LOVE CANAL EMERGENCY DECLARATION AREA HABITABILITY STUDY NIAGARA FALLS, NEW YORK
EPA REGION II

PILOT STUDY FOR LOVE CANAL EDA HABITABILITY STUDY VOLUME II

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PREFACE

This report is Volume II of a two-volume series. Volume I describes the basis for and results of the air and soil pilot studies conducted pursuant to planning the Love Canal habitability study. Volume II presents the sampling design proposed for the habitability study.

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1. INTRODUCTION

The New York State Department of Health (DOH) and the United States Department of Health and Human Services/Centers for Disease Control (CDC) have proposed criteria for determining whether or not the Love Canal Emergency Declaration Area (EDA) is habitable (Love Canal Emergency Declaration Area Proposed Habitability Criteria, DOH/CDC, December 1986). The habitability criteria document recommended that pilot studies involving air and soil sampling be conducted before the habitability study is undertaken. The recommended pilot studies were conducted during 1986.

This two-volume document is a report of the recommended air and soil sampling pilot studies. Volume I (under separate cover) describes the basis for and results of the air and soil pilot studies; Volume II presents the sampling design proposed for the habitability study.

Specifically, Volume II is intended to achieve the following goals: (1) interpret the pilot study data discussed in Volume I; and (2) articulate the assumptions and outline the statistical methods used to determine the number of air and soil samples that should be taken during the full-scale habitability study. Volume II also addresses several other aspects of the proposed sampling design, including sample location and statistical comparison strategies for reducing the spatial, intralaboratory, and interlaboratory variation in the analytical data. Several aspects of the soil sampling design must still be resolved; these are discussed in Section 2.

This document contains the following:

- Description of the soil and air data found during the pilot study

- Discussion of the alternate methods of air sampling considered for the full study

- Discussion of the method used to choose a test statistic for the design of the soil comparison study and to find the range of the number of samples to be taken in a neighborhood

- Recommendations for an air sampling plan

- Recommendations for a preliminary soil sampling plan:

  - Range of sample sizes

  - Alternate allocation schemes for assigning samples to neighborhoods

The recommendations for the air portion of the habitability study are complete, except for final sample size recommendations and verification of the method with the DOH data. Some validation work and the development of a QAPP for the TAGA remain if the recommendations are accepted. As for the soil portion of the sampling plan design, the samples from a DOH study conducted in November of 1986 must be analyzed and these data must be included in the analysis developed from the pilot study. Depending on the outcome of this analysis, the number of samples required for a comparison and the allocation of those samples to neighborhoods could change. We expect, however, that neither the method used to estimate sample sizes nor the design test statistics will change.

Section 2 of this volume provides background information on the habitability criteria and several related issues. Section 3 outlines the statistical methodology used to design the habitability study. Section 4 presents the recommendations, including those addressing both the sampling design and the comparison strategy, resulting from the study development effort. Section 5 discusses the results and implications of the more recent DOH study.

Appendix F contains the full text of the proposed habitability criteria (DOH/CDC, December 1986). Appendix G presents a detailed and technically-oriented account of the habitability study sampling design. Appendix H provides the results of the more recent DOH study, and Appendix I analyzes and discusses the impacts of the DOH study.

2. BACKGROUND

This section provides background information on the habitability criteria and decision, and outlines and describes the status of several related statistical and administrative issues. The habitability criteria document consists of the criteria and 12 appendixes. The criteria were summarized in Volume I, Section 1.1.2, and are included in full as Appendix F in Volume II.

Questions that are commonly asked about the EDA habitability study include:

- Who will make the decision on habitability?

  The responsibility for making the determination of whether the EDA is or is not habitable rests with the New York State Commissioner of Health. The Technical Review Committee (TRC), consisting of representatives from EPA Region 2, the CDC, the DOH, and the New York State Department of Environmental Conservation (DEC), has the responsibility to provide scientific information to the Commissioner as to whether the results from environmental sampling have met the criteria for habitability.

- Why is a comparison approach being taken?

  The habitability criteria call for two types of comparisons: (1) Comparison of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) concentration in EDA soil samples to the level of concern of 1 part per billion (ppb), and (2) comparison of LCIC concentrations found in the EDA to those found in comparison areas. The dioxin comparison will

be addressed in a separate report as part of the habitability study. The comparison areas were selected to be as much like the EDA as possible except that they are not influenced by a hazardous waste landfill. The LCICs were selected to represent chemicals that were found in Love Canal, could possibly have migrated from the canal, and are likely to persist.

In addition to the comparison approach, the following approaches were considered:

- Time trend analysis of environmental data to evaluate the effectiveness of the remedial activities
- Risk assessment
- Application and extrapolation of environmental and health standards, criteria, or guidelines
- Epidemiological assessment
- Comparison of Love Canal after remediation with a state-of-the-art hazardous waste facility that meets existing regulations

Appendix 7 of the habitability criteria document explains why the comparison approach was chosen rather than one of the other approaches. Critical considerations in selecting the comparison approach included the requirements that the habitability criteria (1) apply to Love Canal; (2) be objective, quantifiable, and reproducible; and (3) give a "yes" or "no" answer when applied.

- What are the major statistical and administrative issues involved in the habitability study design and statistical detection of a difference between the EDA and comparison area?

Initial statistical and administrative issues related to the habitability study design and decision were raised in the habitability criteria document and were addressed in its Appendix 10. These issues are summarized in Table 1. Either the resolution of each issue is summarized, or the reader is referred to the relevant sections of this report.

Table 1
DESCRIPTION AND RESOLUTION OF HABITABILITY STUDY
STATISTICAL AND ADMINISTRATIVE ISSUES

Issue Description	Issue Resolution
How will the comparisons be made? What are the parameters of concern?	Explained in habitability criteria document and Section 4, Sample Design Recommendations, in this report.
What level of significance is desired in designing the habitability sampling study and in making the comparisons?	Ninety-five percent significance (stated in habitability criteria document).
How should "significantly different" be defined statistically for design of the habitability sampling study and for making the comparisons?	Defined as an order of magnitude difference for the soil study design in the habitability criteria document; see Section 4 for a discussion of significant difference relative to the comparisons. The air study design recommends sampling only EDA houses and investigating further those with detectable concentrations.
What detection probability (power) should be used in the design of the sampling study after the above three questions have been answered?	Ninety percent power (stated in the habitability criteria document) for soil comparisons. Not applicable for recommended air sampling design.
What measure of the concentration distributions should be used in the design and for the comparisons (e.g., mean, 95th percentile)?	Assumed a shift in distribution of soil concentrations for the design (Appendix G); see Section 4 for the comparisons. Mean or median recommended for habitability study. Not needed for recommended air sampling design.
What are the background concentrations and variabilities of the LCICs?	Nonquantifiable to low ppb range, intra- and interlaboratory variability about same magnitude for soil; see Volume I, Appendix B, Appendix G. Not needed for recommended air sampling design.

Table 1
(Continued)

Issue Description	Issue Resolution
What is the form of the LCIC concentration frequency distribution?	Lognormal or mixture of lognormals; see Appendix G. Not needed for recommended air sampling design.
What statistical tests are most appropriate for evaluating the LCIC data?	Nonparametric tests; see Appendix G
Are equal numbers of samples desired for each neighborhood or equal numbers per unit area, or is some compromise desired?	Number of soil samples proportional to area of neighborhood. See Section 4 and Appendix G. Not applicable for air sampling design.
How many samples need to be taken from each EDA neighborhood and from the comparison area?	Minimum of 10 to 50 for each neighborhood. See Section 4, Appendix G, and Appendix I. Not applicable for air sampling design.

3. APPROACH TO SAMPLING PLAN DESIGN

3.1 AIR PILOT STUDY

3.1.1 ANALYSIS OF DATA

The air pilot study was designed to test instrumentation for measuring concentrations of the air LCICs and to estimate concentration levels and frequency distributions of the LCICs.

The air sampling for the pilot study used two different sampling techniques to test two different approaches to measuring the LCICs in air. The instrumentation and analysis results are covered in detail in Volume I, Appendix A.

The data were stratified by house (occupied or unoccupied), area (EDA or comparison), and location (indoor or outdoor). The results of this study can be summarized as follows:

- Both the TAGA field analysis and GC/MS analysis of air samples in stainless steel canisters are capable of quantifying LCIC concentrations down to the low ppb range. There are advantages and disadvantages to each method.

  The TAGA is unable to distinguish 2-chlorotoluene from 4-chlorotoluene and is not as precise an instrument as the GC/MS. The TAGA is, however, capable of performing real time analysis of air samples and can be used to track LCIC concentration gradients to attempt an identification of sources.

The GC/MS requires a separate canister for each sample, and the time elapsed until analysis can be several weeks. Thus, a large number of canisters will be required for the sampling program. The GC/MS can separate 2- and 4-chlorotoluene and is a more precise instrument at low concentrations.

- Only two of the five strata (EDA and comparison area occupied houses) had any detectable concentrations of the LCICs. Each of the two indoor air strata had one detectable concentration. The estimated frequency of detection is thus 1 out of 30 for both the EDA and the comparison area.

3.1.2 HABITABILITY STUDY DESIGN ISSUES

Based on the pilot study, the TAGA appears to be a preferable method of sampling for air LCICs, assuming that an estimate of the concentration of total chlorotoluene is satisfactory. If measures of both isomers are desired a method of parallel sampling with both TAGA and canisters will have to be developed.

Whatever instrument is chosen, the habitability criteria specify that measurements of airborne LCIC concentrations from each occupied house in the EDA should be compared to some aggregate measure of the distribution of concentrations in the comparison area. Although a particular quantile is not mentioned in the habitability criteria, an often-discussed level of comparison is the 95th percentile. That is, an individual estimated concentration from a home in the EDA would be compared with the 95th percentile of the distribution of estimated concentrations from homes in the comparison area. If the EDA home exceeded this criterion value, the source of the contamination would be investigated.

Three sampling methods that would satisfy the intent of the criteria have been considered.

The first approach would be to select a sufficient number of homes in the comparison areas to estimate the 95th percentile and the 95 percent confidence limits on this percentile. Each estimate from a home in the EDA would then be compared with this estimated 95th percentile.

The major drawback to this approach is that the percentage of nondetects from the pilot study for the comparison area occupied houses is estimated at 97 percent. This implies that the expected value of the 95th percentile is a nondetect. An alternative would be to use a more conservative criterion such as the 99th percentile.

A second approach that would be conceptually closer to the intent of the habitability criteria would be to consider the 95 percent tolerance limit rather than an estimate of the 95th percentile. A nonparametric tolerance limit can be estimated such that there is 95 percent confidence that 95 percent of the values from the comparison area will be less than the tolerance limit. Specifically, if the largest estimated concentration from 90 samples taken from the comparison areas is used as the criterion, then there will be 99 percent confidence that this value is larger than 95 percent of all potential estimated concentrations of samples from this area. For 95 percent confidence in a concentration value being larger than 95 percent of estimated concentrations, 59 samples would be needed (see Conover, 1980).

A third approach is the one recommended for the habitability study. This approach can be developed by examining the first two. First, if there are about 90 occupied houses in the EDA and only 3 of them are expected to have detectable

concentrations of an LCIC, then any criterion would be expected to affect only about 3 occupied houses. Second, the frequency of zero detects for the 30 randomly selected unoccupied houses in the EDA indicated that no unoccupied house with detectable concentrations is expected. If there are any, they should be very few. Because of the small number of detects involved, it is simpler and more efficient to resample any house in which an LCIC is detected and attempt to identify the source of the LCIC rather than to sample comparison areas.

3.2 SOIL PILOT STUDY

3.2.1 ANALYSIS OF DATA

The soil pilot study was designed to test the analytical methods for measuring concentrations of soil LCICs, estimate the concentration levels of LCICs found in the EDA and comparison areas, and estimate the magnitude of sources of variability. The soil pilot study results are discussed in more detail in Volume I, Appendix B, while the success of the analytical methods is discussed in Appendixes C and D.

Appendix G (Volume II) presents estimates of the frequency distributions of the LCIC concentrations and sources of variability. These can be summarized as follows:

- The percentage of nonquantifiable data ranged from 85 to 100 percent for the 8 LCICs.

- Where sufficient data were available, a lognormal distribution or a mixture of lognormal distributions was found to best represent the data.

- Interlaboratory variability was found to be as large or larger than intralaboratory variability for some of the LCICs.

3.2.2 HABITABILITY STUDY DESIGN ISSUES

The methodology followed to develop a sampling design (see Appendix G) was the result of the decision to use a comparison approach to evaluate the habitability of the EDA. The use of a comparison approach suggested a hypothesis testing framework for the comparison of sample concentrations between two areas. (Hypothesis testing is discussed in Appendix 10 of the habitability criteria document.) The sample sizes could be estimated within this framework, given certain performance criteria. The TRC recommended the performance criteria for hypothesis testing, which are included in the criteria document.

The performance criteria specified were:

> The sampling design for the habitability study should be capable of detecting an order-of-magnitude difference in LCIC concentrations between an EDA neighborhood and the comparison area with 95 percent confidence and 90 percent power.

This can be restated less technically as: If the true difference between mean concentrations in the EDA and the comparison area is an order of magnitude (in this case, a factor of 10) then there should be only 1 chance in 10 of not finding a difference. On the other hand, if there is no difference between the areas then there should be only a 1 in 20 chance of mistakenly finding a difference.

Some terms are introduced in what follows to aid in the summary of the methodology developed in Appendix G. These include "null hypothesis," "test statistic," "critical value," "power," "confidence level," and "power curve." These terms are discussed in more detail in Appendix 10 of the habitability criteria document.

The comparison will be performed by collecting soil samples to obtain data from the EDA neighborhoods and comparison areas. The data will then be used to calculate a test statistic (a function of the data and the statistical test being used) which is then compared to a critical value (known from the theoretical behavior of the test statistic function). Generally, if the test statistic is greater than the critical value, the null hypothesis of no difference between areas is rejected. If the test statistic is less than the critical value, then the null hypothesis fails to be rejected.

This can be illustrated by the null hypothesis that all crows are black. The test statistic is the number of non-black crows. The critical value is 1. If 1 non-black crow is seen, then the hypothesis that all crows are black is rejected. If no non-black crows are seen, then the null hypothesis is not rejected. However, the null hypothesis that all crows are black cannot be accepted, since all crows have not been examined. There still may be an albino crow somewhere.

The critical value for most test statistics depends on the number of samples and the desired level of confidence. The confidence level is a function of the probability of making the mistake of saying there is a difference when there is not. The confidence level is one of the performance criteria specified in the habitability criteria.

The number of samples required in a comparison approach is found from the power curve for a statistical test. This curve relates the sample size to the probability of making a second type of error, that of not finding a difference that actually exists. This curve is not uniquely a function of sample size. The entire curve changes as other choices are made for the actual difference and the desired confidence. The desired power is also specified in the performance criteria for the habitability study. A further discussion of the comparison process can be found in Appendix 10 of the habitability criteria document.

In the usual examples of the hypothesis testing technique, all the data are quantified and the distribution is known. Optimal test statistics are available and the sample sizes are found from published tables developed from the power curves for these test statistics. In these classic examples, the major effort of design is the optimal allocation of samples to sites.

However, the analysis of the pilot study data indicated that this is not the case for the EDA or comparison area data. First, a large percentage of the data was below the detection limit of approximately 1 ppb. Second, the data values that were observed were not normally distributed. The effect of these facts was to change the focus of the design effort from sample allocation to the choice of appropriate test statistics and the derivation of the power curves that would allow sample sizes to be estimated.

Candidate test statistics were chosen from the literature, with an emphasis on nonparametric tests. Nonparametric tests were favored because of their "robustness" to

nonnormal and censored data. Because of the lack of published power curves for these test statistics for data similar to that found by the pilot study, it was necessary to develop these curves as part of the design process.

The power curve of a test statistic can be developed with a simulation model. This is accomplished by repeatedly using the model to generate simulated data to which the tests are applied. The model generates simulated data that are then used to calculate a value for the test statistic. Each test statistic can then be compared with the critical value for the test and a decision made as to whether a significant difference was seen. This process is repeated many times and a running score kept as to whether the difference was properly identified. The score, the fraction of times the test identified a change, is then an estimate of the power of the test being modeled.

There are two ways in which the data can be simulated for the model. The first is simply to draw subsamples from the empirical data. However, unless the sample sizes are very large, this risks under-representing extreme values that may occur in subsequent samples. The second is to find a parametric distribution that adequately represents the data and to generate simulated data as realizations of the parametric data. These realizations can then be used in the model to estimate power. The latter course was followed for this design.

The design methdology has emphasized identifying appropriate test statistics for a comparison and generating the power curves required to find the sample sizes required for the specific performance criteria. The overall process can be summarized as:

- Identify candidate test statistics.

- Identify parametric frequency distributions that approximate the empirical frequency distribution of the pilot (or DOH) data.

- Use the parametric distributions in a simulation model to generate the power curve for each candidate test statistic while preserving the other performance criteria (significance and target difference).

- Estimate the range of sample sizes likely from the power curves of the previous step.

- Decide on an allocation scheme for the samples.

This process was followed using the data from the pilot study. It was found that the data from the pilot could be represented by a lognormal or lognormal mixture distribution. Nonparametric tests such as the modified Wilcoxon were the best univariate tests while the Multivariate Rank Sum test was one of the best multivariate tests.

4. SAMPLE DESIGN RECOMMENDATIONS

4.1 AIR

The recommended design for the air portion of the habitability study is as follows:

- Use the TAGA instrument to measure air LCIC concentrations; accept total chlorotoluene as an adequate measure of the chlorotoluenes.

- Sample all houses in the EDA with the TAGA using a 200-foot hose. Attempt to identify and isolate any sources of air LCICs. Monitor outdoor air between sampling of houses.

- Do not sample comparison area houses for air.

4.2 SOIL

The pilot study provided data for analysis and simulation of a variety of sampling schemes. Several major uncertainties have been resolved by this analysis; the following recommendations can be made for the soil sampling design for the habitability study.

- A lognormal distribution or a mixture of lognormal distributions is adequate for modeling the data from the comparison area and the EDA for most LCICs.

- Interlaboratory variability is significant; sample allocation to the analytical laboratories must be made so as to avoid or minimize this source of

variability. Either matched allocation (one neighborhood analyzed by one lab) or randomized blocking (all neighborhoods analyzed by all labs, summary statistics combined to eliminate interlaboratory effects) is recommended.

- Within each neighborhood, sample allocation should be randomized. Earlier studies and the pilot study did not produce strong evidence of likely patterns of areas of contamination within neighborhoods.

- Samples should be allocated among neighborhoods proportional to the area of the neighborhood. A minimum sample size should be set to preserve power in comparisons with small neighborhoods.

- Based on only the pilot data, a minimum of 10 to 50 samples will be needed from each neighborhood to obtain 90 percent power and 95 percent confidence of detecting an order of magnitude difference in mean concentration values between a neighborhood and a comparison area. This range spans the likely range of data distributions, the likely range of contamination types, and the use of univariate comparisons (one LCIC) or multivariate comparisons (all LCICs simultaneously).

- The analysis of the data from the habitability study should judge a significant difference between the EDA and the comparison area based on an order of magnitude difference in a measure of central tendency (median or mean). A suite of potential statistical tests has been identified in Appendix G.

Further refinement of the design and exploration of additional tests will take place during the analysis of the DOH sample data from the new comparison area.

5. DOH SOIL STUDY

During November 1986, the DOH conducted an additional sampling program in the EDA, the comparison area, and three sites in Niagara County (see Figure 1). This sampling program was designed to identify potential non-Love Canal sources of tri- and tetrachlorobenzene, such as air emissions from industrial sources or Niagara Falls city water. The samples were analyzed for the presence of two of the eight soil LCICs: trichlorobenzene and tetrachlorobenzene.

The full results of this DOH study are presented in Appendix H. An analysis of the data follows in Appendix I. A major difference between the data obtained by DOH and the data obtained from the pilot study is in the analytical techniques used; a steam extraction process was used by DOH while solvent extraction was used for the pilot study. Because of this and other analytical differences, the two sets of data are not statistically comparable, although their results are very similar. The samples collected by DOH are currently being analyzed by the analytical methods proposed for the habitability study. When this is completed, a statistically comparable data set will be available for additional analysis.

An analysis of the DOH data revealed that significant differences existed between two of the areas sampled. Specifically, one site in the City of Niagara Falls had a mean value significantly higher (statistically higher--actual concentration values were less than 10 ppb) than those of the other four sites, including the EDA and the comparison area. One other site (the Cheektowaga comparison area) was significantly lower than the other four sites. All significant differences were based on a multiple-comparison test of means with a 95 percent confidence level.

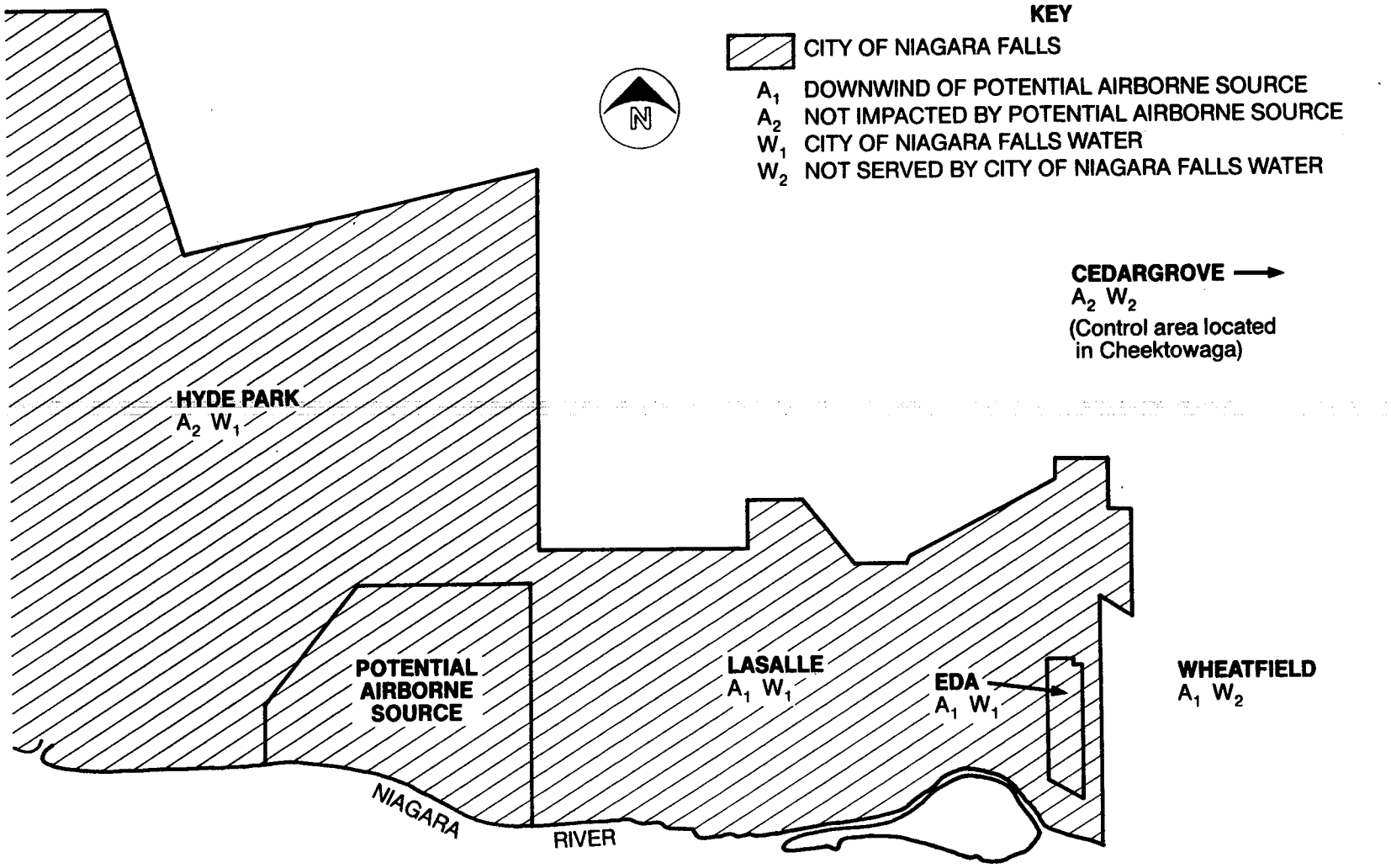


Figure 1
PROPOSED SAMPLE AREAS

Additionally, it appeared that four of the sites (those in Niagara Falls) may have had a different source of tri- and tetrachlorobenzene than the site in Cheektowaga. The difference in sources is suggested by a distinctly different ratio of tri- to tetrachlorobenzene at the Cheektowaga site.

Based on this information, the TRC recommended that an additional comparison area in the City of Niagara Falls be selected for the habitability study. This will allow the Commissioner of Health to have two sets of comparisons available; one between the EDA and the original comparison area and another between the EDA and the new Niagara Falls comparison area.

The habitability design will be completed after the DOH samples have been reanalyzed with the chemical techniques used in the pilot study and the data have been analyzed with the proposed design methodology.

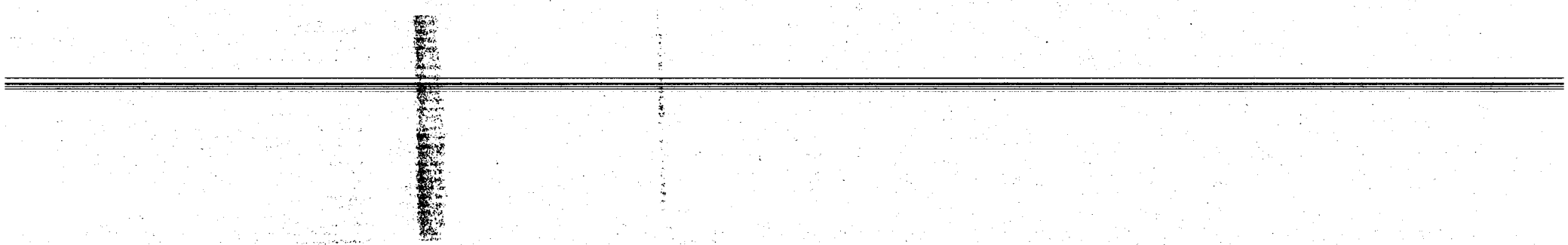
REFERENCES

Conover, W. J. Practical Nonparametric Statistics. New York: John Wiley and Sons. 1980.

New York State Department of Health and Centers for Diseas Control. Love Canal Emergency Declaration Area Proposed Habitability Criteria. December 1986.

APPENDIX F

Love Canal Emergency Declaration Area Proposed Habitability Criteria



LOVE CANAL EMERGENCY DECLARATION AREA
PROPOSED HABITABILITY CRITERIA

New York State Department of Health
Department of Health and Human Services
Public Health Service
Centers for Disease Control

December 1986

FOREWORD

This document, The Love Canal Emergency Declaration Area Proposed Habitability Criteria, was developed over a 2-year period beginning in 1983 by staff of the New York State Department of Health (NYSDOH) and the Department of Health and Human Services--Centers for Disease Control (DHHS-CDC). The document arose in response to a request from the Environmental Protection Agency (EPA) to provide criteria, which if met, could be used to define habitability of the neighborhoods surrounding the Love Canal hazardous waste disposal site.

In 1981, the U.S. Public Health Service (PHS) reviewed the results of environmental testing conducted in the summer and fall of 1980 by EPA and reported the data available did not indicate that the area outside the Canal itself and the two rings of residences to the east and west were uninhabitable. In this review, the PHS cautioned that habitability required that the obvious contamination of the storm sewers and their drainage tracks be cleaned up and that there be a guarantee of a permanent containment of chemicals in the dump. Critics of the PHS assessment, findings, and recommendations pointed out that even though the data available may not indicate that the Love Canal neighborhoods were not uninhabitable, doubts remained concerning whether these areas were habitable. These doubts centered on data gaps on

the EPA monitoring program, lack of adequate comparison data, and incomplete assessments of the toxicological hazards to humans exposed to the very low levels of chemicals found in some samples of EDA soils, air, and surface/groundwaters. The authors of this document are keenly aware of this history, and recognize that regardless of the level of effort directed toward remediation and environmental testing, concerns, and doubts are likely to remain, not only at Love Canal, but at all hazardous waste sites when the potential for exposures in the surrounding community exists. Even so, the NYSDOH and the CDC are attempting to reduce and quantify these doubts by defining criteria applicable to the habitability of the Love Canal neighborhood.

In developing the proposed criteria, a series of open meetings were held in Niagara Falls which involved the general public, scientists from outside of government, concerned local citizens, staff from NYSDOH, New York State Department of Environmental Conservation (NYSDEC), EPA, DHHS-CDC, expert consultants, and contractors and subcontractors working on remediation and habitability. Valuable ideas, suggestions, and guidance were offered by representatives of each group. Many of these recommendations are contained in the documents. Consensus, however, was not reached on all issues. Consequently, these proposed criteria must be the responsibility of DOH and CDC,

the agencies that convened the meetings and drafted the document. The criteria are presented as the most reasonable, practical, and scientifically sound criteria available given the limitations of time and current state of biomedical, engineering, hydrogeologic, and soil sciences.

The proposed habitability criteria are designed to yield information necessary to answer this question: Does the Love Canal hazardous waste disposal site (in its present state of remediation and with the guarantees of EPA and NYSDEC for continuous monitoring and containment) have a measurable impact on the environment of the Emergency Declaration Area (EDA) which in the judgment of the New York State Commissioner of Health renders the entire Emergency Declaration Area or neighborhoods in the EDA not habitable from a public health standpoint? This document recommends additional environmental testing to determine whether differences in frequency of occurrence and/or levels of Love Canal Indicator Chemicals (LCIC) can be demonstrated in soils, ambient air, and indoor air between neighborhoods in the EDA and comparison neighborhoods. The comparison neighborhoods must be like the EDA except that the comparison neighborhoods must not be impacted by a hazardous waste disposal site. Additional testing of residential soil in the EDA is also to be conducted to determine whether the 1 part per billion level of concern for TCDD (2,3,7,8 tetrachlorodibenzo-p-dioxin) is exceeded.

This approach to answering the question of habitability of the EDA presents a host of technologic, logistical, legal, sociologic, and statistical problems. The proposed criteria document and its appendices address those problems as completely as possible. However, the solution to these problems lies in part in the knowledge to be gained in the application of the criteria. NYSDOH and DHHS-CDC therefore recommended a pilot test of the criteria application to be carried out in the fall and winter of 1986-87. The pilot test is designed to develop data which can be used to write detailed protocols for:

1. The analytic laboratory aspects of the environmental testing; i.e., the analytic method tests of soils and air, QA/QC methods, method detection limits, and expected precision, bias, and accuracy.

2. The sampling plan; i.e., the analytes and the number, location, and timing of the sample collection.

3. The statistical design for the array, analysis, and interpretation of the data from the environmental testing.

If the uncertainties raised by this approach to defining habitability (which include):

1. The soundness of the general approach.

2. The willingness of property owners remaining in the EDA and owners in the comparison areas to permit testing.

3. The appropriateness of the environmental media recommended for testing.

4. The appropriateness of the Love Canal Indicator Chemicals (LCIC).

5. Whether valid and applicable statistical tests for differences exist.

6. The ability of the analytic chemistry to differentiate and detect the LCIC at ultra low levels with accuracy)

can be resolved to the satisfaction of the responsible federal, state, and local officials, the concerned public, and the scientific community, then protocols will be designed and peer reviewed for each relevant aspect of the application of the criteria, and a complete project to assess habitability in accordance with the proposed criteria should commence.

The action steps which must be taken in order to make a decision regarding habitability are as follows:

1. Draft "Proposed Habitability Criteria"

2. Submit draft criteria to Technical Review Committee (TRC) and public

3. Conduct peer review of draft criteria

4. Rewrite draft criteria to incorporate peer reviewer recommendations

5. Submit peer reviewer recommendations and final "Proposed Habitability Criteria" to TRC

6. Draft protocol for Pilot Study of "Proposed Habitability Criteria" (air and soil testing of LCICs)

7. Submit Pilot Study to TRC and public for review and approval

8. Implement Pilot Study

9. Submit Pilot Study data and data analysis to TRC and public for review and approval

10. Draft TCDD soil sampling plan and analytic protocol

11. Submit TCDD soil sampling plan and analytic protocol to TRC and public for review and approval

12. Implement TCDD soil sampling and testing

13. Draft protocols using data from Pilot Study (i.e., sampling plan; analytic methods and laboratory QAPP; statistical methodology and data interpretation) for LCIC Study

14. Submit protocols for LCIC Study to TRC and public for review

15. Conduct peer review of draft protocols for LCIC Study

16. Incorporate peer reviewer comments into protocols for LCIC Study

17. Submit protocols for LCIC Study and peer reviewer comments to TRC and public for review and approval

18. Implement LCIC study

19. Present results of Habitability Study (TCDD and LCIC Studies) to TRC and public

20. Identify and/or complete all remedial actions indicated from results of Habitability Study

21. Prepare final report on Habitability Study, TCDD testing and remedial actions and present to NYS Commissioner of Health for habitability determination

22. Complete remediation of TCDD from storm and sanitary sewers, their drainage tracks and outfalls

LOVE CANAL EMERGENCY DECLARATION AREA

PROPOSED HABITABILITY CRITERIA

November 21, 1985

1. INTRODUCTION

As part of the Environmental Protection Agency's (EPA) remedial program at the Love Canal hazardous waste disposal site, a Technical Review Committee (TRC) was formed to provide interagency coordination and oversight for all issues related to the program. The TRC is chaired by EPA and includes senior officials of EPA Region II, the New York State Department of Health (NYSDOH), the New York State Department of Environmental Conservation (NYSDEC), and the Department of Health and Human Services--Centers for Disease Control (DHHS-CDC).

Among the most difficult issues challenging this group is the question of habitability of the Love Canal Emergency Declaration Area (EDA). The EDA consists of the neighborhoods adjacent to and surrounding the site of the Love Canal inactive landfill. The EDA does not include the canal itself nor the area formerly occupied by two rows of demolished homes immediately east and west of the site (Figure 1). Residents of the area were offered relocation assistance; eligible properties

were appraised and purchased by the government at various times as the problem unfolded. Today the site itself has been contained and a system of monitoring has been put in place to ensure the effectiveness of containment. The cleaning of contamination in the sewers and creeks will be completed in 1988. The two rows of homes east and west of the canal have been demolished. Most of the residences in the EDA are still unoccupied, and in various states of disrepair. Appendix 1 presents a chronology of events related to Love Canal and the EDA.

On behalf of the TRC, the NYSDOH and CDC were asked to develop criteria for habitability that could be applied to the EDA and that, if met, could be used by the Commissioner of Health of New York State to make a determination about the habitability of the EDA or of neighborhoods or residences within the EDA. To assist in developing habitability criteria, NYSDOH and CDC sought the opinions and recommendations of 10 distinguished scientists representing a variety of disciplines (Appendix 2). The views and opinions of those scientists greatly assisted the NYSDOH, and CDC in the preparation of this document and are reflected throughout. The development of this document also involved a thorough review of all known environmental monitoring results along with their quality control and

quality assurance documentation, where available; and published and unpublished health study data.

After carefully considering the limitations of available information (Appendix 3) and their scientific interpretations, the scientists concluded that criteria to guide studies and evaluations regarding habitability could and should be established for the EDA (Appendix 4). The process of developing habitability criteria was open to the public, and community involvement was actively solicited throughout the process (Appendix 5). Use of the criteria and the final decision on habitability of the EDA will also involve the public and the citizens affected.

To assure community understanding and support for government actions regarding the EDA, no significant changes in procedures or operations related to Love Canal remediation and management activities (Appendix 6) should be made before community input is sought.

Decisions about implementing the Habitability Criteria and other operations at the Love Canal site must be reported to the public on a regular basis. A library of documents relating to Love Canal should be maintained as a resource for scientists and the community.

2. DEFINITION OF HABITABILITY

For purposes of the task at hand, "habitable" means suitable for human habitation, including all ages, both sexes (including pregnant females) engaged in normal activities. In most situations, including that of the Love Canal EDA, judgments about suitability for human habitation rarely involve a simple "yes/no" response. Important considerations include the degree of certainty about the presence or absence of risks and whether these risks are immediate or delayed, serious or negligible, voluntary or involuntary, and whether restricted habitability or alternative land use is intended. With regard to the Love Canal EDA, the judgment is also complicated by the fact that some residents of the EDA were offered temporary relocation pending an official judgment on the risks posed by the presence of the Love Canal disposal site. This, compounded with the publicly voiced critiques (whether justified or not) of the existing exposure and health assessment data of Love Canal have created questions in the community concerning the risks posed by rehabitation of the Love Canal EDA. To the degree that they exist, any risks would be imposed involuntarily, may cause delayed health effects, and may be related to serious health outcomes.

3. NATURE AND SCOPE OF HABITABILITY CRITERIA

The proposed habitability criteria are intended to apply only to the Love Canal EDA and to be protective of residual effects from the former Love Canal. The criteria are to be as objective and quantifiable as possible, and should yield reproducible results. Several approaches to the development of habitability criteria were discussed within this framework:

1. Identification of time trends in environmental data to evaluate the effectiveness of remediation

2. Risk assessment based on measured levels of chemicals present in the EDA and the extrapolation of animal toxicity data for those chemicals to human health risks

3. Application of environmental and health standards, criteria, and guidelines

4. Epidemiological assessment

5. Comparison of Love Canal after remediation with a state-of-the-art hazardous waste management facility meeting existing laws and regulations

6. Comparison of environmental data from the EDA to similar data from comparable, inhabited areas

7. Combinations of the above

The options were discussed in varying levels of detail. Some were discussed as the primary basis of a habitability decision, others as supplementary or supporting methodologies. The approach proposed as the most appropriate for the determination of habitability in the Love Canal EDA is a combination of using relevant federal and New York State standards, criteria, and guidelines which are generally derived from risk assessments; and comparing levels of Love Canal Indicator Chemicals (LCICs) in the EDA with levels of these chemicals in similar inhabited urban areas not impacted by a chemical landfill. More detailed discussions of this choice are given in Appendix 7.

4. SUMMARY OF RECOMMENDED APPROACH

Relevant federal or New York State standards, criteria, or guidelines for chemicals identified in environmental media and to which residents and potential residents may have significant exposure will be used to assess

the hazard of rehabitation of the EDA. A review of all federal and New York State standards, criteria or guidelines for chemicals in the Love Canal and the EDA indicates that a relevant and applicable standard exists only for TCDD (2,3,7,8 tetrachlorodibenzo-p-dioxin) in residential soils at this time. Modification of existing occupational or industrial/environmental standards such as the U.S. Department of Labor's Threshold Limit Values and the New York State Department of Environmental Conservation's Ambient Air Levels to make them applicable to residential situations was deemed inappropriate.

Measurements of TCDD in the comparison areas will not be made because a level of concern of 1 ppb has been established and therefore knowledge of concentrations of TCDD in the comparison areas is not necessary. A sampling protocol will be followed to determine whether TCDD is present in the soils of the EDA and in concentrations over 1 ppb. If TCDD is found to be over 1 ppb in the EDA or a portion of the EDA, that area will be considered habitable only if remediation can be accomplished and other circumstances do not cause it to be declared not habitable.

Where applicable and relevant standards, criteria, or guidelines are not available, as they currently are not for residential air and soil for most of the chemicals identified thus far in Love Canal and the EDA, a comparison methodology will be used to assess the habitability of the EDA. This approach to determining the relative habitability of the EDA is based on a comparison of environmental sampling results for the LCICs from the neighborhoods (Appendix 8) and residences in the EDA with results from sampling for LCICs in similar inhabited communities not impacted by a chemical landfill. This method assumes that data collected from the comparison areas will correspond to "normal" or habitable conditions which, when compared to similar measurements in the EDA, provide an indication of whether EDA neighborhoods and homes are or are not "significantly different" with respect to contamination by LCIC from those in comparable western New York communities. The comparison approach to developing habitability criteria is based on the assumption that inhabited urban neighborhoods that meet public health and housing codes and are not impacted by a chemical landfill are habitable. The criteria are designed to determine whether the EDA is uninhabitable due to contamination by chemicals which migrated or were displaced from the Love Canal. No criteria will provide assurances that the EDA is "risk free."

Habitability decisions will be based primarily on statistically valid comparisons of low level environmental contamination between EDA neighborhoods and comparison areas. This approach has been designed to identify the potential presence of toxic chemicals related to this hazardous waste disposal site. However, its implementation presents certain major problems:

1. Environmental sampling data collected from the EDA contain a high percentage of reported "non-detect" results for chemicals known to have been deposited in Love Canal. For the selected LCICs, 2 percent of soil LCICs had reported concentrations and 6 percent of the air LCICs had reported concentrations (Appendix 9).

2. Standard technology for detecting chemicals (particularly in soil) is limited at the ultra-low range (i.e., low parts per billion and below) and does not differentiate concentrations under the parts per trillion range.

3. The precision and accuracy of the standard available analytic chemistry technology decrease

in the detection of ultra-low concentrations of chemicals in various environmental (and biologic) samples.

4. Statistical methods are limited for defining significant differences in data sets that include a vast majority of chemical concentrations below the limit of detection (Appendix 10).

5. Statistical capabilities to detect a preset difference with a given sample size are limited by data variability. Increasing variability makes the difference more difficult to detect.

6. There is very little direct observation data which defines the human health effects of exposures to chemicals at low concentrations in environmental media in residential settings.

7. There is little data on background levels of the chemicals of concern in the Love Canal EDA in comparable residential settings in the U.S.

The proposed habitability criteria and the ultimate decision on the habitability of the Love Canal EDA deal with these problems in the following manner:

1. For purposes of reproducibility, unique and heroic laboratory methods should be avoided, however, state-of-the-art methods should be applied to obtain the lowest feasible limits of detection. Accepted laboratory methods with stringent quality assurance and quality control should be followed even though the variability of analytic results may increase at very low concentration levels. Measurements with large inaccuracies will be down-weighted in the statistical comparisons. Estimates of detection limits will be based on appropriate statistical techniques and defined such that the detection limit is the sample concentration which can be detected with 95 percent confidence and which requires 95 percent non-detects in procedural blanks. This determines the probability of false positives and false negatives.

2. Sampling plans should be guided by what is understood about how chemicals from the Love Canal are likely to reach the EDA, focusing on the most plausible pathways for migration.

3. The soil sampling plan should be designed to detect an order-of-magnitude difference between

the EDA neighborhoods and comparison areas for each LCIC. The design should employ criteria of 5 percent overall significance for all comparisons and 90 percent power for an order-of-magnitude difference for each single comparison.

4. The air sampling plan should be designed to characterize the distribution of air LCIC concentrations in the comparison areas. Wind speed and direction should be recorded during ambient air sampling. Indoor air samples should be taken in the basements.

5. For purposes of statistical comparisons, all nondetected concentrations from each laboratory for each LCIC will be considered equal in both the EDA neighborhoods and the comparison areas.

6. Several statistical procedures will be used to compare individual (univariate) and collective (multivariate) properties of LCICs between each EDA neighborhood and the comparison areas. A statistically significant difference should take into account the reliability of data across the observed range of concentrations. One approach is to use more stringent statistical criteria to

detect significant differences for comparisons at very low LCIC concentrations, while less stringent criteria would be used to detect significant differences at higher concentrations.

7. The data sets should be evaluated for general trends and directions as well as for statistically significant differences.

8. The determination of habitability or non-habitability of any EDA neighborhood will require a prudent public health judgment based on a review of the data from the comparison studies as well as all other pertinent factors. The ultimate determination should be explained and justified.

All of the environmental testing data from the comparison studies including the information regarding sampling error, quality control/quality assurance of the laboratory work, and the values reported will be made available to the general public and the scientific community for analysis and interpretation. Data from the comparison areas should be limited sufficiently to protect the privacy of the home owners.

5. SPECIAL PROVISIONS

Before the proposed habitability criteria are used to evaluate the habitability of the EDA, the following provisions should be met:

1. The habitability criteria should be subjected to an independent scientific peer review.

2. A small-scale pilot study should be conducted to demonstrate the feasibility of implementing the habitability criteria as proposed.

3. The sampling and analysis plan for the study should be developed after completion of the pilot study and should be peer reviewed prior to the implementation.

4. The following recommendations, as stated in 1981 by DHHS, must be complied with: "Any judgment regarding the future habitability of the Love Canal area rests on two important requirements. The first reservation is that appropriate measures must be taken to clean up the obvious contamination of local storm sewers and their drainage tracts. Second, the security of Area 11*

*Refers to the actual Love Canal and Rings I and II of residences that surround it.

must be re-evaluated to guarantee permanent containment of chemicals in the dump. To assure habitability into the indefinite future, it is essential that optimal containment methods are installed and maintained and that continuous safeguards are observed to prevent further leakage from the site either through erosion of the clay cover or through its displacement by movement of dump contents."

The contamination of the storm sewers and creeks by 2,3,7,8-TCDD has not been remedied. This has caused two major concerns:

1. If the criteria allow the area to be considered acceptable for habitation prior to completion of remediation, there may be no incentive to complete remediation.

2. If remediation, when implemented, includes the movement of TCDD-contaminated soil and water into the EDA for treatment or storage or both as well as for transport or temporary storage, it may force a reassessment of the habitability criteria for the EDA or render them non-applicable.

Therefore, it is the consensus of the scientific advisors, HHS, and DOH that the collection of environmental samples may proceed and could occur immediately, that an analysis of results could take place, and that comparisons could be made. However, further application of the criteria and decisions on habitability must await full remediation of the contamination of the storm sewers and, where indicated, the sanitary sewers. There must also be an acceptable plan for remediation of the creeks and, if applicable, other areas of known or suspected TCDD contamination such as the 93rd Street School in the EDA. This is intended to protect against human exposure or danger of further contamination of the environment with TCDD. In no event should people be encouraged to move into the EDA until the contamination in the creeks, as it affects the EDA, is remediated.

Based on these concerns, additional technical and administrative safeguards that provide for effective, continuous, and clearly accountable management of the Love Canal site must be in place:

1. The administrative structure should ensure accountability. The agency which administers the remedial program at Love Canal, including operation of the treatment plant, must ensure that

the operation meets all applicable Federal and State standards and regulations and is open to independent outside monitoring and review. Under the November 1984 amendments to the Resource Conservation and Recovery Act (RCRA, 42 U.S.C. 3251 et seq.), EPA has the responsibility to review the operation of state-owned or operated waste treatment facilities.

2. Protocols for all aspects of the remedial action, including the treatment plant operation and supervision, should be developed. The protocols should include a timely synthesis, scrutiny, and application of analytical results for routine control and day-to-day operation of the treatment plant. Analyses should include determinations of the volume of leachates processed, amount and character of sludge generated, leachate characteristics during treatment (influent, midpoint, and effluent), and carbon removal and replacement requirements.

3. Quarterly reports summarizing results of remedial action/treatment plant operations should be prepared, advertised, and made available for public scrutiny.

4. A plan for periodic monitoring of the shallow well water in the EDA by EPA and NYSDEC to determine the effectiveness of remediation should be prepared and implemented. The plan should describe immediate measures that will be taken if the monitoring program reveals vulnerabilities or failures in the remediation activities.

6. COMPARISON STRATEGY

A. Neighborhoods

Criteria for habitability are intended to affect general residential viability over and above the designation of any individual home as "safe." For this reason, sociological advice resulted in the delineation of 13 discrete areas within the EDA that contain obvious arrangements of housing with the potential to become socially logical residential groupings. The delineation of these neighborhoods was based in part on input solicited from some of the community members.

Boundaries of neighborhoods are established by geographic barriers (creeks, roads, etc.), community interactions (location of schools, churches, etc.), and social distinctions (income, ethnicity, etc.). The

current designation for the thirteen neighborhoods is of necessity greatly influenced by geography and much less by other factors since the EDA is largely uninhabited. This situation provides the opportunity to redefine neighborhoods by moving their geographic boundaries if this should be desirable. For example, it is possible to have one small area of contamination at the junction of neighborhoods six, seven, and eight that would, by current definition, make all three neighborhoods not habitable. The option of redefining the boundaries will be maintained to limit the impact of such finding to the area directly involved and to assure contiguity of habitable homes.

A sampling plan will be developed to collect samples to determine the LCIC concentrations in soil throughout each neighborhood in the EDA. The sampling plan will allow the assessment of the chosen aggregate values (e.g., mean, mode, median, percentiles, etc.) of each LCIC in each neighborhood in the EDA and in the comparison areas. In addition, the samples will be available for individual examination and comparison. A sampling location may be retested and appropriate remedial action taken if the individual LCIC concentrations from that location are greater than anticipated.

A neighborhood in the EDA is considered habitable if all three of the following conditions are met:

1. If soil sample measurements of TCDD are less than 1 ppb; and,

2. If the chosen aggregate values (e.g., mean, median, percentiles, etc.) of each non-TCDD LCIC evaluated both individually (univariate) and collectively (multivariate) are not significantly different than the values from the comparison areas; and,

3. If the integrity of the neighborhood with reference to the habitability of individual homes within it and to its location relative to other neighborhoods (habitable or uninhabitable) is maintained.

B. Residences

The air in each residence in the EDA will be sampled for airborne LCICs. The NYSDOH made a commitment to sample air in individual houses within the EDA for two reasons:

1. Air in basements was sampled to seek evidence of migration from the landfill during the early period of the Love Canal crisis (1978). While the findings could not be interpreted conclusively, the results did show varying levels of chemicals; this was a source of great concern to the occupants, and this concern remains.

2. Existing chemicals in each residence need to be assayed prior to reoccupancy to document levels for both the new occupant and the government. It will not be possible to make direct comparisons between empty residences and occupied residences.

Occupied residences in the EDA will be compared to occupied residences in the comparison areas. Residences in the EDA with LCIC concentrations found to be significantly greater than the chosen aggregate concentration of those LCICs measured in the comparison areas will be selected for retesting and remediation if appropriate. Ambient air samples will be taken when indoor air is sampled to assure that findings in the houses are not affected by out-of-doors air conditions. Ambient air data will be available if needed.

The LCIC concentrations measured in unoccupied residences in the EDA will be compared to EDA ambient air LCIC concentrations. Unoccupied residences in the

EDA with air LCIC concentrations significantly greater than the chosen aggregate concentration of those LCICs measured in the EDA ambient air will be selected for retesting and remediation if appropriate.

A residence in the EDA is considered habitable if all three of the following conditions are met:

1. If it is located in a neighborhood judged to be habitable; and,

2. If the results of the air comparisons show that retesting and/or remediation are not necessary; and,

3. If remediation is performed and is shown to be successful. Remediation will be considered successful if LCIC are reduced to the same levels as found in habitable areas.

C. Churches and Commercial Establishments in the EDA

At the request of their respective owners, churches, commercially owned land, and other non-residential properties will be included in the soil sampling protocol, and air in churches and commercially owned establishments will be tested for LCICs. The same

habitability criteria used for residences will be applied.

D. The EDA

The whole EDA will be judged uninhabitable if no habitable neighborhoods can be defined within it by the criteria.

7. COMPARISON AREAS AND SELECTION METHODOLOGY

The comparison areas will be chosen from two or more inhabited urban residential census tracts in western New York State selected on the basis of the following sequentially applied criteria (Appendix 11):

1. Contain soil types and hydrogeological conditions similar to those found in the EDA; and,

2. Have borders located as far from known chemical landfill sites as possible, but no less than one-half mile; and preferably no less than one mile; and,

3. Exhibit similarities to the EDA with respect to Niagara Falls urban industrial framework and industrial base, prevailing winds in relation to industrial point sources of potential

environmental contamination, and selected socioeconomic status indicators such as density, value, and age of housing units.

In essence, the comparison areas will be chosen from two or more census tracts matched as closely as possible with the census tracts comprising the EDA, with the exception of the limitation on proximity to a known chemical landfill.

The methodology for selecting the comparison areas will include the following sequence of steps:

1. Identify and characterize soil types and hydrogeology found in the EDA.

2. Identify and map census tracted areas in western New York with soil types and hydrogeology similar to those of the EDA.

3. Identify and map known chemical landfill sites in and adjacent to the census tracts identified in "2" above.

4. Rank census tracts with EDA-like soil types and hydrogeological conditions by distance from known chemical landfill sites, excluding those census

tracts with borders one-half mile or less from known sites.

5. Compare the remaining census tracts with the two census tracts comprising the EDA for similarity with respect to industrial base, prevailing winds in relation to industrial point sources of potential environmental contamination, and selected socioeconomic status indicators such as density, value, and age of housing.

6. Starting with census tracts closest to known landfill sites, reject tracts which represent the poorest match with the EDA, until the list is reduced to six tracts.

7. Review existing data on landfill sites proximate to the six tracts for any suggestion of potential impact on each of the six census tracts; reject any tracts for which there is evidence of offsite migration from a proximate landfill site which could potentially affect the tract.

8. Visit the remaining tracts and survey for visual comparability with the EDA; reject tracts or portions of tracts which, in the opinion of NYSDOH, are markedly different.

The two or more census tracts which are located farthest from or are the least impacted by known landfill sites and which have met all the other criteria will be selected for use as the comparison areas. The environmental data generated from the sampling of the two or more census tracts will be treated as one data set but data from all census tracts will be available for separate analysis if such analysis is deemed worthwhile.

8. ENVIRONMENTAL MEDIA AND LCICs TO BE CONSIDERED

A. Environmental Media

Soil, ambient air, and indoor air were selected as the environmental media representing the most significant pathways for human exposure to Love Canal chemicals and the most appropriate to sample for purposes of the habitability study. Other media considered included groundwater, surface water, water collected in house sumps, sediments, flora and fauna. The potential of each media as a pathway for human exposure and as a pathway of migration of Love Canal chemicals into the EDA was considered as was the likelihood of detecting Love Canal chemicals in each media with standard analytical procedures (Appendix 9). These considerations served as the basis for the selection of environmental media for comparison sampling. Surface

water, groundwater and water in sumps were given serious consideration as environmental media for comparison sampling but were not selected.

Surface water is excluded as a sampling media for the habitability study because soil sampling is judged to be preferable and more meaningful. Soil is always present, while surface water is not. When present, surface water is chiefly precipitation which has not been absorbed into the soil and evaporated. Chemical levels measured in surface water would be a reflection of those in the soil on which the surface water lies. Also soils will contain all contaminants present; surface water, only the water soluble compounds.

Groundwater is excluded as a comparison media because it does not represent a direct route of human exposure to Love Canal chemicals. Groundwater is not now or ever likely to be a source of domestic water supply in the Emergency Declaration Area and does not thereby represent an ingestion source for EDA residents. Furthermore, existing groundwater chemical and hydrogeological data demonstrate little, if any, groundwater contamination beyond Rings I and II (Appendix 6). In addition, periodic groundwater monitoring is included as one of the special provisions required by the Habitability Criteria and is an integral part of the remedial program. Monitoring

wells are currently located around the Love Canal site at varying distances from the drain and are installed to different depts. Analysis of data collected in 1984 demonstrated that concentrations of Love Canal chemicals if present, were below the detection limits of the sampling and analytical procedures used.

Water for household sumps is not included among the selected environmental sampling media though it is recognized that should contaminated groundwater leak into basements, it would settle in sumps and volatilize in the air. For purposes of the habitability study, indoor air sampling in basements is judged to serve as an adequate indication of exposure to Love Canal contaminants which may be transported in this way (through groundwater into sumps). Sumps also serve as the drain for any domestic product spills which could result in unreliable measurements of Love Canal chemicals.

B. Love Canal Indicator Chemicals

The use of a select number of chemicals to represent a larger number of chemicals has been used as an approach to assess the potential for and extent of chemical contamination at other hazardous waste sites in Western New York. Fundamental to the selection of Love Canal Indicator Chemicals (LCICs) is an understanding of

their intended use in the comparison aspect of determining the habitability of the EDA. The key question to be answered through comparative sampling of soil and air is whether the concentrations of LCICs found in the EDA are or are not "significantly different" from the concentrations of the same chemicals found in comparison areas in Western New York. This approach assumes that the LCIC are indicative of a larger group of chemicals originating from the Love Canal, that the EDA may have been affected by the migration of chemicals from the Love Canal, and that the data collected from comparison areas corresponds to "normal background" levels of LCICs. The data obtained from comparative sampling, along with that from dioxin sampling, will be used to assess the relative habitability of the EDA.

The process used to select the LCIC involved several steps. The first was to identify all chemicals known or suspected to have been deposited at the Love Canal. These chemicals are listed in Table I in Appendix 9.

The second was to review the chemical, physical, and biological properties of the chemicals to determine which were more appropriate for use as media-specific indicator chemicals. The six factors considered to evaluate the appropriateness of the chemicals as indicators of contamination by a larger group of Love

Canal Chemicals included: solubility, absorbency, stability and reactivity, biodegradability, ability to be measured using standard analystical techniques, and ubiquity. Those Love Canal Chemicals with unsatisfactory physical, chemical and biological properties for media specific sampling as well as ubiquitous chemicals are listed in Table II in Appendix 9.

The third step was to determine through a review of all existing environmental data which chemicals were found in Rings I and II as well as in the EDA and which showed a decreasing gradient from Rings I and II to the EDA, indicating a high potential for migration or displacement from the Canal. The application of these selection criteria for considered chemicals are summarized by media in Table 5 in Appendix 9.

Based on these selection criteria the following chemicals were selected as LCICs for air and soil:

Air

chlorobenzene

2-chlorotoluene

4-chlorotoluene

Soil

total BHC

beta BHC

gamma BHC

chlorobenzene

1,2-dichlorobenzene

1,2,4-trichlorobenzene

1,2,3,4 tetrachlorobenzene

2-chloronaphthalene

The use of a limited number of indicator chemicals will allow for greater analytical sensitivity, more reliable quality assurance and quality control of sampling and analyses, and greater ease of interpretation during the full scale habitability study.

9. QA/QC OF ENVIRONMENTAL DATA

Any environmental data used in determining habitability should meet the requirements for QA/QC as discussed in Appendix 12. Future environmental sampling protocols should be reviewed by the community and the TRC before they are implemented. EPA standards for QA/QC should be adhered to in any future environmental analyses.

10. CONSENT FOR SAMPLING

All environmental sampling recommended in this document will require written consent of the landowners. It is recommended that a pilot study be conducted as soon as possible to determine the willingness of property owners to participate in this study.

11. OTHER IMPORTANT CONSIDERATIONS

The criteria for determining habitability, as specified above, were based on existing knowledge of toxicology and are expected to protect future residents of the area against detectable harm from any residual levels of Love Canal chemicals that may remain. Nonetheless, to address certain basic indicators of public health in Love Canal--with the understanding that the results of future studies may reflect exposures before relocation, unmeasured factors related to the response to a perceived crisis, or undetermined exposures after relocation--the scientific experts recommended that the NYSDOH determine the following:

1. Whether Love Canal residents have experienced an increased mortality rate relative to other comparable U.S. urban areas.

2. Whether the rate of cancer has increased among Love Canal residents relative to other comparable U.S. urban areas.

3. Whether the rate of congenital malformations or other adverse reproductive outcomes have increased among Love Canal residents relative to other comparable U.S. urban areas. (The above indicators of general health status will be reviewed in the comparison areas).

4. Whether studies can be designed to determine if other chronic diseases or social problems that can be independently verified have occurred more frequently in Love Canal residents.

5. Whether small-animal surveillance is feasible and useful.

Although the above determinations are not directly related to the development of habitability criteria, the major importance of the Love Canal episode requires that New York State health officials assure the public and scientific community that these questions will be addressed and reported in a timely manner.

APPENDIX G
Sampling Plan Design for EDA Habitability Study

Appendix G

SAMPLING PLAN DESIGN
FOR EDA HABITABILITY STUDY

CONTENTS

TABLES

FIGURES

G.1.0 STATISTICAL ISSUES OF THE COMPARISON APPROACH

G.1.1 BACKGROUND

The proposed Love Canal habitability criteria (New York State Department of Health and Centers for Disease Control, December 1986) call for a comparison methodology to assess the habitability of the Love Canal Emergency Declaration Area (EDA). The EDA habitability assessment will be based on a comparison of environmental concentrations of Love Canal indicator chemicals (LCICs) in neighborhoods and residences in the EDA with measured concentrations in similar inhabited communities not impacted by a chemical landfill. This method assumes that data collected from the comparison areas will correspond to typical or habitable conditions and will provide an indication of whether EDA neighborhoods and homes are or are not "significantly different," with respect to contamination by LCICs, from those in comparable western New York communities.

The soil sampling design presented here was developed to identify differences in LCICs, if they exist, between EDA neighborhoods and the comparison area. However, implementing the design requires that a number of issues first be addressed.

The major issues of the sampling design and their resolutions are the following:

- Environmental sampling data collected from the EDA contain a high percentage of reported "nondetect" results for chemicals known to have been deposited in Love Canal. Classical statistical methods require that the proportion of nondetected observations be small.

For purposes of statistical comparisons in the habitability study, the habitability criteria require that all nondetected concentrations from each laboratory for each LCIC be considered equal in both the EDA neighborhoods and the comparison areas.

- The ability to detect a specified difference with a given sample size is determined by data variability. Increasing variability makes a difference more difficult to detect. Preliminary results indicate that EDA soil chemical concentrations are variable. This variability arises from natural (spatial) variability within the soil and from added laboratory variability because of sample handling and analysis.

  The habitability criteria specify that the design of the sampling plan for the statistical comparison will use an order-of-magnitude difference between the EDA neighborhoods and comparison areas for each LCIC. Further, the design will employ criteria of 5 percent overall significance for all comparisons and 90 percent power for an order-of-magnitude difference in mean concentrations for each comparison.

- Interpretation of results for multiple chemicals makes the comparison a multivariate problem. If there is a correlation between the LCICs, then the correlation matrix must also be estimated. In addition, detection of a statistically significant univariate difference for one of the LCICs may not be sufficient to indicate contamination in the multivariate comparison. Similarly, a multivariate comparison may find differences that are not significant in the univariate comparisons. For the

habitability study several statistical procedures will be used to compare individual (univariate) and collective (multivariate) properties of LCICs between each EDA neighborhood and the comparison areas. Statistically significant differences should take into account the reliability of the data across the range of concentrations observed for the various LCICs.

This appendix presents the methodological approach for the preliminary sampling design for the habitability study using the data collected during the pilot study (see Section G.2). The proposed habitability criteria are taken as fixed, that is, only the significance level (0.05), power (0.90), and minimum detectable difference (one order of magnitude in mean concentration) set by the habitability criteria are considered. The data from the DOH study were not available during the development of the methodology. A final design will be available after the methodology has been verified with the additional data.

G.1.2 FACTORS INFLUENCING THE SAMPLING PLAN

Given the proposed habitability criteria for the statistical comparison approach, the remaining design parameters to be selected are:

- The number of samples to be taken in each Love Canal EDA neighborhood and in the comparison area
- The number of laboratories involved in analyzing the data and the division of samples among laboratories

- The allocation of samples to each EDA neighborhood and comparison area

These design issues are influenced by the three major sources of variability encountered in the chemical concentrations. These sources of variability are:

- Natural variability due to the variability of chemical levels in the soil and variability that may have been introduced into the EDA by potential contamination mechanisms

- Interlaboratory variability due to different equipment, reagents, personnel experience, and other factors

- Intralaboratory variability due to recalibration of equipment, sampling, or handling

The pilot study gathered the data needed to determine the magnitude and influence of these sources of variability (see Appendixes B and C).

From this information, a methodology was developed that resulted in the preliminary sampling design described below.

The methodology can be summarized as follows:

- A variety of candidate test statistics were examined to determine the range of sample sizes required to satisfy the habitability criteria.

- The test statistics were evaluated by a Monte Carlo model using probability distributions representative of the pilot study data.

- Sensitivity analyses of the model were done to determine the range of sample sizes necessary due to natural variability from different contamination mechanisms and different relative levels of spatial, interlaboratory, and intralaboratory variability.

The results of the analysis are a preliminary range of sample sizes, methods to reduce interlaboratory variability, and methods to reduce intralaboratory variability.

The remainder of this appendix is organized as follows: Section G.2 discusses the pilot study data as they pertain to the sampling plan design, Section G.3 discusses the statistical methodology used for the preliminary design, and Section G.4 summarizes the preliminary design.

G.2.0 CHARACTERISTICS OF THE PILOT STUDY DATA

This section discusses the pilot study soil data from the statistical perspective required for sampling plan design. The pilot study results were discussed previously in Appendixes B and C in Volume I of this document. The data set used is listed in Attachment G-1 along with summary statistics by area and laboratory. These data include the unverified values below 1 parts per billion (ppb). The assumption used in including these values is that although each individual value is the result of random processes that make identification and quantification uncertain, collectively these values contain information about the probability distributions that characterize the EDA and comparison area.

Although including unverified values below 1 ppb extended the range of concentrations for which quantified values were obtained, many samples still had no discernible concentrations of the LCICs. These samples were considered to have concentrations of the LCICs below the truncation limit of the instrumentation. The term "truncation limit" is used here to avoid confusion with the method detection limit that is a property of the analytic process and not an individual sample analysis.

G.2.1 PROBABILITY DISTRIBUTIONS OF LCIC SOIL SAMPLES

As discussed in Appendix B, the pilot study design specified that all soil samples be split and analyzed by two of the three participating laboratories. The samples were allocated to the three laboratories in a balanced fashion. For one-third of the samples, both splits of each sample went to the same laboratory, while for the remaining two-thirds of

the split samples, the two splits of each sample went to two different laboratories. Through this design, systematic laboratory-related differences in measurements could be identified. In addition to the between-laboratory sample splits, approximately one-third of the samples within each laboratory were split in order to obtain information about the magnitude of the variability in the measurement process itself (i.e., intralaboratory variability).

Histograms of all of the data obtained from samples from the EDA and comparison area are presented in Figures G-1a through h. Between- and within-laboratory splits are represented in the figures in order to give a visual characterization of the sum of spatial, laboratory, and measurement variation. The bars labeled with "0" represent concentrations below the truncation limit. The first bar represents concentrations above the truncation limit to the lower limit of the third bar. Limits for the bars are halfway between the points specified. Thus, for chlorobenzene in the comparison area (Figure G-1b) the first bar represents nonquantifiable values, the second bar reflects concentrations above the truncation limit but less than 0.1, and the third bar represents concentrations between 0.1 and 0.20.

An examination of the histograms quickly reveals that, with the exception of trichlorobenzene and tetrachlorobenzene, large proportions of the samples contained LCIC concentrations below the truncation limit. Highly truncated fractions were observed in both the EDA and comparison areas for nearly all of the LCICs. The other feature of these data is the general similarity between the EDA and comparison area distributions for all the LCICs except trichlorobenzene and tetrachlorobenzene.

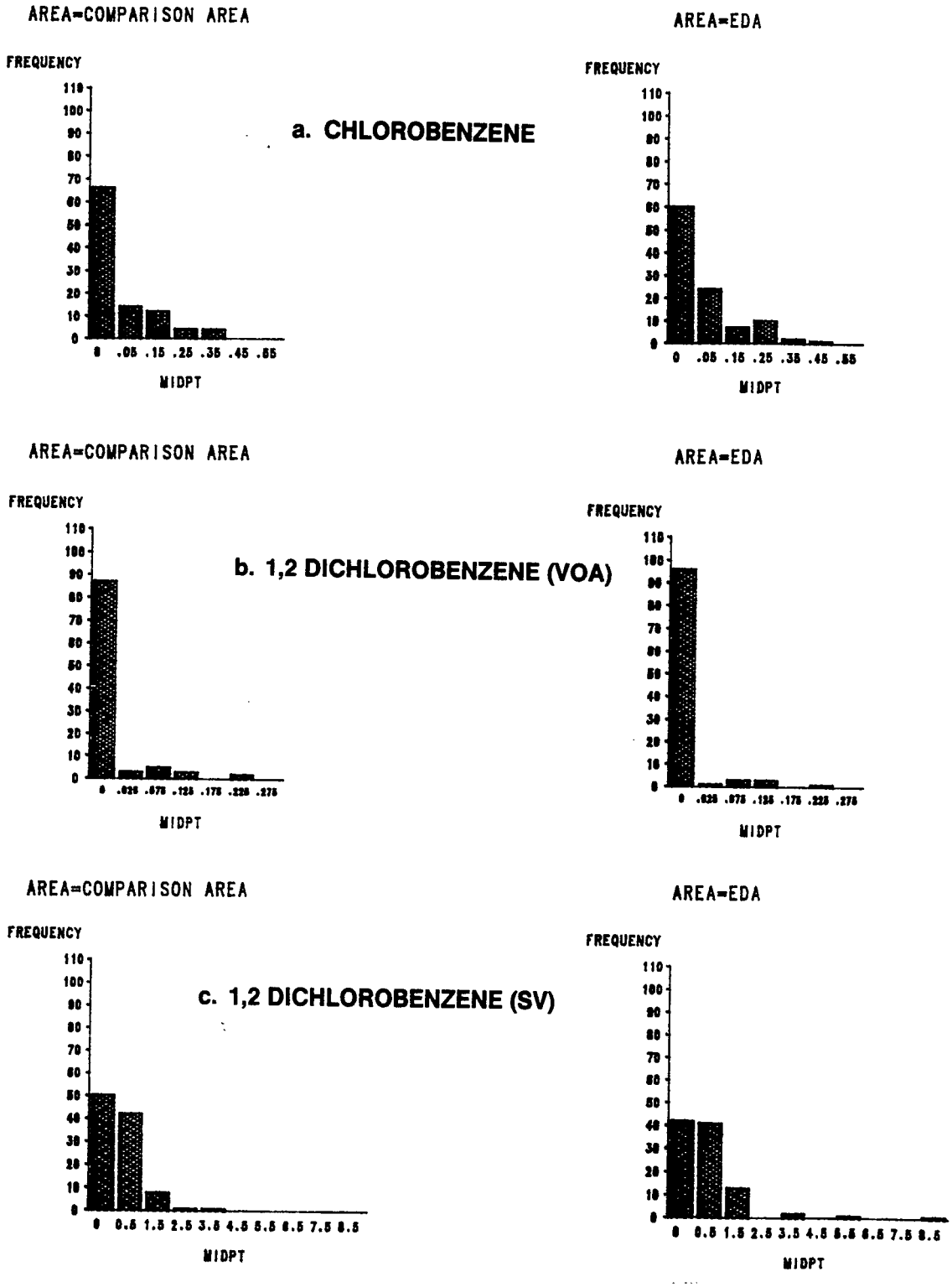


Figure G-1a, b, c
HISTOGRAMS OF ALL-LABORATORY PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA

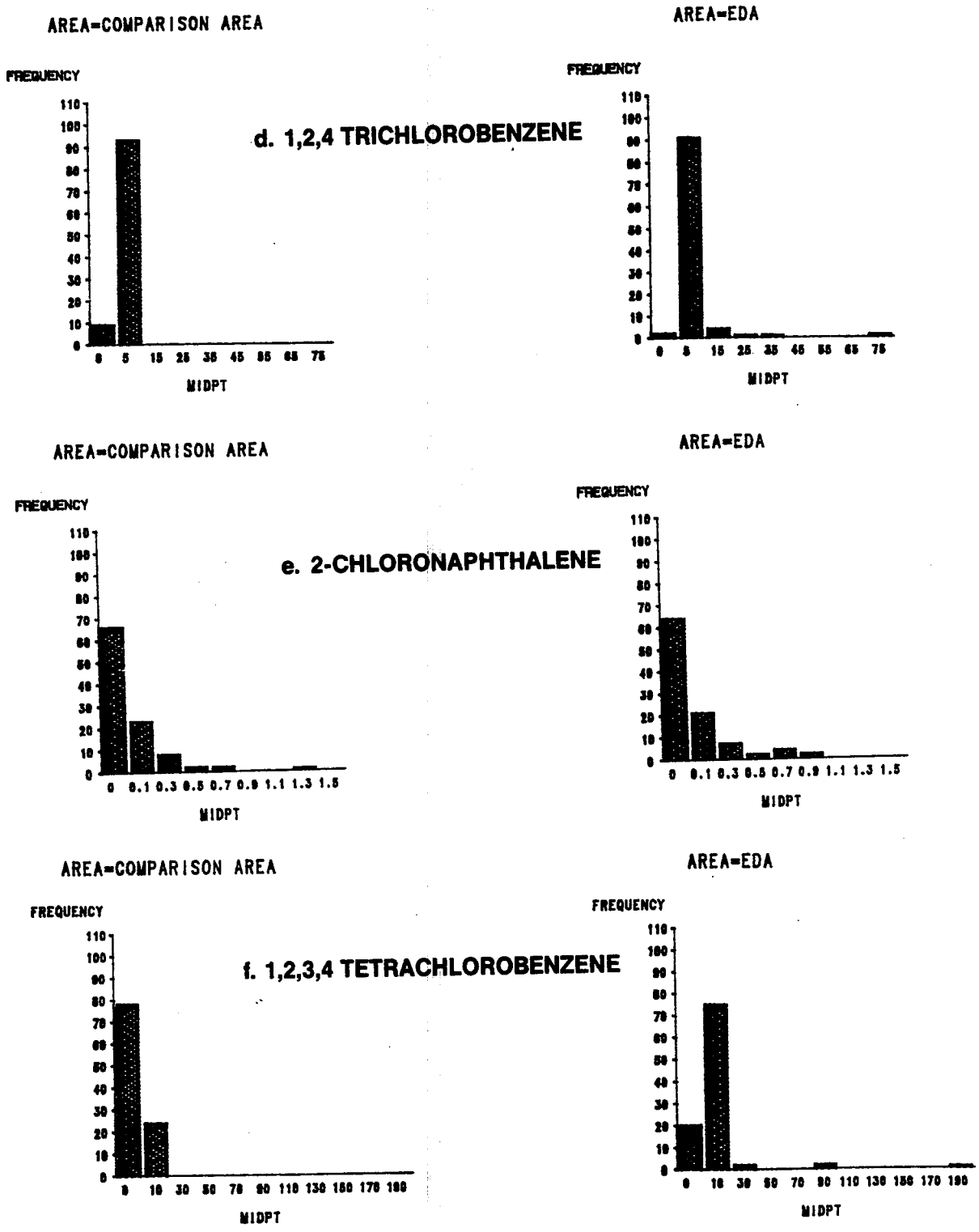
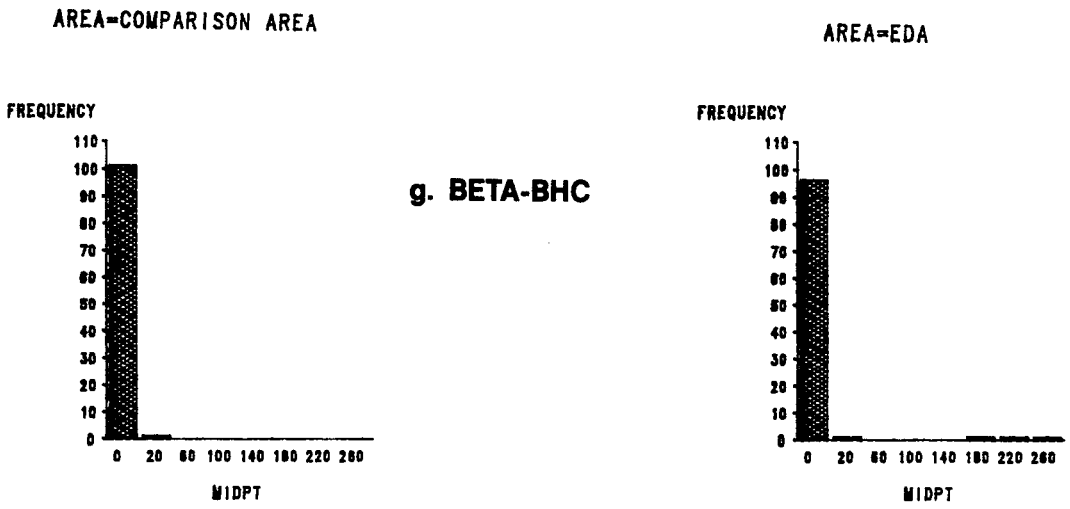


Figure G-1d, e, f
HISTOGRAMS OF ALL-LABORATORY PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA



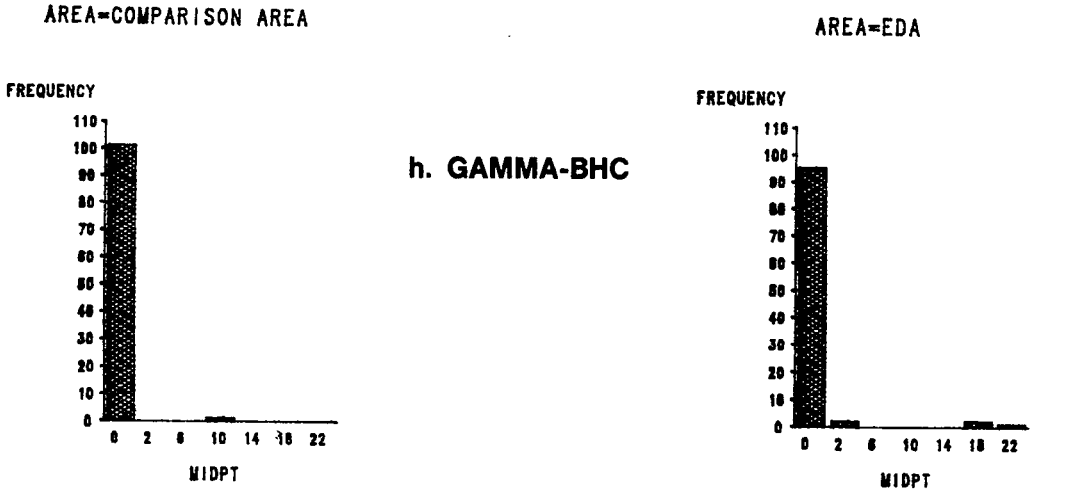


Figure G-1g, h
HISTOGRAMS OF ALL-LABORATORY PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA

In an effort to characterize the probability distribution underlying the data, lognormal distributions were fitted to the observations. The lognormal distribution has two appealing properties. First, it is compatible with some of the most important properties of the data (bounded below by zero and positively skewed). Second, it represents a normal distribution in log space, and normal distributions are well understood.

The parameters of the distributions were estimated using maximum likelihood methods that accounted for the likelihood below the truncation level, that is, the estimated parameters $\hat{\theta}$ ($\hat{\theta}_j$, j=1,..n) are the solution to:

$$\hat{\theta} = \max_{\theta,\ j=1,..n} F(x_d, \theta)^{n-n_d} \prod_{i=1}^{n} f(x_i, \theta)$$

where $F(x_d)$ is the value of the cumulative distribution function at the truncation level x_d (that is, the fraction of truncated data), n is the total sample size, n_d is the number of quantifiable observations, θ are the parameters of the distribution, and f(x) is the probability density function (PDF) of the lognormal distribution. The Kolmogorov-Smirnov statistic was used to assess the goodness of fit of the lognormal distribution to the data.

The maximum likelihood estimates of the lognormal parameters (which are the location and dispersion parameters μ_y and σ_y, respectively, of the normal distribution representing the logarithms of the data) and the results of the Kolmogorov-Smirnov tests are given in Table G-1.

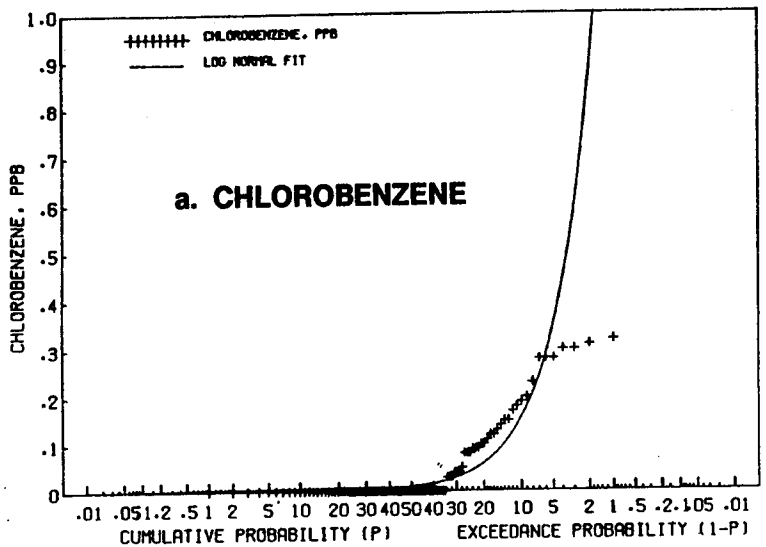
Table G-1
PARAMETER VALUES FOR LOGNORMAL FITS TO PILOT STUDY SOIL SAMPLES ALONG WITH KOLMOGOROV-SMIRNOV STATISTICS

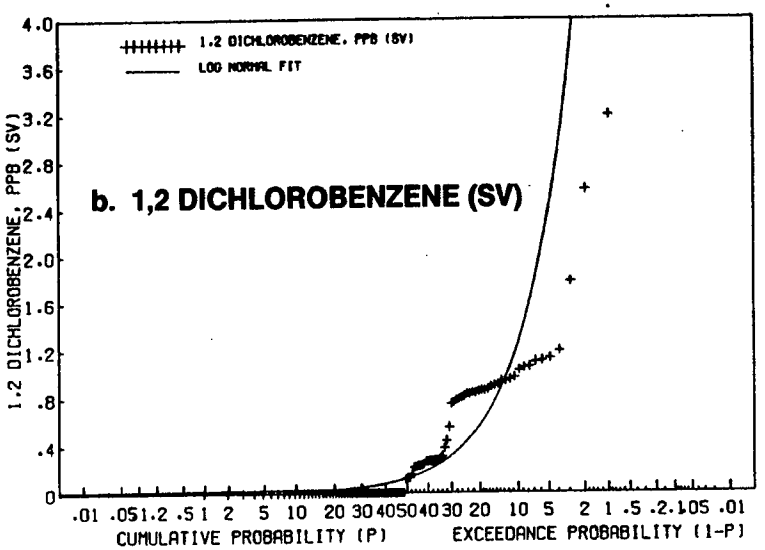
	Comparison Area				
	N	Censoring Level	$\hat{\mu}_y$	$\hat{\sigma}_y$	KS
Chlorobenzene	100	0.02	-4.699	2.220	0.089
Dichlorobenzene (VOA)	100	0.01	-8.657	3.664	0.035
Dichlorobenzene (SV)	102	0.10	-2.081	1.794	0.130
Trichlorobenzene	102	0.05	-1.456	.804	0.092
Chloronaphthalene	102	0.06	-3.339	1.492	0.044
Tetrachlorobenzene	102	0.03	-5.379	2.717	0.058

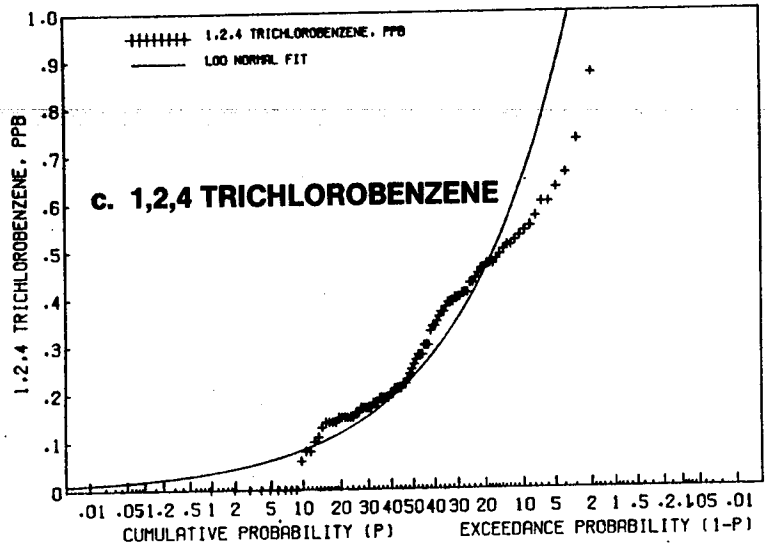
	EDA				
	N	Censoring Level	$\hat{\mu}_y$	$\hat{\sigma}_y$	KS
Chlorobenzene	104	0.01	-4.883	2.546	0.097
Dichlorobenzene (VOA)	104	0.01	-11.331	4.539	0.026
Dichlorobenzene (SV)	100	0.10	-1.749	1.807	0.134
Trichlorobenzene	100	0.06	-0.172	1.233	0.142
Chloronaphthalene	100	0.03	-4.198	2.296	0.106
Tetrachlorobenzene	100	0.20	-0.401	1.754	0.099

For a significance level of 0.10 and for large N, the critical value of the Kolmogorov-Smirnov statistic is $1.22/\sqrt{n}$. Thus, for n = 100, $KS_{critical} = 0.122$. From Table G-1, the null hypothesis that the data comes from the lognormal distribution can be rejected for dichlorobenzene (SV) and trichlorobenzene in the EDA.

The fitted lognormal distributions for several of the comparison area LCICs are plotted in Figures G-2a through d. An examination of these figures provides insight into the reasons for the departures from the lognormal form. For example, the lognormal distribution is unimodal. The mode is usually easily identified either near the left extreme of the distribution (e.g., chlorobenzene in the comparison area, see Figure G-1b) or at some distance from the left extreme (e.g., trichlorobenzene in the EDA, see Figure G-1h). The







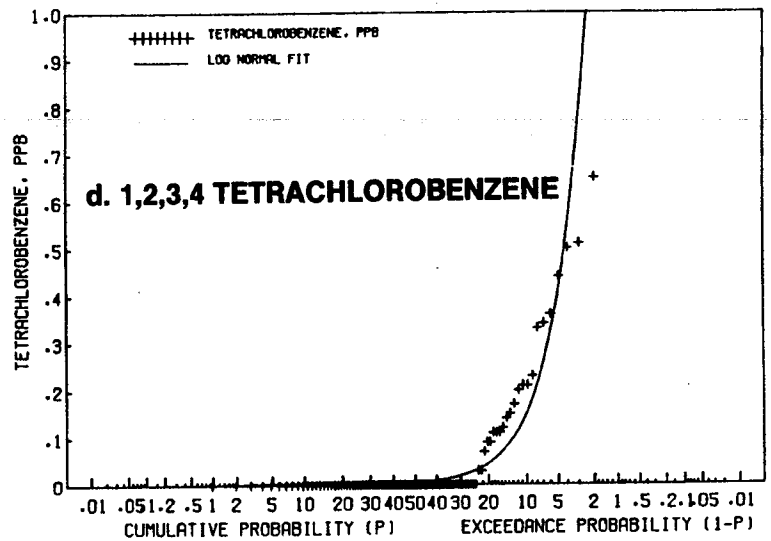


Figure G-2a, b, c, d
FITTED LOGNORMAL DISTRIBUTIONS (COMPARISON AREA)

frequency distributions of dichlorobenzene from both the EDA and comparison area do not show an obvious single distinct peak. In fact, the broad peaks seen in these distributions may well be composed of two individual peaks associated with two different distributions. This is congruent with the results seen in Appendixes C and D of Volume I, where contamination of some of the reagents with dichlorobenzene in one laboratory was reported.

For example, the left-hand portion of the comparison area distribution, which appears to be lognormal, is similar to the same portion of the EDA distribution. However, the EDA also has an extremely long right-hand tail. This implies that the EDA data for trichlorobenzene may have arisen from two distinct distributions. This was suggested earlier in Appendix B of Volume I where two of the EDA study sections had much higher values of trichlorobenzene than the others. In addition, the long right tail may reflect differential sensitivities between the laboratories' measurement systems at levels far in excess (more than 20 times) of the truncation limit.

The bimodal character of some of the LCICs and the generally poor lognormal fits suggest that an alternate, more flexible distribution may be required. Mixture distributions should better characterize data that are drawn from two distinct populations (e.g., background and contamination). The lognormal mixture distribution is defined as

$$F(x) = pF_1(x) + (1-p)F_2(x)$$

where

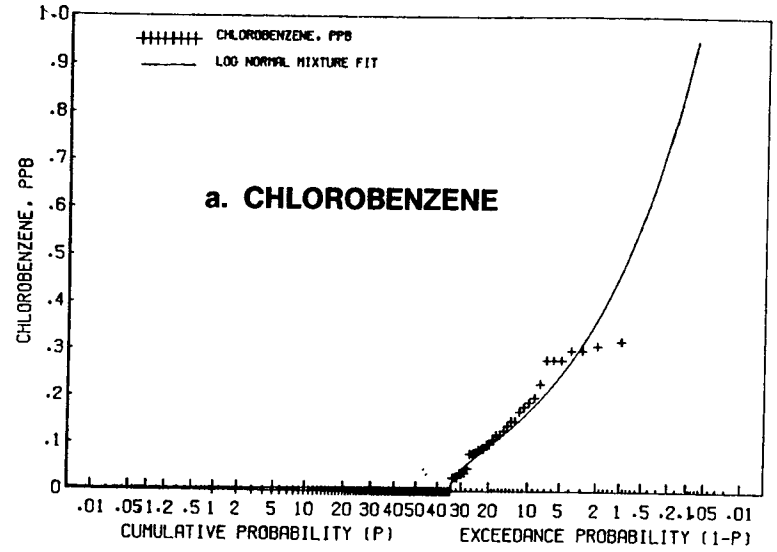
$F_1(x)$ and $F_2(x)$ are lognormally distributed with parameters μ_{y1}, σ_{y1}, and μ_{y2}, σ_{y2}, respectively, and p is the proportion of F_1 in the mixture.

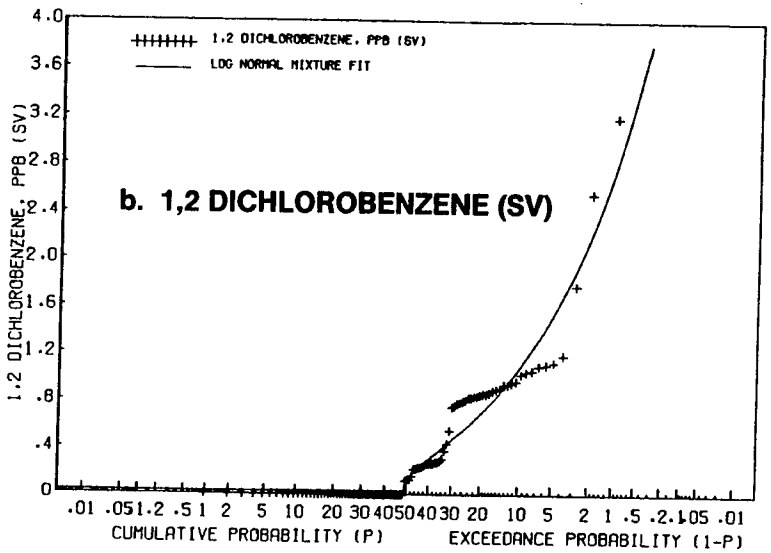
Maximum likelihood parameter estimates for mixture distributions fits were obtained using an optimization (search) procedure. Two cases were considered. In the first, all five parameters, (μ_{y1}, μ_{y2}, σ_{y1}, σ_{y2}, and p) were estimated; in the second, the number of parameters was reduced to four by assuming that $\sigma_{y1} = \sigma_{y2}$. Constraining $\sigma_{y1} = \sigma_{y2}$ made little difference to the fits and had the advantage that it reduced the number of parameters to be estimated.

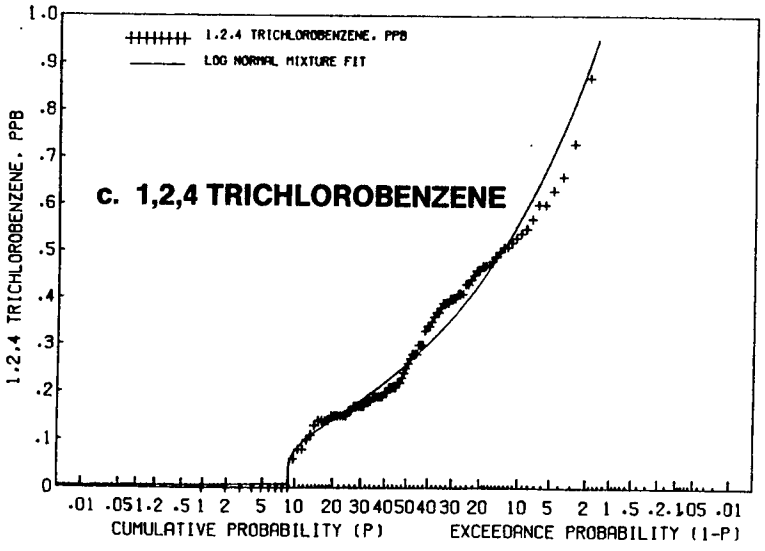
The resulting fits for chlorobenzene, dichlorobenzene (semivolatile), trichlorobenzene, and tetrachlorobenzene are given in Figures G-3a through d for the comparison area and Figures G-4a through d for the EDA. The corresponding model parameters are given in Table G-2a and the mean, standard deviation, and coefficients of skewness and kurtosis implied by the fitted parameters are given in Table G-2b. For those LCICs not reported in Figures G-3 and G-4 and Tables G-2a and b, the number of quantifiable observations from the pilot study was too small to allow fitting of a distribution.

Table G-2a
FITTED LOGNORMAL MIXTURE PARAMETERS FOR PILOT STUDY DATA

Chemical	Area	μ_{y1}	μ_{y2}	σ_{y1}	σ_{y2}	p
Chlorobenzene	Comparison	-4.8	-2.0	0.62	0.62	0.68
	EDA	-5.1	-2.2	0.78	0.78	0.62
1,2-Dichlorobenzene (SV)	Comparison	-3.7	-0.50	0.73	0.73	0.50
	EDA	-0.45	-9.8	0.91	0.91	0.57
1,2,4-Trichlorobenzene	Comparison	-3.3	-1.2	0.53	0.53	0.11
	EDA	-2.7	0.41	0.71	0.71	0.094
Tetrachlorobenzene	Comparison	-3.7	-3.9	1.5	1.5	0.97
	EDA	-0.004	-7.8	1.9	1.9	0.51







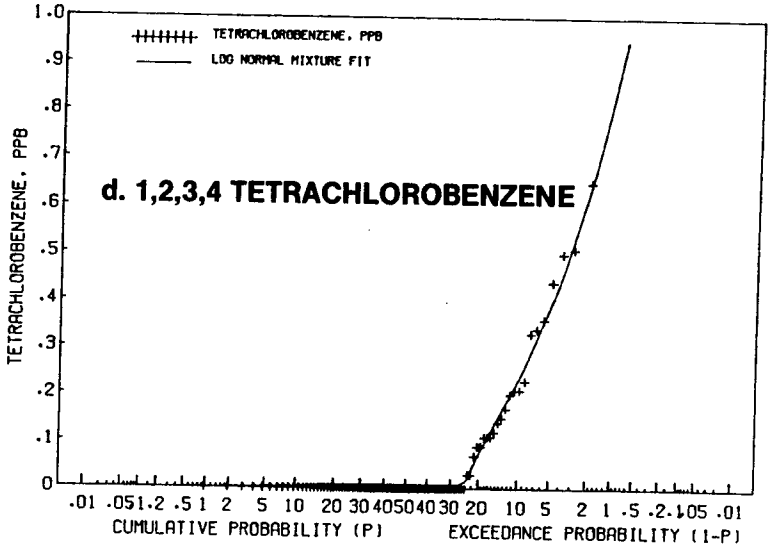
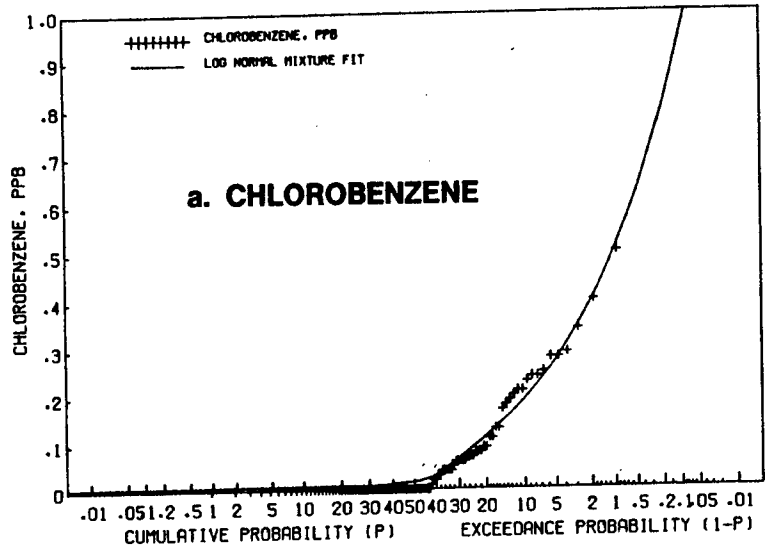
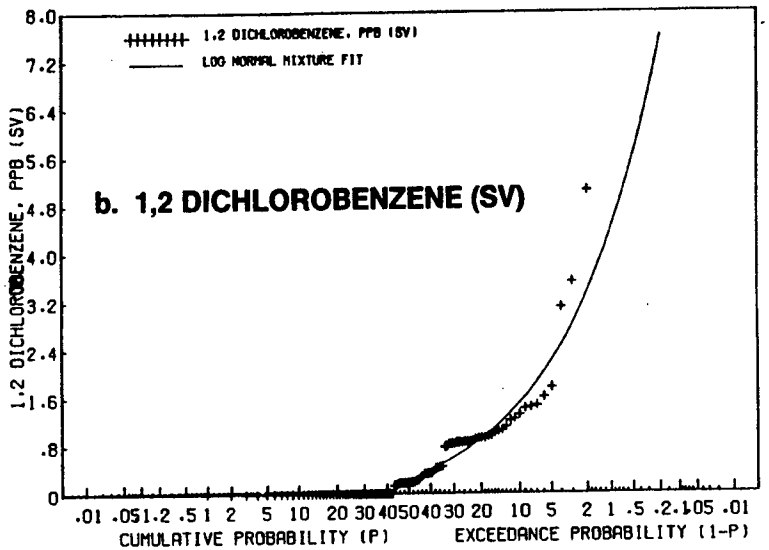
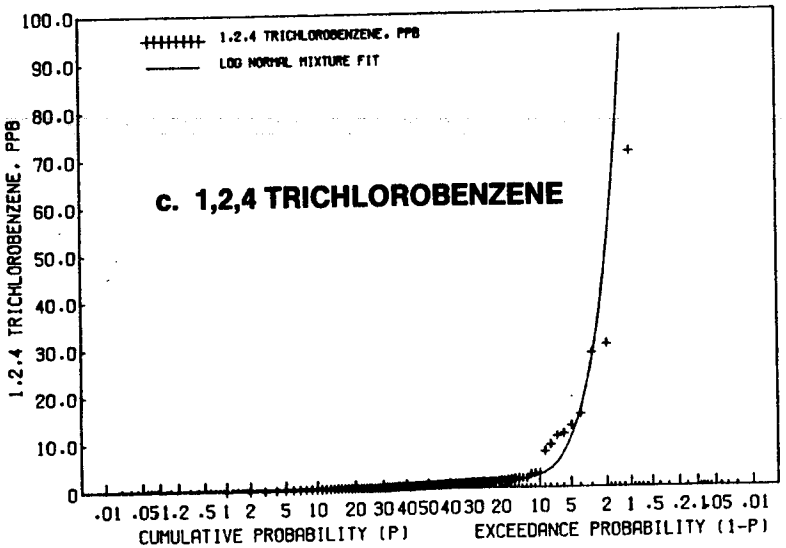


Figure G-3a, b, c, d
FITTED LOGNORMAL MIXTURE DISTRIBUTIONS FOR PILOT STUDY IN COMPARISON AREA







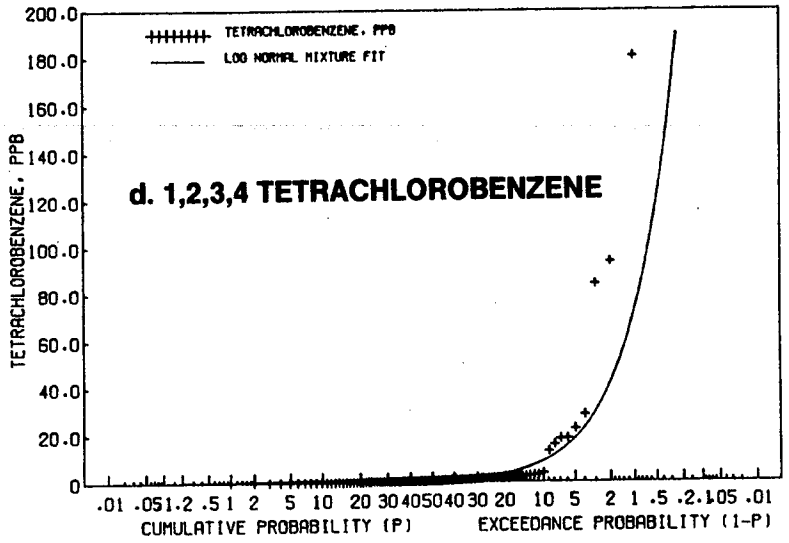


Figure G-4a, b, c, d
FITTED LOGNORMAL MIXTURE DISTRIBUTIONS FOR PILOT STUDY IN EDA

Table G-2b
MOMENTS INFERRED FROM FITTED LOGNORMAL MIXTURE PARAMETERS

Chemical	Area	Mean, μ	Standard Deviation, σ	Skew, γ	Kurtosis, λ
Chlorobenzene	Comparison	0.059	0.096	2.6	27
	EDA	0.062	0.11	3.5	51
1,2-Dichlorobenzene	Comparison	0.41	0.60	2.84	35
	EDA	0.55	0.96	4.6	86
1,2,4-Trichlorobenzene	Comparison	0.31	0.20	2.11	31
	EDA	1.8	1.6	2.8	39
Tetrachlorobenzene	Comparison	0.079	0.241	37	>10,000
	EDA	32	28	360	>100,000

Figures G-3 and G-4 show that the lognormal mixture fits are generally quite good, with the exception of dichlorobenzene and tetrachlorobenzene (EDA only). The problem with dichlorobenzene was traced to contamination during the analysis by one of the laboratories. For model fitting purposes, analyses from all laboratories were treated as interchangeable, but Figures G-3b and G-4b clearly show the effect of laboratory bias, which is further investigated below. The reason for the poor EDA tetrachlorobenzene fits (Figure G-4d) is less apparent.

G.2.2 INTERLABORATORY VARIABILITY

An initial way to investigate interlaboratory variability is again to use histograms to represent the data from the individual laboratories. These are given in Figures G-5a through h. Summary statistics for the laboratory data are provided in Table G-3. An examination of the frequency distributions suggests that indeed there are laboratory differences in the measurements. For example, CAA and EMS

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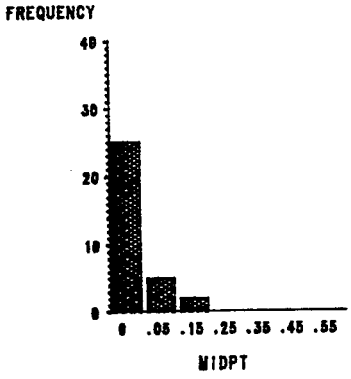

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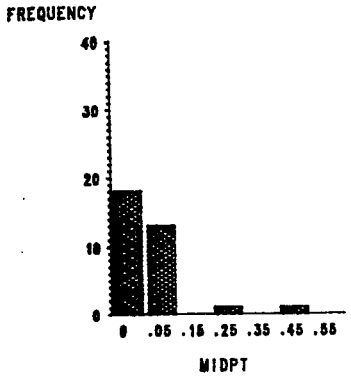

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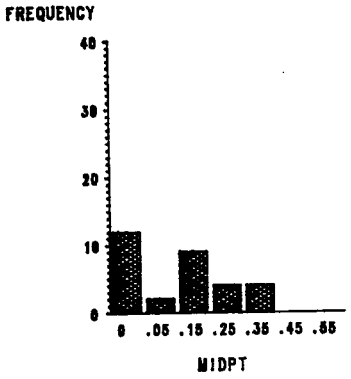

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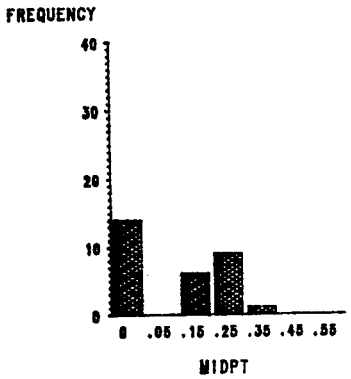

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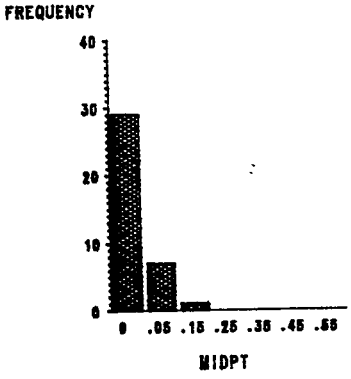

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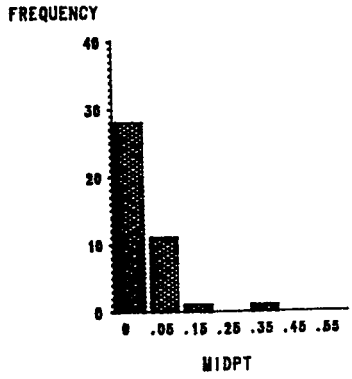

Figure G-5a
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: CHLOROBENZENE

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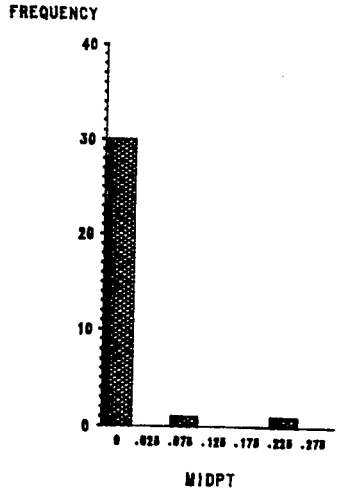

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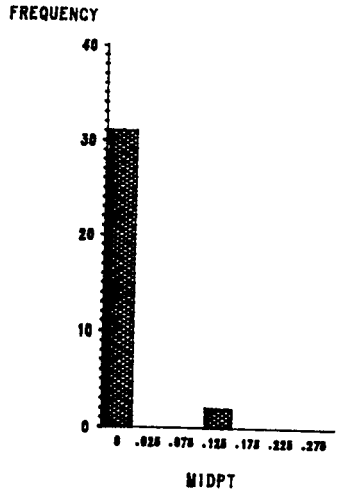

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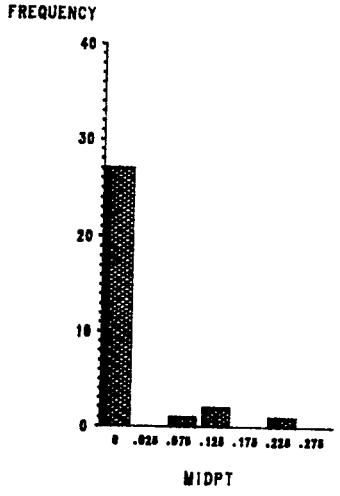

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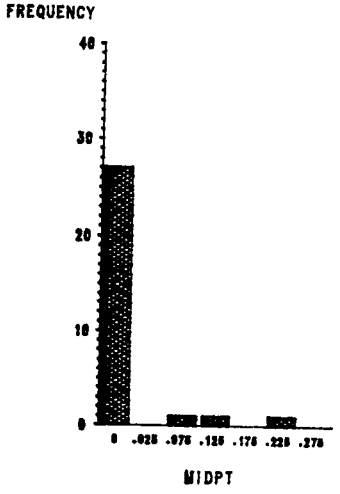

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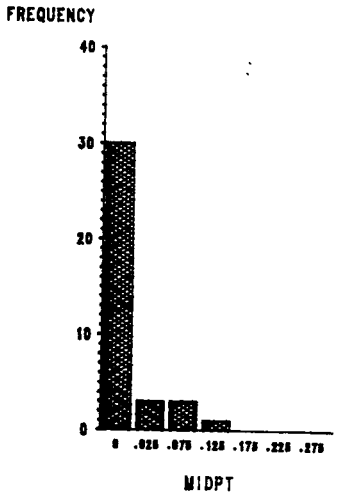

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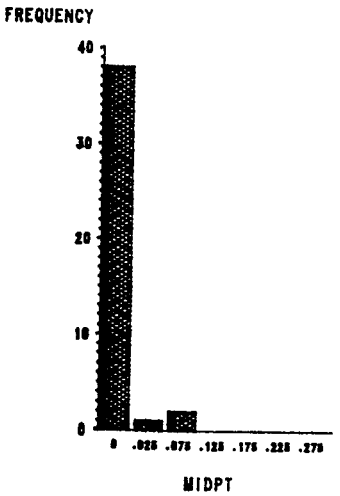

Figure G-5b
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: 1,2 DICHLOROBENZENE (VOA)

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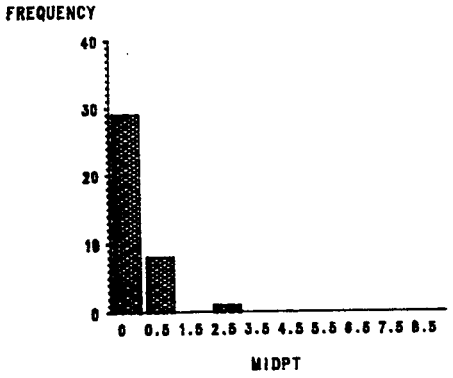

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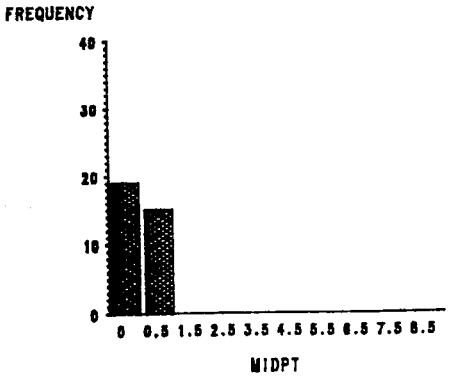

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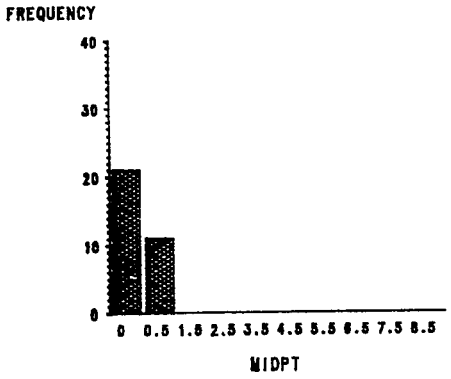

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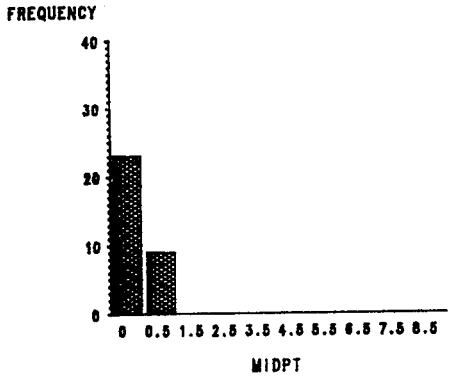

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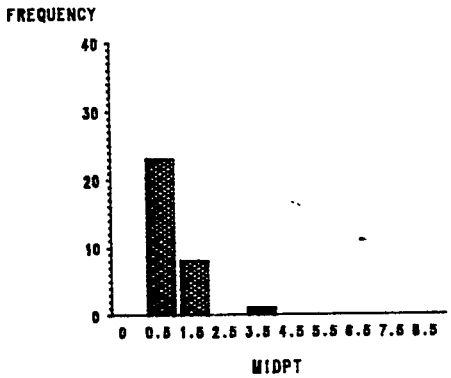

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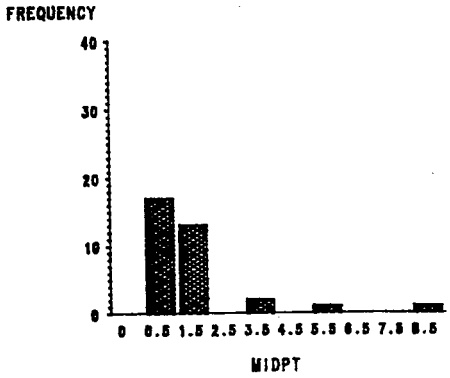
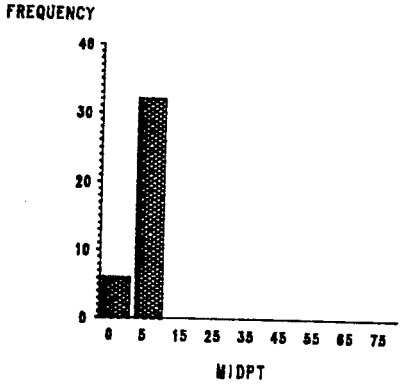


Figure G-5c
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: 1,2 DICHLOROBENZENE (SV)

AREA=COMPARISON AREA LABORATORY ID=CAA



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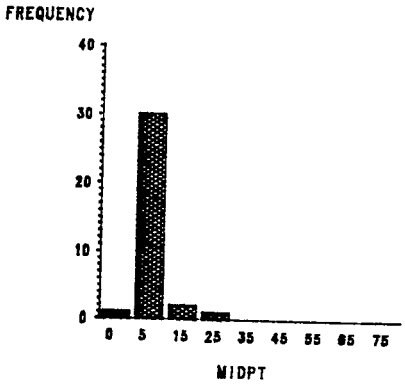
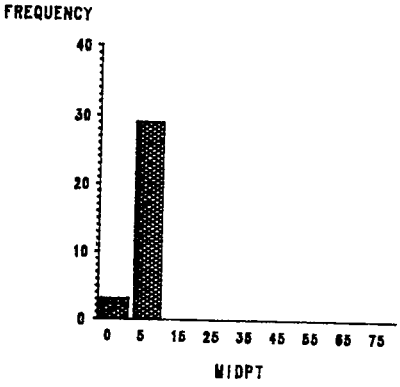


AREA=COMPARISON AREA LABORATORY ID=EMS



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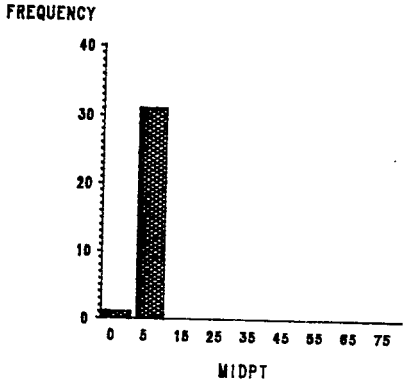

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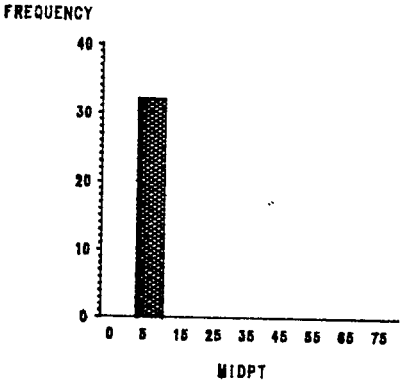

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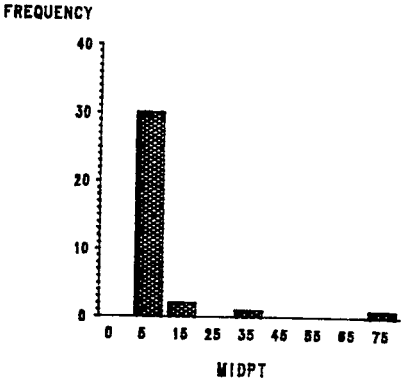
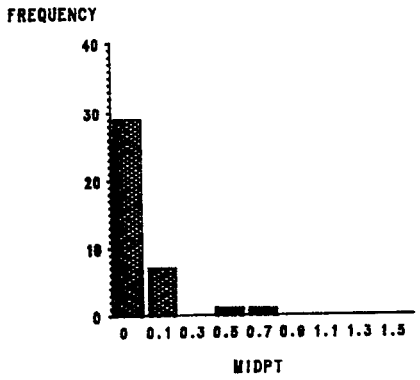


Figure G-5d
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: 1,2,4 TRICHLOROBENZENE

AREA=COMPARISON AREA LABORATORY ID=CAA



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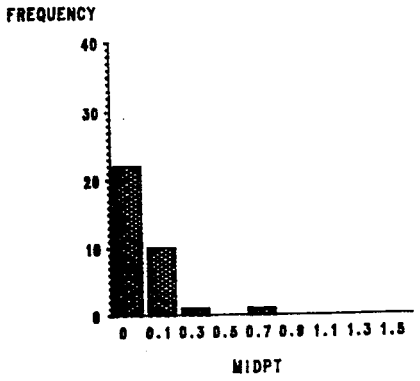

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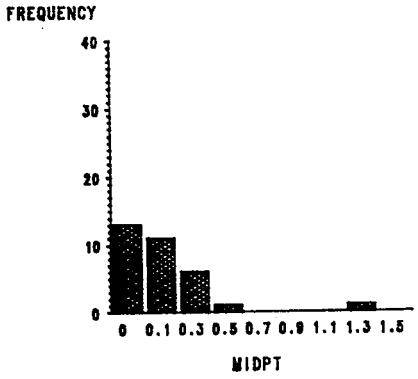

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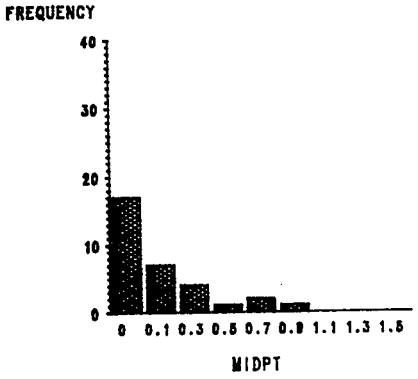

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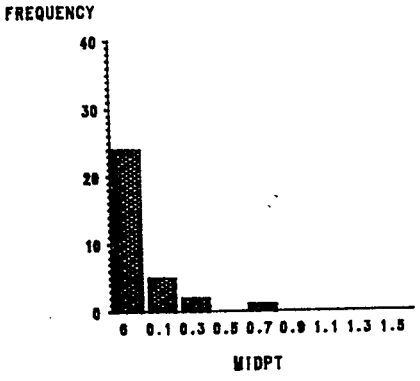


AREA=EDA LABORATORY ID=MGM

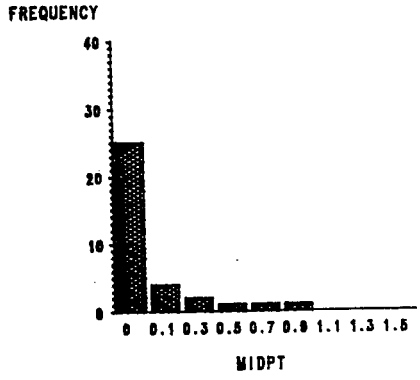
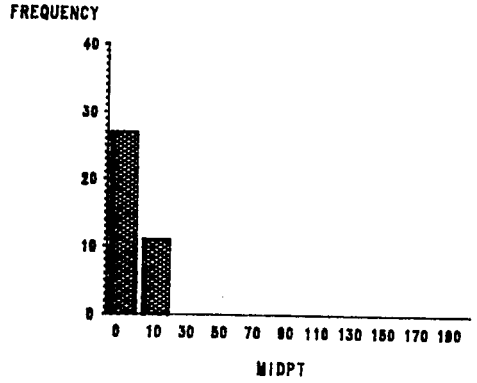


Figure G-5e
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: 2-CHLORONAPHTHALENE

AREA=COMPARISON AREA LABORATORY ID=CAA



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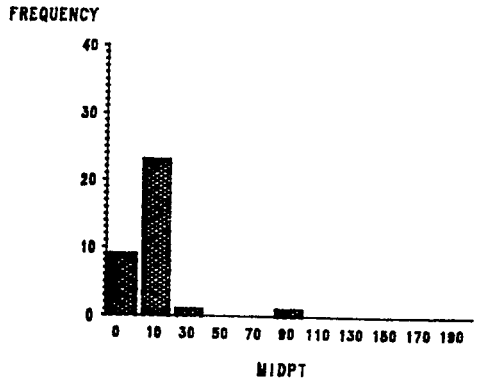

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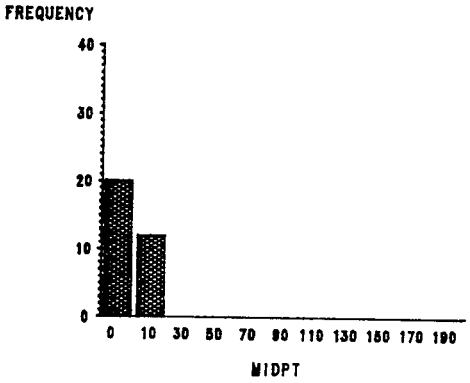

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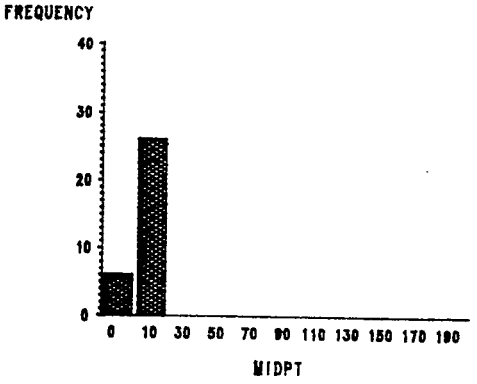

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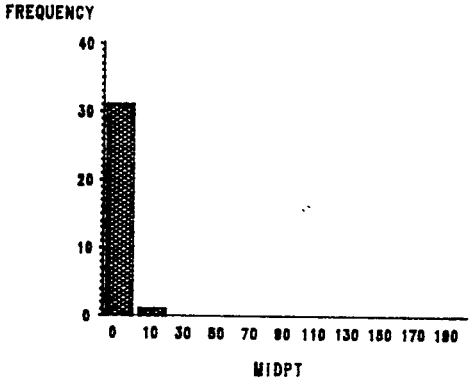

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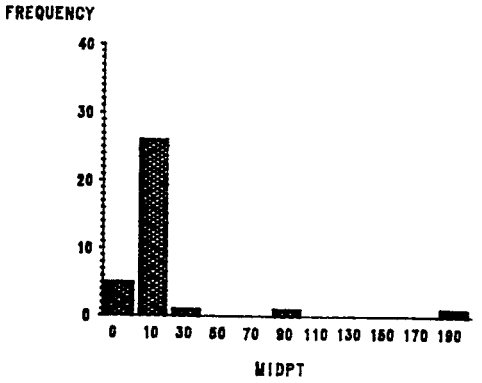
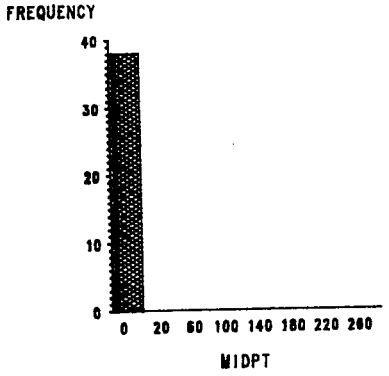


Figure G-5f
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: 1,2,3,4 TETRACHLOROBENZENE

AREA=COMPARISON AREA LABORATORY ID=CAA



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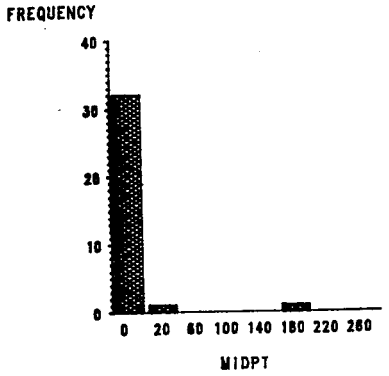
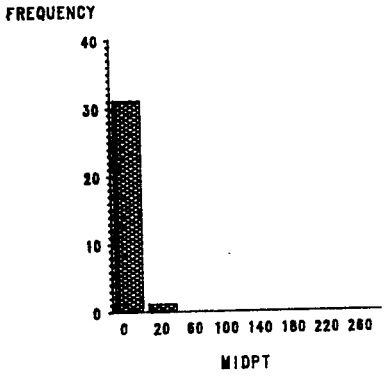
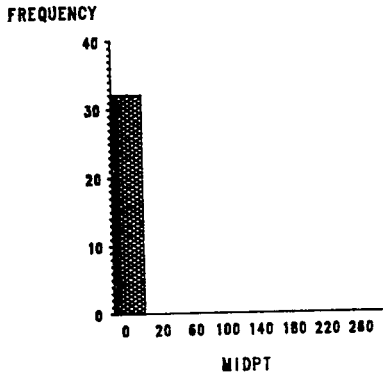


AREA=COMPARISON AREA LABORATORY ID=EMS



AREA=EDA LABORATORY ID=EMS



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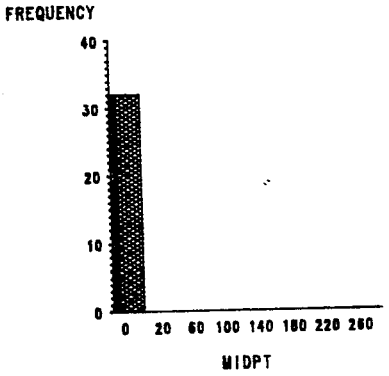

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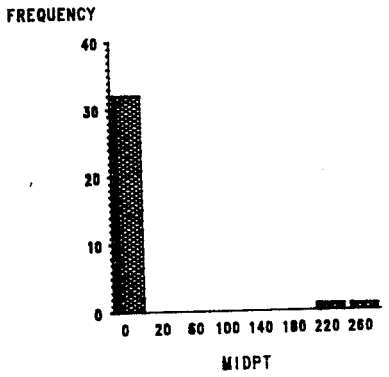
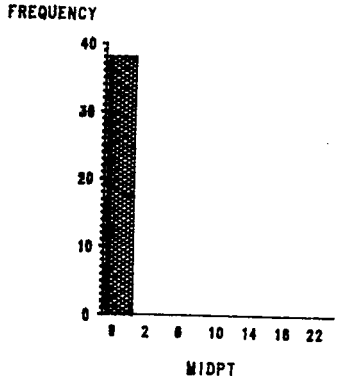


Figure G-5g
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: BETA-BHC

AREA=COMPARISON AREA LABORATORY ID=CAA



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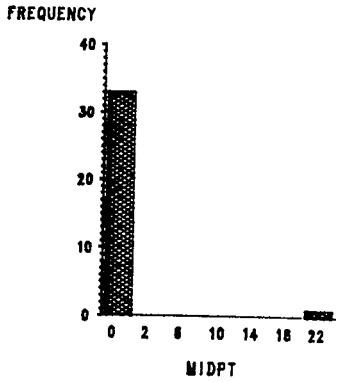

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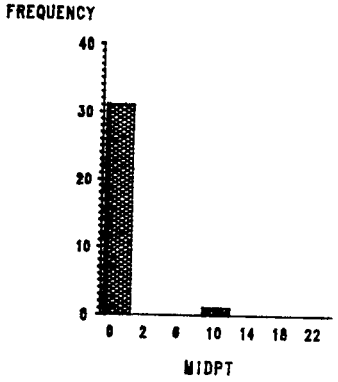

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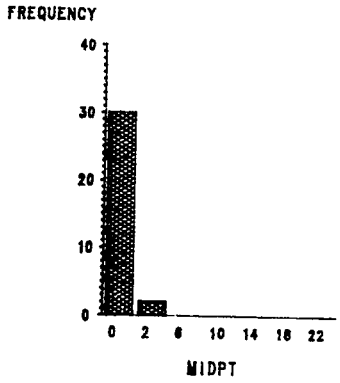

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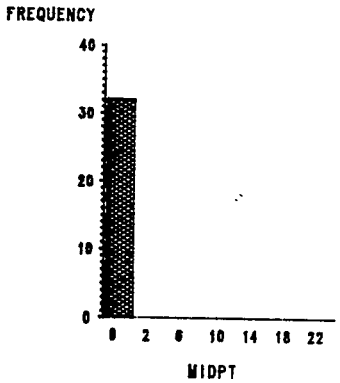

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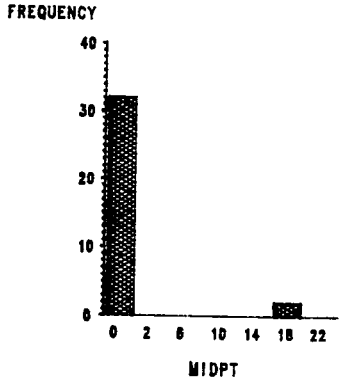


Figure G-5h
HISTOGRAMS OF PILOT STUDY LCIC SOIL CONCENTRATION ESTIMATES FOR COMPARISON AREA AND EDA BY LABORATORY: GAMMA-BHC

Table G-3
ANALYSIS OF INTERLABORATORY VARIANCE

Chlorobenzene

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	1.146	0.65	0.422
Site (area)	88	1.765	1.98	<0.001
Laboratory	2	18.085	20.31	<0.001
Residual	112	0.891		

Dichlorobenzene (VOA)

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	1.136	2.37	0.127
Site (area)	88	0.470	1.06	0.379
Laboratory	2	0.030	0.07	0.937
Residual	112	0.451		

Dichlorobenzene (SV)

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	3.638	1.93	0.168
Site (area)	88	1.880	1.18	0.203
Laboratory	2	150.969	94.87	<0.001
Residual	110	1.591		

Trichlorobenzene

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	88.133	45.08	<0.001
Site (area)	88	86.030	3.05	<0.001
Laboratory	2	13.155	20.55	<0.001
Residual	110	0.640		

Chloronaphthalene

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	0.324	0.13	0.7209
Site (area)	88	2.583	1.54	0.016
Laboratory	2	5.070	3.10	0.049
Residual	110	1.637		

Table G-3
(Continued)

Tetrachlorobenzene

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	489.878	79.92	<0.001
Site (area)	88	6.130	4.18	<0.001
Laboratory	2	0.823	0.56	0.572
Residual	110	1.466		

Beta-BHC

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	2.065	0.55	0.461
Site (area)	88	3.759	9.17	<0.001
Laboratory	2	0.002	<0.01	0.997
Residual	110	0.410		

Gamma-BHC

Source	Degrees of Freedom	Mean Square	F Statistic	p Value
Area	1	1.483	0.65	0.4225
Site (area)	88	2.283	5.31	<0.001
Laboratory	2	0.034	0.79	0.455
Residual	110	0.430		

report between 18 and 30 percent truncated values for dichlorobenzene (SV), while MGM has none. Laboratory differences are also apparent in chlorobenzene where the MGM and CAA distributions appear to be quite similar, but distinct from the EMS distributions. The likely cause for these differences is the contamination of blanks discussed earlier.

These kinds of comparisons are suggestive but by no means definitive. Since the laboratories did not receive all the samples taken from the EDA and comparison areas, observed differences between laboratory data distributions could be related to the samples provided. A rigorous approach to the interlaboratory comparison can be made with analysis of variance methods. Through this methodology, the interlaboratory differences in concentrations at each of the sample sites can be examined. Analyses of variance with factors for area (EDA or comparison area), site within area, and laboratory were performed to determine the extent of systematic interlaboratory variation in the LCIC concentrations. In these analyses, truncated values were changed to 0.01. The data were then logarithmically transformed to provide data groupings that more closely conformed to the ANOVA assumptions of normality and homoscedasticity. The results of these analyses also are given in Table G-3.

In interpreting these results, a small p value (less than 0.05, for example) gives evidence that the source factor contributes significant variation to the overall variance. For the laboratory source, this implies that there is a systematic difference between laboratory measurements. For the site factor, a p value that is large, say greater than 0.2, implies that there is very little site-to-site variation.

These results give strong evidence of significant systematic interlaboratory variability for dichlorobenzene (SV), chlorobenzene, and trichlorobenzene. There is also evidence,

although not as strong, that there are interlaboratory differences in chloronaphthalene measurements. Nonsignificance of the site factors for dichlorobenzene (SV) and dichlorobenzene (VOA) suggest that most of the observed variation is related to the measurement process and that there is little true variation between sites within the EDA and comparison areas.

In addition to identifying the existence of significant interlaboratory variation, it is also useful to determine whether the variation between laboratories is consistent. In other words, is one of the laboratories consistently different from the others or are all laboratories different from each other? To investigate the structure of the interlaboratory variability, the results of the analyses of variance can be utilized. The laboratory factor can be partitioned into two independent pairwise comparisons between sample measurements taken in laboratories. The statistical significance of the departure of these differences from a mean value of zero can then be assessed. Table G-4 presents these results for those compounds in which significant interlaboratory variation was detected. For convenience, all three comparisons are given.

These results indicate that no single laboratory was consistently different from the others for different chemicals. Thus, in a larger study it will be extremely important to account for laboratory differences both in the design and in analysis strategies. It will be necessary to balance the allocation of control area and EDA samples among laboratories. Disproportionate allocation of samples will be likely to bias comparisons between the two areas.

Table G-4
MEAN OF DIFFERENCES BETWEEN SPLIT SAMPLES

Compound	Laboratory Comparisons CAA-EMS	CAA-MGM	MGM-EMS	Inference
Chlorobenzene	-0.115[a]	0.010	-.104[b]	EMS differs from other labs.
Chloronaphthalene	-0.07[b]	0.012	-0.030	EMS differs from other labs.
Dichlorobenzene (SV)	-0.074	-1.095[a]	1.187[a]	MGM differs from other labs.
Trichlorobenzene	0.243	-1.389[a]	0.556[a]	MGM differs from other labs.

[a] $p<0.01$.
[b] $p<0.05$.

G.2.3 VARIANCE COMPONENT ANALYSIS

In addition to consideration of laboratory differences, the relative magnitude of sources of variation in soil sampling is important to the comparison study design. Specifically, it is important to estimate the variability between sites, between laboratories, and within laboratories. Since we might expect differences between the EDA and comparison area with respect to the degree of spatial (site-to-site) variation, the three sources of variation will be analyzed separately by area. A standard variance component estimation scheme was used to obtain variance estimates for compounds with a reasonable quantifiable fraction (less than 80 percent truncated). The results are presented below in Table G-5.

Table G-5
VARIANCE COMPONENT ESTIMATE

	EDA			Comparison Area		
	Site	Between Laboratory	Within Laboratory	Site	Between Laboratory	Within Laboratory
Chlorobenzene	0.36	1.85	0.82	1.24	3.62	3.92
Chloronaphthalene	14.83	0.544	24.46	0.55	2.15	32.52
Dichlorobenzene (SV)	126.22	646.34	680.64	0.00	242.13	155.03
Tetrachlorobenzene	547.03	0	0	0.45	0.70	19.18
Trichlorobenzene	6,834	493	1,675	0	31.89	25.28

These estimates put some of the other results into perspective. First, it is clear that the interlaboratory variance is a large portion of total variance for chlorobenzene and dichlorobenzene in both the EDA and comparison areas. In the comparison area, there is no significant site-to-site variability in tetrachlorobenzene, indicating that the variability in the observed distribution is (almost) entirely due to the measurement process. However, for tetrachlorobenzene in the EDA, the between-site variance is so large that it overwhelms the other variance estimates. This is because of the large range of tetrachlorobenzene values and relatively small amount of variation between laboratories on splits of these samples. As might be expected, the spatial variation associated with trichlorobenzene samples in the EDA is also quite large because of the combination of both large and small values obtained there. By comparing the variance components in the EDA with their counterparts in the comparison area, one can see that measurement error as well as the differences between laboratories increases as the magnitude of the measurement increases.

The conclusion that can be drawn from these results is that between-laboratory variation in measurements was often as large or larger than that found within laboratories. Thus, a design that provides for contrasts between control and comparison area measurements arising from the same laboratory will greatly improve its sensitivity. For some of the LCICs, the variance of within-laboratory comparisons will be reduced by a factor of two relative to the variance in comparisons that do not take the laboratories into account, assuming these labs are typical. In addition, the impact of bias that would result from disproportionate allocation of comparison area samples to laboratories that differ systematically cannot be overemphasized. If the distribution of samples to laboratories is not randomized effectively, differences between areas will be confounded with differences between laboratories. The direction of the effect of this confounding will be uncertain, resulting in either false positive or false negative inferences. Although sample splits among laboratories can give some insight into the direction of potential biases, a better means to protect against these problems will be through randomized blocking or similar methods.

G.2.4 CORRELATION BETWEEN THE LOVE CANAL INDICATOR CHEMICALS

In the development of hypothesis tests to compare levels of the LCICs in the EDA with those observed in the comparison area or areas, it will be important to account for the false positive inferences that might occur by chance because of the application of large numbers of statistical tests. This situation is exacerbated if the data are correlated. To gain an understanding of the degree of covariation that can be expected in the LCIC, Spearman rank correlation coefficients were calculated for the chemicals in both the EDA and

comparison area. Prior to analysis, averages were computed by sampling site. The results are given in Tables G-6a and G-6b.

From these tables, it is clear that most correlations are not significantly different from zero. In the comparison area, the only correlations in excess of 0.6 are between tetrachlorobenzene and trichlorobenzene and between dichlorobenzene (SV) and trichlorobenzene. The latter correlation is the only one that is significantly different from zero in both the EDA and comparison areas. All of the remaining nonzero correlations are between compounds with very large nondetect fractions. In these cases, the observed correlation reflects the concordance between a large number of nondetects in a pair of chemicals rather than a linear relationship between measurements. When one plots these data, there is no evidence of any systematic relationship in the values above the detection limit. Thus, it appears that a minimal amount of correlation is present in the LCICs. There appears to be only one correlation of any consequence, that between dichlorobenzene (SV) and trichlorobenzene.

G.2.5 CONCLUSIONS FROM PILOT STUDY DATA

The purpose of the pilot study was to collect data required to assist in the comparative sampling plan called for in the proposed habitability criteria. After analysis, the following conclusions were reached:

- Even with the improved laboratory protocols, as much as 85 to 90 percent of the data from the comparison area may have concentrations below the truncation level.

Table G-6a

PILOT STUDY SAMPLE SPEARMAN CORRELATION MATRIX FOR COMPARISON AREA

(p values for H_o: $\rho = 0$ vs H_a: $\rho \neq 0$ are in parentheses)

	Chemical							
	Chloro-benzene	Dichloro-benzene (VOA)	Dichloro-benzene (SV)	Tri-chloro-benzene	Chloro-naph-thalene	Tetra-chloro-benzene	B-BHC	G-BHC
Chlorobenzene	1.00000 (0.00)	0.17 (0.26)	-0.11 (0.47)	0.10 (0.50)	0.38 (0.011)	0.088 (0.56)	0.066 (0.66)	0.12 (0.44)
Dichlorobenzene (VOA)		1.00 (0.00)	-0.21 (0.17)	-0.099 (0.52)	0.23 (0.12)	0.21 (0.17)	-0.09 (0.55)	-0.13 (0.38)
Dichlorobenzene (SV)			1.00 (0.00)	0.69 (0.00)	-0.24 (0.11)	-0.19 (0.22)	0.02 (0.89)	-0.24 (0.12)
Trichlorobenzene				1.00 (0.00)	0.13 (0.38)	0.18 (0.23)	0.17 (0.26)	-0.20 (0.19)
Chloronaphthalene					1.00 (0.00)	0.64 (0.00)	0.30 (0.045)	0.25 (0.10)
Tetrachlorobenzene						1.00 (0.00)	0.32 (0.03)	0.07 (0.63)
Beta-BHC							1.00 (0.00)	0.35 (0.02)
Gamma-BHC								1.00 (0.00)

Table G-6b
PILOT STUDY SAMPLE SPEARMAN CORRELATION MATRIX FOR EDA
(p values for H_o: $\rho = 0$ vs H_a: $\rho \neq 0$ are in parentheses)

	Chemical							
	Chloro-benzene	Dichloro-benzene (VOA)	Dichloro-benzene (SV)	Tri-chloro-benzene	Chloro-naph-thalene	Tetra-chloro-benzene	B-BHC	G-BHC
Chlorobenzene	1.00 (0.00)	0.084 (0.58)	-0.13 (0.39)	0.077 (0.61)	0.12 (0.44)	0.13 (0.39)	0.35 (0.018)	0.071 (0.64)
Dichlorobenzene (VOA)		1.00 (0.00)	-0.15 (0.34)	-0.096 (0.53)	0.20 (0.18)	0.063 (0.68)	0.23 (0.12)	0.25 (0.091)
Dichlorobenzene (SV)			1.00 (0.00)	0.37 (0.013)	0.087 (0.57)	0.14 (0.36)	- 0.24 (0.11)	-0.16 (0.30)
Trichlorobenzene				1.00 (0.00)	0.037 (0.81)	0.77 (0.00)	-0.12 (0.43)	-0.064 (0.68)
Chloronaphthalene					1.00 (0.00)	0.072 (0.64)	0.40 (0.0070)	0.51 (0.00)
Tetrachlorobenzene						1.00 (0.00)	0.15 (0.34)	0.21 (0.17)
Beta-BHC							1.0 (0.0)	0.54 (0.0001)
Gamma-BHC								1.0 (0.0)

- Insufficient data are available to design the sampling plan using empirical distributions drawn directly from the pilot study data. In data sets with high fractions of quantifiable concentrations, the values were often due to extraneous factors (laboratory contamination or non-Love Canal contamination). Therefore, it is recommended that the sampling plan design be based on parametric probability distribution and that, to the extent possible, the distributions be parameterized using the pilot study data.

- The variability in LCIC concentrations in the comparison area can be represented by lognormal probability distributions. The variability in LCIC concentrations in the EDA can be represented by lognormal mixture probability distributions where the mixture can be used to represent possible Love Canal-related contamination.

- Intralaboratory (measurement) error appears to be significant for certain chemicals.

- Between-laboratory concentration differences are significant for several of the LCICs. Careful blocking of laboratory and samples from the comparison areas and EDA neighborhoods must be considered in the sampling design.

- Correlation among LCIC chemicals appears negligible and can be ignored during the sampling plan design.

G.3.0 SAMPLING DESIGN METHODOLOGY AND RESULTS

G.3.1 OVERVIEW

The sampling design methodology is based on a Monte Carlo modeling approach where power curves were estimated empirically using hypothetical data sets that are statistically similar to the pilot data sets. The power curves were estimated for each statistical test based on 500 hypothetical data sets. The LCIC concentrations were assumed to follow a lognormal mixture distribution in the EDA.

Two mechanisms of Love Canal contamination are hypothesized. The first mechanism is general contamination resulting in higher average EDA LCIC concentrations. The pilot study data and other environmental chemical data show that higher average concentrations go together with higher chemical variability. Therefore, for general contamination, differences between the EDA and comparison area are evidenced by both the mean and the standard deviation increasing in the same proportions so that the coefficient of variation remains constant.

The second mechanism assumes that the EDA contamination is localized so that the EDA concentration can be modeled as a lognormal mixture. One lognormal component represents background (equivalent to comparison area variability) and the other represents the localized contamination, which has a higher mean value. This results in an overall distribution that has long right tails and is consistent with observed pilot study data. We further hypothesize, based on the pilot study data, that the coefficients of variation in the two components of the lognormal mixture are identical.

As shown in the figures of Section G.2, the parametric distributions represent well the variability of LCIC concentration. It is this variability that affects the sampling plan design. The preliminary sampling plan used representative values of variability obtained by fitting the pilot study data to lognormal (for comparison areas) and lognormal mixture probability models.

Table G-7a gives these parameter values while Table G-7b gives the inferred moments. The parameter "p" in the table gives the mixing fraction. A value of 1.0 results in a lognormal with parameters (μ_{y1}, S_{y1}), i.e., a simple lognormal.

Table G-7a
FITTED PARAMETER VALUES FOR COMPARISON AREA AND PILOT STUDY DATA

Chemical	Area	μ_{y1}	μ_{y2}	S_{y1}	S_{y2}	P
Chlorobenzene	Comparison	-4.599	-0.000	2.220	1.000	1.000
	EDA	-5.107	-2.211	0.781	0.781	0.616
1,2-Dichlorobenzene (SV)	Comparison	-2.081	0.000	1.794	1.000	1.000
	EDA	-0.446	-9.811	0.913	0.913	0.570
1,2,4-Trichlorobenzene	Comparison	-1.456	0.000	0.804	1.000	1.000
	EDA	-2.717	-0.414	0.706	0.706	0.094
Tetrachlorobenzene	Comparison	-5.379	0.000	2.717	1.000	1.000
	EDA	-0.004	-7.775	1.920	1.920	0.807

The design methodology program included examining seven univariate and two multivariate test procedures that spanned a range of approaches to comparisons. A summary of these tests is given in Attachment G-2. Extensive simulations showed that a modified Wilcoxon, Shorack's dispersion F-test, and Mood-Westenberg upper quantile test performed the best for distributions similar to those inferred from the pilot study data for the univariate analysis. Of these, the modified

Wilcoxon was chosen for use in the design simulations. Two tests (a multivariate rank sum test based on average ranks and a multivariate rank sum test based on a χ^2 approximation) were used for multivariate analyses. The average rank test was used for the design simulations.

Table G-7b
INFERRED MOMENTS FOR COMPARISON AREA
AND EDA PILOT STUDY DATA

Chemical	Area	Mean	Standard Deviation	Skew	Kurtosis
Chlorobenzene	Comparison	0.118	1.38	>1,000	>100,000
	EDA	0.062	0.109	3.453	51.87
1,2-Dichlorobenzene (SV)	Comparison	0.624	3.055	>100	>100,000
	EDA	0.554	0.964	4.28	86.86
1,2,4-Trichlorobenzene	Comparison	0.322	0.307	3.73	57.34
	EDA	1.77	1.58	2.83	39.40
Tetrachlorobenzene	Comparison	0.184	7.41	>10,000	>100,000
	EDA	3.191	28.12	360.2	>100,000

All sampling plans were designed to meet the proposed habitability criteria. Specifically, power was fixed at 0.9, significance level at 0.05, and Δ, the difference in means between the EDA and the comparison area, was fixed at an order of magnitude. An order of magnitude difference between means was assumed, as the criteria document is not specific.

G.3.2 SAMPLE SIZE FOR GENERAL CONTAMINATION MODEL

The assumption was made that differences between the comparison area and an EDA neighborhood, due to general contamination, can be represented by shifts in the mean concentration and concentration variability such that the coefficient of

variation (C_v) is constant. Based on the pilot study data, the following moments were used to characterize the comparison area distribution for the simulation:

C_v	Skew	Kurtosis
2	14	625

The simulation was run assuming both 85 and 95 percent nondetects in the comparison area data. Figure G-6 gives the cumulative probability distribution plots for the control area and for the EDA under an order-of-magnitude shift in mean concentration.

The resultant sample sizes required (in each of the EDA neighborhoods and the comparison area) to detect the order-of-magnitude difference at a 0.05 significance level with 0.90 power were as follows:

Nondetect Fraction	Minimum Size Required	Test
0.85	<10	Modified Wilcoxon
0.95	<10	Modified Wilcoxon

G.3.3 SAMPLE SIZE FOR LOCALIZED CONTAMINATION MODEL

The assumption was made that differences between the comparison area and an EDA neighborhood, because of "localized" contamination, can be represented by a mixture of two lognormal distributions. Here one lognormal represents the comparison area and EDA background chemical concentration levels and a second lognormal is mixed to the first distribution in the EDA to represent contamination.

The mixing fraction p is an important parameter and was estimated from the pilot study data to range from 0.3 to 0.5.

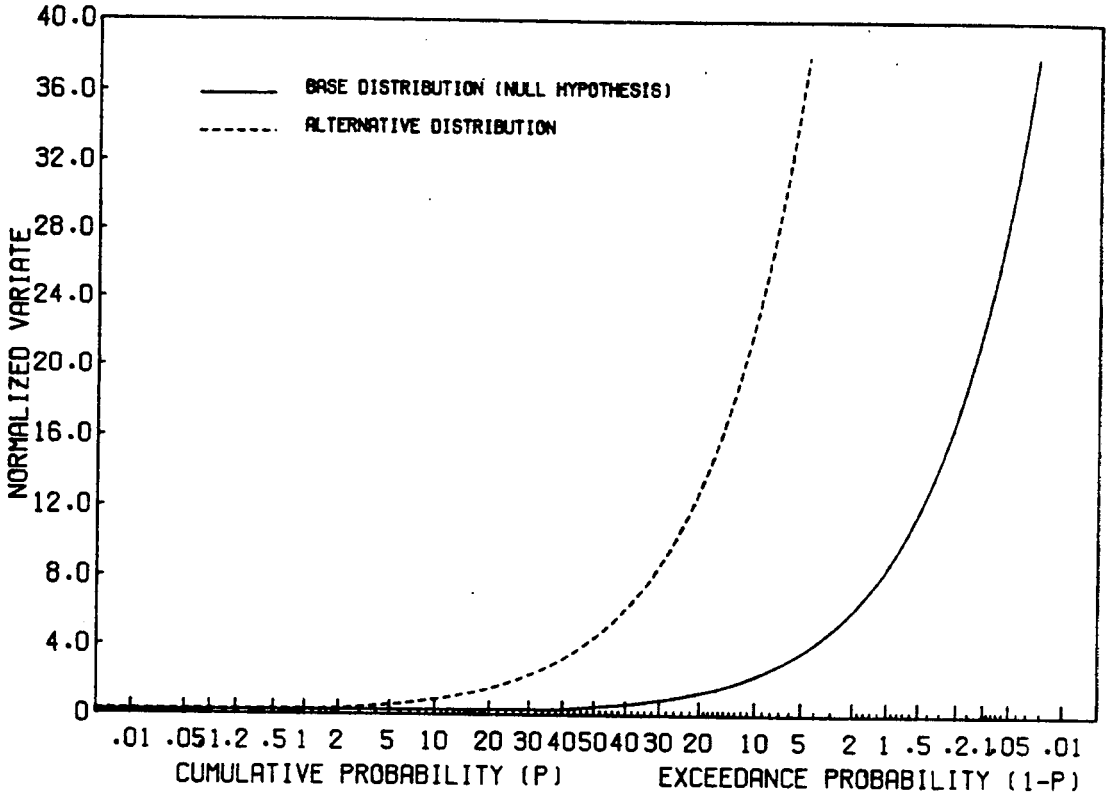


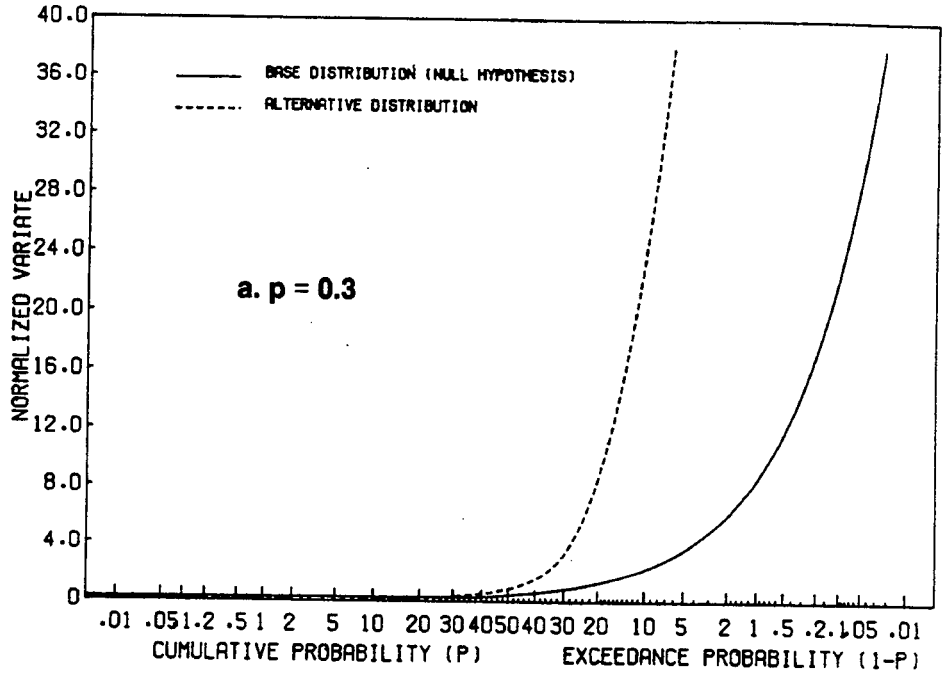
Figure G-6
BASE (COMPARISON AREA) AND ALTERNATIVE (EDA) CUMULATIVE DISTRIBUTION FUNCTIONS USED IN MONTE CARLO SIMULATIONS FOR GENERAL CONTAMINATION CASE

This fraction can be interpreted as the fraction of the EDA that is contaminated. A mixing fraction of 1.0 is equivalent to the general contamination alternative of the previous section. The comparison area concentrations were characterized in the same manner as in the previous section: log-normal with C_v = 2, skew = 14, and kurtosis = 625.

Figure G-7a gives the cumulative probability plots for the comparison area and the EDA using a mixing fraction of 0.3 and an order-of-magnitude shift. For comparison purposes, Figure G-7b shows the cumulative probability for a mixing fraction of 0.5, also with an order-of-magnitude shift. The analysis was run assuming 85 and 95 percent truncated values in the comparison area data for the 0.3 mixing fraction, and 85 percent truncated for the 0.5 mixing fraction. The results were as follows:

Nondetect Fraction	Mixing Fraction	Minimum Sample Size Required	Test
0.95	0.3	47	Modified Wilcoxon
0.95	0.3	35	Modified Wilcoxon
0.85	0.5	21	Modified Wilcoxon

The sampling design results have one characteristic that on first inspection appears anomalous but after some thought appears reasonable. As the fraction of truncation increases, the power for the same sample size increases. This behavior was found for both the univariate and the multivariate results. This situation can be explained as follows for the modified Wilcoxon (rank sum) test. Concentrations below the truncation limit are treated equally; that is, they are assigned an average rank. In some sense the tests almost ignore these data. As the truncation level increases, the number of quantifiable values decreases in the comparion area to such an extent that the EDA samples swamp out the comparison area samples, giving the tests high power. For



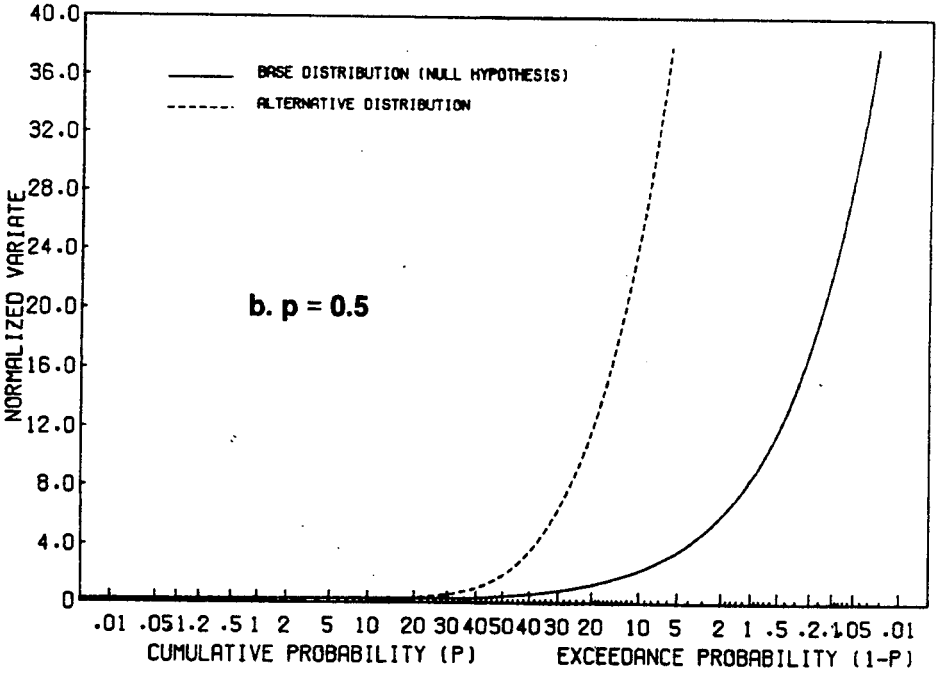


Figure G-7a, b
BASE (COMPARISON AREA) AND ALTERNATIVE (EDA) CUMULATIVE DISTRIBUTION FUNCTIONS USED IN MONTE CARLO SIMULATIONS FOR LOCALIZED CONTAMINATION CASE

example, at a truncation level such that only 5 percent of the values in the comparison area were quantifiable, out of 60 samples one would expect to have 3 quantifiable and 57 truncated. As an order-of-magnitude shift the EDA data might have 60 percent truncated values, resulting in 24 quantifiable values. The 57 truncated values from the comparison area and the 36 truncated values from the EDA are all assigned the same rank; their relative values cannot be determined. Therefore, the test performance would be dominated by the 3 quantifiable values in the comparison area and the 24 in the EDA. Clearly, the difference in the EDA would be easily picked up. If there were 100 percent quantifiable values, the 97 samples that were previously truncated (57 in the comparison area and the 36 in the EDA) and equally ranked now would be ranked individually. In this case the EDA data would not so dominate the comparison area data as to yield the level of power found when 24 quantifiable values were being compared with 3.

G.3.4 SAMPLE SIZES UNDER MULTIPLE COMPARISON TESTS

Finally, a series of test statistics were calculated to determine the sample size requirements for multiple comparisons (simultaneous testing of more than one LCIC). Following the pilot study results, the variables were considered to be uncorrelated. Two cases were considered: a general contamination model and a localized contamination model. In both cases, half the variance was assumed to result from measurement error and half from spatial variability in the underlying process, with the coefficient variation in the comparison area set at 2.0 in both cases. The results were as follows:

Contamination Type	Nondetect Fraction	Mixing Fraction	Minimum Sample Size Required	Test
General	0.85	NA	<10	Average rank; multivariate rank sum
Local	0.85	0.3	28	Multivariate rank sum

G.3.5 STUDY DESIGN CONSIDERATIONS RELATED TO LABORATORY ERRORS

To test the sensitivity of the sample size requirement to measurement error, a series of simulation runs was made assuming that half of the total variance in the comparison area resulted from measurement error. This was accomplished by assuming that each observation was drawn from an underlying distribution representing spatial variability with measurement error superimposed. Both the measurement error and the underlying distribution were taken as lognormal with variance 1.414. The mean of the underlying distribution was 1.0, while the measurement error was shifted to have mean 0.0, so that the composite distribution had a coefficient variation of 2.0, as for the results reported earlier. The order-of-magnitude EDA shift was applied to the underlying distribution only, and not to the measurement error, which had mean 0.0 in both the EDA and comparison neighborhoods. A second case with measurement error was run for the localized contamination alternative. For this case, the comparison area distribution was identical to the general contamination case. The EDA alternative distribution was composed of a lognormal mixture, as in the previously reported case with superimposed lognormal measurement error. As in the general contamination case, only the underlying distribution was subjected to the localized contamination shift.

The results were as follows:

Contamination Type	Nondetect Fraction	Mixing Fraction	Sample Size Required	Test
General	0.85	NA	17	Modified Wilcoxon
General	0.95	NA	12	Modified Wilcoxon
Local	0.85	0.3	48	Mood

G.3.6 STUDY DESIGN CONSIDERATIONS RELATED TO INTERLABORATORY VARIABILITY

The pilot study data suggest that there is significant systematic interlaboratory variability associated with the measurement of some of the LCICs. The proposed study design should guard against laboratory effects that bias contrasts between the comparison area and EDA neighborhoods. For example, consider the following scenario.

Laboratory A's measurements for a compound are systematically higher than Laboratory B's. All of the comparison area samples are assigned to Laboratory A and all of an EDA neighborhood's samples to Laboratory B. In this situation, true differences between the EDA and and comparison area could be offset by laboratory differences, resulting in an unwarranted inference of habitability of the EDA neighborhood. Conversely, if the EDA samples had been allocated to Laboratory A and the comparison samples to Laboratory B, laboratory differences could potentially result in a false inference of nonhabitability.

The obvious solution to this problem is to appropriately randomize the allocation of samples from the two areas to analytical laboratories. Two basic approaches to this randomization are:

- Simple randomized block. Proportionally allocate samples from the EDA neighborhoods and comparison area to the laboratories. Thus, if there are two laboratories participating in the study, allocate one-half of the EDA and comparison area's samples to each of the laboratories. For n laboratories, allocate 1/n of the two areas' samples to each laboratory.

- Matched allocation. Assign each neighborhood's samples to a single laboratory, and have each laboratory analyze the splits of all comparison area samples.

Both of these approaches effectively eliminate the potential for confounding the effects of systematic laboratory variation with differences between the EDA and comparison areas. They do not, however, result in the equal sampling requirements. In order to maintain the same degree of sensitivity in a simple comparison of the two areas, the first randomization scheme requires more samples than the second approach. The interlaboratory variability inherent in the first approach inflates the variance of the area comparison by a component that is essentially the square of the average of the differences between the average concentrations in the laboratories. In the second design, the interlaboratory component of variance is eliminated by having each laboratory sample the comparison area, and assigning EDA neighborhoods to laboratories. Then, all tests are conducted using comparison area samples analyzed by the same laboratory. The reduction in variance is therefore achieved at the expense of an increase in the number of comparison area samples, which must be duplicated in each laboratory. It is convenient to compare results in terms of the average number of samples per neighborhood, which is given by:

$$n^* = n \left\{\frac{1 + m^*}{13}\right\}$$

where:

n = the number of samples to be taken in each EDA neighborhood and in the comparison area

m* = the effective number of laboratories involved (m* = 1 for the randomized design, and is equal to the actual number of laboratories for the paired lab design)

13 = the number of EDA neighborhoods

Figure G-8 shows n* as a function of m* for the paired laboratory design, and for the simple randomized design for an order-of-magnitude shift (general contamination alternative) for power 0.9. Clearly, the paired laboratory design results in fewer samples for m of up to 10 (which is considered to be about the maximum number of laboratories that is logistically feasible). The sample reduction is greatest, of course, for the smallest number of laboratories. The operational decision concerning the number of laboratories to be used must consider the maximum laboratory throughput and the allowable holding time for the samples. It should be cautioned that the results are conditioned on a particular value of variance reduction (about 40 percent); the saving will be smaller for smaller variance reductions.

The pilot study suggested that for some chemicals the interlaboratory component of variance was smaller than 40 percent (see Section G.2.3). Nevertheless, it is clear that considerable savings in terms of required sample size are possible for a matched allocation design.

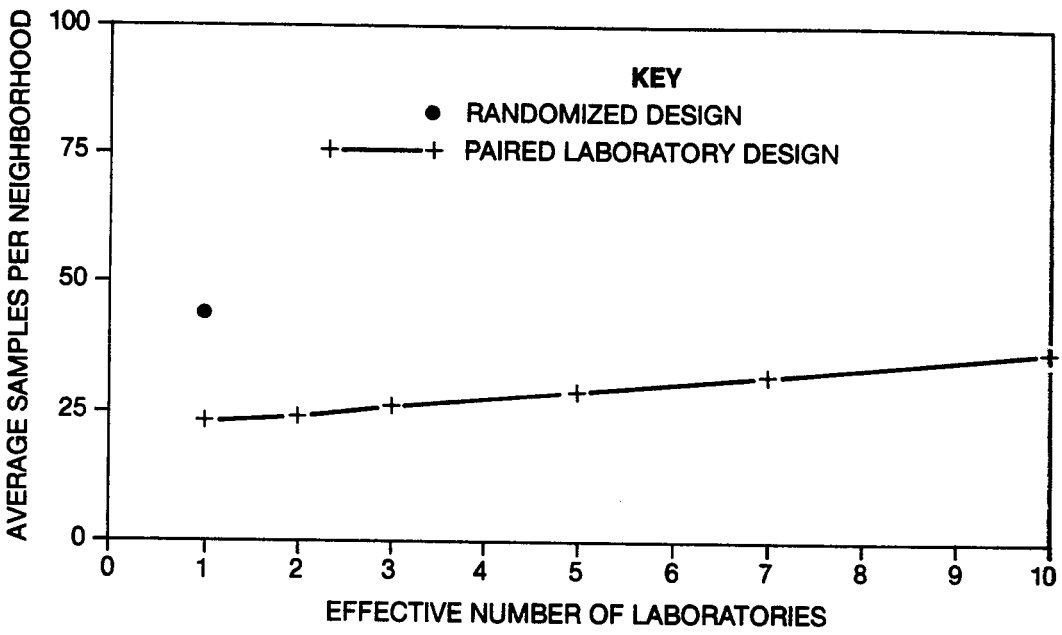


Figure G-8
COMPARISON OF SAMPLE SIZE REQUIRED FOR PAIRED LABORATORY VERSUS RANDOMIZED SAMPLING DESIGN

Although this approach offers a potential savings in terms of sampling costs, there are some complications. These include:

- Difficulty in using the data in ways other than comparing the EDA neighborhoods to the comparison areas. For example, it may be desirable to analyze the EDA data with regard to spatial trends. If neighborhoods are assigned to individual laboratories, these trends will be potentially confounded with laboratory differences.

- Difficulty in the interpretation of neighborhood results. With the matched allocation approach, estimated neighborhood distribution parameters may be laboratory specific.

There is an option that circumvents these problems and requires fewer samples than the matched allocation approach. It uses the first randomization scheme (proportional allocation of EDA neighborhood and comparison area samples to laboratories), but require a more complicated "blocked" data analysis. The approach is as follows:

- Proportionally allocate EDA neighborhood and comparison area samples to the laboratories.

- Statistically compare EDA neighborhood samples analyzed within a given laboratory with comparison area samples analyzed by the same laboratory.

- Combine the results of all of the laboratory-specific statistical comparisons for each EDA neighborhood.

There are several methods available for combining the statistical results. These methods generally produce asymptotically normal test statistics based on the sums of individual test statistics, their expected values, and variances. The techniques of combining statistical results will be used in conjunction with the statistical tests under evaluation. Their properties and robustness with respect to the probability distributions describing the data are being further studied using simulation methods.

The randomized block approach will likely be slightly more efficient than the matched allocation scheme. The matched allocation scheme is more fully developed and will yield a conservative estimate of sample sizes. This was the method used to generate the estimates presented here. Both the matched allocation scheme and the randomized block approach will be impacted by the addition of the new comparison area in Niagara County. A final decision between the two allocation strategies will be made following the analysis of the DOH data.

G.3.7 GEOGRAPHICAL ALLOCATION OF SAMPLES AMONG NEIGHBORHOODS

The analysis so far has concentrated on estimating sample size for a "typical" neighborhood based on the results of the pilot study. The pilot study did not differentiate among neighborhoods, and so the analysis has not allowed for differences among neighborhoods.

The 13 EDA neighborhoods differ greatly in size. This affects the allocation of samples to neighborhoods. If the model estimated number of samples is the number obtained from each neighborhood, then the sampling density will also differ greatly.

One way to approach this is to allocate samples to neighborhoods proportional to neighborhood size. Since the model is based on the pilot study data, which can be taken as estimating the distribution of data from a "typical" neighborhood, the sample size can be interpreted as the number of samples to obtain from the median area neighborhood. Larger neighborhoods would have more samples while smaller neighborhoods would have less. In order to preserve comparison power in the smaller neighborhoods, a minimum number of samples would be set.

A formula for this allocation is:

Let A_m = area of median neighborhood
A_i = area of ith neighborhood
N_m = number of samples required for median neighborhood
N_i = number of samples required for ith neighborhood

$$N_i = \text{MAX}\ [(N_m * (A_i/A_m)),\ (N_m/2)]$$

G.4 PRELIMINARY SAMPLING PLAN DESIGN RECOMMENDATIONS

The pilot study provided data for analysis and simulation of a variety of sampling schemes. Several major uncertainties have been resolved by this analysis and allow the following recommendations to be made for the soil sampling design for the habitability study.

- A lognormal distribution or a mixture of lognormal distributions is adequate for modeling the data from the comparison area and the EDA for most LCICs.

- Intralaboratory variability is significant; sample allocation to the analytical laboratories must be made so as to avoid or minimize this source of variability. Either matched allocation (one neighborhood analyzed by one lab) or randomized blocking (all neighborhoods analyzed by all labs, summary statistics combined to eliminate interlaboratory effects) is recommended.

- Within each neighborhood, sample allocation should be randomized. Earlier studies and the pilot study did not produce strong evidence of likely patterns of areas of contamination.

- Samples should be allocated among neighborhoods proportional to the area of the neighborhood. A minimum sample size should be set to preserve power in comparisons with small neighborhoods.

- Based on only the pilot data, a minimum of 10 to 50 samples will be needed from each neighborhood to obtain 90 percent power and 95 percent

confidence of detecting an order of magnitude difference in mean concentration values between a neighborhood and a comparison area. This range spans the likely range of data distributions, the likely range of contamination types, and the use of univariate (one LCIC) comparisons or multivariate comparisons (all LCICs simultaneously).

- The analysis of the data from the habitability study should judge a significant difference between the EDA and the comparison area based on an order of magnitude difference in a measure of central tendency (median or mean). A suite of potential statistical tests has been identified in Appendix G.

Further refinement of the design and exploration of additional tests will take place during the analysis of the DOH sample data from the new comparison area.

Attachment G-1
LOVE CANAL HABITABILITY SOIL PILOT STUDY
SUMMARY OF RESULTS

CONTENTS

LEGEND FOR SUMMARY OF SAMPLE ANALYSES

ND = Not detected at concentration below 1 ppb

NR = No results were reported because contingency samples were used for reanalysis

NA = The samples were not analyzed because only volatile or semivolatile LCICs, but not both, were required to be reanalyzed

The data qualifiers used by the analytical laboratories are shown below and must be considered when interpreting the data:

U -- Compound was analyzed for but not detected.

J -- An estimated value. This qualifier is used when the data indicate the presence of a compound that meets the identification criteria, but the concentration is less than 1.0 ppb, but greater than zero.

K -- Used when estimating a concentration for a compound where all three characteristic ions are present and maximized within the scan and retention time windows, but the ion abundance ratios are not within guidelines.

B -- The analyte is found in the blank as well as in a sample.

MA -- Used when quantification has been performed by manual integration of peak area or peak height.

R -- Sample was reinjected or reextracted.

RE -- When two sets of data were submitted, the second result is flagged as RE.

Note: This data set represents the latest validation of the data base and may differ slightly from the data used in the analysis.

LOVE CANAL HABITABILITY SOIL PILOT STUDY
SUMMARY OF SAMPLE ANALYSES

Geographic Area: CA1

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPCA1S01	LC2041	EMS	0.11K	N.D.	0.27J	0.38J	0.17J	0.27J	N.D.	N.D.
	LC2114	EMS	0.11J	0.0J	N.D.	0.30J	0.13J	0.14J	N.D.	N.D.
SPCA1S02	LC2021	CAA	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2154	EMS	0.16J,B	N.D.	N.D.	0.21J	N.D.	0.28J	N.D.	0.95K
	LC2290	CAA	N.A.	N.A.	N.D.	0.16J,B	N.D.	0.08MAJ	N.D.	N.D.
SPCA1S03	LC2181	MGM	N.D.	N.D.	1.0B,R	0.70B,J,R	N.D.	N.D.	N.D.	N.D.
	LC2206	MGM	0.08MA,J	N.D.	3.2B,R	1.4B,R	0.5J,MA,R	0.7J,R	N.D.	N.D.
SPCA1S04	LC2049	EMS	0.15K,B	N.D.	N.D.	0.14K	0.7J	0.08K	N.D.	N.D.
	LC2064	MGM	0.8MA,J	N.D.	1.1B,R	0.50B,R,J	N.D.	N.D.	N.D.	N.D.
SPCA1S05	LC2065	MGM	0.09MA,J	N.D.	0.90J,B,R	0.50J,B,R	N.D.	N.D.	N.D.	N.D.
	LC2128	MGM	0.08MA,J	N.D.	1.1B,R	0.05B,J,R	N.D.	N.D.	N.D.	N.D.
SPCA1S06	LC2068	EMS	0.25J	N.D.	N.D.	0.18K	N.D.	N.D.	N.D.	N.D.
	LC2212	EMS	N.D.	N.D.	N.D.	0.14J	N.D.	N.D.	N.D.	N.D.
SPCA1S07	LC2033	MGM	N.R.	N.R.	0.70B,J	0.50B,J	N.D.	N.D.	N.D.	N.D.
	LC2130	EMS	0.26J	0.07K	N.D.	N.D.	N.D.	0.06K	N.D.	N.D.
	LC2284	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPCA1S08	LC2207	EMS	0.15J,B	N.D.	N.D.	0.16J	N.D.	0.11K	N.D.	N.D.
	LC2249	CAA	N.D.	N.D.	N.D.	0.17J	N.D.	N.D.	N.D.	N.D.
SPCA1S09	LC2047	EMS	0.16J,B	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2152	EMS	0.16J,B	N.D.	N.D.	0.21K	N.D.	0.10K	N.D.	N.D.
	LC2276	EMS	N.A.	N.A.	0.23J	0.48J	1.0	1.4	13.9	8.6
SPCA1S10	LC2101	CAA	N.D.	N.D.	N.D.	0.63J,B	0.51J	0.64J	N.D.	N.D.
	LC2184	CAA	0.05J	N.D.	N.D.	0.15J,B	N.D.	0.15J,K	N.D.	N.D.
SPCA1S11	LC2161	MGM	N.D.	N.D.	0.80J,B	0.60J,B	N.D.	N.D.	N.D.	N.D.
	LC2251	MGM	N.D.	N.D.	1.0B	0.6B,J	N.D.	N.D.	N.D.	N.D.
	LC2292	CAA	N.D.	N.D.	N.D.	0.34J,B	0.11MAJ	N.D.	N.D.	N.D.

Geographic Area: CA1

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPCA1S12	LC2077	EMS		N.D.	0.29J	0.41J	0.23J	0.38J	N.D.	N.D.
	LC2164	MGM	N.D.	N.D.	0.80B,J	0.60B,J	N.D.	N.D.	N.D.	N.D.
SPCA1S13	LC2014	MGM	N.D.	N.D.	1.1R,B	0.70B,R	N.D.	N.D.	N.D.	N.D.
	LC2116	CAA	0.06	0.09MA	N.D.	0.16J	N.D.	N.D.	N.D.	N.D.
SPCA1S14	LC2013	CAA	N.D.	N.D.	N.D.	0.21J	N.D.	N.D.	N.D.	N.D.
	LC2073	EMS		N.D.	0.37J	0.46J	0.37J	0.56J	N.D.	N.D.
SPCA1S15	LC2080	CAA	0.03J	N.D.	N.D.	0.14MA,J,B	N.D.	N.D.	N.D.	N.D.
	LC2239	CAA	N.D.	N.D.	N.D.	0.22MA,J,B	N.D.	N.D.	N.D.	N.D.
SPCA1S16	LC2040	MGM	0.10MA,J	N.D.	1.7R,R	0.80B,J,R	N.D.	N.D.	N.D.	N.D.
	LC2105	EMS	N.D.	N.D.	N.D.	N.D.	N.D.	0.20J	N.D.	N.D.
	LC2215	MGM	N.D.	N.D.	0.90J,B,R	0.40J,B,R	N.D.	N.D.	N.D.	N.D.
SPCA1S17	LC2066	CAA	0.04J	N.D.	N.D.	0.05J,B	N.D.	N.D.	N.D.	N.D.
	LC2199	MGM	N.D.	N.D.	0.09J,B	0.05J,B	N.D.	N.D.	N.D.	N.D.
SPCA1S18	LC2147	MGM	N.D.	N.D.	0.90B,J	0.50B,J	N.D.	N.D.	N.D.	N.D.
	LC2191	CAA	N.D.	N.D.	N.D.	0.19J,B	011MA,J	N.D.	N.D.	N.D.
SPCA1S19	LC2059	CAA	0.06J	N.D.	N.D.	0.15J,K	N.D.	N.D.	N.D.	N.D.
	LC2192	MGM	0.11MA	N.D.	1.3B,R	0.40B,J,R	N.D.	N.D.	N.D.	N.D.
SPCA1S20	LC2142	EMS	0.26K	N.D.	0.32J	0.46K	0.28J	0.22K	N.D.	N.D.
	LC2170	CAA	0.04J	N.D.	N.D.	0.30J	N.D.	N.D.	N.D.	N.D.
SPCA1S21	LC2017	EMS	0.18J,B	N.D.	N.D.	0.18J	N.D.	0.06K	N.D.	N.D.
	LC2226	MGM	N.D.	N.D.	0.90J,B	0.50B,J	N.D.	N.D.	N.D.	N.D.
SPCA1S22	LC2173	CAA	N.D.	N.D.	2.1	0.26J,B	N.D.	N.D.	N.D.	N.D.
	LC2180	MGM	N.D.	N.D.	1.0B	0.50B,J,MA	N.D.	N.D.	N.D.	N.D.
SPCA1S23	LC2001	EMS	0.25J	N.D.	N.D.	0.25J	N.D.	0.09K	N.D.	N.D.
	LC2098	CAA	0.11J	N.D.	N.D.	0.21J,B	N.D.	N.D.	N.D.	N.D.

Geographic Area: CA2

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPCA2S01	LC2185	EMS	N.D.	N.D.	0.25K	0.28K	0.09J	0.07J	N.D.	0.50K
	LC2233	CAA	N.D.	N.D.	0.27J,MA	N.D.	N.D.	N.D.	N.D.	N.D.
SPCA2S02	LC2304	MGM	N.D.	N.D.	0.80B,J,R	0.50B,J,R	N.D.	N.D.	N.D.	N.D.
	LC2313	MGM	N.D.	N.D.	0.80B,J,R	0.50B,J,R	N.D.	N.D.	N.D.	N.D.
SPCA2S03	LC2106	MGM	N.R.	N.R.	0.90J,B	0.40J,B	N.D.	N.D.	N.D.	N.D.
	LC2240	EMS	N.D.	N.D.	0.29K	0.41J	0.20J	0.27J	0.50K	N.D.
	LC2378	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPCA2S04	LC2208	CAA	N.D.	N.D.	0.12MA,J	0.10J	N.D.	N.D.	N.D.	N.D.
	LC2228	EMS	N.D.	N.D.	N.D.	0.28K	0.11K	N.D.	N.D.	N.D.
SPCA2S05	LC2311	CAA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	LC2322	CAA	N.D.	N.D.	N.D.	0.17J,B	N.D.	N.D.	N.D.	N.D.
SPCA2S06	LC2030	EMS	0.05J	N.D.	N.D.	0.31J	N.D.	0.09K	N.D.	N.D.
	LC2150	MGM	N.D.	N.D.	0.90J,B	0.40J,B	N.D.	N.D.	N.D.	N.D.
	LC2273	MGM	N.D.	N.D.	0.80J,B	0.50J,B	N.D.	N.D.	N.D.	N.D.
SPCA2S07	LC2048	EMS	N.D.	N.D.	0.22K	0.24J	N.D.	0.09J	N.D.	0.73K
	LC2122	EMS	0.06K	N.D.	N.D.	0.19J	N.D.	N.D.	N.D.	0.47K
SPCA2S08	LC2109	EMS	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	LC2139	MGM	N.D.	N.D.	1.2B	0.60B,J	N.D.	N.D.	N.D.	N.D.
SPCA2S09	LC2018	CAA	N.D.	N.D.	0.16J,MA	0.07J,MA	N.D.	0.07K,J	N.D.	N.D.
	LC2234	MGM	N.D.	N.D.	1.1B	0.60B,J	N.D.	N.D.	N.D.	N.D.
SPCA2S10	LC2024	EMS	0.07K	N.D.	0.16J	0.27J	N.D.	N.D.	N.D.	N.D.
	LC2042	CAA	N.D.	N.D.	N.D.	0.13J,B	N.D.	N.D.	N.D.	N.D.
SPCA2S11	LC2137	CAA	N.D.	N.D.	0.13J	N.D.	N.D.	N.D.	N.D.	N.D.
	LC2194	MGM	N.D.	N.D.	0.70B,J	0.40B,J	N.D.	N.D.	N.D.	N.D.
SPCA2S12	LC2103	CAA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	LC2167	CAA	N.D.	N.D.	N.D.	0.19J	0.10J	0.12J	N.D.	N.D.
SPCA2S13	LC2046	CAA	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2193	EMS	N.D.	0.11J	0.11K	0.18K	N.D.	N.D.	N.D.	N.D.

Geographic Area: CA2

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPCA2S14	LC2308	EMS	0.09K	0.17J	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	LC2326	CAA	N.D.	N.D.	N.D.	0.14J,B	N.D.	0.11J	N.D.	N.D.
SPCA2S15	LC2007	CAA	0.02J,MA	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2153	MGM	N.R.	N.R.	0.60B,J	0.30B,J	N.D.	N.D.	N.D.	N.D.
	LC2342	CAA	N.A.	N.A.	N.D.	N.D.	0.03J,MA	N.D.	N.D.	N.D.
	LC2355	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPCA2S16	LC2083	MGM	N.R.	N.R.	0.80J,B	0.40J,B	N.D.	N.D.	N.D.	N.D.
	LC2120	CAA	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2343	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	LC2369	CAA	N.A.	N.A.	N.D.	0.35J,B,RE	0.34J,RE	N.D.	N.D.	N.D.
SPCA2S17	LC2061	EMS	0.09J	N.D.	0.23J	0.12K	N.D.	0.11K	N.D.	N.D.
	LC2119	MGM	0.03MA,J	N.D.	1.2B	0.50B,J	N.D.	N.D.	N.D.	N.D.
SPCA2S18	LC2084	CAA	0.12J	0.25J	N.D.	0.15J,B	N.D.	0.10J,B	N.D.	N.D.
	LC2242	CAA	N.D.	N.D.	N.D.	0.17J,B	N.D.	0.13J,B	N.D.	N.D.
	LC2267	MGM	N.D.	N.D.	1.1B	0.60B,J	N.D.	N.D.	N.D.	N.D.
SPCA2S19	LC2092	CAA	N.D.	N.D.	0.22J	0.11J,B	0.03J,R	0.10J,MA	N.D.	N.D.
	LC2124	CAA	N.D.	N.D.	0.28J	0.38J,B	0.12J	N.D.	N.D.	N.D.
SPCA2S20	LC2309	EMS	N.D.	0.09K	0.27J	0.28J	0.21J	0.32J	N.D.	N.D.
	LC2317	EMS	0.08J	N.D.	0.16J	0.22K	N.D.	0.11K	N.D.	N.D.
SPCA2S21	LC2307	MGM	N.D.	N.D.	0.80B,J,R	0.50B,J,R	N.D.	N.D.	N.D.	N.D.
	LC2321	EMS	N.D.	N.D.	N.D.	0.18J	N.D.	0.11K	N.D.	N.D.
SPCA2S22	LC2306	EMS	N.D.	N.D.	N.D.	0.20J	N.D.	0.07K	N.D.	N.D.
	LC2310	MGM	N.D.	N.D.	0.90B,J,R	0.50B,J,R	N.D.	N.D.	N.D.	N.D.

Geographic Area: EDA

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPEDAS01	LC2223	CAA	0.50J	N.D.	N.D.	2.0B	3.0	N.D.	N.D.	N.D.
	LC2250	CAA	0.02J	N.D.	N.D.	1.7B	2.4	N.D.	N.D.	N.D.
SPEDAS02	LC2087	CAA	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2222	EMS	N.D.	N.D.	N.D.	0.30K	N.D.	0.04K	N.D.	N.D.
	LC2287	CAA	N.A.	N.A.	N.D.	0.18J,B	N.D.	N.D.	N.D.	N.D.
SPEDAS03	LC2023	EMS	0.17K	N.D.	N.D.	0.38J	0.24J	0.07K	N.D.	N.D.
	LC2188	EMS	0.17K	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2338	EMS	N.A.	N.A.	0.32J	0.86J	1.1	0.79J	8.4	N.D.
SPEDAS04	LC2045	MGM	N.D.	N.D.	1.3B,R	1.2B,R	0.60J,R	N.D.	N.D.	N.D.
	LC2160	EMS	0.12J	N.D.	0.27J	0.78J	0.09J	0.26J	N.D.	N.D.
SPEDAS05	LC2294	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	LC2303	EMS	0.06K	N.D.	0.28J	0.35J	N.D.	0.09K	N.D.	N.D.
	LC2312	MGM	N.R.	N.R.	0.90B,J,R	0.60B,J,R	N.D.	N.D.	N.D.	N.D.
SPEDAS06	LC2107	CAA	N.D.	N.D.	N.D.	0.59J,MA	N.D.	N.D.	N.D.	N.D.
	LC2121	EMS	0.29K	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2373	EMS	N.A.	N.A.	N.D.	0.64K	N.D.	N.D.	N.D.	N.D.
SPEDAS07	LC2182	MGM	N.D.	N.D.	1.1B	1.4B	0.90J	N.D.	N.D.	N.D.
	LC2232	CAA	N.D.	N.D.	0.19J,B	0.32J,B	0.42J,B	N.D.	N.D.	N.D.
SPEDAS08	LC2089	CAA	N.D.	N.D.	0.14R,B,MA	N.D.	0.42R,J	N.D.	N.D.	N.D.
	LC2214	CAA	N.D.	N.D.	0.21R,J,B	0.42R,J,B	0.32R,J	N.D.	N.D.	N.D.
SPEDAS09	LC2044	CAA	0.02MA	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2082	EMS	N.D.	N.D.	0.42J	1.7	1.3	0.12J	N.D.	N.D.
	LC2345	CAA	N.A.	N.A.	N.D.	2.7B	2.0	N.D.	N.D.	N.D.
SPEDAS10	LC2126	MGM	N.D.	N.D.	0.80B,J	0.60B,J	0.40J,K	N.D.	N.D.	N.D.
	LC2141	MGM	N.D.	N.D.	0.90J,B	0.90J,B	0.60J	N.D.	N.D.	N.D.

Geographic Area: EDA

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPEDAS11	LC2012	MGM	0.04MA	N.D.	0.90J,B	1.3J,MA	1.0	N.D.	N.D.	N.D.
	LC2057	MGM	N.R.	N.R.	0.90J,B	1.1B	0.9J	N.D.	N.D.	N.D.
	LC2257	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPEDAS12	LC2029	CAA	N.D.	N.D.	N.D.	0.23J,B	0.20J	N.D.	N.D.	N.D.
	LC2079	CAA	N.D.	N.D.	N.D.	0.38J,B	0.30J	N.D.	N.D.	N.D.
	LC2094	CAA	N.D.	N.D.	N.D.	0.36J,B	0.35J	N.D.	N.D.	N.D.
	LC2159	CAA	N.D.	N.D.	N.D.	0.45J,B	0.36J	N.D.	N.D.	N.D.
	LC2195	CAA	0.04J	N.D.	N.D.	0.33J,B	0.33J	N.D.	N.D.	N.D.
	LC2221	CAA	0.06J	N.D.	N.D.	0.21J,B	0.17J	N.D.	N.D.	N.D.
	LC2237	CAA	0.07J	N.D.	N.D.	0.38J,B	N.D.	N.D.	N.D.	N.D.
SPEDAS13	LC2027	EMS	N.D.	N.D.	N.D.	1.1K	0.92J	N.D.	N.D.	N.D.
	LC2028	CAA	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2271	CAA	N.A.	N.A.	N.D.	0.69J,B	0.70J	0.08MA	N.D.	N.D.
SPEDAS14	LC2075	EMS	0.12J	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2085	CAA	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2356	CAA	N.A.	N.A.	N.D.	0.20J,B	0.20J	N.D.	N.D.	N.D.
	LC2357	EMS	N.A.	N.A.	0.19J	0.39K	0.76J	0.92J	3.0K	3.9K
SPEDAS15	LC2056	EMS	N.D.	N.D.	N.D.	0.35J	N.D.	N.D.	N.D.	N.D.
	LC2086	EMS	N.D.	N.D.	N.D.	0.56J	0.46J	0.23K	N.D.	N.D.
SPEDAS16	LC2291	EMS	0.08K	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2293	CAA	N.D.	N.D.	0.17J,B,MA	0.34J	0.76J	0.08J,B,MA	N.D.	N.D.
	LC2368	EMS	N.A.	N.A.	N.D.	0.20J	N.D.	N.D.	1.2K	1.2K
SPEDAS17	LC2043	EMS	0.18K	N.D.	0.84J	7.6	13.1	0.22J	N.D.	N.D.
	LC2169	CAA	N.D.	N.D.	N.D.	10.8B	15.9	N.D.	N.D.	N.D.
SPEDAS18	LC2314	CAA	N.D.	N.D.	0.23J,B	0.38J,B	0.22J	0.10J,MA	N.D.	N.D.
	LC2320	MGM	N.D.	N.D.	0.90B,J,R	0.90B,J,R	0.20J,R	N.D.	N.D.	N.D.
SPEDAS19	LC2144	EMS	0.17J,B	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2175	CAA	N.D.	N.D.	N.D.	1.1B	1.6	N.D.	N.D.	N.D.
	LC2341	EMS	N.A.	N.A.	0.19J	0.36J	0.33J	N.D.	2.6K	N.D.
SPEDAS20	LC2305	CAA	0.08J	0.10J	0.44J,B	0.93J,B	0.44J,B	N.D.	N.D.	N.D.
	LC2324	CAA	0.04J,MA	N.D.	0.34J,B	0.85J,B	0.51J	0.11J,MA	4.6	N.D.

Geographic Area: EDA

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPEDAS21	LC2026	EMS	0.20J	N.D.	N.D.	0.40J	0.35J	0.11K	N.D.	N.D.
	LC2179	EMS	0.14J,B	N.D.	N.D.	0.47J	0.50J	0.31J	N.D.	N.D.
	LC2210	MGM	N.D.	N.D.	5.1B,R	3.1B,R	1.5R	0.90J,R,MA	N.D.	N.D.
SPEDAS22	LC2282	CAA	N.D.	N.D.	0.14J,B	0.23J,B	0.35J,B	0.08J	N.D.	N.D.
	LC2319	MGM	N.D.	N.D.	0.90B,J,R	1.4B,R	3.1R	N.D.	N.D.	N.D.
	LC2325	CAA	0.07J	N.D.	0.45J,B	0.84J,B	2.0	0.18J	N.D.	N.D.
SPEDAS23	LC2009	EMS	0.05K	N.D.	0.40J	1.5	1.7	0.12K	N.D.	N.D.
	LC2020	EMS	N.D.	0.19J	N.D.	0.92J	1.0	0.06K	N.D.	2.2K
	LC2262	EMS	N.D.	0.05J	N.D.	1.1	1.2	0.09J	N.D.	1.8K
SPEDAS24	LC2148	MGM	N.D.	N.D.	1.0B	1.0B	1.0	N.D.	N.D.	N.D.
	LC2229	EMS	0.18J	N.D.	0.22J,R,E	0.50J,R,E	0.56J,R,E	N.D.	N.D.	1.8K,R,E
SPEDAS25	LC2072	EMS	0.05K	0.09J	N.D.	1.2	2.9	N.D.	N.D.	N.D.
	LC2225	MGM	N.D.	N.D.	0.80J,B	1.2J,B	1.8	N.D.	N.D.	N.D.
SPEDAS26	LC2110	MGM	N.R.	N.R.	0.90J,B	0.90J,B	1.1	N.D.	N.D.	N.D.
	LC2134	CAA	0.24J	N.D.	0.39J,K	0.62J,B	0.87J	N.D.	N.D.	N.D.
	LC2332	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPEDAS27	LC2051	EMS	N.D.	N.D.	N.D.	0.62J	0.75J	N.D.	N.D.	N.D.
	LC2165	EMS	N.D.	N.D.	N.D.	0.73J	0.63J	0.05K	N.D.	N.D.
SPEDAS28	LC2093	MGM	N.D.	N.D.	1.3B,R	0.50B,J,R	N.D.	N.D.	N.D.	N.D.
	LC2211	EMS	0.11J	N.D.	0.33J	0.33J	0.21J	0.15J	N.D.	N.D.
SPEDAS29	LC2002	MGM	N.D.	N.D.	0.90B,J	0.70B,J	1.5	N.D.	N.D.	N.D.
	LC2108	MGM	N.D.	N.D.	1.2B	1.2B	1.0K	N.D.	N.D.	N.D.
SPEDAS30	LC2063	EMS	0.04K	N.D.	0.17J	1.9	2.4	0.18K	N.D.	N.D.
	LC2178	MGM	N.D.	N.D.	0.90B,J	1.1B	N.D.	N.D.	N.D.	N.D.
SPEDAS31	LC2016	MGM	N.D.	N.D.	1.2B	1.8B	2.2	0.50J	N.D.	1.2K
	LC2166	MGM	N.D.	N.D.	1.0B	1.3B	1.6	N.D.	N.D.	N.D.
SPEDAS32	LC2315	MGM	N.R.	N.R.	0.90B,J,R	0.60B,J,R	0.40J,R	N.D.	N.D.	N.D.
	LC2316	CAA	N.D.	N.D.	0.29J,B	0.31J,B	0.28J	0.11J	N.D.	N.D.
	LC2372	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPEDAS33	LC2062	EMS	0.25K	N.D.	N.D.	0.29J	0.30J	0.41J	0.83K	0.61K
	LC2074	CAA	0.03MA	N.D.	0.18R,J,B	0.32R,J,B	0.38R,J	0.04R,J	N.D.	N.D.

Geographic Area: EDA

Site ID	Sampling ID	Lab ID	Analytical Results in Parts Per Billion (ppb)							
			Chloro-benzene	1,2-Dichloro-benzene (VOA)	1,2-Dichloro-benzene (SV)	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachlo-benzene	2-Chloronaph-thalene	Beta-BHC	Gamma-BHC
SPEDAS34	LC2025	EMS	0.27J	N.D.	N.D.	9.0	18.3	N.D.	N.D.	N.D.
	LC2151	MGM	N.D.	N.D.	3.6B	11.0B	19.0B	N.D.	N.D.	N.D.
SPEDAS35	LC2129	MGM	N.D.	N.D.	1.8B,R	0.60B,J,R	N.D.	N.D.	N.D.	N.D.
	LC2162	CAA	0.02J,MA	N.D.	N.D.	0.25J	N.D.	0.09J	N.D.	N.D.
SPEDAS36	LC2011	CAA	0.01J,MA	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2238	MGM	N.D.	N.D.	0.90B,J	1.4B	1.7	N.D.	N.D.	N.D.
	LC2351	CAA	N.A.	N.A.	N.D.	1.2B	1.8	0.09U	N.D.	N.D.
SPEDAS37	LC2318	MGM	N.R.	N.R.	0.90J,B,R	0.70J,B,R	1.1K,R	N.D.	N.D.	N.D.
	LC2323	EMS	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2330	EMS	N.A.	N.A.	0.25K	0.51J	1.1	1.1	5.4K	4.4
	LC2354	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPEDAS38	LC2032	CAA	0.02J,MA	N.D.	0.37J,B	0.71J,B	1.0	N.D.	N.D.	N.D.
	LC2244	MGM	N.D.	N.D.	1.0B	0.80B,J	0.70J	N.D.	N.D.	N.D.
SPEDAS39	LC2258	MGM	N.R.	N.R.	1.0B	0.70B,J	0.40J	0.20J	N.D.	N.D.
	LC2259	MGM	0.03MA,J	N.D.	1.0B	0.60B,J	0.50J	0.10J	N.D.	N.D.
	LC2377	MGM	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SPEDAS40	LC2171	MGM	N.D.	N.D.	1.5B,R	0.90J,B,R	N.D.	N.D.	N.D.	N.D.
	LC2248	CAA	0.09J	0.11J	N.D.	0.33J	0.25J	0.23J	N.D.	N.D.
SPEDAS41	LC2183	EMS	0.17K	N.D.	N.D.	0.49J	0.62J	0.32J	0.71K	0.95K
	LC2220	EMS	0.19K	0.05K,B	N.D.	0.34J	0.43J	0.06K	N.D.	N.D.
SPEDAS42	LC2131	MGM	N.D.	N.D.	1.5B	2.1B	2.1	N.D.	N.D.	N.D.
	LC2198	CAA	0.05J	N.D.	0.34J,MA	1.6B,R	2.5R	0.09J,MA	N.D.	N.D.
	LC2274	MGM	N.D.	N.D.	1.2B	2.8B	4.1	N.D.	N.D.	N.D.
SPEDAS43	LC2010	CAA	0.05J	N.D.	N.D.	28.4B	84.2	0.75J	183.0	21.2
	LC2209	MGM	0.06J,MA	N.D.	3.1B	30.0B,MA	94.0	0.6J,MA,K	250.0MA	18.0
SPEDAS44	LC2081	CAA	N.D.	N.D.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
	LC2100	MGM	0.02MA,J	-	-	-	-	-	-	-
	LC2302	CAA	N.A.	N.A.	N.D.	12.9B,R	22.5R	N.D.	N.D.	N.D.
SPEDAS45	LC2069	EMS	0.22K	N.D.	N.D.	0.865	1.7	0.10K	N.D.	N.D.
	LC2241	MGM	N.D.	N.D.	1.1B	1.1B	2.1	N.D.	N.D.	N.D.

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SUMMARY STATISTICS BY AREA AND LABORATORY

Area	Lab	N	Mean	Variance	Maximum	Percentiles 25th	Median	75th	90th	95th	CV	Percent Truncated
Chlorobenzene												
Comparison	CAA	32	0.01	0	0.12	0	0	0	0.05	0.12	2.35	78.13
Comparison	EMS	31	0.13	0.01	0.32	0	0.13	0.23	0.30	0.31	0.95	38.71
Comparison	MGM	37	0.02	0	0.10	0	0	0	0.08	0.10	2.06	78.38
EDA	CAA	33	0.04	0.01	0.50	0	0	0.06	0.09	0.32	2.29	54.55
EDA	EMS	30	0.12	0.02	0.40	0	0.12	0.22	0.28	0.34	1.05	46.67
EDA	MGM	41	0.03	0	0.34	0	0	0.04	0.08	0.10	2.18	68.29
Comparison	all	100	0.05	0.01	0.32	0	0	0.08	0.19	0.28	1.78	66
EDA	all	104	0.06	0.01	0.50	0	0	0.07	0.22	0.28	1.73	57.69
1,2 Dichlorobenzene (VOA)												
Comparison	CAA	32	0.01	0	0.25	0	0	0	0	0.15	4.34	93.75
Comparison	EMS	31	0.02	0	0.21	0	0	0	0.11	0.17	2.87	87.10
Comparison	MGM	37	0.01	0	0.12	0	0	0	0.06	0.10	2.48	81.08
EDA	CAA	33	0.01	0	0.11	0	0	0	0	0.11	4	93.94
EDA	EMS	30	0.01	0	0.23	0	0	0	0.05	0.16	3.55	90
EDA	MGM	41	0	0	0.10	0	0	0	0	0.05	4.57	92.68
Comparison	all	100	0.01	0	0.25	0	0	0	0.05	0.12	3.15	87
EDA	all	104	0.01	0	0.23	0	0	0	0	0.09	4.20	92.31
1,2 Dichlorobenzene (SV)												
Comparison	CAA	38	0.11	0.18	2.56	0	0	0.03	0.28	0.42	3.79	76.32
Comparison	EMS	32	0.09	0.02	0.38	0	0	0.24	0.28	0.32	1.43	65.63
Comparison	MGM	32	0.99	0.21	3.19	0.81	0.88	1.05	1.17	2.28	0.47	
EDA	CAA	34	0.12	0.02	0.45	0	0	0.21	0.39	0.44	1.29	55.88
EDA	EMS	32	0.09	0.03	0.84	0	0	0.18	0.33	0.57	2	71.88
EDA	MGM	34	1.51	2.32	8.50	0.85	0.98	1.42	3.31	5.91	1.01	
Comparison	all	102	0.38	0.30	3.19	0	0.12	0.81	1.01	1.13	1.45	49.02
EDA	all	100	0.58	1.24	8.50	0	0.19	0.85	1.30	1.75	1.90	42
1,2,3 Trichlorobenzene												
Comparison	CAA	38	0.17	0.02	0.63	0.10	0.16	0.22	0.36	0.42	0.76	15.79
Comparison	EMS	32	0.23	0.01	0.48	0.17	0.21	0.29	0.41	0.46	0.51	9.38
Comparison	MGM	32	0.52	0.04	1.38	0.40	0.47	0.55	0.71	1.05	0.39	
EDA	CAA	34	2.15	28.97	28.36	0.32	0.52	1.11	6.75	16.79	2.50	2.94
EDA	EMS	32	1.14	3.74	8.98	0.35	0.53	1.06	1.83	8.07	1.70	3.13
EDA	MGM	34	4.75	168.48	70.74	0.68	1.13	1.51	13.32	40.31	2.73	
Comparison	all	102	0.30	0.05	1.38	0.16	0.26	0.43	0.54	0.62	0.71	8.82
EDA	all	100	2.71	69.33	70.74	0.38	0.72	1.24	2.99	12.85	3.07	2

Area	Lab	N	Mean	Variance	Maximum	Percentiles 25th	Median	75th	90th	95th	CV	Percent Truncated
2 Chloronapthalene												
Comparison	CAA	38	0.05	0.02	0.64	0	0	0.02	0.13	0.45	2.58	76.32
Comparison	EMS	32	0.15	0.07	1.37	0	0.09	0.19	0.37	0.84	1.72	40.63
Comparison	MGM	32	0.06	0.02	0.67	0	0	0.07	0.22	0.38	2.32	75
EDA	CAA	34	0.06	0.02	0.75	0	0	0.08	0.14	0.36	2.39	64.71
EDA	EMS	32	0.14	0.06	0.93	0	0	0.20	0.56	0.84	1.65	53.13
EDA	MGM	34	0.09	0.04	0.89	0	0	0.10	0.37	0.73	2.27	73.53
Comparison	all	102	0.08	0.03	1.37	0	0	0.11	0.26	0.43	2.21	64.71
EDA	all	100	0.10	0.04	0.93	0	0	0.10	0.30	0.67	2.06	64
1,2,3,4 Tetrachlorobenzene												
Comparison	CAA	38	0.07	0.03	0.65	0	0	0.05	0.35	0.52	2.20	71.05
Comparison	EMS	32	0.09	0.04	1.01	0	0	0.14	0.22	0.59	2.11	62.50
Comparison	MGM	32	0.02	0.01	0.50	0	0	0	0	0.17	5.66	96.88
EDA	CAA	34	4.26	220.26	84.21	0	0.42	1.88	9.31	37.89	3.48	26.47
EDA	EMS	32	1.66	14.46	18.28	0.26	0.57	1.18	2.74	14.91	2.30	18.75
EDA	MGM	34	10.32	1180.33	180.48	0.33	0.85	2.02	23.46	115.44	3.33	14.71
Comparison	all	102	0.06	0.02	1.01	0	0	0	0.21	0.43	2.56	76.47
EDA	all	100	5.49	484.65	180.48	0.25	0.62	1.70	3.70	22.26	4.01	20
Beta-BHC												
Comparison	CAA	38	0	0	0	0	0	0	0	0	100	
Comparison	EMS	32	0.43	6	14	0	0	0	0	4.90	5.66	96.88
Comparison	MGM	32	0	0	0	0	0	0	0	0	100	
EDA	CAA	34	5.50	984	183	0	0	0	0	49	5.68	94.12
EDA	EMS	32	0	0	0	0	0	0	0	0	100	
EDA	MGM	34	14	3429	252	0	0	0	0	242	4.06	94.12
Comparison	all	102	0.14	1.89	13.90	0	0	0	0	0	10.10	99.02
EDA	all	100	6.78	1506.80	251.82	0	0	0	0	0	5.73	96
Gamma BHC												
Comparison	CAA	38	0	0	0	0	0	0	0	0	100	
Comparison	EMS	32	0.27	2.32	8.61	0	0	0	0	3.01	5.66	96.88
Comparison	MGM	32	0	0	0	0	0	0	0	0	100	
EDA	CAA	34	0.62	13.27	21.24	0	0	0	0	5.31	5.83	97.06
EDA	EMS	32	0.07	0.08	1.49	0	0	0	0	0.92	4.28	93.75
EDA	MGM	34	1.09	19.57	18.87	0	0	0	0	18.34	4.06	94.12
Comparison	all	102	0.08	0.73	8.61	0	0	0	0	0	10.10	99.02
EDA	all	100	0.60	11.14	21.24	0	0	0	0	0.58	5.53	95

Attachment G-2
STATISTICAL TEST DESCRIPTIONS

Attachment G-2

STATISTICAL TEST DESCRIPTIONS

CLASSES OF TESTS

This attachment provides summary descriptions of each of the statistical tests that are included in the computer simulation program described in section G.2. Each test falls into one of four classes: (1) two-sample proportion tests, (2) two-sample location tests, (3) two-sample dispersion tests, or (4) two-sample distribution tests.

TWO-SAMPLE PROPORTION TESTS

Two-sample proportion tests address the problem of determining whether there is a difference in the proportion of successes between two populations. For this work, a success can be defined as a nondetectable value of the soil chemical in question; hence the test is used to determine whether there is a difference in the proportion of nondetectable values between an EDA neighborhood and the corresponding control area. The only test in this group we have used is Fisher's Exact test. An alternate test in this group, the Chi-Squared test, was not used because the sample sizes that would result from the soil testing program would be too small for this test to be applicable.

TWO-SAMPLE LOCATION TESTS

Two-sample location tests address the problem of determining whether there is a difference in the central tendency of two populations. The classic parametric two-sample location test, which is valid under the assumption of normal observations and equal variances for the two populations, is Student's t-test (Zar, 1984, p. 126). The Wilcoxon Rank Sum

test (Hollander and Wolfe, 1973, p. 67) is a nonparametric analog to the t-test. It is based on the ranks of the data, and, like all nonparametric tests, has the advantage of robustness with respect to the underlying probability distribution of the data; that is, it does not require that the data be normally distributed, as does the t-test. Another well-known nonparametric two-sample test, the Mann and Whitney test, is equivalent to the Wilcoxon Rank Sum test (see comments in Wilcoxon Rank Sum test description).

TWO-SAMPLE DISPERSION TESTS

Two-sample dispersion tests address the problem of determining whether there is a difference in the spread of two populations. When the data are normally distributed, the well-known F-test is applicable. However, this test is quite sensitive to deviations from normality (in terms of the type I error level) and we have not used it for this reason. There have been many nonparametric tests proposed for the two-sample dispersion problem, but most assume that the median of each population (or the difference between medians) is known. Our analysis of one commonly recommended nonparametric test for dispersion that makes such an assumption showed that the test performed poorly for highly skewed distributions when sample medians were used in place of their true values. Therefore, we have adopted instead two tests that allow for unknown and unequal medians. The first test, attributed to Moses, involves randomly dividing the observations into subgroups of size k for each of the two samples, then applying the Wilcoxon Rank Sum test to dispersion measures computed within each group for each sample area (EDA neighborhood or control). An alternate test, attributed to Shorack, uses the usual F-statistic, with the degrees of freedom modified both for estimation of the median and for non-normality based on the sample kurtosis. It is

based upon approximating the permutation distribution of the F-statistic, and is therefore referred to as Shorack's APF-test.

TWO-SAMPLE DISTRIBUTION TESTS

Two-sample distribution tests address the problem of determining whether the distributions of two populations (as opposed to measures of central tendency or dispersion) differ. Tests for location and tests for dispersion can be thought of as focusing on special cases of distributional differences. The Mood Quantile test tests whether the p^{th} quantile is the same for both populations. If $p = 0.5$, this is another way of testing for equal medians, and in this case the Mood test becomes a two-sample location test. The Kolmogorov-Smirnoff test tests whether the cumulative distribution functions (CDFs) of the two populations differ. It does not focus on any particular metric of the distributions (e.g., moments or percentiles), but instead is based on a measure of discrepancy over the entire cumulative distribution function. While the Kolmogorov-Smirnoff test may be thought of as the most general of the tests in this respect, this generality is achieved at the expense of a loss in power. In addition, some of the assumptions of this test may not be met for small sample sizes or high nondetect fractions. These restrictions are discussed in more detail in the test description.

FISHER'S EXACT TEST FOR EQUAL PROPORTIONS

Both the parametric (Student's t) and nonparametric (Wilcoxon Rank Sum) two-sample tests assume that the observations from each sample are continuously distributed. When the observations are discrete, and in particular, binary (yes/no, success/failure, present/absent), it is possible to test whether the proportion of successes in population 1 is the same as the proportion of successes in population 2. Fisher's Exact test is appropriate for this type of problem.

DATA STRUCTURE

$X_1,\ldots,X_m$ are m independent binary observations from population 1, and $Y_1,\ldots,Y_n$ are n independent binary observations from population 2. The X_i's and Y_j's can take on only the values 0 or 1.

Define $p_1 = Pr(X_i = 1)$, and $p_2 = Pr(Y_j = 1)$
for $i = 1,\ldots,m$ and $j = 1,\ldots,n$.

NULL HYPOTHESIS

H_o: $p_1 = p_2$ versus H_a: $p_1 < p_2$

PROCEDURE

1. Consider the following 2 x 2 contingency table:

	Group 1	Group 2	
Number of 0's	f_{11}	f_{12}	R_1
Number of 1's	f_{21}	f_{22}	R_2
	m	n	N

Fisher's exact test is a conditional test in that once the total number of 0's (R_1) and the total number of 1's (R_2) have been observed, the test assumes that these numbers were fixed to begin with. If R_1 and R_2 are fixed, then a specific probability can be associated with any table that shows the same marginals (m, n, R_1, and R_2). This probability is calculated as $P = [(R_1!)(R_2!)(m!)(n!)/(N!)]/[(f_{11}!)(f_{12}!)(f_{21}!)(f_{22}!)]$.

To perform Fisher's exact test, probabilities are calculated for the observed table and any tables that are "more extreme" than the observed table. In this case, a more extreme table is one that has a smaller number of 1's in Group 1 than what was observed. Hence, an example of a table that is more extreme than the one that was observed is:

	Group 1	Group 2	
Number of 0's	$f_{11}+1$	$f_{12}-1$	R_1
Number of 1's	$f_{21}-1$	$f_{22}+1$	R_2
	m	n	N

Note that the number of more extreme tables one can construct is the minimum of f_{21} and f_{12} because no cell can have less than 0 observations in it.

Therefore, the procedure for performing Fisher's Exact test is as follows:

1. Compute the probability associated with the observed table.

2. Construct the next most extreme table by decreasing f_{21} by 1 (if possible) and making the necessary adjustments to keep the marginals the same. Compute the probability associated with this table.

3. Repeat step 2 until no more extreme tables can be formed.

4. Add up all of the probabilities associated with the observed table and the more extreme tables.

5. Reject H_o at level α in favor of H_a if the sum of the probabilities computed in step 4 is less than α.

ASSUMPTIONS

Fisher's Exact test is really a conditional test, conditional on the margins. Thus, strictly speaking, this test is applicable only in cases where the number of 0's (R_1) and the number of 1's (R_2) is set in advance (not the usual case). This test seems to produce consistent results, however, even when R_1 and R_2 are not set in advance.

COMMENT

In our work Fisher's test is applied to determine whether there is a change in the proportion of concentrations below the detection limit between the EDA and control areas. Because Fisher's test is concerned only with the proportion of nondetects, the test is insensitive to the underlying distribution of the data.

STUDENT'S t-TEST

Student's t-test is probably the best known parametric two-sample test. For several reasons (see text) we do not favor its use. It is included primarily for reference and verification purposes.

DATA STRUCTURE

$X_1,\ldots,X_m$ are m independent observations from population 1 with CDF F, and $Y_1,\ldots,Y_n$ are n independent observations from population 2 with CDF G. N = (m + n) is the total number of observations. The model is:

$$X_i = e_i + \mu_1, \qquad \text{for } i = 1,\ldots,m,$$

$$Y_j = e_{m+j} + \mu_2, \qquad \text{for } j = 1,\ldots,n,$$

where:

$e_1,\ldots,e_N$ = the unobservable errors
μ_1 = the median of population 1
μ_2 = the median of population 2

The parameter of interest is $\Delta = (\mu_2 - \mu_1)$.

NULL HYPOTHESIS

H_o: $\Delta \leq 0$ versus H_a: $\Delta > 0$.

PROCEDURE

1. Compute:

$$\bar{X} = (1/m) \sum_{i=1}^{m} X_i$$

$$\bar{Y} = (1/n) \sum_{j=1}^{n} Y_j$$

$$SS_x = \sum_{i=1}^{m} (X_i - \bar{X})^2$$

$$SS_y = \sum_{j=1}^{n} (Y_j - \bar{Y})^2$$

and set:

$$s_p^2 = (SS_x + SS_y)/(N-2)$$

2. Set $t = (\bar{Y} - \bar{X}) / \sqrt{s_p^2[(1/m) + (1/n)]}$

Reject H_o: $\Delta \leq 0$ at level α in favor of

H_a: $\Delta > 0$ if $t > t_{N-2,\alpha}$

where:

$t_{d,\alpha}$ denotes the $(1-\alpha)$ 100th percentile of Student's t-distribution with d degrees of freedom.

A table of critical values for Student's t-distribution is given in most statistical textbooks.

ASSUMPTIONS

- The e_i's are mutually independent.

- The e_i's come from the same continuous population (i.e., they are identically distributed) with median = 0.

- The e_i's are normally distributed. Note: This implies that μ_1 and μ_2 are also the means of populations 1 and 2, respectively.

WILCOXON RANK SUM TEST

The Wilcoxon Rank Sum test is a nonparametric alternative to the t-test. It performs nearly as well as the t-test when the assumptions of the t-test are met, and in most cases much better when the t-test assumptions are not met. It easily handles censored and missing data.

DATA STRUCTURE

$X_1,\ldots,X_m$ are m independent observations from population 1 with CDF F, and $Y_1,\ldots,Y_n$ are n independent observations from population 2 with CDF G. N = (m + n) is the total number of observations. The model is:

$$X_i = e_i + \mu_1, \qquad \text{for } i = 1,\ldots,m,$$

$$Y_j = e_{m+j} + \mu_2, \qquad \text{for } j = 1,\ldots,n,$$

where:

$e_1,\ldots,e_N$ = the unobservable errors
μ_1 = the median of population 1
μ_2 = the median of population 2

The parameter of interest is $\Delta = (\mu_2 - \mu_1)$.

NULL HYPOTHESIS

H_o: $\Delta \leq 0$ versus H_a: $\Delta > 0$

Or equivalently, H_o: $F(x) \geq G(x)$ for all x

Versus H_a: $F(x) = G(x + \Delta)$ for all x, where $\Delta > 0$.

PROCEDURE

1. Order the N observations from smallest to largest, and let R_j denote the rank of Y_j (j = 1,...,n) in this ordering.

2. Set $W = \sum_{j=1}^{n} R_j$, and reject H_o at level α in favor of H_a if W is too large.

The Wilcoxon Rank Sum test can be modified for the case where r of the X_i's are censored from below at the value C, and s of the Y_j's are censored from below at the value C as follows:

1. Compute the test statistic W as for the usual Wilcoxon test, but treat the censored X's and Y's as tied observations (see comment 3 below). Hence, there is one group of tied observations corresponding to the non-detects, and the size of this group is (r + s).

2. Adjust the variance of the test statistic for the (r + s) ties as per comment 3 below.

ASSUMPTIONS

- The e_i's are mutually independent.
- The e_i's come from the same continuous population (i.e., they are identically distributed) with median = 0.

COMMENTS

1. A table of critical values for W is given in Hollander and Wolfe (1973, pp. 272-282). For large values of m and n, a normal approximation to the distribution of W (under H_o) can be used. In this case, one computes $E_o = n(N + 1)/2$ and $V_o = mn(N + 1)/12$. Set $z = (W - E_o)/\sqrt{V_o}$, and reject H_o at level α in favor of H_a if $z \geq z_\alpha$, where z_α denotes the $(1-\alpha)$ 100th percentile of the standard normal distribution.

2. A correction for continuity may be employed for the normal approximation to the distribution of W, which improves the accuracy of the approximation for moderate to small sample sizes (e.g., for N as small as 10). To use the continuity correction, E_o and V_o are computed as shown above, and z is given by:

$$z = \begin{cases} [(W - E_o) - 0.5]/\sqrt{V_o} & \text{if } (W - E_o) > 0.5 \\ [(W - E_o) + 0.5]/\sqrt{V_o} & \text{if } (W - E_o) < -0.5 \end{cases}$$

3. In the case of ties, all tied observations are given their mid-rank, and the formula for V_o is modified to:

$$V_o = (mn/12)\{N + 1 - [\sum_{j=1}^{g} t_j(t_j^2 - 1)/N(N-1)]\}$$

where:

g = the number of tied groups
t_j = the size of the j^{th} tied group

4. The Wilcoxon Rank Sum test can be shown to be equivalent to the Mann-Whitney test (Mann and Whitney, 1947). The Mann-Whitney U-statistic is computed as:

$$U = \sum_{i=1}^{m} \sum_{j=1}^{n} \text{sgn}(X_i, Y_j)$$

where:

$$\text{sgn}(X,Y) = \begin{cases} 1 & \text{if } X < Y \\ 1/2 & \text{if } X = Y \\ 0 & \text{if } X > Y \end{cases}$$

It can be shown that:

$$U = W - [n(n+1)/2],$$

and thus,

$$W = U + [n(n+1)/2].$$

5. Note that since the null hypothesis is $F(x) = G(x)$ for all x, the test may have some power to detect alternative hypotheses other than a strict location shift. However, the test is designed to detect changes in location, and it should perform best (relative to other tests) against the location alternative.

MOSES SCALE TEST

The Moses Dispersion test is a nonparametric test for change in scale. It is based on ranks, and is closely related to the Wilcoxon Rank Sum test for change in location.

DATA STRUCTURE

$X_1,\ldots,X_m$ are m independent observations from population 1 with CDF F, and $Y_1,\ldots,Y_n$ are n observations from population 2 with CDF G. $N = (m + n)$ is the total number of observations. The model is:

$$X_i = \sigma_1 e_i + \mu_1, \qquad \text{for } i = 1,\ldots,m,$$

and

$$Y_j = \sigma_2 e_{m+j} + \mu_2, \qquad \text{for } j = 1,\ldots,n,$$

where:

$e_1,\ldots,e_N$ = the unobservable errors
μ_1 = the median of population 1
μ_2 = the median of population 2

The parameter of interest is the unknown ratio of scale parameters $\gamma = \sigma_2/\sigma_1$.

NULL HYPOTHESIS

H_o: $\gamma = 1$ versus H_a: $\gamma > 1$.

Or equivalently, H_o: $F(x - \mu_1) = G(x - \mu_2)$ for all x

Versus H_a: $F(x-\mu_1,) = G[\gamma(x-\mu_2)]$ for all x, where $\gamma > 1$.

PROCEDURE

1. Select a positive integer $k \geq 2$ and randomly divide the X and Y observations into m* and n* subgroups of size k, respectively. Discard any extra observations.

2. Let $X_{i1},\ldots,X_{ik}$ denote the k observations in the i'th subgroup of the X's, for $i = 1,\ldots,m^*$. Let $Y_{j1},\ldots,Y_{jk}$ denote the k observations in the j'th subgroup of the Y's, for $j = 1,\ldots,n^*$.

3. Define $C_1,\ldots,C_{m^*}$ by

$$C_i = \sum_{s=1}^{k} (X_{is} - \bar{X}_i)^2, \text{ for } i = 1,\ldots,m^*$$

where:

$$\bar{X}_i = (1/k) \sum_{s=1}^{k} X_{is}.$$

4. Define $D_1,\ldots,D_{n^*}$ by

$$D_j = \sum_{s=1}^{k} (Y_{js} - \bar{Y}_j)^2, \text{ for } j = 1,\ldots,n^*$$

where:

$$\bar{Y}_j = (1/k) \sum_{s=1}^{k} Y_{js}.$$

5. Apply the Wilcoxon Rank Sum test to the C's and D's.

6. In the case of censoring, censored observations are set to half the value of the censoring level for the purpose of computing the C's and D's.

ASSUMPTIONS

1. $X_1,\ldots,X_m$ are m observations from population 1 and $Y_1,\ldots,Y_n$ are n observations from population 2. $N = (m + n)$ is the total number of observations.

2. The e_i's are independently, identically, and continuously distributed.

COMMENT

Note that since the null hypothesis is $F(x) = G(x)$ for all x, the test may have some power to detect alternative hypotheses other than a strict scaling (for instance, upper quantile shifts). However, the test is designed to detect changes in scale, and it should perform best (relative to other tests) against the scaling alternative. The major disadvantage of this test is that the results are dependent on the particular random selection of the random subgroupings of the data. In the sense of statistical expectations (e.g., type I error probability and power) this makes no difference, but for any particular application it may lead to difficulty in interpreting and comparing results.

SHORACK'S APF-TEST FOR DISPERSION

Shorack's test, like the Moses test, is most applicable to detecting shifts in scale. Unlike the Moses test, it is based on the parametric F-test, which is adjusted for estimation of the sample median and for nonnormality based on the fourth sample moment of the data.

DATA STRUCTURE

$X_1,\ldots,X_m$ are M observations from population 1.

$Y_1,\ldots,Y_n$ are n observations from population 2.

$N = (m + n)$ is the total number of observations.

The model is:

$$X_i = \sigma_1 e_i + \mu_1, \text{ for } i = 1,\ldots,m,$$

$$Y_j = \sigma_2 e_{m+j} + \mu_2, \text{ for } j = 1,\ldots,n,$$

where $e_1,\ldots,e_N$ are the observable errors, μ_1 is the median of population 1, μ_2 is the median of population 2, and the parameter of interest is the unknown ratio of scale parameters $\gamma = \sigma_2/\sigma_1$.

NULL HYPOTHESIS

H_o: $\gamma = 1$ versus H_a: $\gamma > 1$

PROCEDURE

1. Compute $\bar{X} = \frac{1}{m} \sum_{i=1}^{m} X_i$, $\bar{Y} = \frac{1}{n} \sum_{j=1}^{n} Y_j$

$$SS_x = \sum_{i=1}^{m} (X_i - \bar{X})^2 \quad \text{and} \quad SS_y = \sum_{j=1}^{n} (Y_j - \bar{Y})^2$$

$$\text{Set } F = \frac{\frac{SS_y}{n-1}}{\frac{SS_x}{m-1}}$$

2. Compute $SQ_x = \sum_{i=1}^{m} (X_i - \bar{X})^4$ and $SQ_y = \sum_{j=1}^{n} (Y_j - \bar{Y})^4$

$$\text{Set } b_2 = \frac{N(SQ_x + SQ_y)}{(SS_x + SS_y)^2}$$

$$\text{Let } d = \frac{2}{b_2 - 1}$$

3. Reject H_o at level α in favor of H_a if $F > F_\alpha\ (df_1, df_2)$, where $df_1 = d(n-1)$, $df_2 = d(m-1)$, and $F_\alpha\ (df_1, df_2)$ denotes the $(1-\alpha)$ 100th percentile of the F-distribution with df_1 and df_2 degrees of freedom. Note that df_1 and df_2 are not necessarily integers.

ASSUMPTIONS

The N e_i's are mutually independent.

The N e_i's come from the same continuous population with median 0.

COMMENT

Because the degrees of freedom are adjusted for nonnormality based on the fourth sample moment, which is unstable for small sample sizes, the small sample behavior of the test is suspect. In addition, there is a problem of determining how to handle nondetected data (we have set nondetected observations to half the detection level). However, our Monte Carlo experiments (see Section G.4) show that the test performs surprisingly well even for relatively small sample sizes and high nondetect fractions, although under these conditions its performance is degraded relative to the nonparametric alternative (the Moses test). For small sample sizes (in our Monte Carlo experiments, on the order of ten in each area), the computed (true) alphas exceed the nominal values. Therefore, the apparent power tends to be overestimated for small samples. Likewise, computational problems result for high nondetect fraction, since the adjusted degrees of freedom cannot be computed. These problems appear to be important only when the nondetect fraction and sample size are such that the number of detectable concentrations in each group are less than about five.

MOOD'S TEST FOR EQUAL QUANTILES

Mood's test can be used to test for changes in a specific quantile of two distributions. It is most applicable to the case where only part of two distributions differ (for instance, the largest values, which may reflect "hot spots" of contamination). The test is based on the same contingency table theory as Fisher's Exact test for proportions. It is less powerful than nonparametric location (Wilcoxon Rank Sum) and scale (Moses) tests for more general alternative hypotheses where there is a difference in the entire probability distribution.

DATA STRUCTURE

$X_1,\ldots,X_m$ are m independent observations from population 1.

$Y_1,\ldots,Y_n$ are n independent observations from population 2.

Let $Q_1(p)$ denote the p^{th} quantile of population 1, and let $Q_2(p)$ denote the p^{th} quantile of population 2. Thus, $Pr(X_i \leq Q_1(p)) = p$, and $Pr(Y_j \leq Q_2(p)) = p$.

NULL HYPOTHESIS

H_o: $Q_1(p) = Q_2(p)$ versus H_a: $Q_1(p) \neq Q_2(p)$, where p is set in advance.

PROCEDURE

1. Let Q(p) denote the p^{th} quantile in the combined sample of X's and Y's. Construct the following 2 x 2 contingency table:

	Gp 1	Gp 2	
Number above Q(p)	f_{11}	f_{12}	R_1
Number not above Q(p)	f_{21}	f_{22}	R_2
	m	n	N

2. Calculate the usual Chi-Squared statistic for this table. The Chi-Squared statistic with the Yate's correction for continuity is given by

$$T = N[|f_{11}f_{22} - f_{12}f_{21}| - (n/2)]^2/[mnR_1R_2]$$

Reject H_o at level α if $T > \chi^2_{1,\alpha}$, where $\chi^2_{d,\alpha}$ denotes the $(1-\alpha)$ 100th percentile of the Chi-Squared distribution with d degrees of freedom.

3. In the case of small frequencies, use Fisher's Exact Test instead of the Chi-Squared Test.

ASSUMPTIONS

The X and Y values are mutually independent and continuously distributed.

COMMENT

When p = 0.5, the p^{th} quantile is the median and the Mood test is identical to the median test. In this special case, the Mood test is only about 67 percent as powerful as the Wilcoxon Rank Sum test.

KOLMOGOROV-SMIRNOFF TEST FOR EQUAL DISTRIBUTIONS

The Kolmogorov-Smirnoff test can be used to test for differences between two (or more) distributions. Its two-sample form used here differs from two-sample tests for location (e.g., Wilcoxon Rank Sum) or scale (e.g., Moses) in that the alternative hypothesis is more general. Rather than a simple location or scale shift, the Kolmogorov-Smirnoff test is affected by any difference in the two distributions. However, in most cases this increase in generality is achieved at the expense of a loss in power against more specific location or scale shift alternatives.

DATA STRUCTURE

$X_1,\ldots,X_m$ are m independent observations from population 1 and $Y_1,\ldots,Y_n$ are n independent observations from population 2.

Let F(x) and G(x) denote their respective, unknown, cumulative distribution functions.

NULL HYPOTHESIS

H_o: $F(x) = G(x)$ for all x

versus

H_a: $F(x) > G(x)$ for at least one value of x.

PROCEDURE

1. Compute the empirical distribution function of the X's, and denote it by $S_1(x)$. That is,

$$S_1(x) = (1/m)(\#\ X_i\text{'s} \leq x)$$

Denote the empirical distribution function of the Y's by $S_2(x)$.

2. Compute $T^+ = \max |S_1(x) - S_2(x)|$, where the maximum is taken over all possible values of x, and $|v|$ denotes the absolute value of a number v.

3. Reject H_o at level α if T^+ is too large. A table of critical values for T^+ is given in Conover (1980, pp. 471-473).

4. A large sample approximation to the 95th percentile of the distribution of T^+ (under H_o) is given by:

$$1.73/\sqrt{n} \text{ if } m = n$$

and by:

$$1.22\sqrt{(m+n)/mn} \text{ for } m \neq n.$$

ASSUMPTIONS

- The samples are random samples.
- The two samples are mutually independent.
- The measurement scale is at least ordinal.
- For this test to be exact, the random variables must be continuous.

COMMENT

The last assumption clearly does not hold in the case of censored (nondetect) data. Our Monte Carlo tests show that

for high nondetect fractions, the true type I error probabilities (alpha) can vary substantially from the theoretical values; the actual values are usually larger. In practice, care must be taken in use of this test for nondetect fractions in excess of (roughly) 30 percent, which rules out its use for many of the LCICs.

MULTIVARIATE WILCOXON RANK SUM TEST
AVERAGE RANK VERSION

The univariate rank sum test can be generalized to multiple variables using a straightforward (albeit ad hoc) procedure based on average ranks. Although its theoretical properties have not been derived, Monte Carlo tests show that it performs quite well in practice, and that the calculated type I error probabilities are quite close to the actual values obtained by simulation.

DATA STRUCTURE

$\underline{X}_1,\ldots,\underline{X}_m$ are m p-variate observations from population 1.

$\underline{Y}_1,\ldots,\underline{Y}_n$ are n p-variate observations from population 2.

$N = (m + n)$ is the total number of observations.

Population 1 has CDF $F(x_1,\ldots,x_p)$, and population 2 has CDF $F(y_1-\Delta_1,\ldots,y_p-\Delta_p)$.

Δ_i denotes the shift between populations 1 and 2 for the i^{th} variable $(i = 1,\ldots,p)$.

Let X_{ij} denote the j^{th} observation on the i^{th} variable for the $\underline{X}$'s $(i = 1,\ldots,p;\ j = 1,\ldots,m)$.

Similarly, let Y_{ij} denote the j^{th} observation on the i^{th} variable for the $\underline{Y}$'s $(i = 1,\ldots,p;\ j = 1,\ldots,n)$.

NULL HYPOTHESIS

H_o: $\underline{\Delta} = \underline{0}$ versus H_a: $\underline{\Delta} \neq \underline{0}$, where $\underline{\Delta}' = (\Delta_1,\ldots,\Delta_p)$, and $\underline{0}$ is a p x 1 vector of 0's.

PROCEDURE

1. Consider each of the p variables separately. For each variable, order the N observations from least to greatest, and let R_{ij} denote the rank of Y_{ij} $(i = 1,\ldots,p;\ j = 1,\ldots,n)$.

2. Compute the average rank of the j^{th} observation, averaged across variables. That is, compute:

$$R_j = \frac{1}{p} \sum_{i=1}^{p} R_{ij}$$

3. Perform the usual univariate Wilcoxon Rank Sum test on the R_j's. Hence, set

$$W = \sum_{j=1}^{n} R_j$$

and reject H_o at level α in favor of H_a if W is too large.

4. A table of critical values for W is given in Hollander and Wolfe (1973, pp. 272-282).

ASSUMPTIONS

- The X's and Y's are mutually independent (but there may be correlation between the multivariate components of each X and Y vector).
- F is a continuous multivariate probability distribution.

COMMENT

This test was devised specifically for this work. Since it is based on a ranking of (average) ranks, it should be quite robust with respect to the underlying probability distribution of the data, and our simulation results bear this out. Because it is adapted from the univariate rank sum test, the same procedures for handling censored (nondetect) data can be applied. Our simulation results show that the test performs quite well for relatively high nondetect fractions, and for a range of intervariable correlations.

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APPENDIX H
DOH Soil Study

CONTENTS

STUDY DESIGN

LOVE CANAL HABITABILITY

SOIL PILOT II SAMPLING PROGRAM

NEW YORK STATE DEPARTMENT OF HEALTH
NOVEMBER 14, 1986

LOVE CANAL HABITABILITY STUDY
SOIL PILOT II SAMPLING PROGRAM

November 14, 1986

BACKGROUND

Preliminary results of the pilot program for the Love Canal Habitability Study show low levels of 1,2,4-trichlorobenzene and 1,2,3,4-tetrachlorobenzene (on the order of 1 ppb) in most of the soil samples collected from the Love Canal Emergency Declaration Area (EDA). Other Love Canal indicator chemicals (primarily beta and gamma hexachlorocyclohexanes) were not consistently present in these samples, raising the possibility that the trichlorobenzene and tetrachlorobenzene may have come from a source other than the Love Canal.

The pilot program sampling of soil in the comparison areas in Cheektowaga and Tonawanda did not show a similar pattern of low level contamination; both 1,2,4-trichlorobenzene and 1,2,3,4-tetrachlorobenzene were found in less than one quarter of the comparison area soil samples. It therefore appears that this low level contamination found in the Love Canal EDA is not indicative of the entire Niagara Frontier.

The correlation between the levels of trichlorobenzene and tetrachlorobenzene in the EDA soil samples was much higher than the correlation between the levels of any other two chemicals. This relationship indicates a common source of the soil contamination.

Purpose

The purpose of this study is to collect additional data that may assist in the design of the Love Canal Habitability Study.

Hypothesis

The available data appear to indicate that the low levels of trichlorobenzene and tetrachlorobenzene found in soil samples from the EDA may be from the same source. Assuming this is the case, it is hypothesized that this source is one or more of the three possibilities listed below. By measuring these contaminants in soil samples from the EDA and from other areas which differ in the extent they would have been impacted by the hypothesized sources, it may be possible to show which sources are more likely and which are unlikely to be responsible for the trichlorobenzene and tetrachlorobenzene contamination in the EDA.

The three suggested possible sources of the detected contamination are:

1. Transport of contaminated material from the Love Canal;
2. Airborne particulate migration and deposition from another source in the Buffalo Avenue industrial complex.
3. Adsorption from City of Niagara Falls water applied to lawns over the years when low levels of these chemicals were present in the water supply.

Soil samples will be collected in five areas. One (the EDA) is close to Love Canal and more likely to have been affected by contaminant migration from the Love Canal. The EDA may also have been impacted by the other two hypothesized sources (air and City water). Two of the areas to be sampled are outside the region served by City of Niagara Falls water. Of these, one is downwind (according to the general westerly and south westerly wind pattern) of the industrial complex. Two sampling areas, in addition to the EDA, are served by City water; one is upwind and one downwind of the industrial complex.

By comparing the results of analysis of soil samples from these five areas (as discussed in the section on Interpretation of Results) it may be possible to draw conclusions about the possible source of the observed soil contamination.

Areas to be sampled

The EDA completely surrounds the Love Canal Site. If the low levels of contaminants identified in soil in this area were the result of airborne particulate migration and deposition from a source other than Love Canal, then the source of this contamination would presumably be located upwind of the Love Canal Area. The prevailing winds are from the southwest and west. Alternatively, the low level soil contamination may be the result of people watering their lawns over the years when the Niagara Falls Water Treatment Plant (NFWTP) bedrock intake tunnel was in use and was impacted by infiltration of chemicals from the S-Area Landfill. To evaluate the alternate hypotheses concerning the source of

EDA soil contamination, 15 soil samples will be collected and analyzed from each of four areas in and around Niagara Falls, and from a control area located away from Niagara Falls. The locations of the sampling areas are shown conceptually in Figure 1. Each area is classified as to whether it is so located as to have possibly received contamination from the hypothesized sources. Thus L_1 indicates Love Canal to be a possible contributing source; L_2 indicates it is not considered a possible source of measureable impact on the area in question. Similarly A_1 and A_2 denote whether an area is or is not located "downwind" of the hypothesized air source and W_1 and W_2 denote whether an area was or was not served by Niagara Falls water. The rationale for selecting the four proposed sampling areas is as follows:

Area 1: The Love Canal EDA will be resampled using this study's sample collection and analytical protocols to maintain consistency within this study and to provide a basis for comparison of these results with those from the soil pilot program. The hypothetical scenario identified on Figure 1 for location 1 indicates:

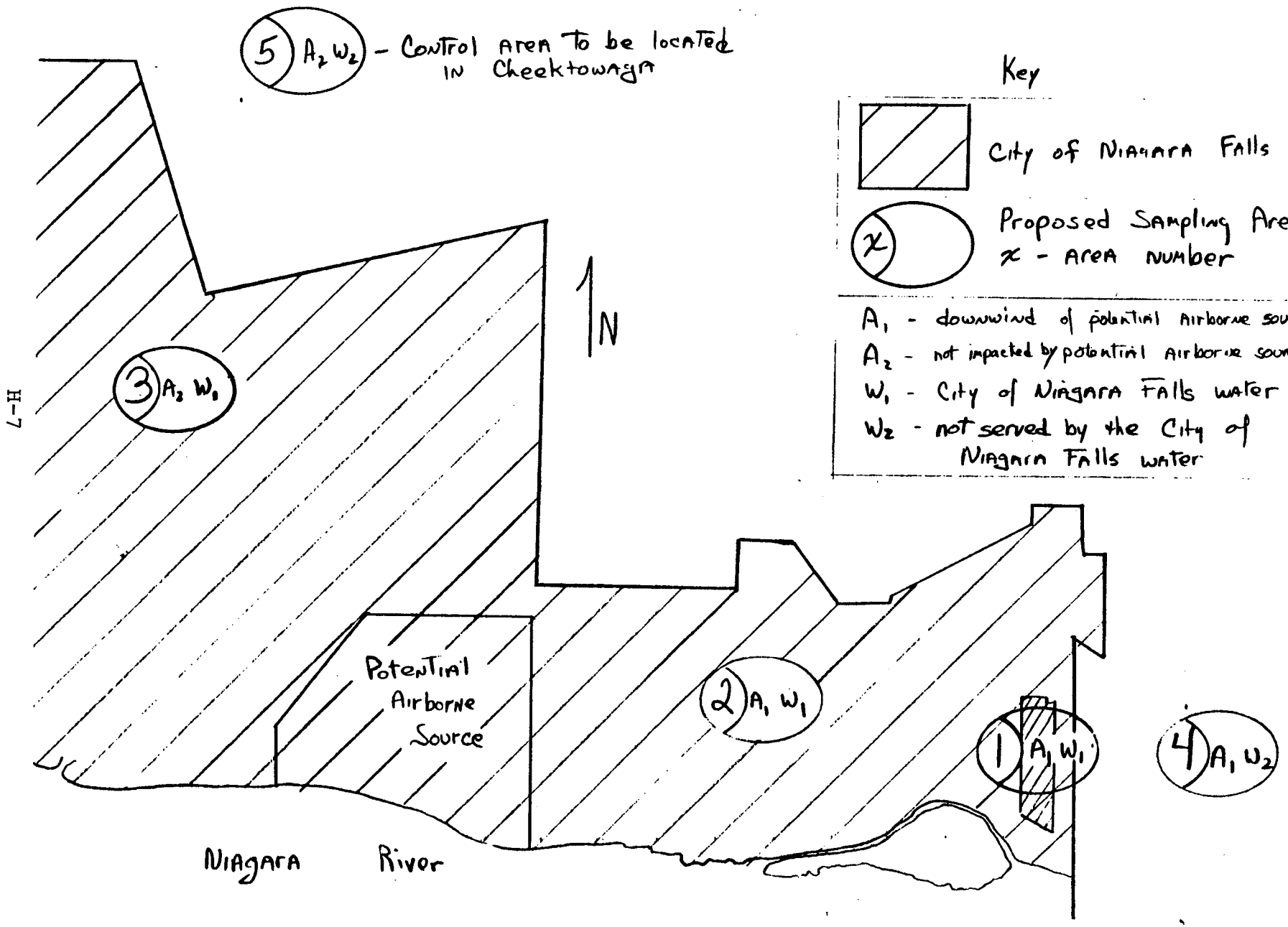
A_1 - within a zone of influence of a potential airborne source

W_1 - served by the City of Niagara Falls Water Treatment Plant.

L_1 - adjacent to Love Canal

Area 2: A residential area located west of the Love Canal EDA will be sampled to provide an area very similar to the Love Canal EDA. This location's hypothetical scenario identified on Figure 1 is the same as location 1 with regard to air and water sources, (A_1, W_1) but it is not close enough to be directly impacted by Love Canal (L_2).

Figure 1 - Proposed Sample Areas



Area 3: A residential area located in the north western section of Niagara Falls will be sampled to provide a set of data which would be indicative of the hypothetical scenario identified on Figure 1 for Location 3 as follows:

A_2 - area located upwind of potential airborne source

W_1 - served by the City of Niagara Falls Water Treatment Plant.

L_2 - not impacted by Love Canal.

Area 4: A rural area north east of the Love Canal EDA will be sampled to provide an area similar to the Love Canal EDA in terms of the potential impact of the hypothesized airborne source (A_1 on Figure 1), but this must be an area in which soil watering with Niagara Falls city water has not occurred (W_2) and which is removed from Love Canal (L_2).

Area 5: An area in Cheektowaga uninfluenced by all three hypothesized sources, which was used as a control area for soil samples in the soil pilot program, will be resampled (A_2, W_2, L_2).

Selection of Potential Sample Sites

The area of the Love Canal EDA is approximately 250 acres. The goal will be to locate three additional sample areas similar in size to the Love Canal EDA and from similar types of residential neighborhoods (see Table 1). The 15 sample sites within each area will be selected at random using the following procedure:

TABLE 1

Proposed Locations of Sample Areas

1. Love Canal EDA.
2. LaSalle area between Pine & Frontier
3. NW Niagara Falls residential area west of Hyde Park.
4. A rural area in the Town of Whentfield east of Love Canal, that would not have been watered except for natural rainfall.
5. A control area in Cheektowaga.

GM:dm/001-a2

Areas 1,2 and 3

Each area was cut into blocks using the existing streets as dividing lines. The blocks that appeared too large were further divided to create more uniformly proportioned blocks. The blocks were then numbered starting in the top left corner moving to the right end, dropping down to the left of the next row,...etc. Approximately forty (40) blocks were created within each area. Five (5) blocks were then chosen by random selection using a random number list.

Each selected block was then sketched with the appropriate street numbers identified on the sketch. Beginning in the north west corner and proceeding clockwise, each residence was assigned a number. Three residences were then chosen by random selection through the use of the random number list. Commercial properties were excluded.

Area 4

This is a rural area. A grid of seventy two (72), 3.5 acre squares was constructed. Fifteen (15) squares were picked by random selection. Samples will be collected from within the selected squares.

Area 5

Fifteen residences were selected at random from a group of 151 homeowners in the Cheektowaga Area who had already granted permission to sample their property.

Outreach - Final Selection of Sample Sites

For each area to be sampled, a list of potential sampling sites (addresses) has been developed using the random selection procedures described above.

The outreach team will telephone the owner of each of those sites, briefly explain the program and ask permission to collect a soil sample. If permission is granted, the outreach team will visit the property owner, at which time the owner will be given a copy of the fact sheet, "Love Canal Soil Pilot II Investigation"; the interviewer will obtain the owner's signature on the permission form; and the property owner will be told approximately when the field team will collect the soil sample.

If a site on this list cannot be sampled because the property owner chooses not to participate, or for any other reason, an alternate site will be chosen for sampling by telephone calls or visits to owners of other properties on the same block in the following order: the first property to the right, the first property to the left, second property to the right, second property to the left, etc. Participants will be sought in this sequence until a sampling site is obtained. Then the outreach program will proceed as described above to obtain written permission to collect a soil sample.

Interpretation of Results

Soil samples from both the Love Canal EDA and the comparison area contained 1,2,4-trichlorobenzene and 1,2,3,4-tetrachlorobenzene, although they were found in many more samples from the former area. The study

area and the comparison area in the Love Canal Pilot Soil Sampling Study are also served by different water systems. These areas are also sufficiently separated so as not to be impacted by the same local sources of contaminated airborne particulate matter. The presence of 1,2,4,-trichlorobenzene and 1,2,3,4,-tetrachlorobenzene in these different areas indicates they may be common environmental contaminants, at least in this region. The present sampling program may provide additional information to identify local sources.

Table 2 presents in chart form possible combinations of results of the Soil Pilot II Sampling Program, with interpretations in terms of likely sources. The sampling areas are indicated in Figure 1. .

Assumed Source - Niagara Falls WTP

It would be expected that similar low levels of 1,2,4-trichlorobenzene and 1,2,3,4-tetrachlorobenzene would be identified in areas 1,2, and 3, because these areas are all served by the Niagara Falls WTP. Area 4 and the control area would not show a similar pattern of contamination because of the different water supply.

Assumed Source - Particulate emissions from Buffalo Ave. Industrial Complex

It would be expected that similar levels of 1,2,4-trichlorobenzene and 1,2,3,4-tetrachlorobenzene would be identified in areas 1, 2 and 4, because these are all within the zone of influence of the prevailing winds, and are located downwind of the industrialized

Table 2 Interpretation of Results

Area 1	Area 2	Area 3	Area 4	Control	Niagara Falls Water Plant	Particulate Deposition	LOVE CANAL	Other
X	X	X	O	O	✓			
X	X	O	X	O		✓		
O	NA	NA	NA	NA				✓
X	O	O	O	O			✓	

Above are anticipated to be the most likely combinations of results Any other combinations would be inconclusive.

X - 1,2,4 trichlorobenzene and 1,2,3,4 tetrachlorobenzene detected in significant similar ratios and/or levels.

O - Indicator chemicals not detected in a significant percentage of samples.

Area 1 - Love Canal EDA

Area 2 - LaSalle Area West of Love Canal EDA

Area 3 - Residential Area in North West Niagara Falls

Area 4 - Rural Area East of Love Canal EDA

Control Area - Cheektowaga

area, a hypothesized point source. Area 3 should not show these trends as it is generally upwind of the potential particulate migration source. The control area should not show these trends as it is geographically removed from the potential zone of influence.

Sample Collection and Handling

Because the preliminary results of the soil pilot program detected 1,2,4-trichlorobenzene and 1,2,3,4-tetrachlorobenzene at low levels (0.05 to 1 ppb), it is necessary to obtain similar detection limits in this Soil Pilot II Sampling Program. It has been necessary for the Department's Wadsworth Center for Laboratory and Research to develop and validate new analytical procedures for this study. It is also essential that procedures for sample collection and handling be randomized to avoid any possible systematic error or bias from laboratory error or contamination of a group of samples in processing or shipping or from improperly cleaned tools or containers.

To the extent possible, samples will be collected at the rate of 15 per day for five days. For the first three days, samples and tools will be sent to Albany by air at the end of each day, the samples to be processed for subsequent analysis and the tools to be cleaned and shipped back to Niagara Falls for re-use. There are enough sets of sampling tools for two days of sampling (30 samples). The samples collected on the last day will be transported back to Albany by the field team.

To avoid systemic errors or bias, the sample containers will not identify the area sampled, samples will be collected from all areas every

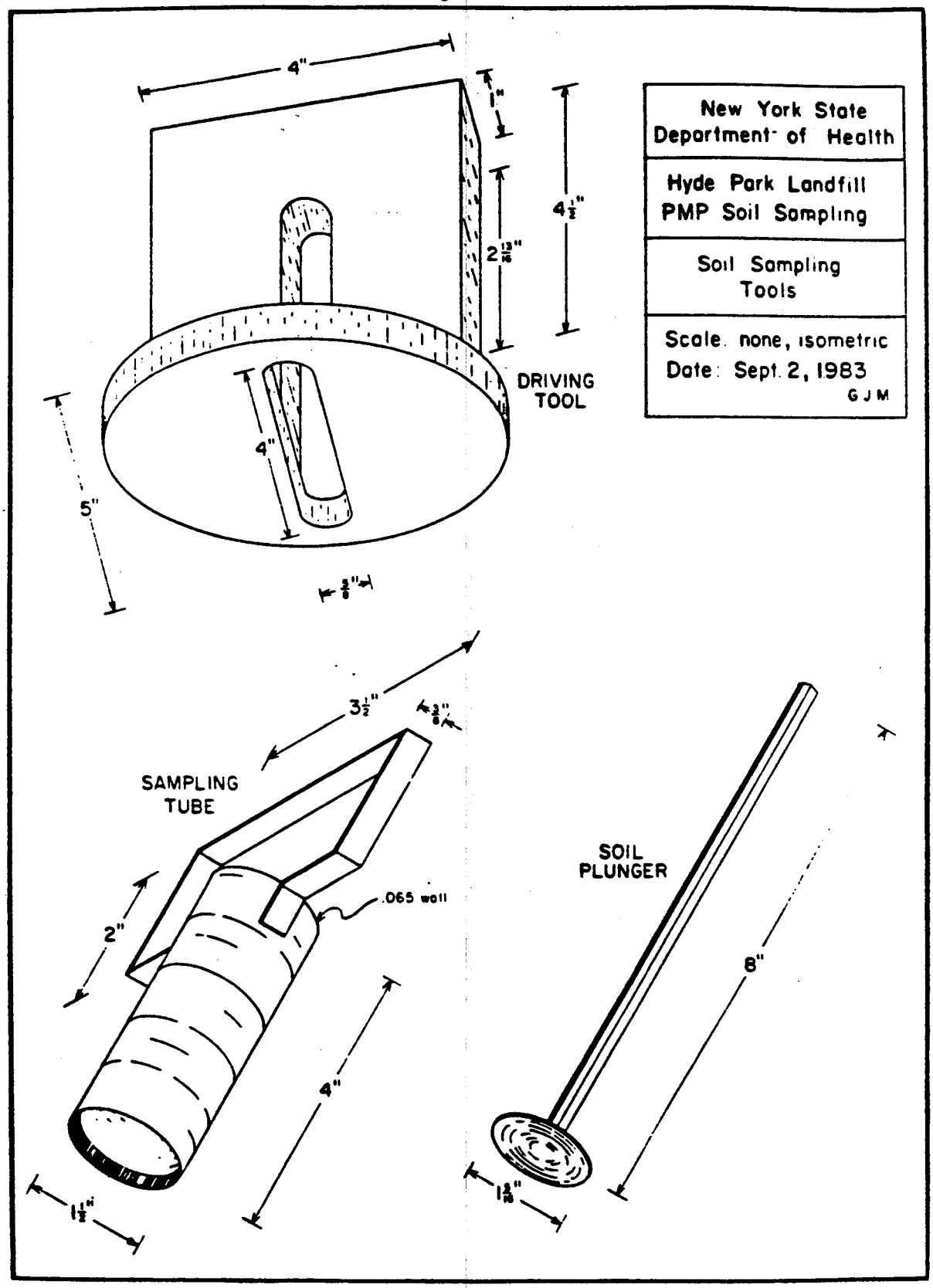
day, and the sampling sites within areas will be selected by a random procedure as described above.

Soil Sampling Protocol

To minimize disturbance from street maintenance and work on buried utilities, the sampling area should be located in the middle of a lawn, and must be more than five meters from the curb or edge of the road. The core samplers shown in Figure 2 will be used to collect the top four inches of soil from two locations, 1 meter apart. These will be composited in the laboratory into one sample for analysis.

Sample collection will be done with the soil sampling tools illustrated in Figure 2. In addition to cotton coveralls the sample collector will wear clean latex gloves and a clean protective apron to prevent cross contamination. Sample bottles (200 ml) with metal screw caps and aluminum foil liners will be used and will be cleaned in accordance with accepted laboratory procedures as per Attachment A, Sample Container Protocol. The exact sampling locations will be identified and sketched in the field log book by triangulating to nearby physical features and magnetic orientation. The sample location code will be logged on the sampling form, Attachment B. A sampling area approximately 1 meter square will be identified on the selected property. Samples will be collected within the sample area(s). Two soil cores spaced approximately one meter apart will be collected. The soil samples will be collected using specially fabricated soil sampling tools - a sampling tube, a soil plunger and a drive head (see Figure 2). The sampling tube and soil plunger will be pre-cleaned as per Appendix A protocols and

Figure 2


4"
1"
4½"
2 13/16"
DRIVING TOOL
4"
5"
⅜"
3½"
SAMPLING TUBE
2"
.065 wall
4"
1½"
SOIL PLUNGER
8"
1⅜"
New York State Department of Health
Hyde Park Landfill PMP Soil Sampling
Soil Sampling Tools
Scale: none, isometric
Date: Sept. 2, 1983
GJM

wrapped in aluminum foil. The clean sampling tools including the mallet and drive head will be placed on a sheet of aluminum foil to separate the tools from the ground surface.

The same sampling tube will be used for the two cores collected at each sample site. Soil samples will be collected by pressing the sampling tube into the soil without tilting or rotating it. In consolidated soil, it may be necessary to drive the cutter to the full depth using a mallet and the drive head shown in Figure 2. When using the drive head, a clean teflon disc will be placed between the tube and the drive head to prevent cross contamination. After the sampling tube has reached the full depth, the handle must be gently twisted to loosen the core so the sampling tube and soil core may be removed from the hole. If the sampling tube cannot be pushed or driven into the soil at a designated location, the sampler will be withdrawn and any soil will be removed for disposal. A new sample will be taken approximately 15 cm away from the initital location using the same sampler. Details of all sampling activities will be recorded in the field log book.

Upon removing the soil core, all materials in the sampling tube will be immediately pushed from the tube (by extruding the core with the soil plunger device shown in Figure 2) into a 200 ml bottle equipped with metal screw cap. Aluminum foil will be used between the cap and bottle. Sample bottle will be identified on the label with the sample date and time, the sample ID Number and the sampler's initials. Sample bottles will be placed in an ice pack cooled shipping box. The samples will be logged in a field log book and sample submission forms (see Attachment 2)

will be completed and submitted for each sample. Shipping will be under Chain of Custody (form TOX, Attachment 3) and will be via State vehicles or overnight commercial carrier. To complete the laboratory record, full identification of the sample locations will be provided after all results are reported as final.

All material collected will be sumitted to the New York State Department of Health, Wadsworth Center for Laboratories and Research, Toxicology Institute laboratory where the 2 sub-samples will be composited and homogenized in a cold room. Sufficient sample(s) will then be removed by quartering.

Personal Equipment shall consist of the following:

1. Latex gloves
2. Coveralls
3. Disposable plastic apron

The Latex gloves and plastic apron will be disposed of after sampling is completed at each site. Coveralls will be changed daily and laundered. Upon completion of sample collection at a site, the soil sampling tools will be placed in a five (5) gallon plastic pail (with the exception of the mallet and drive head). These tools will be brought to a field laboratory as needed and cleaned as per the Appendix E protocols.

Chemical Analyses

The soil samples will be analyzed for 1,2,4 trichlorobenzene, 1,2,3,4-tetrachlorobenze, 1,2,3,5-tetrachlorobenzene and 1,2,4,5-tetrachlorobenzene. Detection limits should be approximately 0.05 ppb. A description of the analytical methods used by the Wadsoworth Center for Laboratories and Research is attached (Attachment D).

ATTACHMENT -A-

LOVE CANAL SOIL PILOT II INVESTIGATION

Sample Bottle and Tool Cleaning Protocol

The following protocol is based on Section 3,A "Cleaning of Laboratory Glassware" detailed in EPA's publication "Manual of Analytical Methods for the Analyses of Pesticides in Human and Environmental Samples", June 1980. Revisions have been made in the EPA protocol in view of the needs of Love Canal Soil Pilot II Investigation.

1. Remove all surface residuals immediately after use and before proceeding with Step 2.

2. Hot soak (in Sparkleen detergent) and scrub both sides throughly using a wire brush.

3. Rinse throughly with hot tap water to remove any residual dust or dirt or soap solution.

4. Rinse with demineralized water to remove any metallic deposits from the tap water rinsing.

5. Bake at 240°C for 30 minutes to remove any residual volatiles.

6. Rinse three times with hexane to flush off any final traces of organic materials and any residual water. Allow to air dry.

7. Repeat rinse with hexane. Allow to air dry.

8. Wrap in aluminum foil.

9. Maintain chain-of-custody using a secure area.

10. Transfer to field with chain-of-custody form, TOX-7 DP.

ACC-1
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NEW YORK STATE DEPARTMENT OF HEALTH
CENTER FOR LABORATORIES AND RESEARCH
ALBANY, NEW YORK 12201

ATTACHMENT -B-

REQUEST FOR ANALYSIS

FOR LABORATORY USE ONLY

LAB ACCESSION NO. ______ SAMPLE REC'D. YEAR MONTH DAY MILITARY HOUR 00-24

TEST PATTERN ______

PLEASE PRINT ALL INFORMATION LEGIBLY IN INK

PROGRAM CODE PROGRAM NAME ______

A. SOURCE NUMBER COUNTY ______

B. DRAINAGE BASIN ______ NAME NEW YORK GAZETTEER NO. TOWN ______

LATITUDE 4 ° ' . "N LONGITUDE 7 ° ' . "W

Z DIRECTION, ALTITUDE OR DEPTH, INCLUDE UNITS

LOCATION (CITY, TOWN OR VILLAGE), WATERSHED, NAME OF INDUSTRY, TREATMENT PLANT, OR WATER SUPPLY NAME OF LAKE, RIVER OR STREAM

EXACT DESCRIPTION OF SITE, NAME OF RESIDENT, STREET ADDRESS, PRECISE SAMPLING POINT

TIME OF SAMPLING

GRAB/COMPOSITE FINISH YEAR MONTH DAY MIL.HRS. (00-24) MINUTE

COMPOSITE START YEAR MONTH DAY MIL HRS (00-24) MINUTE

TYPE OF SAMPLE (SELECT FROM LIST) DESCRIPTION: ______

COMPLAINTS, OBSERVATIONS, REASONS FOR SUBMISSION *(DO NOT CHECK IF ROUTINE SURVEILLANCE)*

- ☐ ILLNESS (A)
- ☐ TURBIDITY (C)
- ☐ NATURAL DISASTER (E)
- ☐ NEW EQUIP OR PROC. (G)
- ☐ INTERRUPTION IN CHLORINATION (I)
- ☐ TASTE/ODOR (B)
- ☐ COLOR (D)
- ☐ FISHKILL (F)
- ☐ EQUIP FAILURE (H)
- ☐ OTHER (J)

REPORT RESULTS TO (NO. OF COPIES): CO FED RO INFO LPHE LAB

SUBMITTED BY (PLEASE PRINT)

TITLE ______ AREA CODE (PHONE NO) ______

ADDITIONAL INFORMATION REGARDING THIS SAMPLE ______

SANITARY BACTERIOLOGY

- ☐ TOTAL COLIFORMS MF CHLORINATED POTABLE WATER
- ☐ TOTAL COLIFORMS MF & SPC UNCHLORINATED POTABLE WATER
- ☐ TOTAL & FECAL COLIFORMS MF NONPOTABLE SURFACE WATER
- ☐ TOTAL COLIFORMS MPN & SPC POTABLE WATER
- ☐ TOTAL & FECAL COLIFORMS MPN CHLORINATED WASTE WATER
- ☐ OTHER ______

ORGANIC CHEMISTRY

- ☐ INSECTICIDES/HERBICIDES
- ☐ PCB'S
- ☐ TRIHALOMETHANES (THM-501)
- ☐ PURGEABLE HALOCARBONS (EPA601)
- ☐ PURGEABLE AROMATICS (EPA602)
- ☐ PURGEABLE COMPOUNDS (EPA503.1)
- ☐ PRIORITY POLLUTANTS — PURGEABLES (EPA624)
- ☐ PRIORITY POLLUTANTS — BASE NEUTRALS, ACIDS, PESTICIDES (EPA625)
- ☐ PETROLEUM PRODUCTS
- ☐ OTHER ______

INORGANIC CHEMISTRY

- ☐ POTABLE WATER, OCSS-I
- ☐ FLUORIDE
- ☐ NITRATE
- ☐ TRACE METALS, SPECIFY ______
- ☐ WQSN
- ☐ PRIMARY STP
- ☐ SECONDARY STP
- ☐ OTHER ______

WHITE COPY - Laboratory   YELLOW COPY - Collector retains

NEW YORK STATE DEPARTMENT OF HEALTH
CENTER FOR LABORATORIES AND RESEARCH
ALBANY, N.Y. 12201

CHAIN OF CUSTODY RECORD

Must be completed for samples which might be used for enforcement proceedings or litigation.

SAMPLE ID (LAB USE ONLY)	FIELD REFERENCE NO.	DATE/TIME COLLECTED	SAMPLE COLLECTION POINT	TYPE: WATER, AIR SOIL, ETC.

SPECIFY METHOD OF PRESERVATION

- ☐ NaOH
- ☐ Cool, 4°C
- ☐ Acidification (specify)
- ☐ Other (specify

TRANSPORTING SAMPLES

DURING TRANSPORT OF THE SAMPLE FROM SAMPLING SITE TO LABORATORY, THE CHAIN OF CUSTODY MUST BE UNBROKEN. GENERALLY THIS WILL REQUIRE THAT THE SAMPLE BE DELIVERED BY THE SAMPLE COLLECTOR OF HIS DESIGNATED REPRESENTATIVE WHO WILL SIGN FOR THE RECEIPT, INTEGRITY AND TRANSFER OF THE SAMPLE DURING SHIPMENT. IF INTEGRITY OF SAMPLE IS QUESTIONED, DESCRIBE PROBLEM ON REVERSE SIDE OF THIS FORM.

CUSTODY OF SAMPLES

	NAME	AFFILIATION	DATE	TIME
1. Sample Container Prepared by				
2. Received by				
3. Received by				
4. Sample Collected by				
5. Sample Received by				
6. Sample Received by				
7. Sample Received by				
8. Sample Received by				
9. Sample Received by				
10. Sample Rec'd Lab by				
11. Sample Accessioned by				

CC-1

NEW YORK STATE DEPARTMENT OF HEALTH
WADSWORTH CENTER FOR LABORATORIES AND RESEARCH
ALBANY, N.Y. 12201

MODIFIED NIELSON-KRYGER STEAM DISTILLATION OF LOVE CANAL SOILS

1. Scope and Application

1.1 This method may be applied to the determination of polychlorinated biphenyls (PCBs) and isomers of hexachlorocyclohexane (alpha-, beta-, gamma-, delta-BHC) in soil, sediment and sludges.

1.2 In particular, the method has been utilized as a screening technique to characterize Love Canal soil samples. In this application, the following compounds were analyzed:

1,2,4-trichlorobenzene

*1,2,3,5-tetrachlorobenzene
*1,2,4,5-tetrachlorobenzene
1,2,3,4-tetrachlorobenzene

* Isomer specific analysis of these compounds will require a demonstration of gas chromatographic separation with authentic standards with the column and temperature conditions chosen for analysis.

1.3 Its use may be extended to analysis of other chlorinated hydrocarbons or analysis of other sample matrices.

2. Summary of Method

2.1 A known weight of solid sample is slurried with organic-free water and is "distilled" into hexane using a modified Nielson-Kryger apparatus. The extract is then treated for sulfur removal and, in most cases, is suitable for gas chromatographic analysis at the 1 ppb detection level without any further clean-up. Mass spectral analysis using single ion monitoring gives a detection limit of 0.05 ppb (when 100 grams of sample are analyzed).

3. Interferences

3.1 The modified steam distillation technique used will provide a significantly "cleaner" extract than some of the more classical techniques such as Soxhlet reflux. The technique is not totally interference-free and the several sample matrices may present a variety of problems of which the analyst must be aware.

4. Apparatus and Materials

4.1 Modified Nielsen-Kryger Condenser with Teflon stopcock and 24/40 glass joint (Ace Glass Co. #65513)

4.2 Ring Stand, Clamps and Rubber Tubing

4.3 Round bottom boiling flask with 24/40 glass joint - 2 liter

4.4 Hemispherical heating mantle - 2 liter

4.5 Variable transformer

4.6 Heat resistant stir plates and magnetic stirring bars

4.7 Pasteur pipets

4.8 Teflon sleeves for 24/40 joint

4.9 Erlenmeyer flasks - 125 ml with 24/40 ground glass joint and ground glass stoppers

4.10 Kuderna-Danish apparatus (K-D)

4.10.1 Evaporative flasks, 125 ml

4.10.2 Snyder columns, six ball or three ball

4.10.3 Receiver ampuls, 10 ml graduated

4.10.4 Boiling bumpers

4.10.5 Vigreaux distilling columns

4.11 Graduated test tubes

4.12 Gas chromatograph - analytical system complete with gas chromatograph capable of splitless on-column injection, electron capture detector (EC), and all required accessories

including column supplies, gases, etc.

4.12.1 Column:DB-5 capillary column, 30 m

4.13 Gas chromatograph with mass selective detector

5. Reagents

5.1 Hexane - nanograde

5.2 Acetone - nanograde

5.3 Organic-free Water; free of interfering compounds by EC gas chromatography

5.4 Anhydrous Sodium Sulfate - checked for impurities by gas chromatography

5.5 Elemental Mercury - triple distilled

5.6 Spiking Solution- 1,3,5 tribromobenzene

5.7 Internal Standard Solution - ^{13}C 1,2,4,5-tetrachlorobenzene

6. Quality Control Procedures

6.1 One distilled water blank and one spike of organic-free water are analyzed with each batch of samples. The spike must contain compounds representative of those being analyzed but need not contain all of the compounds of interest. For the analysis of Love Canal soils, spike the organic-free water with 1,3,5 tribromobenzene and selected analytes. Approximately one sample in twenty is analyzed in duplicate. For all samples to be analyzed by GC/MS spike with 13C 1,2,4,5-tetrachlorobenzene.

6.2 All glassware must be washed with detergent, rinsed with copious amounts of organic-free water and oven dried. Rinse with nanograde solvent just prior to use.

6.3 Magnetic stirring bars should be boiled overnight in conc. HNO3 for effective cleaning.

7. Sample Handling and Preservation

7.1 Samples are collected in wide mouth

glass jars.

7.2 If more than one sample of soil is collected from the same site, the two (or more) samples are combined and mixed in the laboratory.

8. Procedure

8.1 Distillation and Solvent Extraction

8.1.1 Set up steam distillation apparatus as shown in Figure 1.

8.1.2 Prepare samples as follows:

8.1.2.1 For aqueous, quality control samples, measure 800 ml of sample into a 2 liter boiling flask. Add a magnetic stirring bar to flask.

8.1.2.2 For soil samples, place 100 grams of sample into a boiling flask and add 800 ml of organic-free water. Add a magnetic stir bar to flask.

8.1.3 Add spiking solution to the organic-free water spike.

8.1.4 Place boiling flasks in heating mantles positioned directly below the condensers. Mantles are placed on top of heat resistant stir plates. Connect condensers to boiling flasks.

8.1.5 Add 5 ml distilled H_2O and 15 ml of nanograde hexane to condenser (previously cleaned with acetone and hexane) by decanting hexane along inside wall of condenser.

8.1.6 Turn on stir plates for all samples and cooling water for condensers.

8.1.7 Turn on heating mantles adjusting variable transformer for a rolling boil. If more than one set-up, adjust transformers so samples begin boiling

at same time.

8.1.8 Boil for 1 hour. Allow 15-20 minutes for boil to begin.

8.1.9 Drain off organic-free water layer and discard.

8.1.10 Collect extracted hexane distillate (from solvent withdrawal tube) in receiving flask (125 ml Erlenmeyer).

8.1.11 Rinse condenser with 50 ml of hexane and add to receiving flask.

8.2 Sample Clean-up

8.2.1 Remove aqueous layer with Pasteur pipet and discard.

8.2.2 Add anhydrous sodium sulfate (previously cleaned with hexane and checked by GLC) until sodium sulfate is free flowing in sample.

8.2.3 Quantitatively transfer sample (rinse 3 times with small amount of hexane) to a K-D set up and concentrate to 1.0 ml.

8.2.4 Add a few drops (approximately 1.0 ml) of elemental mercury (triple distilled) to the 10 ml glass stoppered K-D ampul. Shake for 30 minutes using mechanical shaker, medium setting. Let settle.

8.2.5 If precipitate does not settle out, filter the extract through silanized glass wool in a Pasteur pipet which has previously been rinsed with hexane. Concentrate by K-D technique to 1.0 ml.

8.2.6 If additional clean-up is required, follow florisil procedure.

8.2.7 Screen for dilution factor using TLC procedure.

8.2.8 Transfer the 1.0 ml of clean extract to a vial and close using a cap with septum. Sample is now ready for GC analysis.

9. Gas chromatography conditions

Instrument: HP 5880 gas chromatograph equipped with ECD
Column: DB-5, 0.25 mm X 30M: 0.25 uM film thickness
Detector temp. 300 degrees C
Injector temp. 180 degrees C
Oven Temperature Profile;
Level 1: Initial temp. 50 degrees C
Initial Time 7 minutes
Program Rate 3 degrees per minute
Final temp. 110 degrees
Final Time 0.1 minute
Level 2: Program Rate 10 degrees per minute
Final temp. 230 degrees
Final time 0.1 minute
Level 3: Program Rate 30 degrees per minute
Final temp. 260 degrees
Final time 20 minutes
Injection volume 3 microlitres: splitless mode
Carrier gas: 10% Argon/methane at 20 psi

10. GC/MS Conditions

Table I gives the experimental conditions for the GC/Mass Selective Detector System operated in Selected ion monitoring mode. Samples are quantitated using an internal standard method based on the ^{13}C 1,2,4,5-Tetrachlorobenzene labelled internal standard.

11. References

Veith, G.D. and Kiwus, L.M. 1977. An Exhaustive Steam-Distillation and Solvent-Extraction Unit for Pesticides and Industrial and Individual Chemicals. Bull. of Environ. Contam. and Toxicol. 17(6).

Love Canal Soil Samples, General overview, Draft 5/12/82, NYState Dep't. of Health, CSMDP/CSL, (originally prepared by Dr. Ron Regal)

IMPLEMENTED: January, 1980, Revised: April 2, 1981, Revised: Nov. 1986
HANDBK42 (LCSOIL2)

S I M A C Q U I S I T I O N 8 Dec 86 2:02 pm DATA:CLBEN.A

solvent delaY 6.01 eM volts 2600 Absolute resulting-voltage 2600

Group	1	2	3	4	5	6	7	8	9	10
# of Ions	12	11	20	20	20	20	20	20	20	20
start Time	6.00	15.00	-----	-----	-----	-----	-----	-----	-----	-----

low mass Resolution NO cycles per second 0.7

ion #	1	2	3	4	5	6	7	8	9	10
m/Z	145.00	179.00	180.00	182.00	214.00	216.00	220.00	222.00	225.00	227.00
Dwell	100	100	100	100	100	100	100	100	100	100

ion #	11	12
m/Z	314.00	316.00
Dwell	100	100

nUmber of plot traces 1 initiaLly ON time Window 10.0

T E M P E R A T U R E P R O G R A M & H E A T E D Z O N E S

rUn time 45.00 eQuilibration time 0.50 Purge off time 1.00

level	initial tEmp	initial time	Rate (°C/Min)	final tEmp	final time	total time
1	80	2.00	8.0	280	43.00	70.00
2						
3						
4						
5						
6						
7						
8						

	actual	Setpt	Limit		actual	Setpt	Limit
Oven (Standby)	189	80	300	Inj Port A	---	Off	250
Inj Port B	250	250	250	Transfer Line	280	280	300
Detector A	---	Off	0				

LOVE CANAL PILOT II

SOIL SAMPLING FIELD REPORT

November 26, 1986
Field Team Members: Gerald McDonald
John Sheehan
Lewis Clarke

Introduction

The pilot soil sampling study to determine habitability of the Love Canal EDA was conducted in the fall of 1986. The analyses from these samples showed a trend in the detection of low levels of 1,2,4-trichlorobenzene and 1,2,3,4,-tetrachlorobenzene in the Love Canal EDA, but not in the control areas located on Tonawanda and Cheektowaga. A question was raised as to the source of the low level contamination since other Love Canal indicator chemicals were not correspondingly detected.

To assist in evaluating the results from the Habitability Study's pilot soil sampling program, the New York State Department of Health prepared a protocol designed to evaluate alternate potential sources of the low level contamination. During the week of November 10, 1986 the NYS Department of Health's Wadsworth Center for Laboratories and Research (WCL&R) validated a procedure to be used to analyze soil for 1,2,4-trichlorobenzene and 1,2,3,4,-tetrachlorobenzene at a detection limit of 0.05 parts per billion (ppb). During the week of November 17, 1986, seventy five (75) soil samples were collected from four areas in and around Niagara Falls and from an area in Cheektowaga. All samples were shipped to WCL&R on the same day they were collected.

Sample Site Selection

Five areas were designated as sampling areas as follows:

Area 1 In the City of Niagara Falls, the Love Canal Emergency Declaration Area (EDA)

Area 2 In the City of Niagara Falls, the LaSalle neighborhood bounded on the north by Niagara Falls Boulevard and on the south by Frontier Avenue and located between 70th and 82nd Streets.

Area 3 In the City of Niagara Falls, the Hyde Park neighborhood bounded on the north by North Avenue and on the south by Linwood Avenue and located between 16th and 32nd Streets.

Area 4 A rural area in the Town of Wheatfield bounded on the west by Williams Road, on the east by the Conrail Haul Road, on the north by Lancelot Drive and on the south by Liberty Drive.

Area 5 In the City of Cheektowaga, bounded on the north by Maryvale Drive, on the south by Genesse Street, on the west by Harlem Road and on the East by Union Road.

Fifteen (15) sampling sites were chosen at random in each of the five areas using the methods described in the protocol. Three advance teams made field visits on November 17th to obtain permission to sample at these randomly selected locations. Enough permission forms were signed by midday

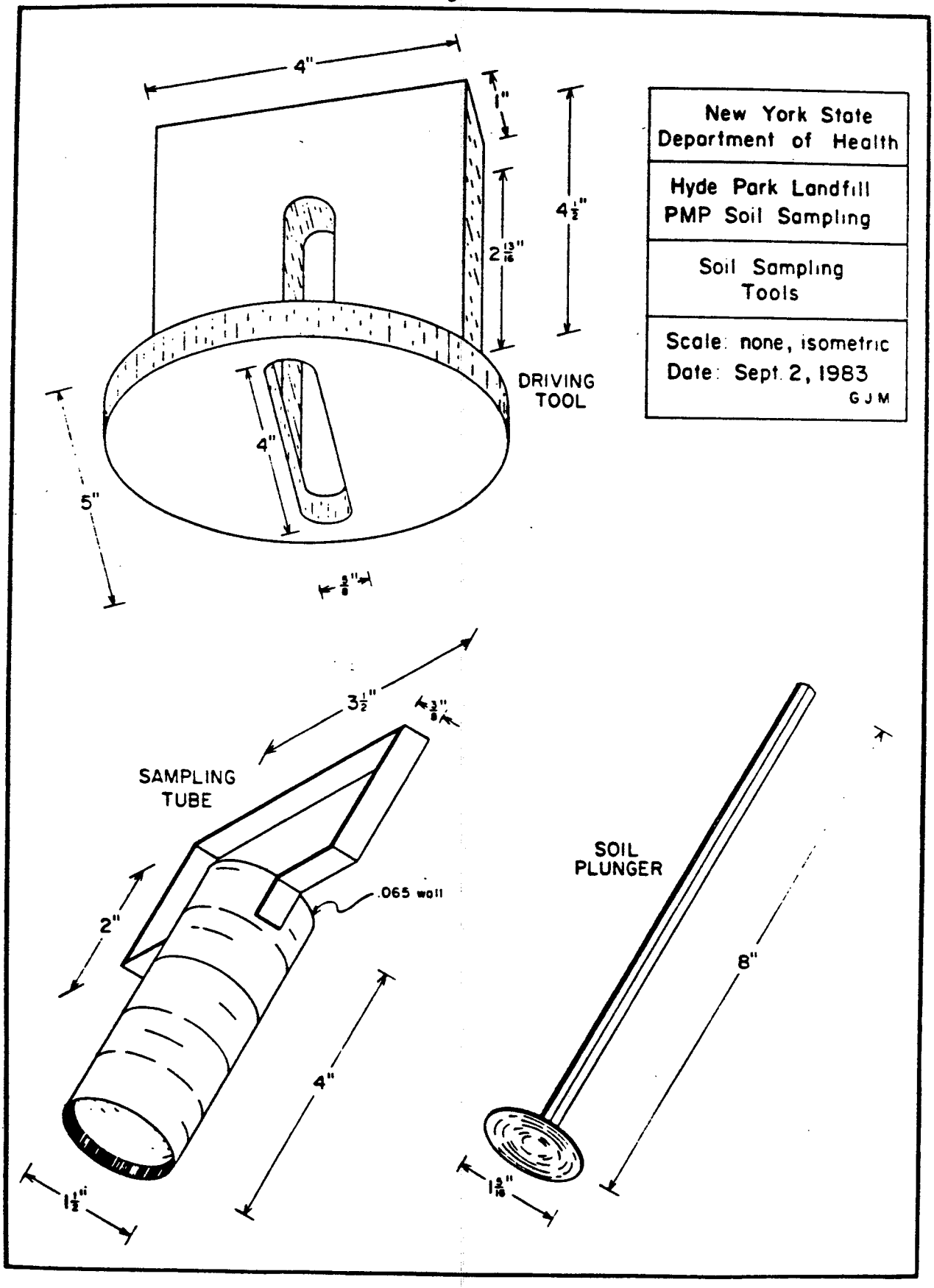
to allow the sample team to collect the scheduled 15 samples on that day. All permission forms were signed by that evening (November 17th), and 15 samples were collected each day for the remainder of the week as scheduled.

To avoid any systematic bias (such as lab error or contamination in shipping, etc.), three samples were collected from each area on each day, rather than collecting all 15 samples from one area in one day. Had a systematic error occurred and all samples from one area had been collected on the same day, that error may not be detectable. With the approach used (3 samples per area per day), systematic errors, if they occur, should be detectable on a per batch (daily) basis. Typically, the sample team collected samples from the designated areas in the following order: Area 4, 1, 2, 3 and 5. This sequence provided the most efficient use of time.

Sample Collection

Two soil cores (h=4" r=1 1/2") were collected from each sample site, with the coring tools shown in figure 1. Thirty (30) sets of tools were available. These along with the 150 sample bottles were pre-cleaned in the laboratory in accordance with the method described in the protocol. Fifteen sets of tools were used on each day. On each day of the first three days the dirty tools were shipped, via Federal Express, back to Albany to be cleaned by WCL&R. These tools were then shipped via U.S. Air PDQ to Buffalo Airport under chain of custody. The tools were picked up in the evening at the Buffalo Airport to be used the next day. The lead security seal was checked each day before opening the shipping box.

Figure 1


4"
1"
4½"
2 13/16"
DRIVING TOOL
4"
5"
⅜"
New York State Department of Health
Hyde Park Landfill PMP Soil Sampling
Soil Sampling Tools
Scale: none, isometric
Date: Sept. 2, 1983
G J M
3½"
⅜"
SAMPLING TUBE
2"
.065 wall
4"
1½"
SOIL PLUNGER
8"
1 9/16"

The sample team consisted of three people. The duties were typically divided as follows:

Member A: filled out all forms, took appropriate field notes including sketching a sample location diagram and made up sample bottle labels.

Member B: made contact with resident, selected and setup at sample site and collected sample.

Member C: gathered and prepared the materials for sampling, triangulated sample location and photographed sample location with known point of reference.

Upon arriving at the sampling location, team member "B" would contact the resident while member "C" gathered the following sampling materials:

1. disposable apron and gloves,
2. sample tool set from locked box,
3. 2 sample bottles from locked box, and
4. other sampling apparatus.

"B" and "C" would proceed to the backyard. "B" would don the apron and gloves, remove sample tools from foil and the first core would be collected. The core would be extracted into a sample bottle by use of the soil extraction jig and plunger. This process was repeated for the second

core 1 meter away. "C" would measure distances between sample location and two fixed points (corner of house or garage), and then take a snapshot of the sample location with at least one reference point. "A" would draw the plot plan using measured dimensions and would also note the photo number. "A" would take the two sample bottles, apply the labels and place them in the chilled shipping box. "B" would wrap dirty sample tools and place them in appropriate bucket. Disposable materials were placed in the trash bucket, and all other sample apparatus were brushed off and placed in the van. The team then proceeded to the next site.

Due to the way some of the handles on the soil coring devices were made, excess chattering was caused in the sample extraction process, especially in well compacted soils. This resulted in a couple of sample bottles being chipped. The chipping was deemed to be minor and these bottles were still used. However, on Thursday, November 20, 1986, a sample bottle broke. This bottle was discarded and another one was used. WCL&R provided a replacement bottle along with the tool shipment on that evening.

Laboratory

All samples were placed in a locked shipping box chilled with frozen ice packs immediately after collection. An accession form was filled out for each sample set. Only a sample ID number was indicated on the accession form, along with the date and time of collection. The sample location descriptions will be enetered into the laboratory's computer after sample results are final. At the end of the day, the accession forms were placed in the box with the samples, the box was locked and sealed with a

Figure 2

Area 1; Love Canal EDA

sample locations

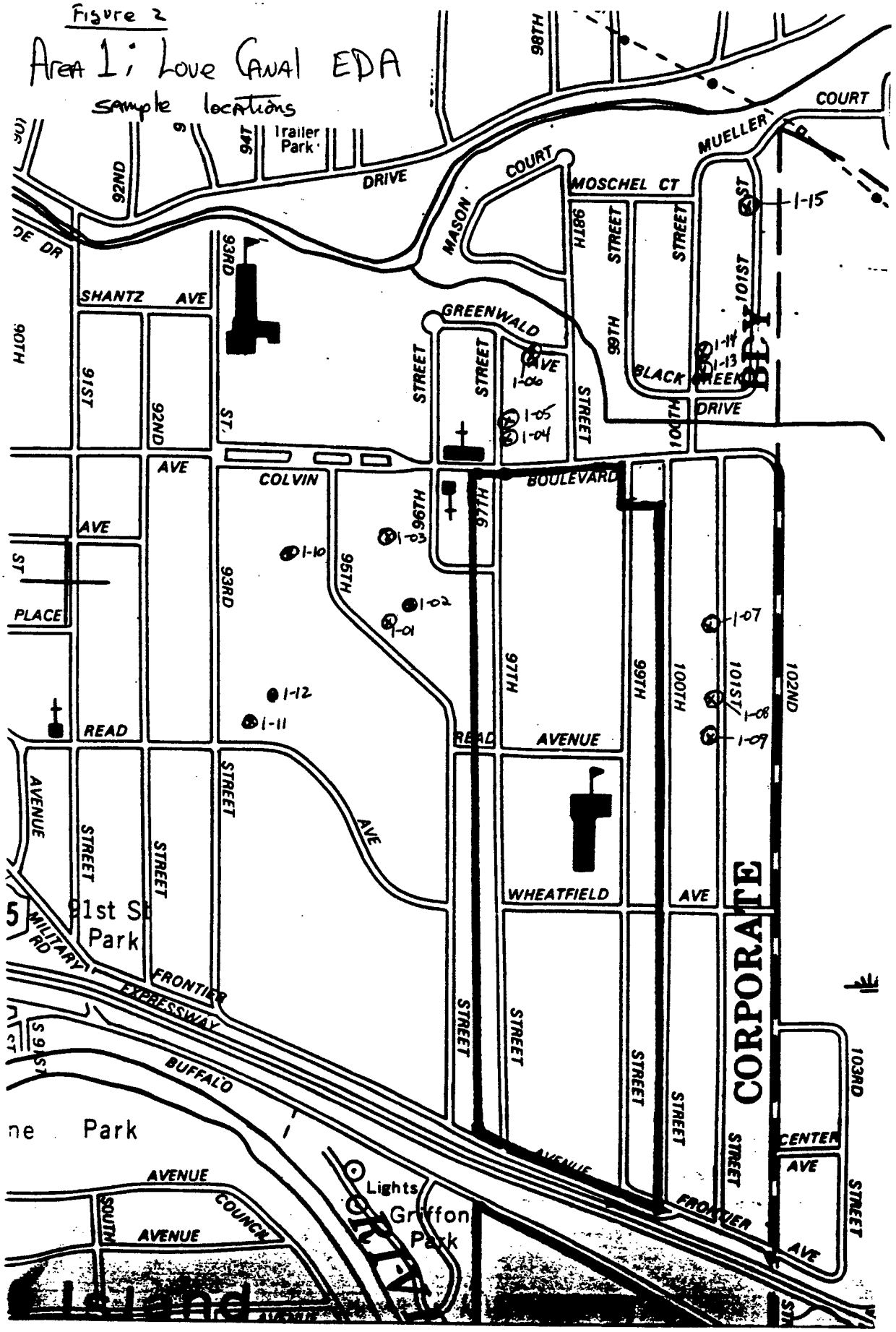
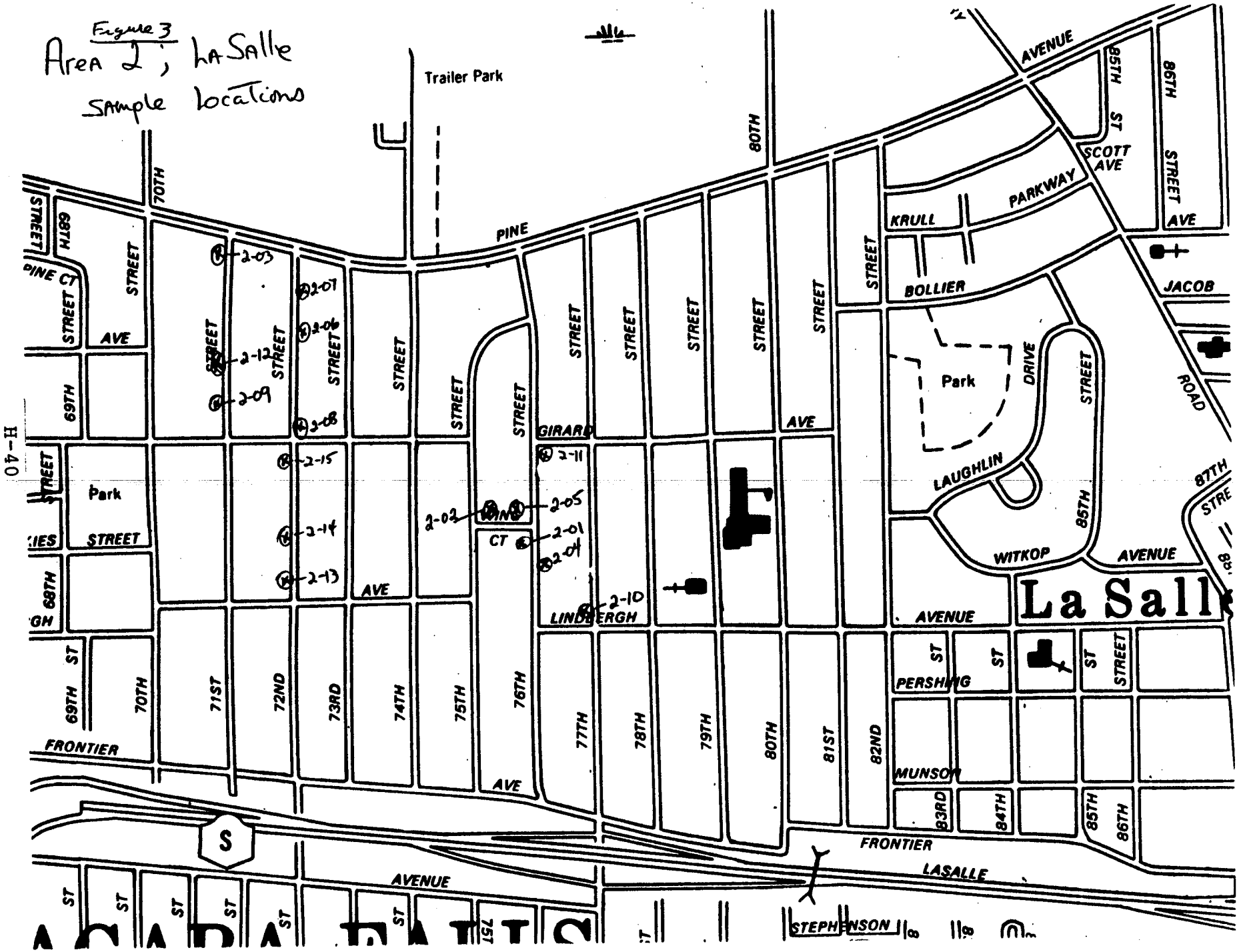


Figure 3
Area 2, LaSalle
Sample locations



H-40

Figure 4
Area 3, Hyde Park
sample locations

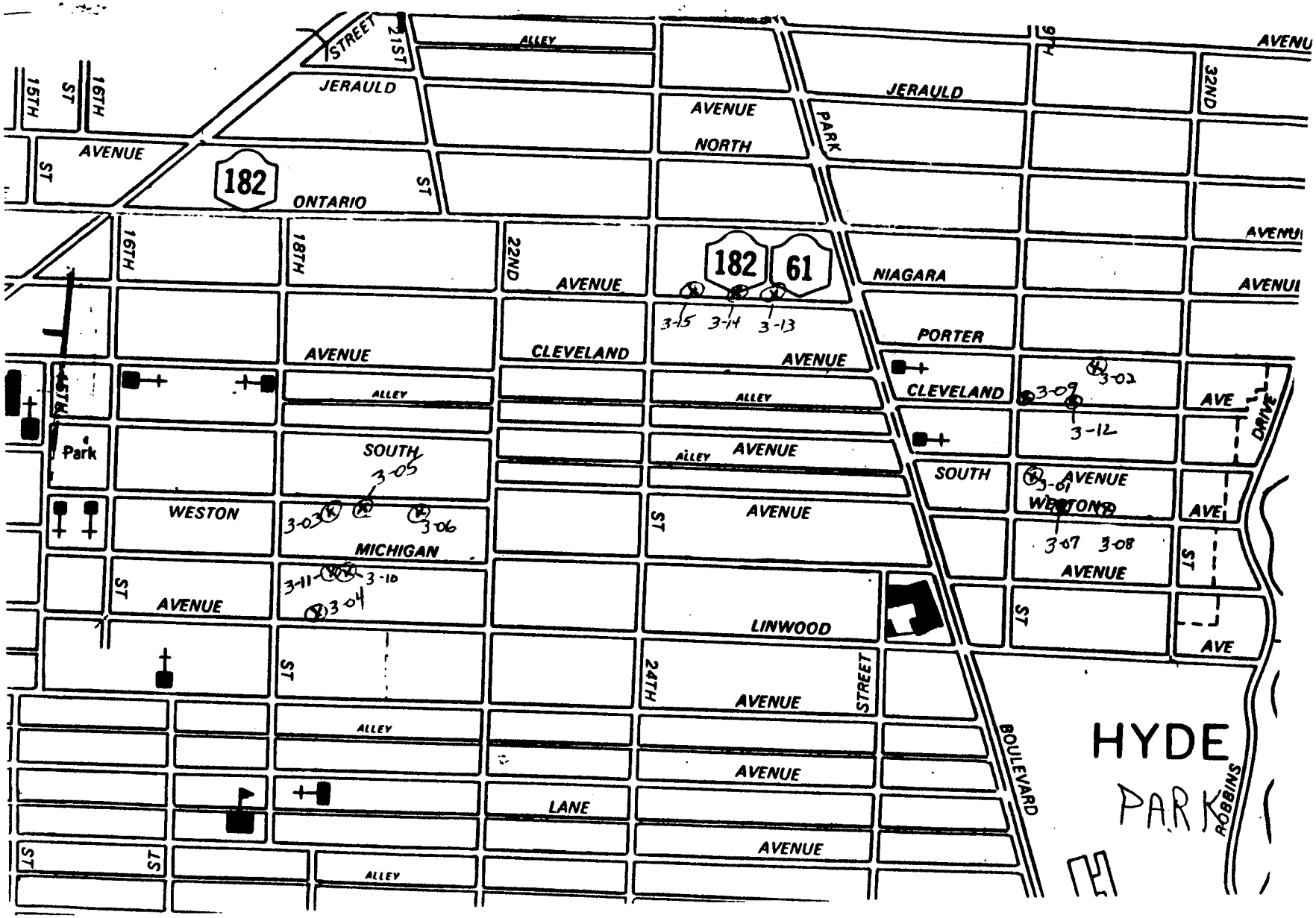


Figure 5
Area 4, Town of Wheatfield. Sample locations

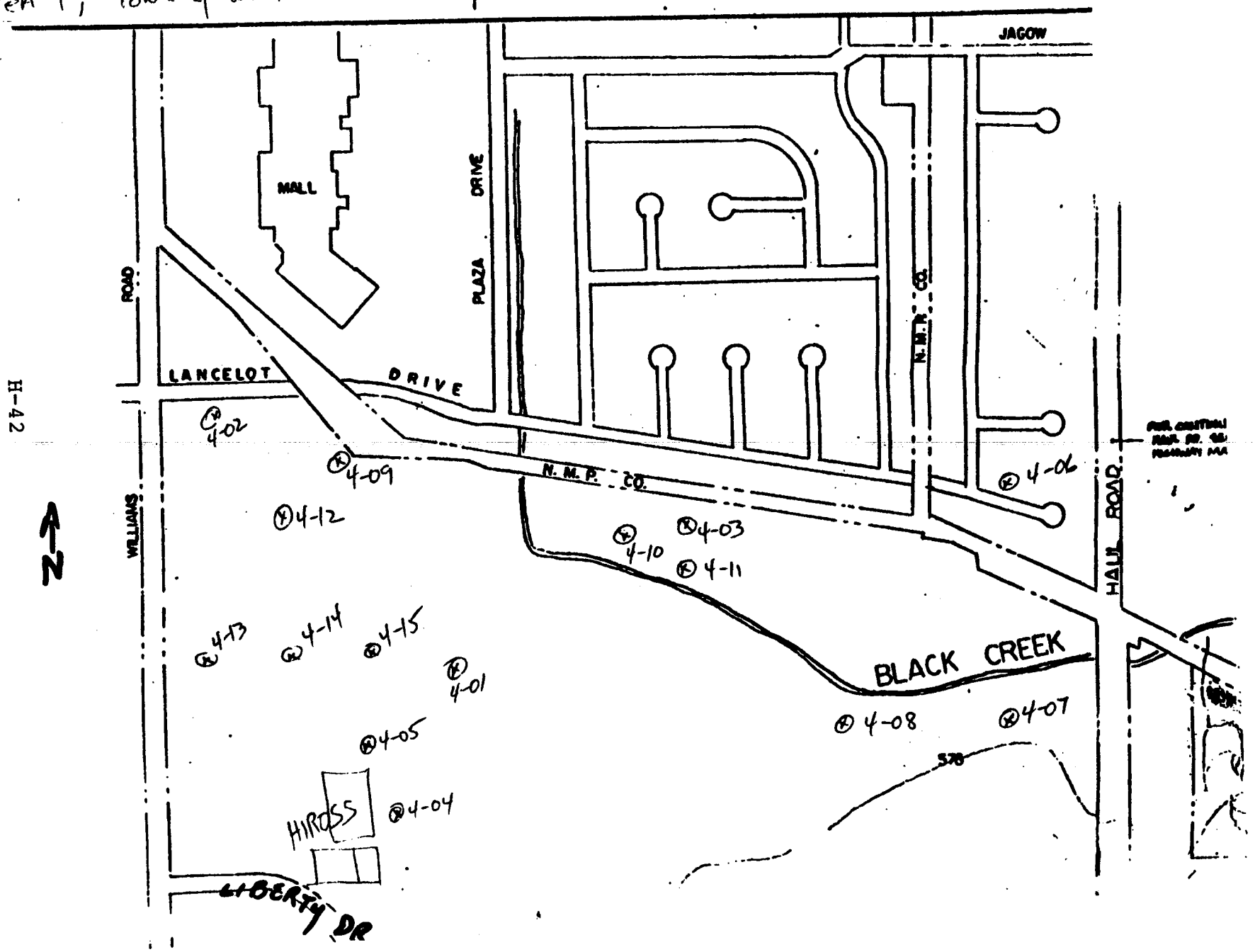


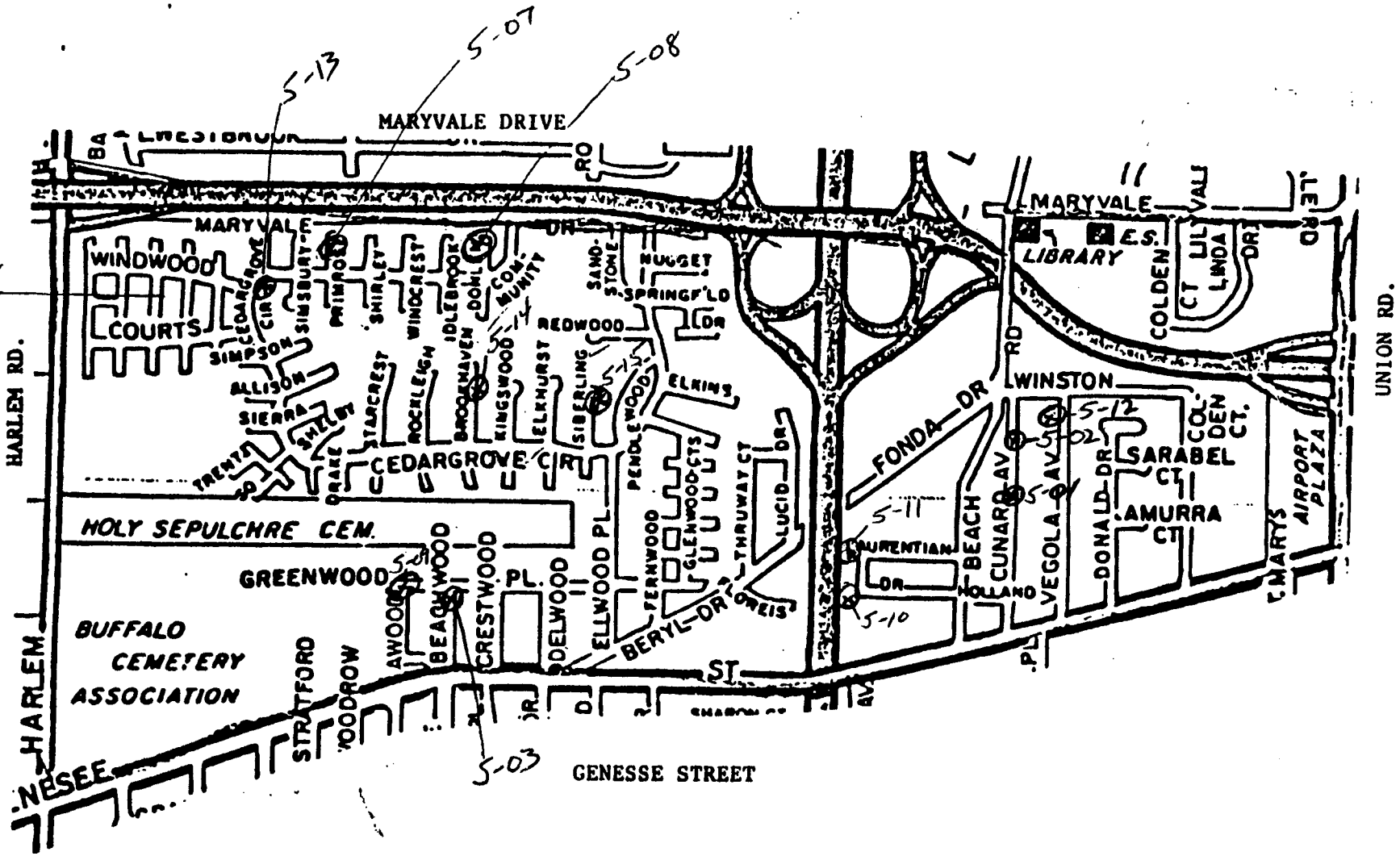
Figure 6

Area 5

CENSUS TRACT NO. 101.2

TOWN OF CHEEKTOWAGA

Sample locations



lead seal. The seal number was entered on the chain of custody record. The box was shipped via Federal Express to WCL&R under chain of custory. On Friday, November 21, 1986, samples were driven back to Albany in the state van and delivered directly to Room D-519 at approximately 7:00 pm.

Table 1 presents a listing of all sample ID numbers and the corresponding locations. Figures 2-6 show sample locations within each area.

Photographs of each sample site and the field log book which contains details of all sample locations are available for review in Room 359.

FINAL ANALYTICAL RESULTS

LOVE CANAL HABITABILITY

SOIL PILOT II SAMPLING PROGRAM

NEW YORK STATE DEPARTMENT OF HEALTH
February 25, 1987

New York State Department of Health
Love Canal Soil Pilot II Investigation
Analytical Results
Love Canal Emergency Declaration Area - Area 1
All values reported in parts per billion (ppb)

Accession No.	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachloro-benzene	1,2,4,5-1,2,3,5-Tetrachloro-benzenes
66077	0.5	0.6	0.6
66078	0.6	0.8	0.7
66064	1.7	0.8	0.8
66106	1.3	1.3	0.9
66107	1.8	2.0	1.8
66108	0.8	0.7	0.9
66159	0.6	1.0	0.9
66160	0.9	1.3	0.9
66161	1.9	4.0	2.3
66197	0.7	0.6	0.8
66198	0.5	0.6	0.7
66199	0.7	0.8	0.9
66241	3.2	1.0	0.9
66242	1.0	1.3	1.3
66243	0.2	0.1	ND

York State Department of Health
Love Canal Soil Pilot II Investigation
Analytical Results
LaSalle Area of Niagara Falls - Area 2
All values reported in parts per billion (ppb)

Accession No.	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachloro-benzene	1,2,4,5-1,2,3,5-Tetrachloro-benzenes
66074	1.3	1.4	2.4
66075	2.7	3.2	5.2
66076	4.2	4.4	6.6
66109	1.6	1.7	2.9
66110	2.3	3.0	4.5
66111	5.2	6.7	7.5
66162	3.2	5.4	6.7
66163	4.9	5.8	8.1
66149	1.6	2.4	3.4
66200	1.3	1.7	3.2
66201	2.8	3.0	5.2
66202	2.2	3.1	4.8
66244	1.7	1.8	2.5
66245	4.2	4.3	7.9
66231	1.3	2.0	3.0

New York State Department of Health
Love Canal Soil Pilot II Investigation
Analytical Results
Hyde Park Municipal Golf Course Area of Niagara Falls - Area 3
All values reported in parts per billion (ppb)

Accession No.	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachloro-benzene	1,2,4,5-1,2,3,5-Tetrachloro-benzenes
66065	1.5	1.5	1.5
66066	1.8	1.5	2.5
66067	1.7	1.1	1.9
66112	3.4	4.1	3.7
66113	1.1	1.1	1.2
66114	1.2	1.0	0.9
66150	3.0	3.5	3.8
66151	1.5	1.4	1.5
66152	3.5	4.2	3.8
66203	1.1	0.9	1.2
66204	1.8	1.8	1.7
66205	1.6	1.7	1.5
66232	1.2	1.5	1.6
66233	1.9	2.6	2.4
66234	1.5	1.4	1.3

New York State Department of Health
Love Canal Soil Pilot II Investigation
Analytical Results
Town of Wheatfield - Area 4
All values Reported in parts per billion (ppb)

Accession No.	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachloro-benzene	1,2,4,5-1,2,3,5-Tetrachloro-benzenes
66071	0.4	0.4	0.4
66072	0.2	0.2	0.4
66073	1.0	0.8	1.3
66103	1.4	1.5	2.4
66104	1.5	1.3	1.4
66105	0.3	0.3	0.4
66156	3.1	2.3	3.7
66157	0.9	0.9	1.4
66158	ND	ND	0.2
66194	1.9	1.8	2.6
66195	2.5	2.2	2.6
66196	0.2	0.3	0.2
66238	0.3	0.6	0.6
66239	0.5	1.3	0.9
66240	0.8	1.3	1.3

New York State Department of Health
Love Canal Soil Pilot II Investigation
Analytical Results
Cedargrove Heights Cheektowage - Area 5
All values reported in parts per billion (ppb)

Accession No.	1,2,4-Trichloro-benzene	1,2,3,4-Tetrachloro-benzene	1,2,4,5-1,2,3,5-Tetrachloro-benzenes
66068	0.2	ND	0.3
66069	0.4	0.2	ND
66070	3.0	1.6	1.1
66115	0.3	0.1	0.1
66116	0.5	0.1	0.2
66117	0.2	0.1	0.1
66153	0.1	0.2	0.2
66154	0.2	0.2	0.2
66155	0.3	0.1	0.1
66206	0.2	ND	0.2
66207	0.5	0.2	0.2
66208	0.6	0.3	0.3
66235	1.9	1.6	1.4
66236	0.7	0.1	ND
66237	0.1	0.1	0.2

APPENDIX I
Analysis and Implications of DOH Study

Appendix I
ANALYSIS AND IMPLICATIONS OF DOH STUDY

CONTENTS

TABLES

FIGURES

I.1 INTRODUCTION

A preliminary analysis of the data collected during the Love Canal Habitability Pilot Study indicated that a higher frequency of detectable concentrations existed for 1,2,4-trichlorobenzene and 1,2,3,4-tetrachlorobenzene than the other Love Canal indicator chemicals (LCICs). A hypothesized cause for this difference was previous contamination of the City of Niagara Falls water supply with low levels of these compounds. In November 1986 the New York State Department of Health (DOH) collected 15 soil samples from each of five locations in Niagara and Erie Counties. The study was designed to examine three potential sources of these compounds: air plumes from industries in the City of Niagara Falls, the City of Niagara Falls water supply, and Love Canal.

The analytical methods used by DOH estimated the concentrations of 1,2,3-trichlorobenzene, 1,2,3,4-tetrachlorobenzene, and other isomers of tetrachlorobenzene. These methods differed from those used in the pilot study analysis. Among other differences, a larger volume of soil was processed for chemical analysis, lowering the detection limits for the compounds compared to those seen in the pilot study.

The results of the DOH study were inconclusive in indicating the source of elevated concentrations of trichlorobenzene and tetrachlorobenzene. All three potential influences showed statistical significance; influences identified as air and water tended to be associated with concentrations higher than the overall mean, while influences identified as Love Canal tended to be associated with concentrations lower than the overall mean.

One result apparent from the study was that sites in the vicinity of the City of Niagara Falls had different patterns of trichlorobenzene and tetrachlorobenzene concentrations from the comparison area in Erie County. The Technical Review Committee therefore recommended the addition of a second comparison area in the vicinity of the City of Niagara Falls to be used for the full-scale habitability study.

I. 2 ANALYSIS OF DOH DATA

The five areas sampled in the DOH study were chosen to represent a partial factorial design for three possible sources of the chemicals: air (from upwind industry), water (from known contamination of the City of Niagara Falls water supply), and the Love Canal (hypothesized source of the LCICs).

The five areas (shown in Figure I-1) were: the Love Canal EDA; LaSalle, a western county residential area; Hyde Park, a northwest county residential area; Wheatfield, a northeastern county rural area; and Cedargrove, a residential area in Cheektowaga (Erie County) that was also used as a comparison area in the pilot study. These areas were chosen to be representative of areas with the potential chemical sources of Love Canal, air, and water (EDA), air and water (LaSalle), water (Hyde Park), air (Wheatfield), and none of these sources (Cedargrove). Table I-1 illustrates this matrix.

Table I-1
POTENTIAL SOURCES OF CONTAMINATION BY AREA

Sampling Area	Love Canal Air Water	Air Water	Air	Water	(None)
EDA	x				
LaSalle		x			
Hyde Park			x		
Wheatfield				x	
Cedargrove					x

Appendix H contains the results of analysis of the samples for 1,2,4-trichlorobenzene, 1,2,3,4-tetrachlorobenzene, and the combined 1,2,4,5 and 1,2,3,5 isomers of tetrachlorobenzene that are not LCICs. The concentration values of the LCICs ranged from nondetect to 4.9 ppb for trichlorobenzene and nondetect to 6.7 ppb for 1,2,3,4-tetrachlorobenzene.

This data set is further summarized in Table I-2, which displays the ranges, mean, and standard deviation for each compound in each area. An analysis of variance (ANOVA) of the data shows that there are significant differences between the areas for all three compounds.

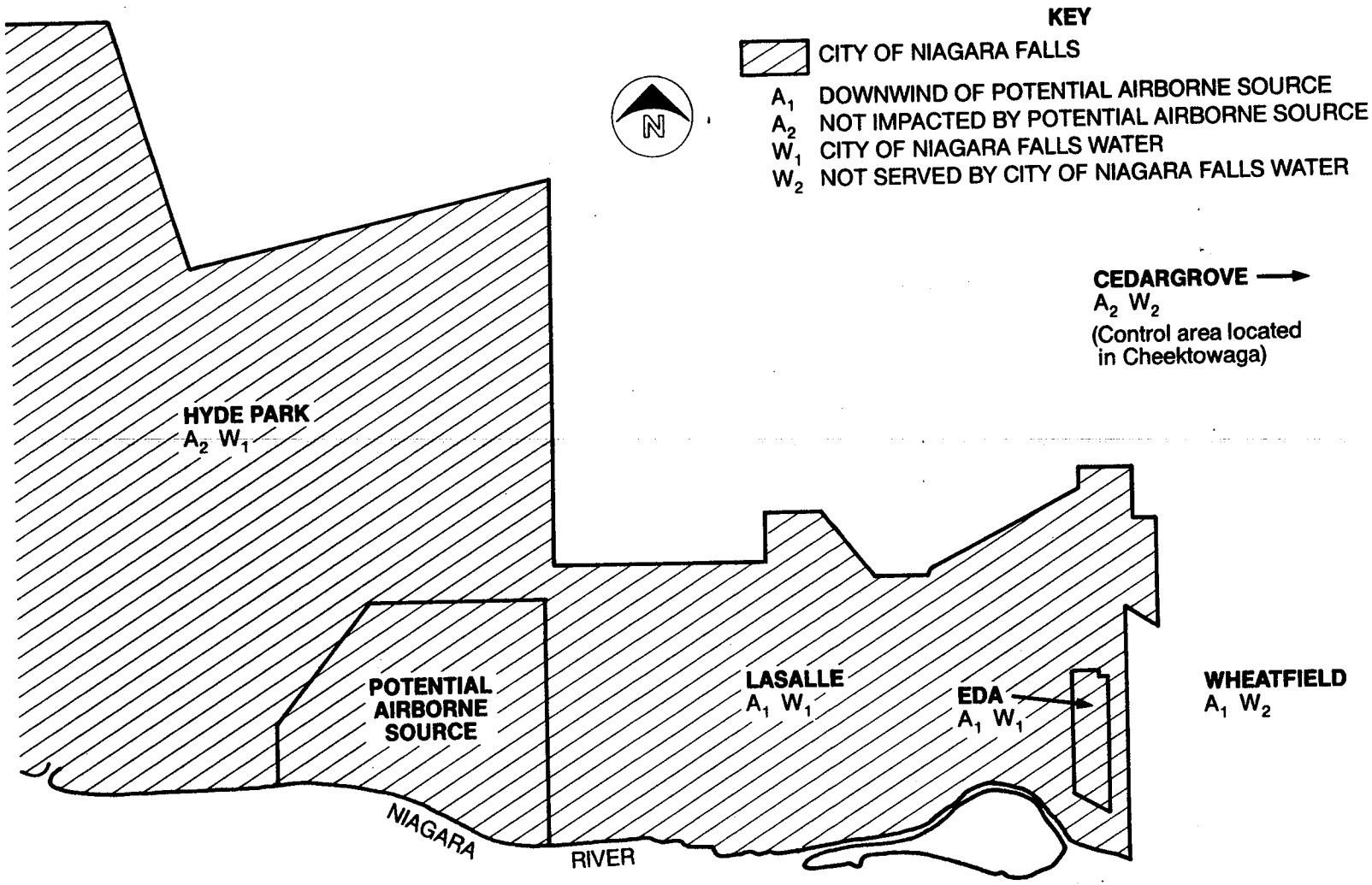


Figure I-1
PROPOSED SAMPLE AREAS

Table I-2
SUMMARY STATISTICS FOR DOH DATA

(1) Love Canal EDA

Total Observations: 16

	TRICBZ	TETCBZ	TETCBZ2
No. of Cases	16	16	15
Minimum	0.200	0.100	0.300
Maximum	3.200	3.800	2.100
Mean	0.975	1.038	0.940
Standard Deviation	0.749	0.874	0.476
Standard Error	0.187	0.218	0.123

---

(2) La Salle

Total Observations: 16

	TRICBZ	TETCBZ	TETCBZ2
No. of Cases	16	16	16
Minimum	1.300	1.400	2.400
Maximum	5.200	6.700	8.100
Mean	2.638	3.225	4.775
Standard Deviation	1.329	1.646	2.029
Standard Error	0.332	0.411	0.507

---

(3) Hyde Park

Total Observations: 17

	TRICBZ	TETCBZ	TETCBZ2
No. of Cases	17	17	17
Minimum	1.000	0.700	0.700
Maximum	3.500	4.200	3.800
Mean	1.924	1.953	2.059
Standard Deviation	0.844	1.111	1.010
Standard Error	0.205	0.269	0.245

Table I-2
(Continued)

(4) Wheatfield

Total Observations: 15

	TRICBZ	TETCBZ	TETCBZ2
No. of Cases	14	14	15
Minimum	0.200	0.200	0.200
Maximum	3.100	2.300	3.700
Mean	1.071	1.100	1.333
Standard Deviation	0.914	0.701	1.065
Standard Error	0.244	0.187	0.275

---

(5) Cedargrove, Cheektowaga

Total Observations: 15

	TRICBZ	TETCBZ	TETCBZ2
No. of Cases	14	13	14
Minimum	0.100	0.100	0.100
Maximum	3.000	1.600	1.400
Mean	0.614	0.377	0.343
Standard Deviation	0.820	0.546	0.394
Standard Error	0.219	0.152	0.105

Summary Statistics for 1,2,4-Trichlorobenzene

Bartlett Test for Homogeneity of Group Variances
CHI-Square = 6.525; DF = 4; Probability = .163

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F	Probability
Between Areas	41.691	4	10.423	11.390	.000
Within Areas	65.884	72	0.915		

Table I-2
(Continued)

Summary Statistics for 1,2,3,4-Tetrachlorobenzene

Bartlett Test for Homogeneity of Group Variances
CHI-Square = 18.995; DF = 4; Probability = .001

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F	Probability
Between Areas	72.377	4	18.094	15.707	.000
Within Areas	81.793	71	1.152		

Summary Statistics for Other Isomers of Tetrachlorobenzene

Bartlett Test for Homogeneity of Group Variances
CHI-Square = 43.509; DF = 4; Probability = .000

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F	Probability
Between Areas	185.057	4	46.264	33.608	.000
Within Areas	99.115	72	1.377		

Table I-3 shows the significant differences found when all possible comparisons are done between areas. The significance is stated at the 95 percent confidence level after correcting for multiple comparisons. This significance is statistical only, since all the levels observed are in the low ppb range.

Using the multiple comparison criteria for significance, LaSalle has significantly higher concentrations than all other areas for all compounds. Cedargrove has significantly lower concentrations for trichlorobenzene than the Niagara County areas except for the EDA. For the tetrachlorobenzenes, Cedargrove is significantly different from only LaSalle and Hyde Park.

The sampling plan was designed to attempt to identify the possible sources of tri- and tetrachlorobenzenes. Table I-4 displays the results of an ANOVA of the areas identified with the potential sources of contamination (air, water, and Love Canal) discussed previously. This analysis was repeated for each of the three compounds reported. The results of all three ANOVAs were the same: all the potential sources were significant. The analysis thus fails to isolate the source of the tri- and tetrachlorobenzenes.

Another way of looking at these data is to create box plots. These are displayed in Figure I-2. Box plots of both concentration data and the natural logs of the concentrations are compared for all five sampling areas. Box plots are created from ranked data, so that using the natural logarithm of the concentrations does not change the rank but does change the scale of the plots.

The box plots display several nonparametric statistics of the data from each area in a manner that can be compared easily. The "box" portion of the plot covers 50 percent of the observations from the 25th percentile to the 75th percentile. The difference between the two ends of the box is known as the interquartile range. The whiskers out of each end of the box extend 1.5 times the interquartile range from the box. This delineates an "acceptable" range for the data. Data outside this range are suspect as potential outliers, possibly not from the same distribution as the bulk of the observations.

The "+" inside the box denotes the value of the median. The "(" to the left of the "+" and the ")" to the right of the "+" mark the lower and upper 95th percentile confidence limits on the median. If these confidence limits do not overlap in range when comparing two areas, then the median concentrations from the areas are significantly different.

Table I-3
SIGNIFICANT CONTRASTS AMONG AREAS

Tukey HSD Test for Multiple Comparisons at 0.05 Significance

Trichlorobenzene

Area	1	2	3	4	5
1					
2	*				
3	-	-			
4	-	*	-		
5	-	*	*	*	

Tetrachlorobenzene

	1	2	3	4	5
1					
2	*				
3	-	*			
4	-	*	-		
5	-	*	*	-	

Tetrachlorobenzene (other isomers)

	1	2	3	4	5
1					
2	*				
3	-	*			
4	-	*	-		
5	-	*	*	-	

Note: *Significant
-Not significant

Table I-4
ANOVA OF DOH DATA

Dependent Variable: 1,2,4-Trichlorobenzene
Squared Multiple R: .385
N: 77
Multiple R: .621

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F-Ratio	P
Air	5.415	1	5.415	5.977	0.017
Love Canal	23.278	1	23.278	25.695	0.000
Water	31.223	1	31.223	34.465	0.000
ERROR	66.133	73	0.906		

Dependent Variable: 1,2,3,4-Tetrachlorobenzene
Squared Multiple R: .462
N: 76
Multiple R: .680

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F-Ratio	P
Air	15.744	1	15.744	13.672	0.000
Love Canal	38.408	1	38.408	33.354	0.000
Water	50.897	1	50.897	44.199	0.000
ERROR	82.911	72	1.152		

Dependent Variable: 1,2,3,4-Tetrachlorobenzene2
Squared Multiple R: .611
N: 77
Multiple R: .782

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F-Ratio	P
Air	56.434	1	56.434	37.250	0.000
Love Canal	102.456	1	102.456	67.628	0.000
Water	102.831	1	102.831	67.875	0.000
ERROR	110.594	73	1.515		

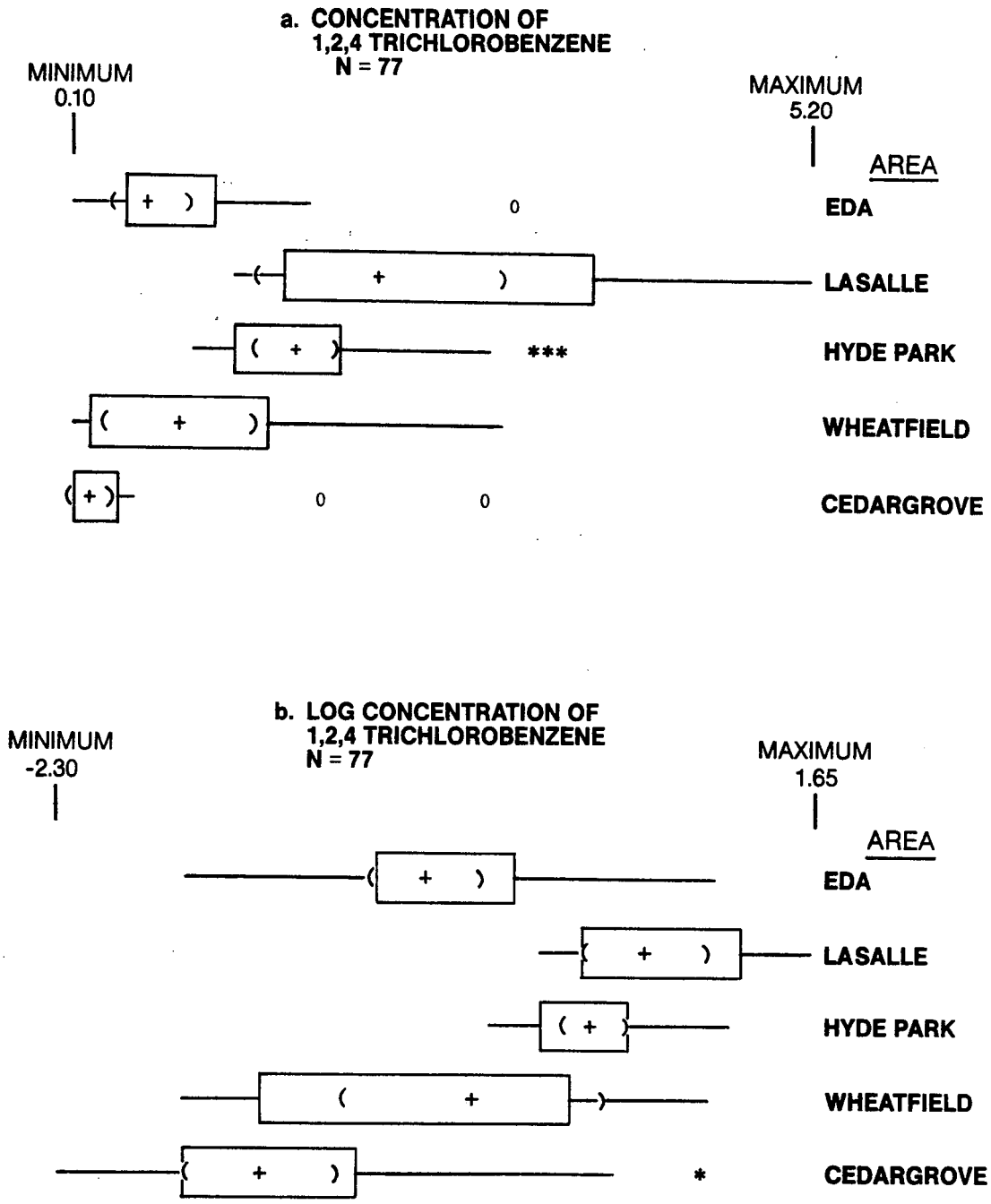


Figure I-2a, b
NONPARAMETRIC COMPARISON OF STUDY AREAS

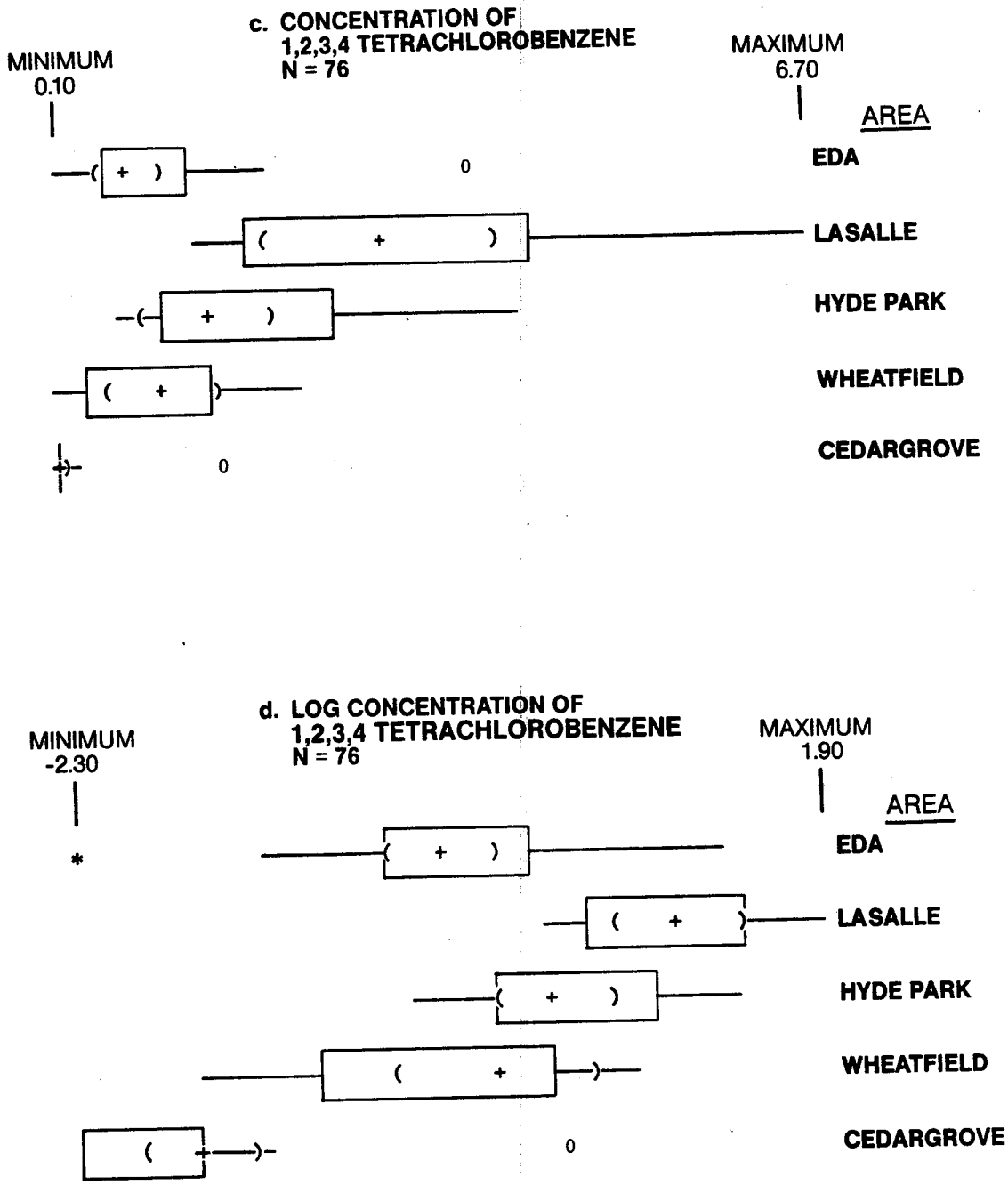
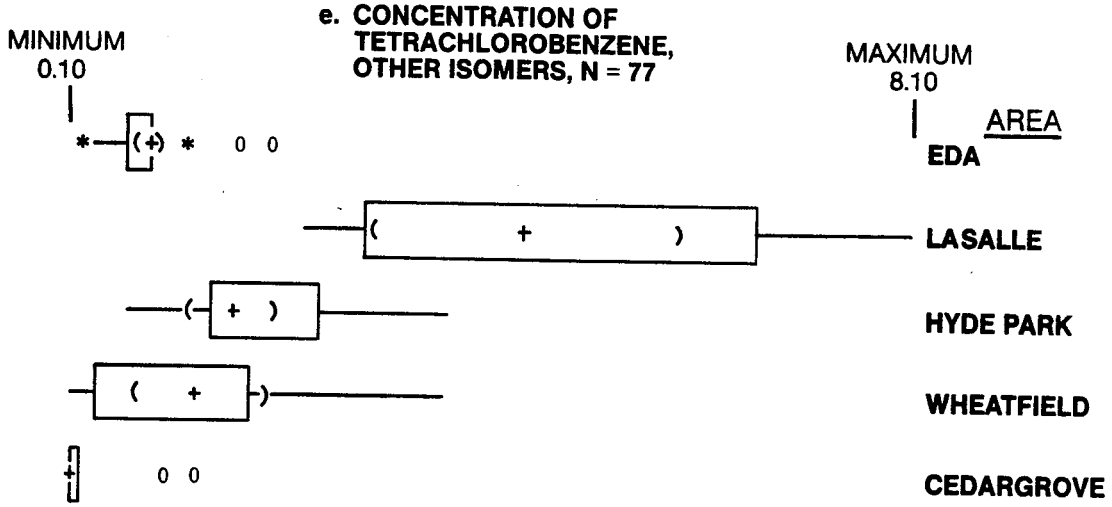
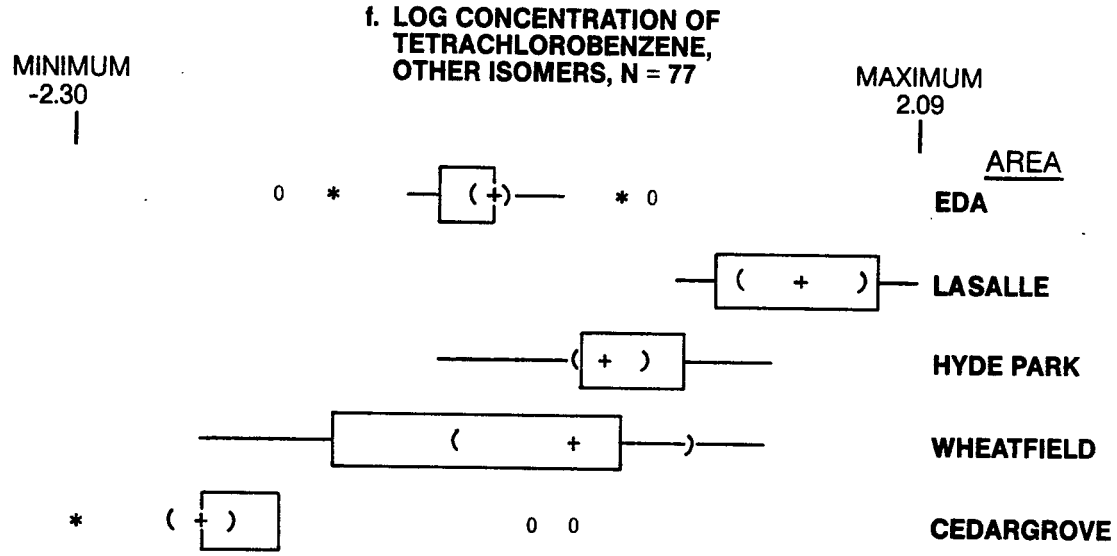


Figure I-2c, d
NONPARAMETRIC COMPARISON OF STUDY AREAS





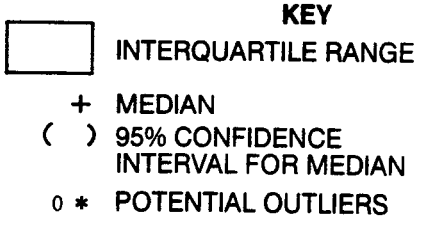
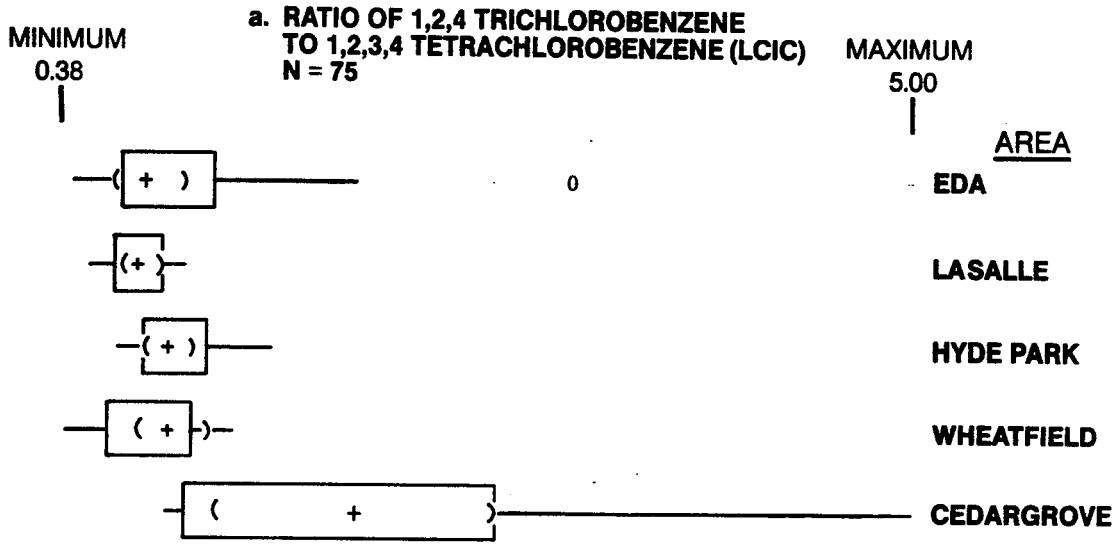


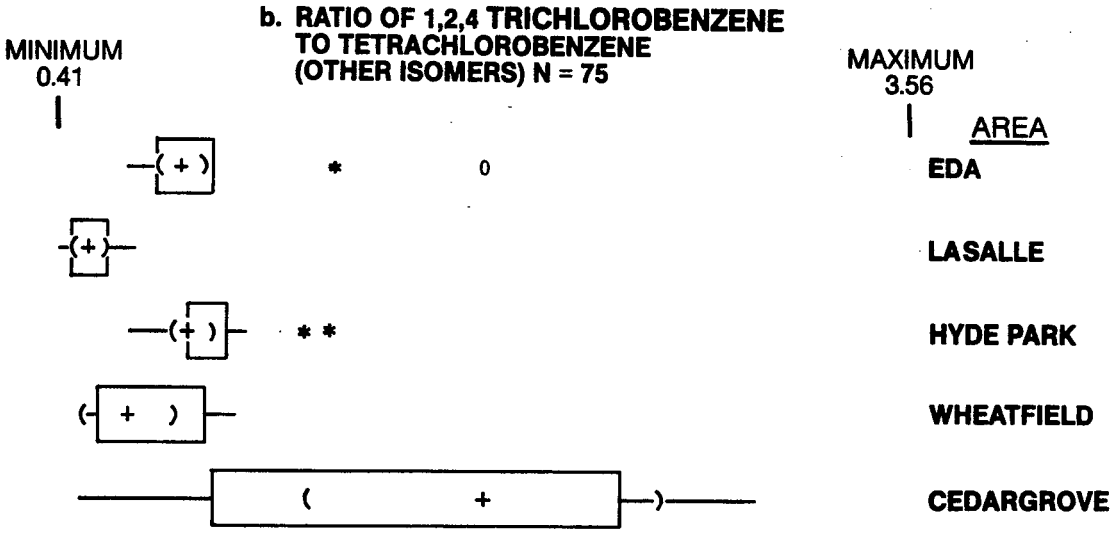
Figure I-2e, f
NONPARAMETRIC COMPARISON OF STUDY AREAS

The box plots tend to confirm the results obtained from previous analysis; the differences seen between means are also reflected as significant differences between medians. In addition, information on the spread of the concentration data from each area is visible.

The final figure, Figure I-3, displays box plots of the ratios observed between the trichlorobenzene concentrations and each of the two reported concentrations of tetrachlorobenzene isomers. The ratio of observed concentrations of the two compounds may be indicative of the source of the compounds. If one source is producing the two compounds at all areas, then the ratio of the concentrations may be relatively constant. However, if more than one source exists, the ratios may fluctuate at all areas or vary from area to area.

In examining the box plots of these ratios it can be seen that the ratios of the LCICs tri- and tetrachlorobenzene are lower and fluctuate less in Niagara County than in the Cheektowaga comparison area. A similar result is seen for the ratio of trichlorobenzene to the other isomers of tetrachlorobenzene, but with a less tight spread of median ratios in the Niagara County areas. The difference in ratios is an indication that sites in Niagara County and Cheektowaga may have different sources of tri- and tetrachlorobenzenes.





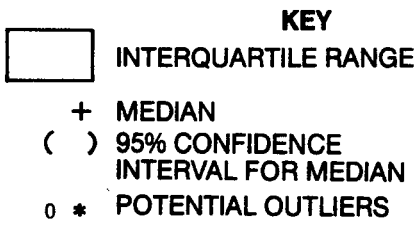


Figure I-3a, b
NONPARAMETRIC COMPARISON OF RATIOS OF 1,2,4 TRICHLOROBENZENE TO TETRACHLOROBENZENE

I.3 CONSEQUENCES OF DOH STUDY

An analysis of the DOH indicated that differences existed between sites in Niagara County and the comparison site in Erie County. A meeting of technical staff of the TRC agencies proposed five alternatives for a modified habitability study based on this information. These alternatives are listed in Table I-5.

Table I-5
ALTERNATIVE MODIFICATIONS OF HABITABILITY CRITERIA

Alternative	LCIC*	Comparison Areas
1	Retain all LCICs	Retain original comparison areas
2	Delete tri- and tetrachlorobenzene	Retain original comparison areas
3	Retain all LCICs	Retain original comparison areas and add an additional comparison area in the City of Niagara Falls
4	Retain all LCICs	Replace original comparison areas with a City of Niagara Falls comparison area
5	Retain all LCICs for original comparison area and analyze for tri- and tetrachlorobenzene in Niagara County comparison area	Retain original comparison areas and add an additional comparison area in the City of Niagara Falls

*Love Canal Indicator Chemical

At the January 31, 1987 TRC meeting these alternatives were discussed. Alternative 1, which involved no change from the original plan, was discussed and finally eliminated as not being able to allow assessment of the impacts of Love Canal on the EDA, independent of other sources. The DOH study showed that there may be sources of the LCICs other than the canal.

Alternative 2 was rejected because it eliminated tri- and tetrachlorobenzene from the list of LCICs examined. These

are the two compounds for which the highest number of detectable concentrations was observed; eliminating them would have rendered the design of the full study more uncertain, and resulted in fewer chemicals for the full habitability decision.

Alternative 4 was eliminated because it contradicted the habitability criteria document. The original comparison areas met the habitability criteria; the DOH sampling areas were not selected to meet the criteria.

The remaining alternatives, 3 and 5, had several advantages and disadvantages. Both alternatives retained all of the LCICs as well as adding a comparison area in the City of Niagara Falls. The difference was that alternative 5 looked only at the tri- and tetrachlorobenzenes in the Niagara Falls comparison area and not the other LCICs. Alternative 3, however, presented additional benefits of allowing the same suite of statistical techniques, including multivariate, to be used on both comparison areas, preserving information on the other LCICs that would be obtained in any case, and allowing the decision process to be symmetric with regard to both areas.

Alternative 3, adding an additional comparison area in the City of Niagara Falls and analyzing for all LCICs, was recommended by the TRC to be used in the habitability study.

The decision to add a comparison area in the City of Niagara Falls will have impacts on the statistical design for the soil part of the habitability study, the analysis of the data from the study, and the decision process on habitability.

Since the analysis of the DOH samples by the method proposed for the habitability study is not yet complete, it is not yet known whether the statistical model developed on pilot study results spans the DOH data. Additional work will be needed to validate the statistical model on the DOH data set. The model will have to be applied seperately to the two comparison areas because the DOH study areas were not chosen to meet the habitability study criteria.

When the model is revalidated on the new soil data, it is not known if the range of sample sizes estimated from the pilot data will cover the range of sample sizes estimated from the DOH data. Thus the preliminary estimated range of sample sizes may have to be changed. The recommended allocation of samples may also change with the addition of a second comparison area.

After the habitability study, the analysis of the data should include an examination of the distributions and

comparisons for two sets of soil data. The comparisons for each of the 6 (or 8) LCICs and the multivariate comparison will be repeated for the new comparison area. This will present the New York State Commissioner of Health with at least twice the number of statistical analyses as would come from the study with one area. This has the advantage of presenting a wider view of how the EDA compares with the typical background site.