b] 1990 data used because 1988 data were not collected for Pinehurst.

Table 6-2
Percent of Yards Remediated, and Estimated Number of Yards Remaining to be Remediated (number of yards)

City	1988 Remediated	2002 Remediated Total[b]	Estimated Number of Remaining Yards[b]
Kellogg[a]	0% (0)	89% (996)	117
Page	0% (0)	48% (20)	22
Pinehurst	0% (0)	87% (180)	28
Smelterville	0% (0)	100% (331)	0
Wardner	0% (0)	31% (57)	124
Site-wide	0% (0)	84% (1584)	293

[a] Kellogg includes outlying communities such as Elizabeth Park, Montgomery Gulch, and Ross Ranch.

[b] These numbers are estimated from the PRP soil database for residential yards only.

Table 6-3a
Observed Decrease in Geometric Mean Yard Soil Lead Concentrations by City (mg/kg)

City	1988	2002	Percent Decrease	RAO
Kellogg[a]	2112	209	90%	350
Page	741	363	51%	350
Pinehurst	431	274	36%	350
Smelterville	2336	122	95%	350
Wardner	1529	497	67%	350

[a] Kellogg includes outlying communities such as Elizabeth Park, Montgomery Gulch, and Ross Ranch.

Table 6-3b
Percentage and Number of Yards = 1000 mg/kg Soil Lead Concentration by City

City	1989 [Percentage (Number)]	2002 [Percentage (Number)]	RAO (Number of Homes)
Kellogg[a]	74% (1113)	17% (256)	0
Page	56% (42)	29% (22)	0
Pinehurst	22% (208)	3% (30)	0
Smelterville	81% (333)	0% (0)	0
Wardner	122% (181)	86% (127)	0

[a] Kellogg includes outlying communities such as Elizabeth Park, Montgomery Gulch, and Ross Ranch.

Table 6-4a
Observed Decrease in Geometric Mean Vacuum Dust Lead Concentrations by City (mg/kg)

City	1988	2002	Percent Decrease	RAO
Kellogg	1648	435	74%	500
Page	597	285	52%	500
Pinehurst	739*	211	71%	500
Smelterville	1212	350	71%	500
Wardner	728	469	36%	500

* 1990 data used since this was the first year dust data were available for Pinehurst

Table 6-4b
Percentage and Number of Homes = 1000 mg/kg Vacuum Dust Lead Concentration by City

City	1988 [Percentage (Number)]	2002 [Percentage (Number)]	RAO (Number of Homes)
Kellogg	77% (37)	14% (11)	0
Page	67% (4)	0% (0)	0
Pinehurst	23% (10)*	5% (1)	0
Smelterville	59% (10)	9% (2)	0
Wardner	33% (1)	0% (0)	0

* 1990 data used because 1988 data were not collected for Pinehurst

SECTION 7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

The primary human health goal of the Bunker Hill Superfund Site Project has been to reduce children's blood lead concentrations to levels consistent with national health initiatives. That effort predated CERCLA, commencing in 1974 following a severe epidemic of childhood lead poisoning in the Silver Valley. The goal was formalized in the 1991 Populated Areas ROD as Remedial Action Objectives (RAOs) for outcome blood lead levels in the several communities within the Box. A cleanup plan was adopted to permanently reduce children's intake of lead from soil and dust sources to levels sufficient to ensure that no more than 5% of the children in any community exhibited blood lead levels of 10 μg/dl or greater, with no child 15 μg/dl or higher.

The strategy to achieve the blood lead goals was to undertake soil and waste removals and capping and stabilization efforts throughout the site that, in turn, would effect reductions in house dust lead to near post-remedial soil concentrations. In combination, these efforts would reduce children's lead intake from soils and dusts to sufficiently low levels to guarantee the blood lead objectives. In the Populated Areas, the soil and dust RAOs included remediation of all yards, commercial properties, and ROWs with lead concentrations greater than 1,000 mg/kg; achieving a geometric mean yard soil lead concentration of less than 350 mg/kg for each community in the site; controlling fugitive dust and stabilizing and covering contaminated soils throughout the site; and achieving geometric mean interior house dust lead levels for each community of 500 mg/kg or less, with no individual house dust level exceeding 1,000 mg/kg.

The cleanup strategy was the first designed and implemented using the IEUBK model for lead. The IEUBK was used to develop site-specific parameters for soil and dust ingestion rates and bioavailability. This was accomplished by relating observed blood lead levels, obtained in the interim Lead Health Intervention Program (LHIP), to environmental media exposure measurements collected in follow-up of high blood lead children and Superfund Remedial Investigation (RI) studies.

Interim and final cleanup activities have been ongoing under CERCLA for nearly twenty years. Nearly all children in the Box were lead toxic in 1974 and 1975. More than 60-80% reductions in lead absorption were achieved in the course of this cleanup. Blood lead goals were reached in 2001-2002. The incidence of lead poisoning has been reduced from near 60% in 1989 to 2% of children age 9 months to 9 years. Ongoing analysis of the declining environmental media concentrations, estimated lead intake rates and blood lead response confirm the predictions made in developing the cleanup strategy and the efficacy of IEUBK in developing, implementing and evaluating the remedy.

These blood lead reductions are the result of a number of initiatives to reduce lead exposures in the total environment. Some decline is due to national efforts to reduce lead in the diet and a variety of consumer goods, including gasoline. Blood lead levels are estimated to have decreased about 1.6 μg/dl in the rural U.S. from 1988 to 1999 as a result of these activities (See Table 5-2). The national decline has helped to reduce absorption for children on this site. However, the major reductions in blood lead levels achieved within the Box are attributable to actions undertaken by the LHIP and community residents to minimize exposures, and to improved environmental conditions resulting from smelter closure and CERCLA remedial efforts.

Quantifying the effect of any specific action at this site is difficult. Lead is ubiquitous in the Silver Valley environment and is presented to children in a variety of media and pathways. The overall risk management program for the site has been an integrated effort to minimize lead intake and uptake through several mechanisms. The blood lead reductions that have been achieved since smelter closure are the aggregate effect of several activities, including:

- The ***Lead Health Intervention Program*** that promotes awareness among area parents and children (1985 to present) through education, biological monitoring, and follow-up counseling.
- The ***Fast-Track Common Use Areas (CUA) Cleanup*** program that removed contaminated soils from public parks, playgrounds, and roadsides (1986).
- ***Interim Fugitive Dust Control*** efforts to mitigate outdoor sources of dust lead particulate (1987 and 1990-93).
- The ***High-Risk Yard Cleanup*** program that replaced contaminated soils in home yards of young children throughout the site (1989-today).
- The ***Geographic Areas Cleanup*** program that replaced contaminated soils within neighborhoods.
- The ***Records of Decision (RODs)*** cleanup activities conducted under the Non-Populated Areas RODs.
- The ***Institutional Controls Program's (ICP)*** management of installed barriers.

The progress in achieving significant blood lead reductions came in increments associated with particular cleanup activities. The cumulative effects of these program initiatives can be discussed in six general eras of the project. Table 7-1 summarizes key indices of remedial progress for each era. The dates and values in Table 7-1 correspond to the end of each era.

> **1985-87:** This era represents the introduction of the LHIP and CUA cleanup. During this time, EP screening and health intervention efforts were introduced, and Fast-Track removals at CUAs and roadsides and temporary dust control efforts were undertaken. By 1988, lead absorption had decreased by about 40%

from 1983 levels near 20 µg/dl to 10 µg/dl arithmetic mean. The incidence of children with blood lead levels exceeding 25 µg/dl dropped from >25% to <2%.

1988-89: This era represents pre-remedial conditions prior to undertaking residential cleanup activities. During this period, the intervention program adopted venous blood lead rather than capillary EP screening and increased the number of children being tested. Few source control activities occurred in these years. The High-risk Yard Cleanup commenced in 1989; however, the benefits of these exposure reductions were not observed until the next year.

Substantial in-migration to Kellogg was noted from 1988 to1989, with the percentage of the children living at their reported address less than six months increasing from 20% to 28% of the population. The total number of children tested also increased by 24%. The majority of children reported at new addresses in 1989 moved into homes with yard soil concentrations greater than the action level of 1,000 mg/kg lead. This factor actually increased the number of children at-risk in the community. Arithmetic mean blood lead levels increased by about 1.5 µg/dl from 1988 to 1989 (8.5 to 9.9 µg/dl) site-wide and the percent of children with levels of 10 µg/dl or greater increased from 46% to 56% of children site-wide. The estimated site-wide geometric mean lead intake from soil and dust was 188 µg/day in 1989.

1990-93: In this period the benefits of the High-Risk Yard Cleanup became evident in 1990. About 500 high-risk homes were remediated from 1989 to 1993. The percentage of children living on contaminated yards was reduced from more than 80% site-wide to 43% in 1990 and 25% by 1991. Mean blood lead concentrations decreased significantly in 1990 and 1991 to levels 35% lower than 1989 and the site-wide incidence of blood lead levels greater than or equal to 10 µg/dl was 15% by 1991. Pinehurst was added to the survey in 1990, and the intervention follow-up blood lead level was reduced to 20 µg/dl in 1991. Arithmetic mean blood lead levels in 1991 were 6.6 µg/dl in Smelterville, 6.9 µg/dl in Kellogg, and 5.1 µg/dl in Pinehurst. Approximately 23% of children had blood lead levels equal to or exceeding 10 µg/dl in Smelterville; 19% in Kellogg, Wardner, and Page; and 5% in Pinehurst.

In 1992, a second substantial increase in in-migration to the site occurred due to housing shortages in adjacent counties. The number of children living on contaminated yards increased despite an additional 84 yards at homes to children being remediated in the previous year. Mean blood lead levels increased by about 1.0-1.5 µg/dl across the site, and the percentage of children with 10 µg/dl blood lead or greater increased to 31% in Smelterville, 32% in Kellogg, and 18% in Pinehurst. Several children were identified in follow-up activities as being new to the area in 1992, and their parents were unaware of the lead hazards. Counseling, follow-up, and remediation of their home yards resulted in an average 60% (or 12 µg/dl) decrease in these children's blood lead levels within 6 months.

In 1993, the trend in in-migration eased, and 19% of children were reported on contaminated yards. Blood lead levels had decreased to slightly below 1991 values with 20% of children in Smelterville, 18% of Kellogg, and 5% of Pinehurst children exhibiting absorption greater than or equal to 10 µg/dl. site-wide geometric mean blood lead levels decreased from 9.9 µg/dl to 4.4 µg/dl and estimated soil/dust lead intake from 188 µg/day to 69 µg/day during this period.

1994-96: During this era, little progress in reducing overall yard soil exposures was achieved, despite the remediation of an additional 476 homes. In 1993, only 39 homes were cleaned up due to delays in PRP negotiations. This was followed by another increase in in-migration to the site. By 1995, these factors resulted in 29% of children site-wide living on contaminated yards, as compared to 19% in 1993. During 1995, 102 children tested were living on contaminated yards, the most since 1990. As a result, there were only modest changes in the population-wide exposure profiles, especially with respect to yard soils in Kellogg.

Community-wide soils and house dust lead concentrations continued to decrease slowly with the progressing cleanup activities. Some progress was noted in 1996, with the geographic areas remediation being practically completed in Smelterville. Gradual declines in the incidence of toxicity were achieved, as both Smelterville and site-wide levels reached 12%, the lowest achieved to date. Arithmetic mean blood leads were 6.4 µg/dl for both Smelterville and Kellogg, and 4.1 µg/dl for and Pinehurst. Site-wide geometric mean blood lead levels, however, remained unchanged at 4.4 µg/dl to 4.7 µg/dl throughout the period. The percentage of children on contaminated yards (High-Risk homes) decreased to 27% in Kellogg, and a total of eight children in the remainder of the site. Estimated soil/dust lead intake decreased modestly from 69 µg/day to 52 µg/day during this period.

1997-2000: This era included the most intensive period of cleanup activity in the Box. The geographic areas cleanup, coupled with the cumulative effect of the High-Risk Yard Cleanup, provided progressively more clean homes and neighborhoods for children throughout the Box. Nearly five hundred residential yards and several substantial geographic areas were remediated during this period. This was reflected in the percentage of children participating in the LHIP that lived in High-Risk homes. By 1997, the percentage of children on contaminated yards was reduced to 9%, to 4% in 1998, 5% in 1999 and 3% in 2000.

In addition to the remedial activities ongoing in the Populated Areas, the smelter complex was demolished and the smelter area landfill was capped and closed. Nearly 2 million cubic yards of highly contaminated tailings were removed from the Smelterville Flats and disposed of in the Central Impoundment Area (CIA). Other large construction projects outside of Superfund were also underway, including the Milo Creek Flood Control Project and resurfacing of streets throughout the site. Construction of a new elementary school and government office complex was accomplished in an area that had formerly been a major fugitive source. Working closely with the ICP, these projects resulted in large areas of the site being capped and stabilized.

By 2000, community-mean soil and dust RAOs had been achieved for most of the Box and the percent of children in High-Risk situations was <5%. Geometric mean house dust lead exposures, that had remained in the 500-600 mg/kg range for several years, decreased significantly to 425 mg/kg in 2000. The decrease resulted in estimated site-wide lead intake from soils and dust at 34 μg/day, down from 52 μg/day in 1996. This was accompanied by a 25% site-wide geometric mean blood lead decrease from 4.7 μg/dl to 3.5 μg/dl. In 2000, 5% of children tested exceeded the 10 μg/dl criteria, down from 12% in 1996.

2001-2002: During this period the USACE began supplementing the PRP home yard remedial program in the Populated Areas. Over 50 yards were remediated and 6% of children remained in High-Risk homes by 2001. The Smelterville Flats were capped in 2000 and the CIA was closed with a clean soil cap in 2001. These projects, combined with the revegetation efforts on the hillsides and the Milo Creek Flood Control Project finally eliminated these major sources of fugitive dust to the Populated Areas. With these actions and the curtailment of construction activities throughout the Non-Populated Areas, a notable decrease in house dust lead levels was observed. Site-wide geometric mean house dust exposure decreased an additional 35% from 425 mg/kg to 279 mg/kg. This resulted in the estimated geometric mean soil/dust lead intake dropping from 34 μg/day to 26 μg/day. This was accompanied by another 33% reduction in mean blood lead levels from 3.5 μg/dl to 2.6 μg/dl. The prevalence of blood lead levels exceeding the 10 μg/dl criteria dropped to 2%.

7.2 Conclusions

The remedial strategy has been successful in achieving the blood lead RAOs. Of those children tested in the past couple years, about 2-3% of children site-wide have blood lead levels of 10 μg/dl, or greater. Less than 1% of children have levels of 15 μg/dl, or greater. The RAOs were achieved by reducing soil and dust lead concentrations to levels that limited estimated mean soil and dust lead intakes for children to 25 μg/day-35 μg/day.

Successfully implementing the strategy required a comprehensive approach to reducing soil lead exposures throughout the community. The primary soil and fugitive dust sources included residential home yards, common use areas, roadside ROWs, commercial properties, hillsides, river floodplain, industrial complex and waste material piles and impoundments. These remedial actions simultaneously effected reductions in soil exposure and reduced soil source contribution to house dust lead concentrations. Reduction of house dust lead to concentrations similar to post-remedial soil levels was requisite to meeting the blood lead RAOs.

There was a substantial decrease in the number children at-risk following the introduction of the ***LHIP*** and ***CUA-Fast-track Cleanup*** in 1985-86. The incidence of children with blood lead levels exceeding 25 μg/dl decreased from greater than 25% to 2%.

Insufficient blood lead data are available from 1983 to1988 to assess dose-response relationships, as EP screening was utilized during this time. Since 1988, there has been sufficient participation in the LHIP throughout the remedial action to assess both representative blood lead levels for the childhood population and the dose-response relationship with soil and dust lead sources.

Substantial decreases in overall absorption levels have been achieved since 1989. Geometric mean blood lead levels decreased by about 75% from near 10 μg/dl in 1989 to 2.6 μg/dl in 2002. About 1.6 μg/dl of the decrease may be attributable to national initiatives to reduce lead exposure in the consumer environment. The remaining decreases occurred incrementally in association with major remedial initiatives implemented in the Box.

The remedial strategy was successful in reducing soil media lead concentrations to target concentrations in areas where work has been completed. About an 85% reduction in soil lead concentrations has been achieved since 1989. Soil cleanup activities remain to be completed in several areas of the Box.

The reduction in soil lead concentrations and elimination of fugitive dust and tracking sources throughout the Box has resulted in substantial reductions in house dust lead levels. Dust lead levels have been reduced by about 75% to a geometric mean concentration of about 370 mg/kg for the Box in 2002. This concentration is near 200 mg/kg lead background levels measured in similarly aged housing and socioeconomically situated communities in northern Idaho outside the mining district. No systematic effort was made to reduce paint exposure in the Box and this may be contributing to the few cases of high dust lead levels observed. Approximately 10% of homes continue to show house dust levels exceeding 1,000 mg/kg lead.

Blood lead levels have decreased consistently with estimated lead intake rates determined from soil and dust lead media concentrations. More than a 50% reduction in blood lead levels and estimated soil/dust lead intake was achieved with the ***High-Risk Yard Cleanup*** in 1989-93. This action reduced the percentage of children in the Box living in homes with contaminated yards from 83% to 19%.

No significant change in blood lead levels or the percentage of children with high blood lead levels was achieved between 1993 and 1996. This was due to a hiatus in the High-Risk Yard Cleanup in 1993, and the in-migration of families moving to contaminated properties in the Box. From 30% to 50% of the families moving to new residences in this period located in homes with contaminated yards. The cycle of new families moving to contaminated homes was broken in 1997, when the ***Geographic Areas Cleanup*** provided a progressively larger inventory of clean homes for new residents. By 1997, 19% of new families moved to contaminated residences and since then, 4% to 12% of families have relocated to contaminated properties.

The majority of remedial activities undertaken pursuant to both the ***Populated and Non-Populated Areas RODs*** were accomplished between 1997 and 2000. During this time, substantial reduction in soil exposures resulted in about a 30% decrease in blood lead levels and estimated soil/dust lead intake. However, dust lead concentrations remained stable at 500-600 mg/kg from 1996-1999. Substantial decreases of about 35% were noted in both dust lead exposures and blood lead levels in 2001-2002. This culminated in blood lead levels that meet the Box RAOs and values near those reported nationally and for communities with similar socioeconomic characteristics.

The dose-response relationship used to develop the cleanup criteria for the Box has remained consistent throughout the cleanup. The increase in blood lead levels per unit of soil/dust lead is about 60% of that estimated by default conditions in the USEPA IEUBK model for lead. The site-specific IEUBK (Box) model using 18% absolute bioavailability (as opposed to the 30% default value) has effectively predicted mean blood lead levels and the percent of children tested to exceed the 10µg/dl health criteria throughout the cleanup.

7.3 Recommendations

Recommendations for future activities in the Box with respect to the LHIP and remedial actions are as follows.

- Continue the Lead Health Intervention Program under the modified 2003 format until completion of the Geographic Areas Cleanup.
- Continue the High-Risk Yard Cleanup Program until completion of the Geographic Areas Cleanup.
- Complete the Populated Areas Geographic Cleanup as quickly as practicable.
- Assess the effectiveness of alternate targeting methods for identifying children with potentially high blood lead levels (other childhood public health programs).
- Assess the sustainability of the soil and dust RAOs.

Table 7-1
Indices of Remedial Progress
(Site-wide Geometric Means at the End of Each Era)

	Blood Lead Levels			Soil/Dust Mean Exposure					Remediation	
Era	Geometric Mean (µg/dl)	Percent = 10 µg/dl	Percent = 15 µg/dl	Yard Soil (mg/kg)	Community (mg/kg)	Neighborhood (mg/kg)	House Dust (mg/kg)	Total Intake (mg/day)	Number of Yards Remediated	% of Children on Contaminated Yards
1988-1989	9.9	56%	26%	2069	1251	2235	1383	188	90	83
1990-1993	4.4	15%	2%	268	724	830	720	69	433	19
1994-1996	4.7	12%	3%	234	470	636	526	52	919	19
1997-2000	3.5	5%	2%	168	242	311	425	34	1387	3
2001-2002	2.6	2%	1%	151	222	267	279	26	1584	4

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Appendix A
Memorandum of 2001 Blood Lead Survey Method Changes

TerraGraphics ENVIRONMENTAL ENGINEERING, INC.

M E M O R A N D U M

TO: Rob Hanson, Project Manager, IDEQ
Jerry Cobb, Senior Environmental Health Specialist, PHD
Elke Shaw-Tulloch, Bureau Chief of Community and Environmental Health, Idaho Division of Health

FROM: Susan Spalinger, Project Scientist, TerraGraphics

DATE: October 14, 2003

SUBJECT: 2001 Blood Lead Screening Methodology Comparison

Purpose: The Idaho Department of Health and Welfare, Division of Health significantly modified the 2001 blood lead screening protocol for the Lead Health Intervention Program (LHIP). The Panhandle Health District (PHD) has conducted the LHIP each summer since 1985 to identify children residing in the Box with high blood lead levels and to provide follow-up services to the families involved. The purpose of this memorandum is to summarize the screening modifications, compare the screening techniques, and provide recommendations for future use of the screening methods. The draft memorandum, dated December 21, 2001, was reviewed by the Lead Remediation and Review Group (LRRG). This is the final memorandum which reflects the LRRG's comments.

Blood Lead Screening Methodology Summary: In the past, blood lead samples have been drawn intravenously and analyzed by ESA Laboratories by graphite furnace atomic absorption spectrometry (GFAAS). In 2001, a new machine was purchased to analyze capillary blood lead samples by finger puncture. The LeadCare® System uses an electrochemical test method with disposable sensors. It is effective for blood lead levels between 1.4 µg/dl to 65 µg/dl for both venous and capillary samples (Zink et al.).

A summary of the procedures used in 2001 LHIP are outlined below.

1. $20.00 cash incentive for participants that live:
   a) within the Bunker Hill Box and are between 6 months and 9 years of age, or
   b) within the CDA River Basin and are between 6 months and 6 years of age.

   (Note: ATSDR funds the screening of the 0-6 year olds in both the Box and the Basin. The State of Idaho Trust provides funding for the 7-9 year olds in the Box.)

2. A screening blood test was done by skin puncture (capillary or finger stick (FS)).
3. Capillary blood samples were collected in a lead-free ESA capillary tube and analyzed immediately using the LeadCare® System.
4. Results of the capillary test were provided to the participant or parent immediately after analysis.
5. Venous samples were collected in 2 lead-free vacutainer tubes (one tube was analyzed using the LeadCare® System and the second was sent to ESA Laboratory for analysis) (Note: ESA Laboratory analysis has been the method used in the past).
6. A quality control program was initiated with the new LeadCare® System.
   a) Venous samples were collected on all children with a LeadCare® FS level $\geq$ 8 µg/dl, and
   b) Venous samples were collected on every tenth child in the Box for confirmation on levels below 8 µg/dl.

Although not a change in the procedures, follow-up activities were conducted for all children with a blood lead level $\geq$ 10 µg/dl. A complete description of PHD's policies and procedures effective March 1, 2001 is contained in the attachment following all tables and figures.

Screening Methodology Comparison: Because of guidelines established for quality control measures, some children had up to three blood lead measurements: LeadCare® finger stick (FS), LeadCare® venous, and ESA venous. Correlations and regressions were performed on the paired data to examine the relationships among the three screening methodologies. In order to determine if a difference exists between the three methods, a Hotelling's T^2 statistic was also performed (Johnson 1998).

For the purposes of comparing the screening methodologies, the CDA River Basin data were combined with the Bunker Hill Box data. Table 1 summarizes the paired data subset (of the 2001 database) for all three blood lead measurements. The minimum detection limit for the LeadCare® System is 1.4 µg/dl, while the minimum detection limit for the ESA lab is 1.0 µg/dl. The maximum blood lead level detected was 20.0 µg/dl with the FS method; however, both venous samples for that child reported less than 20.0 µg/dl. The ESA venous method reports higher average levels than the LeadCare® FS, while the FS reports higher average levels than the LeadCare® venous (Table 1). As observed in Figure 1a, one outlier was identified in the paired data. This outlier was believed to be a contamination problem with the FS method; the FS reported a blood lead level near 15 µg/dl, however, both venous samples were less than 3 µg/dl. Figures 1b-1d show 2-dimensional scatter plots of the three methods.

Table 2 presents the regression and correlation information performed by the manufacturer of the LeadCare® System as well as the data collected by the PHD blood lead program. In both cases, all blood lead levels below the detection limit were excluded from the analyses. The makers of the LeadCare® System report high correlations (R=0.94-0.97); however, most of their data ranged from 1.6 µg/dl to 44.6 µg/dl, while the majority of the PHD data is less than 10 µg/dl (Zink et al.). After examining the scatter plots provided by Zink et al. (for the LeadCare® Analyzer), data points below 10 µg/dl tend to show lower levels for the LeadCare® venous data compared to the GFAAS and 3010B Lead Analyzer lead levels. The PHD LeadCare® venous versus the ESA venous data showed similar regression and correlation results (R=0.94) compared to the data analyzed by the makers of the LeadCare® System. The LeadCare® FS versus the LeadCare® venous data resulted in a correlation of 0.74, while the LeadCare® FS versus ESA venous data resulted in a correlation of 0.84. Although, the regression was not as strong for the LeadCare® venous to the LeadCare® FS data (R^2=0.55).

The Hoteling=s T^2 test reported a significant difference between the three blood lead sampling methodologies (p=0.03). By examining Figure 2, the main difference is observed between the ESA venous and LeadCare® venous data. The ESA venous results tended to report higher blood lead levels than the LeadCare® venous by an average of 0.8 µg/dl. Virtually no difference is detected between the LeadCare® FS and the ESA venous (0.1 µg/dl). However, there is a marginal difference between the LeadCare® venous and FS, with LeadCare® venous results reporting lower blood lead levels than FS by an average of 0.7 µg/dl.

Partitioning the data using the quality control cutoff of a FS level at 8.0 µg/dl, shows that the LeadCare® venous method reports lower blood lead levels than both the other methods when FS levels are ≥ 8.0 µg/dl (Figure 3a). Figure 3b presents the FS data less than 8.0 µg/dl and shows the LeadCare® venous reporting lower blood lead levels than the ESA venous but not the FS. However, this partition introduces a bias, so it is not reasonable to conclude that FS reports higher levels at ≥ 8.0 µg/dl or lower levels at < 8.0 µg/dl. However, it is important to compare how the LeadCare® venous and the ESA venous results vary with respect to the 10 µg/dl intervention level. There were six FS results in the 8.0 µg/dl -8.9 µg/dl range, and of those, one ESA venous level was reported ≥ 10 µg/dl, while zero LeadCare® venous levels were ≥ 10 µg/dl. Of the 11 FS levels in the 9.0 µg/dl -9.9 µg/dl range, two ESA venous levels were ≥ 10 µg/dl, while one LeadCare® venous level was ≥ 10 µg/dl (for a total of three children with different results). Of the 23 FS levels < 8.0 µg/dl, no venous levels were ≥ 10 µg/dl.

Conclusions and Recommendations: A total of 45 children participating in the Box and Basin LHIP provided three blood lead samples, analyzed using three different methods. The LHIP is a public health service and was not designed to be an experiment, and so the Box and Basin participants (with paired data) were combined for this analysis in order to obtain as much data as possible. About 11% of all participating children had venous samples that were used to compare methodology differences. In summary, the FS and ESA venous blood lead results were similar, respectively reporting 15 and 14 children with levels ≥ 10 µg/dl. One child was believed to have an externally contaminated FS result. Of the 11 children with paired data and high (≥ 10 µg/dl) FS levels, all were confirmed by ESA venous, but two were not confirmed by the LeadCare® venous method (excluding the one outlier).

In general:

- ESA venous blood lead levels reported higher results than the LeadCare® FS levels, which in turn reported higher results than the LeadCare® venous levels.
- One outlier was observed where contamination caused a false positive FS level.
- All three methods are correlated.
- There is a significant difference between ESA venous and LeadCare® venous blood lead levels, with a marginal difference between LeadCare® venous and LeadCare® FS levels, and no difference observed between LeadCare® FS and ESA venous levels.

If blood lead screening is to switch to the FS method, then it is recommended that all FS blood lead levels $\geq$ 8.0 µg/dl be confirmed by an ESA venous sample. Confirmatory venous samples need not be run using the LeadCare® Analyzer. However in the 2001 data, one child would not have received follow-up care because the LeadCare® venous result was $\geq$ 10 µg/dl when the FS and ESA venous methods reported values around 9.0 µg/dl.

Screening using the FS method is also less expensive as well as less intrusive. A FS sample costs around $5.00 per sample whereas an ESA venous sample costs approximately $17.00 per sample. A screening method where capillary samples are followed by a confirmatory venous sample when FS levels $\geq$ 8.0 µg/dl would be less expensive but seemingly as reliable as the ESA venous method used in the past.

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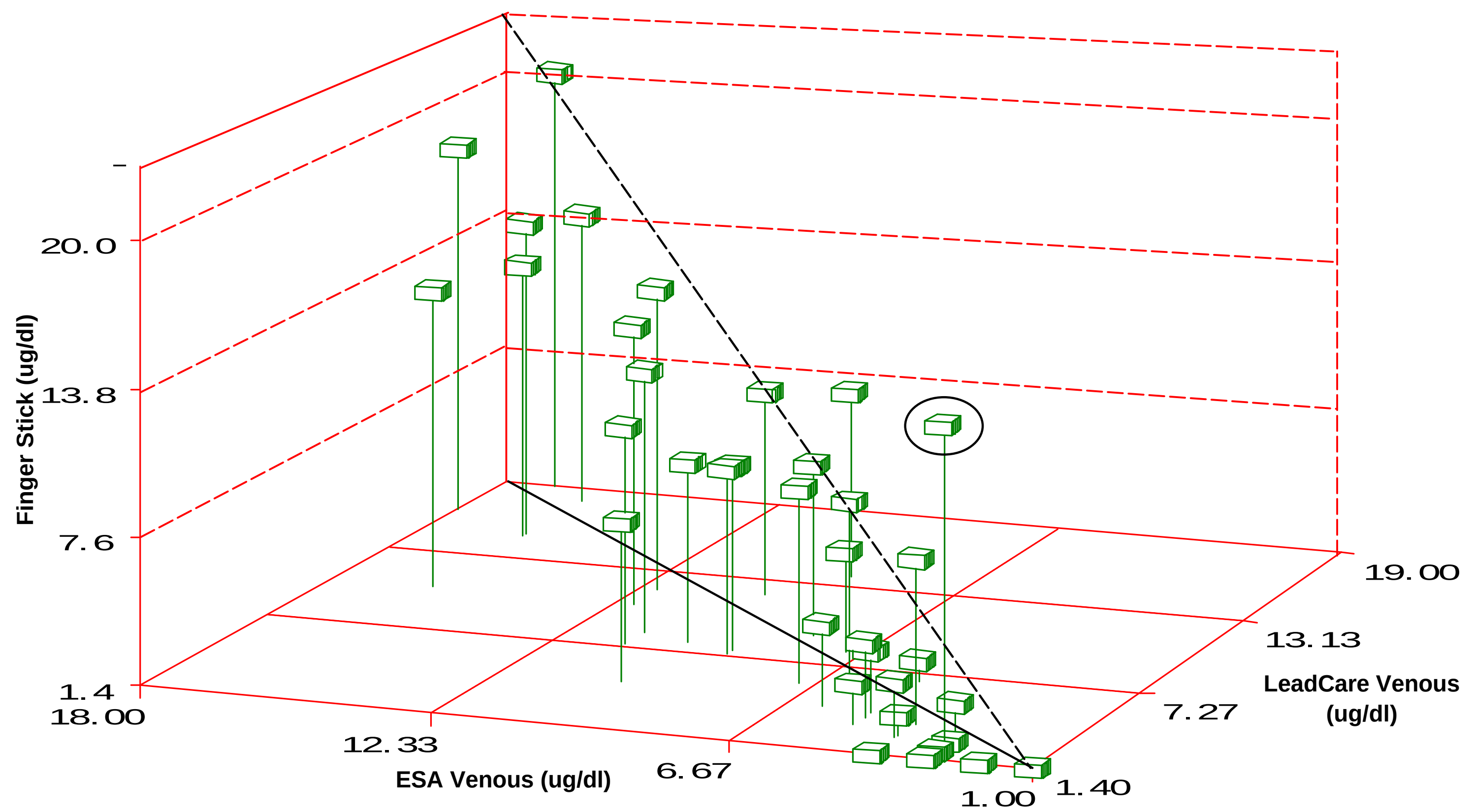
Figure 1a. 3-D Scatter Plot of Paired Blood Lead Data



Outlier=circled data point

Figure 1b. Scatter Plot of ESA Venous to LeadCare Venous Blood Lead Data

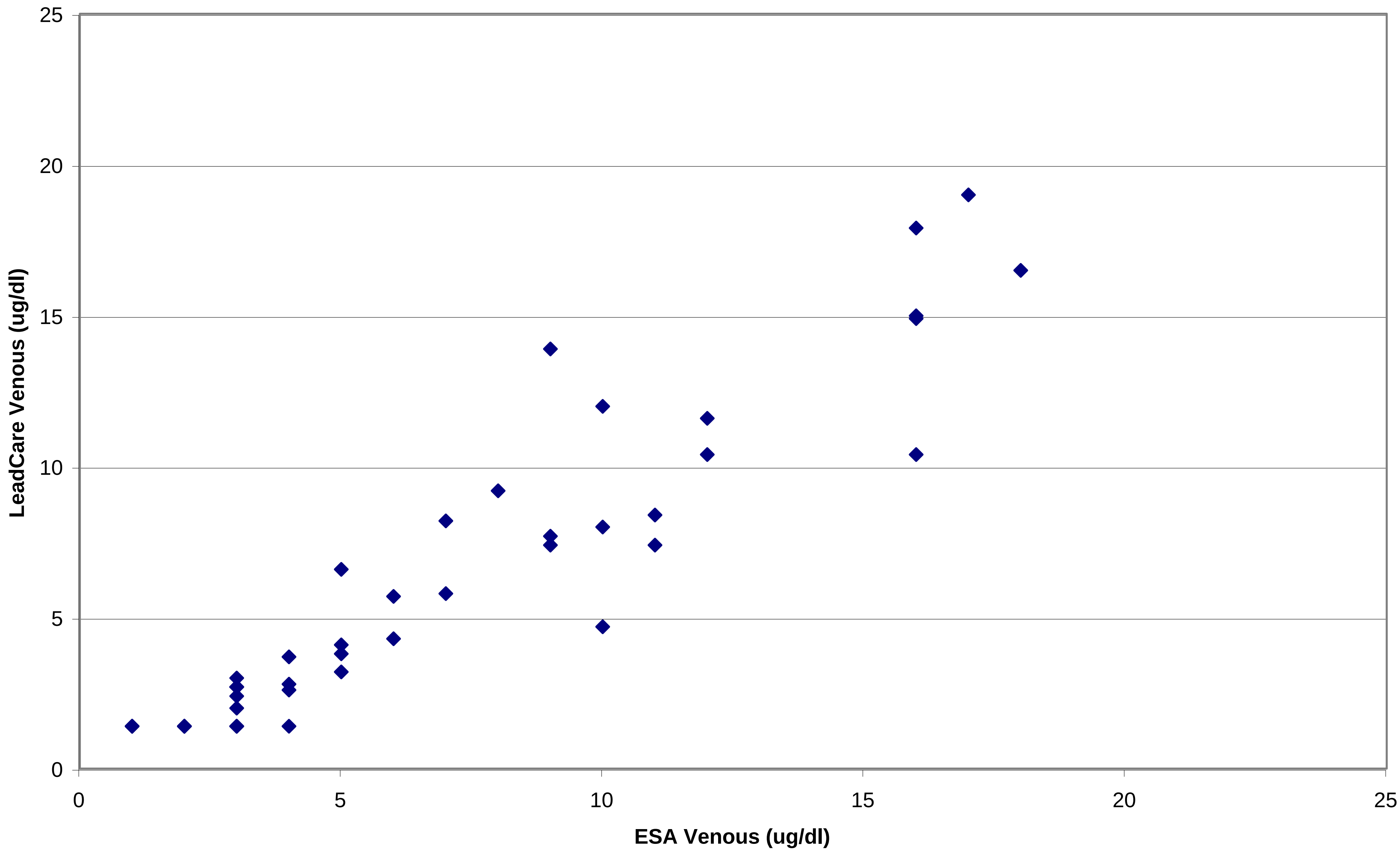
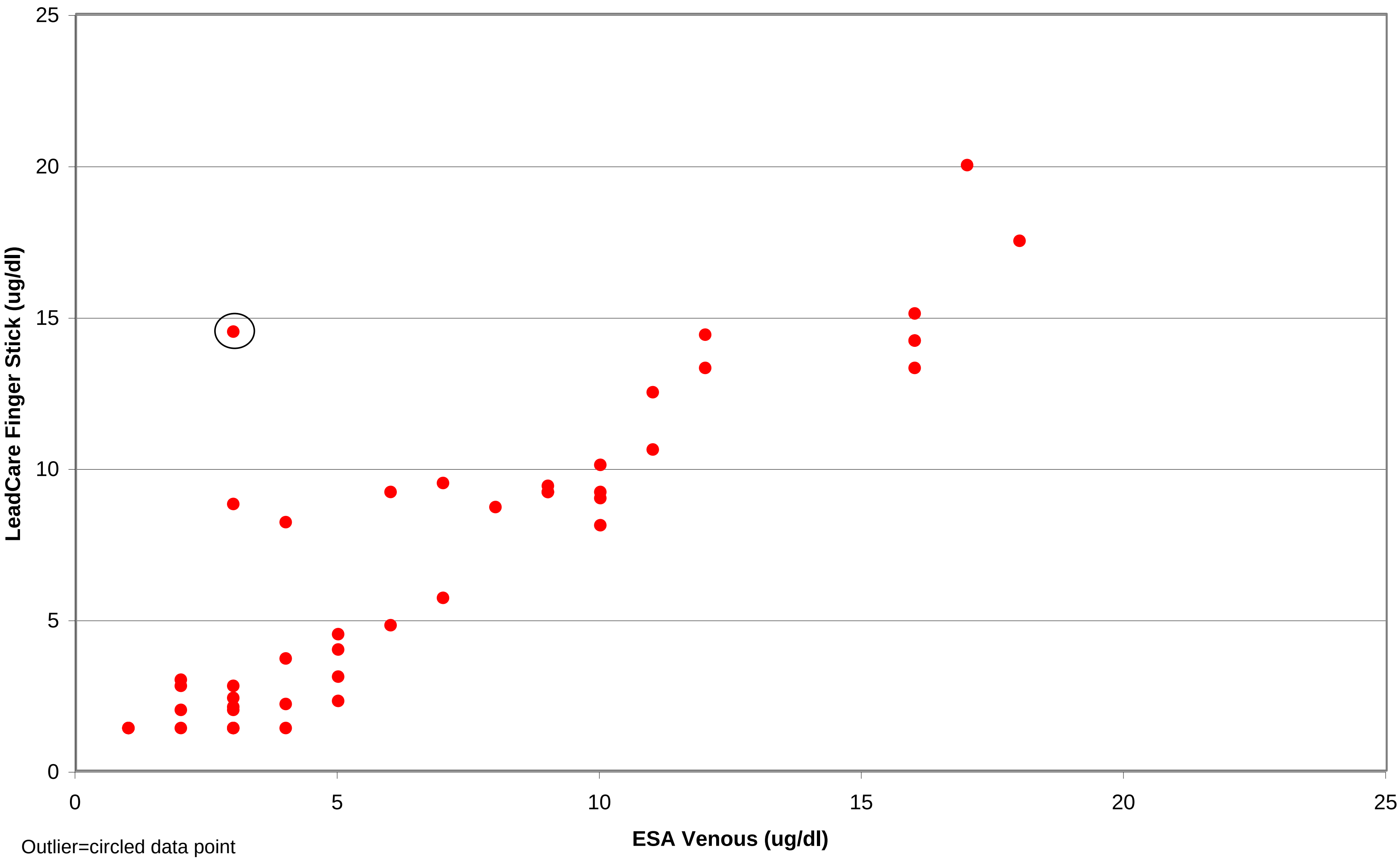


Figure 1c. Scatter Plot of Finger Stick to ESA Venous Blood Lead Data



Outlier=circled data point

Figure 1d. Scatter Plot of LeadCare Finger Stick to LeadCare Venous Blood Lead Data

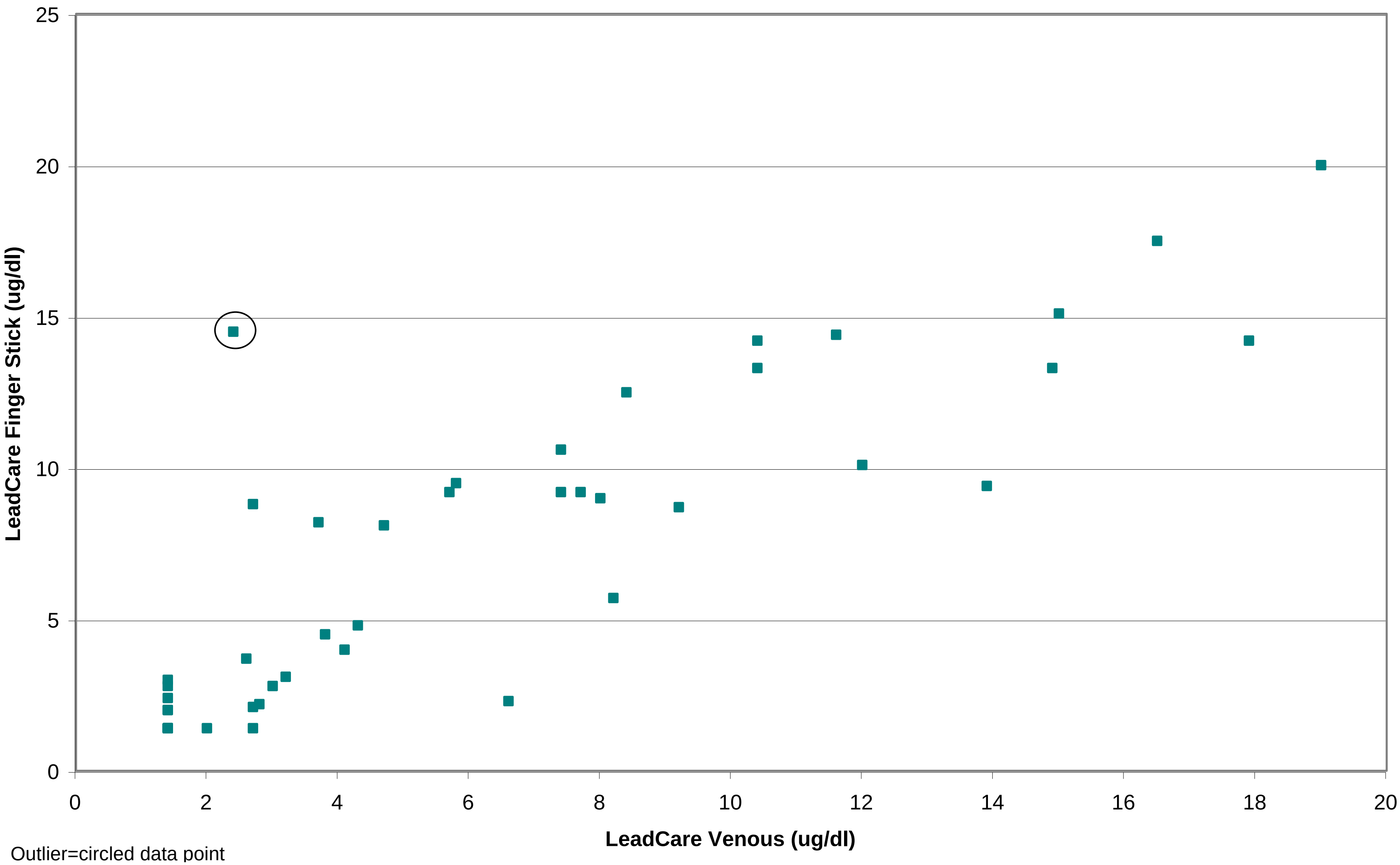


Figure 2. Average Difference and 95% Confidence Limits for Methodology Comparisons

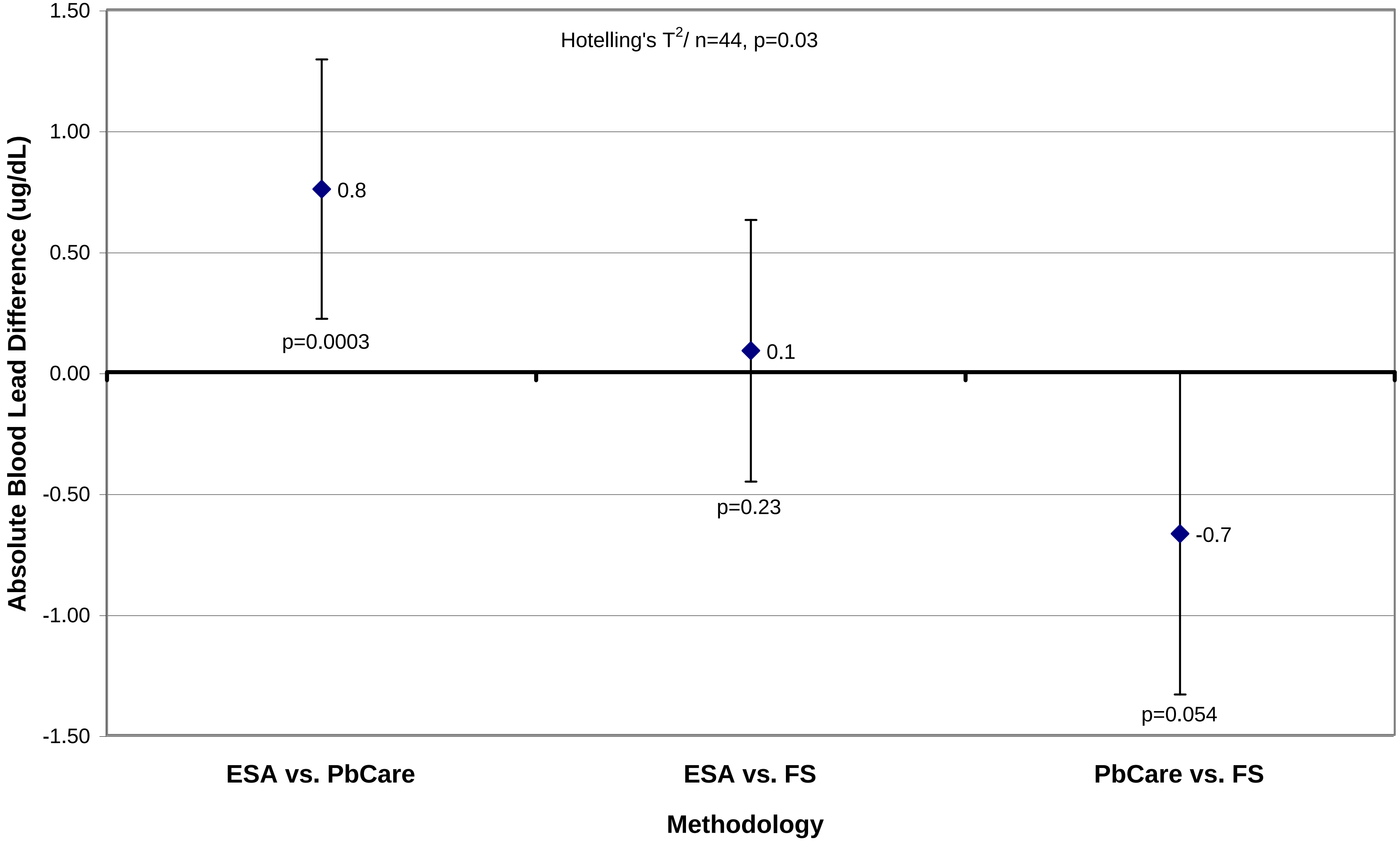
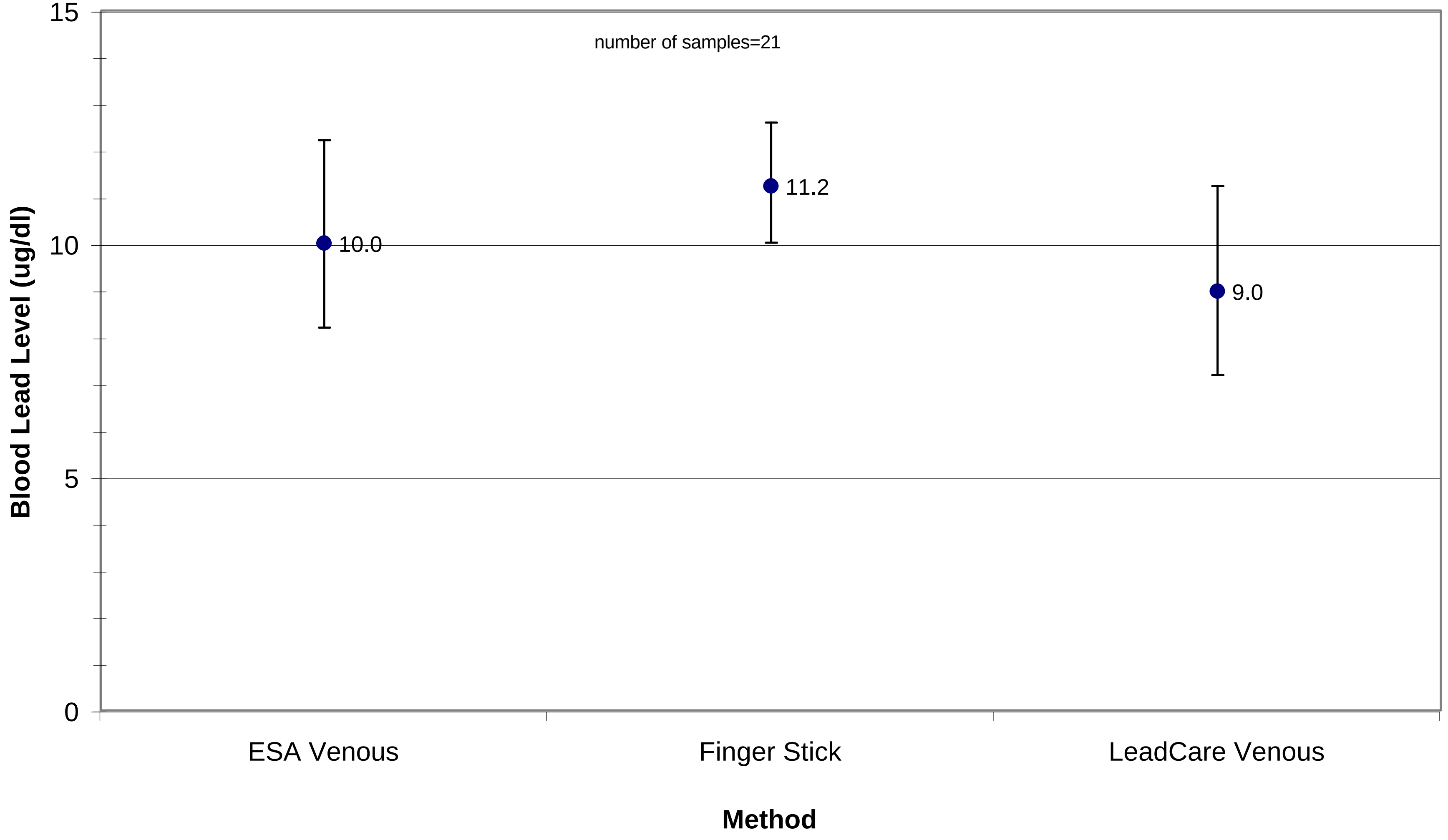


Figure 3a. Geometric Mean and 95% Confidence Intervals of the Three Sampling Methods for FS ≥ 8.0 ug/dl



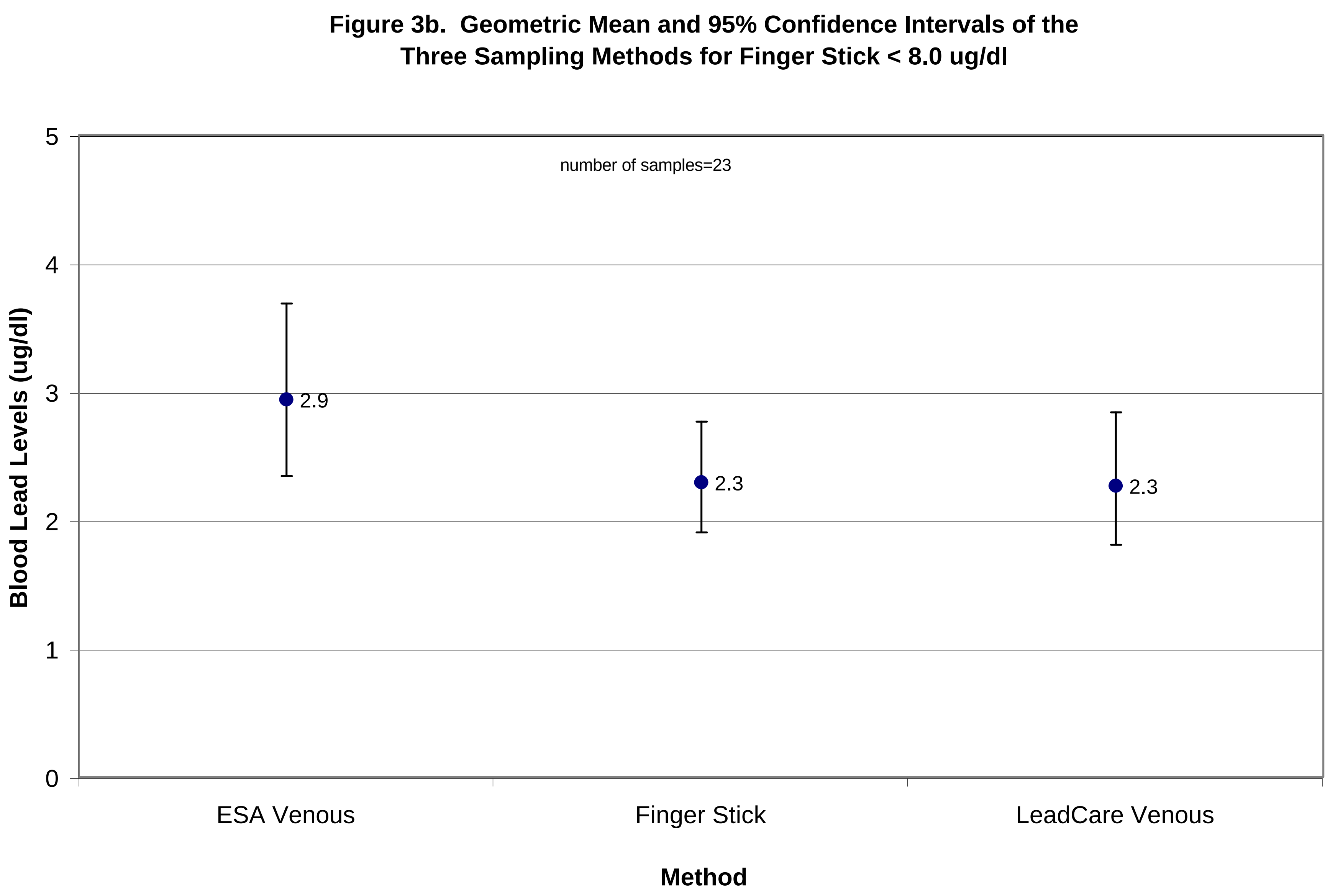


Figure 3b. Geometric Mean and 95% Confidence Intervals of the
Three Sampling Methods for Finger Stick < 8.0 ug/dl
number of samples=23
Blood Lead Levels (ug/dl)
0
1
2
3
4
5
2.9
2.3
2.3
ESA Venous
Finger Stick
LeadCare Venous
Method

Table 1. 2001 Paired Blood Lead Data[a]

	ESA VENOUS	LEADCARE FINGER STICK	LEADCARE VENOUS
N[b]	44	44	44
Min (ug/dl)[c]	1.0	1.4	1.4
Max (ug/dl)	18.0	20.0	19.0
Average (ug/dl)	7.0	6.9	6.2
St. Dev.	4.96	5.20	5.10
Geometric Mean (ug/dl)	5.3	4.9	4.4
Geometric St. Dev.	2.23	2.42	2.40

[a] These data are a combination of Box and Basin LHIP participants.

[b] Excludes one outlier believed to be a FS contamination problem.

[c] Detection Limits: 1.0 ug/dl ESA Venous and 1.4 ug/dl LeadCare FS & Venous - detection limits were used when the blood lead level was below detection limit (BDL)
ESA Venous: 0 samples BDL
LeadCare FS: 7 samples BDL
LeadCare Venous: 10 samples BDL

Table 2. Regression and Correlation Summaries for Laboratory Data and BHSS/Basin Data

Laboratory Studies Performed by the Makers of the LeadCare System (Zink et al.)			Data Collected from the 2001 PHD Lead Health Intervention Program	
LeadCare Venous vs. Model 3010B Lead Analyzer (directly reported from Figure 1*)			**LeadCare Venous vs. ESA Venous**	
Number of Samples	97		Number of Samples	34
Slope	1.023		Slope	1.07
Intercept (ug/dl)	2.67		Intercept (ug/dl)	-0.28
Correlation coefficient R	0.97		Correlation coefficient R	0.94
Range (ug/dl)	1.6 - 39.3		Range (ug/dl)	1.4 - 19.0
			R^2	0.89
LeadCare Venous vs. GFAAS Analytical Method (directly reported from Figure 2*)			**LeadCare Venous vs. LeadCare Finger Stick**	
Number of Samples	234		Number of Samples	32
Slope	0.979		Slope	0.75
Intercept (ug/dl)	0.94		Intercept (ug/dl)	0.33
Correlation coefficient R	0.94		Correlation coefficient R	0.74
Range (ug/dl)	1.6 - 41.3		Range (ug/dl)	1.4 - 20.0
			R^2	0.55
LeadCare Venous vs. GFAAS Analytical Method (directly reported from Figure 3*)			**LeadCare Finger Stick vs. ESA Venous**	
Number of Samples	112		Number of Samples	39
Slope	1.07		Slope	0.87
Intercept (ug/dl)	-0.57		Intercept (ug/dl)	0.26
Correlation coefficient R	0.97		Correlation coefficient R	0.84
Range (ug/dl)	1.8 - 44.6		Range (ug/dl)	1.0 - 20.0
			R^2	0.70

*see Zink et al.

Footnote: Any samples below LeadCare detection limit of 1.4 ug/dl were not included in these analyses

Panhandle Health District Lead Health Intervention Program

Policies and Procedures
Effective March 1, 2001

GENERAL POLICIES

Blood lead tests are available by request from persons who are at risk from lead exposure and who live in the Bunker Hill Superfund Site or the Coeur d'Alene River Basin.

Due to funding limitations, the screening may not be free. If there is a fee for the test, clients are informed prior to the blood draw.

Prior to blood draws, the parent/legal guardian or adult participant must sign a Consent Form and complete the appropriate Questionnaire.

A $20 cash incentive for participation is paid to each participant who lives in the Bunker Hill Superfund Site, **and** is between 6 months and 9 years of age, **and** participates during the announced dates for the annual summer screening.

A $20 cash incentive is paid to each participant who lives in the Coeur d'Alene River Basin, **and** is between 6 months and 6 years of age, **and** participates during the announced dates for the annual summer screening.

Screening blood tests are done by skin puncture. (A venous sample may be substituted at the request of the parent/participant.) Sites for skin puncture are finger, big toe, heel, or earlobe. The preferred site for infants under 1 year of age is the big toe or heel. The finger is preferred for all other ages. Capillary blood samples are collected in a heparinized, lead-free ESA capillary tube and analyzed immediately.

Results of all blood analyzed on the LeadCare Analyzer are recorded in the *Laboratory Test Log* notebook.

Results of capillary tests are provided to the participant or parent immediately after analysis using the designated forms. Parents/participants are encouraged to provide their family physician with a copy of the screening results.

All elevated capillary blood lead levels (10μg/dL or greater) are confirmed by a venous sample. This sample is collected at the same visit as the capillary sample. The venous sample is collected in two 3 ml. EDTA or Heparin containing lead-free vacutainer tubes. The blood in one tube is analyzed using the LeadCare Analyzer and the second tube is sent to ESA Lab for analysis.

Blood lead levels of 25μg/dL or greater are reported immediately to the Lead Health Intervention Program Coordinator or Public Health Nurse.

A public health nurse and/or environmental health specialist provides follow-up services for all children with blood lead levels of 10µg/dL or greater. A home visit with the parents is scheduled as soon as possible. During the home visit, a multi-page questionnaire is completed to determine exposure sources and risk factors. The home environment is inspected for sources of lead. Parents are counseled on interventions including nutrition, personal and household hygiene, and ways to break exposure pathways. Referrals are made for appropriate services needed such as developmental screening and WIC.

A "Confidential Elevated Lead Report Form" is completed and sent to the Idaho Department of Health and Welfare (Epidemiological Services) for each person with an elevated blood lead level (10µg/dL or greater) in accordance with Idaho regulations.

During the 2001 screening, as part of a Quality Control program, venous samples are also collected on 10% of all children tested in the Box and on all children with a capillary blood lead level of 8µg/dL or greater.

Results of venous tests are mailed to the parent/participant within two weeks after they have been received from ESA Lab.

Each day of operation, prior to running any patient samples, the technician verifies that the LeadCare Analyzer is functioning properly. This is done by watching the machine for the SELF TEST OK, by verifying that the Calibration Code on the machine matches the code on the Test Kit, and by analyzing quality control samples (high and low) and verifying that they are within the established values. Results of the Self Test and Calibration check are recorded in the *Maintenance Log* in the *Laboratory Test Log* notebook. Results of quality control testing are recorded in the *Laboratory Test Log*.

Proficiency testing is done on a monthly basis. Five samples are analyzed during the months of January, May, and September to comply with CLIA License requirements. Three samples are analyzed during each of the remaining 9 months of the year. Proficiency testing materials are obtained through enrollment in the Wisconsin State Laboratory of Hygiene Lead Proficiency Testing Program. All Proficiency Testing information and results are kept in the *Proficiency Testing* notebook.

All staff who perform blood lead testing and analysis are trained to use the LeadCare Analyzer. The initial training includes:

1. Viewing the LeadCare Training video.
2. Review of the contents of the LeadCare *User's Guide* and the *Policies & Procedures Manual*.
3. Maintenance and cleaning of the LeadCare Analyzer.
4. Quality control procedures.
5. Sample collection, identification, and storage.
6. Sample analysis.
7. Recording of results.
8. Reporting results.
9. Troubleshooting and malfunctions.
10. Customer service access.

The initial training is documented on the LeadCare Analyzer Training Checklist.

Competency in using the Analyzer is verified by testing quality control samples each time the Analyzer is used and by each staff member participating in proficiency testing at least annually. An annual review of policies and procedures is conducted with staff each spring. Verification of training and competency is kept in the *Proficiency Testing* notebook.

The *LeadCare Analyzer User's Guide* is the final authority on questions related to analysis of blood samples for lead testing.

Blood draws for monitoring occupational exposure to lead are available. All occupational lead testing is done on venous blood samples and the blood is analyzed by ESA Lab. The employer or employee is responsible for the cost of blood analysis and shipping the samples to ESA Lab. Blood lead results are mailed to the employee and to the employer after payment has been received. This service is provided as a courtesy and Panhandle Health District is not responsible for ensuring that employers are meeting the requirements of OSHA or other regulatory agencies.