Appendix B

Design of the EPA Monitoring Study

Summary

One aspect of the OTA review of the 1980 Environmental Protection Agency's (EPA) monitoring study focused on the sampling design. The following specific problems with the sampling procedures used by EPA led OTA to judge the outcome of the study indeterminant with regard to the extent (or distribution) and level of chemical contamination, and its site and regional variability:

- The monitoring study used uneven numbers of sampling sites across media and **12** regions (10 in the emergency declaration area (EDA), the canal, and the control area). The numbers of sampling sites were not in proportion to sizes of the regions, which vary by a factor of 10. One reason for this situation was that EPA assumed that higher levels of contamination existed closer to the canal. Consequently, some regions farther away from the canal had very little sampling; the distribution of sampling among regions in the EDA was particularly inadequate. Initial beliefs about the possible routes of transport of toxic chemicals from the canal to and through the EDA may also have influenced numbers of sampling sites in environmental media. To the extent that these assumptions about patterns remain unproven or unsupported by the results of the study, it can be concluded that the sampling may not have detected contamination present in the EDA which does not correspond to the patterns assumed initially by EPA.
- The numbers of sampling sites used were insufficient to determine accurately the levels of contamination within some regions.
- As for environmental media, the extent of sampling was very broad and included air, surface and ground water, soil, sediment, and biota. However, the effort across media was uneven, and there was no examination of yearly seasonal variations. Within the EDA, those media sampled most extensively were soil, air, and sump water. Ground water was sampled less extensively and biota were sampled least often of any of the environmental media.
- Too few replicate samples were collected per site to evaluate site variability; thus, the data on absolute concentrations of chemicals detected within any one region may not be meaningful.
- The study lacked adequate control data; thus comparisons among regions are difficult. However, as discussed more fully later, DHHS did not rely entirely on the control area data in its habitability decision.

Scope of the EPA Monitoring Study

In 1980, the EPA designed and implemented an extensive monitoring study of the EDA.[1] The goals of the study were:

1. to determine the extent and level of contamination in the area defined by President Carter in his emergency declaration order (fig. B-1),
2. to assess the short- and long-term implications of ground water contamination in the general vicinity of Love Canal, and
3. to assess the relative environmental quality of the EDA.

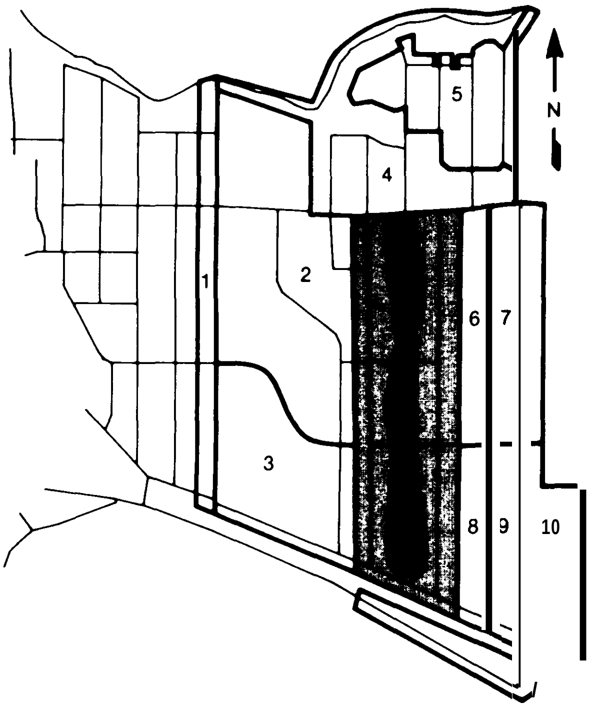
The design of the study was developed based on two assumptions. First EPA expected that the levels of contamination would be very high. **Also, EPA assumed that the greatest contamination would exist nearest the canal. EPA sampled five environmental media (air, soil, sediment, water, and biota). Sampling sites were selected in 12** regions: 10 subregions of the EDA, a region directly adjacent to the Love Canal, and a control region that included selected sites throughout the Niagara Falls area. Distribution of sites within a region was generally random. The number of sampling sites per region decreased with increased distance from the canal. Additional sites were sampled at the request of EDA residents and at places of possible migration routes from the canal landfill. A total of **150** chemicals were chosen for analysis, including chemicals that were known to have been deposited within the landfill.

The EPA evaluated the data in two ways: one compared absolute concentrations of chemicals detected within the EDA with available environmental standards and with concentrations detected at control sites.[2] Of secondary importance to EPA was a comparison of the frequency of detection of chemicals in the EDA to the frequency detected at control sites. EPA concluded that the only places within the EDA with significant contamination from Love Canal chemicals were the sediments of storm sewer systems and their surface water outfalls.

[1] ***Environmental Monitoring at Love Canal*** **(Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. I, II, III.**

[2] **R. Dewling, U.S. EPA Region II, personal communication during a meeting with OTA on May 12, 1983.**

Figure B-1.—The 10 Subregions of the EDA Included in the EDA Monitoring Study



'' Indicates approximate location of the canal landfill within the Love Canal region.

SOURCE: Woodward-Clyde Consultants, *Evaluation of Proposed Remedial Action program Love Canal, Project 1, Leachate Containment System, Niagara Falls, New York* prepared for Wald, Harkrader & Ross, Washington, D. C., August 1982.

Evaluation of the Sampling Effort

There are certain principles for environmental sampling that must guide any monitoring program.[3] OTA used these principles as criteria for an evaluation of the EPA monitoring effort. As indicated in table B-1, the OTA analysis suggests that the number of sites and replicate samples taken at each site were insufficient to determine extent and level of contamination for all of the EDA.

1. Are spatial and temporal factors considered?

The EPA study attempted to investigate spatial patterns that could be evidence of chemical migration from the landfill. Sites were chosen to represent three regions: an **area adjacent to** the canal, the **EDA,** and control **area. No** samples were taken directly from the landfill site for fear of interfering with the integrity of the cap and sidewalls of the canal. Because of the time constraints imposed on EPA, there was no attempt to determine annual variability in the extent of contamination.

2. Were the choice and number of control sites appropriate to distinguish among levels of contamination for the control area, EDA, and Canal regions?

There is a general consensus within the scientific community that all environmental studies require baseline data to which the test area can be compared. Such baseline data can be control sites that are similar to the test sites except for the variable of concern (in this study the presence and concentrations of Love **Canal** chemicals); baseline data can also be established standards for the chemicals of concern. If statistical analyses are to be conducted comparing control and test site, uncertainties in interpretation can be reduced if numbers of control sites are equal to, or closely approximate, numbers of test sites.

Because of the way EPA designed the sampling effort and because of the fact that the controls were located farthest from the **canal, the number of control** sites was very small. For example, 11 control sites were chosen for ground water samples. The number of control sites for other environmental media also **was** small; a maximum number of nine sites was sampled as controls for soil analyses. For surface water and sediment, as well as drinking water, only five control sites were identified. Sump water and storm sewers (both water and sediment) were sampled only at one site in the control area.

Because the control sites for ground water were adjacent to and formed a ring around the EDA, there is concern that some of these sites were not suitable as controls. For example, it is not clear that these control sites were free of contamination from chemicals similar to those disposed in the canal landfill. Because the landfill had been in operation since the late 1940's, there is the possibility that chemicals could have migrated within the ground water to sites designated as controls. For example, analysis of water table elevations prior to installation of the leachate collection system indicate that flow of the overburden ground water system was away from the canal, toward the location of control sites.[4] There is the added problem that at least two of the control sites were located ad-

[3] R. H. Green, *Sampling* Design *and Statistical Methods for Environmental Biologists (New York: John* Wiley & Sons, 1979).

[4] Woodward-Clyde Consultants, *Evaluation of Proposed Remedial Action Program Love Canal, Project 1, Leachate Containment System, Niagara Falls, New York,* prepared for Wald, Harkrader & Rosa, Washington, D. C., August 1982.

Table B-l.–Criteria Used To Evaluate EPA Sampling Effort

Criteria	Design of the study
Spatial/temporal factors:	• Only spacial factors included in the study • No seasonal variations considered
Choice/number of controls:	• Controls for ground water adjacent to EDA; possibility of chemical migration to control sites from Canal • Two control sites adjacent to another Landfill • Number of control samples too few for adequate analysis
Equal number of sites:	• Unequal sample sites among regions • Not allocated in proportion to size of the regions
Replicates:	• inconsistency in number of replicates taken per site • Not used to estimate variability within and among sites • Replicates treated as separate site samples
Verification of methods:	• No verification of sampling, handling, and analytical methods done prior to initiation of the study

EDA - emergency declaration area.

SOURCE: Office of Technology Assessment.

jacent to another known landfill, southwest of the Love Canal area.

3. Were equal numbers of sites allocated among regions and environmental media?

Equal (or nearly equal) numbers of sampling sites among regions facilitate interpretation and reduce uncertainties in results of statistical comparisons among regions. If very different numbers of sites are used, indeterminance can exist for those sites sampled least often. If equal numbers of sampling sites per region are not possible, a standard practice is that the numbers of samples be allocated in proportion to the size of each region.

Because of the assumptions guiding the design of the EPA study, the number of sites sampled across regions were not equal nor were they in proportion to the differences in sizes among regions, as indicated in table B-2. For example, the entire EDA is approximately $3^1/_3$ times the size of the Love Canal region (see table B-3), yet the number of sampling sites do not reflect this difference. It should be noted that the sampling effort did include sites chosen at the request of EDA residents and because of possible migration routes from the landfill.

Even for subregions within the EDA, the number of sites were not allocated on a proportional basis (see figs. B-2 through B-9.) For some media, site locations are naturally limited. For example, sump samples were obtained only in houses located in wet areas (fig. B-5); surface water and sediment samples were possible only from creeks (fig. B-7). However, for environmental media such as air, soil, and ground water (both shallow and deep) allocation could have been proportional to the area of each subregion. If this had been done, the data would reflect a more accurate picture of environmental contamination over all of the EDA.

It should be emphasized that by designing a sampling effort with preconceived assumptions about the outcome of the study, the use of the data can be limited. In this instance, the EPA data were used to make judgments about the overall habitability of the EDA. Because numbers of sites sampled decreased with increasing distance from the canal, uncertainties exist about contamination in some areas. For example, EDA-I had samples collected from only one or two sites (depending on the medium of concern) for the entire region. This sampling effort is hardly sufficient to determine the overall level of contamination for this subregion.

4. Were replicate samples taken for each site?

It is very important that any monitoring effort include replicate samples (i.e., identical samples from one site). The appropriate number of replicates will vary depending on the anticipated impact that variability within individual sites may have on the conclusions drawn from the data. If an assessment relies on absolute concentrations, replicate samples can be used to estimate the variance in concentration at a particular site. Without replicates, confidence in the absolute concentrations cannot be indeterminate.

Replicate samples from one site are used to estimate the amount of variance inherent at that site. Samples collected at several different sites enable art estimation of the variability inherent in a region. These estimates of variability may not be equal. Differences between them will depend on the evenness of distribution of a chemical within the environment, the properties of the medium being examined, and the presence of those factors that enhance or inhibit degradation of the chemical.

Table B-2.—Number of Sites and Samples for Target Substances

Environmental media	Regions[a]												
	1	2	3	4	5	6	7	8	9	10	EDA	LC	C
Ground water													
Shallow well:													
Sites	1	13	9	5	3	3	6	3	2	4	49	18	11
Samples[b]	1	11-13	8-9	5	2-3	2-3	5-6	2-3	1-2	1-4	36-47	9-21	9-11
Deep well:													
Sites	1	11	9	5	5	2	6	3	2	6	50	17	15
Samples	0	7-1o	4-5	2-4	2-4	1	4	1	1	2-4	24-32	6-13	11-16
Sump water:													
Sites	2	2	0	8	1	3	7	2	4	4	33	13	1
Samples	1-2	8-18	0	9-22	3-8	2-8	8-22	1-6	3-14	7-9	92-104	6-16	1-5
Drinking water:													
Sites	1	3	1	7	3	4	4	3	3	2	34	3	5
Samples	1	1-3	1	3-7	1-3	2-4	1-4	2-3	2-3	2	10-31	lt,3	lt,4-5
Surface water:													
Sites	0	o	0	5	o	0	0	0	0	0	5	0	5
Samples	0	0	0	lt,2-4	0	0	0	0	0	0	2-4	0	lt,3-5
Storm sewer water:													
Sites	1	3	3	6	1	1	1	1	1	4	22	4	1
Samples	1	3t	l,3t	1-4	1	lt	1†	1	1t	1,4t	5-19	2,3†	1
Soil:													
Sites	7	15	9	16	12	9	16	9	10	10	113	23	9
Samples	2-5	14-15	4-9	9-16	9-12	1-9	8-15	6-9	3-10	8-10	71-109	13-23	5-9
Volatiles	9	28	18	30	24	18	31	18	19	18	213	45	17
Sediment:													
Storm sewer:													
Sites	1	3	3	6	0	1	1	1	1	4	22	4	1
Samples	1	1-3	1-2,3t	1-3	0	1	1	1	1	1-2	5-15	1-4	1
Surface water:													
Sites	0	0	0	5	o	0	0	0	0	0	5	0	5
Samples	0	0	0	1t,4	0	0	0	0	0	0	3-4	0	1-5
Air:													
Living:													
Sites	1	6	5	8	5	6	6	6	6	5	54	6	
Samples T[c]	9	60	52	76-79	60-61	66	56	49-50	62	46-47	538-542	63-64	30'31
Samples P	3	26	20	48	25-26	27	42	35	43	22	292	32	28
Basement:													
Sites	0	6	0	7	5	6	6	6	6	0	42	6	0
Samples T	0	10-11	0	12	12	10	22	9	10	0	83-84	11	0
Samples P	0	12	0	11	11	9	20-21	9	11	0	85-86	8	0
Outdoor													
Sites	0	6	0	7	5	6	6	6	6	0	42	6	0
Samples T	0	11	0	10	12	9	21	11	11	0	81-83	10	0
Samples P	0	9	0	9	12	7-8	19	10	9-10	0	77-79	10	0

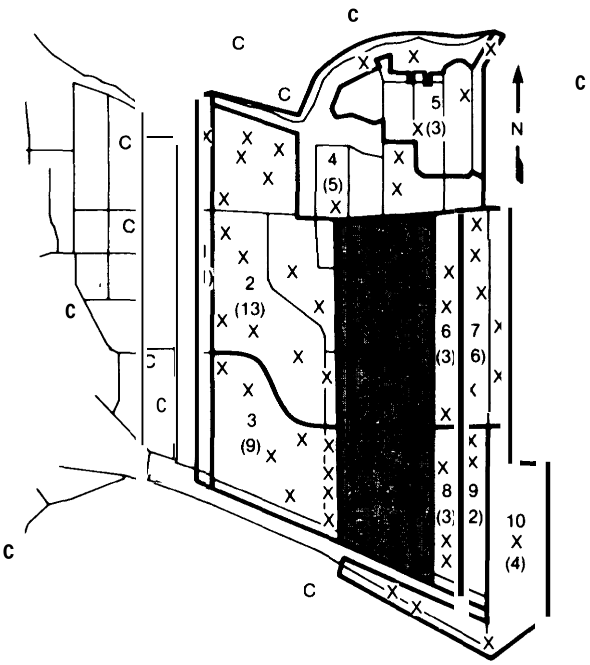
†Sampled only for K-stable potassium, cesium, radium, Americium.
[a]Columns 1 through 10 represent subregions in the emergency declaration ares (EDA); LC represents the region adjacent to the Canal, and C represents the control region.
[b]Represents range of total analytical samples verified and entered into the EPA data base for each target substance; e.g., in EDA-2 some target substances were analyzed using 11 shallow well samples and other substances using 13 samples.
[c]T represents the total number of samples analyzed with the Tenax method; P represents the total number analyzed with the PFOAM method.

SOURCE: U.S. Environmental Protection Agency, *Environmental Monitoring at Love Canal, Volume III.*

As illustrated in table B-2, multiple samples per site were collected only for sump water samples, for volatile compound analyses in soil, and for air analyses.[5] For example in EDA-2, two sump water sites were identified from which 8 to 18 samples were collected for chemical analyses. The range (8 to **18)** indicates that for some compounds as few as 8 samples were analyzed and recorded in the data base; for other chemicals, analyses were performed with **18** samples collected at the two sites. For all soil sites, two samples per site were collected for analysis of volatile compounds. Two methods were used to analyze air samples. For the Tenax method nearly 10 replicates per site were collected; four replicates per site were collected for analysis using the PFOAM method. It is dif-

[5]*Environmental Monitoring at Love Canal,* op. cit., vol. 11.

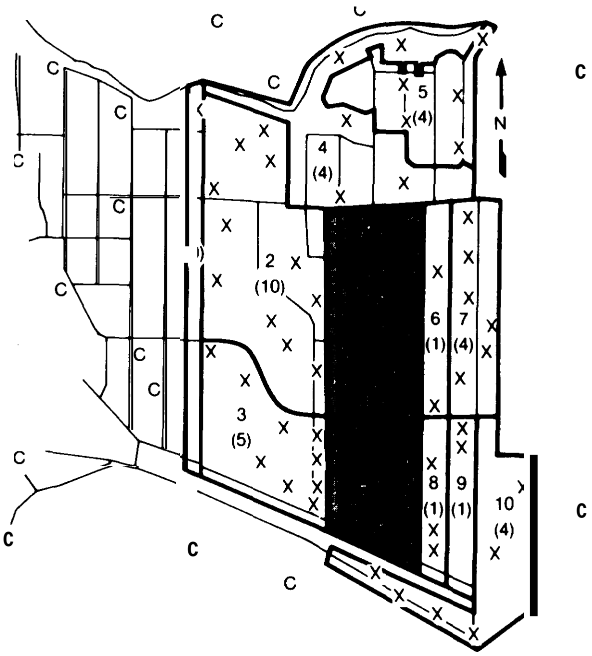
Figure B-2.-Distribution of Shallow Well Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each well; C represents location of control wells; ( ) indicates maximum number of samples collected per region.

SOURCE: Environmental *Monitoring* at *Love Canal* (Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 14.

Figure B-3.–Distribution of Deep Well Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each Well; C represents location of control wells; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love* Canal (Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982, vol. III, p. 19.

Table B-3.—Approximate Size of EDA Study Regions

Region	Square yards (in thousands)	Football field[a] equivalence
1	80	16
2	300	60
3	100	20
4	200	40
5	90	18
6	50	10
7	100	20
8	30	6
9	30	6
10	70	14
Total	1,000	200
Love Canal region	300	60

[a]Calculated by assuming a football field is approximataly equal to 5,000 yd^2.

SOURCE: Calculated from maps provided by the Love Canal Area Revitalization Agency.

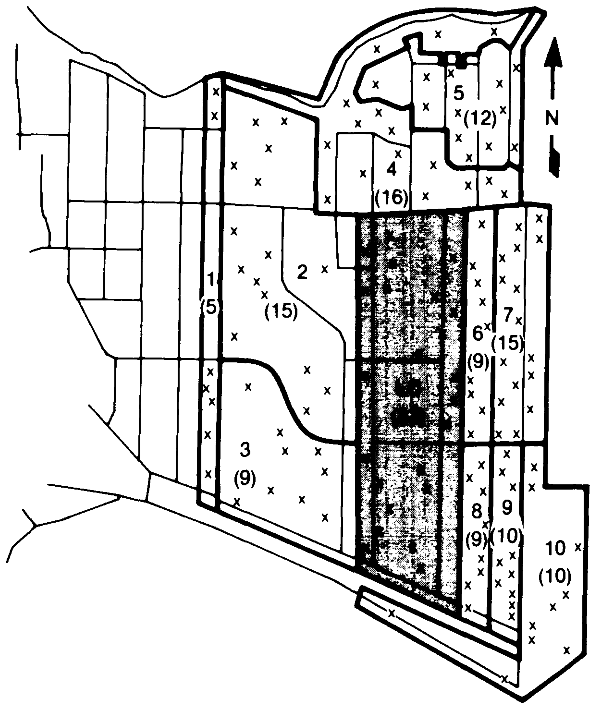
ficult to determine whether these multiple samples were actual replicates.

If, in fact, these multiple samples were collected as replicates, EPA did not follow the normal practice of using them to estimate variability within the site. Such estimates are particularly important when low levels of contamination are encountered and when an assessment of habitability is based on absolute concentrations of chemicals, as was the case in this study. The decision to treat replicates as actual samples was unfortunate as it increases uncertainties about the significance of differences in observed concentrations among control, EDA, and Love Canal regions.

5. Were the sampling and analytical techniques verified?

All sampling and analytical methods have certain biases associated with them—e.g., differences in results can occur if slightly different procedures are followed, if different personnel perform the analyses, and if different collection and analytical equipment are used. If results of environmental studies are to be properly interpreted, it is necessary to identify these biases.

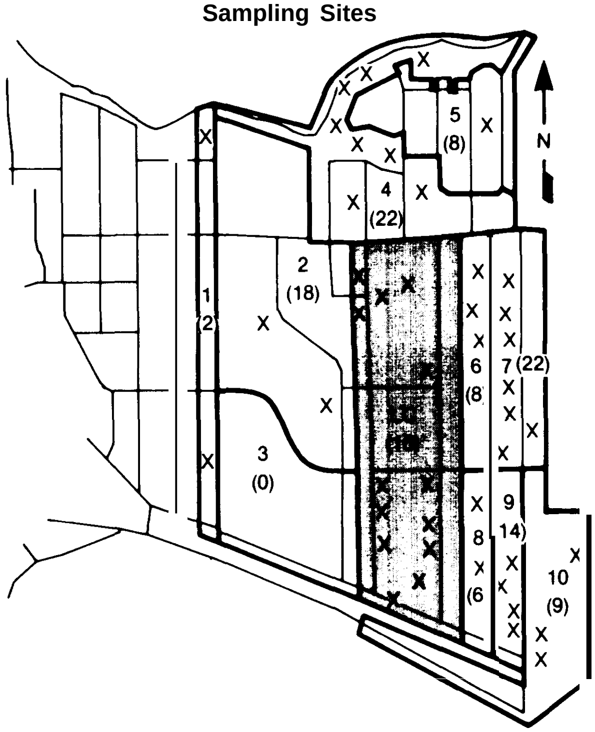
Figure B-4.—Distribution of Soil Sampling Sites



KEY: Numbers denote subregions, X Indicates approximate location of each site; ( ) Indicates maximum number of samples (nonvolatile) collected per region

SOURCE: Environmental *Monitoring at Love Canal* (Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 23.

Figure B-5.—Distribution of Sump Water Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of sites; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 33.

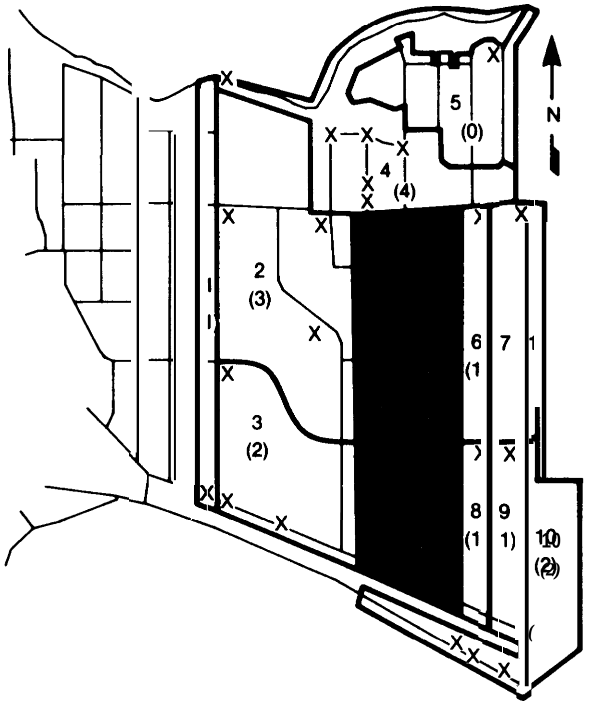
Because of time constraints, EPA could not conduct any preliminary analyses that would have identified biases inherent in the techniques chosen for this monitoring study.

In addition, EPA did not verify that the methods used for sample collection and analysis were suitable for the conditions at Love Canal. For example, the methods of obtaining samples could have been a major contributor of the large number of below detection results that were obtained. Soil samples were obtained by using a soil corer, which obtained a core 1 3/8 inches in diameter and **6** feet in depth. Seven cores were taken at a site; two cores, representing two samples per site, were analyzed for volatile chemicals. The remaining five cores were homogenized and treated as *one sample per* site. Such a method could have serious consequences for detecting soil contamination. If the compounds are present at low concentrations and / or within only a small region of the core, the practice of compositing five cores to produce one sample will dilute any concentration level and make detection extremely difficult. Because of this dilution factor associated with this particular sampling technique, even if hot spots exist at a site the measured values would be lower than actual environmental concentrations. *The use of such sampling techniques calls into question the validity of using absolute contamination values as the basis for a habitability decision.*

Similar problems existed for ground water samples. For example certain ground water samples were invalidated by EPA, because it was suspected that inadequate purging had occurred.[6] Hydrant water was used as a drilling fluid during construction of the wells. Prior to collecting samples the wells had to be purged, removing all hydrant water. EPA officials thought that hydrant water had been collected rather than aquifer water. Appropriate location of sampling wells is critical to obtaining representative samples with which to judge the extent of ground water contamination. Plumes of chemicals, which may have densities **greater than water, can travel in directions different from the**

[6] *Environmental Monitoring at Love Canal,* op. cit., vol. I, p. 238.

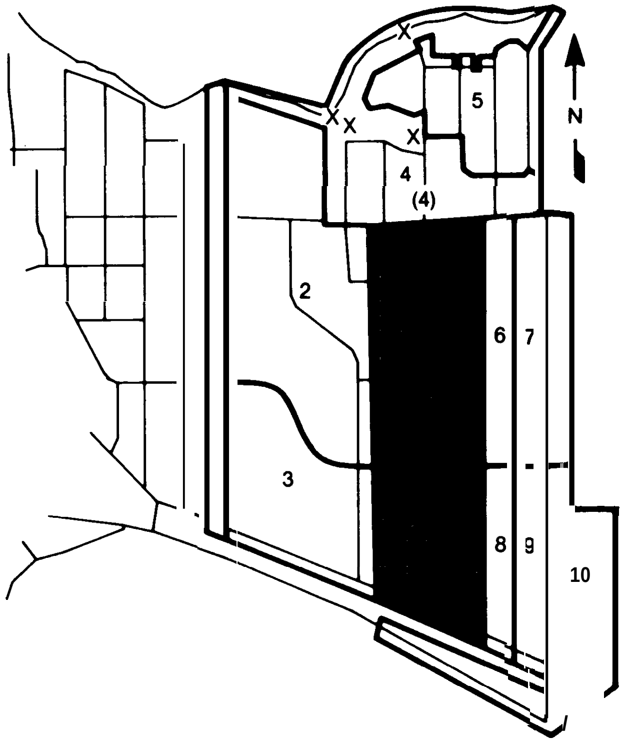
Figure B-6.— Distribution of Storm Sewer Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each storm sewer; ( ) indicates maximum number of samples (water or sediment) collected per region.

SOURCE: *Environmental* Monitoring *at Love* Canal (Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 41.

Figure B-7.—Surface Water Sampling Sites Along the Black Creek and the Bergholtz Creek



KEY: Numbers denote subregions; ( ) indicates maximum number of samples collected for region 4.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D. C.: U.S. Environmental Protection Agency, EPA0600/4-82-030, May 1982, vol. III, p. 51.

ground water flow and can migrate into undetected fissures.' Thus, when this occurs analysis of samples taken from those wells placed to match ground water flow patterns would not likely lead to detection of the contaminated plume.[8]

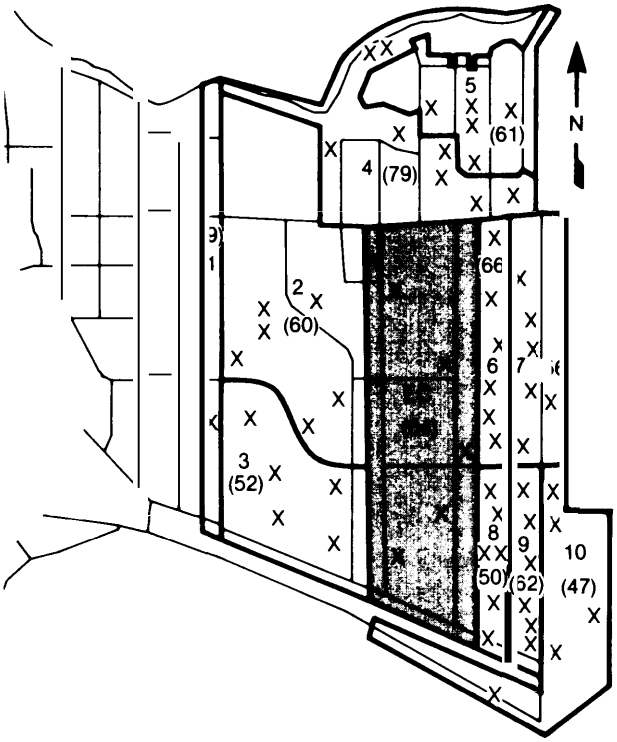
Analytical methods likewise were not verified for Love Canal environmental conditions and study mechanisms prior to initiation of the monitoring effort. If EPA had attempted such verifications, problems associated with sample extraction (e.g., for dioxin), analyses of air samples using the PFOAM method, and uneven analytical capabilities among laboratories could **have** been resolved before enormous effort and resources had been expended. Absence of the verification was probably a direct result of the fact that EPA was under great pressure to do the study quickly. In retrospect, providing time prior to initiation of the monitoring study to verify methods likely would have resulted in more definitive answers.

Proper sample handling is a critical element in environmental monitoring programs. All samples taken in the field tend to lose a variable portion of the substances to be monitored during sampling, handling, and storage. A standard technique for determining the percent of loss is to add a specified amount of known substance (to "spike") to certain field samples. The concentration of the spiked substance is measured in the laboratory; any differences between the amount added in the field and the amount measured in the laboratory represents the percent lost during sample handling. Analytical results of unspiked samples thus can be adjusted to reflect these losses. Loss of concentrations during sample handling can result from chemicals bonding to the sample medium or containers, to vola-

[7]The geology beneath the canal landfill has not been studied extensively. Fractures have been noted in parts of the Niagara Falls region. E. Koszalka, U.S. Geological Survey, Long Island, N.Y., personal communication, March 1983.

[8]Ground water monitoring problems are discussed further in *Technologies and Management Strategies for Hazardous Waste Control*, "Chapter 7: The Current Federal-State Hazardous Waste Program" (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-M-l%, March 1983).

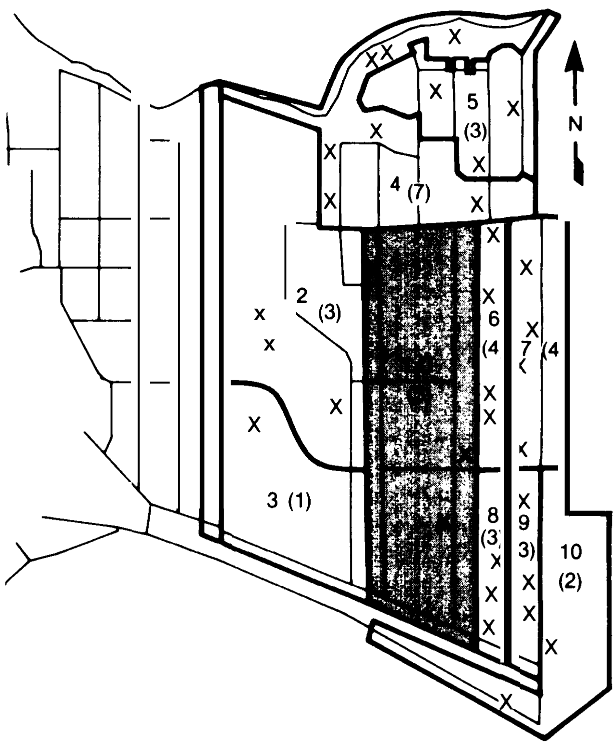
Figure B-8.-Distribution of Air Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each site; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1962), vol. III, p. 61.

Figure B-9.—Distribution of Drinking Water Sampling Sites



KEY: Numbers denote subregions; X Indicates approximate location of each site; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1962), vol. III, p. 74.

tilization, or to other chemical-physical processes that may occur during handling and storage.

This technique was not employed in the EPA study for water, soil, or sediment samples. Blind spiked samples were included in the field sample analyses for air. Consequently, reliable estimates of loss for most substances cannot be made. (However, EPA did estimate percent recovery for extraction of dioxin from field samples.) Particularly for volatile chemicals and for those samples collected during the warmest periods of the monitoring program (which spanned August to October), loss of substances could have occurred. Analysis of air samples, however, did not reveal pronounced seasonal variations. It is uncertain whether other media would reveal a similar lack of variation.

Field spiking was omitted from the EPA protocols to eliminate the possibility of accidental contamination of all field samples with target substances.[9] In addition EPA was presented with certain difficulties regarding implementation of spiking for their field samples. Spiking with all 150 target substances would be extremely difficult; choosing a few compounds to serve as representatives of the total set has several uncertainties associated with it. For example, it would be difficult to verify that the representative compounds behaved similarly to the **150** chemicals within the variety of environmental media investigated in this study. Identification of these representative compounds would have required additional time, and EPA was under pressure to complete its large study within **6** months.

Conclusions About the Sampling Strategy

Perhaps the most serious failings of this study were:

[9] J. Deegan, statement and supplementary testimony before the subcommittee on Commerce, Transportation, and Tourism of the Committee on Energy and Commerce, U.S. House of Representatives, 97th Cong., serial No. 97-197, Aug. 9, 1982.

1. the inadequate numbers of sites sampled in different regions,
2. varying intensity of sampling of different environmental media, and
3. the lack of replicate samples with which to estimate site variability in concentrations of chemicals.

The numbers of collected samples per region and the number of measurements available per target substance are insufficient to serve as a representative picture of the potential contamination either in the EDA or within subregions of the EDA. For example, EDA-1 covers an area of approximately 80,000 square yards (approximately equal to **16** football fields, as shown in table B-3). Only one or two sites, depending on the environmental media, were sampled to represent potential contamination. Similarly, nine or fewer sites were sampled for all media to represent EDA-6, an area approximately equal to 50,000 square yards and directly adjacent to the Love Canal region.

The lack of sufficient sites and inability to estimate sample variations within sites presents serious consequences for an assessment of habitability based on absolute concentrations. Without estimates of variability, confidence in reported concentration values must be limited. For example, "trace" is considered to represent levels less than 100 parts per billion (ppb) in the EPA study; the possibility exists that site variability could range by an order of magnitude. Analysis of replicate sample; from a site would verify whether trace represents 100 ± 10 ppb or 100 ±200 ppb. Because human health effects can result from chronic exposure to concentrations in the ppb and parts per million (ppm) ranges, it is necessary to know with some level of confidence that the values reported for an area represent actual environmental concentrations.

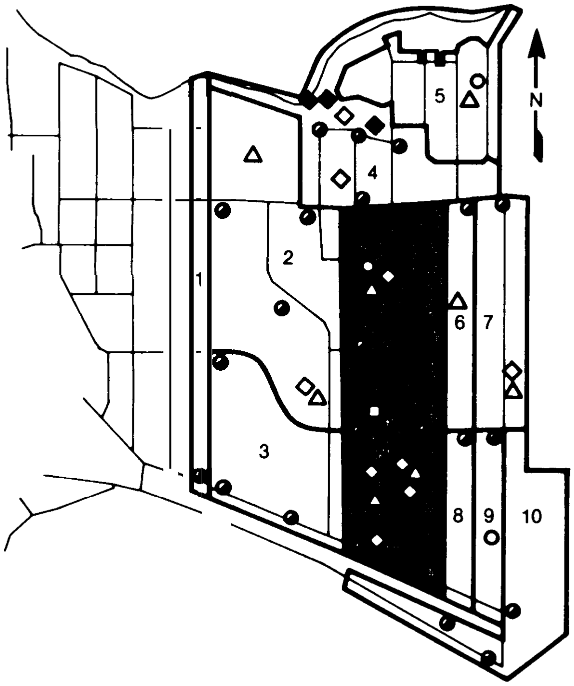
Dioxin is probably the most toxic of the contaminants (in low concentrations) known to be present in Love Canal, and an analysis of the data for this chemical illustrates the OTA concern about the sampling effort. Monitoring for dioxin was insufficient with respect to extent, level and replication, as shown in table B-4 and figure B-10. Only 6 out of 21 submedia were sampled in the EDA; 3 were sampled in control areas; and 7 submedia were analyzed in the Love Canal. Of the 10 regions in the EDA, only 2 were sampled for sump water contamination and 3 each for air and soil. No samples were collected in deep well, shallow well,

Table B-4.—Sampling Effort for Dioxin

	EDA (10 subregions)			Controls		Love Canal region	
	Total regions	Total sites	Total samples	Total sites	Total samples	Total sites	Total samples
Water:							
Deep well	0	0	0	0	0	3	2
Shallow well	0	0	0	0	0	3	2
Sump	2	4	0	0	0	5	2
Surface	1	3	3	1	1	0	0
Drinking	0	0	0	0	0	0	0
Storm sewer	0	0	0	1	1	4	1
Sanitary sewer	0	0	0	0	0	0	0
Soil	3	3	4	0	0	3	4
Sediment:							
Sump	0	0	0	0	0	0	0
Storm sewer	9	18	18	0	0	4	4
Sanitary sewer	0	0	0	0	0	0	0
Surface water	1	3	3	0	0	0	0
Air:							
Living area	3	2	3	1	1	1	1
Basement	0	0	0	0	0	0	0
Outdoor	0	0	0	0	0	0	0
Biota:							
Oatmeal	0	0	0	0	0	0	0
Potatoes	0	0	0	0	0	0	0
Crayfish	0	0	0	0	0	0	0
Dog	0	0	0	0	0	0	0
Maple	0	0	0	0	0	0	0
Mice	0	0	0	0	0	0	0
Worms	0	0	0	0	0	0	0
Totals		33	36	3	3	23	16

SOURCE: U.S. Environmental Protection Agency, op. cit., Vol. II.

Figure B-10.– Distribution of Dioxin Sampiing Sites



SOURCE: *Environmental Monitoring at Love Canal* (Washington, D. C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 77.

drinking water, storm sewer water, or sanitary sewer water. Surface water and sediment were sampled in one subregion. It should be noted, however, that the volubility of dioxin in water is extremely low (**0.2** ppb). Storm sewer sediment was collected in nine of the EDA regions. Also, this substance has not been detected previously in air samples, except when present on dust, near incinerators, or in smoke from forest fires. Thus, EPA may have reduced the extent of sampling because of assumed distribution primarily in soil and sediment.

For a determination of the possible level of dioxin contamination in the EDA, the amount of sampling was very limited for dioxin. For most of the regions, including the 10 subregions of the EDA, no more than five sites were sampled per region. Storm sewer sediment sampled in the EDA is the one exception. Given the large area covered by both the Love Canal and EDA (see table B-3), this level of sampling effort seems insufficient to estimate the potential contamination in the Love Canal area.

Within each of the major sampling regions (EDA, control area, and Love Canal), few replicate samples were taken. Variability in concentrations within a single site could be possible, but without replicates this variability cannot be estimated. Lack of replicates reduces the certainty associated with comparison of dioxin concentrations among the EDA, Love Canal, and control area. Distinctions between regions require estimates of variation within each individual region as a basis for comparison. Consequently, in the extreme case of no replication, it is impossible to determine whether the regions, regardless of absolute concentrations, differ because of normal site variability or because of actual regional variations.

OTA compared this extent and level of sampling for dioxin at Love Canal with recent EPA protocols for dioxin sampling in Missouri.[10] The Eastern Missouri Dioxin program has collected samples from some **30** areas, including Denny Farm (1979), Times Beach (1982), and Quail Run (1983). Two important differences emerged.

1. In Eastern Missouri, preliminary surveys were conducted to identify areas of highest contamination,
2. Within the boundaries of these highly contaminated areas, the level of sampling was between 4 and 37 times as great as in the Love Canal EDA (table B-s).

Table B-5.—Comparison of Dioxin Sampling Effort Between Eastern Missouri and the EDA

	Area (acres)	Total samples	Samples per acre
Denny Farm (1979).	4.5	30	6.7
Love Canal EDA (1980)	200	36	0.18
Times Beach (1982)	640	500-600	0.78-0.93
Quail Run (1983)	24	113	4.7

SOURCE: Environmental Promotion Agency, Region VII, Kansas City, Mo., May

Some important differences exist between the Eastern Missouri program and the Love Canal effort. First, the analytical capability to analyze for dioxin has advanced tremendously since 1980. Second, the detection limits are different for the two programs: 20 parts per trillion for Love Canal and 1 ppb for Eastern Missouri. This leads to significant gains in turnover time and laboratory capacities. Third, at Love Canal, EPA was faced with analyzing for a broad diversity of substances known to have been disposed in the landfill, while in the Eastern Missouri program, dioxin was the only target substance. Fourth, in Eastern Missouri, EPA is not operating under a presidentially declared Federal Emergy Management Agency state of emergency **as** was the situation at Love Canal. Therefore, time was not a limiting factor.

[10] Gale Wright, William Keffer, Will Bun, William Fairless, and John Whitland, U.S. EPA Region VII, Kansas City, Me., personal communication, May 27, 1982.