Setting Priorities for Prevention of Childhood Lead Poisoning

in the City of Providence

by

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Thesis

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Abstract

Despite six years of enhanced efforts to reduce lead contamination in homes and ensure that children live in safe and healthy environments, 21% of Providence children tested for lead in the first three quarters of 1998 had blood-lead levels above the Center for Disease Control's level of concern (10 μg/dl). In the spring of that year, at the request of the Mayor's Policy Office, the Environmental Studies 192 class at Brown University identified five indicators of poor housing quality -- Environmental Violations, Housing Code Violations, Section 8 status, Non-Owner Occupancy, and Assessed Building Value -- that could be used to identify problematic housing in the city. Case-control analyses of these indicators against addresses where Providence children resided when tested for lead in 1997 showed strong statistical significance for all indicators. Addresses cited for environmental violations in 1997 had the strongest correlation, with a child residing in a property with an environmental violation having a lead poisoning risk close to two times greater than a child who lived in a property without an environmental violation.

Based on more extensive indicator analyses, identifying properties with a history of lead poisoning, and determining whether funding should be directed towards low-income areas, I have proposed priority-setting options for the City's Housing and Urban Development Lead Hazard Control Program. The aim of my thesis is to prevent lead poisoning before it occurs, by providing the City with a means to target housing that poses the greatest risk to children.

Beginning with further indicator analyses, I determined that correlations between blood-lead data for the years 1997 and 1998 (combined) and the five indicators continued to remain statistically significant. Again, environmental violations and code violations

showed the strongest correlations, with Risk Ratios of 1.88 [95% Confidence Interval (CI): 1.64-2.16] and 2.24 [CI: 1.93-2.60], respectively. One available option for the City is to target addresses where children have not yet been poisoned but that have had both environmental and code violations in the past.

Other analyses suggested that targeting addresses with a history of multiple lead poisonings should be a priority. Two-percent (2%) of the residential addresses in the city housed 51% of the children with elevated blood-lead levels (EBLs - 15 μg/dl and above) and 32% of the addresses where a child resided in 1998 were addresses with a history of multiple poisonings in 1993-1997. This means that if the City had remediated all the houses where multiple poisonings had occurred, 930 addresses in total, a third of the 1998 poisonings would have been prevented. Targeting addresses where a poisoned child resided after an abatement is another available option. Of the 148 properties that had been abated in the past (according to DOH records), approximately half of these properties have had another lead-poisoned child residing there after the abatement. Socioeconomic analyses also provide support to the idea that resources would be more wisely directed towards targeting individual addresses rather than entire low-income neighborhoods.

Before the address lists necessary for implementation of the recommended priority-setting options can be released to the City, confidentiality concerns must be resolved.

Acknowledgments

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To my ES192 colleagues, the DOH, City of Providence Code Enforcement Office, the Department of Planning and Development, PHA, and Providence Plan, thank you for providing the data that formed the foundation of this thesis and all your hard work in propelling indicator analyses off the ground last year.

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To my family, for standing by me through the good and the bad and for teaching me to trust in myself.

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Chapter One

"As early as 1786, Benjamin Franklin, in a letter to his friend Vaughan, discussed the "mischievous effects of lead," wisely predicting, "You will observe with concern, how long a useful truth may be known and exist, before it is generally received and practiced on".[1]

Introduction

The "useful truths" about lead and the poisoning that it causes have been known since ancient times. However, after even a cursory glance at the history of the disease, one will notice that more often than not pertinent information and knowledge of the metal's ills have been erroneously construed, misunderstood or ignored.

Throughout its history, lead has been used for a variety of commercial, medicinal, technological and artistic purposes. Widespread use of lead was documented in Greek and Roman cultures for such things as wine preservatives and sweetners, medicinal remedies, pottery glazes, aqueduct linings, cooking utensils, and coinage. The adverse health effects of utilizing lead in wine, first reported by 15th century physicians to include intestinal symptoms resembling colic, temporal paralysis, and seizures, encouraged countries to issue decrees prohibiting the use of lead compounds in wines and other beverages. Despite such examples of the early knowledge of the toxin's ills, lead continued to be used around the world and eventually became known as an ideal paint additive for the benefits of greater color intensity and longevity. Even until the late-20th century, well after other countries such as Germany, France and Australia had banned

[1] Pueschel, Siegfried M., James G. Linakis, Angela C. Anderson. *Lead Poisoning in Childhood.* Paul Brookes Publishing Co., Baltimore, 1996, p.10.

paint from household use in the early 1900's, lead paint continued to be used on residential surfaces in the United States.[2]

While voluntary paint industry standards called for limiting lead content to 1% in the late 1940's and early 1950's,[3] it was not until 1978 that the Consumer Product Safety Commission banned the manufacture and use of lead paint containing more than 0.06% lead by weight for residential surfaces, furniture and toys.[4] This late passage of federal legislation to control the use of lead-based paint, combined with a struggling economy and deteriorating housing stock in the older urban cores of the northern industrial cities, were two causal factors for the severe lead poisoning problem in this country and particularly in the Northeast region.

The purpose of this thesis is to pinpoint the sources of the lead poisoning problem in one of New England's older urban areas, the City of Providence. I begin with a general overview of childhood lead poisoning, its causes and effects, and the deteriorating U.S. housing stock. I then delve into the lead poisoning issue in Providence and introduce the background analyses on high-risk housing in the city conducted by Brown University's Environmental Studies 192 class. Next, my focus will turn to the research I have conducted to analyze further the lead poisoning and deteriorating housing stock problems in the city. To conclude, I introduce priority-setting options and

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[2] Ibid, p.6.

[3] "Lead Paint Hazards in Housing." Alliance to End Childhood Lead Poisoning. Website: http://www.aelcp.org/2/lead101.html. May 20, 1999.

[4] "Preventing lead poisoning in young children: A statement by the Centers for Disease Control." US Department of Health and Human Services. Centers for Disease Control. Atlanta, GA: USDHHS, October 1991, p. 18.

recommendations for the City's recently awarded Housing and Urban Development (HUD) Lead Hazard Control Grant.

Lead Poisoning and Children

> " Childhood lead poisoning has long been considered to be the most serious environmental health threat to children in the United States, estimated to cost society billions of dollars."[5]

Despite the many studies conducted on the substance, the Third National Health and Nutrition Examination Survey (NHANES III (1991-1994), the most recent nationwide, cross-sectional health survey studying persons aged one year or older) reported in 1994 that 900,000 American children aged one to five years have blood-lead levels higher than the Centers for Disease Control's level of concern (10 μg/dl).[6]

Although lead was once thought to be dangerous to children only at high levels of exposure, "the Centers for Disease Control lowered the blood-lead level of concern from 60 to 10 micrograms per deciliter" between the years 1978 to 1991. Lead has been shown to affect nearly every system of the body and studies have linked blood-lead levels as low as 10 μg/dl to the increased risks of learning disabilities, behavioral problems, growth impairment, hearing and visual damage as well as other brain and central nervous system problems in children.[7] Lead affects young children to a greater degree than adults because their bodies, brains and central nervous systems are still developing and are more

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[5] "Medicaid: Elevated Blood Lead Levels in Children." United States General Accounting Office. Report to the Ranking Minority Member, Committee on Government Reform and Oversight, House of Representatives. February 1998. GAO/HEHS-98-78, pp. 2-3.

[6] "Screening for Elevated Blood Lead Levels." American Academy of Pediatrics: Policy Statement. *Pediatrics*. June 1998; 101: 1072-1078.

sensitive to toxins. Children also absorb lead more efficiently than adults. Studies show that approximately 15% of ingested lead is absorbed by well-nourished children, rising up to 50% in iron-deficient children.[8] In addition, children's tendency to place much of what they pick up into their mouths places them in closer contact with lead-contaminated dust and soil in and around the home.[9]

Lead poisoning costs society billions of dollars. By damaging children's brains and interfering with the way they learn and behave, lead poisoning increases the societal costs of special education for children who have been severely lead-poisoned. Based on audited costs for special education in 1990-1991 and using a low relative risk of 2.0 for special education in lead-poisoned children with a mean blood-lead level (BLL) of 15 μg/dl, the Rhode Island Department of Health (DOH) estimated the avoidable lifetime costs in one RI birth cohort to be $9-18 million, more than half of which would fall on the City of Providence.[10] This cost burden is an important factor for government officials to consider, since cost-benefit calculations often omit the societal costs of treating lead-poisoned children. While the costs of full abatement of leaded paint are seen by some as prohibitively expensive, they are outweighed by avoiding the societal costs of lead-poisoned children.

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[7] Goldman, Lynn R. "Information the key to preventing childhood lead poisoning." *Journal of Environmental Health.* May 1997*;* 59: 45.

[8] Linakis, James G. "Childhood Lead Poisoning." *Rhode Island Medicine*. January 1995; 78: 22.

[9] "Preventing lead poisoning in young children: A statement by the Centers for Disease Control." US Department of Health and Human Services. Centers for Disease Control. Atlanta, GA: USDHHS, October 1991, p. 18.

[10] Simon, Peter R., William P. Dundulis, Jr., Lynn Boulay, Robert R. Vanderslice. "Lead Poisoning Among RI Preschoolers: the Cost." *Rhode Island Medicine*. April 1995; 78:122.

The Environmental Protection Agency's order to stop adding lead to gasoline in the 1970's and 1980's, later regarded "as one of the major public health triumphs of the 20th century," was the first federal initiative that had a positive impact on the lead poisoning problem, albeit by accident.[11] Between 1976 and 1994, "the mean blood-lead concentration in children dropped from 13.2 μg/dl to 3.2 μg/dl, in direct proportion to the amount of tetraethyl lead produced."[12] Today, the 3 million tons of lead on an estimated 57 million privately-owned housing units built before 1980 "remains the most common high-dose source of lead exposure" for young children.[13] Lead dust that is generated from deteriorating paint surfaces and friction areas around older wooden windows and doors, often found in poorly-maintained, early 20th century urban housing containing a high percentage of lead paint, has been shown to be a significant pathway for this lead exposure.[14,15] Severe weathering problems, also prevalent in older housing, tend to exacerbate the paint deterioration and dust problems. Proper maintenance of interior and exterior paint surfaces, windows and doors, and roof and rain gutters may alleviate a number of the paint deterioration and lead problems found in older housing units.

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[11] Lead was removed because it poisoned the catalyst in catalytic converters, needed by US car companies to comply with Clean Air Act requirements. The health benefits of removing lead were not noted until later.

[12] Needleman, Herbert L. "Childhood lead poisoning: The promise and abandonment of primary prevention." *American Journal of Public Health*. December 1998; 88: 1871-1877.

[13] "Preventing lead poisoning in young children: A statement by the Centers for Disease Control." US Department of Health and Human Services. Centers for Disease Control. Atlanta, GA: USDHHS, October 1991, p. 18.

[14] "Report on the National Survey of Lead-Based Paint in Housing." United States Environmental Protection Agency. Office of Pollution Prevention and Toxics. EPA 747-R95-003. April 1995, pp. v-vi.

[15] "The Relation of Lead-Contaminated House Dust and Blood Lead Levels Among Urban Children." Draft Final Report, Submitted April, 1994. Department of Pediatrics, Biostatistics, and Environmental Medicine. University of Rochester School of Medicine and Dentistry. pp. 2, 19.

Providence, Rhode Island

As a northeastern industrial city with a history of middle and upperclass out-migration from urban to suburban areas, the City of Providence has an older housing stock which has been left in a state of decline, gradual disrepair and abandonment since the middle of this century. Once comprising a large percentage of the housing in the city's urban areas, owner-occupied properties were slowly transformed into rental units controlled by absentee landlords. The prevalence of two and three-family homes found throughout the city was the result of earlier stressors which included a frequently depressed economy and sudden immigration in the period between the mid-1800s and the Depression. For immigrants working in factories in the area, two and three-family homes "were more economical than single-family homes, and about as comfortable."[16] The Rhode Island Statewide Planning Department estimates that of the approximately 66,000 housing units in Providence, 90% of them were built before 1978 and 60% were built before 1940.[17] According to survey data from the U.S. Department of Housing and Urban Development, 90% of residences built before 1940 contain lead, while 62% of those built between 1960 and 1979 contain lead.[18] Providence's housing figures are

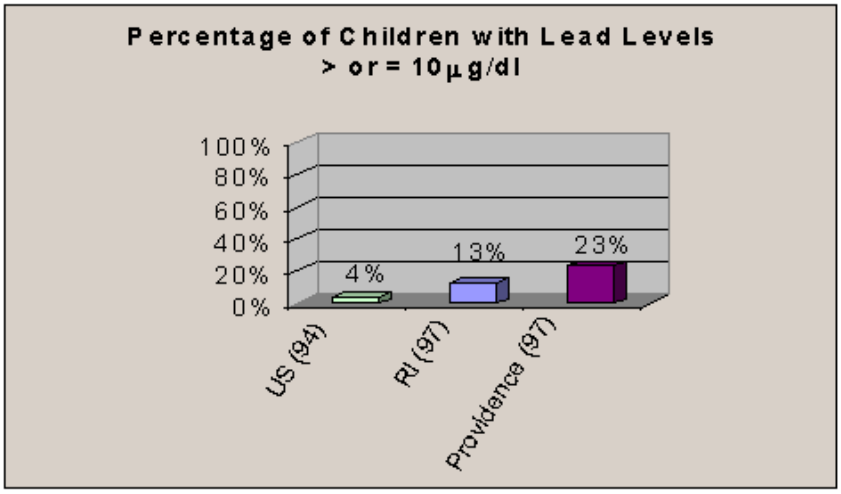
[16] "What could be more Rhode Island than a triple-decker?" *The Providence Journal.* February 28, 1999.

[17] Point, Al. Personal telephone communication. Rhode Island Department of Administration, Division of Planning. July 1998.

[18] Margai, F., Walter, S., Frazier, J., and Brink, R. "Exploring the Potential Environmental Sources and Associations of Childhood Lead Poisoning." *Applied Geographic Studies*. 1997; 1: 254.

significant because they show Providence not only has an aging housing stock, but also a pre-1978 housing stock that contains a high percentage of lead-based paint.

This large percentage of older housing, combined with the city's high rate of lead poisoning, has led one environmental advocacy group, the Conservation Law Foundation based in Boston, Massachusetts, to designate Providence as "the lead poison capital of the United States".[19] While BLLs in Providence have continued to decline in recent years, from 43% of children showing BLLs of 10 μg/dl and above in 1993 to 21% of children tested in the first three quarters of 1998, the prevalence of lead poisoning in Providence children remains higher than the rest of the state and the U.S.



As you can see by the chart above,[20] four-percent of U.S. children showed BLLs of 10 μg/dl in 1994, while in 1997, 13% or 1 in 8 children in Rhode Island and 23% or 1 in 5 children in Providence had elevated BLLs. Within low-income areas of the city rates are much higher, with greater than 30% of all children tested in these areas showing

[19] "Lead poison capital." *The Providence Journal.* Editorial. May 19, 1998.

[20] Sources: CDC (NHANES III) 1994 US Data and RIDOH 1997 Blood Lead Data.

elevated BLLs in Fiscal Year 1996 (Figure 1). So while the state and city continue to have a high prevalence of elevated blood-leads, an updated U.S. prevalence rate would most likely have dropped below 4%.

Purpose for the Study

Knowing the high prevalence of BLLs in the city, the Mayor's Policy Office of the City of Providence approached the Center for Environmental Studies (CES) at Brown University in early 1998 with the request that a class devise a means to determine whether visual curbside surveys to assess housing condition could be predictive of lead poisoning. While the surveys being conducted by the City's Planning and Development Department were not intended to assess lead poisoning risk, the City was interested in correlating housing quality data with blood-lead data for the identification of problematic housing.

The City hoped, through these analyses, to prevent further poisoning in high-risk units by reducing the risks of lead through cleaning, remediation or abatement. This desire to focus on primary prevention rather than acting after a child is identified as having a high lead level, has become the new direction taken by local city, state and public health officials nationwide. However, while many researchers stress that "preventive actions must be taken to remove sources of lead in the child's environment before poisoning occurs,"[21] others believe that primary prevention strategies will not become the focus for some time:

> "The 1991 CDC statement ["Preventing lead poisoning in young children"] was intended to move us into an era of *primary* prevention efforts for lead poisoning, that is, elimination of lead hazards before children are poisoned.

[21] Linakis, James G. "Childhood Lead Poisoning." *Rhode Island Medicine*. January 1995.

> Unfortunately, it is quite apparent that we are still several years from such an approach, and, in fact continue to deal with lead through a strategy of *secondary* prevention, that is, by screening susceptible children to identify those with lead poisoning, and then treating them."[22]

While secondary prevention continues to be the primary means by which the lead-poisoning problem in Providence and Rhode Island is addressed,[23] the momentum towards a future of primary prevention in the state and City of Providence is encouraging.

Safe Housing Task Force and the HUD grant

As Brown's environmental studies seminar class (ES192) began to collect the necessary survey data, the City moved forward with its agenda to prevent lead poisoning in Providence. In the spring of 1998, Mayor Cianci formed the Mayor's Safe Housing Lead Task Force charged with studying the complexities of the problem, ensuring the health and well-being of Providence children, and developing a multi-faceted aggressive strategy that is "responsive to local needs and conditions" and the available resources of the City.[24] The Task Force convened semi-monthly for six months as three subcommittees: Housing, Funding, and Health and Education and released their recommendations in November 1998. Continuing to strive towards a primary prevention focus, the City applied for and was awarded a $4 million HUD Lead Hazard Control Grant this spring. The ES192 study, included in the City's proposal for the HUD grant,

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[22] Needleman, Herbert L. "Childhood lead poisoning: The promise and abandonment of primary prevention." *American Journal of Public Health*. December 1998; 88: 1871-1877

[23] While the Rhode Island General Assembly has tasked the DOH with a comprehensive lead poisoning prevention plan, the Legislature funded only limited secondary prevention strategies in the state until this year, when $800,000 will be allocated to the Housing Resources Commission for primary prevention purposes.

[24] "Mayor Cianci Appoints Safe Housing Lead Task Force." Press Release. The Executive Office, City of Providence, RI. March 9, 1998.

provided HUD with a statistical picture of the severity of deteriorating housing and lead-poisoning problems in the city. Funding from the grant will be used for cleaning, remediating and abating housing units, providing lead education to local communities, and offering lead training courses to certify community members to conduct safe lead hazard cleaning and stabilization activities.[25] The primary component of this thesis will recommend priority-setting options to the City of Providence and grant partners for targeting and allocating funding to problematic properties in the city as part of this HUD grant.

Indicator Analyses

Indicators of Poor Housing Quality – ES192 Background Research

The original intent of the ES192 course was to identify high-risk housing in the city based on existing survey data of housing condition. However, the ES192 class noticed early in the semester that there was a limitation to using this data -- it was trickling in to us in such small quantities that additional ways to assess housing quality were necessary to gain statistical power. For this reason, additional characteristics or indicators of housing quality were tested for correlations with elevated blood-leads. Our hypothesis was that, given a set of indicators of poor housing quality, we would be able to determine if a child was at greater risk for lead poisoning when living in a house with one of these indicators as opposed to living in a house without the indicator.

Five indicators were selected for the analyses: past Housing Code Violations (i.e., deteriorating paint, dilapidated roof); Environmental Violations (i.e., trash in yard);

[25] "The Providence Healthy Housing Partnership." City of Providence application for Department of Housing and Urban Development Lead Based Paint Hazard Control Program. May 29, 1998.

Section 8 status (federally subsidized private housing); Assessed Building Value; and, Non-Owner Occupancy. We obtained the list of 1997 Code Violation data from the City's Housing Code Enforcement Office, the 1997 Environmental Violation database from the City's Department of Public Works, the 1997 Tax Assessor's database from the City's Planning and Development Department, and a list of current HUD-subsidized Section 8 voucher properties from the Providence Housing Authority. The list of Owner Occupied addresses was derived from the Tax Assessor's database by matching billing addresses with the street addresses to determine if the owners resided at the listed properties (owner-occupied when the billing address is the same as the street address). Our essential data -- all blood-lead samples drawn from children in Providence in 1997 -- was provided by the Rhode Island Department of Health (DOH). The blood-lead data included the following: Child ID (coded for confidentiality purposes); Date of Birth; Date of Test; Type of Test (either venous or confirmed capillary); Blood-Lead Level; and, Address at which the child resided at the date of the test. Universal screening of children ages 6 months to 6 years for lead began in 1991 after the Rhode Island General Assembly passed the Childhood Lead Poisoning Prevention Act.[26] According to a study conducted by the DOH on a cohort of RI children (all born in the first four months of 1996), 65% had been screened by 18 months of age and the screening rate for high-risk children was 73%.[27]

All databases were cleaned and analyzed using MSExcel 97 and basic cohort and case-control statistical analyses (cleaning and analyses described in Methods, Appendix

[26] "Lead Poisoning in children can be detected, prevented." *The Providence Journal*. May 12, 1998.

[27] Feeley, Susan. Rhode Island Department of Health. E-mail correspondence with Kimberly Mowery, February 9, 1999.

I). All address maps were created for this and future analyses using Maptitude and ArcView 3.1. For statistical analyses, we defined a lead-poisoned child as one with an elevated blood-lead level (EBL) of 15 μg/dl or above. This was selected after the DOH informed us that the accuracy of BLL tests were + or – 4 μg/dl.[28] Therefore, case-control cutoffs of 0-10 μg/dl and 15+ μg/dl would provide us with two distinct groups: a low-BLL control group and an elevated BLL case group.

1997	**Risk Ratio**	**Lower Bound**	**Upper Bound**
Environmental Violations			
Cohort	1.84	1.58	2.14
Case-Control	2.14	1.78	2.57
Code Violations			
Cohort	1.69	1.34	2.07
Case-Control	1.93	1.51	2.47
Non-Owner Occupancy			
Cohort	1.28	1.11	1.47
Case-Control	1.34	1.15	1.57
Building Value			
Cohort	1.25	1.10	1.42
Case-Control	1.49	1.19	1.86
Section 8			
Cohort	1.33	1.09	1.62
Case-Control	1.40	1.12	1.76

This table represents a component of the data analyzed by the ES192 class. Using case-control and cohort analyses and the five aforementioned indicators of high-risk, we determined that code violations and environmental violations had the highest correlations and therefore showed the greatest risk, followed by Section 8, non-owner occupancy and building value. As explained in Methods, Appendix I, increased risk is shown when the Lower Bound of the confidence interval is greater than 1.0. To give an example, the code

[28] Zierler, Sally. Rhode Island Department of Health. Correpondence between Harold Ward and Ms. Zierlier. Spring, 1998.

violations Risk Ratio and Lower Bound, according to case-control analyses, are 1.93 and 1.51, respectively. This means that a child residing in a property with a code violation has at least a lead poisoning risk of 51%, but most likely has a risk 93% greater than a child who lives in a property without code violations in 1997. The ES192 class determined that all five indicators showed statistically valid correlations with lead poisoning.

1997 – 1998 Indicator Analyses

Curious to see whether the indicators remained statistically significant using a larger amount of data, I reanalyzed the case-control correlations using updated versions of the indicator databases, when available, and the 1997 and 1998 (combined) blood-lead databases. As before, all blood-lead data were provided by the DOH (1998 data is only through the third-quarter of the year). An updated version of the Section 8 database was provided by the PHA, the 1998 Code Violation database by the City's Code Enforcement Office, and the 1998 Environmental Violations database by Helen Drew in DOH. The original Tax Assessor's database and list of Owner Occupancy addresses were used, as updated versions were not available. As may be seen in the table below, code violations show the strongest correlation, with a RR of 2.24, followed by environmental violations, building value, Section 8 status, and non-owner occupancy. Again, all indicators show statistically strong Risk Ratios and Lower Bounds of greater than 1.0. When compared to the 1997 analyses, these new analyses show a stronger correlation between each of the five indicators of poor housing condition and the increased risk of lead poisoning.

1997 and 1998		Risk Ratio	Lower Bound	Upper Bound
Environmental Violations		1.88	1.64	2.16
Housing Code Violations		2.24	1.93	2.60
Non-Owner Occupancy		1.35	1.18	1.54
Building Value		1.69	1.35	2.12
Section 8		1.44	1.20	1.73

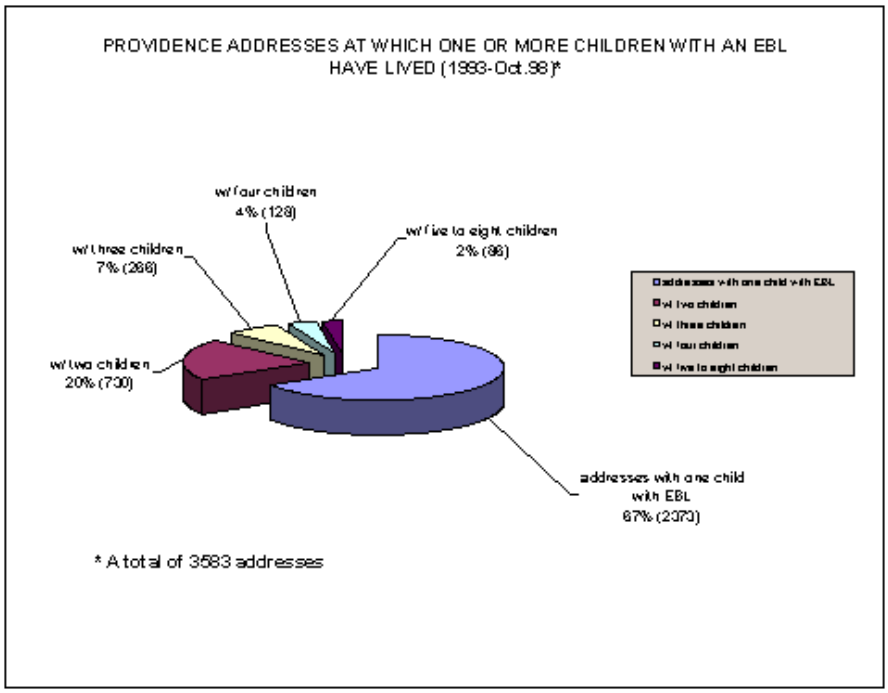
Figure 2 is a map of Providence that illustrates the distribution of 1,296 children with EBLs in 1997 and 1998. Figure 3 is a map of the distribution of addresses with code violations where lead-poisoned children resided in 1997 through October 1998. Both maps show a crescent shaped distribution throughout the city, with the highest concentrations of EBLs and environmental violations in the northern, western, and southern regions of the city.

Chapter Two

Summer 1998 – Addresses with Multiple Poisonings

In the Summer of 1998, while we were attending the Mayor's Safe Housing Lead Task Force Housing Subcommittee meetings, a debate arose as to whether children poisoned in the city's housing were poisoned in only a small number of properties, termed "lead-mills," or in a large number of properties spread throughout the city's neighborhoods. To attempt to resolve this debate, we set out to determine whether multiple poisonings have occurred in a small or large percentage of Providence's residential addresses.

In total, there are 16,069 addresses in the city where children have resided at the time they were tested for lead. Of these addresses, 46% have housed a child with a BLL of 10 μg/dl. Further analyzing approximately six years worth of DOH blood-lead data, we determined that 3,583 residential addresses have housed one or more children with BLLs of 15 μg/dl and above (at the time the samples were drawn). (see Methods, Appendix I for calculations and description). Approximately one-third, or 1,210 addresses, have had multiple poisonings with two or more poisoned children tested at the address during the six-year period (see chart below).



As referred to earlier, Providence has an estimated 66,000 residential housing units. Ideally, we would determine whether a child residing in a particular housing unit had an increased risk of lead poisoning versus other housing units at that address or at other addresses, but unfortunately this analysis was impossible. This was due to an inherent constraint of our data -- all indicator and blood-lead databases contained limited housing unit information. For example, within the DOH blood-lead databases, an address entry may refer to the apartment where a child resided at the address, say 3R referring to third floor, right side but, in other sample entries, this apartment information is absent from the computer file. For the latter, only an address is given despite the fact that the property is known to have several units. For this reason, we have detailed unit information for some children and very limited information for others, knowing only that they resided somewhere in the house. The absence of this detailed address information

for all entries in the DOH blood-lead databases prevents us from determining risk on a unit basis and only allows us to assess risk at an address level. In addition, the minimal amount of housing-unit-specific information found in the housing quality indicator databases also prevented the assessment of risk on a unit basis. Therefore, when cleaning data, all addresses with unit information were converted into street numbers and street names to allow for proper address matching between databases. A 135 Smith Street in one database would then correlate to a 135 Apt. C Smith Street in another database.

Thus, taking the total number of residential addresses in the city as approximately 40,000 addresses, according to coding in the Tax Assessor's database,[29] the 3,583 addresses where poisoned children lived over the six-year period would be 9% of the city's total residential addresses or 22% of the 16,069 addresses where children have been screened. A limited number of City-owned public housing and residential properties owned by non-profit organizations would not be listed in the database. However, after conducting several address matching analyses using the Tax Assessor's database, we were surprised to find that one-third of the addresses reported as residence of tested children did not match to the Tax Assessor's database. While we have no independent way of determining how many residential addresses there actually are in the city, we may use our analyses to estimate that approximately one-third of the city's residential addresses do not appear in the residential-coded section of the database (estimated to be approximately 13,000 addresses). Several possible explanations may explain this inconsistency. The first, as mentioned above, is Public Housing and non-profit addresses are not included in the Tax Assessor's database. To determine whether

[29] Residential addresses in the Tax Assessor's database are coded as either 1, 2 or 3. One = single family home; 2 = 2-5 apartments; and, 3 = 6+ apartments.

this would account for the address deficit, I attained a list of the Public Housing addresses from the PHA and found that there were 424 listed addresses. Obviously, the absence of Public Housing addresses would not account for the large discrepancy. Unfortunately, I was unable to attain a list of the residential properties owned by non-profit organizations. The second reason this inconsistency may exist is that addresses listed in the database include only one street address (109 Smith Street) while the property may consist of several units located at two addresses (109-111 Smith Street). To account for the absence of this second address, Richard Weinberg of the City's Planning and Development Department adjusted the address list by including the second street number for the address (111 Smith Street) when the higher street number was missing and the property was listed once (109 Smith Street) but coded as having two or more units. As a number of addresses may still be absent from the database if incorrectly coded or if the lower street number rather than the higher was missing, a portion of the 13,000 figure may be accounted for by this billing address practice. A third reason addresses are missing may be due to the antiquity of the database and the incorrect coding of residential properties. For the latter, some of the residential addresses within the database appear to be incorrectly coded as non-residential properties. This incorrect coding would have decreased the number of address matches found between our lead databases and the associated assessed building value column in the Tax Assessor's database. Regarding the antiquity of the database, while tax bills are collected each year, property values within the City have not been assessed since 1987. The outdated nature of these tax assessments, combined with the City's confusing plat/lot system, may have limited the

amount of information available on the location or size of all residential addresses in the city, thereby explaining some of the inconsistencies found in the database.

In order to correct for the one-third discrepancy in residential addresses discussed above, I adjusted the 40,000 listed residential addresses in the Tax Assessor's database by one-third (multiplying the unadjusted 40,000 figure by .33 and adding the result to 40,000) to attain 53,680, as an estimate for the actual number of residential addresses in the city. Then, dividing the 3,583 addresses where poisoned children lived by this adjusted figure, gives an estimate that 6.7% of the residential properties have housed a lead-poisoned child over the six-year period.

Using these same unadjusted and adjusted figures for the 1,210 addresses with more than one poisoning, 2.3% (adjusted) and 3.0% (unadjusted) addresses in the city have contained multiple lead-poisoned children. A map of the 1,210 addresses with multiple poisonings shows the same crescent shape distribution throughout the city as referred to earlier. (Figure 4).

The number of poisoning events that have occurred at these addresses is another way of determining the severity of the lead poisoning problem in the city's residential addresses. Each poisoning event represents that a poisoned child resided at an address, but not necessarily that the child was poisoned as a result of exposure to lead at that location. Thus, if a child moved between addresses, was tested again, and still showed an EBL, they would be counted twice in our calculations. The number of poisoning events was determined by multiplying each address grouping (see pie chart) by the number of children with EBLs at that address to attain 5,631 total poisoning events at residential addresses in Providence, 3,258 of which occurred in the 1,210 multiple-poisoning

addresses. That is, approximately 60% of the poisoning events occurred in approximately 2.5% (mean of the adjusted and unadjusted address figures) of the city's residential properties.

These calculations show over half of the city's poisoning events occurred in a relatively small percentage of the city's residential properties, which illustrates the point that children are neither being poisoned in an overwhelming majority of the residential properties around the city, nor are children being poisoned in a very small number of lead mills (which would drop the percentage to an even smaller figure than above, because only a few hundred homes would be causing the problem). As additional analyses found later in my thesis will explain, children tested for lead in Providence have been found to reside in only one-third of the residential properties in the city over a six-year period. Therefore, targeting the small number of properties found to be problematic may have wide-ranging preventative effects.

Taking the residential address analysis even one step further, I determined that there were 4,424 poisoned children residing at 3,027 addresses (Methods, Appendix I) and that more than one poisoned child had resided at 885 addresses. Using the mean of adjusted and unadjusted residential address figures as before, 885 addresses accounts for approximately 2% of the city's residential addresses. Therefore, 2,254 or roughly half of the children with EBLs resided at an estimated 2% of the city's residential addresses. Again, I would like to stress that this is important for setting priorities for prevention, funding and abatement purposes. That multiple children with EBLs resided in a relatively small number of the city's total residential properties over a six-year period suggests that these houses or houses with these characteristics be given priority.

Confidentiality Issues

Under the Rhode Island Confidentiality of Health Care Information Act,[30] the DOH must ensure that each child's private medical health care records are not released for public use or external purposes. In order for us to obtain DOH blood-lead data for our study, we were required to submit a proposal to the DOH Internal Review Board (IRB) in the spring of 1998. The IRB approved our request and released blood-lead data to CES for the 192 study in the late spring of that year. Under our agreement with DOH, CES is permitted to use blood-lead address information for research purposes, but we are unable to release address information to the City for the purposes of identifying, remediating and/or abating problematic housing through the HUD lead grant. To protect the confidentiality of each child, the DOH created unique child IDs for the blood-lead databases we were provided, thereby allowing us to distinguish individual children by their ID without requiring that we know a child's name. Hence, the crux of our confidentiality problem lies in whether the address where a child resided when tested for lead constitutes "private medical information".

We believe, however, that a child's confidential medical information will not be revealed if <u>only</u> address histories based on multiple children's lead data are released. We argue that address histories contain composite information from at least two or more children and therefore an individual child's private medical information will not be violated, nor the identity of a lead-poisoned child at a property revealed, by releasing an address where multiple lead-poisoned children have resided. Instead, the address of a problematic property will be released based on that residence's prior history of lead

[30] Rhode Island General Laws -- Section 5 – 37.3.

poisoning. We proposed this argument to the DOH in April 1999 and as of 26 July 1999 have not received a response.[31] Until we know whether addresses can be released, we have proposed alternative, albeit less-effective, means of targeting high-risk housing in the city. The alternative concepts introduced in the setting priorities section of this thesis may be able to alleviate the confidentiality problem without requiring an address release agreement.

It is important to consider the other side of the confidentiality issue as well. What are the ramifications to the children, families and tenants at these locations if address information is released? The balance between tenant's rights and protecting children's health is often blurred. Children and their families have the right to anonymity and, for this reason, children's private medical information is protected. However, when is the line drawn for how far address confidentiality will go before children's health may be jeopardized? On the other hand, tenant's rights are often violated when landlords discover or are notified by the DOH that a child in their tenement is lead-poisoned and retaliate by evicting the family. If, by some circumstance, our list of addresses were released to the press, this type of retaliation may be more frequent. This could be particularly true in lower income areas of the city where tenants may not know that their rights enable them to demand that the landlord disclose the lead hazards and fix the lead problems in his or her rental units. Therefore, we must ensure that if our request to

[31] Dr. Nolan, Director of the DOH, responded directly to the City's request that addresses be released at a meeting held at the DOH. Dr. Nolan pointed out that the City already knew of many of the worst cases identified by CES, or those cases that have been referred to Code Enforcement, and she asked that the City start with those addresses while DOH continues to consider our request.

release address information to the city is granted, tenant's rights and the rights of children are kept in mind.

Two options that may be available to sidestep the confidentiality and eviction issues include: 1) the DOH has offered to send letters to all families and owners in the priority addresses inviting them to come forward for assistance; and/or, 2) the City, CES, non-profit organization, state agency or a coordinated effort between several of the aforementioned could go through the DOH IRB process again with the proposal that positive interventions will be provided for all families at problematic addresses where an EBL or history of multiple poisonings have been identified. The second option, recommended by Lynn Bibeault of the DOH,[32] would require an applicant to go through the full DOH IRB application process in order to attain access to a list of addresses that could be used as part of a lead hazard reduction study and/or program. Positive interventions would need to be made available to all addresses released to the applicant for the purposes of the study or program and education and cleaning components included for those tenants and landlords not interested in pursuing remediation or abatement.

Address Profiles

In order to better determine the trends and severity of poisonings for addresses in which multiple lead-poisoned children have resided, address profiles were created for each of the 1,210 addresses. (A sample list of 25 address profiles is included as Appendix III). For confidentiality reasons, the street names or address numbers are not included in the list enclosed in the Appendix. Address profiles include descriptive

[32] Bibeault, Lynn. Rhode Island Department of Health. Personal communication. July 22, 1999.

information for each address generated by using DOH 1993-October 1998 blood-lead data, a DOH inspection database for the years 1993 through April 1998, a listing of HUD I and III properties provided by Kelly Farrente of the DOH, the Tax Assessor's database, and Section 8 and Public Housing databases provided by the Providence Housing Authority. Each address profile includes information such as the total number of children tested for lead at the address, average BLL for all tests, percentage of children who had been tested and were poisoned, DOH inspection status information (i.e., inspections, abatements), Section 8 and Public Housing status. Additional column descriptions are included in Appendix II. Priority was given to information that we believed was relevant for identifying and targeting properties as high-risk. For example, the %B/C column or the percentage of children tested at an address who were poisoned may help us determine whether an address has poisoned a number of the children who have resided there. When the percentage is high, this information may indicate that we are targeting a property where children are being poisoned rather than a property into which previously lead-poisoned children are moving.

The purpose of these profiles is to identify the properties that pose the highest risk to children by looking at the history of lead poisoning and past inspection and abatement actions for properties where multiple lead-poisoned children have resided. Additional analyses using an address list of the Greater Elmwood Neighborhood Services (GENS)[33] transitional houses may be necessary to determine where properties are that are lead-safe

[33] A non-profit organization based in the Elmwood region of Providence dedicated to eliminating childhood lead poisoning in Providence and the state through education, parent support, advocacy and lead hazard abatement programs.

but children have high BLLs. The final product is a list of properties that may be prioritized for abatement and remediation based on a set of detailed profile information.

Further analyses of the 1,210 address profiles determined that 321, or 27% of the addresses had some form of DOH action in the past. DOH action may include inspections of the property after a lead-poisoned child is identified, cases that were closed because a child moved or closed due to an abatement at the residence, and properties that were involved in the HUD I or III abatement programs. Additional descriptions are included in Appendix II under the list of possible DOH actions. Of the 321 addresses that had some form of DOH action, 148 or 46% had a record of an abatement, were abatements pending soil, or were listed as HUD I or III properties. While this figure does not take into account the approximately 70 properties abated through the Greater Elmwood Neighborhood Services (GENS),[34] this figure accounts for approximately 50% of the 288 properties listed as closed due to past abatements or abatements pending soil[35] in DOH records for the City of Providence since 1992.

The table below lists the totals and percentages of other DOH status codes. Because several addresses included different codes for separate units within the property, the total of the second column is slightly higher than the total address figure listed above. This is due to the inspection database including detailed unit information for each of the addresses they inspected unlike the other databases we have used. Thus, the DOH records may show that one unit in a property where a lead poisoned child resided was

[34] Carbone, Joan. Greater Elmwood Neighborhood Services. Telephone communication. July 9, 1999.

[35] Thirty of the 148 addresses were closed cases pending soil, contributing to 14 of the 72 addresses where poisoned children have resided after a past abatement. At present, the City's Housing Court rarely enforces the DOH's request that contaminated soil be removed at sites where abatements have occurred. This lapse in enforcement may contribute to some of the repoisonings that appear to be occurring.

inspected in 1993 and another unit was coded for future inspection in 1995, but the child moved before the inspection could occur. While there are only 30 addresses with different actions taken in separate units, the figures below may be slightly inflated, as they refer to units within addresses rather than the addresses themselves.

DOH Status Breakdown
for 321 Addresses where 2+ children with EBLs have Resided

Status Description	Total # of Addresses with this description	Percentage of 321 Addresses listed in DOH Inspection database
Child Moved	56	17%
Child > 6 years	3	1%
No Response	20	6%
BLL < 25 μg/dl	7	2%
Refused Inspection	8	2%
Medical followup > 3 mo.	14	4%
Parents = Owners	23	7%
Abated/ HUD Properties/ Closed – Pending Soil	148	46%
Referred to Legal/Code Enforcement	33	10%
Open	21	7%
Misc: No Violation Closed by Dr. Simon	7	2%

To give an example of a status description in the table above, of the 321 addresses listed in the DOH inspection database where two or more children with lead poisoning had resided, 56 addresses or 17% of the total were not inspected because a child moved before the inspection could take place. Other status descriptions refer to situations when the DOH could not inspect a unit because a child was greater than six years of age; when a unit was inspected but the DOH case was dropped because the parents of the child were the owners of the property, in which case the child is left in the care of the family physician rather than the DOH; or cases in which units were referred to the City of

Providence's Code Enforcement Office for legal action because the owner of the property had failed to comply with DOH requests.

To my surprise, of the 148 properties that had been abated in the past, 72 or 49% of these properties have had another lead-poisoned child residing there after the abatement occurred. One possible explanation for this could be that only one unit in a property was abated while the other units continued to remain hazardous for young children. Additional explanations may be that children poisoned in another house moved into the property after the abatement or that a child with an ongoing EBL continued to reside in the property. However, given the magnitude of abated properties where poisoned children have resided after the time of abatement, I doubt the above concerns to be the case. I believe these properties may still pose significant risks to children and will most likely require some form of further remediation in the near future.

Size of the Housing Pool

Since our analyses began in the Spring of 1998, the size of the housing pool in which children are migrating has been an unsettled question for us. We know that children in the city, particularly those in the poorer, minority areas, move frequently from one housing unit to another for a variety of reasons, but we have been unable to determine the frequency with which they move.[36] In addition, we have not known

[36] Providence Plan conducted a study on the mobility of school-aged children from one Providence neighborhood to another for the period Fall 1986 through Spring 1995 based on the Providence School System's Fall Enrollment data. While the census tracts involved in the analysis encompassed larger areas than the city's traditional neighborhood designations, Providence Plan determined 14.6% of school-aged children moved from neighborhood to neighborhood during the time period. When the East Side was compared to Elmwood and Federal Hill, the East Side's transiency was approximately 5% compared to rates of 15% for Elmwood and 26% for Federal Hill. In the future, Providence Plan would like to reconduct the study by looking at the rate of transiency among individual children rather than at the larger neighborhood scale. (Personal communication with Jim Vandermillen).

whether children are moving around in the same housing pool or, instead, are moving to new addresses not found in the DOH blood-lead data. Both of these questions, the frequency of moves and the size of the housing pool, are pertinent because they allow us to determine whether recommendations to clean, remediate, and abate properties with a history of lead poisoning makes sense. In essence, if an address has multiple poisonings over a six-year period, would it make sense to abate that property if the chances of another child residing there are slim?

I conducted this analysis by looking at the number of old versus new addresses that arise in the DOH blood-lead database for each year between 1993 through October 1998. This was analyzed by generating a list of addresses where children had lived each year and comparing this figure against the total number of addresses for prior years. The data and detailed description of this analysis may be found in Methods, Appendix I.

In total, there are 16,069 addresses in the 1993-October 1998 DOH blood-lead database. Dividing this by the adjusted number of residential addresses in the city (53,680), 30% of the city's residential addresses have had a lead-tested child residing in them during the past six years.[37] As expected, I found that the percentage of new addresses decreases each year as the number of old addresses increases. For example, when comparing the total number of addresses in 1998 (5,431) with the 1993 through 1997 address list, 77% of the addresses were old compared to 23% that were new. This had decreased from the 1997 comparison to 1993-1996 data of 72% old addresses and 28% new. (see Appendix I). From this analysis, it would seem that children in

[37] According to Al Point in the Rhode Island Division of Planning, the only estimates on the total number of low-income housing in the city are based on Section 8 and public housing figures. Further analyses to determine the approximate number of low-income housing, accounting for factors other than Section 8 and public housing, are needed.

Providence are moving within the same housing pool because the number of new addresses appearing each year is decreasing. A plot of the ratio of new to old addresses for each year from 1994 through 1998 shows this trend. As the top graph in Figure 5 illustrates, when plotted, the ratio for each of the five years is decreasing with a projected trend estimated to drop below a ratio of 0.2 by 2002. This indicates that, by 2002, children are more than five times as likely to move into an address already in the housing pool compared to an address outside the pool where a tested child has not resided before.

While we are unable to determine exactly the size of this housing pool or the number of Providence addresses children reside within, movement in the city does not appear to be random. Assuming children, particularly in poor areas, will have limited numbers of low-income properties to move into, we can expect the housing pool for children to reach a maximum limit based on the fact that, in approximately six years time, only 16,069 residential addresses have appeared in the DOH blood-lead databases. As seen in the second graph in Figure 5, the cumulative total addresses for the period from 1993 through 1998 indicates that the housing pool for children may reach maximum size at around 20,000 addresses. The significance of this figure is that the City will only need to think about lead hazard reduction in approximately a third of Providence's residential properties.

Another way of looking at these data is, instead of simply targeting housing where children have resided in the past, targeting housing with a *history* of lead poisoning may be a better approach. To determine if this actually is the case, the next analysis I conducted was to take a list of all addresses where a child had a 15+ BLL in 1998 and compare this to my list of 1993-1997 addresses. After this analysis, I found that out of

the 588 15+ addresses that appeared in 1998, only 15% of these addresses were new. Thus, if the City decided to target addresses with a 15+ BLL in 1998, 85% of these would have been addresses where a child had resided before. But, this still does not determine the number of 15+ addresses in 1998 with a history of lead poisoning. To determine this, I compared my list of 15+ addresses in 1998 with a list of 1993 through 1997 addresses where at least one child with an EBL had resided in the past and found that 44% of the 1998 addresses were new while 56% were addresses with a history of one or more poisonings in 1993-1997. Then, continuing this analysis by comparing the 15+ addresses in 1998 to a list of addresses where two or more children with EBLs had resided in the past, I determined that 68% of my 1998 addresses were new while 32% were addresses with a history of multiple poisonings in 1993-1997. This means that if the city had remediated all the houses where multiple poisonings had occurred, 930 addresses in total, 32% or roughly a third of the 1998 poisonings would have been prevented. This supports our recommendation that properties with a history of lead poisoning are the most problematic in the city and the ones that should be targeted first for intensive remediation and lead abatement, if reducing high-risk housing is the highest priority.

Socioeconomics

Background

A number of studies have shown a correlation between low socioeconomic status, poor housing condition and high blood-lead levels in children. One study found that "Children at highest risk … [of a study done of the Twin Cities metropolitan area] were those who were racial minorities, living in poverty, residing in the central city, living in housing built before 1950 or of unknown age, and those who had a history of or a sibling

with a history of lead poisoning."[38] Another study showed that the age of residential housing, residence in an old house with peeling paint and the mother's education had positive predictive value for identifying children whose BLLs were greater than 10 μg/dl.[39] In a study comparing Providence County to Worcester County, Massachusetts, the authors stated their belief that children living in poverty tend to be at higher risk "because of diet, reduced access to information and health care, and the increased likelihood that they live in old housing and in areas of general environmental degradation."[40]

Another study that correlated environmental factors to elevated blood-leads found lead exposure to be affected by geographical location (inner city versus suburbs or rural communities), housing quality, and limited options for low-income and minority groups to live outside the inner city because of institutional housing policies and practices. The authors reiterated what other studies have shown, that disadvantaged children have been "more susceptible to lead contamination because many live in old substandard housing in the inner cities, which are sometimes characterized as "lead belts."[41] Children receiving care under Medicaid have also been shown to be at higher risk. A study conducted by the United States General Accounting Office's Health, Education, and Human Services

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[38] Nordin, James, Sharon Rolnick, et al. "Lead levels in high-risk and low-risk children in the Minneapolis-St. Paul Metropolitan Area." *Pediatrics*. January 1998; Vol. 101: pp.72-76.

[39] Haan, Mary N., Marianne Gerson, and B. Anne Zishka. "Identification of children at risk for lead poisoning: An evaluation of routine pediatric blood lead screening in an HMO-insured population." *Pediatrics*. 1996; 97: 79.

[40] Bailey, Adrian J., James D. Sargent, and Megan K. Blake. "A Tale of Two Counties: Childhood Lead Poisoning, Industrialization, and Abatement in New England". *Economic Geography: Special Issue for the 1998 Annual Meeting of the Association of American Geographers*. March 1998, p. 97.

[41] Margai, F., Walter, S., Frazier, J., and Brink, R. "Exploring the Potential Environmental Sources and Associations of Childhood Lead Poisoning." *Applied Geographic Studies*. 1997; Vol. 1, No. 4: 255.

Division found that "lead toxicity is a significant problem for children receiving care under Medicaid." Medicaid children were more than three times as likely to have high BLLs (10 μg/dl and above) than children not receiving Medicaid. This accounts for an estimated one in 12 children in the program aged 1 to 5 or 500,000 children, with an additional 350,000 children on Medicaid presumably having high levels of lead in their blood but not having been tested for it.[42]

Socioeconomic factors are important to the analyses in this thesis because they provide additional information relevant to deciding where resources for lead hazard control and abatement should be directed. If case-control analyses of addresses in low-income areas only, using the same five indicators, do not remain statistically significant, this would suggest that resources could be directed towards these areas in their entirety rather than selecting individual problematic properties. On the other hand, if our indicator analyses remain statistically significant when isolating these areas, this would say that priority-setting of individual addresses in these areas is still important.

In the following four separate analyses (looking at controlled building value, regression analyses, census tract block group analyses, and the South Providence Enterprise Community), I have attempted to show that priority-setting within the low-income neighborhoods remains an important way to target high-risk and problematic properties.

[42] "Medicaid: Elevated Blood Lead Levels in Children." United States General Accounting Office. Report to the Ranking Minority Member, Committee on Government Reform and Oversight, House of Representatives. February 1998. GAO/HEHS-98-78, p.2.

1997 and 1998 Case/Control Analyses – Controlled for Assessed Building Value ($1,000 - $75,000)

		Risk Ratio	Lower Bound	Upper Bound
Housing Code Violations		2.05 (2.24)	1.66	2.54
Environmental Violations		1.77 (1.88)	1.46	2.14
Section 8		1.37 (1.44)	1.04	1.80
Non-Owner Occupancy		1.52 (1.35)	1.26	1.83

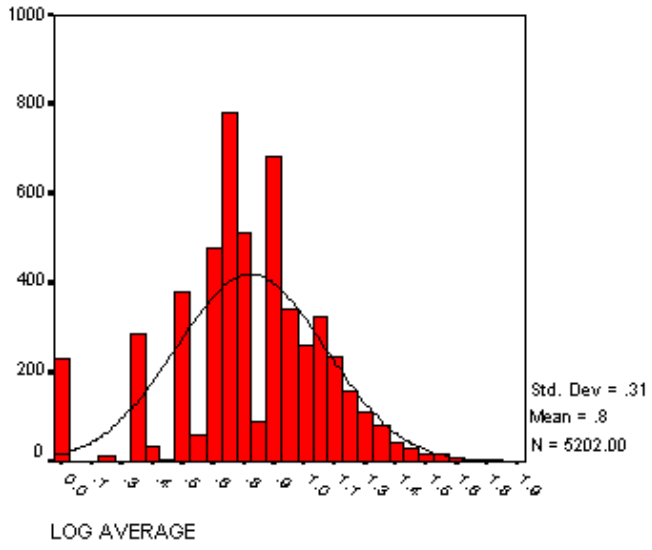
In order to determine whether the analyses we had conducted continued to have significant correlations in low-value housing, hypothesizing that this housing would be found in the low income areas of the city, I reanalyzed the 1997 and 1998 BLL data for four indicators after isolating only those addresses in the database with low property values, from $1,000 to $75,000. The $75,000 figure was selected after determining that the median building value for addresses in the database was approximately $76,000.[43] As can be seen by the table above, all analyses remain significant (for comparison purposes, the parenthetical risk ratios are from the prior 1997-1998 indicator analyses), with environmental violations and code violations again showing the strongest correlations. This shows that all indicator correlations remain strong even in the lower socioeconomic sector and, therefore, prior analyses were not selecting out children in the lowest value, and thus highest risk properties.

[43] This analysis is based on the assumption that the data we have for assessed building value represents the condition of the property; therefore, properties with lower building values represent the low-income addresses of our analyses while properties with higher values represent those in higher income areas. This analysis also does not take into account a value per unit assessment, nor does it account for apartment buildings that may have high-assessed building values but tenants of lower income status residing within them.

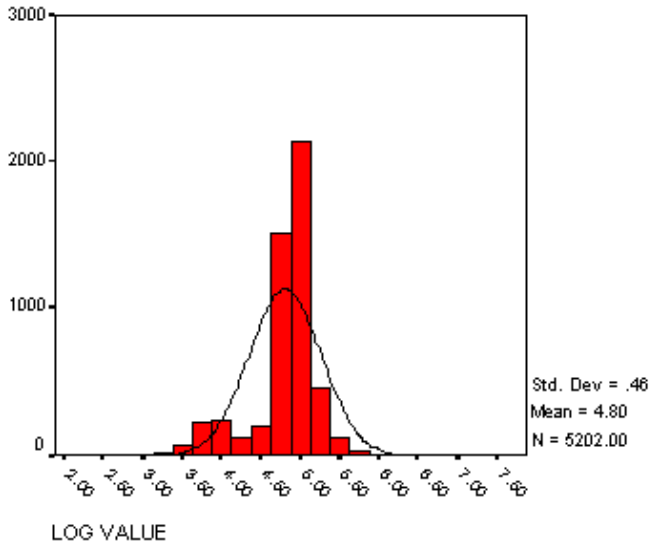
Regression Analysis

I used the SPSS 7.5 statistical processing tool to perform a linear regression analysis on the average blood-lead level of 1997 addresses and their associated assessed building values to determine how average blood-lead level, my dependent variable, is affected by the assessed building value, independent variable, of the addresses where children resided when tested in 1997. According to the SPSS information guide, "this analysis tool performs linear regression analyses by using the "least squares" method to fit a line through a set of observed observations." In total, there were 5,203 addresses in 1997 where children resided when tested, were listed in the Tax Assessor's database and had an assessed building value. Because both variables are log normal, I took the log of the average BLL of each address and the associated assessed building value to generate the two normal distribution curves found below.

Normal Distribution Curve of BLL Averages for 1997 Addresses listed in the Tax Assessors Database (.8 = 6.3 μg/dl)

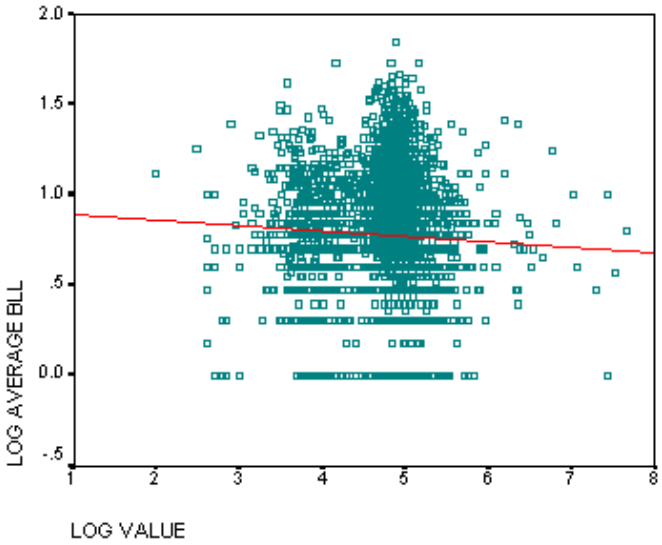


Normal Distribution Curve of Assessed Building Values for 1997 Addresses in the Tax Assessors Database (4.75 = $56,300)



Then, using the program to perform a linear regression of the two variables, I attained the graph shown below.

Linear Regression Model comparing Log Normal Building Value to Log Normal Average BLL



The downward sloped fit line shows that there may be a small relationship between low assessed building values and high average blood-lead levels at the 1997 addresses analyzed. Running a model summary and ANOVA analysis on the data, I found that the R square is .002 and the Significance is .001. This tells us that the data is significant, but only .2% of the lead averages show a relationship to building value. The relationship between the two variables was much stronger in the case-control analyses introduced earlier.

Census Tract Block Group Analyses

According to a 1996 analysis of lead exposure in Providence County census tracts, measures of poverty were an important predictor of lead exposure at the community and individual level.[44] Taking this study into consideration, I selected three census tract block groups with the assistance of Lynn Carlson, the GIS analyst for CES, and compared the block groups by using two census characteristics: 1) Number of families below poverty with children under 18 and 2) Number of children in the block group ages five and under. All three census tract block groups were in different areas of the city and were selected to compare characteristics of a low income block group to medium income and upper income block groups. For the first characteristic, assuming that a high number of families below poverty with children under 18 designated a low income block group, we selected a block group in South Providence with 118 families below poverty to compare to a block group in the northern Providence region of the city

[44] Sargent, James D., et al. "Census Tract Analysis of Lead Exposure in Rhode Island Children." *Environmental Research*. 1997; 74: 165.

with 36 families below poverty and a block group on the East Side with 6 families below poverty. As may be seen in Figure 5, after plotting all 1997 blood-lead tests in the city and taking the average for each census tract block group we were comparing, the mean blood-lead levels for the 3 block groups ranged from 7.0 μg/dl for the lowest income block group to 6.0 μg/dl for the medium and 4.0 μg/dl for the block group with the fewest families below poverty. The graduated ranges on the Figure's legend, which identifies varying blood-lead levels, also shows that the South Providence block group has a higher proportion of blood-lead levels greater than 9 μg/dl.

Figure 6 shows a map of the entire city with census tract block groups labeled for the Count of Persons Ages 0 to 5 Years. While the three comparison block groups may be difficult to see in the map, the respective counts for lowest income block group to highest are 593, 215, and 196, respectively. To determine the prevalence of 10 μg/dl and above blood-leads in these block groups, I divided the number of observed blood-leads above 10 μg/dl in the earlier map by the total Count of Children Ages 0 to 5 to find that the South Providence block group has a prevalence of 9% versus the northern Providence block group with 2.7% and the East Side block group with 1.8%.

This analysis of three census tract block groups in the city confirms the DOH's 1996 findings that the prevalence of lead poisoning in certain areas of the city, particularly in areas with greater poverty, is higher than in others. However, the analysis did not show the same degree of difference in the 1996 analysis for the block groups selected, nor did it find a large difference in the mean blood-lead levels between the block groups.

South Providence Enterprise Community Analysis

The next analysis I conducted to determine the feasibility of targeting problematic homes within the city's economically depressed areas was an analysis of the five indicators of poor housing quality within the southern region of the city's Enterprise Community. As part of the Providence Enterprise Community Program that began in 1994, the City has received several million dollars in federal funds to develop a comprehensive community and economic development agenda for the city's under-served areas. Within the designated Enterprise Community (see Figure 12), the City of Providence estimates that nearly half of the residents live below poverty levels and unemployment is nearly one and one-half times the citywide rate.[45]

1997 and 1998 Enterprise Community		**Risk Ratio**	**Lower Bound**	**Upper Bound**
Environmental Violations		1.74 (1.88)	1.40	2.16
Housing Code Violations		1.89 (2.24)	1.51	2.36
Non-Owner Occupancy		0.95 (1.35)	0.78	1.16
Building Value		1.41 (1.69)	0.94	2.12
Section 8		1.15 (1.44)	0.87	1.52

The chart above shows the results of the case-control analyses I conducted using addresses where children residing within the southern region of the Enterprise Community (includes the South Providence, West End, Elmwood and South Elmwood neighborhoods, census tracts 2-7, 11, 12 and 14) were tested for lead in 1997 and 1998.

[45] "The Providence Healthy Housing Partnership." City of Providence application for Department of Housing and Urban Development Lead Based Paint Hazard Control Program. May 29, 1998.

As before, the parenthetical risk ratios are used for reference purposes and represent the 1997 and 1998 combined indicator analyses for all of Providence. While environmental violations and code violations Risk Ratios and Lower Bounds remain statistically strong in this analysis, the remaining three indicators (non-owner occupancy, assessed building value and Section 8) show no significance because the Lower Bounds are less than 1.0. These results indicate that within the city's low-income areas a number of options may be appropriate. Targeting individual properties for remediation and abatement rather than the entire area appears still to make sense when environmental and code violation indicators are utilized. However, Section 8, non-owner occupancy and assessed building value indicators appear to have less relevance within the southern Enterprise Community. This may be the result of a large prevalence or homogeneity of properties in this region with these housing characteristics.

Section 8 and Public Housing Analyses

The last analysis that I conducted stemmed from a debate between the Rhode Island Attorney General's office, CES and the HUD Office of Lead Hazard Control concerning Section 8 housing in the city. The particulars of the debate are too extensive to detail; it is sufficient to say that the findings of the ES192 class are one source of the disagreement. In 1997, a child who resided at a property with at least one Section 8 unit had a 40% greater risk of having an EBL than a child residing at an address with no Section 8-subsidy. In his letter of May 6, 1999, David E. Jacobs, Director, Office of Lead Hazard Control stated, "Because Section 8 housing is occupied by low-income persons, and because blood-lead levels are known to be related to poverty, one would *expect* to see increased blood-lead levels in Section 8 families." That is, Dr. Jacobs was

arguing that a higher rate of poisoning was not the result of poorly-maintained Section 8 housing, but was instead a direct result of poverty. This was an apparently desperate attempt to explain why children living in Section 8 housing were *more* likely to be poisoned, when they would be expected to be *less* poisoned than average, because HUD housing is supposed to be inspected and found to be lead safe before being approved for Section 8 status.[46]

To respond to this peculiar argument, we compared Section 8 housing to Public Housing in Providence to determine whether a child was at greater risk of being lead-poisoned in Section 8 housing than in the city's public housing. The two major differences between Public Housing and Section 8 housing are 1) the City owns Public Housing while Section 8 houses are privately-owned; and 2) Public Housing was built much later than the majority of Section 8 housing, has been heavily invested in for lead inspections and abatement, and therefore contains little to no lead paint. The similarity between the two is that both have the same minimum income requirements for families to become enrolled in the programs.[47] Dr. Jacobs argument would predict that lead-poisoning rates would be similar. After running a case-control analysis of BLLs of children living in Section 8 housing versus children in Public Housing in 1997, using Section 8 and Public Housing data attained from the Providence Housing Authority, I found that children living in Section 8 housing were *four times as likely* to be lead

[46] Jacobs, David E. Director, Office of Lead Hazard Control, U.S. Department of Housing and Urban Development. Letter to Sheldon Whitehouse, Rhode Island Attorney General. May 6, 1999.

[47] Woodhead, Nancy. Providence Housing Authority. Personal telephone communication. May 19, 1999.

poisoned compared to children living in Public Housing. This signifies the severity of the lead poisoning problem in Section 8 housing in the city, which under federal law is required to be lead safe.

Chapter Three

Setting Priorities for the City of Providence

Partners for the City of Providence's HUD Lead Hazard Control Grant Program (Program), which include the City's Department of Planning and Development, Greater Elmwood Neighborhood Services (GENS), Childhood Lead Action Project (CLAP), and the Mayor's Policy Office, are currently in the process of determining how to set priorities for the Program. The City's HUD grant proposal laid out a tier-based process for setting priorities for cleaning, stabilizing and lead remediation and abatement work, based in part on analyses provided by CES. Below I have introduced alternatives for determining and prioritizing which residential addresses should be placed in each of the three tiers, based on differing assumptions about the causes of lead poisoning.

The Program's Tier System

The proposed remediation program is divided into the three tiers:

Tier I: 375 units in the target area will receive limited inspection and appropriate cleaning and stabilizing services using the CLEARCorps model.

Tier II: 200 units will be eligible for moderate repair loans of $2,500 maximum to be specified and authorized by a licensed inspector and the Lead Program Manager.

Tier III: 100 units will be eligible for hazard abatement loans of $7,500 maximum per property as specified and authorized by a licensed inspector and the Lead Program Manager.

Tier I will target 375 units in the target area, including Providence's Enterprise Community, the majority of which is located in the dark region shown in Figure 1. These units would receive limited inspections, cleaning and stabilizing using the CLEARCorps model. CLEARCorps is a joint public-private endeavor currently located in seven U.S. cities, with Providence to be the eighth, which focuses on "a cost-effective solution to

reducing lead exposure" by using trained community members to clean and repair homes to make them lead safe, "educate residents on lead-poisoning prevention techniques, and encourage residents of treated housing units to maintain low levels of lead dust through specialized cleaning efforts."[48]

Under Tiers II and III, units will be eligible for moderate repair and lead abatement loans. These properties would be characterized as having conditions more egregious than the homes targeted for CLEARCorps cleaning and stabilization work and would require greater resource and time investments.

Here is a summary of the results reported in earlier chapters that are relevant to selecting housing units for remediation in each tier.

- **Approximately 2.5% of the residential addresses correlate with 60% of the poisoning events**
- **Approximately 2% of the residential addresses contained 51% of the children with EBLs**
- **85% of the addresses where a child with a 15+ EBL resided in 1998, a child had resided before**
- **32% of the addresses where a child with a 15+ EBL resided in 1998 were addresses with a history of multiple poisonings in 1993-1997**
- **50% of the properties listed as abated in the DOH inspection database had a lead-poisoned child residing in them after the abatement**

Priority-Setting Options

Suggestions for setting priorities and selecting housing units for remediation for all three program tiers are offered in the following pages with my targeting recommendations presented in Chapter 5. Options could be selected individually or in combinations. The general assumptions we are basing these recommedations on include: 1) A child was poisoned at the address where they resided at the time of the blood-lead

[48] Duckart, Jonathan P. "An Evaluation of the Baltimore Community Lead Education And Reduction Corps (CLEARCorps) Program." *Evaluation Review*. June 1998; 22: 373-402.

test (described in detail in Limitations, Chapter 4); 2) The DOH blood-lead data, taken over a six-year period and representing an estimated 75% of Providence children, are the best indicators of the location of the risk of childhood exposure to lead; and, 3) A sufficient number of owners of selected properties will be willing to allow inspectors onto the premises for lead hazard testing and assessments and subsequently for remediation.

Each recommendation includes the tier category the option will best fit into; the general concept or idea behind the recommendation; any assumptions required by the concept; conditions that are necessary for the concept to be successful; and, the mechanism required to produce the data necessary for the recommendation. All options encompass data analyses introduced earlier in this thesis, with the exceptions of clustering analyses and Option 1 which targets addresses with a history of mid-range blood-lead levels (10-14μg/dl) in a manner similar to the earlier multiple poisoning address analyses.

1. **Target Houses For Cleaning And Stabilizing Where Multiple Children With Blood-Lead Levels In The Mid-Range (10-14μg/dl) Have Resided Regardless of Clustering.**

   Category: Tier I

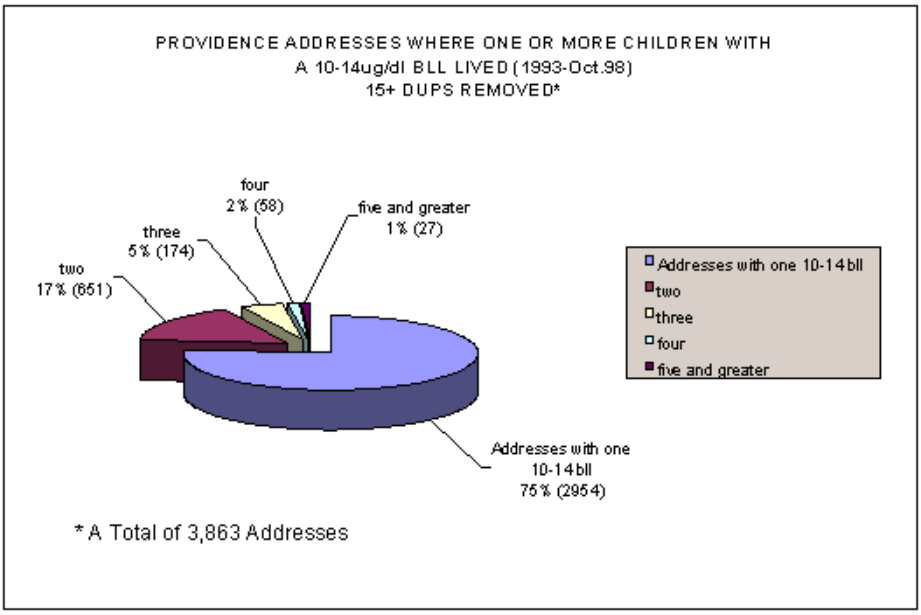
   Concept: The CLEARCorps model should be used on housing that presents a moderate risk of exposure to lead.

   Assumptions: Addresses that correlate with high blood-lead levels (BLLs) are likely to require Tier II and III remediation, and thus to be unsuitable for CLEARCorps techniques. Cleaning and stabilizing is more likely to be appropriate for housing that presents a moderate risk of exposure. *The best indicator of moderate risk is correlation of addresses with multiple, mid-range BLLs (10-14μg/dl).*

   Necessary Conditions: DOH will need to approve of the release of addresses, preferably of individual houses, to the CLEARCorps group, or DOH can contact the families and owners for the Program.

   Mechanism: Creation of an address list based on multiple mid-range BLLs (10-14μg/dl).

The idea behind this concept is to target properties with a history of only mid-range BLLs for the CLEARCorps model. Because these properties pose a moderate lead poisoning risk to children, but do not have a history of EBLs, the condition of these properties may not be as severe as the higher risk properties. Shown in the pie chart below is a breakdown of this address list with a total of 910 addresses identified as having a history of multiple mid-range BLLs.



A map of the distribution of these multiple mid-range BLLs is included as Figure 7. At present, a problem with this concept is that CES is unable to release address information to the City. Instead, DOH would have to contact the homeowners. Additionally, Joan Carbone of GENS has expressed her concern that once the CLEARCorps process has begun, and a property is tested for lead, if lead levels are high, the property will need to be cleaned, remediated, or even abated to a point where the lead levels meet clearance standards as required by HUD regulations. For this reason, properties for Tier I will have to be selected conservatively to ensure lead clearance standards are met after cleaning and lead testing. Otherwise, too many properties that enter as Tier I may be pushed to Tiers II and III because their lead levels after CLEARCorps remediation may be higher than required clearance standards. Therefore, the HUD regulations create a perverse situation -- they force GENS to select housing with the lowest rather than the highest risk in order to target the largest number of properties at the lowest cost.

2. Target Houses with a Poisoned Child after a Past Abatement.

Category: Tier I and II

Concept: Addresses with another lead-poisoned child residing there after a past abatement should be targeted for cleaning and stabilizing.

Necessary Conditions: Release of address profiles for properties with this characteristic or DOH can contact the owners or residents for the Program.

Mechanism: List of these properties is available from the address profile list.

As referred to before, of the approximately 150 properties with a history of multiple poisonings that have been abated in the past, about 50% of these properties have had another lead-poisoned child (15+ μg/dl) residing within them. Figure 8 shows a map of the distribution of these 72 addresses. While Joan Carbone of GENS thinks these properties would be ideal for the CLEARCorps model of cleaning and minimal repairs, I tend to disagree. I believe, because several of these properties have only had one unit in the structure abated (26 of the 72 addresses or 36% are coded as 2 to 5 unit structures with only one unit abated), the remaining units may be in serious deteriorated condition.

3. Target Houses That Have Been Proven To Poison Children Seriously Over Time

Category: Tiers II and III.

Concept: Addresses with multiple poisonings over the 6-year period are the highest risk properties in the city and should be targeted for stabilization and lead abatement work.

Assumption: Repair costs for the highest risk cases will not go beyond the Program's budget requirements or, if they do, owners will be willing to assume the extra costs or find other grant funds to pay the difference.

Necessary Conditions: Release of all address profiles for properties where two or more children with EBLs have resided between 1993-1998 or DOH can contact these property owners for the Program.

Mechanism: Prioritization of the list should be based on DOH action at the address. Top priority would be addresses with prior DOH action for some of the units at the property, to reduce the chance of recontamination when cleaning up units where adjacent units have been cleaned in the past and because prior DOH action might indicate higher BLLs at the property. Second priority would be given to those addresses with no prior DOH action. Additional prioritization of the list may be based on one or several of the following: total number of EBLs at the address, average BLL greater than 20 μg/dl, % tested who were poisoned (total number of children with an EBL divided by the total number of children who resided at the property at the time of their test).

ADDRESS	# w/EBL	# TESTED	%(B/C)	AVG BLL	BLL RANGE	RANGE YRS w/EBL	# UNITS	# INSP/ABTD	DOH STATUS	98 SECT 8	97 OWN OCC	BLDG VALUE
WAVERLY	3	3	100%	38.8	20--47	93,96	2 to 5	1/1	CI - Abatement - 93		YES	49400

An example of an address profile for an address on "Waverly" is given above. Prioritization of this address profile may be based on the total number of children at the address who showed an EBL (100%); the average blood-lead level for the address (38.8 μg/dl); or the fact that a child showed an EBL at the address in 1996 despite the fact that there was an abatement at the property in 1993. Further analyses using blood-lead data could determine, on a case-by-case basis, whether addresses listed in the table have poisoned several children within the same family or the same child for a long period of time.

This concept is recommended for the maintenance and abatement tiers, however release of the addresses or DOH referral is required for this concept to be successful.

4. Healthy Homes Approach: Targeting Homes Where Poisoned Children And Asthmatics Have Lived.

Category: Tiers II and III

Concept: Address homes that are contributing to more than one environmental health problem to increase risk reduction efficiency.

Necessary Conditions: Release of the 353 addresses where poisoned children and asthmatics have resided or DOH can contact these residents for the Program.

Assumption: There are certain characteristics of a house that increases the risk that a child will become lead poisoned there, which also increases the risk that the house is dangerous for an asthmatic. In addition, we are assuming that actions taken to reduce lead poisoning will also reduce asthma for the reason that HUD funding will pay only for *lead work* within properties which qualify for the Program. Individual addresses must also be released for this option.

Mechanism: Identify houses from DOH lead poisoning data that also are listed in the RI Hospital and Miriam Hospital databases of asthmatics. This could also be done using multiple-poisoning addresses to narrow choices.

This is a holistic approach that has been recommended by Kim Mowery, the other CES student I have worked with on the issue of lead poisoning in Providence. Her thesis looks at the issue of combating lead poisoning and asthma through the creation of healthy homes.[49] I believe this concept, combined with Option 3, would be a strong approach towards targeting high-risk addresses for abatement.

5. Targeting Areas Rather Than Individual Addresses For Cleaning And Stabilizing

Category: Tier I

Concept: If the current confidentiality restriction cannot be modified, areas (blocks, block groups or street segments) with moderate-risk addresses (but including addresses where no poisoning has occurred) would be identified rather than individual addresses.

Mechanism: Targeting would be done by mapping data and determining priority blocks for CLEARCorps to visit. As above, the data for this analysis would be those addresses where multiple children have resided with mid-range BLLs (10-14μg/dl).

Figure 10 shows an enlarged map of a region of South Providence with the block in the lower left hand corner as a potential candidate for this approach.

[49] Mowery, Kim. *Housing Conditions in Providence – Enough to Make You Sick?* Center for Environmental Studies, Brown University. May 1999.

Because the CLEARCorps model is based on a neighborhood approach of targeting blocks rather than individual houses, this approach may be as effective as Option 1. An important component of adopting a CLEARCorps model for an "area" level is the elimination of low-risk properties within a target area and the identification of additional problematic properties. By cleaning those properties where children have resided but never been poisoned and targeting the most egregious properties in an area, valuable information on neighborhoods in Providence will be attained not only for the HUD program but for future lead remediation programs as well.

6. Combined Address List To Target High-Risk Properties

Category: Tiers II and III.

Concept: If the confidentiality restrictions cannot be relieved, CES would create a combined address list containing the results of two different methods of predicting lead poisoning risk – one from DOH blood-lead data and the other using poor housing condition data (e.g. housing code violations, environmental violations). The combined address list would protect confidentiality while still allowing the City to target the most egregious properties.

Mechanism: Combination of the multiple poisonings address list with the addresses identified as high-risk from housing conditions but that did not yet have a child residing there with an EBL (i.e., the properties with both code and environmental violations but no identified EBLs in 1997-1998).

Figure 11 shows the 143 addresses in 1997 with combined environmental and code violations where a child with an EBL did not reside in 1997. The idea behind this concept is that addresses with both environmental and code violations represent a list of high-risk addresses that may poison children in the future due to the statistical correlations of these two indicators to elevated blood-lead levels in earlier analyses. This list, combined with a list of addresses in the DOH inspection database which

have been closed and referred for Legal/Code Enforcement,[50] would evade the confidentiality restriction because both lists are public records and open for public access.

7. Neighborhood Approach -- Target High-Risk Houses Based On Their Location In Relation To Other High-Risk Properties

Category: Tiers II and III.

Concept: There are some clusters of high-risk housing, as identified by multiple poisonings. Following the Heart of Elmwood model, targeting such clusters might improve the quality of an entire block or neighborhood.

Assumption: Access could be gained to most of the properties in a cluster for lead hazard inspections, assessments and remediation work.

Mechanism: The properties would be identified based on an analysis of clusters in the city derived from mapping the multiple poisonings list (a list of properties where two or more children with elevated blood-lead levels (15μg/dl and above) have resided over a 6-year period).

Figure 10 shows an image of one such cluster along the street that transects the bottom of the diagram. The street has a row of high-risk addresses surrounded by several addresses where children have resided in the past. The concept here is to solve the lead poisoning problem one cluster at a time, as the Greater Elmwood model has accomplished within a nine-block area. This option approaches lead reduction in a more holistic manner. By improving entire blocks and/or several blocks within a neighborhood, the added benefit of greater neighborhood pride is attained. Tenants may be more likely to seek out these properties and landlords may have a greater incentive to clean up their properties if several of their neighbors have done the same.

[50] The DOH has provided the City of Providence a list of closed cases referred for legal and code enforcement on a regular basis.

8. Isolated Property Approach -- To Address Recontamination Concerns

Category: Tiers II and III.

Concept: According to the abatement experience of GENS,[51] there is a high recontamination of abated properties by lead soil and dust originating from neighboring unabated properties. A Cincinnati, Ohio study conducted by C.S. Clark, et al. supports this idea. Researchers found that Cincinnati's extensively rehabilitated housing, which had primarily been gutted, exteriors stripped of paint, and repainted with low-lead or lead-free paint, "frequently existed in close proximity … with houses containing abundant sources of lead." Although these rehabilitated houses contained lower lead paint levels than the city's public housing (built since the 1930's), "children in rehabilitated housing had higher blood-lead levels than children in public housing, suggesting that lead sources in the immediate neighborhoods of the rehabilitated housing may be factors."[52] Once remediated, houses surrounded by other houses where poisonings have never occurred should have a lower risk of recontamination.

Assumption: Surrounding properties that have housed children in the past but have never housed a poisoned child are low-risk properties.

Necessary Condition: The confidentiality restriction must be relieved or DOH could contact these homeowners.

Mechanism: Identifying high-risk houses surrounded by low-risk properties. Hence, the identified address would be surrounded by houses that were not identified as high-risk through either the multiple poisonings or poor housing condition indicators and, therefore, are properties that would have a small likelihood of recontaminating the remediated property.

Again, Figure 10 is used to illustrate this concept. In the right hand top corner is a high-risk property surrounded by homes where children have resided in the past but with no record of multiple poisonings. The idea here is to abate this high-risk home with the assurance that recontamination of this property from soil and dust originating from other high-risk homes will be relatively low. This option is

[51] Carbone, Joan. Greater Elmwood Neighborhood Services. Meeting between GENS, CES, Mayor's Policy Office and City of Providence to discuss priority setting options for the HUD grant. April 9, 1999.

[52] Clark, C.S., et al. "Condition and Type of Housing as an Indicator of Potential Environmental Lead Exposure and Pediatric Blood Lead Levels." *Environmental Research.* 1985; 38: 46-53.

recommended for the maintenance and abatement tiers as lead hazards at isolated properties would need to be remediated or abated for this strategy to be successful. However, in addition to the assumption listed above, the list of general assumptions introduced earlier must be in effect for this concept to be effective.

9. Targeting Homes Through Coordination With The Visiting Nurses Association

Concept: Coordinate the identification of high-risk homes for the Program through the Visiting Nurses Association's (VNA) home visits to high-risk children in Providence.

Mechanism: VNA annually visits the homes of an estimated 6,000 children defined as high-risk by the DOH. In July, 1999, VNA commenced a visiting program for addresses where children with blood-lead levels of 15-19μg/dl reside. Nurses could distribute information about the program to the families and recruit residents to sign agreements for the Program.

During a meeting with Dr. Patricia Nolan, Director of the DOH, and other DOH members and grant partners, this concept was highly recommended as a way to enter homes, use the nurses to identify them as high-risk through a visual assessment, and encourage tenants and landlords to participate in the City's HUD Program. I believe this concept would work well combined with one or several of the other eight concepts because it provides access to properties that may otherwise be difficult to enter.

Chapter Four

Limitations

Limitations of our data analyses have become evident during the past year that I have been working on this issue. Problems with the Tax Assessor's database have been evidenced throughout this thesis and were discussed at length in Chapter Two. The majority of the inconsistencies appear to be a result of the database being used for billing purposes rather than for use as a master address list of all residential properties within the city.

Other limitations include:

- There is no good way to determine that a child was poisoned at the address where they resided when tested. Children in Providence, particularly in lower income areas, are known to have a high rate of transience. A child moving two or three times a year is not an infrequent event. For this reason, we will never be able to determine *with certainty* that a child was poisoned at a particular address (without conducting individual case histories). A child may have been poisoned at a Smith Street address where they resided a few weeks earlier or, perhaps, the grandmother's house, day care center or playground down the street. However, the strong correlations of all five of our indicator analyses show that our results remain significant despite the presence of this uncertainty in our data.
- Analyses conducted in this thesis do not translate readily to the increased risk a particular child may have when residing at x-address, but rather estimate the increased risk a population of children may encounter when residing in problematic housing within Providence. Therefore, rather than assuming that a particular

- While the majority of environmental violation and code violation addresses are actively found by inspectors through large-scale geographic canvassing, a small number of the addresses may have been targeted by the City after receiving a complaint call. CES has found such trends in the City's Code Violation data. However, address targeting would pose a problem only if the complaints had to do with lead hazards in a particular area.
- The Owner's Occupancy database was derived from the Tax Assessor's database by matching the billing address with the street address. However, the number of owner-occupied properties will be underestimated due to the aforementioned discrepancies in the Tax Assessor's database.
- As mentioned previously, most information we have is based on addresses, not housing units. Therefore, we are unable to determine which units children have resided in, been poisoned in, or whether a particular child resided in a unit after a past abatement. As a result, priority-setting in this thesis has focused on targeting an entire property rather than just the individual units within a house. This does not pose a strong limitation for the HUD Program because Joan Carbone of GENS is determined to abate all units in a targeted address.

- Accurate owner address information has not been available. Locating this information could be problematic and time consuming even if CES is able to release our address lists to the City or if DOH contacts the owners.
- Regarding the DOH Inspection database, the BLL that triggered an inspection was reduced from 25 to 20 μg/dl in 1996. This would have affected which properties the DOH inspected before this date. In addition, our definition of a lead-poisoned child also makes it seem that DOH action was not taken at several properties where children resided with EBLs. For example, if four children with EBLs of 15-19 μg/dl had resided at an address between 1993 through 1996, under our 15+ μg/dl definition of lead poisoning, we would define those four children as lead-poisoned despite the fact that not one of their blood-leads was higher than 19 μg/dl. However, because the DOH does not define a child as poisoned until they have an EBL of 20+ μg/dl, the DOH would not have inspected the address in the past.
- DOH enhanced regulations for inspections and abatement became effective on July 1, 1993. Units listed as abated in the DOH inspection database prior to this date may be problematic due to the less stringent nature of the regulations. Therefore, children residing in properties where an abatement occurred in 1992 or early 1993 may show higher EBLs than children residing in properties abated after July 1, 1993.
- For the City's HUD Program, participation in the Program is voluntary. While the City's Code Enforcement Office, DOH, and the Court can place considerable pressure on landlords to participate in the Program, I fear that many landlords in the poor areas of the city will be unwilling or financially unable to comply. My

Chapter Five

Discussion and Conclusion

Childhood lead poisoning in the City of Providence **is** a serious problem. This is particularly true in low-income areas where a large percentage of deteriorating, turn of the century housing exists. This thesis identifies a number of options the City may use to identify and target problematic housing for the purposes of cleaning, stabilizing and abatement through the HUD Lead Hazard Control Program. By using indicators of poor housing condition that correlate to high blood-leads, the City could identify housing that has a statistically higher risk of poisoning children in the future. Other approaches that may be used include targeting housing that has a history of poisoning children or housing where multiple children with mid-range BLLs have resided.

In the decision matrix illustrated below, I have listed the eight targeting options available for the Program, broken down into the three tiers, and based on a determination of 1) whether problematic addresses will be released to the City or owners and residents of the properties will be contacted for the Program through a DOH intermediary, or 2) whether confidential address information will remain protected. Options are numbered in the order they were presented earlier with Option 9 (Visiting Nurses Association) absent from the matrix because 1) of its status as a currently-operating DOH program, and 2) the DOH recommends this option for use in conjunction with any of the eight options listed above.

DECISION MATRIX

	ADDRESSES RELEASED/ DOH INTERMEDIARY					CONFIDENTIALITY PROTECTED		
	Multiple Mid-Range BLL Addresses (Option 1)	Past Abatement (Option 2)	History of Multiple Poisonings (Option 3)	Healthy Homes (Option 4)	Isolated Property (Option 8)	Targeted Areas (Option 5)	Combined Address List (Option 6)	Neighbor-hood Approach (Option 7)
Tier I								
Tier II								
Tier III								

To give an example of two available options for Tier I, Option 1, using multiple mid-range BLL addresses, and Option 2, targeting properties where children have resided after past abatements, could be used for locating addresses for cleaning and minimal stabilization through the CLEARCorps model. Both options would require that addresses be released to the City or that the DOH directly invite residents and owners of the properties to participate in the Program.

The dark boxes above represent my recommendations for targeting problematic addresses through the HUD Program. I believe Option 5, targeting areas with several moderate-risk properties for cleaning and stabilizing, would be the most effective option for Tier I. This is based on the fact that CLEARCorps has historically focused their cleaning campaigns on block or neighborhood *areas* rather than *individual* properties. This option would enable mapping procedures to be used for the selection of smaller

block or neighborhood areas where large concentrations of moderate-risk properties are found. Therefore, Option 5 allows CLEARCorps to more successfully and efficiently target moderate-risk areas than Option 1, which directs CLEARCorps crews to visit *individual* moderate-risk properties throughout the larger target area. The added benefit of this option is that confidential address information would be protected because CLEARCorps would be given only the block or neighborhood location of these moderate-risk property clusters and a list of individual addresses would not be necessary.

For Tier II, Options 2 and 3 are recommended for targeting addresses with a history of multiple poisonings and problematic abatements, both of which require high-risk addresses to be released to the City or owners and residents of the properties to be recruited for the Program through a DOH intermediary. The address lists generated for these options are ideal for Tier II because they include properties with a history of multiple poisonings, properties where poisoned children have resided after past abatements, and encompass addresses that may require more concentrated remediation work, such as minimal repairs, but not necessarily Tier III abatements. These options would be more efficient than 6 and 7 because they identify the highest-risk addresses in the target area rather than approaching the problem by targeting the area in its entirety through a hit or miss approach.

For Tier III, I recommend Options 3 and 4. As with Tier II, these options identify the most problematic properties in the city based on their histories instead of approaching the problem through a blind-fold. Therefore, rather than focusing on the target area and speculating which properties are the most problematic in the area, Options 3 and 4 use address lists to determine the exact location of the high-risk properties. These address

lists are likely to contain egregious properties that may be ideal candidates for Tier III abatements.

At the time I am writing this thesis, in July 1999, the DOH is still giving consideration to our request to release problematic addresses to the City for prevention and enforcement purposes. At this time, a date for the decision and the outcome are unknown. In order to target high-risk properties throughout the city efficiently and within the funding constraints of the HUD grant, I believe the targeting strategies introduced in this thesis that identify addresses or small, concentrated areas for cleaning, stabilizing and abatement make the most sense. A less effective means would be to target the census tract block groups where several problematic addresses have been located, which is much more of a hit or miss approach.

The renewed prevention focus and receipt of the $4 million HUD grant illustrates the progress the City is making towards controlling this childhood disease. While HUD funding may target only a small number of the city's problematic homes, the creation of the Task Force and Lead Hazard Control Program have already opened communication pathways between grant partners and community members. In Providence, a coordinated effort by all actors – parents, tenants, private homeowners, local, state and federal governments, and non-profit agencies – will be necessary to wipe out this disease. So far, the City's progress has been received with enthusiasm. But, until punitive incentives exist for landlords to clean up their properties and fix the lead problems, I doubt that the best of intentions will go very far.

VI. Appendices

Appendix I

Methods

Case-Control and Cohort Analyses

Case-control and cohort tests were used by ES192 for analyses of 1997 blood-lead data to determine the statistical validity of the correlations between elevated blood-leads (15 μg/dl and above) and the five indicators of housing characteristics. For the analyses found later in this thesis, only the case-control analysis was used but all other procedures remained the same.

All data were cleaned by removing unit/apartment references in addresses and ensuring that street names were spelled correctly when compared to the *Rhode Island Authentic Street Guide*.[53] This was conducted to ensure that address names between databases would be equivalent so Excel could determine whether addresses matched. After cleaning the original DOH 1997 blood-lead data of 12,152 records, we extracted the highest blood-lead level for each child, leaving 9,378 records. Because the highest risk children are tested several times throughout the year in many instances, this procedure was used to avoid bias in the sample. For a case-control analysis, the data were then separated into four groups to create a 2x2 matrix with the following information: Children with EBLs (15+ μg/dl) who resided at addresses *with the Indicator* **(a)**, for example, Code Violations; Children with EBLs who resided at addresses *without Code Violations* **(b)**; Children with low BLLs (0-10 μg/dl) who resided at addresses *with Code Violations* **(c)**; and, Children with low BLLs who resided at

[53] *Rhode Island Authentic Street Guide*. Meg Maps, Connecticut, 1998.

addresses *without Code Violations* **(d)**. Then the Risk Ratio is calculated by dividing a/b by c/d, the Variance by adding 1/a + 1/b + 1/c + 1/d; and the 95% confidence interval for the Upper and Lower Bounds by using the formulas: $e^{\ln(RR) \pm 1.96\sqrt{var[\ln(RR)]}}$ and var[ln(RR)] = 1/a + 1/b + 1/c + 1/d. The table below is an example of the 2x2 matrix:

	ADDRESSES WITH CODE VIOLATIONS	ADDRESSES WITHOUT CODE VIOLATIONS	
NO. KIDS WITH BLLs (15+)	263 (a)	1033 (b)	1296
NO. KIDS WITH BLLs (0-10)	1133 (c)	9986 (d)	11119
TOTAL	1396	11019	12415

Cohort analyses are conducted in a similar fashion but data are broken into children with EBLs and children without EBLs (0-10 μg/dl) instead.

Building Value Analyses

Case-control analyses using building value as an indicator are more difficult to analyze because, unlike the other indicators, which are bivariate (meaning that an address was either 1) owner occupied or 2) non-owner occupied), building values are assessed using a range of values from $0-$5,000,000. Because building value is characterized as multivariate (addresses have numerous integer values), I trimmed the data for 1997 and 1998 analyses into two distinct groups: a low-assessed value group of $1,000 to $49,999

and a high-assessed value of $100,001-$749,999. The lower end of the database (under $1,000) and upper end ($750,000 and above) were removed to ensure that large scale apartment complexes worth millions of dollars and properties with building values of very small amounts, possibly a result of the problems in the Tax Assessor's database, were not skewing our analyses. The middle cut, determined by finding the median of approximately $76,000 and cutting $25,000 in each direction, was conducted to attain two distinct groups (a high and low) for the case-control analysis. A similar procedure was used for the building value analysis conducted in the South Providence Enterprise Community but because the median fell much lower, at $54,000, I cut approximately $25,000 in each direction to attain a low-value group of $1,000-$29,999 and a high-value group of $80,001-$749,999.

Analyses for Addresses with Multiple Poisonings

Using DOH blood-lead data for 1993 through October 1998, addresses were cleaned and all floor and apartment references were removed. The highest blood-lead level per child ID per address was determined and all 14 and under BLLs were deleted. A pivot table function was utilized to generate a list of addresses with one or more children with an EBL residing there during the six-year period. These data were then placed into a pie chart and locations were mapped using an address-matching program.

Analyses for Percentage of Residential Addresses, Poisoning Events and Percentage of Children in Addresses with Multiple Poisonings

1. By creating a list of all addresses where a child had been tested between 1993 through the first three quarters of 1998, and running the exact function on the addresses, thereby isolating one entry per individual address, I determined there were 16,069 residential addresses in the city where children resided and were tested during this time period. Based on prior calculations of addresses to determine that children with EBLs of 15+ μg/dl have resided in 3,583 residential addresses in the city and children with mid-range blood-leads (10-14 μg/dl) have resided in 3,863 residential addresses, a total of 7,446 or 46% of the residential addresses in the city where a child was tested between 93-98 contained a child with a blood-lead level of 10+ μg/dl.
2. In the Providence Tax Assessor's database, 40,362 addresses in the city are listed as residential (either single-family homes, multi-family homes (2-5 units), or apartments (6+ units). Based on past analyses using this database, approximately one-third of the DOH address data do not match. As a result, an estimate of the total number of residential addresses in the city would be derived by adjusting the listed residential address figure by one-third and equal approximately 54,000 total residential addresses in the city as a rough estimate. A possible reason for the low-matchability rate between the Tax Assessor's and DOH database may be the exclusion of public housing properties from the Assessor's database. However, after attaining a list of public housing in the city from the Providence Housing Authority, with a total of 400 public housing addresses, there does not appear to be the enormous amount of public housing in the city that would account for the 30% inaccuracy rate in the database.

3. Taking the residential address analysis one step further, the total number of children with EBLs residing in addresses rather than the total number of poisoning events was determined by taking the highest BLL/child/year, combining all years, isolating all 15+ EBL tests, sorting by ID, running the exact function, and deleting all duplicate tests, resulting in an address list of the highest EBL, per child, for all years. Through this analysis, there were 4,424 individual children residing at 3,027 addresses. This way, each child is accounted for at the address where they resided with their highest EBL.
4. Adjustment of the total number of residential addresses does not matter much. 3,583 addresses housed one or more children and 1,210 addresses housed 2+ multiple children with EBLs. Using the adjusted total residential address figure for the city, 3583/53618 or 6.7% of the city's residential addresses housed 1+ child with an EBL and 1210/53816 or 2.3% of the addresses had multiple children with EBLs. These percentages are raised only slightly when using the unadjusted figure for the city's total residential addresses: 3583/40362 or 8.9% and 1210/40362 or 3.0% respectively.

The Housing Pool

To look at the number of old versus new addresses that arise in the DOH blood-lead database for each year between 1993-October 1998, data was analyzed by running the exact function on all data entries for each separate year, removing the trues (duplicates) and then using the Vlookup function to run the individual address lists per year against the prior years.

Total Number of Addresses in 94 = 7,055 (List compared to 93)
New: 3698
Old: 3357

Total Number of Addresses in 95 = 6,256 (List compared to 93 and 94)
New: 2454
Old: 3802

Total Number of Addresses in 96 = 6143 (List compared to 93-95)
New: 1905
Old: 4258

Total Number of Addresses in 97 = 6393 (List compared to 93-96)
New: 1768
Old: 4625

Total Number of Addresses in 98 = 5431 (List compared to 93-97)
New: 1236
Old: 4195

Looking Closer at 1998:
Taking list of all 10+ addresses for 1998 and comparing to 93-97 Address list
Total: 1362
New: 212
Old: 1150

List of 15+ BLLs addresses for 1998 compared to 93-97 address list
Total: 588
New: 87
Old: 501

10-14 BLLs
Total: 964
New: 145
Old: 819

15+ List for 1998
Compared to addresses where 1+ children had EBLs in 93-97
Total: 588
New: 261
Old: 327

15+ List for 1998
Compared to addresses with multiple (2+ EBLs) in 93-97
Total: 588
New: 402
Old: 186

Appendix II

ADDRESSES IN PROVIDENCE WHERE 2 OR MORE CHILDREN WITH ELEVATED BLOOD LEVELS HAVE LIVED DURING 1993 - October 1998

Included in the associated table are detailed descriptions of 25 addresses in Providence where two or more children with EBLs (Elevated Blood-Lead Levels – 15µg/dl or above) have lived during the years 1993 through October 31, 1998. Street names and address numbers have been omitted for confidentiality purposes. Brief descriptions of the columns in the table follow:

Column #	Column Heading	Description
A	ADD	List of 25 Providence addresses where two or more children with EBLs have lived during the 1993-1998 time period. Street names and address numbers have been omitted.
B	# w/EBL	Total number of children per address whose blood-lead test results revealed an EBL of 15µg/dl or above while the child resided at the address during the time period.
C	# TESTED	Total number of children per address who received a blood-lead test while residing at the address during the 6 year time period.
D	%(B/C)	The # w/EBL divided by the # TESTED at the address, revealing the overall percentage of children who had an EBL while residing at the address.
E	AVG BLL	The average of all blood-lead tests reported for children living at the address.
F	BLL RANGE	Lowest to Highest BLL range for all blood-lead tests reported for children living at the address on the date of testing.
G	RANGE YRS w/EBL	The range of years during which a high blood-lead was reported for children residing at the address.
H	# UNITS	The number of housing units at the address calculated by address matching the Tax Assessor's database to the DOH blood-lead database.
I	# INSP/ABTD	The first number represents the total number of units at the address inspected by the DOH. The second number represents the total number of units that appear to have been abated at the address. Both figures are based on a DOH inspection database that CES received last summer.
J	DOH STATUS	According to the DOH inspection database, the current status of the address is listed. The symbol (Cl) stands for a Closed Status while (Open) identifies the case as still pending according to the DOH records. After the (Cl) abbreviation, the reason for the case closure and the date of closure will follow.
K	98 SECT 8	According to a list provided by the Providence Housing Authority, whether the property had Section 8 status in 1998.

L	PUB HSG	According to a list provided by the Providence Housing Authority, whether the property had public housing status in 1998.
M	OWN OCC	Whether the owner of the property resides at the address. Determined by using the Tax Assessor's database.
N	BLDG VALUE	Based on the Tax Assessor's database, the building value of all property at the address. #N/A represents the absence of the address from the Tax Assessor's database.

List of Possible DOH Actions

Based on ADDRESS STATUS CODE in DOH Inspection database

Open
Cl – DOH Action Complete, Ref. To Legal/Code Enforcement
Cl – Child Moved
Cl – Refused Inspection
Cl – No Response to Letters, Phone Calls, etc.
Cl – Child > 72 months of age
Cl – No Violation
Cl – Parent = Owners; Ongoing Violation
Cl – Referred to DOH for Legal Action
Cl – Backlog – Awaiting Initial Inspection
Cl – BLL less than 25
Cl – Medical follow-up > 3 months
Cl – Not Recommended for Alternative Housing
Cl – Pending Soil
Cl – Per Family Health/ Dr. Simon
Open – Interior Abated – Exterior Pending
Open – Exterior Abated – Interior Pending
Open – Pending HUD
Open – Pending Elmwood
Open – Address Under Investigation
Cl – Closed-Limited Directed Inspection
Open – Address Referred to Section 8 Housing
Cl – Inspected prior to regulations

Appendix III

Address Profiles

A	B	C	D	E	F	G	H	I	J	K	L	M	N
ADD	**# w/ EBL**	**# TESTED**	**% (B/C)**	**AVG BLL**	**BLL RANGE**	**RANGE YRS w/EBL**	**# UNITS**	**# INSP/ ABTD**	**DOH STATUS**	**98 SECT 8**	**PUB HSG**	**97 OWN OCC**	**BLDG VALUE**
1	3	8	38%	17.6	1--35	93-96	2 to 5	1/1	1) Cl - Abatement - 93 2) Cl - Child Moved-94				113400
2	3	11	27%	9.3	2--29	94,98	2 to 5	1/1	Cl - Abatement - 93	YES			107100
3	4	9	44%	11.0	2--18	94-95,97	2 to 5	2/2	Cl - Abatement - 93,96				107100
4	4	12	33%	15.7	5--32	93,97-98	2 to 5	0/0	Cl - Child Moved - 98				48900
5	3	5	60%	11.2	3--28	93,95-96	2 to 5	3/3	Cl - **HUD I Property**				118000
6	2	8	25%	10.5	2--20	93,95	2 to 5	3/3	Cl - **HUD III Property** - 98 46-48 Goddard St.				64700
7	2	6	33%	12.0	5--25	93-94	1	2/2	Cl - **HUD III Property** - 98 87-89 Ontario St.				47200
8	3	5	60%	13.9	1--29	96-97	--------	5/5	Cl - **HUD III Property** - 98 -- 15-17 Sumter St.				#N/A
9	4	10	40%	17.5	5--28	93-97	2 to 5	3/3	Cl - Legal Act. - 98 **HUD III Property** - 98				0
10	4	6	67%	24.4	7--37	97-98	--------	1/0	Cl - Ltd. Dir. Insp - 98				884700
11	2	2	100%	18.1	10--27	94,98	--------	0/0	Cl - Med. Followup > 3 mo. - 95				#N/A
12	2	5	40%	14.3	7--37	93,95	2 to 5	0/0	Cl - Medical Followup >3mo. - 95			YES	69500
13	3	3	100%	18.7	11--27	94-96	--------	1/0	Cl - No Response - 96				#N/A
15	4	7	57%	17.7	5--29	93,95-98	2 to 5	0/0	Cl - No Response-93				40000
16	4	13	31%	9.6	4--18	9,395,096	2 to 5	0/0	Cl - No Response-93			YES	41100
17	2	2	100%	19.5	3--35	93-94	1	1/0	Cl - No Viol - 94			YES	54600
18	2	2	100%	26.8	20--63	96-98	--------	1/0	Cl - No Viol. - 97				#N/A
19	3	4	75%	12.5	3--30	93,95-96	--------	1/0	Cl - No Violation - 94		YES		#N/A
21	2	2	100%	14.8	2--29	93-95	2 to 5	1/0	Cl - Parents=Own - 93			YES	80200
22	4	8	50%	19.4	1--35	96-97	1	1/1	Cl - Pending Soil - 97				40300
24	2	5	40%	21.7	8--50	93,96	2 to 5	1/0	Cl - Ref. To Legal - 93				35100
25	3	3	100%	28.2	25--36	94-95	--------	1/0	Cl - Ref. To Legal - 96				3700

VI. Figures

Figure 1

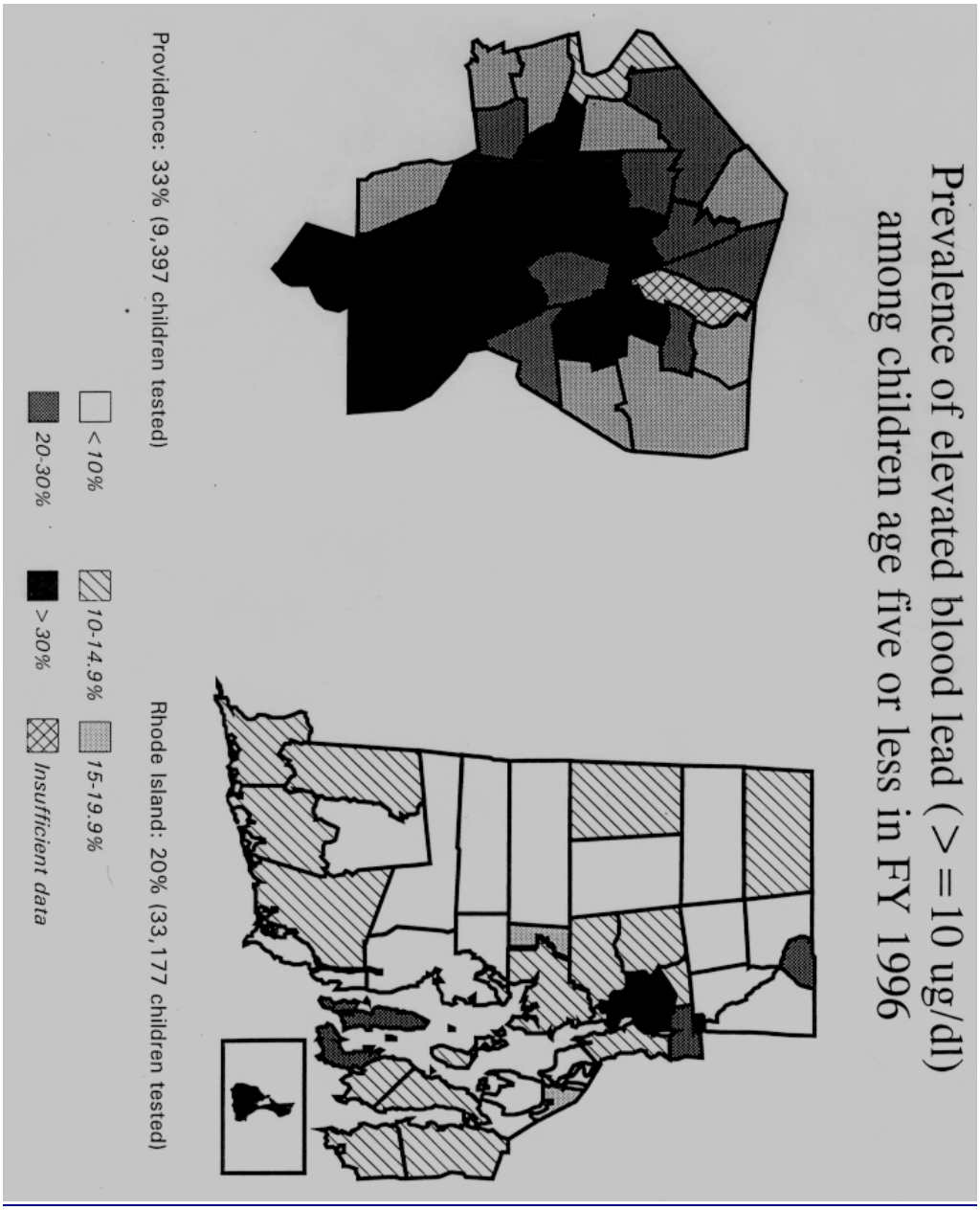


Figure 2

Providence Children with EBL's (15µg/dl and above) in 1997-Oct 1998 (Total = 1296)

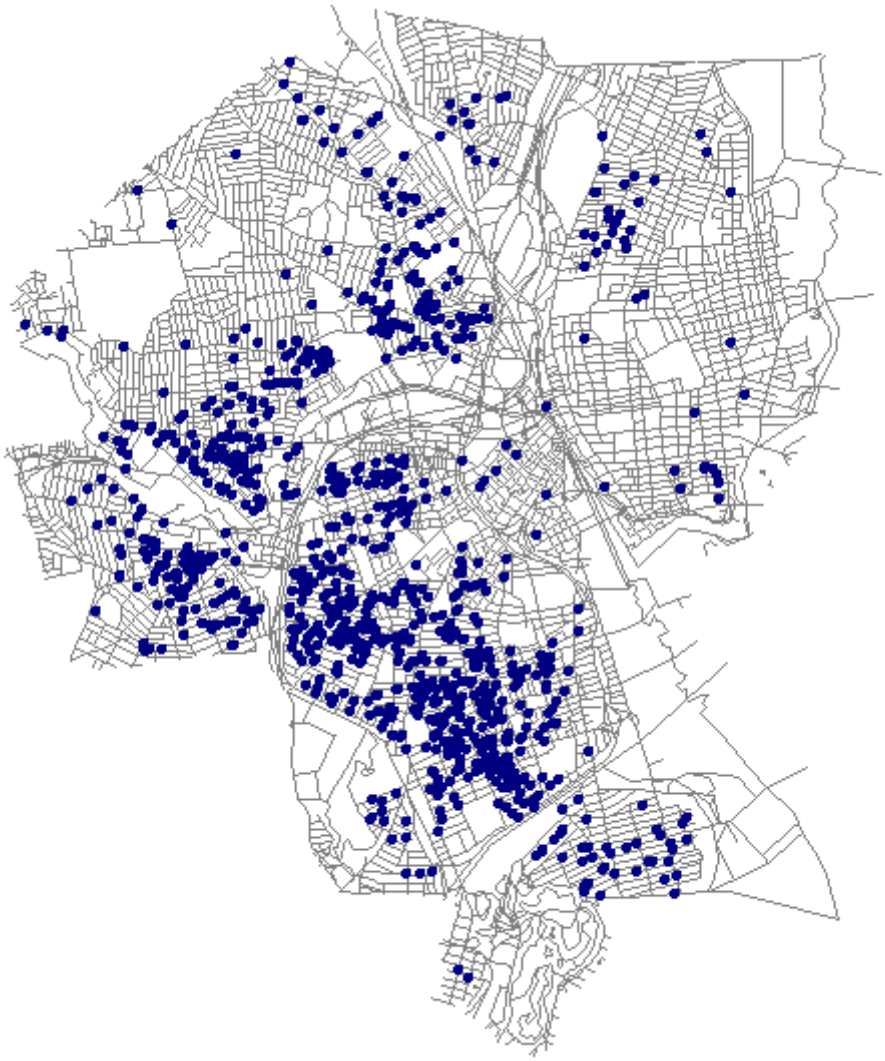


Figure 3

Housing Code Violations and BLLs ≥15 ug/dL 1997-Oct 1998 (Total = 263)

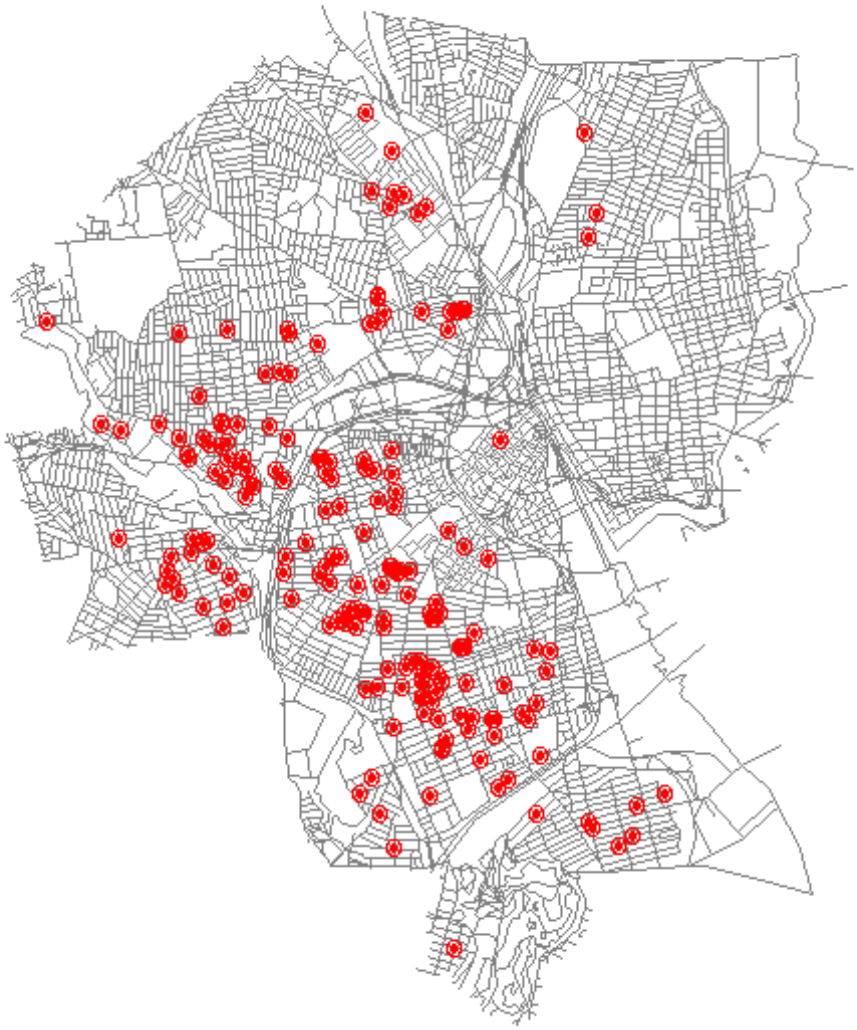


Figure 4

Providence Addresses Where Multiple Children Have Resided With Elevated BLLs (15μg/dl and greater) (1,210)

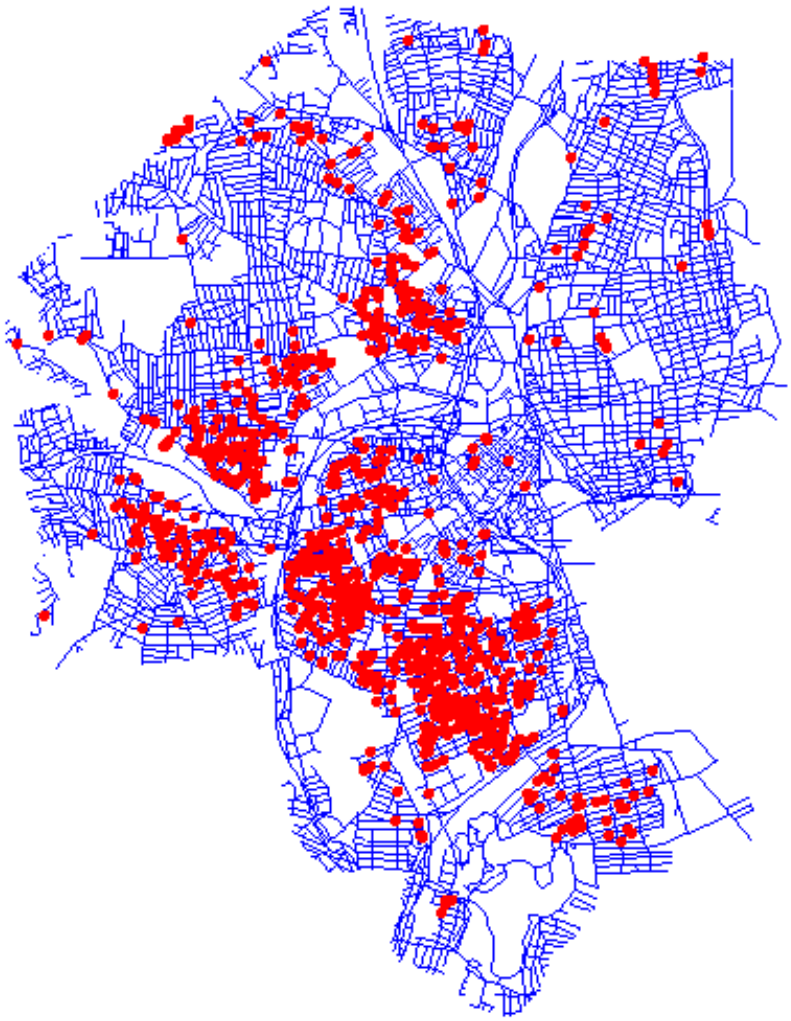
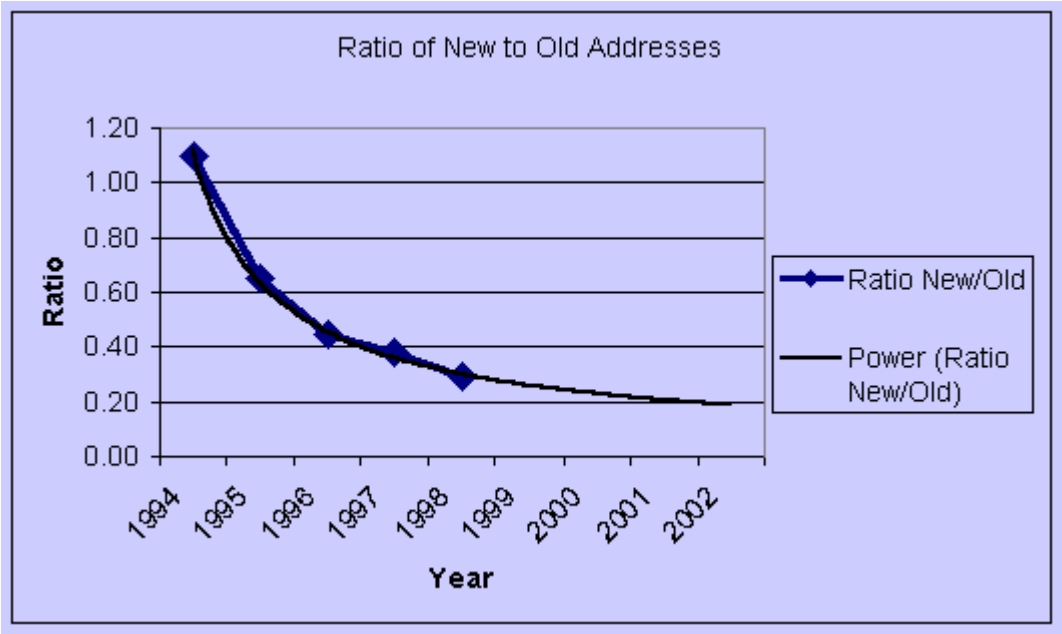


Figure 5

Estimated Growth of the Housing Pool



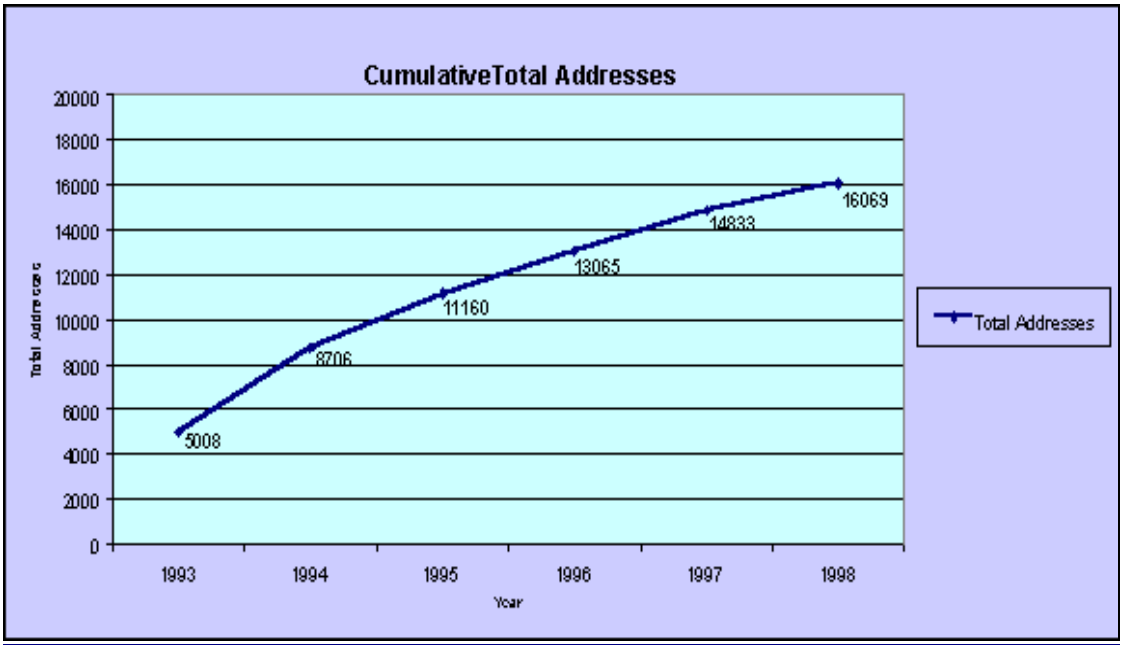


Figure 6

Blood-Lead Level Comparison in Three Providence Block Groups Using Number of Families Below Poverty with Children under 18

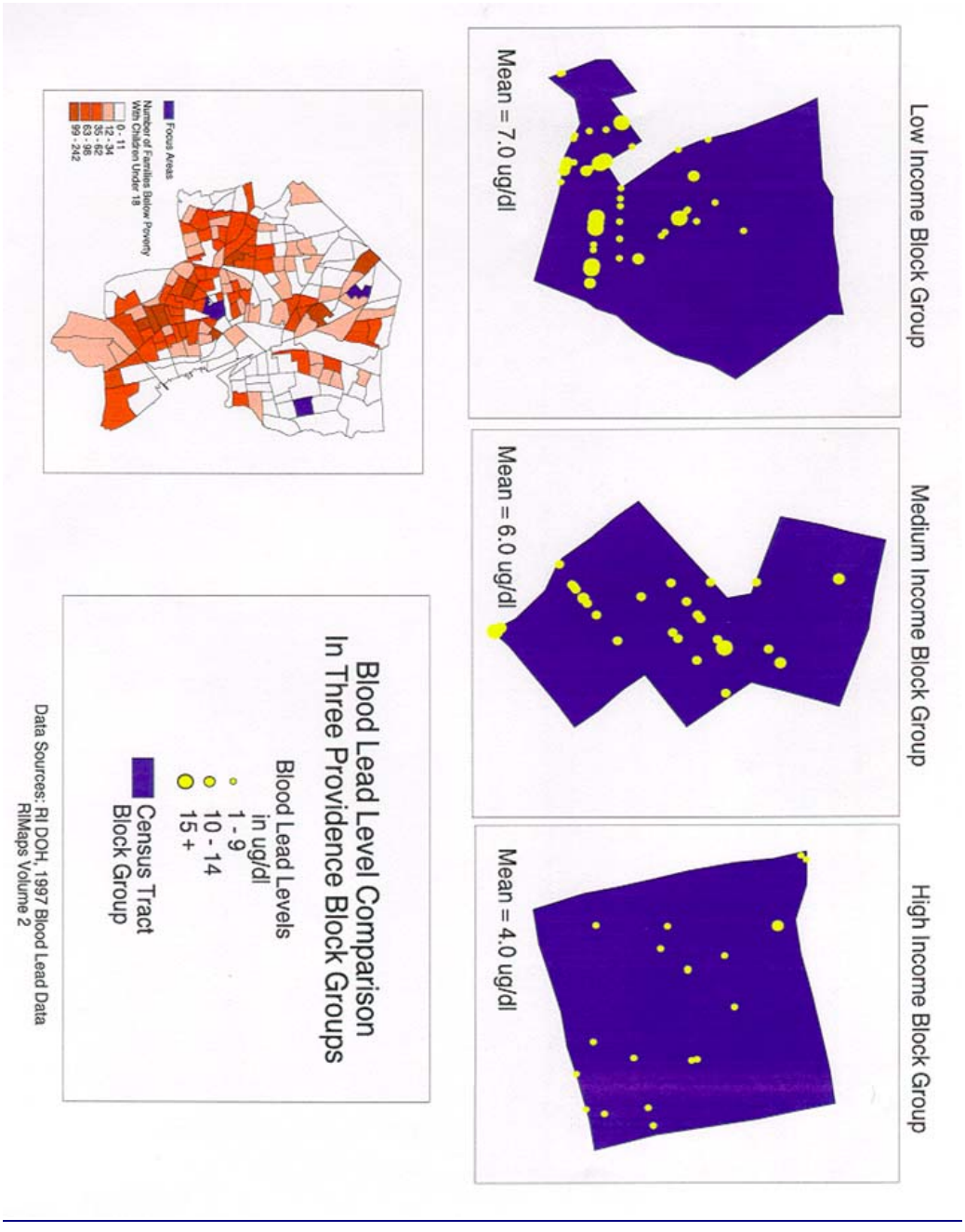
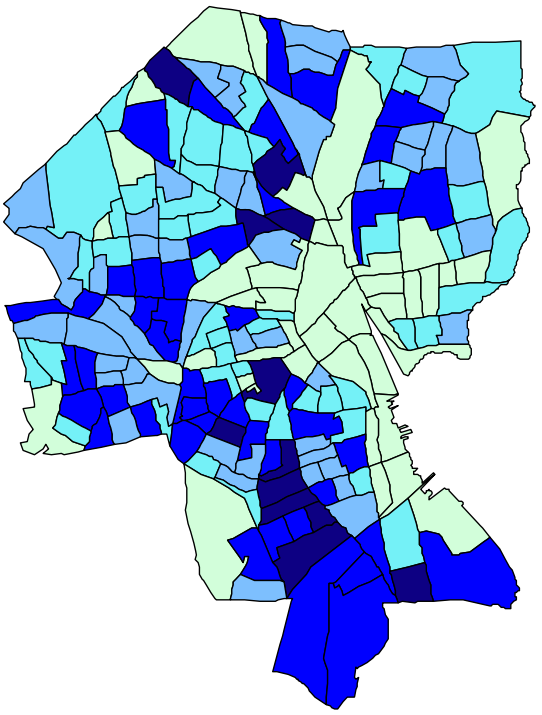


Figure 7

Providence Census Tract Block Groups Count of Persons 0-5 yrs.



Count of Person 0 to 5 years old.shp
- 0 - 25
- 26 - 60
- 61 - 104
- 105 - 172
- 173 - 350

N
W E
S

Figure 8

Providence Addresses Where Multiple Children Have Resided With Mid-Range Blls (10-14µg/dl) (910)

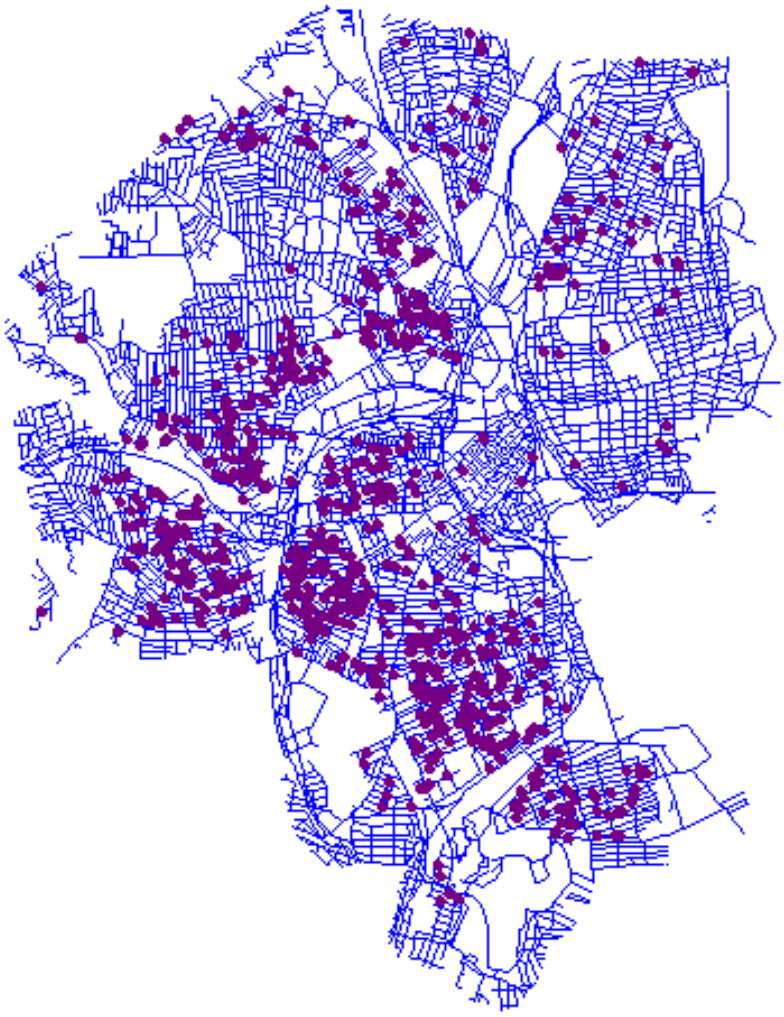


Figure 9

Providence Addresses with a Poisoned Child After a Past Abatement

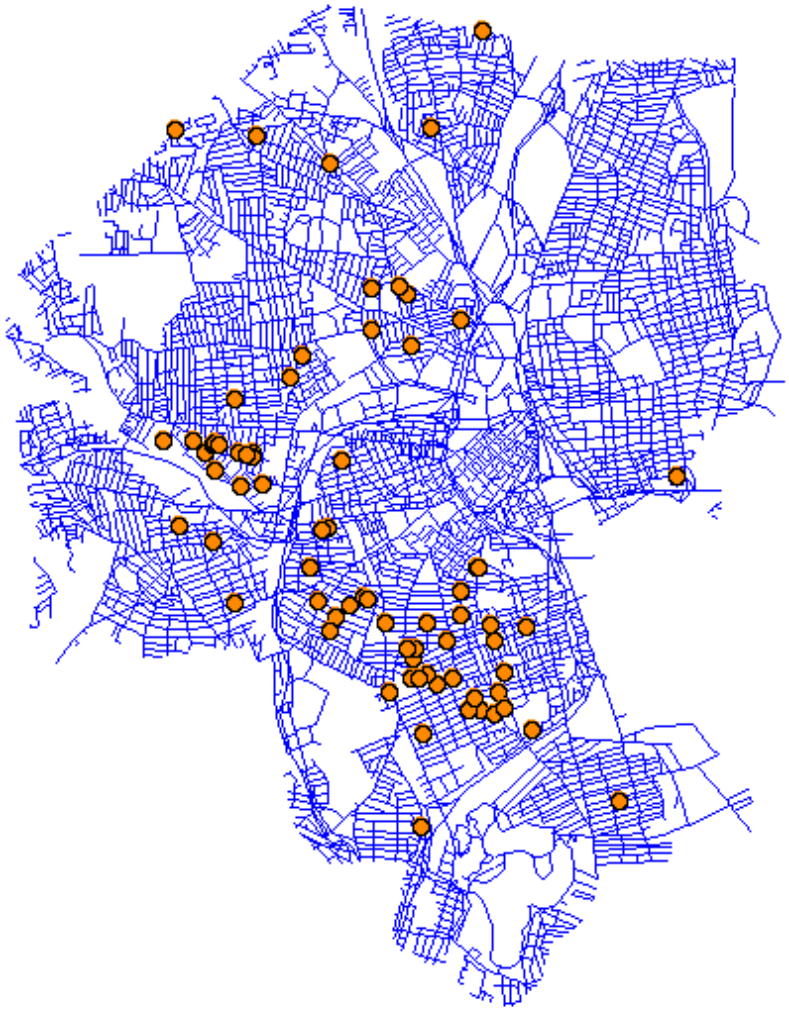


Figure 10

Houses with Asthmatics and Lead-Poisoned Children (353)

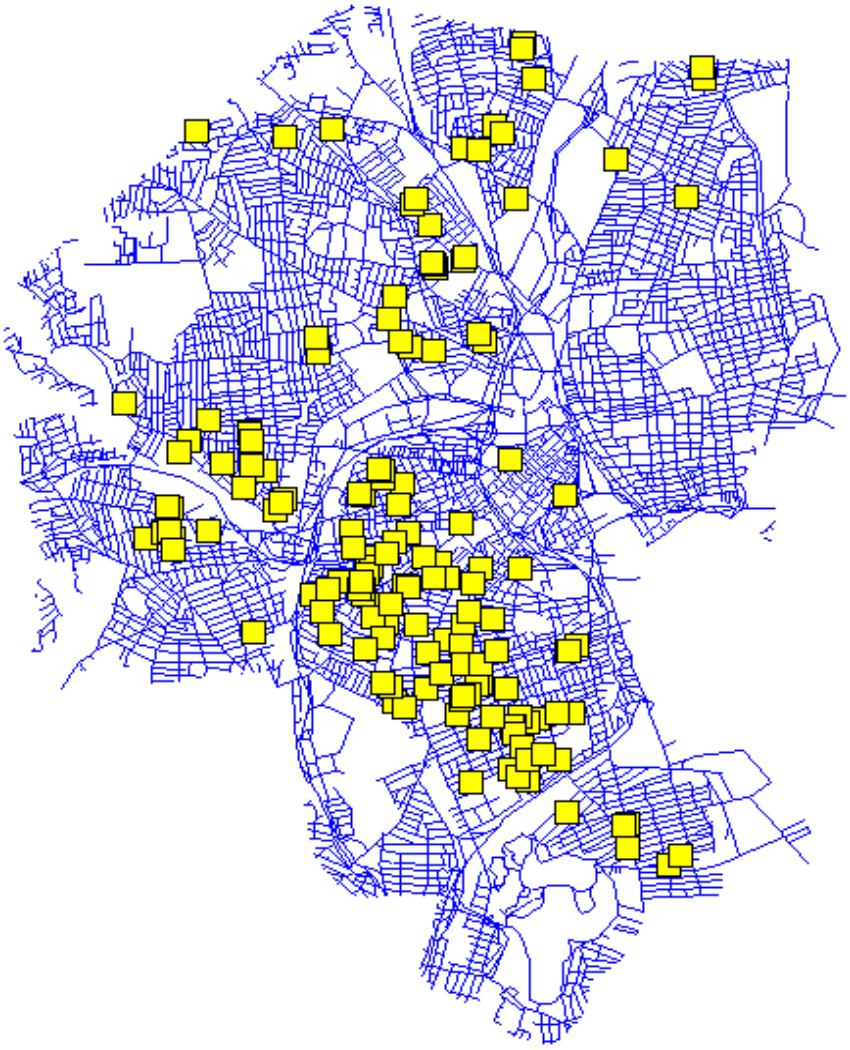
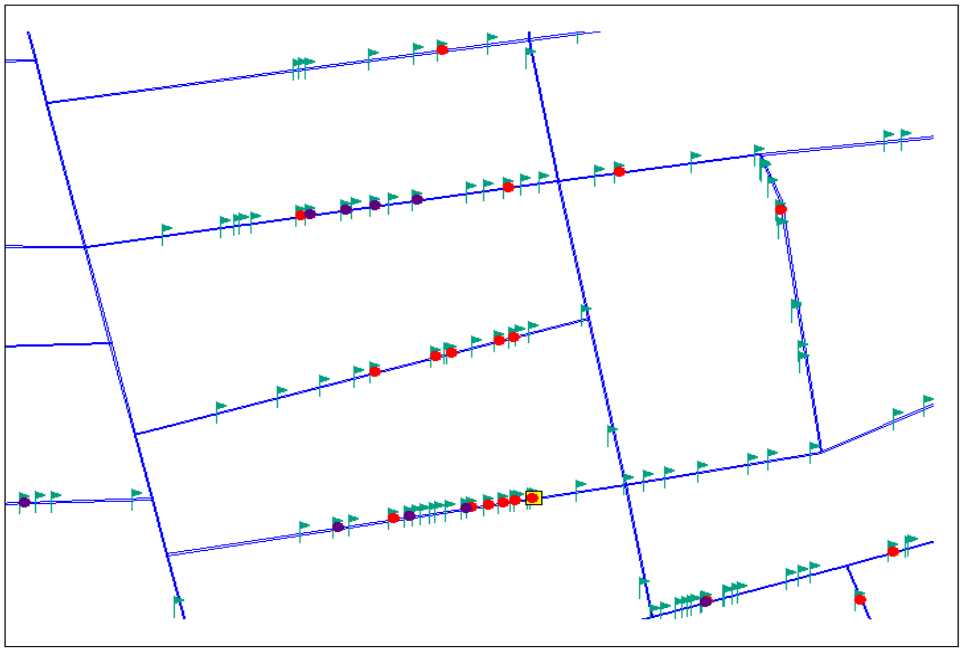


Figure 11

Enlargement of Multiple Mid-range BLLs, Multiple Poisonings, Asthma Addresses and Addresses where Children Have Resided (1993-1998)



Enlarged Image of a Region of South Providence

- Addresses with 2 or more 10-14 BLLs
- Addresses with 2 or more 15+ EBLs
- Asthma Addresses
- Addresses where Children have lived (93-98)
- Providence Streets

Figure 12

Environmental Violations and Code Violations with No Associated EBLs in 1997 (143)

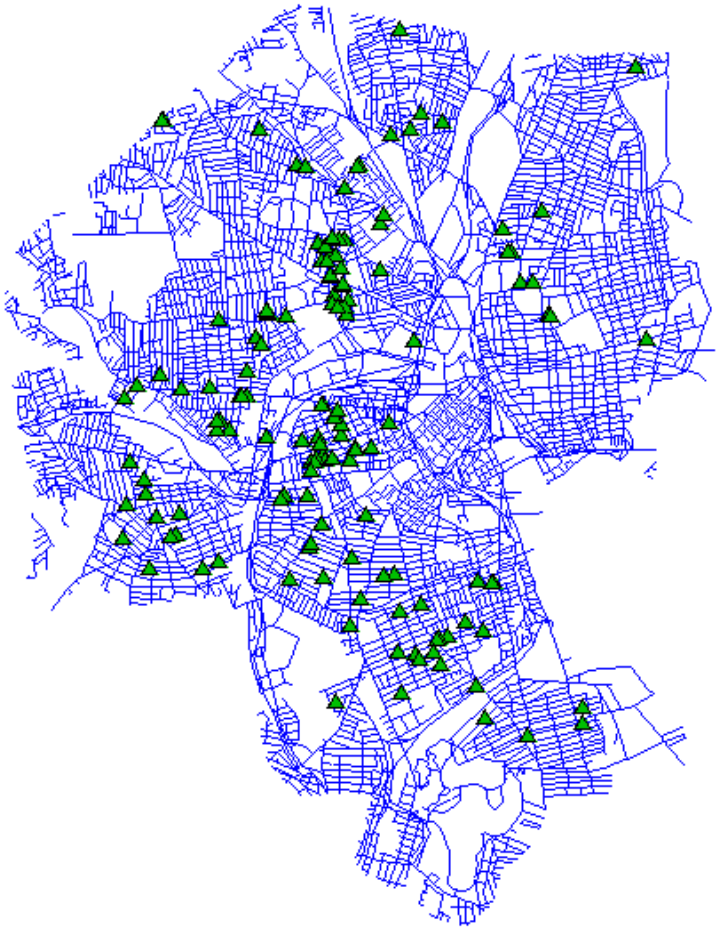


Figure 13

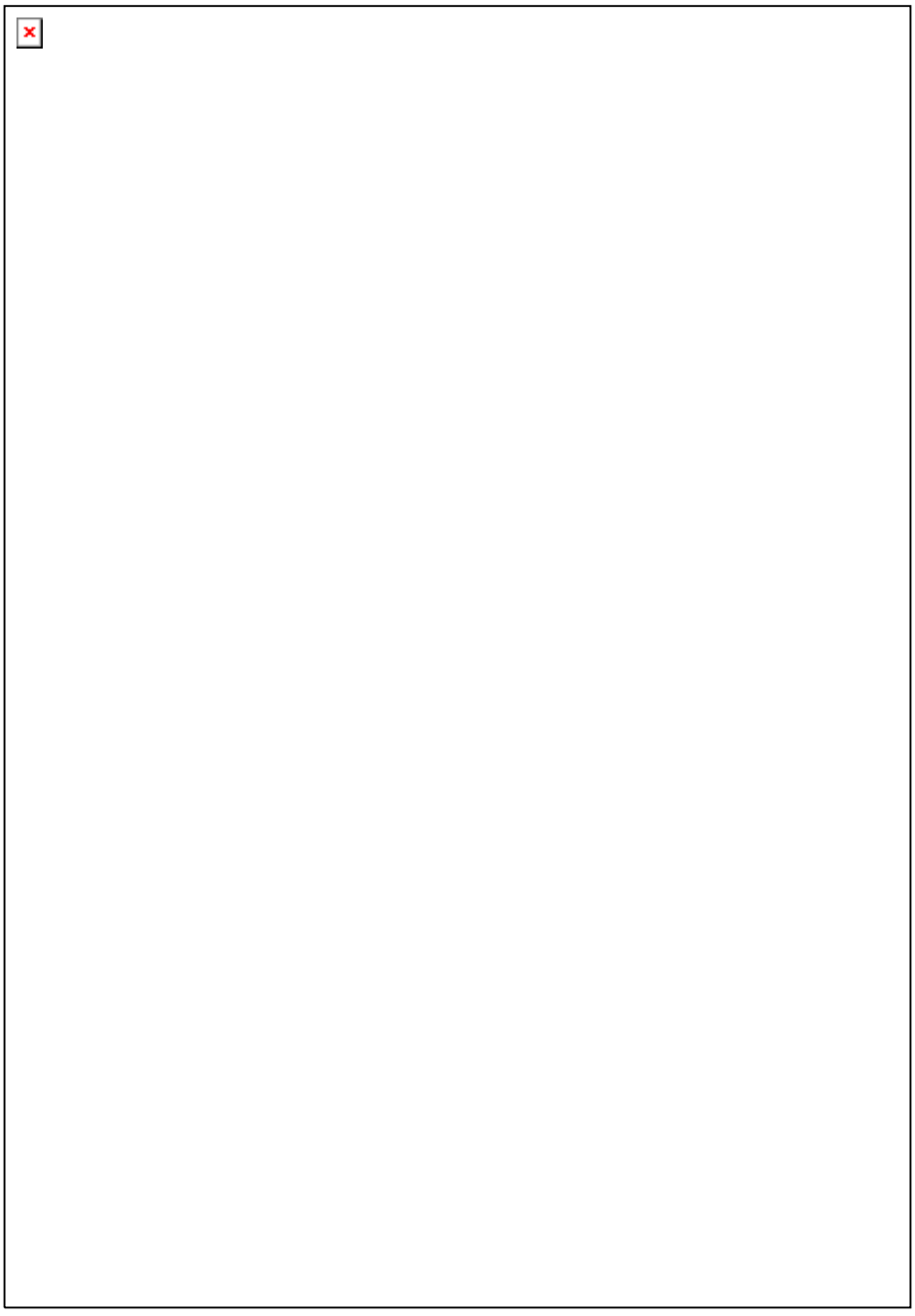
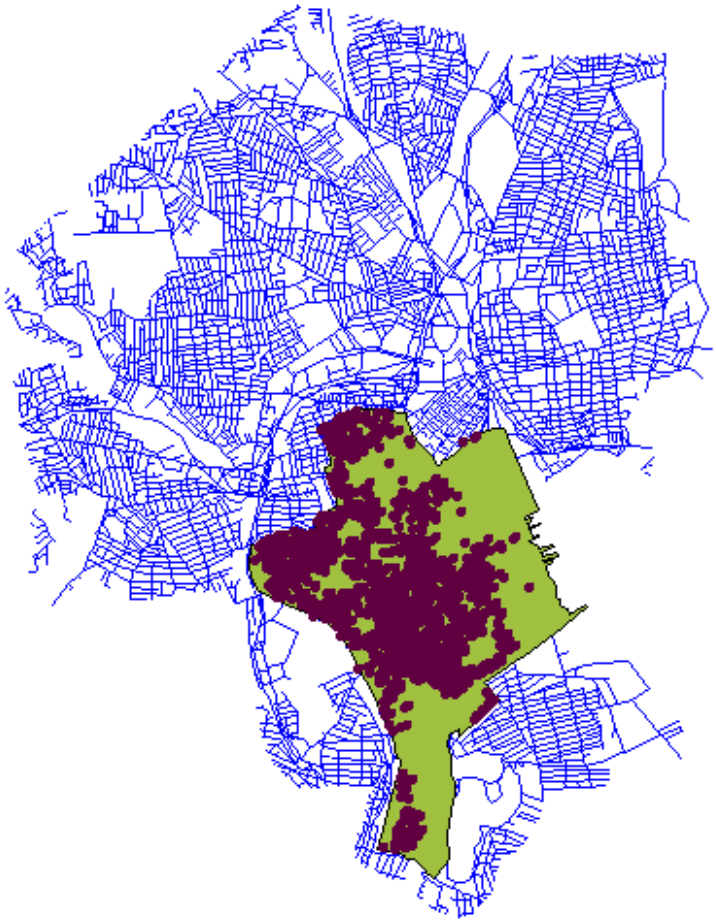


Figure 14

Providence Map Illustrating the Southern Region of the Enterprise Community (4,260 lead tests in 1997-Oct. 1998)

558 Elevated Blood-Leads



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