Appendixes

Appendix A
Remediation

Summary

There are four areas of uncertainty that can affect projections of the long-term integrity of the remedial technology. Before any decision on habitability can be made, these uncertainties must be addressed and solutions identified.

1. Remedial Action in the Emergency Declaration Area (EDA).—The areas in the EDA contaminated with high levels of dioxin have not yet been cleaned up. Moreover, until just a few months ago storm sewers leading from the canal region to the EDA and known to contain dioxin remained open. It is possible that during the past few years—after completion of the EPA monitoring study—dioxin may have been transported within or beyond the EDA. A study to determine the full extent of contamination in and near the sewers is not completed.

2. Leak Detection Systems.—The long-term integrity of the remedial technology is not certain. Reliable methods are needed to allow detection of damage (leading to permeability) to the two basic elements of the containment system. These elements, intended to minimize water entering the canal, are the cap over the canal area and the concrete barrier wall to be built around it. There is no dispute about the need for repair and replacement of the cap and leachate collection system over time. Yet how it will be done is not clear. How structural damage or clogging of the drain system will be detected, and how repair and replacement can be carried out safely remain unanswered.

3. Monitoring Programs.—Assurance of sufficient warning about any potential migration and accumulation of chemicals from the canal is essential. Plans are underway for developing a long-term monitoring plan for ground water in the area immediately adjacent to the canal but not in the EDA. It is also necessary to design more extensive ambient monitoring of environmental media other than ground water (e.g., air, soil, and biota). Media other than ground water are possible routes of exposure to toxic chemicals. For example, depending on the properties of chemicals disposed in the canal and properties of the soil through which the ground water moves, some chemicals could be filtered out and could accumulate in soil or possibly in biota. Humans might become exposed to either. In addition, damage to the cap could allow release of volatile compounds into the air.

4. Institutional **Mechanisms for Long-Term Protection of the EDA Residents.**—The fourth major area of uncertainty concerns the long-term ability of government institutions to remember, fund, and carry out commitments for long-term continued monitoring and maintenance of the site. The full range of institutional issues surrounding very long-term commitments for managing uncontrolled hazardous waste sites under the Superfund program have not been addressed. Current cost estimates for routine operation, maintenance, and replacement of the leachate collection system are about $0.4 million now, $4.2 million in the year 2005, and $8.5 million in 2030. There is no guarantee that State officials 20 or 100 years from now will either remember or honor this commitment. Furthermore, there are few institutional mechanisms in place to assure continuity in transferring vital information on Love Canal from one generation to the next. Nor does it appear that New York State has taken unequivocal, binding, and permanent title of the canal area in a manner that prevents future use of the site.

Categories of Remedial Technology

Technical options for remedial action implemented under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) can be categorized as either waste control or environment control.[1] Table A-1 lists the types of technologies in these two categories and illustrates some of the advantages and disadvantages of each. The implementation of any of them will depend on site-specific conditions. In some situations, a combination of waste and environment control strategies would be required.

Waste control refers to the removal of the hazardous material from a site, followed by some treatment that reduces the potential harm of hazardous compounds and subsequent disposal of the waste or treatment residue in an appropriate facility. The treatment can involve destruction of toxic components of the excavated material through chemical, physical or biological processes, or immobilization of the hazardous components.

At present, the application of destruction techniques has been limited to excavated materials or small area spills treated by biodegradation and chemical processes. Some thermal destruction technologies are available. Thermal destruction of large volumes of contaminated material, such as excavated soil, is a new ap-

[1] *Technologies and Management Strategies for Hazardous Waste Control,* "Chapter: Technologies for Hazardous Waste Management: Uncontrolled Sites" (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-M-l96, March 1983).

Table A-l.—Advantages and Disadvantages of Control Technologies

Type	Advantages	Disadvantages
Waste control technologies		
Excavation and removal followed by treatment or disposal	• Good for containerized or bulk disposal	• High initial costs • Potential higher risk during cleanup • Relocation of risk unless waste is treated • Not cost effective for low-level hazardous waste or uncontainerized buried waste in large area
Excavation with onsite treatment	• Expose waste to complete treatment	• High initial cost • Difficult to assure monitoring effectiveness • Some risk of exposure • Not cost effective for large amount of low-hazard waste
Neutral ization/stabilization	• Useful in areas where waste excavated prior to mixing • Low risk of exposure if injection method is used	• Limited application • Requires long-term land use regulations • Eventual off site migration if reaction is incomplete
Biodegradation	• Low costs	• Difficult to maintain optimum conditions to keep reaction going
Solution mining	• Useful in homogeneous uncontainerized solvent-soluble, buried solid hazardous waste	• Can result in uncontrolled release
Environmental control:		
Isolation, containment, and encapsulation	• Useful for large volumes of mixed hazardous and domestic waste and low-hazard waste	• Effectiveness depends on physical conditions • Long-term O&M needed
Ground water diversion and recovery	• Useful if soils are permeable or if there are high perched water tables	• Requires wastewater treatment option • Process is slow • O&M monitoring • Not effective for insoluble or containerized material
Surface water diversion	• Easy to implement • No transport of waste offsite	• Can create flooding off site
Ground and surface water treatment	• Can be used onsite or offsite	• May generate hazardous sludges, spent carbon • Long-term monitoring
Gas collection or venting	• Low costs	• Site safety and fire hazards • Off site air pollution • Long-term monitoring and O&M

O&M—operating and maintenance.

SOURCE: Office of Technology Assessment, op. cit., p. 210.

plication and data on its efficiency are limited. Thus, these technologies currently have not received widespread consideration as a remedial technology.

An alternative to destruction is the immobilization of hazardous components. This is achieved by encapsulating the excavated material in some impermeable matrix. When placed in soil or marine environments, migration of hazardous constituents is then prevented (or at a minimum, the rate of migration is decreased); thus, the risk to public health and the environment is reduced.

These control technologies can be used effectively when the waste has been deposited in containers and removal from the site can be accomplished readily. It also can be implemented at those sites where hazardous components have not become distributed throughout environmental media. For example, it is used at those sites where bulk disposal has occurred and before widespread migration of the material within the soil has taken place. However, if the contaminated area is large, e.g., measured in several acres, waste control techniques are difficult and costly to implement.

In the case of an accidental spill, removal and subsequent treatment can be effective, if remedial action is not delayed and boundaries of the spill can be identified easily. Under appropriate site conditions, treatment techniques can be used without removal of the contaminated material, e.g., in situ biological or chemical degradation of soil contaminated through an accidental spill of hazardous chemicals.

Environment control options include those techniques that contain or isolate hazardous material, divert water movement away from a site, or treat contaminated water sources. A review of 23 landfill sites suggests that environment control is the more common remedial strategy currently in use.[2] The technologies for containment are not new; rather they are adapted from structural or civil engineering procedures and consist of the installation of caps, barrier walls, and drainage systems.[3 4] At many sites, containment technology is used in combination with water diversion techniques. These latter include changing the flow of surface water to prevent flow into a contaminated site or removal and treatment of ground water that has been contaminated.

Because the strategy of environment control does not remove sources of contamination, it is necessary to include safeguards that increase the likelihood of long-term integrity of containment and reduce effects of failure should it occur. Well-developed environmental monitoring programs are essential safeguards. Monitoring should include all environmental media: water, air, soil, and biota. Moreover, some sort of leak detection system is necessary to warn of possible release of contaminants through the natural or synthetic barriers of the containment structure.

When comparing these two categories of remedial technology, *advantages and limitations* can be identified. For example, environment control offers certain advantages over waste control in that large areas of contamination (e.g., many acres) can be controlled. In addition, installation costs are generally less for environment control technologies than for waste control. Environment control technologies eliminate the potential transfer of risk from one area to another; for some waste control options this transfer of risk is a major consideration. Moreover the use of environment control technologies does not create risks for transportation accidents. Environment control, however, requires long-term (i.e., forever) operation and maintenance. In contrast, waste control includes treatments that completely destroy the hazardous material, eliminating long-term hazards. Both environment control and those waste control options that only immobilize hazardous components must include long-term monitoring programs.

A major concern associated with either type of remedial action is the limited experience with these techniques. Sites using either waste or environment control have not been in existence long enough to provide sufficient data about the long-term integrity of the methods. For example, a review of sites where environment control has been in place indicates that the "oldest site" has had a clay barrier wall (5-to 8-ft thick) only since 1976.[5] Monitoring at this site has not yet indicated leakage through the wall. Remediation at the oldest sites incorporating barrier systems using synthetic materials (e.g., asphalt-bentonite, cement-bentonite) were completed only in 1979.[6] Thus, our experience regarding long-term integrity of containment technology is limited.

Uncertainties exist for waste control options, also. Unless the extent of contamination can be characterized in detail, i.e., the types and concentrations of all constituents are known, complete destruction of hazardous elements cannot be validated. New constituents could be formed as products of the biological, chemical, or thermal processes taking place. These new constituents could be as, or more hazardous than, the original compounds.

Much theoretical work has been done to predict the performance of remedial technology. While the information gained through the use of theory and models is important, it must be emphasized that at present *no field experience exists.* The persistence of many waste constituents is much longer than the effective lifetime of the environment control technologies; the degree of hazard for components in wastes may be increased by waste control treatments. Thus, environment control may simply postpone risks to public health and the environment to future generations, and waste control may create new hazards.

[2] E. Nagle, Environmental Law Institute, personal communication, April 1983.

[3] C. Kufs, et al., "Alternatives to Ground Water Pumping for Controlling Hazardous Waste Leachates," *Management of Uncontrolled Hazardous Waste Sites*, Hazardous Materials Control Research Institute, 1982, pp. 146-149.

[4] P. A. Spooner, R. S. Wetzel, and W. E. Grube, "Pollution Migration Cut-off Using Slurry Trench Construction, " *Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research institute,* 1982, *pp. 191-197.*

[5] *Nagle, op. cit.*

[6] *Ibid.*

Evaluation of Alternative Technologies at Love Canal

In accordance with CERCLA requirements, EPA did a cost-effectiveness analysis of alternative technologies for remedial action at Love Canal. Their analysis considered only environment control technologies. OTA identified factors that are relevant to consideration of waste control options:

1. **Given the large area of the landfill and adjacent land, waste control technologies likely would be costly, possibly greater than environment control by orders of magnitude. For example, excavating and** *treating 49* acres of contaminated soil to a depth of possibly 15 ft (equal to nearly 2 million tons of contaminated soil) would be a major and expensive task with current technologies, particularly in water saturated zones.
2. Workers as well as residents in the EDA would be exposed to hazardous substances through the excavation process and formation of potentially hazardous products by operation of a waste treatment system.
3. Given the broad range of chemicals that were originally dumped in the canal and the variety of products that could result from natural and enhanced degradation as well as thermal combustion processes, the outcome of destruction efforts is uncertain with present technology. Demonstration studies would be required to evaluate the efficacy of the **waste** control treatments. These studies would delay completion of remedial action and possibly increase the risk to residents remaining in the EDA.
4. The problem of finding an ultimate disposal site for treatment residue would be difficult to resolve without knowing its hazardous quality. Disposal of such residues in a new site could result in merely relocating health and environmental risks.

The environment control alternatives considered by EPA included four altematives:[7]

1. No additional action beyond operation and maintenance of a leachate collection system.
2. Cut-off and plugging utility lines, in addition to alternative 1. All utility conduits that are possible routes for lateral movement from the site would be plugged and all utility lines beyond the containment areas would be cleaned.
3. Alternatives 1 and 2, plus installation of a partial wall. A subsurface wall would be installed at points of natural migration routes from the site—e.g., sand lens or drainage swales.
4. Alternatives 1 and 2, plus complete containment of the contaminated area. Construction of a barrier wall that would completely enclose the site.

A summary of the lifecycle costs for these alternatives is presented in table A-2. Although initially the costs are greatest for option 4, over a period of 50 to 200 years this alternative is expected to result in the lowest total cost to the State. As indicated in table A-3, each alternative was also evaluated based on expected performance. Alternative 4 provides the greatest relative protection for public health and the environment.

Table A-2.—Summary of Lifecycle Costs (present worth In 1981 dollars-1 x 10[a])

	1 year	50 years	100 years	200 years
Alternative 1:				
Capital		—	—	—
O&M	0.25	12.73	25.46	50.92
Replacement	—	1.04	7.29	20.19
Total	0.25	13.77	32.75	71.11
Alternative 2:				
Capital	0.61	0.61	0.61	0.61
O&M	0.25	12.73	25.46	50.92
Replacement	—	1.04	7.29	20.19
Total	0.86	14.38	33.36	71.72
Alternative 3:				
Capital	1.99	1.99	1.99	1.99
O&M	0.20	10.09	20.17	40.34
Replacement	—	0.79	8.17	22.02
Total	2.19	12.87	30.33	64.35
Alternative 4:				
Capital	2.55	2.55	2.55	2.55
O&M	0.14	7.02	14.04	28.08
Replacement	—	1.49	1.49	21.35
Total	2.69	11.06	18.08	51.98

NOTE: Alternative 1—No additional action beyond installation of leachate collection system.
Alternative 2—Utility cut-off containment.
Alternative 3—Partial slurry well containment.
Alternative 4—Complete slurry wall containment.

SOURCE: CH_2M-Hill, op. cit.

When Congress included the requirement of conducting cost-effective analyses in the Superfund legislation, the intent was that both waste and environment control alternatives would be considered. While it is apparent that alternative 4 is preferred over alternatives 1 through 3, OTA questions the omission of some consideration for of any waste control technology in the cost-effectiveness analysis. As indicated above, present waste control technology cannot handle efficiently the large volumes of contaminated material that exist at the Love Canal site. Therefore, choosing environmental control options makes sense

[7]CH_2M-Hill, Immediate Remedial Action-Uncontrolled Hazardous Waste Disposal Sites, Zone 1, preliminary draft report for U.S. EPA Region II, April 1982.

Table A-3.—Performance Criteria Evaluation

	Rank[a b c]			
Criterion	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Initial cost	1	2	3	4
O&M cost	3	3	2	1
Lifecycle cost	3	4	2	1
Long-term environmental impact	4	3	2	1
Short-term environmental impact	1	2	3	4
Construction site health and safety	1	2	3	4
Community health and safety	4	3	2	1
Technical reliability	1	2	2	2
System reliability	4	3	2	1
Community acceptance	4	3	2	1
Construction duration	1	2	3	3
Achieve objectives	4	3	2	1
Meet project bid date	1	2	2	2

[a]Ranking ranges from "1" = best to "4" = worst. Equal rankings denoted by equal low numbers.
[b]Alternative 1 . No additional action beyond leachate collection system.
Alternative 2 - Utility cut-off containment.
Alternative 3 - Partial slurry wall containment.
Alternative 4 . Complete slurry wall containment.
[c]No weighting factors have been applied to performance criteria

SOURCE: CH_2M-Hill, op. cit.

as a short to medium term action, pending development of technology to deal permanently with the material. However, *environment control cannot and should not be considered a long-term or permanent solution.*

Many people have cited the great uncertainty of assuring long-term protection using environment control technologies. No effective alternative has been advanced. New York State officials are convinced that greater efforts should be expended on research and development of detoxification and destruction techniques thus, eliminating the need for long-term commitments to protection of a large land area. Once these technologies have been developed, they must be given serious consideration in any cost-effectiveness analyses for remedial technology. Although waste control options might be extremely costly to implement, it is possible that these would compare favorably with total costs over a 200-year time period for environment control options. In addition, the complete elimination of the hazard due to waste control treatments may outweigh objections to the high cost for implementing this type of remedial action and the short-term risks to workers and residents due to excavation of the material.

Control Action at the Love Canal Site

Because of the large area involved and environmental distribution of wastes disposed in the canal, the remedial action chosen by EPA and the New York State Department of Environmental Conservation (NYS/DEC) follows a strategy of environment control. Two types of technologies are used: a leachate collection system, for which construction began in 1978; and a containment system, for which construction work was planned for June 1983. These technologies are commonly used for remedial action.[8 9 10]

The *drainage system* became operational in 1979 and is to continue indefinitely with planned repair and replacement. The system consists of a clay cap covering the immediate area of the original landfill; a French drain system rings the cap enclosing an area of approximately 23 acres.

Ground water migrates through the site into the drainage system, is pumped into an onsite treatment facility, and put into clarification tanks where water and sludge phases are separated. The average flow through the system is 8 gallons per minute (gpm); the maximum capacity is 200 gpm and peak flows of 48 gpm have been recorded during the wet Season,[11] The water phase is drawn through an activated carbon system and effluent discharged into the municipal sewage system.

Effluent standards have been established by the City of Niagara Falls specifically for discharge of effluent from this facility. For every day that the treatment facility is operational, analyses are performed to determine whether these standards are being met. Analyses include tests for the presence of priority pollutants (see table A-4) determination of effluent pH levels (the effluent is neutral), and analyses of levels of total organic carbons (tests the efficiency of the activated carbon system), and total chlorinated hydrocarbons. A review of available data on constituent levels within treated leachate indicates that the *highest value* recorded for any of the priority pollutants was 46 parts per billion (ppb).[12] Even this low concentration has been detected only occasionally; most results of the analyses indicate no detection. State and city officials consider values in the ppb range to be sufficiently low because the effluent receives further treatment in the public wastewater treatment system.[13] Residues from the treatment

[8]*Spooner, Wetzel and Grube, op. cit.*
[9]*J. C. Evans and H. Fang "Geotechnical Aspects of the Design and Construction of Waste Containment Systems, " Management of Uncontrolled Hazardous Waste Sites*, Hazardous Materials Control Research Institute, 1982.
[10]*Handbook for Remedial Action at Waste Disposal Sites* (Washington, D. C.: U.S. EPA Municipal Environmental Research Laboratory, EPA-625/6-82-006, June 1982).
[11]CH_2M-Hill, op. Cit., p. 3-1.
[12]W. J. McDougall, R. A. Fusco, and R. P. O'Brien, "containment and Treatment of the Love Canal Landfill Leachate," *Journal WPCF*, vol. 52, No. 12, 1980, pp. 2,914-2,924.
[13]N. Kolak, New York State Department of Environmental Conservation, personal communication, March 1983.

Table A-4.—Priority Poiiutants

Volatile organic compounds
- Acrolein
- Acrylonitrile
- Benzene
- Carbontetrachloride
- Chlorobenzene
- 1,1-Dichloroethane
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- 1,1,2-Trichioroethane
- 1,1,2-2-Tetrachloroethane
- Chloroethane
- 2-Chloroethylvinyl ether
- Chloroform
- 1,1-Dichloroethylene
- 1,2-Trans-dichioroethyiene
- 1,2-Dichioropropane
- 1,3-Dichioropropene
- Ethylbenzene
- Methylene chloride
- Methyl chloride
- Methyl bromide
- Bromoform
- Dichlorobromomethane
- Trichlorofluoromethane
- Chlorodibromomethane
- Tetrachloroethylene
- Toluene
- Trichloroethylene
- Vinyl chloride
- Bis (chloromethyl) ether

Base-neutral extractable organic compounds
- Acenacphthene
- Benzidine
- *1,2,4-Trichlorobenzene*
- Hexachlorobenzene
- Hexachloroethane
- Bis (2-chloroethyl) ether
- 2-Chloronaphthalene
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichiorobenzene
- 3,3'-Dichlorobenzidine
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- 1,2-Diphenylhydrazine
- Fluoranthene
- 4-Chlorophenyl phenyl ether
- 4-Bromophenyl phenyl ether
- Bis (2-chloroisopropyl) ether
- Bis (2-chioroethoxy) methane
- Hexachlorobutadiene
- Hexachlorocyclopentadiene
- Isophorone
- Naphthalene
- Nitrobenzene
- N-nitrosodimethylamine
- N-nitrosodiphenylamine
- N-nitrosodi-n-propylamine
- Butyl benzyl phthalate
- Di-n-butyl phthalate
- Di-n-octyl phthalate
- Diethyl phthalate
- Dimethyl phthalate
- Benzo(a)anthracene
- Benzo(a)pyrene
- 3,4-Benzofluoranthene
- Benzo(k)fluorathene
- Chrysene
- Acenaphthylene
- Anthracene
- Benzo(ghi)perylene
- Fluorene
- Phenanthrene
- Dibenzo(a,h)anthracene
- Ideno(l,2,3-cd)pyrene
- Pyrene
- Bis (2-ethylhexyl) phthalate

Acid extractable organic compounds
- 2,4,6-Trichlorophenol
- Parachlorometa cresol
- 2-Chlorophenol
- 2-Nitrophenol
- Pentachlorophenol
- 2,4-Dimethyphenol
- 4-Nitrophenol
- 2,4-Dinitrophenol
- 4,6-Dinitro-o-cresol
- 2,4-Dichlorophenol
- Phenol

Pesticides and PCBs
- Aldrin
- Dieldrin
- Chlordane
- 4,4'-DDT
- 4,4'-DDE
- 4,4'-DDD
- a-Endosulfan
- b-Endosulfan
- Endosulfan sulfate
- Endrin
- Endrin aldehyde
- Heptachlor
- Heptachlor epoxide
- a-BHC
- b-BHC
- q-BHC
- w-BHC
- PCB-1242
- PCB-1254
- PCB-1221
- PCB-1232
- PCB-1248
- PCB-1260
- PCB-1016
- Toxaphene
- 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)

Metals
- Antimony
- Arsenic
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel
- Selenium
- Silver
- Thallium
- Zinc

Miscellaneous
- Asbestos
- Total cyanides

SOURCE: K. A. Brantner, R. B. Pojasek, and E. L. Stover, "Priority Pollutants Sample Collection and Handling," *Pollution Engineering,* March 1981, p. 35.

process are presently being stored onsite for future treatment. The NYS/DEC plans to develop **a** pilot project to investigate the potential for plasma arc incineration as a treatment process for the sludge.[14]

Hydrogeological assessments suggest that the leachate collection system is operating successfully.[15] Recent data on water table elevations indicate that ground water in the region between the drain and the landfill is being drawn into the collection system; likewise, data for the area immediately beyond the drain and adjacent to the EDA also indicate flow toward the collection system.[16]

[14] For a description of this technology see *Technologies and Management Strategies for Hazardous Waste Control,* op. cit., pp. 172-173.

[15] These were performed by CH$_2$M-Hill, contractors for U.S. EPA; their report was not available to OTA. A separate evaluation of the system was made by Woodward-Clyde Consultants, *Evaluation of Proposed Remedial Action Program Love Canal Project 1, Leachate Collection System, Niagara Falls, New York* Aug. 10,1982, prepared for Wald, Harkrader & Ross, Washington, D.C. According to Woodward-Clyde, their conclusions on ground water flow and the efficacy of the leachate collection system were essentially the same as CH$_2$M-Hill.

[16] Data provided by J. L. Slack, NYS/DEC, May 19, 1983, during a meeting with OTA, NYS/DEC, U.S. EPA, New York State Department of Health (NYS/DOH), and New York State Department of Law (NYS/DOL).

The containment component of the remedial action will involve the installation of a barrier wall around the canal, encompassing an area of approximately 49 acres.[17] The wall will be constructed of **concrete (a** width of 24 inches) and will extend to a depth of about 15 ft to be anchored into clay found at that depth. This clay is very impermeable with hydraulic conductivity (i.e., the rate at which water will move through the strata) estimated to be in the range of 0.1 to 0.01 inches per year.[18] A synthetic membrane cap will be installed to cover the entire 49 acres, including the existing clay cap. This membrane will extend beyond the barrier wall. Thus, it is expected that surface runoff will not penetrate the enclosed area. Twelve inches of sterile earthfill will be placed on top of the membrane cover; 6 inches of top soil will be the final cover. This top soil will be grass seeded. All existing trees, shrubs, and other plants will have been removed from the area prior to installation of the synthetic membrane cap. Only plants with a shallow root system can be allowed to be grown within the 49-acre area. Long rooted plants would eventually penetrate the cap.

The exact placement of the barrier wall will be determined using two sets of data: results obtained from the 1980 Environmental Protection Agency's (EPA) monitoring study and 1983 data *on* the extent of dioxin contamination in soils immediately surrounding the canal. * EPA has concluded that major contamination from Love Canal compounds does not extend beyond the land immediately adjacent to the canal.**

According to Federal and State officials the wall will serve three purposes:[19]

1. *The wall reduces the volume of water dawn into the leachate collection system.* Based on results from the **1980** EPA monitoring study, officials assume that the water outside the 49-acre perimeter is relatively clean—i.e., contaminants are present at concentrations of only parts per billion or less. By including this clean water in the collection system, the ongoing operation and maintenance costs will be quite large (see table A-2, alternative 1). These costs must be covered by State funds into the indefinite future. Reducing the volume of water that flows through the drainage system should result in a decrease in operation and maintenance costs for the State. Also once the 49 acres are contained by the barrier wall and surface covers, it is expected that very little precipitation will infiltrate into the contaminated area. The rate of flow through the drainage and leachate collection system is expected to decrease below the current average rate of 8 gpm.
2. *The wall provides further control against migration of contaminants from the canal into the residential areas.* Should problems develop with the leachate collection system at some time in the future, the barrier wall will serve as backup protection for EDA residents. Such protection, however, is dependent on there being no undetected damage to the wall or cap over time. While leachate-collection system problems are being resolved, the wall would postpone migration of compounds.
3. The *wall prevents migration of chemicals into the deep aquifer below the landfill.* Results of a recent modeling effort indicate a third advantage to having a barrier wall.[20] After the wall is installed, a reversal of waterflow is expected between the shallow and deep aquifers, i.e., instead of movement from shallow aquifer to deep aquifer, the flow will be from deep aquifer to shallow aquifer. While some reversal may be occurring due to operation of the collection system, the extent of the reversal should be greater with the wall. If the model conclusions are correct, the wall will provide the *only* real means for reducing deep aquifer contamination.

NYS/DEC recognizes the need for continued monitoring once the remedial action has been completed. Although not yet completed, a ground water monitoring strategy is being planned. Because NYS/DEC considers that all mobile compounds will be present in the ground water, no soil or air monitoring is planned. State officials consider that any chemicals bound to the soil will not be mobile. The synthetic cap is expected to prevent volatilization, therefore air monitoring would not be necessary .21

The EPA monitoring study identified chemicals in sediment from both storm sewers and storm sewer discharge points in surface waters. Cleanup of the storm sewers within the canal area has been completed and utility pipes were plugged in early **1983.** Chain-link fences have been installed to discourage access to

[17] Specifications for the barrier wall at Love Canal are provided in NYS/DEC, Love *Canal Project 1 Site Containment System, Niagara Falls, New York,* vol. 1, August 1982.

[18] L. R. Silka and J. W. Mercer, "Evaluation of Remedial Actions for Groundwater Contamination at Love Cam], New York," *Management of Uncontrolled Hazardous Waste Sites,* Hazardous Waste Control Research Institute, 1982, pp. 159-164.

● The new data on dioxin contamination were not available to OTA. They are being collected by a contractor for NYS/DEC.

● *See app. C for OTA's analysis of the EPA conclusions.

[19] R. Dewling, U.S. EPA Region II, personal communication, March 1983; and N. Nosenchuck, NYS/DEC, personal communication, May 1983.

[20] Geotrans, Inc., *Cross-Sectional Simulations To Examine Proposed Wall at Love Canal, New York,* oral presentation given to OTA, May 12, 1983.

[21] Statements made by NYS/DEC during a meeting on May 19, 1981.

contaminated areas in Bergholtz and Blackfoot Creeks. Disposal of the contaminated sewage sediment awaits permits from U.S. EPA. There are **375** drums of this material being stored at the treatment facility. No *action has yet been taken for contaminated storm sewers within the EDA.*

NYS/DEC initiated a monitoring study to determine the extent of contamination within the storm sewer systems located in the EDA. Chemicals of concern in this study include priority pollutants and dioxin. A total of 1,000 samples have been analyzed. The study results are not yet available.

Discussions with the Love Canal Area Revitalization Agency (LCARA) indicate that decisions on the future use of the properties within the EDA have not been made.[22] The Agency plans to delay any such decisions until the OTA review is released. An environmental impact assessment is required by State law before any reuse of the EDA is allowed. LCARA has begun the assessment process.[23] Some sense of urgency is felt by the Agency to resolve the issue of habitability so that revitalization plans can be developed. It should be noted that 100 residences within the EDA are currently occupied. A majority of these (66 units in Griffon-Manor and Senior Citizen housing) are situated adjacent to the canal area.

Uncertainties Associated With the Remedial Action

There are four areas of uncertainty that can affect projections of the long-term integrity of the remedial technology:

1. Remedial action in the EDA.
2. Leak detection systems for the barrier wall and leachate collection system.
3. Long-term monitoring programs.
4. Institutional mechanisms for long-term protection of EDA residents.

While this brief OTA review cannot provide any suggestions for reducing the impact that these uncertainties may have, it is imperative that any decision of habitability consider them and their consequences for continued protection of the residences in the EDA.

Remedial Action in the EDA

Both EPA and NYS/DEC officials have based their analysis of the need (or lack thereof) for remedial action in the EDA, beyond that required for the storm sewer system, solely on the results of the 1980 monitoring study. The major concern was whether contamination observed in this area resulted from migration of chemicals from the Love Canal landfill. Because the EPA monitoring study indicated that the only portions contaminated by Love Canal wastes (within the EDA) were storm sewers and surface water sediments, no large scale remedial action is planned.

According to NY officials, the actual extent of contamination in the storm sewers has not been fully deterrnined.[24] A monitoring study is in progress and once the data are available, a decision will be made about an appropriate method of cleanup. With the installation of the barrier wall and cover, future contamination of the EDA from Love Canal chemicals is not anticipated.

Unfortunately, the 1980 monitoring data were not sufficient to determine if hot spots of contamination exist. Although data are recorded by subsection of the EDA, all values were averaged for the area as a whole. If hot spots do exist and remain untreated, the area will continue to pose a threat to the health of the residents.

Leak Detection Systems

Any analysis of the effectiveness of the remedial action must include some consideration of the capability to detect failure at some time after the system is complete. A major limitation of environmental control systems, however, is that there are few methods to test their continued integrity. Any cracks that develop in the wall could serve as possible routes for migration of chemicals. If the leachate collection system is working properly, such cracks should not pose a threat for outward migration of contaminants. If the system does not operate properly, however, pooling of ground water could occur near subsurface structures. These could consist of rock formations within the area as well as the basement structures containing rubble from destroyed houses on land immediately adjacent to the canal. Subsurface barriers could impede downward movement of ground water and facilitate lateral movement through breaks in the wall.

Officials at NYS/DEC estimate that a well-made concrete wall should last for at least 50 years. Even if it lasts twice the expected lifetime, cracks can be expected. The only means to detect these cracks would be a decrease in the water table elevations. The synthetic membrane cap has an estimated lifetime of 20

[22] R. Morris, Executive Director, LCARA, Niagara Falls, N. Y., personal communication, March 1983.
[23] Statements made by LCARA officials at a meeting on May 19, 1983.

[24] J. Slack, NYS/DEC, personal communication, March 1983, restated at a meeting on May 19, 1983.

years. Evaluation of water-table elevation data and changes in volume of leachate collected in the drainage system are the currently available methods of determining the existence of damage.

Monitoring Programs

A final area of uncertainty concerns long-term monitoring strategies. The monitoring effort that is planned may not provide sufficient warning about migration and accumulation of chemicals outside the barrier wall. The State plan requires only a ground water monitoring program.[25] It is presumed that all mobilized chemicals would eventually migrate into the shallow aquifer system within the barrier wall.

While ground water monitoring is a necessary safeguard for containment technology, it is possible to have contamination of soil and air before substantial levels of contaminants are detected in ground water samples. For example, if cracks develop in the cap, volatile compounds would be released to the air rather than be transported through water. This situation existed when damage to the original cap occurred, and noxious odors were apparent around the canal area.[26] Also, those chemicals that have a strong affinity for organic material can be filtered out of contaminated water as it passes through soils high in organic components; this property is typical of clays found in the vicinity of the canal. Thus, any migration of contaminated water outside of the barrier wall could lead to a build-up of such chemicals in the soil and perhaps be taken up by vegetation. However, at present no plans exist to do any surveillance monitoring of air, soil, or biota.

Such accumulation and uptake of these types of chemicals, often compounds that are very persistent in the environment, would not be detected through ground water monitoring. It is likely that the absence of chemicals in the ground water samples would be interpreted as no contamination of the area surrounding the canal when, in fact, contamination in soil and biota could be present. It may be prudent for NYS/DEC to develop a monitoring strategy that observes biotic changes in areas adjacent to and outside the barrier wall as well as analyzing soil and ground water samples.

Institutional Mechanisms for Long-Term Protection of EDA Residents

The first area of uncertainty surrounding the planned remedial action concerns the need for long-term appropriations by the State of New York and future restrictions on the use of the canal property. Costs for operation, maintenance, and replacement of the wall, covers, and leachate collection system are high. For example, current expenditures for operation and maintenance of the treatment facility is approximately $0.4 million.[27] Included within the lifecycle costs presented in table A-2 are requirements for replacement of the following:

- synthetic cover every 20 years,
- major equipment at the treatment facility every 20 years,
- treatment plant building every 50 years,
- leachate collection system every 50 years.

Institutional and legal mechanisms are needed to provide some assurance of a long-term commitment to meet these costs. Although the current State administration may be completely committed to providing sufficient funds for maintenance of the remedial action, there are no guarantees that 10, 20, or 50 years from now the same commitment will hold. Because the remedial action chosen was environment control rather than waste control, the source of contamination will not be eliminated.

It should be emphasized that the current problem in Love Canal arose because the *original use of the canal was ignored or forgotten and improper use of the land* initiated. The original deed given by Hooker Chemical Co. to the Niagara Falls Board of Education included statements about the hazardous nature of the contents of the canal.[28] The Board chose to ignore these warnings and proceeded with construction of sewer systems that cut through the canal wall and a school that damaged the cap.

Without strong institutional mechanisms that will guarantee continued protection for the EDA, these original problems could reoccur 50 years from now, when the current actors in this unfortunate drama have left the scene. At present the State has a temporary easement for an undetermined time, which provides some protection against improper use of the land. However, the canal property currently has three different owners: the southern region is owned by a private citizen; the central section belongs to the Board of Education; the northern portion is owned by the City of Niagara Falls. If at any time in the future the State of New York relinquishes its temporary easement, these owners will be free to utilize their property as they see fit. There are presently no strong legal or institutional mechanisms that will prevent resale and reuse of the land by the current owners.

[25] J. Slack, NYS/DEC, personal communication, March 1983.

[26] Statements made by State officials during a meeting with NYS/DEC, NYS/DOH, NYS/DOL, and LCARA on May 19, 1983.

[27] N. Kolack, NYS/DEC, personal communication, April 1983.

[28] E. Zuesse, "Love Canal, the Truth Seeps Out," *Reason*, February 1981, pp. 16-33.