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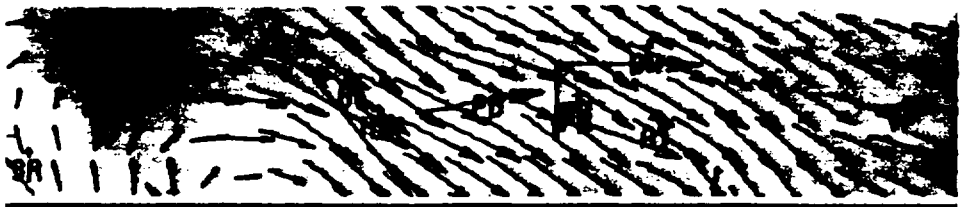

DAMES & MOORE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF:
5HS-11

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

PPG Industies, Inc.
Mr. Mal Petroccia
Environmental Sciences Center
260 Kappa Dr.
Pittsburgh, PA 15238

PPG Ind., Inc.
Mr. David Cannon
One PPG Place
Pittsburgh, PA 15222

E. I. DuPont
Mr. Bernie Saydlowski
Barley Mill Plaza
P21-1152
Wilmington, Delaware 19880

E. I. DuPont
Mr. Ross Austin
Legal Department
1007 Market St.
Wilmington, Delaware 19898

Dear Sirs,

The February 3, 1989 Bowers Landfill Feasibility Study Report, incorporating the enclosed modifications and those contained in the Ohio Environmental Protection Agency's February 21, 1989 letter to you (for the enclosed comments "page IX source 4-the 2nd one" and "page 4-6 source 4", the United States Environmental Protection Agency approach to addressing the comment will be used rather than the Ohio EPA's), is approved, per the 1985 Consent Order, by the U.S. EPA and the Ohio EPA.

Sincerely,

Erin M. Moran
Remedial Project Manager
United States Environmental Protection Agency

Deborah Strayton
Site Project Manager
Ohio Environmental Protection Agency

Enclosure

ATTACHMENT

SPECIFIC CHANGES TO
FEASIBILITY STUDY, THIRD DRAFT,
FEBRUARY 3, 1989

Page	Comment Source*	Comment
iv	4	The second full paragraph should be replaced with the equivalent paragraph from the second draft FS. The paragraph should read: "The landfill represents a potential threat of future contaminant releases that may present a danger to public health, welfare, and environment. This potential exists because portions of the landfill are poorly covered, and there is evidence that hazardous wastes were deposited in the landfill. Semiannual flooding by the Scioto River, usually in the spring and winter, also contributes to the threat of contaminant release."
ix	4	The last sentence of the second paragraph should be deleted.
ix	4	The last sentence of the last paragraph should be deleted.
3-11	1	The phrase "Once a year" should be deleted from the last sentence on this page.
3-18	5	The third sentence of the second paragraph should be changed to read: "Bowers Landfill is not expected to generate significant quantities of gas; after 20 years of inactivity, the majority of the disposed municipal refuse will have biodegraded."
4-6	4	The last sentence of the second paragraph should be deleted.
4-7	1, 2	The first paragraph should be changed to read: "The diverse vegetative cover may result in greater evapotranspirative withdrawal from the surficial soils than would occur with shallow rooted grass or legume species. However, roots from this vegetation provide a direct entry of precipitation and flood waters into the waste materials. The presence of this vegetation may indicate that the landfill is partially saturated."
4-10	4	The last sentence of the third full paragraph should be deleted.
4-11	5	The last sentence of the first full paragraph should be deleted.

* 1 U.S. EPA comments on second draft FS (October 11, 1988)
2 OEPA comments on second draft FS (October 11, 1988)
3 U.S. EPA comments on revisions to Alternatives 4, 8, and 9 and Appendix D (January 27, 1989)
4 Changes to second draft FS not specifically requested by U.S. EPA or OEPA; some of these changes are presented in facsimile from David Cannon, PPG (February 6, 1989)
5 Additional changes to third draft FS based on U.S. EPA review

Page	Comment Source	Comment
4-21	4	The last two sentences of the second full paragraph should be revised to read: "In summary, there is no evidence that potential leachate generation is a cause of water pollution, and thus leachate collection is not currently necessary. However, OAC 3745-27-10(H)(1) may be relevant and appropriate in the future. This regulation requires that leachate must be collected if it is detected during the 3-year monitoring period after closure in such quantities that the Director or Health Commission believes that a substantial threat to water pollution exists."
4-41	3	The words "repairs to the side slopes and" should be deleted from the second sentence of the second full paragraph.
4-43	5	The last sentence of the first paragraph should be deleted.
5-2	4	The next to last paragraph on this page should be revised to read: "There would be no reduction in toxicity, mobility, or volume; potential infiltration would be approximately 34 percent of precipitation. The present vegetative cover of trees, shrubs, and grasses would remain and would provide some protection against erosion (except immediately adjacent to the river). However, root systems from trees on the landfill top and side slopes would provide a direct pathway for flood waters and precipitation to contact underlying waste materials. Further, over time, the combination of saturated soil conditions during flooding and high winds could result in complete uprooting of trees on the landfill side slopes and the exposure of waste materials. There are no costs associated with this alternative."
5-2	5	The last paragraph on this page should be revised to read: "No remedial action would be taken to remove, control migration from, or minimize exposure to chemicals. Visible surface debris would remain, and areas of erosion and ponding would not be repaired. Public health risks due to current levels of contamination, as identified in the EA, would be unchanged:"
5-3	5	The second full paragraph on this page should be revised to read: "There would be no reduction in toxicity, mobility, or volume. No remedial action would taken to control migration of or exposure to chemicals. As with Site Alternative 1, the current vegetative cover would remain. The long-term risks due to infiltration through or failure of this cover would not be reduced. Visible surface debris would remain and areas of erosion and ponding would not be repaired."
5-4	5	The first sentence on this page should read: "Public health risks due to current levels of contamination are as follows:"
5-4	5	The third full paragraph on this page should read: "Under the worst case scenario, the carcinogenic risk from current levels of contamination is within the target risk range and in fact near the lower end of the risk range. The hazard index does not represent a significant noncarcinogenic risk. However, long-term risks due to infiltration of the cover and potential failure of the side slopes would not be reduced by this alternative.

Page	Comment Source	Comment
5-4	1	The last paragraph should be revised to read: "Portions of State of Ohio Department of Health Rule HE-24 for licensed solid waste landfills may be 'relevant and appropriate' to closure of the landfill. Under HE-24-09, the 'cover shall be of earth . . . prevent . . . unsightly appearance, will permit minimal percolation of water.' The final cover shall '. . . be graded to serve its intended purpose . . .' Portions of current State of Ohio solid waste closure standards may be relevant and appropriate to remedial action of the landfill. The appearance of the diverse vegetative cover, more than 20 years after ceasing landfilling, would be improved by removal of surface debris and by surface repairs. However, this alternative would not 'permit minimal percolation of water' and would not attain relevant and appropriate portions of current closure standards, such as a two-foot minimum cover depth. Repairs to the landfill cover and regrading would improve surface runoff, reducing ponding and somewhat reducing infiltration. Erosion control at areas that may be exposed to high river velocities would improve erosion protection."
5-5	4	The following paragraph should be inserted above the first full paragraph on this page: "The natural diversity of plant species indicates that they should maintain their dominance of the site. However, the current vegetative cover may have minimal long-term effectiveness. Root systems from trees on the landfill top and side slopes would provide a direct pathway for flood waters and precipitation to contact underlying waste materials. Further, over time, the combination of saturated soil conditions during flooding and high winds could result in complete uprooting of trees on the landfill side slopes and the exposure of waste materials."
5-5	5	The first full paragraph should be changed to read: "There would be no reduction in toxicity or volume; there would be some reduction in the potential for migration attributable to repairs to the landfill cover. However, because of the limited nature of these repairs, the reduction in infiltration would be minor."
5-5	5	The third full paragraph on this page should read: "Public health risks due to current levels of contamination are as follows:"
5-5	1	The last paragraph on this page should be changed to read: "Deed and site restrictions would be effective in preventing ground water ingestion and limiting exposure to contaminated soils. The repairs to the landfill cover and erosion protection, together with an ongoing maintenance plan for the landfill surface and vegetative cover, should result in some control of releases to the environment. Under the ground water monitoring program, if concentrations show a statistically significant upward trend, then a protective action would be triggered. However, the long-term effectiveness and overall protection offered by Alternative 3 is less than for alternatives which include a complete cover of the existing landfill surface."
5-6	1	The last sentence of the first paragraph should be deleted.
5-6	5	The word "mobility" should be deleted from the fourth paragraph.

Page	Comment Source	Comment
5-7	1, 4	The last sentence of the second full paragraph should be deleted.
5-7	5	The second sentence of the fourth full paragraph should be changed to read: "Bowers Landfill is not expected to generate significant quantities of gas; after 20 years of inactivity, the majority of the disposed municipal refuse will have biodegraded."
5-7	5	The word "mobility" should be deleted from the last paragraph.
5-8	1, 4	The last sentence of the fourth full paragraph should be deleted.
5-8	5	The word "mobility" should be deleted from the last paragraph.
5-9	5	The word "mobility" should be deleted from the first sentence of the last paragraph.
5-10	5	The word "mobility" should be deleted from the first sentence of the last paragraph.
5-11	5	The following sentence should be added to the end of the fifth full paragraph: "However, the side slope cover would not comply with closure standards."
5-12	5	The first sentence of the second paragraph should read: "There would be no reduction in toxicity or volume, but mobility of contaminants would be reduced."
5-12	4	The last sentence of the fifth paragraph should be deleted.
D-5	3	The last sentence of the first paragraph should be replaced with the following sentences: "Relatively small changes in the estimates for the physical properties of soil can have a significant effect on the estimated side slope stability. Therefore, a more detailed study of side slope stability, based on geotechnical measurements of soil properties, will be conducted during the design phase."

REPORT

FEASIBILITY STUDY
BOWERS LANDFILL
CIRCLEVILLE, OHIO

JOB NO. 00850-042-017
FEBRUARY 3, 1989

DAMES & MOORE

DAMES & MOORE A PROFESSIONAL LIMITED PARTNERSHIP

February 3, 1989

Ms. E. Moran
U.S. EPA, Region V
230 South Dearborn Street
Chicago, Illinois 60604

Ms. Deborah Strayton
Ohio EPA, Central District Office
1800 Water Mark Drive
Columbus, Ohio 43266-0149

Dear Ms. Moran and Ms. Strayton:

Re: Report, Feasibility Study, Bowers Landfill

On behalf of PPG Industries, Inc. and E.I. DuPont de Nemours & Company, this letter transmits 14 copies (9 to U.S. EPA and 5 to OEPA) of the Feasibility Study for the Bowers Landfill prepared by Dames & Moore.

The report contains responses to the comments by USEPA and OEPA on the Second Draft Report, Feasibility Study, Bowers Landfill issued by Dames & Moore on August 19, 1988. Subsequent to issue of the Second Draft Report, two additional agency submittals have been made:

- Site Alternatives 8 and 9, submitted December 13, 1988
- Site Alternative 4, submitted December 22, 1988

This report also contains responses to the comments made by USEPA and OEPA on these submittals.

At the request of the agencies, Chapter 6, Preferred Alternative Conceptual Design, has been deleted from the report. Other changes have been made to the report as explained to you in letters issued today by the companies.

Yours very truly,

DAMES & MOORE

CJ Riley

Chris J. Riley, P.E.
Senior Chemical Engineer

S. Edwards

Stuart Edwards, P.E.
Partner (Ltd.)

STATE OF OHIO
STUART EDWARDS
E-47213
REGISTERED PROFESSIONAL ENGINEER

CJR:vkf:Bowers B

USEPA (9)
OEPA (5)
cc: M.W. Petroccia - PPG (3)
B.K. Saydlowski - DuPont (4)
J. Dirgo - PRC (1)

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EXECUTIVE SUMMARY

Dames & Moore performed a Remedial Investigation (RI) at the Bowers Landfill, Circleville, Ohio, between July 1986 and March 1988. The purpose of the RI was to characterize the physical, biological, and chemical environment at and near the site, and to assess the nature and extent of contamination at the landfill. The degree of risk represented by the landfill was subsequently estimated through completion of a final Endangerment Assessment (EA). This Feasibility Study (FS) was conducted to develop, assess, and discuss appropriate alternatives for site remediation.

PURPOSE

The purpose of the FS is to identify and to evaluate a range of remedial alternatives for the site as required by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and a Consent Order entered by the appropriate parties dated February 22, 1985 along with the attachments thereto. The FS is to result in selection of the most "cost-effective remedial alternative that effectively mitigates and minimizes threats to, and provides adequate protection of, the public health, welfare and environment," as specified in 40 CFR 300.68(i). The need to evaluate remedial alternatives for the site was based on the findings of the RI and conclusions of the EA.

SITE BACKGROUND AND PROBLEM AREAS

Site Background

Bowers Landfill, shown in Drawing 2 of the FS, is located in Pickaway County, approximately 25 miles south of Columbus, Ohio, and 2 miles north of the city limits of Circleville, Ohio. The L-shaped landfill extends northerly from the Circleville-Florence Chapel Road, then turns west and continues towards the Scioto River for about 1,000 feet. It is bordered on the north and west by agricultural land on an alluvial floodplain and to the east by a drainage ditch between the landfill and a bluff.

The landfill is situated on the alluvial floodplain and is vegetated by a relatively heavy growth of grasses, weeds, and shrubs with a large number of trees, principally on the slopes of the berms, that reach heights of 20 feet or more.

The surface soils in the site vicinity are silty clay and clay averaging approximately 10 feet in thickness. Below the upper fine-grained sediments are two sand and gravel alluvial aquifers separated by a silty clay zone that is 10 to 20 feet thick. Shale bedrock occurs below the lower aquifer at depths below ground surface from 40 to 100 feet.

Based upon information presented in the RI, ground water recharge at the site is from the east and discharges to the west or southwest. The floodwater of the river typically reaches the toe of the landfill several times each year and overtops the entire landfill an average of once every 5 to 10 years.

Site History

The landfill, which was never licensed under State of Ohio Rule HE-24, probably commenced operation in late 1958 or in 1959, and ceased operation in 1969. It is reported that the majority of waste material deposited on the site consisted of residential refuse. Additionally, wastes also came from at least three manufacturing plants and two grain elevators in the area. Wastes sent to the landfill from PPG Industries and E.I. DuPont de Nemours Company, Inc. were estimated to total 1,700 and 6,000 tons of material, respectively. These wastes included plant refuse and organic and inorganic chemicals. Refuse was burned at the facility over a period of several years.

According to a report from a person assumed to be familiar with the operation (Burgess & Niple, 1981), the method of landfilling was an area-type fill; excavation did not occur, but rather, refuse was deposited directly on the ground and covered with soil from the sand and gravel operation. Miscellaneous debris is visible along portions of the landfill, that may be the result of inadequate covering or of dumping after the landfill operation was shutdown.

Areas of Interest

Site problems were defined based on the findings of the RI and the conclusions of the EA.

Surface water at the site was considered in the EA to be a potential risk by direct ingestion, ingestion of aquatic animals, and by direct contact with surface water by aquatic animals. The EA states that the risk due to ingestion of surface water is based on a lifetime exposure, and the criterion is not directly applicable to the limited exposure under this scenario; furthermore, the risk is very low due to infrequent exposure and the low contaminant levels found at the site. The EA considered that the risk from ingestion of aquatic animals is limited, and also states that the risk from direct contact with surface water by aquatic animals may overestimate the potential risks. On the basis of the low levels of risk represented by the exposure routes, surface water does not warrant remediation at the site.

The EA identified ingestion of ground water as a potential risk under a worst case exposure scenario due to the presence of barium and benzene. The potential risk identified in the EA due to ingestion of ground water assumes that the point of exposure is from wells that in the future potentially may be located downgradient of the landfill. The EA considered it unlikely that wells would be placed in such an area, since it is regularly flooded.

The EA concluded that the risk due to barium is probably very small. The Maximum Contaminant Level (MCL) and Contract Required Detection Limit (CRDL) for benzene are 5 μg/L. Benzene was found, near the CRDL, at only one sample location, during each of two sampling rounds, at concentrations of 6 μg/L and 4 μg/L, respectively. These data indicate that worst case benzene contamination at the site averages the MCL and results in an incremental carcinogenic risk within the target range of 10^{-4} to 10^{-7}. The potential remedial alternatives for the ground water address the low risks associated with barium and benzene.

Surface soils were identified in the EA as a potential risk on the assumption that children would ingest soil while on the site. The three compounds of concern in surface soils are total PAHs, PCBs, and lead. The incremental carcinogenic risks for total PAHs and PCBs, based on the worst case, are within the target range of 10^{-4} to 10^{-7}. Based on the maximum lead concentration (179 mg/kg) at one sampling location and the worst case soil ingestion rate, a potentially significant noncarcinogenic risk was calculated in the EA; the EA states that the risk may be overestimated because it involves worst case assumptions. Under the most probable case scenario, there is not a potentially significant

noncarcinogenic risk. Additionally, the Centers for Disease Control (1985) has stated that lead in soil and dust appears to be responsible for blood lead levels in children increasing above background levels when the concentration in soil or dust exceeds 500 to 1,000 mg/kg. This range is well above the maximum lead concentration found in soils at Bowers Landfill (179 mg/kg). This further supports the fact that the calculated risk may overestimate the actual risk.

The potential remedial alternatives for the surface soils address the low risks associated with lead, PCBs, and PAHs. The highest levels of each of these contaminants were at or in the immediate vicinity of the landfill.

The landfill presents risks to the public health, welfare, and the environment as a consequence of exposed surface debris, potential exposure to contained wastes, and the potential for future releases of contaminants. However, during recent investigations, there has been no evidence of leachate seeps from the landfill. It is not clear that the low levels of chemicals detected downgradient of the landfill are attributable to the landfill.

PERFORMANCE GOALS

Of the number of compounds detected at the site, nine indicator chemicals were selected in the EA and were used to establish strategies for remediation. The indicator chemicals are the most concentrated, toxic, mobile, and persistent compounds of those detected, and therefore are potential chemical-specific ARARs.

At the time operations ceased, State of Ohio Department of Health Rule HE-24 regulated licensed solid waste landfills. The Bowers site was not licensed. This rule and current state landfill closure regulations may, however, be "relevant and appropriate."

The performance standards for surface soil were derived from the EA and designed to meet the acceptable risk range for public health.

REMEDIAL ACTION ALTERNATIVES

The selection of site remedial actions results from a successive development and screening process. First, the general response actions (GRAs) that address remediation of individual site areas are listed. These general response actions are subdivided into specific

technologies that are screened for applicability and feasibility for remediation. Those technologies that pass this screening are assembled into media-specific alternatives that address each of the site problem areas. In accordance with U.S. EPA *Interim Guidance on Superfund Selection of Remedy* (OSWER Directive No. 9355.0-19), alternatives are to be developed where feasible and practicable to include the following:

1. Treatment alternatives for source control that would eliminate the need for long-term management (including monitoring).

2. Alternatives involving treatment as a principal element to reduce the toxicity, mobility, or volume of site wastes.

It is also required to develop two additional alternatives:

1. An alternative that involves containment of waste with little or no treatment, but provides protection of human health and the environment primarily by preventing potential exposure or reducing the mobility of the waste.

2. A no action alternative.

Descriptions are developed for each alternative to enable subsequent evaluations to be carried out. The initial alternative screening is a broad and largely qualitative assessment of each alternative. The alternatives are evaluated on a general basis with respect to their effectiveness, implementability, and cost.

Those media alternatives carried through this screening are combined into site remedial alternatives that address remediation of all the identified problem areas at the site. Nine site alternatives resulted from this analysis. The summary table on the next page shows each component of the site alternatives in a matrix form, together with economic information. The following descriptions define each site alternative and include a comparison of each one with the others.

Alternatives that Require No Action

Site Alternative 1:

- **No action**

Under this Site Alternative 1, no remedial action would be taken to remove, control migration from, or minimize exposure to chemicals. This alternative is not recommended.

SUMMARY MATRIX
BOWERS LANDFILL SITE ALTERNATIVES

Remedial Action	1	2	3	4	5	6	7	8	9
•No action	x								
•Ground water monitoring		x	x	x	x	x	x	x	x
•Deed and site restrictions		x	x	x	x	x	x	x	x
•Management of surface debris			x	x	x	x	x	x	x
•Improvements to landfill side slopes									x
•Local repairs to existing landfill cover			x						
•Erosion control and drainage improvements			x	x	x	x	x	x	x
•Natural clay cover over landfill				x	x	x			
•Natural clay cover over landfill top									x
•Gas venting system					x	x	x	x	
•Leachate collection system					x	x	x	x	
•Flood protection dike						x	x		
•Synthetic membrane cap over landfill							x	x	
Total Present Worth ($ million)	0.0	0.5	2.2	4.3	6.7	12.2	13.8	8.6	3.4

Alternatives that Involve Containment of Waste with Little or no Treatment, but Provide Protection of Human Health and the Environment Primarily by Preventing Potential Exposure or Reducing the Mobility of the Waste

Site Alternative 2:

- **Ground water monitoring**
- **Deed and site restrictions**

Under Site Alternative 2, deed and site restrictions would be imposed, and a ground water monitoring program would be operated at the site. Public health risks from ingestion of soils would be zero under the most probable scenario and, under the worst case scenario, would result in a carcinogenic risk towards the low end of the target range. The site does not represent a potential noncarcinogenic risk. The imposition of a deed restriction preventing use of the site for ground water extraction between the landfill and the river would result in a risk of zero for both the most probable and worst case exposure scenarios.

The ground water monitoring program would detect any increase in contaminant levels. If concentrations should show a statistically significant upward trend, a protective response would be triggered.

Present worth is estimated at $0.5 million, and implementation time, at 1 month.

Site Alternative 3:

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Local repairs to existing landfill cover**
- **Erosion control and drainage improvements**

Site Alternative 3 combines the advantages of Site Alternative 2, in reducing risks to public health from ingestion of soils and ground water, with improvements to the landfill cover and to erosion control and drainage.

The appearance of the current stable and diverse vegetative cover, more than 20 years after ceasing landfilling operations, would be improved by removal of surface debris and by surface repairs. Management of the vegetation would maintain the present evapotranspirative withdrawal over what would occur with a cover of shallow-rooted grasses. Repairs to the landfill cover would improve surface runoff and reduce ponding and infiltration. Erosion control at areas that may be exposed to high river velocities would

further improve erosion protection. These improvements, together with an ongoing maintenance program for the landfill surface and vegetative cover, should continue to control any significant releases to the environment.

The public health risks calculated under the worst case scenario would be generally the same as for Site Alternative 2, but any future potential risks would be reduced. The ground water monitoring program would ensure detection of any future potential release and trigger a protective action, if necessary. In summary, this site alternative would be protective of the public health and environment, could be readily and rapidly implemented while having few short term impacts, and is cost-effective.

Present worth is estimated at $2.2 million, and implementation time, at 3 months; up to 1,225 truckloads are estimated to transport surface debris, clay for landfill repairs, and riprap for erosion protection.

Site Alternative 4:

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Natural clay cover over landfill**

Site Alternative 4 involves the same features as Site Alternative 3, but instead of repairing the cover, the present vegetative cover would be removed and a natural clay cover would be installed. Public health risks from ingestion of soils and ground water would be slightly reduced compared to Site Alternative 2 by the installation of a natural clay cover over the landfill, and improvements to erosion control and drainage, and slightly reduced compared to Site Alternative 3 by the installation of a natural clay cover over the landfill. The natural clay cover would enclose essentially all areas of soil with elevated levels of lead.

The landfill would be covered in accordance with current State of Ohio solid waste landfill closure standards. The cover would reduce infiltration to approximately 10 percent of precipitation. Preparation would require removal and disposal of the existing vegetative cover, together with importation of the clay (if the field to the west of the landfill is not used). Up to 8,200 truckloads are estimated to transport surface debris, clay for landfill repairs, and riprap for erosion protection. This is substantially more than haulage requirements for the previous site alternatives.

Present worth of this alternative is estimated at $4.3 million, and implementation time, at 10 months.

The landfill would be covered in accordance with current solid waste landfill closure standards, and the site alternative would be protective of the public health and environment. It would, however, be less cost-effective than Site Alternatives 2,3, and 9.

Site Alternative 5:

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Natural clay cover over landfill**
- **Gas venting system**
- **Leachate collection system**

Site Alternative 5 is the same as Site Alternative 4, except that the cover would incorporate a gas venting system and a leachate collection system.

State of Ohio solid waste landfill closure standards would be exceeded. The landfill is expected to be essentially inert after 20 years of inactivity, particularly considering that the majority of the waste material was residential refuse, which readily biodegrades. This is further supported by the fact that there have been no reports of gas activity (though small quantities may be generated under the cap from decaying vegetation). Thus, there is no evidence that gas venting would be necessary. During the RI, there was very little evidence of seeps or leachate. Since there is no evidence of a significant leachate discharge, a leachate collection system is not required.

Present worth is estimated at $6.7 million, and implementation time, at 10 months. Approximately an additional 1,250 truckloads of gravel for the gas venting and leachate collection systems may be required for this alternative over that required for Site Alternative 4.

This site alternative would exceed current solid waste landfill closure standards and would be protective of the public health and the environment. It would, however, be less cost-effective than Site Alternatives 2,3,and 9.

Site Alternative 6:

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Drainage improvements**
- **Natural clay cover over landfill**
- **Gas venting system**
- **Leachate collection system**
- **Flood protection dike**

Site Alternative 6 is the same as Site Alternative 5, with the addition of a flood protection dike.

The dike would be effective at shielding the landfill from the 100-year flood and further reducing infiltration of surface water. In conjunction with the clay cover, and gas venting and leachate collection systems, there is minimal potential for migration of contaminants.

Present worth is estimated at $12.2 million, and implementation time at 18 months.

More than 20,000 truckloads of material may be needed to implement this site alternative, including approximately 12,000 truckloads to construct the flood protection dike.

There is no evidence of an upward trend in chemical concentrations, even though the field to the west of the landfill is flooded several times each year. Except for the ends adjacent to the river, there is no evidence of erosion of the landfill as a result of flooding. Since, under Site Alternatives 3, 4, 5, 8, and 9, these ends would be protected by riprap, there is no evidence that a flood protection dike is warranted or would be cost-effective.

Site Alternative 7:

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Drainage improvements**
- **Gas venting system**
- **Leachate collection system**
- **Flood protection dike**
- **Synthetic membrane cap over landfill**

Site Alternative 7 is the same as Site Alternative 6, with the addition of a synthetic membrane cap over the low-permeability clay cap.

State of Ohio solid waste landfill closure standards do not require synthetic membrane caps. The synthetic membrane cap would reduce infiltration to 0.01 percent of precipitation.

Present worth is estimated at $13.8 million, and implementation time, at 18 months. The replacement of the natural clay cover by a synthetic membrane cap would cost an additional $1.7 million. This additional expenditure would not be cost-effective since there is no evidence of an increase in ground water chemical concentrations.

Site Alternative 8:

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Gas venting system**
- **Leachate collection system**
- **Synthetic membrane cap over landfill**

Site Alternative 8 is the same as Site Alternative 5, with the addition of a synthetic membrane cap over the low-permeability clay cap.

State of Ohio solid waste landfill closure standards do not require a synthetic membrane cap. The synthetic membrane cap over the landfill would reduce infiltration to 0.01 percent of precipitation.

Present worth is estimated at $8.6 million, and implementation time at 10 months. The replacement of the natural clay cover by a synthetic membrane cap would account for $1.7 million. This additional expenditure would not be cost-effective since there is no evidence of an increase in ground water chemical concentrations.

Site Alternative 9:

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Improvements to landfill side slopes**
- **Erosion control and drainage improvements**
- **Natural clay cover on on landfill top**

Site Alternative 9 combines the benefits of a natural clay cover on the landfill top, of the type described under Site Alternative 4, with the improvements to the side slopes of Site Alternative 3.

The landfill top would be covered in accordance with current State of Ohio solid waste landfill closure standards. The landfill side slopes have been shown to be stable, based upon preliminary calculations. Furthermore, the broad diversity of vegetation on the side slopes provides surficial and deep stabilization, and protects against erosion from precipitation and periodic flooding. Repairs to the side slopes, together with erosion control in areas that may be exposed to high river velocities, would further improve protection. These improvements, together with an on-going maintenance program for the landfill surface vegetative cover, should continue to control releases to the environment.

Infiltration through the landfill cover is estimated at 15.8 percent of precipitation. The public health risks would be slightly reduced compared to Site Alternative 3 by the installation of a natural clay cover over the landfill top. The ground water monitoring program would ensure detection of any future potential release and trigger a protective action, if necessary. In summary, this site alternative would be protective of the public health and environment, could be readily implemented while having relatively few short-term impacts, and is cost-effective.

Present worth is estimated at $3.4 million, and implementation time at 8 months. Up to 5,200 trucks are estimated for transport of surface debris, clay for landfill repairs, and riprap for erosion protection.

LIST OF ACRONYMS

AIC	Acceptable Chronic Intake Level
ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criteria
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR	Code of Federal Regulations
CRDL	Contractual Required Detection Limit
DuPont	E.I. DuPont de Nemours and Company
EA	Endangerment Assessment
EPA	Environmental Protection Agency
FS	Feasibility Study
GRA	General Response Action
HDPE	High Density Polyethylene
HELP	Hydrologic Evaluation of Landfill Performance Model
HSL	Hazardous Substance List
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goals
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
ORC	Ohio Revised Code
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PPG	PPG Industries
PRC	Planning Research Corporation
PRP	Potential Responsible Party
PTI	Permit to Install
PW	Present Worth
PVC	Polyvinyl Chloride
RAMP	Remedial Action Master Plan
RCRA	Resource Conservation and Recovery Act of 1976
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act of 1986
SCS	Soil Conservation Service
SPHEM	Superfund Public Health Evaluation Manual
USGS	United States Geological Survey
WQC	Water Quality Criteria

1.0 INTRODUCTION

The Bowers Landfill, near Circleville, Ohio, is the site of a Remedial Investigation/Feasibility Study (RI/FS) that is being conducted pursuant to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The responsibilities created by the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), are discharged through implementation of the NCP. SARA authorizes a remediation plan for sites that pose a potential threat to public health and the environment.

The Bowers Landfill currently ranks 170 on the National Priorities List (NPL) of 1,077 sites.

Region V of the U.S. Environmental Protection Agency (U.S. EPA) is the lead federal agency for the Bowers Landfill RI/FS. Two of the potentially responsible parties (PRPs) are on record as users of the site for waste disposal and have funded this study: PPG Industries (PPG) and E.I. DuPont de Nemours and Company (DuPont).

The basis for the RI/FS scope of work was initially included in a Remedial Action Master Plan (RAMP) prepared for the site (U.S. EPA, 1983). The scope of work was further defined in the course of discussions between PPG, DuPont, U.S. EPA, and Ohio Environmental Protection Agency (OEPA), resulting in establishment of a Consent Agreement between these parties. Dames & Moore was selected by PPG and DuPont to conduct the RI/FS.

A draft RI report was submitted on July 30, 1987, based on a primary investigation that took place during the period from July 1986 through May 1987. The RI report, revised from the draft to address U.S. EPA/OEPA comments, was submitted November 18, 1987. The Endangerment Assessment (EA) was prepared by Planning Research Corporation (PRC) and issued as a draft report to the U.S. EPA on December 14, 1987. A supplemental field investigation was conducted in February and March 1988, and a revised RI report was issued on April 28, 1988. A final EA was prepared by PRC and issued to the U.S. EPA on May 12, 1988. A second draft FS report was issued on August 19, 1988 and included responses to Agency comments to the draft FS report issued June 1, 1988. A

final RI was issued on August 22, 1988. This final FS report includes response to Agency comments on the second draft FS report.

1.1 SITE DESCRIPTION

Bowers Landfill is situated in Pickaway County, approximately 25 miles south of Columbus, Ohio, and 2 miles north of the city limits of Circleville, Ohio. Drawing 1 is a map showing the site vicinity. The site is located near the northwest corner of the intersection of Island Road and Circleville-Florence Chapel Road, on the eastern edge of the Scioto River Valley, in Section 3, Township 4 North, Range 22 West.

The L-shaped landfill extends northerly from the Circleville-Florence Chapel Road, then turns to the west and continues toward the river for about 1,000 feet (Drawing 2). It is approximately 4,000 feet long and averages about 125 feet across. The elevation of the top of the landfill is approximately 665 feet and has an average height of about 10 feet. The sides are sloped at about 2 to 1 (horizontal to vertical).

An unpaved (dirt) road runs along the top of the landfill for most of its length. Based on observations during the field investigation, vehicle traffic is limited to an occasional crossing of the northern portion of this road by farmers to gain access to the cultivated field between the landfill and the Scioto River. The extent of this traffic is believed to be several days during the growing season for field preparation, planting, pesticide/herbicide application, and harvesting. Approximately the southern two-thirds of the road is apparently not used, and there is a locked chain barrier at the southern entrance.

The landfill is vegetated with a relatively heavy growth of grasses, weeds, and shrubs, and contains a large number of trees, principally on the slopes of the berm, with some reaching heights of 20 feet or more. A technical memorandum presenting an evaluation of the site vegetation is presented in Appendix A.

The volume of material in the landfill was estimated by surveying the length of the landfill and by establishing four cross sections of the landfill at approximately 1,000-foot intervals (Burgess & Niple, 1981). It was found that the volume of material in the landfill, including clean fill that was used as cover, is about 130,000 cubic yards.

Miscellaneous debris is visible along portions of the landfill. It appears that some of the debris was never properly covered, while the remainder was probably deposited after the landfill operation was shut down. Most of the exposed material is in the form of shredded and rolled plastic film. The remains of several drums are partially visible at a few locations. The drums are rusted and appear to have been present for an extended number of years. There is no noticeable odor associated with the landfill, nor has any effect (stress) on the vegetative cover been noted. A fair abundance of wildlife (deer, squirrels, and raccoon) has been noted.

Runoff from the landfill is down either of the side-slopes to ditches running along the sides of the landfill. The ditch on the west side of the landfill is typically quite shallow and not well developed. Although the ditch drains southward, it is overgrown by vegetation in many places, and is subject to ponding as a result of high places along its course. A point of discharge for this ditch to the Scioto River is apparently not present, due to a levee (natural or artificial) along the river near the southern boundary. Instead, flow appears to pond in the southern portion of the property during wet periods, until infiltration and evapotranspiration slowly reduce the ponded volume. The majority of this ditch was observed to be dry during most of the field study.

The ditch to the east of the landfill also flows south, discharging into the Scioto River through a culvert pipe running beneath the landfill. The outlet of this culvert appears to have been covered with sediment over the years, and appeared as a spring in the bank along the Scioto River during the investigation. The culvert pipe may be partially clogged, since drainage of the ditch appeared to be relatively slow. This ditch was observed to contain water throughout most of the year, and may receive some inflow in the form of ground water discharge from the sand and gravel deposits to the east.

1.2 SITE HISTORY

The property on which the landfill is situated was purchased in June 1957 by John M. Bowers, D.D.S., of Circleville. Based upon inspection of a 1957 aerial photograph, the property in question included a cultivated field and woodlands. A small stream flowed to the south along the eastern side of the property, along the base of a bluff. This stream entered the Scioto River just above the Circleville-Florence Chapel Road bridge (Burgess & Niple, 1981).

The aerial photo also indicates that clearing of the woodland along the Scioto River near the bridge was underway at that time. The photo shows no evidence of a sand and gravel operation, nor does it indicate that any landfilling had begun.

It is reported (Burgess & Niple, 1981) that sand and gravel operations were initiated by Dr. Bowers in the eastern portion of the site in 1958. The operation was located about 150 feet east of the present landfill location and about 2,000 feet north of Circleville-Florence Chapel Road. The original excavation was advanced into a hillside, at an elevation above that of the future landfill.

Shortly after opening the sand and gravel operation, Dr. Bowers commenced the landfill operation (most likely in 1958 or 1959). According to a report from a person assumed to be familiar with the operation (Burgess & Niple, 1981), the method of landfilling was an area-type fill; excavation did not occur, but rather, refuse was deposited directly on the ground and covered with soil from the sand and gravel operation. However, recent discussions with another individual claiming to be familiar with site operations (McFarland, 1986) suggest that some excavation of the existing ground may have occurred near the southern site boundary during early operation prior to landfilling. The excavation was reported to have contained some water and to have been backfilled with construction debris.

Access to the site during the early years of landfill operation appears to have been from Island Road, past the sand and gravel pit, and across a wooden bridge over the drainage to the landfill. According to one observer, the filling operation began at the northwest end of the landfill near the Scioto River and progressed southward toward Circleville-Florence Chapel Road. However, very little first-hand knowledge or recorded information is available to document the early years of landfill operation.

As the landfill extended to the south, access was gained from Circleville-Florence Chapel Road. Use of this access route apparently necessitated installation of a pipe to accommodate flow in the drainage ditch running between the landfill and the hill to the east. On the basis of aerial photos, it appears that the pipe may have been installed during 1967. Water from the ditch was carried beneath the landfill and into the Scioto River through this pipe.

According to information on file with the OEPA, the majority of waste materials deposited on the site consisted of residential refuse collected by the City of Circleville as well as by several private haulers in the Circleville area. There are reports that wastes also came from at least three manufacturing plants and two grain elevators in the area. A list of wastes sent to the landfill from PPG and Du Pont as reported in the Eckhardt survey is provided here as Table 1.

There are no operating records for the landfill, and the owner (Dr. Bowers) is now deceased. Consequently, it has proven virtually impossible to determine the sources of refuse or what its composition may have been. In 1981, interviews were conducted with several people who were familiar with the landfill operation. Information obtained during these interviews includes the following:

- Over a period of several years, refuse was burned at the facility. This resulted in at least four "cease burning" orders from the Ohio Department of Health.
- A 1967 report from the Ohio Department of Health states that about 150 open truck loads were received monthly, plus wastes hauled in by private autos and trucks. The report estimated that about 40 percent of the waste was generated by various industries operating in the area, including PPG and Du Pont, among others.
- It was reported that drums of unknown substances and bulk liquids were deposited on the landfill.
- Responses to the House Subcommittee on Oversight and Investigation by PPG and Du Pont in 1978 contained estimates of about 1,700 and 6,000 tons of material, respectively, sent to the landfill from 1965 to 1968 (see Table 1).

It is concluded that the landfill commenced operation in late 1958 or 1959, and ceased operation in 1969. During its operation, the site was known locally as the Island Road Landfill, the Metz Landfill, the Red Bridge Landfill, and the Bowers Landfill.

1.3 ENVIRONMENTAL SETTING

1.3.1 Geological Conditions

A review of information collected during the drilling/monitoring well installation phase of the RI, as illustrated in Drawing 3, suggests the following relative to geologic conditions:

- Surficial geology in the site vicinity is characterized by the presence of silty clay and clay, averaging approximately 10 feet in thickness. This material is most likely related to floodplain deposition of fine sediment by the Scioto River, and appears to be continuous over much of the site and the field to the west.

- Underlying the surficial clay is a zone of brown sand and gravel, exhibiting somewhat variable thickness and degree of sorting. The average thickness of this unit is approximately 25 to 30 feet. The presence of this material is most likely related to late glacial and post-glacial (recent) fluvial action.

- This sand and gravel deposit is, in most locations, underlain by a relatively thick (10 to 20 feet) gray silty-clay zone which, due to the observed poor degree of sorting and presence of angular pebbles/gravel, appears to be glacial till. This material may be a remnant of earlier glacial ground moraine deposition that occurred as an ice sheet advanced or receded over previously deposited fluvial sediments and/or bedrock.

- A gray sand, with lesser amounts of gravel, is present beneath the till at most locations. This material appears to be more well sorted and uniform than the more shallow fluvial sediments previously described. This unit may be associated with the presence of a pre-glacial or interglacial stream channel. Some apparent "erratic" shale fragments were observed in association with this zone, generally near the upper surface of the sand.

- Shale bedrock was observed below this sand zone at several drilling locations, ranging in depth below ground surface from 40 to 100 feet. The apparent bedrock surface trends, as identified during this drilling program, agree closely with previous subsurface data obtained in the general region, in that bedrock topography slopes to the south and west from an apparent inter-valley bedrock high located just east of the site (ODNR, 1975).

1.3.2 Soils

The soil types found in the vicinity of the site are from the Eldean-Genesee-Warsaw Association. They are found in floodplains, outwash plains, and stream terraces. This association is characterized by nearly level to sloping, well-drained soils formed in moderately fine-textured to coarse-textured glacial outwash and alluvium.

Most of the farming field situated between the landfill and the Scioto River is formed on the Genesee soil. It is classified as a silt loam; the Unified Soil Classification System designation is CL or ML. Liquid limits are typically in the range of 26 to 40, and the Plasticity Index is normally between 3 to 15. The northeast corner of the farm field and much of the landfill area is classed as the Shoals Series, described as a silt loam. The Unified Soil Classification System symbol associated with this series is CL or CL-ML. In these soils, the range of Liquid Limits is from 22 to 40, and the Plasticity Index is typically between 4 and 15.

The landfill appears to be placed on a layer of silty clay that is interpreted as being continuous across much of the site, based upon data obtained from the drilling program. Samples taken from this layer in the field to the west of the landfill at SO-8 and in the field to the north of the landfill at SO-9 show permeabilities of 3×10^{-8} cm/sec and 5×10^{-8} cm/sec, respectively. In the event that these soils are for a site remedial action, more soil samples would be taken to determine the suitability of the soils in the local fields. The exception to the continuity across the site may involve the esker to the east of the landfill. Based upon available data for MW-1 (Burgess & Niple, 1981), the upper clay may not be continuous beneath the esker. There is no evidence to suggest that the integrity of this layer was affected by excavation at the landfill. According to a report from a person familiar with the operation, the method of landfilling was an area-type fill; excavation did not occur, but rather, refuse was dumped directly on the ground and covered with soil. However, recent discussions with another individual claiming to be familiar with site operations suggests that some excavation of the existing ground may have occurred near the southern site boundary during early years prior to landfilling operations.

1.3.3 Surface Water

The dominant hydrologic feature in the vicinity of the site is the Scioto River. It is the largest river in central Ohio, draining an area of 3,217 square miles upstream of the site (USGS, 1977). The Scioto flows south from an area northwest of Columbus and empties into the Ohio River near Portsmouth, Ohio.

Based upon recent unpublished data (U.S. Army Corps of Engineers, 1986), the following approximate flood flows and associated stages may be expected in the vicinity of the site:

Flood Return Period (years)	Discharge near Circleville (cfs)	Water Stage near Circleville (feet, msl)	Water Stage near Site (feet, msl)*
1	30,200	660.9	662.3
2	40,200	662.5	663.9
5	57,000	664.5	665.9
10	74,800	665.9	667.3
20	94,000	667.4	668.8
50	128,600	669.6	671.0
100	157,900	671.4	672.8

*Site data obtained by addition of 1.43-foot correction to Circleville data to compensate for elevation change.

In an average year, the farm field between the landfill and the Scioto River is under water for about 29 days, usually in the spring and winter (Burgess & Niple, 1981). During the current study, two flood events occurred at the site (October and November, 1986). Crest stage elevations for these events were in the range of 662-663 feet msl, based on field observations and Corps of Engineers data.

Runoff from the landfill is down either of the side slopes into ditches on either side of the landfill. Water in the east ditch flows to the south and discharges into the Scioto River via a culvert constructed through the Scioto River levee. As stated in an earlier section, the ditch on the west side of the landfill is not well developed and ponding of water in that ditch is common. Ponding is most likely to occur during periods of precipitation.

1.3.4 Ground Water

Ground water in central Ohio occurs in the pore spaces of unconsolidated materials and bedrock. The uppermost bedrock unit in the site area is the Ohio Shale, which, because of its low permeability, is not a producer of ground water. Additionally, the quality of water from that formation is presumed to be non-potable due to the presence of naturally occurring salts and sulfides. Deeper formations also contain non-potable water.

Ground water conditions in the unconsolidated glacial/alluvial materials include the vadose (unsaturated) zone and the phreatic (saturated) zone. Throughout the Scioto River Valley, the top of the saturated zone is typically in the range of 10 to 20 feet below surface.

Regionally, natural recharge to aquifers in the Scioto Valley occurs through infiltration from precipitation, from infiltration of Scioto River water during high stage conditions, and from underflow through buried valley walls. The amount of recharge from any given source is primarily a function of existing geologic conditions. It appears that, on a regional scale, recharge from the Scioto River during flooding represents a minor contribution because of the relatively short duration of flooding and the existence of relatively impermeable surficial soils in the alluvial valley. The primary sources of recharge are from infiltration of precipitation falling on the land surface, and from underground movement of ground water from aquifers in the adjacent upland area.

In the vicinity of the study area, it would appear that recharge to ground water occurs primarily through infiltration of precipitation on locations to the east of the landfill. In these areas, surficial clay soils appear to be absent, and more permeable sand and gravel soils are present to allow fairly high infiltration rates. However, to the west and north of the landfill, clay soils are present to greatly reduce infiltration capacity; therefore, recharge in these areas is considered to be limited.

Ground water levels in the area generally reflect topographic conditions. Ground water movement is toward the Scioto River unless locally reversed by pumping from large well fields. The closest known well field is the Circleville municipal field, located approximately 1.5 miles to the south, and downstream of the site. The well field presently consists of three production wells completed in the alluvial aquifer and producing a combined yield of approximately 1.65 million gallons per day (City of Circleville, 1987). The distance between the site and this well field is regarded as being far in excess of that which may affect ground water movement in the vicinity of the site, given the relatively high permeability of the sand and gravel aquifer and its unconfined nature.

Pumping from sand and gravel pits near the site is reportedly for aggregate washing operations (Strum and Dillard, 1987). The washwater is returned to the pit after use; therefore, ground water flow patterns in the area are probably not influenced by this activity.

Several small-capacity private water wells are known to exist in the area. Based on a review of available well logs and discussions with local residents, all private wells are believed to be completed in the unconsolidated sand and gravel materials. There are no known water wells within a mile of the landfill in a downgradient direction, as all wells appear to be located across the Scioto River or on topographically higher (upgradient) areas. Because the river is assumed to act as a linear ground water discharge boundary during most of the year, there is no evidence of ground water flow across the river channel.

1.4 LAND USE

Land use in the vicinity of the site falls into four principal categories; agricultural, quarrying, residential, and undeveloped. The largest of those in terms of land requirements is agricultural (cash grain and livestock farming). In 1969, about 96.7 percent of the total county land area was in farms. On the basis of 1984 aerial photographs (Chicago Aerial

Survey, 1984), farming is estimated to account for about 90 percent of land used within 1 mile of the site. Several sand and gravel operations, both active and inactive, are located in the vicinity of the site. It is estimated that they account for about 2 percent of the land use within 1 mile of the site. Land requirements for residential purposes within 1 mile of the site are estimated to represent less than 1 percent of the land use. Undeveloped land consists primarily of woodlands along the Scioto River and in other places throughout the area. It is estimated to account for slightly less than 8 percent of the land within 1 mile of the site.

1.5 PROJECT ORGANIZATION

The project was carried out in five phases: an RI Phase I, a draft EA, an RI Phase II, a final EA, and the FS. Data gathered during the RI Phase I were used to assess the nature and extent of contamination and to evaluate the need for remedial action at the site. Data gathered during the RI Phase II were used to reassess the need for remediation of certain site area media. The FS develops applicable technologies into remedial alternatives for the site as a whole.

1.5.1 Remedial Investigation (RI) Activities

Five tasks made up the bulk of the RI Phase I activity:

- Surface water and sediment sampling and analysis
- Surface soil sampling and analysis
- Ground water sampling and analysis
- Data reduction and evaluation
- Preparation of the RI report

The initial investigations of the RI were designed primarily to evaluate the absence or presence of contamination at the site. Low contaminant levels in surface soils and ground water were detected locally at the site. An additional phase of field activities was implemented for verification and to further define background conditions.

Five tasks made up the bulk of the RI Phase II activity:

- Installation of two additional monitoring wells
- Ground water sampling and analysis of samples taken from three wells previously monitored and two new wells
- Surface soil sampling and analysis of samples taken at three locations previously sampled and seven new locations
- Data reduction and evaluation
- Preparation of the RI report

The RI Phase II data generally confirmed the findings of the RI Phase I.

1.5.2 Endangerment Assessment (EA)

The RI characterized the level and distribution of the compounds that are present at the site, and described the current condition of the landfill. Data gathered during the RI were used to evaluate the exposure routes of site releases to potential receptors. The EA was conducted to assess potential human health effects that may result from exposure to site releases in the absence of remediation. Physical, demographic, and geographic factors were evaluated to assess the extent, if any, of potential harm to the public.

The EA process consisted of the following components: contaminant identification, exposure evaluation, toxicity evaluation, and risk characterization. The EA determined both maximum and representative concentrations of contaminants, and then computed corresponding risks under both worst case and most probable case exposure scenarios. The EA presented potential risks associated with noncarcinogenic chemicals as the Hazard Index (HI). The HI is the ratio for the daily dose for a chemical to the acceptable chronic intake level (AIC) for that chemical. The AICs are based on long-term exposure studies and are designed to protect sensitive populations. If the HI for an exposure scenario exceeds one (that is, if the daily dose exceeds the AIC), there is a potential risk from the exposure. Potential risks from carcinogenic chemicals were presented as incremental cancer risk (ICR). ICRs were evaluated in the EA using a carcinogenic potency factor. The incremental risk of developing cancer is the product of the carcinogenic potency factor and the average lifetime dose of the chemical in question. The ICR is presented as a probability (for example, 10^{-6}, or 1 cancer per million people exposed). Recent U.S. EPA guidance indicates that the target carcinogenic risks resulting from exposures at a

Superfund site may range between 10^{-4} to 10^{-7}. Using this range as a baseline, a risk level greater than 10^{-4} is considered to present a significant risk, and levels smaller than 10^{-7} are considered insignificant. Risk levels between 10^{-4} and 10^{-7} are within the target range.

The EA used both representative concentrations and worst case concentrations to develop exposure scenarios. Based on representative concentrations--the geometric mean of the concentrations--of contaminants at the site, and the most probable case exposure scenarios, the EA identified five exposure routes with potentially significant risks. The exposure routes, compounds, their representative concentrations, and the associated risk are:

Exposure Route	Compound	Geometric Mean Concentration	Risk
1. Ingestion of ground water	Barium	330 µg/L	0.17 Hazard index
	Benzene	0.7 µg/L	10^{-6} Cancer risk
2. Ingestion of surface water	PCBs	0.55 µg/L	Exceeds AWQC
3. Ingestion of aquatic animals	Mercury	0.13 µg/L	Exceeds AWQC
4. Ingestion of soils	Lead	78 mg/kg	0.14 Hazard index
	Total PAHs	0.68 mg/kg	Not greater than background
	PCBs	0.24 mg/kg	5×10^{-9} Cancer risk
5. Direct contact with surface water by aquatic animals	Mercury	0.13 µg/L	Exceeds 4-day AWQC

For the worst-case exposure scenario, the exposure routes, compounds, their maximum concentrations, and the associated risk are:

Exposure Route	Compound	Maximum Concentration	Risk
1. Ingestion of ground water	Barium	2,070 µg/L	1.04 Hazard index
	Benzene	6 µg/L	9×10^{-6} Cancer risk
2. Ingestion of surface water	PCBs	2.6 µg/L	Exceeds AWQC
3. Ingestion of aquatic animals	Mercury	0.2 µg/L	Exceeds AWQC
4. Ingestion of soils	Lead	179 mg/kg	3.2 Hazard index
	Total PAHs	26 mg/kg	2×10^{-6} Cancer risk
	PCBs	3.6 mg/kg	7×10^{-7} Cancer risk
5. Direct contact with surface water by aquatic animals	Mercury	0.2 µg/L	Exceeds AWQC

The following is a summary of the conclusions of the EA, based upon the risks due to both the worst case and most probable case exposure scenarios:

Exposure Route

1. "PRC performed a quantitative analysis of the risk [due to ingestion of ground water] by calculating most probable case and worst case daily doses and average lifetime doses for persons drinking 2 liters of contaminated ground water per day over a 70-year lifetime. [PRC] identified, under worst case, a potential noncarcinogenic risk from barium (HI=1.04). PRC also identified a potential carcinogenic risk due to benzene under both scenarios. The incremental cancer risk for lifetime ingestion of ground water under worst case scenario exposure conditions was 9×10^{-6}. That is, for every 1 million people exposed under these conditions, 9 cases of cancer would be expected. The probable case risk estimate was 1×10^{-6}. These risks slightly exceed (sic) the target range of 10^{-4} to 10^{-7}." "...PRC considers the likelihood of exposure by this scenario to be small. The area between the Bowers Landfill and the Scioto River is regularly flooded. Therefore, there is a low probability that ground water in this area would be used as a drinking water source in the future."

2. "PRC compared maximum surface water concentrations with U.S. EPA guidelines and criteria for acute or short-term exposure. When short-term guidelines were not available, PRC compared maximum concentrations with guidelines for long-term or chronic exposure. Of the indicator compounds found in the surface water, only PCBs exceeded a guideline. ...Although this indicates a potential risk, the AWQC is based on lifetime exposure to 2 liters of contaminated water per day. Thus, the AWQC is not directly applicable to the infrequent exposure and small amount of water ingested under this exposure scenario."

3. "PRC identified a limited risk for ...ingestion of aquatic animals from the Scioto River. Only one indicator chemical, mercury, was found above background concentrations in the Scioto River near Bowers Landfill. The maximum mercury concentration in river water slightly exceeded the AWQC for ingestion of aquatic life; the average mercury concentration was below the AWQC. ...PRC considers the risk to be limited because mercury was found in only one single river water sample and because the maximum concentration only slightly exceeded the AWQC."

4. "PRC identified a potential noncarcinogenic risk [for ingestion of surface soils] under the worst case scenario for exposure to lead (HI=3.20). The risk was estimated by comparing the calculated dose with acceptable chronic intake levels for lead published by U.S. EPA. This comparison may overestimate potential risks, because the exposure conditions evaluated ...represent subchronic, rather than chronic, exposure. However, U.S. EPA has not developed an acceptable subchronic intake level for lead. Further, maximum lead concentrations in soils at Bowers Landfill are well below the guidelines recommended by the Centers for Disease Control to protect children in residential areas (500 mg/kg to 1,000 mg/kg).

   "PRC also identified an incremental carcinogenic risk of 3×10^{-6} under the realistic worst case exposure. That is, for every 1 million children exposed under these conditions, 3 cancer cases are expected. Most of the incremental carcinogenic risk was attributed to PAHs, with only minor contributions from PCBs and chlordane. This risk falls within the target range of 10^{-4} to 10^{-7}. ...PAHs found near Bowers Landfill may be due in part to other activities that produce these chemicals since PAHs were also found in background samples. Worst case risks calculated under this scenario may overestimate actual risks because they are based on maximum soil concentrations and a worst case soil ingestion rate. Most probable case carcinogenic risks for soil ingestion were 5×10^{-9}."

5. "PRC determined that there is potential risk to aquatic life exposed to mercury in river water. The maximum mercury concentration exceeded the 4-day AWQC for aquatic life. This comparison may overestimate the potential risks, since mercury was found in only one river water sample."

General "In interpreting [the above risks], ...two limiting factors must be considered. First, some of the potential exposure pathways have a low probability of occurring. For example, exposure to contaminated ground water will occur only if drinking water wells are placed between Bowers Landfill and the Scioto River. PRC considers this unlikely, since the area is regularly flooded. Finally, some of the indicator chemicals evaluated in this endangerment assessment may have come from sources other than the landfill. This is particularly true of chlordane, which may have been used as a pesticide in agricultural areas near the landfill."

1.5.3 Feasibility Study (FS) Activities

Seven tasks made up the bulk of the FS:

- Identification and screening of remedial technologies
- Development of alternatives
- Initial screening of alternatives
- Description of alternatives
- Detailed analysis of alternatives
- Summary of site alternatives
- Preparation of final FS report

In effect, the FS selects remedial technologies that can be utilized for this site, combines them to form remedial alternatives, then screens out those that are inapplicable and infeasible.

2.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

In this section, remedial technologies are identified and screened. This screening follows the general guidance provided in U.S. EPA's *Draft Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (March 1988), which suggests the following steps:

1. Identify areas of interest at the site in terms of environmental media
2. Identify general response actions that address remediation of the areas of interest
3. Identify specific remedial action technologies for each general response action, and screen the technologies to eliminate those that are inapplicable and infeasible based on site conditions and waste characteristics

2.1 AREAS OF INTEREST

Site problems at the Bowers Landfill were determined based upon the results of the Remedial Investigation (RI) and upon the conclusions of the Endangerment Assessment (EA). The following sections review each environmental medium at the site and evaluate the possible need for remedial action.

2.1.1 Surface Water

The potential risks identified by exposure routes 2, 3, and 5 of the EA (see Section 1.5.2 of this FS) are all related to the surface water at the site. Each is based on the compound in question for that pathway exceeding an Ambient Water Quality Criteria (AWQC), rather than a calculated risk. The EA consultant, Planning Research Corporation (PRC) provided a qualitative discussion of risk for each of these routes in the EA. The risk from ingestion of surface water was based on a single occurrence of PCB found in the duplicate sample (but not in the original sample) from a drainage area near the southern end of the landfill. PRC stated that the risk from ingestion of surface water is "very low due to the infrequent exposure and the low contaminant levels found at the site." The maximum PCB concentration was 2.6 µg/L, at sample location 21; this compares to the AWQC of 0.0126 µg/L. It should be noted that an upstream background concentration of 1.2 µg/L at sample location 18 also exceeded the AWQC. PRC stated that, because the AWQC is

based on lifetime exposure, "the criterion is not directly applicable to the limited exposure that would occur under this scenario."

The risk from ingestion of aquatic animals and direct contact with surface water by aquatic animals is based on isolated occurrences of mercury. The maximum mercury concentration was 0.2 µg/L, compared to the AWQC of 0.146 µg/L. PRC stated that the risk from ingestion of aquatic animals is "limited." They also stated that the risk from direct contact with surface water by aquatic animals "is based on the maximum mercury concentration and may overestimate the potential risk."

Given the low levels of risk that are represented by these exposure routes, surface water does not warrant remediation at the Bowers Landfill site.

2.1.2 Ground Water

The potential risk identified in the EA due to the ingestion of ground water assumes a point of exposure from wells that potentially may be installed between the landfill and the river. PRC stated that it is unlikely that wells would be placed in this area since it is regularly flooded. The two compounds of concern in the EA for ground water are barium and benzene. The RI states that the high concentrations of barium may be due to natural variations; and that the source of benzene is either associated with carbonaceous or hydrocarbon-containing shale encountered during drilling or associated with contamination from the landfill. Thus it is not clear whether or not the landfill is the source of these compounds.

The EA states that the risk due to barium is "probably very small," since the hazard index, under a worst case exposure scenario, only slightly exceeds unity. The hazard index was calculated based upon a maximum downgradient concentration of 2,070 µg/L detected in one well screened in the deep aquifer. Barium was detected in this well at 2,020 µg/L, 2,020 µg/L, and 2,070 µg/L for rounds 1, 2, and 3, respectively. However, the next lower contamination level recorded elsewhere at the site was 691 µg/L, approximately one third of the maximum. The hazard index, under the most probable case exposure scenario is 0.17, and therefore does not represent a noncarcinogenic risk.

The EA states that the incremental carcinogenic risk for benzene, using worst case data, are within the target range of 10^{-4} to 10^{-7}. The Maximum Contaminant Level (MCL)

and the Contract Requred Detection Limit (CRDL) for benzene are 5 µg/L. Benzene was found, near the CRDL, during the first and third sampling rounds only at sample location P-6B, a well screened in the deep aquifer, at concentrations of 6 µg/L and 4 µg/L, respectively. These data indicate that worst case benzene contamination at the site averages the MCL, and results in an incremental carcinogenic risk within the target range of 10^{-4} to 10^{-7}. Since benzene was detected, on one occasion at a level above its MCL, and since the hazard index for barium, under the worst case exposure scenario, exceeds unity, remedial alternatives were developed to address the potential problem.

2.1.3 Surface Soils

The potential risk identified in the EA from surface soils assumes that children exhibiting pica behavior will ingest soil while on the site. Based on the results of the EA, the three compounds that are of concern in surface soil are total PAHs, PCBs, and lead. There is no conclusive evidence that these compounds originated at the landfill. The maximum concentrations of PAHs were measured at sample location SO-39 on the landfill. The EA states that the worst case, incremental carcinogenic risks for total PAHs, and PCBs are within the target range of 10^{-4} to 10^{-7}, but since they are present in some samples at levels above background, under worst case, remedial alternatives were developed to address this potential problem.

The EA states that the hazard index under the worst case exposure scenario of 3.2 for lead "may overestimate the actual risk" since it is based on a maximum lead concentration at one sampling location at the site (179 mg/kg) and the worst case soil ingestion rate. The hazard index under the most probable case exposure scenario is 0.14. In spite of the elevated hazard index for lead, under a worst case exposure scenario, actual risks from soil ingestion may be limited for two reasons. First, it should be noted that the hazard index was determined by using the acceptable daily intake for chronic exposure (AIC), which assumes chronic exposure. The type of exposure evaluated under this scenario (30 ingestions over a 3-year period) is subchronic; however, there is not a subchronic acceptable intake dose available for comparison. Second, the Centers for Disease Control (1985) has stated "...lead in soil and dust appears to be responsible for blood lead levels in children increasing above background levels when the concentration in soil or dust exceeds 500 to 1,000 mg/kg." This range is well above the maximum lead concentration found in soils at Bowers Landfill (179 mg/kg). Therefore, the calculated risk may overestimate the actual risk.

The potential remedial alternatives for the surface soils address the low risk associated with lead as well as PCBs and PAHs. The highest levels of each of these contaminants were at, or in the immediate vicinity of, the landfill.

2.1.4 Landfill

The landfill presents risks to the public health, welfare, and the environment as a consequence of exposed surface debris, potential exposure to contained wastes, and the potential for future releases of contaminants. However, during recent investigations, there has been no evidence of leachate seeps from the landfill. It is not clear that the low levels of chemicals detected downgradient of the landfill are attributable to the landfill. There is no evidence that the current vegetative cover is not acting as an effective cover. The healthy tree cover has, over the last several decades, acted as an effective mechanism to protect the landfill surface from erosion by periodic flood events. This is discussed in greater detail in Appendix A.

The potential remedial alternatives for the landfill focus on containment of the wastes in the landfill, thereby reducing the potential for release of contaminants.

2.2 GENERAL RESPONSE ACTIONS

A General Response Action (GRA) is a broad class of response that addresses remediation of one or more of the site problems. GRAs exceed, attain, or partially attain cleanup goals by decreasing releases, threats of release, or pathways of exposure. Without necessarily identifying specific technologies, each GRA identifies actions pertinent to remediation of the site problems. Based on information from Section 2.1 - Areas of Interest, a number of general response actions have been developed. Table 2 lists the GRAs identified for the site. From this list of GRAs, all possible technologies were identified and screened for applicability and feasibility based on specific characteristics of the Bowers Landfill site. The remaining technologies were then assembled into operable units.

2.3 PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES

Table 3 represents the results of the initial screening step of the FS process, in which technologies are identified and screened to develop potential remedial alternatives. This step has been carried out in accordance with 40 CFR 300.68(g), which states: "Alternatives developed...will be subject to an initial screening to narrow the list of potential remedial actions for further detailed analysis."

Screening takes into account the effectiveness of each remedial technology, whether it can be implemented, and its cost. While proven technologies receive prime consideration, innovative technologies are considered when there is reason to believe that the innovations will improve performance or implementation, or when they have less adverse impact than other remedial technologies.

Some remedial technologies involve treatment, while others may involve containment. Cost alone is not used to discriminate between these alternatives. Where several alternative treatments could be applied, cost may be used as one criterion for selection from the available treatment technologies.

The screening process identifies potential technologies and provides a brief explanation for retaining or excluding each technology. This screening is carried out against each of the site problems, namely the landfill, surface soils, and ground water. The surface soils that may require remediation are generally located on the landfill. Remedial technologies for each site problem are reviewed. For the landfill, remedial technologies reviewed are focused on containment of the wastes in the landfill. The technologies are grouped by general response action (e.g., leachate controls). For technologies that can be used in several configurations, functional subgroupings are screened; for technologies that may use different materials (e.g., capping using either clay or synthetic membranes), subgroupings are screened.

The no action alternative is included as a baseline against which potential technologies can be measured. The no action alternative can apply either to the whole site or to selected site areas of interest.

The following presents the logic sequence used for screening the technologies:

- **No.** Any technology that is not viable in remediating a problem area was screened out. This resulted whenever application was precluded by site or waste characteristics. Any technology that is not practical, or that is difficult or unreasonable to implement, was also screened out based on several factors including:

  - Reliance on unproven technology
  - Unsuitability based on engineering judgment (e.g., unreliable, poor performance)
  - Uncertainty whether it can achieve the remedial objective in a reasonable period of time

- **Not applicable** (NA). Any technology that addresses remediation of a non-existing problem was screened out.

- **Yes**. Those technologies that survived the previous screening tests were retained for further evaluation.

In developing Table 3, particular care was taken whenever a technology was screened out. This was because only those technologies that survived the screening process were to be considered in the remaining stages of the FS.

2.4 DISCUSSION OF APPLICABLE REMEDIAL TECHNOLOGIES

The remedial technologies that survived the screening process and that can be applied to the landfill, surface soils, or ground water are listed in Table 3. The following discussions briefly describe these technologies.

2.4.1 Surface Soils Remediation

2.4.1.1 No Action

Under this response action, no remedial action would be taken for the surface soils. This alternative is required to be considered by the NCP to provide a baseline against which all other alternatives can be compared.

2.4.1.2 Deed and Site Restrictions

Site use and access would be restricted through legal deed or title restrictions at the property to prohibit future site development or excavation. The property would be fenced and posted for no trespassing. No other remedial site work would be done.

2.4.1.3 Soils Excavation

Under this response action, soils would be removed from their present location for treatment or disposal elsewhere. Standard soils excavation equipment would be used, including backhoes and dozers. Such equipment works on the principle of loading a bucket with soil, lifting it, and dumping it.

2.4.1.4 Stabilization/Solidification

Under this response action, stockpiled contaminated soils would be fed to a pug mill via a hopper. In the pug mill, the soils would be broken down to a uniform particle size. Stabilizing chemicals would also be fed into the mill, where they would be blended with the contaminated soils. These chemicals would react with contaminants in the soil to form non-soluble salt complexes. The stabilized soil would then harden to form a solidified, monolithic mass.

2.4.1.5 Offsite Disposal

Under this response action, excavated contaminated soils would be transported to a RCRA permitted landfill for disposal. This would be an effective and reliable technology, since contaminants would be removed from the site. Soils would be loaded onto trucks as part of the excavation process. The trucks, licensed to carry hazardous waste, would transport soils to the offsite landfill by public highways. It is likely that the soils would not be classified as hazardous.

2.4.2 Landfill Remediation

2.4.2.1 No Action

Under this response action, no remedial action would be taken for the landfill. This alternative is required to be considered by the NCP to provide a baseline against which all other alternatives can be compared.

2.4.2.2 Deed and Site Restrictions

Site use and access would be restricted through legal deed or title restrictions at the property to prohibit future site development or excavation. The property would be fenced and posted for no trespassing. No other remedial site work would be done.

2.4.2.3 Management of Surface Debris

The landfill area and its immediate vicinity would be cleared of surface debris that may be removed offsite for disposal. Generally, only those items separated from the landfill would be removed; those items partially visible would probably be covered in a landfill remedial action.

2.4.2.4 Capping

Capping would be used to cover buried and partially buried waste materials to prevent their contact with surface waters that may infiltrate through the waste into the ground water. Capping could be applied in specific areas to repair the existing cover, or to cover the entire landfill surface. Capping would prevent direct contact with the waste or contaminated soils by acting as a barrier between waste and receptors. Capping could be accomplished using various materials; clay and synthetics may be appropriate.

A clay cover consists of a single layer of low-permeability soil, covered with a single layer of topsoil that is vegetated. Such a cap would meet current solid waste landfill criteria and would significantly reduce infiltration of water and associated leachate production.

A synthetic membrane would reduce surface water infiltration into the landfill, reducing the quantity of contaminated leachate potentially generated. By using multiple alternative layers of impervious material and free-draining media, infiltration of water into the landfill would be reduced compared to a clay-only cap. Such a cap would typically be used for closure of a hazardous waste landfill.

2.4.2.5 Repairs to Cover

Areas of the landfill that have been damaged by erosion, or are inadequately vegetated, would be repaired by adding soils, compacting and revegetating.

2.4.2.6 Drains and Sumps

Leachate from the landfill would be collected by a drain system discharging into several collection sumps. The drains would consist of gravel beds around the periphery of the landfill. Collected leachate would be pumped, either periodically or continuously, for treatment or disposal. Treatment may consist of discharging the leachate to Circleville's publicly owned treatment works (POTW), or a similar offsite treatment plant.

2.4.2.7 Ground Water Monitoring

Under this response action, no remedial action would be taken for the landfill. However, a long-term monitoring program would be implemented to monitor potential migration of contaminants. Samples of ground water would be collected and analyzed on a regular basis.

2.4.2.8 Gas Venting

Organic vapors that may collect under the landfill cover would be removed. The system would eliminate the potential for excessive pressure to build up within the landfill that could lead to stressing or potential rupture of the cover.

Before placement of an impervious cover over the landfill, the waste surface would be covered with a layer of gravel. Because gravel has a high voidage fraction, gases could travel freely through this layer to vent pipes, which would be installed at regular intervals

over the landfill surface. The pipes would vent landfill gas to the atmosphere, or to a gas treatment system.

2.4.2.9 Flood Protection

The landfill lies within the 100-year floodplain of the Scioto River, and flooding may erode the cover materials. If this were to occur, then waste could migrate offsite, or water could mix with the waste and produce a potentially hazardous leachate. The landfill cover, which has successfully withstood numerous periodic flooding events, could be protected by placing armor stone or riprap on exposed surfaces. These erosion control measures would provide additional protection to the existing landfill cover.

Alternatively, a flood containment levee or floodwall would completely isolate the landfill from floodwaters. A levee would provide definitive protection, since it would prevent floodwaters from entering the landfill. A levee is an earthen embankment, whereas floodwalls are generally built of concrete or sheet piling. Levees may be built as perimeter embankments surrounding a landfill located on a floodplain, or they may be erected along slope faces at the base of a landfill to ward off periodic inundation.

Since levees have relatively long, flat slopes, a high embankment may require a very wide base. Typically a concrete floodwall may be preferred as an alternative if space is limited, or if there is a shortage of fill material, or if real estate costs are high. At the site, concrete may be appropriate where areas of the landfill encroach on the river.

2.4.2.10 Channels and Waterways

Earthen channels would be used to divert runoff from entering the landfill area and prevent ponding against the landfill. Channels are wide, shallow ditches with trapezoidal, triangular, or parabolic cross sections. Diversion channels would intercept runoff from the landfill surface. Channels, which may be stabilized with vegetation or stone riprap, would be used to collect diverted water and transfer it offsite.

2.4.3 Ground Water Remediation

2.4.3.1 No Action

Under this response action, no remedial action would be taken for the ground water. This alternative is required by the NCP to be considered in order to provide a baseline against which all other alternatives can be compared.

2.4.3.2 Deed Restrictions

A deed restriction would be imposed on the site, restricting future use of the site for extraction of ground water downgradient of the landfill.

2.4.3.3 Ground Water Monitoring

Under this response action, no remedial actions would be taken for the ground water. However, a long-term monitoring program would be implemented to monitor potential migration of contaminants. Samples of ground water would be collected from monitoring wells and analyzed on a regular basis.

2.4.3.4 Ground Water Extraction

Ground water would be extracted from the deep aquifer at the site using wells equipped with downhole pumps. The wells would be located so that the contaminants in the ground water would be removed. Extracted ground water would require treatment or disposal.

The ground water extraction rate would be a function of the hydraulic properties of the aquifer. Extraction would continue until remediation goals for the aquifer were met.

2.4.3.5 Metals Precipitation

Metallic compounds would be removed from an aqueous stream by adding an alkaline compound in a stirred tank reactor. A precipitate of metal hydroxide or metal sulfate would form, which would settle out of the water stream. Metal sludge resulting from the precipitation process would be disposed offsite. Substantial research and

development would be required to determine suitable alkaline additives and precipitation conditions.

2.4.3.6 Activated Carbon Adsorption

Organic compounds would be removed from an aqueous stream by passing it through a tank containing granular activated carbon. Organics would be attracted to the carbon and would diffuse through the water, becoming attached to the surface of the carbon. Periodically, the carbon would become saturated with organic chemicals and would have to be disposed and replaced.

2.4.3.7 Discharge to River

Water would be discharged to a nearby body of surface water pursuant to the National Pollutant Discharge Elimination System (NPDES) program. Water treatment and effluent monitoring may be required. Samples would be drawn from the discharge line to confirm compliance.

2.4.3.8 Discharge to POTW

Water would be discharged to a local publicly owned treatment works under a wastewater discharge permit. The water would be pumped from wells to tanker trucks, which would transport it by road to the POTW. Provisions would be made to draw samples for analysis from the discharge line in order to ensure compliance with the requirements of the permit.

3.0 ASSEMBLY AND SCREENING OF MEDIA ALTERNATIVES

3.1 INTRODUCTION

In this section, applicable remedial technologies identified in Section 2.4 are assembled into media-specific alternatives addressing the landfill, ground water, and soils.

The result of the screening process described in Section 2.0 was a list of technologies, presented here in Table 4, that address remediation of the landfill, ground water, and soils. Alternatives were then developed from this information by combining practical and feasible technologies from several general response actions to form an alternative specific to that site area. Further assembly of media-specific alternatives into alternatives that address the site as a whole is discussed in Section 3.5. The overall purpose of the screening process is to reduce the list of potential alternatives to a manageable size for detailed evaluation.

In accordance with U.S. EPA's *Interim Guidance on Superfund Selection of Remedy* (OSWER Directive No. 9355.0-19), alternatives are to be developed to include the following:

1. Treatment alternatives for source control that would eliminate the need for long-term management (including monitoring).

2. Alternatives involving treatment as a principal element to reduce the toxicity, mobility, or volume of site waste.

Two additional alternatives also must be developed:

1. An alternative that involves containment of waste with little or no treatment, but provides protection of human health and the environment primarily by preventing potential exposure or reducing the mobility of the waste.

2. A no action alternative.

Descriptions are developed in this section for each alternative, to enable subsequent evaluations to be carried out. The initial alternative screening is a broad and largely qualitative assessment in which alternatives that are clearly infeasible or inappropriate are eliminated. Those remaining are evaluated against three broad considerations--public health, the environment, and cost. The cost screening is conducted only after the

environmental and public health screenings have been performed; this allows an initial assessment of each alternative relative to the others, and eliminates those that do not provide adequate protection. Public health and environmental considerations are evaluated based upon issues including: the degree of attainment of Applicable or Relevant and Appropriate Requirements (ARARs); the degree of reduction in toxicity, mobility, or volume of hazardous constituents; and reliability. Each alternative is described in the format established in the Feasibility Study Work Plan, as follows:

> **Effectiveness.** Alternatives will be evaluated as to whether they adequately protect human health and the environment; attain federal and state ARARs or other criteria, advisories, or guidance; significantly and permanently reduce the toxicity, mobility, or volume of hazardous constituents; are technically reliable, or are effective in other respects. Reliability includes the potential for failure and the need for replacement of the remedy.
>
> **Implementability.** Alternatives will be evaluated as to the technical feasibility and availability of the technologies each alternative would employ; the technical and institutional ability to monitor, maintain, and replace technologies over time; and the administrative feasibility of implementing the alternative.
>
> **Cost.** The costs of construction and any long-term costs to operate and maintain the alternatives will be evaluated. A detailed cost analysis is not necessary at this time. As stated in U.S. EPA's *Draft Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (OSWER Directive 9355-3-01, March 1988), the cost analysis is based on engineering judgment. During the initial screening, cost is an important factor when comparing alternatives providing similar results, but is not important in comparing treatment and nontreatment alternatives. The preliminary costs presented in this section are superseded by those presented in the more detailed estimates included in Section 4.0.

Following this three-factor screening, media alternatives that passed the screening were assembled into alternatives that address remediation of the site as a whole. The assembled site alternatives are described in Section 3.5.

3.2 PERFORMANCE GOALS

3.2.1 Introduction

Performance goals, the desired level of cleanup for Superfund sites, are determined on a case-by-case, site-specific basis. The U.S. EPA *Superfund Public Health Evaluation Manual* (SPHEM) (U.S. EPA, 1986) outlines the procedures necessary to identify and define remedial performance goals at a particular site.

The performance goals are derived from ARARs, or in their absence, from estimated carcinogenic risks and/or noncarcinogenic acceptable intake levels.

The following sections describe the selection of ARARs and the derivation of site-specific performance goals for the Bowers Landfill site.

3.2.2 Applicable or Relevant and Appropriate Requirements (ARARs)

3.2.2.1 Introduction

General ARARs were defined by the U.S. EPA on August 27, 1987 in the *Federal Register*, 52: 32496. "Applicable requirements" are those federal, state, and local public health and environmental standards, regulations, guidelines, advisories, and ordinances that deal with a hazardous substance, pollutant, contaminant, remedial action, location, or other aspect of a Superfund site. "Relevant and appropriate requirements" are standards that may not specifically apply, but that "address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site."

ARARs include:

- Ambient or chemical-specific requirements
- Performance, design, or other action-specific requirements
- Locational requirements

Ambient or chemical requirements set health- or risk-based concentration limits for specific substances, pollutants, or contaminants. Action-specific requirements set controls or restrictions on hazardous substances, pollutants, or contaminants. Locational requirements restrict activities depending on site characteristics or the local environment.

Section 121 of SARA requires that the remedy for the site must meet all ARARs unless one of the following conditions is satisfied:

- The remedial action is an interim measure where the final remedy will attain the ARAR upon completion.
- Compliance will result in greater risk to human health and the environment than other options.

- Compliance is technically impractical.
- An alternative remedial action will attain the equivalent of the ARAR.
- For state requirements, the state has not consistently applied the state requirement in similar circumstances.
- Compliance with the ARAR will not provide a balance between protecting the public health, welfare, and the environment at the facility and the availability of fund money for response at other facilities.

3.2.2.2 Applicable or Relevant and Appropriate Federal Requirements

Federal standards and requirements that are potential sources of ARARs for the site were provided by the U.S. EPA on April 27, 1988. The ARARs were relevant to remedial alternatives identified in the Alternative Arrays Document, submitted to the U.S. EPA on March 31, 1988, which addressed remediation alternatives for ground water, surface soils, and the landfill in accordance with the draft Endangerment Assessment (EA) of December 14, 1987. The RI report was issued April 28, 1988; and subsequent to issue of the final EA on May 12, 1988, alternatives included in the Arrays Document were revised to account for the removal of arsenic as an indicator chemical. The federal ARARs include chemical-specific, action-specific, and location-specific requirements.

Chemical-specific ARARs

Chemical-specific ARARs for indicator chemicals in the ground water and the surface water at the Bowers Landfill site are identified in Table 4-1 of the EA. To date, U.S. EPA has not developed chemical-specific ARARs for soil.

Action-specific ARARs

Table 5 identifies performance, design, or other action-specific requirements that may constitute ARARs for the site remedial alternatives discussed in Section 3.5. Action-specific requirements are triggered by the specific remedial alternatives selected for a site. For example, if hazardous wastes are removed from a site, RCRA regulations would be applicable. Alternatively, if hazardous wastes are capped but are not disturbed or moved, RCRA requirements are not made applicable, but technical requirements may be relevant and appropriate. In addition to identifying ARARs, Table 5 lists alternatives for the

landfill, ground water, and soils that may be "applicable" or "relevant and appropriate" to each ARAR.

Location-specific ARARs

Because Bowers Landfill is located within the 100-year floodplain of the Scioto River, two location-specific requirements can be considered as potential ARARs. The first is the floodplain management requirement contained 40 CFR 6, Appendix A, *Statement of Procedures on Floodplain Management and Wetlands Protection*. The second requirement is contained in 40 CFR 264 Subpart B, *General Facility Standards*. Specifically, 40 CFR 264.18 provides location standards for RCRA facilities located within floodplains.

3.2.2.3 Applicable or Relevant and Appropriate State Requirements

General

Chapter 3745 of the Ohio Revised Code (ORC) created the Ohio Environmental Protection Agency (OEPA) and outlined the powers and duties of that agency of state government. Chapter 6111 ORC establishes a requirement that no new sources of water pollution may be installed in Ohio without first obtaining a Permit to Install (PTI) from the Director of OEPA. Chapter 3734 ORC establishes a requirement that no installation of a solid waste disposal facility may be undertaken without a plan approval by the Director. Rules for implementation of these requirements are given in Chapter 3745-31 of the Ohio Administrative Code (OAC). In particular, Rule 3745-31-05 lists the criteria the Director must use in making decisions to issue a Permit to Install or plan approval.

Hazardous and Solid Waste

ORC Chapter 3734 provides statutory authority for the regulation of solid and hazardous waste activities in the State of Ohio, and should be considered as a source of potential state ARARs. Section 3734.02(H) requires prior authorization by the Director of OEPA before any physical disturbance takes place in an area where a hazardous waste facility has operated. Section 3734.05(C)(6) establishes the criteria that the Hazardous Waste Facility Board uses to determine the adequacy of an application for a hazardous waste facility installation and operating permit.

The OEPA hazardous waste regulations developed on the basis of Chapter 3734 of the ORC are found in Section 3745-50 through 3745-69 of the OAC. With few exceptions, these regulations closely track U.S. EPA hazardous waste regulations. However, Rule 3745-53-11 does require transporters of hazardous waste that originates or terminates in the State of Ohio to register with the Public Utilities Commission of Ohio and to obtain an Ohio transporter registration number.

Air

ORC Chapter 3704 establishes OEPA's authority to regulate and control air pollution within the State of Ohio. The rules developed and implemented by OEPA on the basis of Chapter 3704 are found in Sections 3745-15 through 3745-25 of the OAC. Rule 3734-15-07 prohibits creation of an air pollution nuisance and is a state ARAR for actions taken at the Bowers Landfill. Rule 3745-17-08 places restrictions on emission of fugitive dust and is also a state ARAR for any alternative that may potentially produce dust emissions during construction or implementation.

Water Pollution Control

ORC Chapter 6111 establishes OEPA's authority to set water quality standards (Section 6111.041) and regulate water pollution sources. The rules developed and implemented by OEPA on the basis of Chapter 6111 are found in Sections 3745-1 through 3745-13 of the OAC. OAC Section 3745-33 states the rules specific to Ohio's National Pollutant Discharge Elimination System (NPDES) permit program.

Site-Specific ARARs

Table 6 identifies potential state ARARs for the landfill, ground water, and soils.

3.2.3 Indicator Chemicals

Of the chemicals tentatively identified at the site, three inorganic and six organic compounds were selected in the EA for use in evaluating the potential impacts associated with contamination at the site. The indicator chemical selection process was based upon:

- Representative concentration
- Medium-specific and chemical-specific toxicity constants
- Estimated potential mobility
- Persistence

Final selection, discussed in the EA, resulted in nine indicator chemicals:

1. Barium
2. Lead
3. Mercury
4. Benzene
5. Chlordane
6. 4-methylphenol
7. Polychlorinated biphenyls (PCBs)
8. Polynuclear aromatic hydrocarbons (PAHs)
9. Tetrachloroethene

Table 7 lists the concentrations of the indicator chemicals in the relevant environmental media. This table summarizes portions of Tables 3-3, 3-6, 3-7, and 3-9 from the EA. For ground water, only monitoring wells downgradient of the landfill were used; for the Scioto River and the river sediment, only sampling points downstream of the landfill were included; for soils, only sampling locations on or adjacent to the landfill were included.

3.3 ASSEMBLY OF MEDIA ALTERNATIVES

Media alternatives were assembled by combining the technologies shown in Table 4 (which passed the technology screening process) into pathways for each site problem. In accordance with the U.S. EPA guidelines, at least one alternative was developed for each of the categories listed in Section 3.1, unless stated otherwise. Alternatives are developed in the following discussions to provide the decision maker with a range of remedial alternatives. For clarity in evaluation, the alternatives are developed such that they are consistent within themselves by providing similar levels of protection. The alternatives developed for the Bowers landfill are based upon the Alternatives Array Document submitted to the U.S. EPA on March 31, 1988. Alternatives are grouped by category for ease of analysis, and are listed below.

3.3.1 Alternatives for the Landfill

Alternatives that Require No Action

Alternative 1:

- No action

Alternatives that Involve Containment of Waste with Little or No Treatment, but Provide Protection of Human Health and the Environment Primarily by Preventing Potential Exposure or Reducing the Mobility of the Waste

Alternative 2:
- Ground water monitoring
- Deed and site restrictions

Alternative 3:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Local repair to existing landfill cover
- Erosion control and drainage improvements

Alternative 4:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Erosion control and drainage improvements
- Natural clay cover over landfill

Alternative 5:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Erosion control and drainage improvements
- Natural clay cover over landfill, together with leachate collection system and gas venting system

Alternative 6:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Natural clay cover over landfill, together with leachate collection system and gas venting system
- Drainage improvements
- Flood protection dike

Alternative 7:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Drainage improvements
- Flood protection dike
- Synthetic membrane cap over landfill with leachate collection system and gas venting system

Treatment Alternatives for Source Control that Would Eliminate the Need for Long-Term Management (including monitoring)

No feasible or practical alternatives. Treatment alternatives for the landfill were rejected in the technology screening evaluation (shown on Table 3).

Alternatives Involving Treatment as a Principal Element to Reduce the Toxicity, Mobility, or Volume of Site Waste

No feasible or practical alternatives. Treatment alternatives for the landfill were rejected in the technology screening evaluation (shown on Table 3).

3.3.2 Alternatives for Ground Water

Alternative that Requires No Action

Alternative 1:

- No action

Alternatives that Involve Containment of Waste with Little or no Treatment, but Provide Protection of Human Health and the Environment Primarily by Preventing Potential Exposure or Reducing the Mobility of the Waste

Alternative 2:

- Ground water monitoring
- Deed restrictions

Alternative 3:

- Ground water monitoring
- Extract ground water
- Discharge to POTW

Treatment Alternatives for Source Control that Would Eliminate the Need for Long-Term Management (including monitoring)

No feasible or practical alternatives. All treatment alternatives will require ground water monitoring.

Alternatives Involving Treatment as a Principal Element to Reduce the Toxicity, Mobility, or Volume of Site Waste

Alternative 4:

- Ground water monitoring
- Extract ground water
- Treat by metals precipitation and carbon adsorption
- Discharge to POTW

3.3.3 Alternatives for Surface Soils

Alternatives that Require No Action

Alternative 1:

- No action

Alternatives that Involve Containment of Waste with Little or No Treatment, but Provide Protection of Human Health and the Environment Primarily by Preventing Potential Exposure or Reducing the Mobility of the Waste

Alternative 2:

- Deed and site restrictions

Alternative 3:

- Excavation of soils and offsite disposal

Treatment Alternatives for Source Control that Would Eliminate the Need for Long-Term Management (including monitoring)

No feasible or practical alternatives. Alternative 4 for soils is not a treatment alternative for source control that would eliminate the need for long-term management (including monitoring) because the remedy would require ground water monitoring.

Alternatives Involving Treatment as a Principal Element to Reduce the Toxicity, Mobility, or Volume of Site Waste

Alternative 4:

- Excavation of soils and treatment by stabilization/solidification

3.4 SCREENING OF ALTERNATIVES

3.4.1 Landfill

3.4.1.1 Alternative 1 for the Landfill
•No action

Under Alternative 1 for the landfill, no remedial action would be taken for the landfill. This alternative is required by the National Contingency Plan (NCP) to be considered in order to provide a baseline against which all other alternatives may be compared.

Effectiveness. Miscellaneous debris, including shredded and rolled plastic film and several drums, would remain on the landfill surface. The landfill vegetation, which consists of a relatively heavy growth of grasses, shrubs, and trees (see Appendix A) would remain. The vegetative cover would reduce erosion of the landfill by runoff. The site vegetation has maintained the landfill cover during natural rainfall and flooding events for almost 20 years with little sign of stress or erosion. This diverse vegetative cover, including hydrophytic (moisture-loving) trees, results in greater evapotranspirative withdrawal from the landfill cover than would occur from shallow-rooted species alone.

There have been reports of leachate seeps from the sides of the landfill; however, during the 1986-1987 field investigations, very little evidence of seepage was noted. Under this alternative, however, the landfill would continue to be exposed to periodic flooding from the Scioto River. Thus, the potential remains for future release of contaminants.

Implementability. None.

Cost. There would be no costs associated with this landfill alternative.

Recommend. Evaluate further as required by NCP.

3.4.1.2 Alternative 2 for the Landfill
•Ground water monitoring
•Deed and site restrictions

Under Alternative 2 for the landfill, no remedial action would be taken, but access to and use of the site would be limited through imposition of deed restrictions. Deed restrictions imposed on the property would restrict disturbance of the landfill surface. The perimeter of the site (consisting of the landfill, field to the west, and drainage ditch to the east) would be fenced and posted for no trespassing. At least one lockable gate would be provided to allow authorized access to the site for monitoring and maintenance.

A ground water monitoring program would be operated at the site in order to detect any increase in contaminant levels. The ground water monitoring program would consist of collecting samples from several monitoring wells located hydraulically downgradient of the landfill. Monitoring would record ground water chemical concentrations and provide data sufficient to trigger a protective response if concentrations show a statistically significant upward trend.

Effectiveness. This landfill alternative would protect public health and the environment, without incorporating current State of Ohio solid waste landfill closure standards. This alternative is based largely on institutional enforcement of deed restrictions on land and ground water development.

This alternative would prevent future use of the site by imposing deed restrictions and would prevent human contact with soils by restricting site access. Infiltration through the cover and potential future transport of contaminants from the landfill contents would not be reduced under this alternative. To compensate for this, a ground water monitoring program would be implemented that is patterned after Subpart F of 40 CFR 264 and 40 CFR 265. The final monitoring requirements and any compliance program would be the subject of U.S. EPA and OEPA approval. The program would consist of collecting samples at least semi-annually from several monitoring wells located hydraulically downgradient of the landfill and analyzing for indicator parameters. After a few rounds of sampling, a list of indicator chemicals would be agreed upon. These indicator chemicals would be used as a basis for the sample analysis. Once a year, the samples would be analyzed for volatile organic compounds, semivolatile organic compounds, and metals from the TCL.

Should the ground water monitoring program show a generally upward trend in chemical concentrations, characterized by a statistically significant increase, an investigation into the source of the contamination would begin. This would involve sampling hydraulically upgradient monitoring wells as well as resampling downgradient monitoring wells. If contaminant levels continue to increase, a corrective action plan would be developed. Specific details would be developed in the design stage.

The specifics of the program would be developed at a later stage of the project. The following is an example of such a plan, and is used in the FS for cost estimating purposes only: The ground water monitoring program would consist of collecting samples twice a year from eight wells, located at well locations 5, 6, and 7, along the hydraulically downgradient side of the landfill. Once a year, the samples would be analyzed for volatile organic compounds, semivolatile organic compounds, and metals from the TCL. Otherwise, they would be sampled for barium and benzene only. The final monitoring requirements would be subject to U.S. EPA and OEPA approval.

Implementability. Implementation would be effected at low river stage. It is anticipated that construction could be accomplished within 1 month and could be easily scheduled. Periodic inspection and maintenance would be required after high river conditions.

Cost. Initial capital costs are estimated at approximately $165,000 based upon 7,500 feet of chainlink fence at an installed cost of $20/foot and legal fees of $15,000. There would be no capital costs associated with ground water monitoring. Operating and maintenance costs would be incurred over 30 years, primarily for maintenance of the fence following periods of river flooding.

Recommend. Evaluate further.

3.4.1.3 Alternative 3 for the Landfill
- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Local repair to existing landfill cover**
- **Erosion control and drainage improvements**

Alternative 3 for the landfill would include deed and site restrictions and monitoring as described in Alternative 2, together with repair of portions of the landfill surface, provision of erosion protection, and drainage improvements.

Surface debris would be removed from the landfill, since in some cases it may create a channel through which surface water could enter the landfill. By debris removal and subsequent surface repair, the potential for infiltration through the cover would be reduced. Areas of the landfill surface that have been damaged by erosion, or are inadequately vegetated, would be repaired by adding soils, compacting, and revegetating. Erosion protection would be provided on landfill areas adjacent to the river where they may be subject to higher surface water velocities during flooding. This would reduce the potential for erosion of the cover in those areas when the river is in flood. Armored protective covering of riprap would be provided at areas of high erosion potential, such as the northern and southern tips of the landfill. At areas where ground stability may be low, such as the river bank at the northern and southern tips of the landfill, sheet piling may be driven into the bank prior to installation of the riprap. A concrete wall may be constructed as an alternative to sheetpiling; such a decision would be made at the engineering design stage. Drainage improvements would be provided to the periphery of the landfill to prevent the ponding of water against the cover, to reduce the potential for erosion, and to minimize infiltration of water into the landfill.

Effectiveness. This landfill alternative would be effective in containing significant releases to the environment, without incorporating current State of Ohio solid waste landfill closure standards.

The existing site vegetation is a highly stable ecosystem that provides both surficial and deep stabilization and protects against erosion from precipitation and periodic flooding. Repairs and regrading of the landfill cover, together with erosion control, would further improve erosion protection.

Some reduction in infiltration through the cover would be realized by evapotranspirative withdrawal from the landfill cover by the moisture-loving tree species, and from the repairs to the landfill surface, which would improve surface runoff and reduce ponding.

The existing vegetation should maintain its domination of the site and result in continued stability. Disturbance of the landfill surface would be prevented by imposing deed restrictions, and soil contact would be prevented by restricting site access. A carefully managed ground water monitoring program of the nature outlined in Alternative 2 would ensure that any concentration changes in the ground water parameters would be determined through comparison with prior data, and that the need for future response actions, as appropriate, would be identified. These actions would be effective in reducing public health risks.

The alternative would involve some trucking of materials to and from the site; otherwise it would pose no unusual risks to the community or local environment. Level D personal protection, consisting of coveralls, gloves, rubber boots, and hard hats, would be required for workers implementing the site remediation and erosion protection operation.

Implementability. Implementation of this landfill alternative would be effected at low river stage utilizing standard earthmoving equipment. It is anticipated that construction would take 3 months. Regular maintenance would be essential, with inspection and appropriate corrective action taken after prolonged rainfall, or after flooding of the river.

Cost. The capital cost of this landfill alternative would be approximately $1.3 million. This would include $15,000 for deed and site restrictions. The remainder of the cost would be made up principally of material costs for the erosion control measures, including approximately 1,500 feet of sheetpiling at $300 per foot, and 2,500 cubic yards of riprap at $40 per cubic yard. Local repairs to the landfill would be approximately $100,000, which would cover the cost to remove surface debris, effect repairs to the cover, and revegetate the site.

Recommend. Evaluate further.

3.4.1.4 Alternative 4 for the Landfill
- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Natural clay cover over landfill**

Alternative 4 for the landfill would include the site fencing and monitoring described in Alternative 2, together with stripping the landfill of all vegetation, installing a natural clay cover over the landfill, and providing erosion protection.

Consistent with current State of Ohio solid waste disposal regulations, cover material would have low permeability to water, good compactability, cohesiveness, and relatively uniform texture. Suitable materials include loam, sandy loam, silty loam, clay loam, silty clay, or sandy clay. As stated in the RI, surficial geology in the site vicinity is characterized by the presence of silty clay and clay, averaging approximately 10 feet in thickness. This material appears to be continuous over much of the site, including the field to the west where sample SO-8 was taken, and the field to the north where sample SO-9 was taken. The permeability of SO-8 was measured at 3 x 10-8 cm/sec, and the permeability of SO-9 was measured at 5 x 10-8 cm/sec. These data, and the observed slow percolation of standing water in the field to the west, suggest that these areas may be a source for cover materials. More samples would need to be collected and tested for permeability prior to selection of this area as a borrow source.

The cover would be graded to assist drainage of rain and floodwaters away from the landfill to minimize infiltration of water. As well as minimizing infiltration through the cover, the additional cover materials would prevent direct contact with contaminated materials. The clay would then be covered by a layer of topsoil, which would then be revegetated to prevent erosion.

Armored protective covering of riprap would be provided at areas of potentially high erosion, such as the northern and southern tips of the landfill. At areas where ground stability may be low, such as the river bank at the northern and southern tips of the landfill, sheet piling may be driven into the bank prior to installation of the riprap. A concrete wall may be constructed as an alternative to sheetpiling; such a decision would be made at the design stage.

Effectiveness. This landfill alternative would protect public health and the environment. Covering the landfill with 2 feet of natural clay soils would employ current State of Ohio solid waste landfill closure standards and would reduce rain and floodwater infiltration through the cover and potential leaching of contaminants into ground water. Grading of the cover to assist drainage would minimize the length of contact time with water. Direct contact with the waste would also be prevented. Deed restrictions would

prevent future contact with waste, and a ground water monitoring program would monitor migration of contaminants. The effectiveness of the cover would be assessed by implementing the ground water monitoring program.

This alternative would not prevent floodwaters from coming into contact with the landfill surface. This, however, should be mitigated by erosion control measures implemented adjacent to the river, where high velocities occur during flooding. Infiltration would be low since clay covers typically reduce infiltration to less than 10 percent of precipitation.

This alternative involves substantial trucking of materials to and from the site; otherwise it would pose no unusual risks to the community or local environment.

Level D personal protection would be required for workers implementing the site covering and erosion protection operation.

Implementability. Implementation of this landfill alternative would involve the use of standard earthmoving equipment. A large number of trucks would be moved into and out of the site. Removed vegetation would be trucked to a nearby landfill for disposal. Natural clay soils from the area may be trucked in from local sources if the field to the west is not used. If so, the trucking operation may continue throughout the implementation period. It is expected that the local community would express concern over the safety of this operation, the potential of accidents, and wear-and-tear on the roads.

Implementation time is estimated to be approximately 1 year.

Regular maintenance would be essential to the success of this alternative. Inspection of the cover and appropriate corrective action would be required after prolonged rainfall, or after flooding of the river. Maintenance of the vegetative cover would be required to maintain the integrity of the clay cover; periodic mowing of the surface vegetation would be a necessary maintenance item. If proper maintenance is performed, the cover should be protective indefinitely.

Cost. The capital cost of this landfill alternative would be approximately $3.0 million. This cost would include the clay cover at approximately $12 per cubic yard for approximately 52,000 cubic yards of clay, and $8 per cubic yard for 55,000 cubic yards of

topsoil. Erosion control measures and access restrictions would make up the balance of the cost.

Recommend. Evaluate further.

3.4.1.5 Alternative 5 for the Landfill
- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Natural clay cover over landfill, together with leachate collection system and gas venting system**

Alternative 5 for the landfill would be the same as Alternative 4, with the addition of a leachate collection system and gas venting system. The cover would employ current State of Ohio solid waste landfill closure standards. The natural clay cover, grading, drainage, revegetation, and erosion control would be the same as described under Alternative 4.

Alternative 5 would consist of stripping the landfill surface of all vegetation, installing a gravel gas and leachate collection layer, and covering the entire surface with a layer of clay and then a layer of topsoil. Once all of the vegetation is removed from the landfill, the surface would be graded to provide a continuous slope from a line along the top of the landfill to both sides. A layer of granular material would then be placed over the landfill. A trench would be constructed along each side of the landfill, and perforated PVC pipe would be centered in the trench. The granular collection layer would intersect the trench at the bottom of the landfill. The granular layer would be crowned along the top of the landfill to vent gas to pipes installed every 100 feet. This 12-inch granular layer would allow leachate seeping out of the landfill to be collected in the PVC pipe at the bottom and would allow gas escaping from the landfill waste to be collected and vented to the atmosphere through vent pipes along the top of the landfill. It is possible that gas treatment may be required. If so, the gases may be passed through a vapor phase carbon adsorption system consisting of several disposable carbon canisters.

The leachate collection piping would be sloped to sump pumps that would discharge the liquid to a temporary holding tank prior to treatment. Treatment may involve hauling the leachate to Circleville's POTW, or to a similar offsite treatment plant.

The gravel collection layer would be covered with a layer of compacted natural clay and then a layer of topsoil. The topsoil would be seeded and mulched to provide a good grass cover which would help prevent erosion.

Effectiveness. This landfill alternative would exceed current State of Ohio solid waste landfill closure standards. State standards call for ventilation structures, as necessary. The Bowers Landfill is expected to be essentially inert after 20 years of inactivity, particularly since the majority of the disposed waste was residential refuse, which readily biodegrades. There may, however, be small quantities of gas generated under the cap from decaying vegetation that was trimmed before capping. There have been no reports of cracking of the landfill surface or gas bubble releases from ponded areas--two typical indications of gas venting. Hence, there is no evidence that gas venting would be necessary. Since there is no evidence of a significant leachate discharge, a leachate collection system is not required.

Upgrading the landfill cover with a natural clay cover would reduce the amount of infiltration passing through the landfill material. Installation of leachate and gas collection systems would prevent any potential buildup and release of leachate and/or gas. Leachate and gas generation have not thus far been identified as a problem at the site. Leachate potentially generated within the landfill would be collected and discharged for treatment or disposal. Any gases that may be generated within the landfill would be released to prevent buildup of pressure under the cap or the migration of gas through the subsoils.

Filling and grading of the site would effectively reduce the possibility of direct contact with the landfill waste. The clay cap would reduce the infiltration percolation through the waste and, therefore, reduce the transport of contaminants. Deed restrictions and fencing would support and strengthen the effectiveness of the soil cover in limiting direct contact.

The natural clay cover and erosion protection would require regular maintenance to remain protective. The useful life of the site cover would depend on proper operation and maintenance to maintain the finished grades against the effects of erosion and settlement. With these proper procedures, the cover should be protective indefinitely.

Routine monitoring of ground water would be carried out to identify future changes in contaminant concentrations. Monitoring would be effective in detecting water quality changes and identifying the need for future response actions, as appropriate.

This landfill alternative would not prevent floodwaters from coming into contact with the landfill surface. This should not be a significant concern for the same reasons stated under Alternative 4.

Except for the large volume of truck traffic, this alternative would pose no unusual risks to the community or local environment.

Level D personal protection would be required for workers carrying out the site covering and erosion protection operation.

Implementability. Implementation considerations would be similar to those for Alternative 4. Proven and reliable equipment would be used. The construction work would involve moving a large number of trucks into and out of the site. Maintenance of the cover would include periodic refilling and grading of the landfill should erosion or settlement occur. Implementation time is estimated to be approximately 1 year.

Cost. The initial capital costs would be approximately $4 million. The cost would include the clay cover at approximately $12 per cubic yard for approximately 52,000 cubic yards of clay, and $8 per cubic yard for 55,000 cubic yards of topsoil. Other costs include erosion protection at approximately $500,000; the gas venting system would require 25,000 cubic yards of gravel at $20 per cubic yard; the leachate collection system cost is estimated at $200,000 (trench, granular material, liner, piping, pump, and tank).

Based on leachate prediction calculations using the HELP model, approximately 1 million gallons per year may be expected. Assuming discharge to the Circleville's POTW, charges of $0.0281/gallon would result, plus trucking costs. Total costs for leachate collection are estimated at approximately $50,000 per year.

Recommend. Evaluate further.

3.4.1.6 Alternative 6 for the Landfill

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Natural clay cover over landfill, together with leachate collection system and gas venting system**
- **Drainage improvements**
- **Flood protection dike**

Landfill Alternative 6 is the same as Alternative 5, except that a flood protection dike would be installed in place of erosion protection.

The provision of flood protection would involve construction of a dike around the west and north sides of the landfill and a concrete wall at the south and northwest corners of the landfill where there is not sufficient room between the landfill and the river.

Storm water within the flood control dike and in the ditch to the east of the landfill would be collected in a gravity drainage system discharging water to the river through check valves. Alternatively, a pumping system could be used that would automatically activate once the water reached a pre-set level.

Effectiveness. The landfill improvements would exceed current State of Ohio solid waste landfill closure standards as described under Alternative 5. The flood protection dike would provide additional benefit by ensuring that the landfill is protected from a 100-year flood. The structure would minimize erosion of the existing soils cover during flood events.

Except for the large volume of truck traffic, this alternative would pose no unusual risks to the community or local environment. Regular maintenance would be required, and if properly performed, this alternative would be effective indefinitely.

Health and safety of workers in contact with the landfill surface would be initiated at Level D personal protection, with careful monitoring of dust conditions.

Implementability. The flood protection dike could be readily constructed from the clay soils generally available from the surrounding floodplain. As stated in the RI and discussed earlier under Alternative 4, surficial geology in the site vicinity is characterized

by the presence of silty clay and clay, averaging approximately 10 feet in thickness having permeabilities (based on sampling done during the RI) of less than 10^{-7} cm/sec.

Readily available excavation and earthmoving equipment would be used. Implementation would involve moving a large number of trucks into and out of the area. With periodic inspection and maintenance, flood protection dikes are considered to be reliable. Implementation time is estimated to be approximately 2 years.

Cost. Initial capital costs would be approximately $9 million. This figure would include all the costs, totaling $3.5 million as for Alternative 5, and approximately $5.5 million in addition for a flood protection dike. This cost is based on a dike 3,800 feet long, approximately 20 feet high, and having 3 to 1 (horizontal to vertical) slopes with a 12-foot-wide top. Approximately 200,000 cubic yards of material would be required at a typical installed cost of approximately $27.50 per cubic yard.

Recommend. Evaluate further.

3.4.1.7 Alternative 7 for the Landfill
- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Drainage improvements**
- **Flood protection dike**
- **Synthetic membrane cap over landfill with leachate collection system and gas venting system**

Alternative 7 for the landfill is the same as Alternative 6, except that a synthetic membrane cap would be used instead of a natural clay cover. Additional action required to provide a synthetic membrane cap would be the installation of a high density polyethylene (HDPE) synthetic liner above the clay layer, topped by a drainage layer and a topsoil layer. The topsoil would be seeded and mulched to minimize erosion, to provide a vegetative protective cover.

Construction of the leachate-gas collection system and flood protection dike would be as described in Alternatives 5 and 6, respectively.

Effectiveness. This landfill alternative would exceed current State of Ohio solid waste landfill closure standards, as described under Alternative 6. In addition, by the use

of a synthetic membrane cover, this alternative would meet closure standards for hazardous waste landfills.

The flood protection dike would provide additional benefit by ensuring that the landfill is protected from a 100-year flood. This structure would prevent erosion of the existing cover soils during flood events. Upgrading the landfill cover with a synthetic membrane cap would substantially reduce the amount of infiltration passing through the landfill contents. Installation of leachate and gas collection systems would prevent any potential buildup and uncontrolled release of these substances, as described in Alternative 5.

Regular maintenance would be required, and if properly performed, this alternative would be effective indefinitely.

Health and safety of workers in contact with the landfill surface would require use of Level D personal protection, with careful monitoring of conditions.

Implementability. Synthetic membrane caps have been used to cover many landfills, and have been documented to adequately reduce infiltration of rainfall into engineered landfills. The clay material required for the cap and flood protection dike could be readily obtained locally and could be placed using readily available excavation equipment. The synthetic liner is a well-tested and proven technology commonly employed at many landfill sites. The leachate and gas collection systems could be readily constructed using existing technology. Implementation would involve moving a large number of trucks into and out of the area.

Operation and maintenance of the cap and collection systems would require periodic inspection and repair. Implementation time is estimated to be approximately 2 years.

Cost. Initial capital costs would be $10.0 million. This would include all the costs of Alternative 6, with the addition of a synthetic layer over the cap. Approximately 650,000 square feet of liner would be required at $1 per square foot, together with a drainage layer of approximately 25,000 cubic yards at $20 per cubic yard.

Recommend. Evaluate further.

3.4.2 Ground Water

3.4.2.1 Alternative 1 for Ground Water
•No action

Under Alternative 1 for ground water, no remedial action would be taken. This alternative is required by the NCP to be considered in order to provide a baseline from which all other alternatives can be compared.

Effectiveness. Potential ground water contaminants--benzene and barium--would be left in place. The EA calculated both a most probable and a worst case exposure scenario for benzene to have risks of 1×10^{-6} and 9×10^{-6}, respectively, which are within the target risk range. The EA identified a potential noncarcinogenic risk from barium under the worst case scenario; however, the hazard index only slightly exceeds unity, and therefore, the actual risk is "probably very small." Furthermore, the most probable scenario identifies a hazard index of 0.17. These risks assume that, in the future, wells will be installed at the site to supply drinking water. There are currently no known downgradient wells within a mile of the site. Furthermore, the EA states that "there is a low probability that the ground water between Bowers Landfill and the Scioto River would be used as a drinking water source because this area is frequently flooded." The low risk levels, combined with the low probability that drinking water wells would be installed between the landfill and the river, further reduce the actual risk level of this alternative.

Public health concerns with this alternative would be directed at a potential change in contaminant levels in the ground water, as well as installation of additional ground water wells in conjunction with residential development of the area. Such a change in contaminant levels could be due to leaching of contaminants from the landfill under a No Action alternative for landfill remediation.

Implementability. None.

Cost. There would be no costs associated with this ground water alternative.

Recommend. Evaluate further as required by NCP.

3.4.2.2 Alternative 2 for Ground Water
•Ground water monitoring
•Deed restrictions

Under Alternative 2 for ground water, no remedial action would be performed. However, a long-term monitoring program would be set up to monitor concentrations and potential migration of contaminants, as described under Alternative 2 for the landfill.

A deed restriction would be imposed on the site, which would restrict future use of the site for extraction of ground water downgradient of the landfill. The deed restrictions would be permanently recorded and would continue to restrict ground water use if the property were sold.

Effectiveness. Ground water monitoring would be effective in determining the levels of contaminants in the ground water.

A deed restriction would be an effective method for preventing use of the ground water. The small risks associated with ingestion of ground water containing barium and benzene, which were determined in the EA, would be reduced to zero. Hence, a deed restriction would be fully protective of public health.

Implementability. A ground water monitoring program would be developed for the site and would be approved by the U.S. EPA and OEPA. The plan would stipulate which wells at the site were to be sampled, the frequency of sampling, and the parameters to be analyzed. Ground water samples would be collected and analyzed according to methods described in EPA's *A Compendium of Superfund Field Operations Methods* (December 1987).

Deed restrictions would be filed at the local deed registry. Implementation time is estimated at less than 1 month.

Cost. Capital costs would be limited to deed restrictions. Operating costs for sampling eight wells and analyzing the samples twice per year are estimated at approximately $20,000 per year.

Recommend. Evaluate further as a reliable, cost-effective alternative that is fully protective of public health.

3.4.2.3 Alternative 3 for Ground Water
- Ground water monitoring
- Extract ground water
- Discharge to POTW

Under Alternative 3 for ground water, contaminated ground water would be extracted from the aquifer and trucked to Circleville's POTW.

Benzene was detected in well P-6B, a well screened in the lower aquifer just off the west side of the landfill. Barium was detected in well P-5B, screened in the lower aquifer at the southern tip of the landfill. The objective of an extraction well system is to capture all of the contaminated ground water and to minimize extraction of uncontaminated water. Therefore, in order to effectively extract barium and benzene, ground water would be extracted only from these wells where such extraction were determined to be necessary. There is no reason to believe that these contaminants are present in other locations or that there is a continuous plume of contamination.

Two extraction wells pumping at 10 gpm each would be installed in the lower aquifer near the existing monitoring wells where barium and benzene were detected. The wells would penetrate to a depth approximately 70 feet below the surface. The extraction wells should remove ground water from a radius of approximately 100 feet from the pumps. Based upon the low levels of contaminants, it is expected that background concentrations would be reached within several years.

The pumps would discharge to a collection tank system, where tank trucks would periodically collect loads for trucking to Circleville's POTW, or a similar offsite treatment unit. Ground water could be treated in the nearby POTW at Circleville. Extracted ground water would be discharged to the POTW under a wastewater discharge permit for a period of several years, after which time the aquifer is projected to be clean. Discharges would be regularly monitored to ensure compliance with the permit.

This alternative is dependent upon the City of Circleville POTW's accepting a flow of 10 million gallons per year, which would constitute 0.7 percent of the plant's design capacity. It is possible that the POTW would reject a stream that originates from a Superfund site. In order to discharge the ground water into the sewer system, it would be

transported by truck a distance of 2 miles to the POTW, the nearest discharge point. At 20 gpm of flow, six truckloads of water would be transported per day.

Effectiveness. This ground water alternative would be effective in removing contaminants from the aquifer. This alternative is, however, the least preferred remedy according to SARA, which in Section 121(b) states that "the offsite transport and disposal of hazardous substances or contaminated materials without such treatment should be the least favored alternative remedial action where practicable treatment technologies are available."

Implementability. Ground water extraction wells would have to be designed and installed at the site. Drilling operations could create a hazard at the site by raising contaminated dust. Such a hazard would be mitigated by the use of facial respirators by the drillers. An electricity supply would be required at the site in order to operate the extraction pumps. Regular ground water monitoring of upgradient conditions and pump discharge conditions would be required to monitor the effectiveness of the extraction. Implementation time is estimated at several months.

It is expected that the local community would express concerns over the trucking operation, the potential for accidents, and wear-and-tear on the roads.

Cost. Based upon treatment charges at Circleville's POTW of $0.0281 per gallon, treatment costs are estimated at approximately $300,000 per year. Trucking charges are estimated at $50,000 per year per truck, totaling $100,000, assuming use of two trucks. Thus, total charges are $400,000 per year. Capital costs would be approximately $100,000 for two wells, the associated piping, and a collection tank.

Recommend. Reject this ground water alternative because it is the least preferred remedy under SARA, would offer no improved protection to public health over Alternative 2, yet would involve substantially higher costs.

3.4.2.4 Alternative 4 for Ground Water

- **Ground water monitoring**
- **Extract ground water**
- **Treat by metals precipitation and carbon adsorption**
- **Discharge to Scioto River**

Under Alternative 4 for ground water, contaminated ground water would be extracted from the aquifer and pumped to an onsite ground water treatment plant. The ground water extraction system would be identical to that described for Alternative 3 for ground water. The 10-gpm stream from well P-6B would be pumped to a carbon adsorption system, where benzene would be removed, and a 10-gpm stream from P-5B would be pumped to a metals precipitation system, where barium would be removed. The benzene-free and barium-free streams would be combined and discharged to the Scioto River.

The carbon adsorption system would remove virtually all organic compounds from the water stream by physical and chemical adsorption of organics onto the surface of carbon particles. Granular activated carbon (GAC) is most frequently used in wastewater treatment. The ground water would be pumped through a bed of GAC, until the bed became saturated with contaminants. At that time, the GAC would be replaced.

The metals precipitation would remove barium and other minerals from the ground water by pH adjustment. Ground water would be pumped continuously through a stirred tank reactor, where a pH of 9.3 would be maintained by adding lime to the reactor. Barium would react with the lime to form the insoluble barium hydroxide, which would precipitate from the solution. The solids would be separated from the ground water in a continuous thickener, followed by a sand filter as a polishing step.

The two treated streams would be combined and discharged to the Scioto River.

Effectiveness. This ground water alternative would be effective in removing contaminants from the aquifer. The carbon adsorption system would remove in excess of 99.9 percent of organic chemicals from the ground water stream. The metals precipitation system would remove approximately 90 percent of the barium. Therefore, both treatment processes would be effective in achieving remediation goals.

Additional chemicals in the ground water could make the metals precipitation process very inefficient. Naturally occurring minerals, such as iron, could also precipitate. Not only would this require substantial quantities of lime, but also, large volumes of sludge may be produced.

Implementability. The implementability of the ground water extraction system is identical to that described for ground water Alternative 3. The metals precipitation system would require extensive bench- and pilot-scale research and development work in order to determine the optimum levels of chemical addition, residence time in the reactor and filters, and degree of agitation in the reactors. The goal is to remove as much barium as possible, while removing as little of the other minerals as possible.

Substantial engineering work would be required prior to procurement and installation of the equipment. Several pieces of equipment would be required, including a feed preparation system for lime, which would be delivered in dry form, but added to the reactor as a slurry; and a backwash system for the sand filter, consisting of a holding tank and a backwash pump. Implementation time is estimated to be 1 year.

The treatment plant would require the part-time attention of at least two people experienced in precipitation reactions. They would also regularly monitor precipitation conditions in the reactor to ensure that design constraints are met. They would organize and coordinate sludge disposal. The carbon adsorption system would require very little attention, but the outlet would have to be regularly sampled to detect saturation of the carbon.

Cost. A typical 20-gpm package treatment unit for metals removal has a capital cost of approximately $100,000. Peripheral equipment, including extraction wells, a gathering system, and carbon treatment and discharge lines, are expected to cost approximately $100,000. Thus, total capital cost would be $200,000. Typical operating charges for ground water monitoring manpower, maintenance, and sludge handling are expected to be $100,000 per year.

Recommend. Reject this ground water alternative since it would offer no improved protection to public health over Alternative 2, yet would involve substantially higher capital and operating costs.

3.4.3 Surface Soils

3.4.3.1 Alternative 1 for Soils
•No action

Under Alternative 1 for soils, no remedial action would be taken. This alternative is required by the NCP to be considered in order to provide a baseline against which all other alternatives are compared.

Effectiveness. Potential soil contaminants addressed in Section 2.1.3--lead, total PAHs, and PCBs--would be left in place. The exposure pathway for ingestion of soils is associated with small, localized areas of the site. Areas of contamination are primarily the landfill and areas immediately adjacent to it. Concentrations in the field to the west of the landfill are generally at background levels.

The hazard index for lead, based on the worst case scenario, would remain at 3.2. The hazard index may overestimate the actual risk because it assumes both the maximum lead concentration and a worst-case soil ingestion rate. Furthermore, this value is based upon a maximum detected lead concentration of 179 mg/kg and compares to a range of 500 to 1,000 mg/kg reported by the Centers for Disease Control; in this range, the blood lead levels in children increase above background. In addition, the hazard index, based on the most probable case, is 0.14 and thus does not represent a noncarcinogenic risk.

PAHs and PCBs would exhibit worst case carcinogenic risks of 2×10^{-6} and 7×10^{-7}, respectively; both of these values lie within the target risk range. Under the most probable scenario for PCBs, carcinogenic risks are 5×10^{-9}, considered an insignificant risk. The most probable scenario risk for PAHs was not calculated in the EA because average concentrations are not greater than background.

Since only a portion of the landfill surface was sampled, it is possible that higher concentrations may occur elsewhere. However, 21 samples were taken on the landfill, giving a geometric mean lead value of 78 mg/kg. In addition, in developing the sampling plan for the RI, locations were chosen based upon areas where leachate seeps were found in previous investigations and where concentrations would thus be expected to be higher.

The public health concerns with leaving the soils in place without remediation are limited because of the low level and isolated nature of the contamination.

Implementability. None.

Cost. There would be no costs associated with this soils alternative.

Recommend. Evaluate further as required by NCP.

3.4.3.2 Alternative 2 for Soils •Deed and site restrictions

Under Alternative 2 for soils, no direct remedial action would be taken, but access to and use of the site would be restricted. Access would be restricted by posting no trespassing signs and erecting a fence around the perimeter of the site (consisting of the landfill, the field to the west, and the drainage ditch to the east). At least one lockable gate would be provided to allow authorized access to the site. Use of the site would be limited by imposing deed restrictions to restrict disturbance of the landfill surface. The viability of continued farming of the field to the west would be determined as part of any remedial plan.

Effectiveness. The exposure scenarios determined in the EA for soils ingestion would be changed by limiting site access and by placing restrictions on present and future use of the site. Small children would no longer be at risk, and exposure would be limited to trespassers. Under the most probable exposure scenario, the fence would prevent all access to the site, and thus would prevent all direct contact with contaminants. Therefore, the risks associated with soils ingestion under this scenario would be zero. Under the worst case scenario, risks would be reduced.

Implementability. Implementation would be effected at low river stage. It is anticipated that construction would take less than 3 months and could be easily scheduled. Annual inspection and maintenance would be required immediately after high river conditions.

This operation would be carried out with conventional small commercial equipment. In the vicinity of the landfill, personnel would wear Level D protection, consisting of

coveralls, gloves, rubber boots, and hard hats. Air monitoring would be conducted during excavation or digging in the vicinity of the landfill. Provisions would be made in the health and safety plan to upgrade protection to Level C if monitoring detects contaminants above trigger levels. Equipment and personnel decontamination facilities may be required. Wastewater from decontamination would be stored in drums for offsite treatment, or discharged to the river under permit. Implementation time is estimated to be 1 month.

Cost. Initial capital costs are approximately $165,000, based upon 7,500 feet of chainlink fence at an installed cost of $20/foot, and legal fees of $15,000. Operating and maintenance costs would be incurred over a period of 30 years, primarily for maintenance of the fence following periods of high water or flooding of the Scioto River.

Deed and site restrictions are already required for all landfill alternatives with the exception of No Action. Thus, the net cost of this alternative for soils is zero.

Recommend. Evaluate further.

3.4.3.3 Alternative 3 for Soils
•Excavation of soils and offsite disposal

Under Alternative 3 for soils, contaminated soils would be excavated and placed in lined trucks to be hauled offsite to an approved disposal facility.

More detailed information would be required for implementation of this alternative. Additional soils sampling may be required and would be defined during the remedial design phase. Guidelines for any additional soils sampling would be taken from reports such as *Statistical Methods for Evaluating the Attainment of Superfund Cleanup Standards, Volume 1: Soils and Solid Media* (U.S. EPA, 1988).

Effectiveness. This alternative would remove contaminated soils from the site thereby breaking the potential exposure route. However, offsite disposal is the least preferred remedy according to SARA.

Implementability. Implementation of this soils alternative would be effected during low river stage using commercial excavation equipment. Dust control measures

may be required, consisting of spraying river water or water purchased from other sources over the excavation area with truck-mounted spray equipment.

Personnel would wear Level D protection. Equipment and personnel decontamination facilities may be required. Wastewater from decontamination would be stored in drums for offsite treatment, or discharged to the river under permit. Implementation time, including potential sampling, is estimated at 6 months.

Cost. Costs for excavation of surface soils and offsite disposal would be approximately $140,000. This is based primarily on disposal and transportation costs of $150 per yard to a secure landfill. As stated in Section 3.1, costs for the screening of alternatives are based on engineering judgment. Thus, as a preliminary estimate, soils in three areas of the site where high levels of contamination were detected would be excavated; those would be at SO-34, SO-39 on or adjacent to the landfill, and SO-44 just off the south tip of the landfill. Each excavation pit would have a radius of 50 feet from the test boring, and a depth of 1 foot. These dimensions are based on information in the RI regarding the extent of contamination and on the mobility of contaminants in soils. Hence, the total volume of soils to be excavated and disposed would be 900 cubic yards.

Recommend. Reject because this soils alternative is the least preferred remedy under SARA. Also, it is not cost-effective and offers no improved protection to public health under the most probable scenario when compared to Alternative 2.

3.4.3.4 Alternative 4 for Soils
•Excavation of soils and treatment by stabilization/ solidification

Under Alternative 4 for soils, the identified areas of soils with lead contamination above background levels would be excavated and the contaminants stabilized/solidified by chemical fixation. In this process, the contaminated soil would first be mixed with stabilizing chemicals to minimize leaching potential; then the stabilized material would be allowed to harden or solidify into a monolithic mass. Chemical fixation has been used in similar applications worldwide and is beginning to be used at several Superfund sites.

As a preliminary estimate, 900 cubic yards of soil would be excavated and stockpiled. Soil from the stockpile would be fed to a pug mill, which is a proven piece of equipment often used for chemical fixation of clay soils. Approximately 25 to 50 percent

by weight of immobilization chemicals would be added. These are normally a cement-type material that would effectively bind the inorganic metals in non-soluble salt complexes. This process has been proven with similar soil contaminants at volumes substantially in excess of those proposed at the Bowers Landfill. The stabilized material would remain onsite unless leaching tests show otherwise.

Effectiveness. The exposure risks for soils ingestion would be eliminated since the solidified material would form a large solid block, which could not fit into the mouths of children, the primary receptors. The exposure of workers may, however, outweigh the exposure of the general public to the contaminants with deed and site restrictions imposed.

Implementability. Implementation of the alternative would be effected during low river stage utilizing commercial earthmoving equipment over a period of 3 months. Dust control measures using water sprays would be required. Excavation of soil would have to be coordinated with remedial activities for the landfill because the majority of locations of high lead concentrations are on, or immediately adjacent to, the landfill.

Personnel would wear Level D protection. Equipment and personnel decontamination facilities may be required. Wastewater from decontamination would be stored in drums for offsite treatment, or discharged to the river under permit.

Cost. The costs of excavation of surface soils and treatment by stabilization/solidification would be approximately $185,000. This is based upon stabilization/solidification costs of approximately $150 per cubic yard and on research and development costs of $50,000.

Recommend. Reject this soils alternative since it is not cost-effective and offers no improved protection to public health under the most probable scenario when compared to Alternative 2.

3.5 ASSEMBLY AND DESCRIPTION OF SITE ALTERNATIVES

3.5.1 Assembly of Site Alternatives

As described in Section 3.4, two of the alternatives for the surface soils, all of the alternatives for the landfill, and two ground water alternatives have been retained for further evaluation. Site alternatives have been developed by combining media alternatives in a logical and progressive manner, to effect improvements in the site environment and to achieve ARARs. The site alternatives are categorized in accordance with the U.S. EPA guidelines stated in Section 3.1 and are as follows:

Alternatives that Require No Action

Site Alternative 1:

- No action

Alternatives that Involve Containment of Waste with Little or No Treatment, but Provide Protection of Human Health and the Environment Primarily by Preventing Potential Exposure or Reducing the Mobility of the Waste

Alternative 2:

- Ground water monitoring
- Deed and site restrictions

Alternative 3:

- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Local repair to existing landfill cover
- Erosion control and drainage improvements

Alternative 4:

- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Erosion control and drainage improvements
- Natural clay cover over landfill

Alternative 5:

- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Erosion control and drainage improvements
- Natural clay cover over landfill together with leachate collection system and gas venting system

Alternative 6:

- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Natural clay cover over landfill together with leachate collection system and gas venting system
- Drainage improvements

- Flood protection dike

Alternative 7:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Drainage improvements
- Flood protection dike
- Synthetic membrane cap over landfill with leachate collection system and gas venting system

Alternative 8:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Erosion control and drainage improvements
- Synthetic membrane cap over landfill with leachate collection system and gas venting system

Alternative 9:
- Ground water monitoring
- Deed and site restrictions
- Management of surface debris
- Erosion control and drainage improvements
- Improvements to landfill side slopes
- Natural clay cover over landfill top

Treatment Alternatives for Source Control that Would Eliminate the Need for Long-Term Management (including monitoring)

No feasible or practical alternatives.

Alternatives Involving Treatment as a Principal Element to Reduce the Toxicity, Mobility, or Volume of Site Waste

No feasible or practical alternatives.

3.5.2 Description of Site Alternatives

3.5.2.1 Description of Site Alternative 1 •No action

Under site Alternative 1, no further remedial investigation, study, or monitoring would be conducted. The site would remain as it exists with no further action by EPA, except as required under SARA.

Under SARA Section 121(c), the site remedy must be reviewed no less often than each 5 years after initiation of the remedy. The review is required wherever a remedial action results in any hazardous substances, pollutants, or contaminants remaining at the

site, and checks that human health and the environment are being protected. The review provision applies to all site alternatives.

3.5.2.2 Description of Site Alternative 2
•Ground water monitoring
•Deed and site restrictions

Ground Water Monitoring

A long-term monitoring program that would be patterned after Subpart F of 40 CFR 264 and 40 CFR 265 would be set up to monitor concentrations and potential migration of contaminants. The final monitoring requirements and any compliance program would be subject to U.S. EPA and OEPA approval. The program would consist of collecting samples at least semiannually from several monitoring wells located hydraulically downgradient of the landfill and analyzing for hazardous constituents. After a few rounds of sampling, a list of indicator chemicals that would be used for the basis of future analyses would be agreed upon. These indicator chemicals would be used as a basis for the sample analysis.

Should the ground water monitoring program show a generally upward trend in chemical concentrations, characterized by a statistically significant increase, an investigation into the source of the contamination would begin. This would involve sampling hydraulically upgradient monitoring wells, as well as resampling downgradient monitoring wells. If contaminant levels continue to increase, a corrective action plan would be developed. Specific details of the program would be developed during the design stage.

Deed and Site Restrictions

Deed and site access restrictions would be placed across the site area as defined by Drawing 4; this would encompass the landfill, the field to the west, and the ditch to the east.

Deed restrictions would prohibit future use of the site for extraction of ground water downgradient of the landfill and would restrict disturbance of the landfill surface. The viability of continued farming of the field to the west of the landfill would be determined as part of any remedial plan.

The purpose of site restrictions would be to limit access to the site, thereby preventing direct contact with the waste material in the landfill and the contaminated soil. As shown in Drawing 4, site restrictions would be provided by the erection of a fence, approximately 7,500-feet-long, around the site. The fence would be of steel post and chainlink construction, and would be 6 feet tall. Access to the site, by authorized personnel, would be provided by one or more double-swing, lockable gates.

3.5.2.3 Description of Site Alternative 3
- **Ground water monitoring (Section 3.5.2.2)**
- **Deed and site restrictions (Section 3.5.2.2)**
- **Management of surface debris**
- **Local repairs to existing landfill cover**
- **Erosion control and drainage improvements**

Site Alternative 3 incorporates the ground water monitoring and the deed and site restrictions, previously described, together with remediation of portions of the landfill surface and the provision of erosion control and drainage improvements (Drawing 5).

Management of Surface Debris

The landfill area and its immediate vicinity would be cleared of surface debris. Most of the currently exposed material consists of shredded or rolled plastic film, but rusted and partially decomposed remains of appliances, discarded tires, assorted domestic waste, and drums are also evident. The visible waste items would be removed from the site by a front-end loader and lined truck, and transported to a suitable hazardous waste landfill or, for nonhazardous debris, a nearby sanitary landfill.

Local Repairs to Existing Landfill Cover

After the surface debris has been removed, the landfill would be inspected to identify surface areas that show signs of erosion, are worn down by vehicular and recreational traffic, or were inadequately covered when landfilling ceased. These areas would be cleared of vegetation and repaired by taking natural clay soil from the adjacent field, or similar borrow source, and applying it in 6-inch lifts, before compaction, until the repair areas are uniform with the surrounding surface. Low spots on the crown of the landfill would be filled also by following the same procedure. The objective would be to regrade low areas to provide a uniformly sloping surface that would drain water off the surface of the landfill. A review of Drawing 15 shows most of the side slopes are flatter

than 2:1 (horizontal to vertical) and that 2:1 slopes are quite localized, generally being limited to the eastern side slope and landfill tips. Low points would be regraded to ensure that ponding, or collection of runoff, would not occur. Erosion rifts either on the top or sides would be repaired with fill, probably taken from the west field. Drainage patterns would be surveyed, and areas of high velocity, such as gullies, would be filled and areas prone to ponding regraded.

The existing cover would be maintained or improved in accordance with recommendations made in the technical memorandum evaluating the site vegetation (Appendix A). The access road would be cleared, regraded, and maintained annually to eliminate ponding. This road would be used for access to selectively control vegetative species growth and development. Selective cutting would be done to provide "release" for overstory species, and dead vegetation and trees would be removed.

Where vegetation must be removed for surface repairs, the areas would be covered with soil adequate to sustain vegetation. The areas would be reseeded with fast-growing vegetation of similar species as the existing vegetation. The areas would be protected to prevent erosion and fertilized and watered until plant growth is established.

The cover would be inspected on a regular basis for structural integrity and vegetation growth in accordance with the maintenance program outlined in Appendix A.

Erosion Control and Drainage Improvements

Erosion protection would be provided on those areas of the landfill prone to the scouring effects of swift-flowing water from the river prior to and during flooding events that may be detrimental to the integrity of the cover. The areas most likely to be subjected to these effects would be the northwest portion of the landfill and the southeast corner, both of which are located adjacent to the river's edge. A system of armor stone (riprap) would be used in these areas to supplement the resistance to erosion provided by the existing cover.

To provide additional erosion protection and to dissipate the energy of the river flow, stones would be placed on the north-facing slope of the western edge of the landfill from the river's edge east approximately 100 feet, as shown in Drawing 5. In the event that the stones could not be placed effectively on the western (river) edge of the landfill

without actually going into the river, a sheetpile would be constructed to support the stone fill in this area. The sheetpile would be constructed immediately at the edge of the river, possibly even extending into the river. Stones would be placed up the west slope between the sheetpile and the landfill, meeting those stones placed on the north slope. The stones would also extend around to the south side of the west end and run east approximately 50 feet for protection from eddies as the river flows past the landfill. A concrete wall may be constructed as an alternative to sheetpiles; such a decision would be made at the design stage.

Similar protection measures would be implemented at the southern edge of the landfill where it meets the river. The upriver slope would have 100 feet of stone placed on it, and the slope parallel to the river and the east slope would have 50 feet of stone placed along it. In setting the stone, care would be exercised not to damage the surface of the landfill.

Improvements would be made to the side slopes to provide continuously sloping surfaces that would improve drainage patterns and eliminate ponding. The sides would be stabilized where the integrity of the cover is poor, including erosion rifts, areas of heavy root exposure, and severe slopes. To allow repairs to be made on the east slope, the east ditch would be dewatered to the extent possible, and a temporary access road would be built along the base of the landfill. Additional details of the improvements to the side slopes are discussed under Site Alternative 9.

The site drainage would require improvement to prevent ponding against the landfill. The area between the landfill and the river would be regraded where necessary to allow water to flow away from the sides of the landfill. This could be accomplished by combining site regrading with the work on the landfill cover. The drainage ditch running along the west side of the landfill would be graded for drainage flow from north to south and natural discharge into the Scioto River. High points would be cut down and vegetation would be removed as necessary. Drainage flow through the ditch on the eastern edge of the landfill running north-south would also be improved. Provisions would be made to cut down the high point between the north end of the ditch and the field to the north of the landfill. This would prevent water from ponding up against the landfill after a high water event or intense or extended periods of precipitation, by allowing the field to drain into the ditch.

The discharge pipe for the drainage ditch, located at the southern end of the ditch, would be replaced with a larger one. A 36-inch-diameter corrugated metal pipe would be placed under the road accessing the site and continue on out to the river. The point where the ditch meets the pipe would be lined with compacted clay and riprap to eliminate erosion around the pipe. The pipe would be sloped at a minimum gradient of 2 percent to prevent sediments depositing in the pipe. Trash racks would be installed at either end of the pipe to minimize or prevent blockage of the pipe by debris. The ditch and drainage pipe would be inspected periodically for damage, obstruction, or deterioration due to flooding or an unusually violent storm. The trash racks would be regularly emptied, and the pipe would be repaired if necessary.

Discharges from the drainage ditch may be required to meet the requirements of the NPDES program.

3.5.2.4 Description of Site Alternative 4

- **Ground water monitoring (Section 3.5.2.2)**
- **Deed and site restrictions (Section 3.5.2.2)**
- **Management of surface debris (Section 3.5.2.3)**
- **Erosion control and drainage improvements (Section 3.5.2.3)**
- **Natural clay cover over landfill**

Site Alternative 4 is similar to Site Alternative 3, except that a natural clay cover would be placed over the landfill instead of making repairs to the existing cover (Drawing 6). The landfill in its present condition does not have a protective cover of uniform thickness and type of material. Compared to the existing cover, a natural clay cover would reduce and retard infiltration, and minimize migration through the waste of water that could eventually be released as leachate. The clay layer would have a protective, vegetated cover built over it to promote drainage, and to minimize erosion or abrasion of the clay cover.

As shown in Drawing 3, the hydrogeologic investigation concluded that the landfill appears to be placed on a layer of silty clay that is interpreted as being continuous across much of the site. The clay cover would be constructed of similar material and would be in accordance with the requirements of OAC 3745-29-09(F)(4).

Trees would be removed by laborers using chain saws. The trees would be cut down and trimmed. As much subsurface vegetation would be removed as feasible, without exposing significant amounts of waste. The remaining tree stumps would be ground down

to the surface with power grinders pulled across the landfill by tractors. Smaller vegetation, including trees less than 2 feet in diameter, would be cut down with mechanical cutting equipment known as bushhogs, which would be pulled by tractors. These activities may expose the landfill contents to precipitation or flooding. The exposed cover would require several applications of broadleaf herbicides to systemically kill the woody species and prevent tree growth through the new cover.

All removed vegetative material, including trees and smaller vegetation, would be loaded into haulage trucks and transported to a local landfill. Tissue samples would be taken to determine chemical uptake and confirm whether the vegetation is hazardous or nonhazardous. If nonhazardous, it would be disposed of in a sanitary landfill; otherwise the vegetation would be disposed of in a secure landfill.

Preliminary information in the RI describes the landfill to be approximately 10 feet high, 4,000 feet long, 125 feet wide (at the top), and to have, on average, a 2:1 (horizontal to vertical) side slope. Based upon this conceptual information, it is estimated that 52,000 cubic yards of natural clay, and 54,500 cubic yards of top layer soil would be required to cover the landfill. This preliminary information, while being adequate to establish overall cover requirements, is not adequate as a basis for the slope stability calculations which are made in Appendix D using location specific data shown on the site topographic map (Drawing 15). A review of this drawing shows most of the side slopes are flatter than 2:1 and that 2:1 slopes are quite localized, generally being limited to the eastern side slope and landfill tips.

The cover to be placed over the landfill would be constructed in accordance with the provisions of OAC 3745-27-09 and would consist of the following (typical section, Drawing 7):

1. A well-compacted clay layer, at least 24 inches thick, consisting of nonputrescible materials having low permeability to water, good compactability, cohesiveness, and relatively uniform texture.

2. A vegetated top cover at least 24 inches thick supported by vegetation that will effectively minimize erosion without need for continuing application of fertilizers, irrigation, or other man-applied materials to ensure viability and persistence.

The top cover and bottom clay layer would be emplaced in lifts, not exceeding 6 inches before compaction.

The vegetated cover would be graded to a final slope of between 3 and 5 percent on the top, while the clay cover would have an outward slope of 2 percent. Side slopes of all layers on the landfill would be graded to give continuous slopes. Preliminary slope stability calculations (Appendix D) show the side slopes would be stable. This analysis was based upon soil samples collected from the side slopes, published data on relevant soil properties, together with a review of the slope configuration detailed on the existing topographic map for Site Alternative 9 (Drawing 15). An additional slope stability evaluation would be carried out during the design phase based upon the results of a more detailed site topographic survey and additional soil sampling data. Slopes deemed unstable would be regraded, covered with soil, and vegetated.

On completion of the landfill cover, the entire surface would be reseeded, fertilized, and watered to assure plant growth. The plant species chosen would have root systems that would not be expected to penetrate beyond the vegetated layer and possibly damage the integrity of the natural clay layer.

The cover would be inspected for structural integrity on a regularly scheduled basis and repaired as necessary. It is possible that subsidence depressions could occur from decaying vegetation remaining under the landfill cover. These depressions would be repaired as part of this maintenance program. Following periods of flooding, the landfill cover would be inspected for signs of erosion. Additional sheetpiling or riprap would be provided as necessary in areas that may require erosion protection.

3.5.2.5 Description of Site Alternative 5

- **Ground water monitoring (Section 3.5.2.2)**
- **Deed and site restrictions (Section 3.5.2.2)**
- **Management of surface debris (Section 3.5.2.3)**
- **Erosion control and drainage improvements (Section 3.5.2.3)**
- **Natural clay cover over landfill (Section 3.5.2.4)**
- **Gas venting system**
- **Leachate collection system**

Site Alternative 5 would be similar to Site Alternative 4, except that the landfill would incorporate a gas venting system and a leachate collection system (Drawing 8).

Gas Venting System

As shown in Drawing 9, a 12-inch layer of gravel would be installed over the landfill surface once vegetation was cut down and removed. A network of perforated pipe, approximately 6 inches in diameter, would be laid in the coarse stone bed at 100-foot intervals, where the gases could be collected and vented to the atmosphere, preventing pressure buildup under the cap. The gravel layer would have a geofabric placed over the top to prevent clogging of the void spaces.

The 24-inch clay cover would be installed over the granular layer, followed with the 24 inches of vegetative cover, in the same fashion described for Alternative 4. Gas vents would connect to the perforated pipe and exit vertically through the clay and cover soil layers on top of the landfill. The vent pipes will be tied into the cap system so as not to allow the penetration of liquid into the landfill.

It is possible that gas treatment may be required. If so, the gases may be passed through a vapor phase carbon adsorption system consisting of several disposable carbon canisters. However, such treatment is not anticipated.

Leachate Collection System

As shown in Drawing 9, leachate collection would consist of a trench, located at the toe of the landfill, filled with granular drainage material. Embedded in the coarse material would be a perforated PVC pipe that would catch and direct the flow of leachate to a collection point in the trench system. It would then be pumped out to a temporary holding tank and discharged periodically for treatment. Treatment may consist of discharging to Circleville's POTW, or a similar offsite treatment plant. The clay cap would be constructed over the trench with the granular gas venting material integrating with the granular material in the trench. The trench would be 2 feet deep, 1 foot wide, and would be constructed below the base of the landfill to collect the leachate from the waste. Soils testing would be necessary to confirm the continuity of the clay layer at the landfill. The hydrogeologic investigation (discussed under Site Alternative 4) concluded that the landfill appears to be placed on a layer of silty clay that is interpreted as being continuous across the site. Recent discussions with an individual claiming to be familiar with the site operations suggests that some excavation may have occurred near the southern site boundary during early years

prior to landfilling operation. No information has been obtained to suggest that the pit did not penetrate the silty clay.

3.5.2.6 Description of Site Alternative 6

- **Ground water monitoring (Section 3.5.2.2)**
- **Deed and site restrictions (Section 3.5.2.2)**
- **Management of surface debris (Section 3.5.2.3)**
- **Drainage improvements (Section 3.5.2.3)**
- **Natural clay cover over landfill (Section 3.5.2.4)**
- **Gas venting system (Section 3.5.2.5)**
- **Leachate collection system (Section 3.5.2.5)**
- **Flood protection dike**

Site Alternative 6 would be similar to Site Alternative 5, except that erosion protection, would be replaced by the construction of a flood protection dike to prevent inundation of the landfill by the Scioto River (Drawing 10).

Construct Flood Protection Dike

The implementation of flood protection would involve construction of a dike around the west and north sides, and a concrete wall at the south and northwest corners of the landfill, where there is not sufficient space for a dike between the river and the landfill.

Construction would begin with tieing a concrete wall into the higher elevations to the southeast of the landfill. The concrete wall would continue for approximately 250 feet along the river to the south of the landfill. The wall would be constructed a sufficient distance away from the toe of the landfill to allow access to the west side of the site. Once the wall reached the open floodplain to the west of the landfill, it would be tied into the flood dike. The flood dike would continue for 2,500 feet along the west side of the landfill to the northwest corner, crossing the floodplain diagonally. Another concrete wall would be constructed along the river at the northwest corner of the landfill for approximately 320 feet. (Note: In the event of insufficient space between the landfill and the river to construct a stable concrete wall, a system of sheetpiles with stone backing would be erected in place of the concrete). A flood dike would be constructed for an additional 1,250 feet along the northern edge of the landfill.

As shown in Drawing 11, the flood dike would be constructed with 3:1 (horizontal to vertical) side slopes and would be approximately 12 feet wide at the top. The elevation of the top would be 675 feet, which would be approximately 2 feet above the 100-year

flood elevation of 672.8 feet mean sea level (msl). The core of the flood dike would be constructed of an impervious clay material, and the side slopes would be of random fill, taken from the floodplain to the west of the landfill. The sides of the dike along the river would be protected against erosion by surface water by concrete riprap or rock fill. The concrete wall would be the same height as the dike. The thickness would be 12 inches at the top and 18 inches at the bottom for stability. The base of the wall and the core of the flood dike would be keyed into the clay layer that extends under the landfill, thereby preventing the percolation of floodwater under the dike and into the landfill.

Stormwater collection within the flood control dike and in the ditch to the east of the landfill would be collected in a gravity drainage system discharging water to the river through check valves. Alternatively, a pumping system could be used that automatically activates once the water reaches a pre-set level. The drainage ditch would be graded so that water would be directed to the discharge system.

3.5.2.7 Description of Site Alternative 7

- **Ground water monitoring (Section 3.5.2.2)**
- **Deed and site restrictions (Section 3.5.2.2)**
- **Management of surface debris (Section 3.5.2.3)**
- **Drainage improvements (Section 3.5.2.3)**
- **Gas venting system (Section 3.5.2.5)**
- **Leachate collection system (Section 3.5.2.5)**
- **Flood protection dike (Section 3.5.2.6)**
- **Synthetic membrane cap over landfill**

Site Alternative 7 is similar to Site Alternative 6 except that a synthetic membrane cap over the landfill would be used rather than a clay cap as the primary impervious barrier to moisture entering the landfill (Drawing 12).

Construct Synthetic Membrane Cap Over Landfill

The design of the landfill cap would be similar to the details for a RCRA cap as shown in Drawing 13. A RCRA cap consists of a 24-inch vegetative soil layer (topsoil), a 12-inch granular drainage layer (permeability of $K = 1 \times 10^{-3}$ cm/sec or greater), a synthetic membrane (at least 20-mil thickness), and a 24-inch low-permeability layer (permeability of $K = 1 \times 10^{-7}$ cm/sec or less).

After removal of all vegetation, a 12-inch layer of coarse gravel would be spread across the entire surface of the landfill to accommodate the gas collection and venting

system. A permeable geofabric would be placed over the gravel, followed by a 2-foot-thick layer of compacted clay with a permeability of either 1×10^{-6} cm/sec or 1×10^{-7} cm/sec. A 20-mil (minimum) HDPE synthetic membrane would be placed directly on the compacted clay layer and anchored into the soil beyond the leachate collection trenches described in Section 3.5.2.5. All seams would have extrusion welds to assure a solid liner impervious to all moisture. Where gas vent pipes pass through the liner, installation would be in such a manner as to provide a leakproof seal around the vents. A 12-inch drainage layer of at least 1×10^{-3} cm/sec hydraulic conductivity would be placed over the HDPE liner, followed by 24 inches of cover soil, as described in Section 3.5.2.4.

Once the synthetic liner was installed, care would be exercised not to puncture or damage the structural integrity of the membrane during successive cover operations. Landfill slope considerations and periodic inspection and repair after flooding would be as described for Site Alternative 4.

3.5.2.8 Description of Site Alternative 8

- **Ground water monitoring (Section 3.5.2.2)**
- **Deed and site restrictions (Section 3.5.2.2)**
- **Management of surface debris (Section 3.5.2.3)**
- **Erosion control and drainage improvements (Section 3.5.2.3)**
- **Gas venting system (Section 3.5.2.5)**
- **Leachate collection system (Section 3.5.2.5)**
- **Synthetic membrane cap over landfill (Section 3.5.2.7)**

Site Alternative 8 is similar to Site Alternative 7, without the flood protection dike (Drawing 14). Since all components have been described earlier, no additional description is necessary for this site alternative.

3.5.2.9 Description of Site Alternative 9

- **Ground water monitoring (Section 3.5.2.2)**
- **Deed and site restrictions (Section 3.5.2.2)**
- **Management of surface debris (Section 3.5.2.3)**
- **Erosion control and drainage improvements (Section 3.5.2.3)**
- **Improvements to landfill side slopes**
- **Natural clay cover over landfill top**

Site Alternative 9 is similar to Site Alternative 4, except that the natural clay cover would be placed only on the landfill top, leaving the sides subject to localized improvements, as necessary (Drawing 15). Placing a clay cover on the top of the landfill

would significantly reduce infiltration due to precipitation. The vegetative layer placed over the clay cover would enhance drainage and would minimize erosion of the clay cover.

Improvements to Landfill Side Slopes

Based upon a site evaluation, the side slopes would require repairs. The objective would be to provide continuously sloping surfaces that would drain water off the side slopes. A maximum slope of 2 to 1 (horizontal to vertical) would be achieved. A review of Drawing 15 shows that most of the side slopes are flatter than 2:1 and that 2:1 slopes are quite localized, generally being limited to the eastern side slope and the landfill tips. In the following paragraphs, repairs to the side slopes are described that may be required in areas of high erosion and at localized areas where stability is a concern. These repairs would improve surface runoff from the side slopes and eliminate standing water. This action would prevent ponding and reduce infiltration through the cover in areas of poor drainage such as the existing terraces. Soil used for repair would be in accordance with OAC 3745-27-9(F)(4).

A more detailed investigation of the existing cover soils would be conducted during the predesign phase of the project to establish the nature and extent of these repairs. The depth of soil on the side slopes would be measured at discrete points laid out on a grid system throughout the area where waste was disposed. Measurement would be accomplished by making small excavations through the cover using a hand trowel, hand auger, or equivalent. The soil retrieved would be analyzed and classified by the Soil Conservation Service (SCS) system. ASTM Standard D-44, Particle-Size Analysis of Soils, or an equivalent test, would be performed to classify the existing cover soil.

The east side slope by the drainage ditch would need some repairs. These repairs would be made with the objectives of increasing the depth of cover and also providing continuously sloping surfaces with a maximum slope of 2 to 1 (horizontal to vertical). The drainage ditch would be dewatered to the extent possible using the culvert installed for natural drainage supplemented by a dewatering pump, as necessary.The water would be discharged into the Scioto River. This pumping system would be operated throughout the construction period to accommodate run off from both the landfill and the esker. A temporary construction access road would be built along the base of the landfill. As required, new random soil fill would be pushed into the ditch, covered with a stabilizing layer of gravel if necessary, and compacted to construct the road. The sides of the landfill

would be stabilized where the integrity of the cover is poor, including erosion rifts, areas of heavy root exposure, and severe slopes. Drainage patterns would be surveyed, and areas of high velocity, such as erosion rifts, would be filled and regraded to match the adjacent contours. These repairs could be accomplished by depositing fill material on the side slopes in 6-inch lifts and compacting it, working from the landfill top or from the temporary access road and compacting it on the side slopes. Compacting may be achieved by using portable mechanical equipment. Where compaction is not practical, riprap would be placed on the filled area. The exposed tree roots on the side slopes would also be covered by the same technique used for repairing the erosion rifts. Trees at the water line, which have extensive root exposure, would be removed if repairs to the side slopes do not give adequate coverage. In areas where slopes are severe, additional stabilization could be accomplished by machine-placed riprap or by supporting the slopes using such techniques as sheet piling or soil cement.

The site evaluation showed the presence of terraces, typically having a topographic relief of several feet, on a limited portion of the west slope. Terraces may also exist on other side slopes. The slope of these areas would be modified as necessary to improve drainage, by depositing soil in 6-inch lifts and compacting to achieve continuously sloping surfaces and thus eliminate ponding. Existing vegetation on the terraces would not be disturbed, if possible.

Removal of surface debris from the side slopes and on the landfill top would be carried out together. This operation would be accomplished under an approved health and safety plan. Debris from the side slopes would be removed manually if the items are small. Larger items would be removed by light equipment such as backhoes, and where the sides are steep, by using winches operated from the top or bottom of the landfill.

If they are small, partially buried items would be removed in the same manner. Any larger items that are partially buried would not be disturbed in order to preclude disturbing other adjacent buried material. Items left in place would be covered as part of the repair operation.

General thinning of tree cover would be carried out over the side slopes by removing young trees having diameters less than 3 inches at breast height, or height lower than 15 feet. Removal of vegetation on the side slopes would be carried out manually, or where items are large, by operating winches from the top or bottom of the landfill. It is

anticipated all understory vegetation would be removed. Removal of this understory vegetation would promote the development of denser ground cover (that may include shady grass and legume species) and would enhance development of larger trees that provide additional stability to the side slopes. The effectiveness of this approach is evidenced by the results of the past 20 years where large diameter trees have provided stability to the side slopes without noticeable uprooting during periods of severe weather. In addition, certain trees, such as cedar and pine, that produce high shade cover and inhibit growth would be removed. In areas where placing soil for cover improvements could impact future growth, it may be necessary to selectively remove vegetation. This selective removal would be performed where needed, because placement of additional soil cover would otherwise smother the tree roots and cause tree losses. This tree loss would result from excess compaction, changes in surficial percolation and physical tree root smothering. However, this selected tree removal would result in improved understory and ground cover growth opportunities.

The cover would be inspected on a regular basis for structural integrity, erosion, and vegetation growth in accordance with the maintenance plan outlined in Appendix A.

Natural Clay Cover Over Landfill Top

The natural clay cover would be constructed over the top of the landfill as shown in Drawing 15. The limit of the cover would be confirmed during Remedial Design, but would generally follow the outline of the top of the side slopes. The specific mechanism of attachment of the cover to the side slopes would be determined at the time of Remedial Design. This may involve first smoothing the junction between the landfill top and the side slopes to an intermediate slope between the two surfaces. The clay cover would then be tapered across this surface. The vegetated top cover would be placed over the cover and tapered in the same manner. The cover would be tapered to continue the grade of the side slopes after improvement. It would be necessary to place 32,200 cubic yards of natural clay and 33,800 cubic yards of top layer soil to cover the landfill top. The cover to be placed over the landfill top would be constructed in accordance with provisions of OAC 3745-27-09, as described in Site Alternative 4.

Drainage control berms would be constructed at the top of the side slopes to collect surface run off and divert it to the base of the side slopes through several chutes. This action would reduce run off and the associated potential of cover erosion. The berms

would be constructed of compacted natural clay and would be continuously draining. These berms would run along the periphery of the landfill top cover. Dimensions of the berm cross section would be determined during the remedial design phase, however, general configuration would be similar to that shown in *Remedial Action Technology for Waste Disposal Sites*, Edition 2, K. Wagner, Section 3.5.1. The drainage ditches at the base of the slopes on the west and east of the landfill would be improved as described under Site Alternative 3.

Trees and existing debris will be removed and disposed of as described under Site Alternative 4. In areas where access is difficult, removal actions would be supplemented by pulling cables connected to mechanical equipment operated on the landfill top or base.

On completion of the landfill cover and side repairs, the landfill top and areas of the side where improvements were made would be seeded, fertilized, and watered to assure plant growth. The plant species chosen for the top cover would have root systems that would be expected not to penetrate beyond the vegetative layer and possibly damage the integrity of the natural clay layer. The plant species chosen for the side slopes would have a strong root structure to help reduce erosion and would include shady grass and legume species.

The cover would be inspected for structural integrity on a regularly scheduled basis and repaired as necessary.

4.0 DETAILED ANALYSIS OF ASSEMBLED ALTERNATIVES

This section provides an analysis of the assembled alternatives in detail, as required by 40 CFR 300.68(h). This regulation requires that alternatives be refined and specified in detail, indicating the appropriate conventional or innovative technology, with a detailed cost estimate showing the distribution of costs over time. The evaluation assesses engineering implementation as well as the reliability and constructability of the alternatives. It also indicates the extent to which an alternative meets or exceeds federal requirements, and estimates risks to public health or the environment should the alternative be implemented. If any adverse environmental effect is anticipated, the evaluation addresses how the effects will be minimized and provides an estimate of the cost of mitigation.

4.1 CRITERIA USED FOR EVALUATION

Seven key criteria were considered in evaluating and comparing the alternatives. These criteria, as outlined in the U.S. EPA *Draft Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (OSWER Directive 9355.3-01, March 1988) are:

- Compliance with ARARs
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Long-term effectiveness and permanence
- Implementability
- Cost
- Overall protection of human health and the environment

Criteria relating directly to factors that SARA §121(b)(1)(A-G) mandates the U.S. EPA to assess are marked for reference purposes in the descriptions below with the appropriate letter. **A** denotes the long-term uncertainties associated with land disposal; **B** denotes the goals, objectives, and requirements of the Solid Waste Disposal Act; **C** denotes the persistence, toxicity, mobility, and propensity to bioaccumulate of hazardous substances and their constituents; **D** denotes short- and long-term potential for adverse health effects from human exposure; **E** denotes long-term maintenance costs; **F** denotes the

potential for future remedial action costs if the alternative remedial action in question were to fail; and G denotes the potential threat to human health and the environment associated with excavation, transportation, and redisposal or containment.

4.1.1 Compliance with ARARs

Alternatives are assessed as to whether they attain ARARs or other federal and state environmental and public health laws, including, as appropriate, chemical-specific ARARs, location-specific ARARs, and action-specific ARARs (B).

4.1.2 Reduction of Toxicity, Mobility, or Volume

The degree to which alternatives employ treatment that reduces toxicity, mobility, or volume is assessed. Factors include the degree of expected reduction in toxicity, mobility, or volume (B) and the residuals that will remain following treatment (C).

4.1.3 Short-Term Effectiveness

The short-term risks that might be posed to the community, workers, or the environment during implementation of the alternative, including potential threats to human health and the environment associated with excavation, transportation, and redisposal or containment are evaluated (D,G). The time until full protection will be achieved is estimated.

4.1.4 Long-Term Effectiveness and Permanence

Alternatives are assessed against the magnitude of residual risks in terms of amounts and concentrations of waste remaining after implementation of a remedial action (A,B,C,G); type and degree of long-term management required, including monitoring and operation and maintenance (A,B,G); potential for exposure of human and environmental receptors to remaining waste (D,G); long-term reliability of the engineering and institutional controls (A,B,F,G); and potential need for replacement of the remedy (F).

4.1.5 Implementability

Alternatives are assessed against factors such as present capabilities to actually construct the structures required, the time necessary for construction, and time required to implement the alternative. Implementation time includes research and development, engineering, procurement, construction, and time required to effect remediation.

Implementability also includes such technical issues as the ability to perform an intended function, as well as reliability in meeting operating and maintenance requirements, as demonstrated under similar conditions.

4.1.6 Cost

The present worth of each alternative is estimated (E). The present worth of an alternative is the sum of capital and the present value of future operating costs. The operating cost is spread over many years of operation, and it is assumed that money is invested (available) now to cover these future costs. Because of the element of time involved, interest, or discount rate, is taken into account. For this project, a 10 percent discount rate is assumed. The present value of a future cost is the amount that must be invested now at a given interest rate (10 percent) to yield enough money to cover the annual operating cost in the future.

The purpose of these estimates is to allow cost comparison of the alternatives in order to make choices between them. They are not intended as budget requirements for site remediation. Significant assumptions used in estimating are that no inflation will occur over the lifetime of the alternative, and that there will be no time delays during construction. Estimates for material handling were developed, where possible, from *Means Site Work Cost Data* (1988).

The cost estimates have an accuracy of -30 to +50 percent, commensurate with the level of detail available in a feasibility study. This is considered satisfactory for comparing alternatives, but the estimates are not intended for budgetary planning.

4.1.7 Overall Protection of Human Health and the Environment

Data gathered during the RI were used to evaluate the exposure routes for site releases to potential receptors. The EA was conducted to assess potential human health effects that may result from exposure to site releases in the absence of any site remediation. Physical, chemical, demographic, and geographic factors were evaluated to assess the extent, if any, of potential harm to the public. Based on the findings of the EA, the FS addresses remediation of surface soils, ground water, and the landfill because they were found to pose potentially unacceptable health risks.

Potential exposures and incumbent risks to workers involved with construction and implementation of the alternative selected will, to the extent practicable, be addressed by implementation of a comprehensive health and safety plan appropriate for the anticipated activities.

The EA identified and evaluated potential exposure pathways. To be considered a complete pathway, the pathway must include four elements: (1) a source and mechanism of chemical release to the environment, (2) an environmental transport medium (e.g., soils), (3) a point of potential human contact with the contaminated medium (exposure point), and (4) a human exposure route (e.g., soils ingestion) at the exposure point. If any of these four elements is missing, under both the current use and the future use exposure scenarios, the pathway was deemed unlikely to be complete and was not given further consideration. The following sections summarize the exposures and risks associated with the various potential remedial alternatives for the site.

In Section 3.0, nine remedial alternatives are identified for the site. A summary of the effect of each alternative, using the most probable ground water exposure scenario, is shown below. As concluded in Section 3.0, ground water remediation shows no improvement in protection over imposition of deed restrictions. Where the exposure pathway is complete, the table indicates "Yes." Where the exposure pathway is incomplete, the table indicates "No." "No" is a desirable situation. The chart demonstrates only the most probable exposure scenario. A fundamental assumption of this scenario is that, under the most probable exposure scenario, a fence around the site would deter people from entering, hence breaking the pathway for soils ingestion.

	Site Alternative (Most Probable Case)								
Pathway	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Ground water	Yes	No	No	No	No	No	No	No	No
Surface soil	Yes	No	No	No	No	No	No	No	No

Appendix B presents the basis for the public health evaluation, discusses relevant assumptions, and presents the results for each site alternative. The appendix shows both most probable and worst case exposure scenarios.

4.2 EVALUATION OF SITE ALTERNATIVES

4.2.1 Site Alternative 1
•No action

No remedial action would be taken to remove or control potential migration of chemicals at the site.

4.2.1.1 Compliance with ARARs

As stated in Section 1.2, it is concluded that the Bowers Landfill ceased operation in 1969. State of Ohio solid waste landfill closure standard OAC 3745-27-10 became effective on July 29, 1976. The Bowers Landfill ceased accepting wastes prior to this date and thus the regulation is not "applicable" to the landfill. It may, however, be "relevant and appropriate" to certain landfill remedial actions. At the time operations ceased, State of Ohio Department of Health Rule HE-24 regulated licensed solid waste landfills. The Bowers site was not licensed. This rule may, however, be "relevant and appropriate."

There is no information regarding the state of the landfill at the time operations ceased. Current conditions show, however, that more than 20 years after cessation of landfilling, the existing site vegetation is a highly stable ecosystem.

The existing cover does, however, show signs of need for repair. There are signs of erosion, particularly at the area immediately adjacent to the river; there are areas of surface ponding; and there is visible surface debris remaining.

Tables 5 and 6 list potential action-specific ARARs identified by U.S. EPA and OEPA for the site. Action-specific ARARs determine how a remedy selected to address public health and environmental dangers should be implemented. The No Action alternative is required by the NCP. Under this alternative, no remedy is implemented, and thus, action specific ARARs are not "applicable."

4.2.1.2 Reduction in Toxicity, Mobility, or Volume

No remedial action would be taken at the site. The waste would remain in the landfill; there would be no reduction in toxicity, mobility, or volume. However, it is estimated that the existing cover would reduce the potential for migration of waste because infiltration through the cover would be reduced to approximately 34 percent of precipitation based upon the results of the HELP model (Appendix C).

4.2.1.3 Short-Term Effectiveness

No remedial action would be performed; therefore, there would be no short-term risks associated with this alternative. Current levels of risk would remain.

4.2.1.4 Long-Term Effectiveness and Permanence

Direct contact with contaminated soils would be possible under a No Action scenario. Even though there is little evidence of migration, migration of chemicals from the landfill to either ground water or surface soils would be possible since the site is prone to flooding from the Scioto River. Floodwaters could infiltrate into the landfill and saturate it. Chemicals could then leach into the ground water and migrate. Erosion by the river would continue at the northernmost tip of the landfill.

The landfill surface has a stable vegetative cover incorporating a broad diversity of woody and non-woody species that have adapted well to the site. These species provide a root system in the landfill which, except immediately adjacent to the river, provides both surficial and deep stabilization to protect against erosion from precipitation and periodic flooding events. The surficial fibrous root network of the ground cover vegetation prevents surface sheet erosion from periodic storm events, while the more deeply rooted woody species provide additional stabilization against periodic flood events.

The diverse vegetative cover results in greater evapotranspirative withdrawal from the surficial soils than would occur with shallow-rooted grass or legume species. The specific tree species at the site are hydrophytic (moisture-loving) and thus uptake greater amounts of moisture, resulting in reduction of infiltration into the waste materials.

The plant species that have developed naturally at the site have demonstrated their ability to withstand environmental conditions over the years since operations have ceased. Invasion of the site by endemic plant species from surrounding areas represents a positive biological indication that the site is capable of providing essential growth requirements for a broad range of native plant species. There is no evidence that the existing vegetative cover at the site will deteriorate in the future. In addition, it is doubtful that pest or pathogen infestations would reduce the woody species domination because a large number of different species is present in the overstory.

In accordance with SARA Section 121(c), the site remedy would be reviewed at least each 5 years after initiation. The review is required wherever a remedial action results in any hazardous substances, pollutants, or contaminants remaining at the site, and checks that human health and the environment are being protected. The review provision applies to all site alternatives.

4.2.1.5 Implementability

Implementation of this alternative would require no effort.

4.2.1.6 Cost

No costs are associated with this alternative.

4.2.1.7 Overall Protection of Human Health and the Environment

Under Site Alternative 1, the site would remain as it currently exists. No remedial action would be taken to remove, control migration from, or minimize exposure to chemicals, in any of the affected environmental media. Risks due to possible ingestion of contaminated soils would remain at current levels. The landfill would remain a risk since

there would still be a possibility of chemical release by leaching or of direct contact with the waste.

No effort would be made to control the future use of the property or adjacent land. There would be potential for residential development and installation of a drinking water supply. The public health evaluation assumes that such development would take place in the future.

A detailed exposure scenario is presented in Appendix B in Table B-3. The most probable exposure scenario would result in a carcinogenic risk that would be within the target risk range of 10^{-4} to 10^{-7}; the total hazard index for exposure to noncarcinogenic chemicals would be less than unity, which does not represent a potential noncarcinogenic risk. The worst case exposure scenario would result in a carcinogenic risk that would again be in the target risk range, but the cumulative hazard index, for all noncarcinogenic indicator chemicals in the surface soils and ground water, would have a value of 4.64. The EA computed a hazard index of 4.52, but this did not include lead in the ground water, which has an individual hazard index of 0.14; the remaining discrepancy (0.02) is due to rounding in both computations. The method of calculation of both the carcinogenic risk and the hazard index is the same as that in the EA, and is explained on Table B-2 in Appendix B. Based on the hazard index of greater than unity, there is a potential risk associated with exposure to noncarcinogenic chemicals at the site and under a worst case exposure scenario.

Direct contact with contaminated soils would be possible. Lead-contaminated soils would remain, with a worst case hazard index for lead of 3.2, indicating a potential noncarcinogenic risk. However, the Centers for Disease Control (CDC) has published clean-up guidelines for lead concentrations in residential soils that it associates with an acceptable risk. The clean-up values are between 500 and 1,000 mg/kg, well above the maximum lead concentration found in soils at the site (179 mg/kg). Therefore, this calculated risk may overestimate the actual risk. Furthermore, the EA shows that, under the probable case, the hazard index is 0.14, which means actual concentrations are below the acceptable intake for chronic exposure (AIC), and thus the soil does not represent a potential noncarcinogenic risk. The most probable and worst scenarios were calculated based upon geometric mean and maximum measured concentrations of total lead in soil samples, respectively.

PAHs would remain in the soil and, according to the EA, would exhibit an estimated cancer risk of 2×10^{-6} under the worst case scenario. PAHs were not calculated under the most probable scenario because concentrations are not greater than background. The SPHEM states that cancer risks of between 1×10^{-4} and 1×10^{-7} lie within the target risk range for remedial alternatives; risks below 1×10^{-7} are considered insignificant.

PCBs would remain in the soil and, according to the EA, would exhibit an estimated cancer risk of 7×10^{-7} under the worst case scenario and 5×10^{-9} under the most probable scenario.

Contamination identified in the monitoring wells for barium and benzene downgradient of the landfill would remain in the lower aquifer. There are no drinking water wells known to exist in the upper aquifer between the landfill and the river (the direction of ground water flow). Furthermore, no wells are known to exist in the lower aquifer within 1 mile downgradient of the site. Thus, risks are based on potential future receptors at the site who may use ground water as a source of drinking water. However, as noted in the EA, there is a low probability that the ground water between the landfill and the river would be used as a drinking water source because the area is regularly flooded.

Under the worst case scenario, the hazard index is 1.04, just above the AIC, for barium ingestion in ground water, and is 0.17 for the most probable case scenario. A hazard index of greater than unity represents a potential noncarcinogenic risk. Under worst and most probable scenarios for benzene ingestion, the carcinogenic risks are 9×10^{-6} and 1×10^{-6} respectively, lying within the target range. It should be noted that the worst case scenario for barium is based upon three isolated samples from one well (P-5B) screened in the lower aquifer. All other samples yield hazard indices of less than unity for barium. As noted in the RI, high concentrations of several inorganic species appear to be present in most of the lower aquifer samples (P-5B, P-6B, and P-8B). This apparent difference in water quality between the upper and lower aquifers may be due to natural variations.

Under worst and most probable scenarios, the carcinogenic risks for benzene ingestion in ground water are 9×10^{-6} and 1×10^{-6}, respectively. The worst case scenario is based on one well (P-6B), screened in the lower aquifer, which was sampled at 6 µg/L, just above the MCL. The RI provides the following as possible explanations for the source

of benzene in well P-6B: (1) the compound is associated with carbonaceous or hydrocarbon-containing shale encountered during drilling, or (2) the compound is associated with contamination from the landfill.

4.2.2 Site Alternative 2

- **Ground water monitoring**
- **Deed and site restrictions**

Deed and site restrictions would be imposed at the site, and a ground water monitoring program would be set up to monitor the levels and the potential migration of chemicals in the ground water. Otherwise, Site Alternative 2 is the same as Site Alternative 1.

4.2.2.1 Compliance with ARARs

Issues relating to ARARs were discussed under Site Alternative 1. OSHA regulations under 20 CFR 1910.120 are "applicable" to this and all subsequent site alternatives. In addition, portions of the ground water monitoring requirements under 40 CFR 264 Subpart F and other similar state and federal regulations may be "relevant and appropriate" to this and all subsequent alternatives.

4.2.2.2 Reduction in Toxicity, Mobility, or Volume

No remedial action would be taken at the site. The waste would remain in the landfill; there would be no reduction in toxicity, mobility, or volume. However, it is estimated that the existing cover would reduce the potential for migration of waste because infiltration through the cover would be reduced to approximately 34 percent of precipitation.

4.2.2.3 Short-Term Effectiveness

The potential for direct contact with chemicals would be substantially reduced by imposing access and deed restrictions on the site. There would be no calculable risk to young children, the primary receptors.

This alternative would involve no excavation other than minor local soil removal for fence post installation around the perimeter of the site. As a result, installation of the fence

would pose no additional threat to human health and the environment. The operation would be carried out in accordance with an approved health and safety plan for the site. Workers are not expected to be exposed to increased risks in excess of those associated with general construction.

4.2.2.4 Long-Term Effectiveness and Permanence

This alternative would not reduce contamination at the site. Site conditions show that the existing vegetation is a highly stable ecosystem. It is effective at protecting against erosion, except immediately adjacent to the river. Evapotranspiration from surficial soils is higher than from shallow-rooted grass or legume species. There is also no evidence that the existing vegetative cover will become less effective in the future.

A ground water monitoring program that is patterned after Subpart F of 40 CFR 264 and 40 CFR 265 would be operated at the site so as to detect any increase in contaminant levels. The ground water monitoring program would consist of collecting samples from several wells located hydraulically downgradient of the landfill. Ground water monitoring would record future ground water chemical concentrations and provide data sufficient to trigger a protective response, if concentrations show a statistically significant upward trend. The final monitoring requirements and any compliance program would be the subject of U.S. EPA and OEPA approval. Specific details of such a protective response would be developed during the design stage, but may include further ground water monitoring followed by possible ground water remediation. It is anticipated that, with the exception of No Action, all site alternatives would incorporate similar protective responses.

Deed restrictions would be effective in preventing future use of the site for extraction of ground water downgradient of the landfill. Access restrictions would be effective in preventing unauthorized access to the site and would restrict direct contact with exposed waste material in the landfill, or with contaminated soils. The fence would enclose all soils measured at the site that are contaminated above background levels. These soils are all located on, or adjacent to, the landfill. The presence of a secure fence would discourage casual trespassers from entering the site. People could not, therefore, come unwittingly into contact with exposed waste materials in the landfill or with the contaminated soils.

A health and safety plan would be developed for the site. Personnel collecting samples would be required to wear clothing meeting OSHA safety standards. Since there are no monitoring wells located on the landfill, there could be no direct contact with waste materials, and there would thus be no increased health or safety risk created by implementing ground water monitoring.

Maintenance would involve periodic inspection and replacement of fencing and posts, particularly after flood events.

4.2.2.5 Implementability

Ground water monitoring would be effective and reliable in providing data on the levels of and potential migration of contamination. Such data could be used to determine the need for future remedial action, if warranted.

Fencing and posting would be easily built. The security fence could be erected by local labor and would involve the use of commonly available light construction equipment and routine procedures.

Site access restrictions would be effective, if the fence is properly maintained. Such maintenance would include regularly inspecting the fence for damage, inspecting the soils around the fenceposts for erosion, and checking the security and integrity of the gate. Inspections, together with any appropriate repairs, would be required after periods of flooding or drought.

Maintenance requirements are not expected to be greater than normal, except where the fence is exposed to areas of high stream velocity along the banks of the river.

It is expected that the security fence could be constructed within a month.

4.2.2.6 Cost

Initial capital costs for deed and site restrictions are estimated at $0.17 million. Operating and maintenance costs for ground water monitoring and fence maintenance are estimated at $31,000 per year. At a discount rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $0.5 million. Table 8 presents supporting information for these estimates.

4.2.2.7 Overall Protection of Human Health and the Environment

Under Site Alternative 2, no removal or migration control measures would be implemented. However, installation of a fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent use of the land and the ground water at the site.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B on Table B-4.

The most probable exposure scenario would result in both a carcinogenic risk and a hazard index of zero. This exposure assumes that the fence would prevent all people from entering the site, and that deed restrictions would prevent use of ground water. The worst case exposure scenario assumes that some people would enter the site, despite the fence, and come into contact with the soils; deed restrictions would still prevent use of ground water. The worst case scenario would result in a carcinogenic risk that would be within the target risk range at 4.58×10^{-7}, and a hazard index of 0.277. A hazard index of greater than unity represents a potential noncarcinogenic risk.

4.2.3 Site Alternative 3

- **Ground water monitoring (4.2.2)**
- **Deed and site restrictions (4.2.2)**
- **Management of surface debris**
- **Local repairs to existing landfill cover**
- **Erosion control and drainage improvements**

Improvements would be made to the landfill and the remainder of the site in several areas. Waste material visible on the landfill surface would be removed, the integrity of the existing cover would be upgraded in locations where there has been deterioration, the site

and landfill drainage patterns would be improved, and erosion control would be added to landfill areas exposed to high river velocity. This alternative would be the same as Site Alternative 2, but with the addition of management of surface debris, local repairs to the existing landfill cover, and erosion control. The following discussions evaluate only the effect of these additions.

4.2.3.1 Compliance with ARARs

As stated under Site Alternative 1, current State of Ohio solid waste landfill closure standards are not "applicable." Portions may be, however, "relevant and appropriate" to certain categories of remedial actions for the landfill.

Federal action-specific ARARs that govern hazardous waste treatment, storage, and disposal facilities under 40 CFR 264 did not become effective until November 30, 1980, after the date that the Bowers Landfill ceased accepting wastes. Thus, this regulation is also not "applicable" to the site, but portions may be "relevant and appropriate" to certain categories of landfill remedial actions, such as transportation and disposal of any hazardous waste from the site and ground water monitoring.

State of Ohio Health Rule HE-24, with objectives of reducing percolation of water, providing erosion protection, improving visual aesthetics, and preventing vector attraction may be "relevant and appropriate."

This alternative results in some reduction in percolation. The present diverse vegetative cover on the landfill, including moisture-loving trees, results in greater evapotranspirative withdrawal from the surficial soils than would occur with shallow-rooted grasses. Repairs to the landfill surface and subsequent regrading would improve surface runoff, reduce ponding, and also result in some reduction of infiltration through the cover.

This alternative provides erosion protection. The existing site vegetation is a highly stable ecosystem. The broad diversity of vegetation provides a root system in the landfill that gives both surficial and deep stabilization and protects against erosion from precipitation and periodic flooding. It is possible that the root systems could permit direct entry of precipitation through the cover and increase the likelihood of leachate generation. However, during the RI, very little evidence of seeps or leachate were noted. Repairs and

regrading of the landfill cover, together with erosion control at areas that may be exposed to high river velocities, would further improve erosion protection.

This alternative improves the visual aesthetics of the site and prevents vector attraction by removal of debris and limited surface repair. The site would represent a valuable habitat for a range of wildlife common to the region. The dense vegetation on the landfill would provide concealment and cover for terrestrial and bird species. It is possible, however, that hunters and their families may ingest terrestrial animals and birds contaminated by releases from the site. No tissue samples were taken during the RI; however, the EA concluded that any exposure via this pathway is expected to be very limited.

The diversity of plant species that have developed naturally at the site indicates that they should maintain their domination of the site and result in continued stability.

Regulation 40 CFR 264.18 requires facilities in floodplains be designed, constructed, and maintained to prevent washout of any hazardous waste by a 100-year flood. Regulation 40 CFR 6, Appendix A, requires construction to be implemented in a way that will minimize potential harm to the flood plain. These regulations are not applicable because no facility is being constructed in the floodplain. In addition, neither of these regulations were in effect at the time operations ceased. Portions of these standards may be "relevant and appropriate" to certain landfill actions. Erosion control improvements would be made to the landfill tips at areas that may be exposed to high river velocities. Local repairs would be made to the cover to minimize future erosion of the cover. A long-term maintenance plan would be implemented to maintain these improvements. These and other landfill actions would be implemented in such a manner as to maintain or improve drainage patterns at the site. Construction activities would not be carried out during periods of potential flooding.

The degree of protectiveness of human health and the environment is discussed in Section 4.2.3.7. In brief, the alternative would continue to prove effective at attaining the performance objectives of the time of closure. Additionally, it would protect human health and the environment through a combination of onsite actions, ground water monitoring, deed and site restrictions, and continued maintenance. If ground water monitoring shows a

statistically significant upward trend in contaminant concentrations, a corrective action plan would be implemented.

4.2.3.2 Reduction in Toxicity, Mobility, or Volume

This alternative would not reduce toxicity, mobility or volume (with the exception of the small amounts of surface debris that would be removed). The waste would remain onsite. However, local repairs to the existing landfill cover would achieve some reduction in the potential for migration of the contaminants because of the reduction in infiltration. This reduction would result because those areas having inadequate cover would be repaired with natural clay soil, and the improved cover would allow less precipitation to percolate through the waste, thus achieving some reduction in leachate generation.

4.2.3.3 Short-Term Effectiveness

There would be no unusual short-term risks to the community, workers, or the environment during implementation. The alternative would involve minor, short-term construction-related, safety concerns from the operation of small earthmoving equipment. The alternative would not involve disturbance to the existing landfill cover beyond removal of surface debris.

It may occasionally be necessary to remove partially buried trash, with the resulting potential of exposing workers to contaminated waste. Surface debris would be removed by personnel wearing appropriate protective equipment. A health and safety plan would be designed to protect personnel from risk associated with exposure to waste during landfill surface repair operations and improvement to the drainage ditches around the base of the landfill.

Approximately 1,225 truckloads may be required to implement this alternative. It is estimated that approximately 50 truckloads of surface debris would be hauled offsite. Approximately 12,000 cubic yards of soil would be required to repair the existing cover and, if obtained from offsite, would involve hauling 800 truckloads onsite. Approximately 3,750 tons of riprap would be imported for erosion control involving 375 truckloads.

In the short term, this alternative is expected to be effective in continuing to control significant releases to the environment.

4.2.3.4 Long-Term Effectiveness and Permanence

Implementation of this alternative is expected to be protective over the long term. The improvements to the soil cover would eliminate contact with the exposed landfill waste. In addition, local repairs to the cover would improve runoff; minimize future erosion of the cover; and achieve some reduction in the potential for leachate production. Filling of open gullies and erosion rifts, as well as the elimination of surface depressions, would reduce the amount of liquid that penetrates the landfill surface. The amount of leachate reduction cannot be estimated, but a net reduction is expected based on the improved surface profile and enhanced drainage.

Removal of waste presently lying on the ground would improve the aesthetics of the landfill and reduce the potential for contact with exposed material and eliminate existing infiltration pathways created by partially buried waste. If the exposed material is indeed hazardous, this action would remove a pathway for exposure.

The existing site vegetation is a highly stable ecosystem that is effective in protecting against erosion (as shown in Appendix A). The addition of riprap adjacent to the main river channel would enhance this protection. This erosion control measure would provide protection to the landfill at locations adjacent to the Scioto River, including the northernmost tip of the landfill at the river where some erosion has occurred. During flood events, the river has the potential to erode the upstream faces of the landfill, thus exposing the waste to the environment. Installation of riprap in conjunction with sheetpiles, if necessary, at the northwest and southwest portions of the landfill, where erosion potential is highest, would maintain the structural integrity of the landfill and prevent erosion and resultant erosive exposure of waste. Erosion control would maintain the structural integrity of the landfill.

Improving the site and landfill drainage would reduce the potential for saturation of the landfill from standing ponded water. These improvements would reduce potential contact of surface water with the waste. Improvements would be made to the landfill

drainage in such a manner that the existing naturally developed and vegetated slopes would be maintained wherever possible.

Maintenance would include regular inspections, repairs to the landfill cover and management of the mixed vegetation on the landfill. Periodic refilling and grading would be done in areas of the landfill where the inspections indicate erosion or land subsidence may be occurring, or where settlement may occur. Eroded areas or gullies in the cover may require regrading after large storm events. Management of the mixed vegetation on the landfill would be directed at maintaining the existing stability and integrity of the cover. Operations would include mowing, selective brush removal, and selective thinning on a yearly schedule. If well maintained over the long-term, this alternative is expected to be effective in continuing to control any significant releases to the environment.

4.2.3.5 Implementability

Implementation of surface waste removal would involve mobilizing personnel to walk the site and physically pick up any trash that is manageable by hand. A small front-end loader would be used to transport the hand picked trash and to pick up any large, bulky objects that are unmanageable by hand. This type of equipment can be easily maneuvered around sites with many obstacles, in this case trees and bushes.

Improvements to the landfill cover would be effected using small front-end loaders. Surface imperfections could be filled in and compacted with material from the west field. If this material were to be used, it would be tested for hazardous characteristics before application.

Small front-end loaders could also be used to install riprap on the side slopes of the landfill for erosion control. Installation of sheetpiling would require pile driving equipment and a bulldozer.

Site drainage improvements would involve the use of a bulldozer to grade the surface adjacent to the landfill and promote drainage away from the edge of the landfill, eventually providing a drainage slope running north to south. The drainage ditch improvement could in all probability also be accomplished with a small front-end loader. The replacement of the discharge pipe underneath the entrance road would require the use

of a large backhoe to dig up the existing pipe and replace it with a new one. Should the pipe run under the landfill, tunneling equipment would be used. Precautions would be taken to protect workers and minimize disruption of waste.

The project could be readily implemented using conventional construction equipment. It is estimated that implementation time for this alternative would be 3 months.

4.2.3.6 Cost

Initial capital costs for implementation of this site alternative are $1.4 million. Operating and maintenance costs for ground water and soils monitoring, and maintenance of the fence, the landfill surface, and erosion control and drainage improvements are estimated at $80,000 per year. At a discount rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $2.2 million. Table 9 presents supporting information for these estimates.

4.2.3.7 Overall Protection of Human Health and the Environment

Under Site Alternative 3, visible landfill surface debris would be removed and repairs and improvements would be made to the landfill cover. This action would reduce migration of contaminants by reducing surface water infiltration into the landfill. However, this alternative would not remove or contain any of the soils contaminants, contact with which is the primary public health concern. As discussed under Site Alternative 2, a secure fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent use of the land and the ground water.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B in Table B-5.

Exposure risk scenarios are the same as for Site Alternative 2. The most probable exposure scenario would result in both a carcinogenic risk and a hazard index of zero. The worst case exposure scenario assumes a carcinogenic risk within the target risk range, at 4.58×10^{-7}, and a hazard index of 0.277. A hazard index of greater than unity represents a potential noncarcinogenic risk.

4.2.4 Site Alternative 4

- **Ground water monitoring (4.2.2)**
- **Deed and site restrictions (4.2.2)**
- **Management of surface debris (4.2.3)**
- **Erosion control and drainage improvements (4.2.3)**
- **Natural clay cover on landfill**

A natural clay cover, consisting of 24 inches of topsoil over 24 inches of compacted natural clay, would be placed over the existing landfill to reduce and retard infiltration, and minimize the migration of liquid through the waste. Such liquids could eventually be released as leachate. The clay cover would also enclose zones of contaminated soils that are on or immediately adjacent to the landfill. Site Alternative 4 would be the same as Site Alternative 3, but with the addition of a protective natural clay cover over the landfill. The following discussions evaluate only this addition.

4.2.4.1 Compliance with ARARs

The landfill would employ portions of the current State of Ohio solid waste landfill closure standards as outlined in OAC 3745-27-10, Closure of Sanitary Landfills. The clay cover would attain the standards of OAC 3745-27-09(F)(4), and would have a low permeability to water, good compactability, and relatively uniform texture.

The landfill sides would be graded to give continuously sloping surfaces, having a maximum horizontal to vertical ratio of 2 to 1. The steeper slopes are located primarily on the east side of the landfill, next to the drainage ditch. Preliminary slope stability calculations (Appendix D) show the side slopes would be stable. This analysis was based upon soil samples collected from the side slopes, published data on relevant soil properties,and the slope configuration detailed on the existing topographic map for Site Alternative 9 (Drawing 15). An additional more detailed slope stability evaluation would be carried out during the design phase based upon additional soil sampling data and the results of a more detailed topographic survey. If any faces are deemed unstable, the design slope would be modified as necessary.

Upon completion, the cover would be inspected for structural integrity on a regularly scheduled basis and repaired as necessary. Following periods of flooding, the

landfill would be inspected for signs of erosion. Additional sheetpiling or riprap would be provided as necessary in areas that may require erosion protection.

The landfill is expected to be essentially inert because it has not been operated for 20 years and, according to OEPA files, the majority of the waste materials deposited on the site consisted of residential refuse. Such material generally has a biodegradation time of less than 20 years. There may, however, be small quantities of gas generated under the cap from decaying vegetation that was trimmed before capping. During the field investigation for the RI, there was no noticeable odor from the landfill and no elevated gas concentrations were detected during the health and safety monitoring done as part of these studies. There have been no reports of cracking of the landfill surface, typically observed when gas pressure builds up under a landfill surface; nor have there been reports of gas bubble releases during periods when the landfill surface contained ponded water. In summary, there is no evidence that gas venting would be necessary. Accordingly, OAC 3745-27-10(C)(5), which calls for ventilation structures as necessary to control gas migration, is not appropriate.

During the RI, very little evidence of seeps or leachate was noted, though leachate and seeps have reportedly been observed previously (Burgess and Niple, 1981). As directed by the U.S. EPA, three groups of sampling carried out prior to the RI (U.S. EPA, 1980; Burgess and Niple, 1981; and OEPA 1982 and 1983) were not considered. The primary reasons for this decision were that the results do not reflect current contaminant concentrations at the Bowers Landfill, and the quality of the data are not known. In summary, there is no evidence that potential leachate generation is a cause of water pollution, and thus leachate collection is not necessary. Accordingly, OAC 3745-27-10(H)(1), which requires that if within the 3-year monitoring period after closure leachate is detected in such quantities that the Director or the Health Commission believes that a substantial threat to water pollution exists, then leachate shall be collected, is not appropriate.

The natural clay cover would provide additional protection from potential contact with the landfill by increasing the depth of the soil and clay barrier to 4 feet. The cover would enclose all but one of the areas of elevated lead contamination recorded above background, thus further reducing the potential risk of soil ingestion. Contact with this one remaining area of elevated lead concentration, SO-44, off the southern tip of the

landfill, would be restricted by the site access provision. The determination of those areas that are noted to have lead contamination above background is based upon results from the RI, in which 37 soil samples were taken: 5 in background locations, 21 at locations on or adjacent to the landfill, and 11 in the field to the west. This information, although limited, shows the following:

	Geometric Mean (mg/kg)	Maximum Concentration (mg/kg)
Background	47	74[E]
On or adjacent to landfill	78	179
Field to west	59	102[E]

[E] Estimated value (indicates that concentration is estimated due to interference during analysis)

These data were used to conclude that the highest lead levels are at or in the immediate vicinity of the landfill.

The addition of a clay and topsoil layer to the existing landfill cover would reduce the infiltration characteristics of the landfill cover. Leachate production, together with the potential for future ground water contamination, would be reduced. A carefully designed ground water monitoring program would ensure detection of any change in ground water contaminant levels before offsite migration occurs.

Effective control of releases to the environment from waste in the landfill would be achieved by these actions.

4.2.4.2 Reduction in Toxicity, Mobility, or Volume

This alternative would not reduce the toxicity, mobility, or volume of the waste (with the exception of the small volume of surface debris that would be removed). However, the addition of a natural clay cover over the landfill would reduce the potential for migration of the waste because infiltration through the cover would be reduced to 9.8 percent of precipitation.

4.2.4.3 Short-Term Effectiveness

There would be no unusual short-term risks to the community or to workers during the implementation of this alternative, if properly managed. The alternative would involve short-term construction-related safety concerns similar to those described in Site Alternative 3. This alternative, however, would involve significantly greater construction activity than Site Alternative 3, and thus safety concerns would be proportionately greater.

During remedial activities, exposure to the waste would be limited to the removal of visible waste and to any waste immediately underlying the existing vegetation that is to be removed. Provided that removal of vegetation and construction of the clay cap is conducted progressively over the landfill area, and that an appropriate health and safety plan is implemented, then onsite and offsite exposure would be minimal. Dust generation during construction would be reduced by the use of water sprays.

The major health and safety concerns involved in the implementation of this alternative would be to workers during construction of the cover. Excavation, transportation, and application of the soil carries with it a level of risk that has been quantified by the U.S. government. During implementation of this alternative, workers would be at the site for several months, and may be frequently exposed to chemicals including herbicides required to prevent plant emergence through the reconstructed cover.

There may be safety risks imposed on the local community from moving a large number of trucks onto and off the site. It is estimated that up to approximately 8,200 truckloads would be required to implement this alternative. Approximately 52,000 cubic yards of clay would be imported if the clay from the field to the west were not used, and 54,500 cubic yards of topsoil would be imported. Approximately 7,500 truckloads would be required to haul the clay and soil. In addition, between 100 and 300 truckloads of vegetation would be hauled offsite for disposal and 375 truckloads of riprap would be required. The local community may be concerned over the potential for accidents and the wear-and-tear on the roads.

4.2.4.4 Long-Term Effectiveness and Permanence

The risks of exposure following implementation of Site Alternative 4 would be reduced. A natural clay cover of low permeability would be an effective means of reducing infiltration entering the landfill to 9.8 percent of precipitation, and of reducing the potential for leachate generation. The clay layer would enhance surface runoff and provide protection to the existing landfill from erosion and wear. In addition, the protective layer of clay over the landfill would reduce the potential for accidental uncovering of waste material. The majority of soils contaminated above site background levels would be covered. Contaminated soils not covered would be enclosed by the fence.

The primary function of the low-permeability clay cover is to inhibit infiltration of precipitation into the landfill, thereby reducing the amount of water contacting the underlying waste. Covers of this type are an integral part of many landfill designs. Their technology has proven to be reliable and effective. A vegetative layer over the clay layer would protect the clay from erosion and weather damage and generally maintain the integrity of the landfill. Zones of lead-contaminated soils that are on, or immediately adjacent to, the landfill would be buried under the clay and vegetative layers, thereby breaking the exposure pathway.

According to results from the HELP model, shown in Appendix C, the addition of a natural clay cover would reduce infiltration into the landfill to 9.8 percent of precipitation. Installing such a natural low-permeability cap would be effective in reducing infiltration into the landfill, and of reducing the potential for leachate generation. Installing such a cap would result in no reduction of risk to public health under the most probable scenario and a small reduction under the worst case scenario. The ground water monitoring program would record future ground water chemical concentrations and provide data sufficient to trigger a protective response, if concentrations show a statistically significant trend.

Long-term effectiveness of the cover would be provided by ensuring the side slopes are protected from erosion. As discussed in Appendix D, riprap would be provided where required for protection from the scouring effects of flood waters. Riprap would be provided over the southern and northern tips of the landfill adjacent to the river, and may also be provided along portions of the northern face of the landfill and along sections of the landfill side slopes adjacent to the southern tip. Further analysis would be necessary

during the remedial design phase to more closely estimate scouring velocities and determine the extent of armour protection required.

Erosion protection must also consider the effect of wave action from flood events. Appendix D shows that the frequency of occurrence of high winds causing significant waves (in combination with a flood event) should not warrant additional erosion protection. This conclusion is supported by the fact that there is no evidence of erosion from wave action on the north face of the landfill (where wave action effects are expected to be the highest) after more than 20 years.

Maintenance of the cover would involve mowing the vegetation, inspecting the surface for cracks, settlement, and ponding of water, and making appropriate repairs. Maintenance requirements for the cover can be expected to be greater than the present cover after flood events due to the limited subsurface stabilizing capability of the grass. Damage to the cap could occur from erosion, from plant roots breaking through the surface, from subsidence due to decaying roots, from penetration by burrowing animals, or from vandalism. Direct exposure to wastes as a result of such damage is unlikely because waste materials would be isolated at least 4 feet below the surface. If repairs to the clay or reseeding were required, this would be carried out immediately. Repairs to the clay would consist of patching with fresh clay.

The minimum effective design life of caps is generally 20 years (K. Wagner et al., *Remedial Action Technology for Waste Disposal Sites*, Noyes Data Corporation, Park Ridge, N.J., 1986, pp. 19 et seq.). Proper maintenance can maintain the former effectiveness. If well maintained, there would be virtually no long-term threat to public health or the environment.

The maintenance program would also include inspection of the cover for structural integrity on a regularly scheduled basis. Following periods of flooding, the landfill cover would be inspected for signs of erosion and repaired as necessary. This program would include repair of riprap protection, as necessary, and inspection for damage from scouring, wave action, and debris, together with repair as necessary.

4.2.4.5 Implementability

A natural clay cover would not require the implementation of any unusual construction practices. Initially, following removal of visible waste, the existing trees and shrubs would have to be cut down as close to the ground surface as possible before the cover materials could actually be installed. The exposed cover would require several applications of broadleaf herbicides to systemically kill the woody species and prevent tree growth through the new cover. The vegetation would be loaded into trucks and disposed of in an offsite sanitary or secure landfill (depending upon results from tissue sample testing). The source of the clay may be the field to the west of the landfill; clay permeability data and availability is discussed in Sections 1.3.1 and 1.3.2. Alternatively, natural clay soils from the area may be trucked in. There would be a need for backhoes, graders, bulldozers, and compacting equipment. The vegetative soil layer would be constructed of soil from the site or from an offsite source. There are many companies specializing in landscape planting of construction projects. Seeding would be carried out during a period when river flooding is unlikely.

For this and subsequent alternatives to minimize erosion during flooding or high rainfall events, the project should be segmented into work areas. Implementation should be sequenced to minimize the area of soil exposed at any one time.

The time required to implement this alternative would be approximately 10 months, unless activities were disrupted by flood events.

4.2.4.6 Cost

Initial capital costs for this site alternative are estimated at $3.2 million. Operating and maintenance costs for ground water monitoring, maintenance of the fence, erosion control, and drainage improvements are estimated at $116,000 per year. At a discounted rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $4.3 million. Table 10 presents supporting information for these estimates.

4.2.4.7 Overall Protection of Human Health and the Environment

Under Site Alternative 4, visible landfill surface debris would be removed, and a new cover would be constructed over the landfill. This action would both reduce migration of contaminants by reducing surface water infiltration into the landfill and contain most of the contaminated soils. There would remain one area of the site where people could be exposed to contaminants under a worst case scenario. As under Site Alternatives 2 and 3, the presence of a secure fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent use of the land and the ground water.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B in Table B-6.

Exposure risk scenarios are the same as for Site Alternative 2, with the exception that only one area of elevated lead contamination would be exposed. The most probable exposure scenario would result in both a carcinogenic risk and a hazard index of zero. The worst case exposure scenario assumes that some people would enter the site, despite the fence, and come into contact with the soils; deed restrictions would still prevent use of ground water. Exposure to such soils would result in an insignificant carcinogenic risk of 4.38×10^{-8} and a hazard index of 0.241, which does not represent a potential noncarcinogenic risk.

4.2.5 Site Alternative 5

- **Ground water monitoring (4.2.2)**
- **Deed and site restrictions (4.2.2)**
- **Management of surface debris (4.2.3)**
- **Erosion control and drainage improvements (4.2.3)**
- **Natural clay cover over landfill (4.2.4)**
- **Gas venting system**
- **Leachate collection system**

Site Alternative 5 the same as Site Alternative 4, except that the clay cover would incorporate a gas venting system and a leachate collection system. The following discussion evaluates only these additions.

4.2.5.1 Compliance with ARARs

The landfill would be covered in accordance with State of Ohio solid waste landfill closure standards as outlined in OAC 3745-27-10, Closure of Sanitary Waste Landfills. Under this alternative, State of Ohio solid waste landfill closure standards would be exceeded. The clay would attain the standards of OAC 3745-27-09(F)(4). There is no evidence that a gas venting system or leachate collection are necessary.

4.2.5.2 Reduction in Toxicity, Mobility, or Volume

Site Alternative 5 would not reduce the toxicity, mobility, or volume of the waste (with the exception of the small volume of surface debris that would be removed). However, a leachate collection system would remove some mobile contaminants from the landfill. The addition of a clay cover over the landfill would reduce the potential for migration of the waste because of reduced infiltration through the cover would be reduced to 9.8 percent of precipitation.

4.2.5.3 Short-Term Effectiveness

Short-term risks to the community and workers would be similar to those for Site Alternative 4. During implementation of this alternative, workers would be at the site for a number of months, and would be frequently exposed to chemicals. They would come into contact with the soils by both dermal contact and inhalation of dust. As determined in the EA, risks associated with such contact should be low. However, the volumes of dust present at the site during implementation would be higher than those assumed in the EA, and so the risks to site workers may be significant, if workers are unprotected. Standard health and safety procedures, such as those set forth by OSHA, would be required during construction.

Safety risks imposed on the local community from truck traffic would be increased over Site Alternative 4 by the extra haulage to implement the gas venting and leachate collection system. It is estimated that 25,000 cubic yards of gravel would be imported, involving an additional 1,250 truckloads. A total of approximately 9,400 truckloads would be required to implement this alternative.

4.2.5.4 Long-Term Effectiveness and Permanence

As discussed previously, neither the toxicity nor the mobility of the chemicals would be reduced. In order for a chemical to migrate, it must come into contact with a solvent such as water. The presence of the natural clay cover would reduce infiltration of surface waters into the landfill.

The toxicity of the contaminants would be of concern only if there were potential for direct contact with them. The clay cover would act as a barrier that would break the contaminant pathway to the receptor. Therefore, the cap would be effective in removing the existing public health concern over contact with contaminated soils that are on, or immediately adjacent to, the landfill.

The gas venting system is expected to be an effective technique for removal of any gas produced. This system is, however, not expected to be necessary, as discussed under Site Alternative 4.

The potential leachate collected in the sumps would periodically be pumped into a temporary holding tank prior to offsite treatment. Treatment may consist of discharging to Circleville's publicly owned treatment works (POTW), or similar offsite treatment plant. Volumes are estimated to be 1,340,000 gallons per year based upon HELP model runs shown in Appendix C.

Operation and maintenance requirements for the gas venting and leachate collection system will be provided by manufacturers. Maintenance frequency is expected to be higher than that required for the clay cover. Pumps associated with the leachate collection system and any other rotating equipment are expected to be replaced after a typical operating life of approximately 15 years.

4.2.5.5 Implementability

The clay layer would be placed on the landfill and compacted using standard earthmoving equipment. A source of gravel for the drainage layer should be easily located in the site vicinity. In general, the construction would be a simple process and could be carried out largely by local labor using nonspecialized earthmoving equipment. There

would be no problems associated with implementation, with the exception of flooding of the river and the large number of trucks required to implement the alternative.

The time required to implement this alternative would be approximately 10 months, unless activities are disrupted by flooding events.

4.2.5.6 Cost

Initial capital costs for this site alternative are estimated at $4.3 million. Operating and maintenance costs for ground water monitoring, maintenance of the fence and erosion control and drainage improvements, and leachate collection and disposal are estimated at $251,000 per year. At a discounted rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $6.7 million. Table 11 presents supporting information for these estimates.

4.2.5.7 Overall Protection of Human Health and the Environment

Under Site Alternative 5, visible landfill surface debris would be removed, and a multilayer low-permeability cap would be constructed over the landfill. This action would both reduce migration of contaminants by reducing surface water infiltration into the landfill and contain most of the contaminated soils. As under Site Alternative 4, there would remain one area of the site where people could be exposed to contaminants under a worst case scenario. As under Site Alternatives 2 and 3, the presence of a secure fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent use of the land and the ground water.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B in Table B-7.

Exposure risk scenarios are the same as for Site Alternative 4. The most probable exposure scenario would result in both a carcinogenic risk and a hazard index of zero. The worst case exposure scenario assumes that an insignificant carcinogenic risk of 4.38×10^{-8} and a hazard index of 0.241. A hazard index greater than unity represents a potential noncarcinogenic risk.

4.2.6 Site Alternative 6

- **Ground water monitoring (4.2.2)**
- **Deed and site restrictions (4.2.2)**
- **Management of surface debris (4.2.3)**
- **Drainage improvements (4.2.3)**
- **Natural clay cover (4.2.4)**
- **Gas venting system (4.2.5)**
- **Leachate collection system (4.2.5)**
- **Flood protection dike**

Site Alternative 6 is identical to Site Alternative 5, with the addition of a flood protection dike; therefore, only the effect of the dike is addressed in the following discussions.

4.2.6.1 Compliance with ARARs

Under this alternative, State of Ohio solid waste closure standards would be exceeded.

4.2.6.2 Reduction in Toxicity, Mobility, or Volume

This alternative would not reduce the toxicity, mobility, or volume of waste (with the exception of the small volume of surface debris that would be removed). However, the addition of the flood protection dike would reduce the potential for migration during flood events. The addition of a clay cover over the landfill would reduce the potential for migration of the waste because infiltration through the cover would be reduced to 9.8 percent of precipitation.

4.2.6.3 Short-Term Effectiveness

Short-term risks to the community and workers would be similar to those for Site Alternative 4, with the exception that exposure would be longer due to the construction of the flood dike.

The major health and safety concerns involved with the implementation of this alternative would be to workers during construction. Large earthwork and construction operations are, in themselves, a potentially dangerous activity. Standard health and safety

procedures such as those set forth by OSHA would be required to protect all personnel involved with this project.

Safety risks imposed on the local community from truck traffic would be increased over Site Alternative 4 by the extra haulage to construct the flood protection dike if material from the west field is not used. It is estimated that 3,600 cubic yards of concrete, 83,060 cubic yards of soil and 93,000 cubic yards of clay may need to be imported. This would involve 12,000 truckloads.

4.2.6.4 Long-Term Effectiveness and Permanence

The presence of the flood protection dike would further reduce infiltration of surface water into the landfill. The dike would be constructed to shield the landfill from the 100-year flood; therefore, the only water that could come into contact with the cap would be precipitation.

Maintenance of the flood protection dike would include regularly scheduled inspections to ensure its integrity. Additional inspections would take place after severe weather. The dike would be inspected for evidence of caving, sloughing, erosion, and settlement. If repairs to the dike or reseeding were required, this would be carried out immediately. Repairs to the dike would consist of patching with fresh clay.

Construction of flood control dikes is a proven, long-term effective method of eliminating flood hazards. There would be virtually no long-term threat to public health and the environment.

Operation and maintenance of this alternative would be similar to Site Alternative 5, with some additional inspection and repair for the dike.

4.2.6.5 Implementability

A suitable borrow source would be located nearby as described in Site Alternative 4. There should be sufficient clay volume in the field to the west of the landfill for this operation, and thus the source of the clay could be this field. Suitable clay would be excavated from the source using standard equipment and would be hauled to the site. The

dike would be constructed using similar equipment and techniques to those for Site Alternative 5.

The time required to implement this alternative would be approximately 18 months, unless substantial flood events were to hamper construction.

4.2.6.6 Cost

Initial capital costs for this site alternative are estimated at $9.1 million. Operating and maintenance costs for ground water monitoring, maintenance of the fence and flood dike, and leachate collection and removal are estimated at $325,000 per year. At a discount rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $12.2 million. Table 12 presents supporting information for these estimates.

4.2.6.7 Overall Protection of Human Health and the Environment

As under Site Alternatives 4 and 5, there would remain one area of the site where people could be exposed to contaminants, under a worst case scenario. As under Site Alternatives 2 and 3, the presence of a secure fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent disturbance of the landfill surface and restrict future use of the site for extraction of ground water downgradient of the landfill.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B in Table B-8.

The most probable exposure scenario would result in both a carcinogenic risk and a hazard index of zero. The worst case exposure scenario assumes that soils would result in an insignificant carcinogenic risk of 4.38×10^{-8} and a hazard index of 0.241. A hazard index greater than unity represents a potential noncarcinogenic risk.

4.2.7 Site Alternative 7

- **Ground water monitoring (4.2.2)**
- **Deed and site restrictions (4.2.2)**
- **Management of surface debris (4.2.3)**
- **Drainage improvements (4.2.3)**
- **Gas venting system(4.2.5)**
- **Leachate collection system (4.2.5)**
- **Flood protection dike (4.2.6)**
- **Synthetic membrane cap over landfill**

Site Alternative 7 is the same as Site Alternative 5 with the addition of the flood protection dike together with a synthetic liner over the low-permeability clay cap. Thus, only those issues related to the combination of the flood protection dike and synthetic membrane cap are addressed here.

4.2.7.1 Compliance with ARARs

Under this alternative, State of Ohio solid waste closure standards would be exceeded. A synthetic membrane cap over the landfill would result in a cover typically used for closure of hazardous waste landfills.

4.2.7.2 Reduction in Toxicity, Mobility, or Volume

This alternative would not reduce the toxicity, mobility, or volume of waste, with the exception of the small volume of surface debris that would be removed. However, the addition of the flood protection dike would reduce the potential for migration during flood events. The addition of the synthetic liner would reduce infiltration to 0.01 percent of precipitation and reduce the potential of leachate migration. This percolation assumes zero leakage from potential mechanical penetrations through the synthetic membrane in addition to the assumptions listed in Appendix C.

4.2.7.3 Short-Term Effectiveness

Short-term effects, including risks imposed on the local community by trucks, would be similar to those for Site Alternative 6. The additional construction involved in the installation of the synthetic liner would not involve any significant additional risks to the public or workers.

4.2.7.4 Long-Term Effectiveness and Permanence

The presence of the flood protection dike would further reduce infiltration of surface water into the landfill below that calculated for the synthetic membrane cap because of the additional protection during flood events.

Maintenance requirements for the flood protection dike would be as described under Site Alternative 6.

Maintenance of the cap would include regularly scheduled inspections to ensure its integrity. Extraordinary inspections would take place after severe weather to confirm the integrity of the cover and erosion protection. The synthetic membrane cap would be inspected for evidence of subsidence, erosion of the surface, and growth of large species of vegetation that may have deep roots that could invade the clay layer and penetrate the liner. Normal maintenance would include surface repair and removal of any vegetation that may be expected to have a deep root system.

If well-maintained, this alternative is expected to be protective over the long-term.

4.2.7.5 Implementability

A suitable borrow source would be located in an adjacent area (as described in Site Alternative 4) that contains sufficient low-permeability clay for use in building the flood protection dike and synthetic membrane cover. The time required to implement this alternative would be approximately 18 months, unless substantial flood events were to hamper construction.

4.2.7.6 Cost

Initial capital costs for this site alternative are estimated at $10.4 million. Operating and maintenance costs for ground water monitoring, maintenance of the fence and flood dike, and leachate collection and removal are estimated at $366,000 per year. At a discount rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $13.8 million. Table 13 presents supporting information for these estimates.

4.2.7.7 Overall Protection of Human Health and the Environment

As under Site Alternatives 4, 5, and 6, there would remain one area of the site where people could be exposed to elevated levels of contaminants under a worst case scenario. As under Site Alternatives 2 and 3, the presence of a secure fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent use of the land and the ground water.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B in Table B-9.

Exposure risk scenarios are the same as for Site Alternative 4. The most probable exposure scenario would result in both a carcinogenic risk and a hazard index of zero. The worst case exposure scenario would result in an insignificant carcinogenic risk of 4.38×10^{-8} and a hazard index of 0.241. A hazard index of greater than unity represents a potential noncarcinogenic risk.

4.2.8 Site Alternative 8

- **Ground water monitoring (4.2.2)**
- **Deed and site restrictions (4.2.2)**
- **Management of surface debris (4.2.3)**
- **Erosion control and drainage improvements (4.2.3)**
- **Gas venting system (4.2.5)**
- **Leachate collection system (4.2.5)**
- **Synthetic membrane cap over landfill**

Site Alternative 8 is the same as Site Alternative 5, with the addition of a synthetic liner over the low-permeability clay cap. The following evaluation therefore addresses only the effect of the synthetic liner.

4.2.8.1 Compliance with ARARs

Under this alternative, the cover would exceed the requirements of the State of Ohio solid waste landfill closure standards. This cover design is typically used for closure of operating RCRA hazardous waste landfills. The Bowers site is not an operating hazardous waste landfill. The RCRA regulations that govern hazardous waste treatment, storage, and

disposal facilities under 40 CFR 264 did not become effective until November 19, 1980. The Bowers Landfill ceased accepting wastes prior to that date, and thus the regulation is not "applicable," but portions may be "relevant and appropriate" to certain categories of landfill remedial actions such as transportation and disposal of any hazardous waste from the site and ground water monitoring.

According to the results of the HELP model (shown in Appendix C), the addition of a synthetic membrane liner would reduce percolation through the cover to 0.01 percent of precipitation versus 9.8 percent through the clay cover. This percolation assumes zero leakage from potential mechanical penetrations through the synthetic membrane in addition to the assumptions listed in Appendix C.

4.2.8.2 Reduction in Toxicity, Mobility, or Volume

This alternative would not reduce the toxicity, mobility, or volume of waste, with the exception of the small volume of surface debris that would be removed. However, the addition of the synthetic liner would reduce infiltration to 0.01 percent of precipitation and reduce the potential of leachate migration.

4.2.8.3 Short-Term Effectiveness

Short-term effects, including risks imposed on the local community by trucks, would be similar to those for Site Alternative 5. The additional construction involved in the installation of the synthetic liner would not involve any significant additional risks to the public or to workers.

4.2.8.4 Long-Term Effectiveness and Permanence

The presence of the synthetic membrane over the landfill would further reduce infiltration of surface water. According to the results of the HELP model (shown in Appendix C), infiltration would be reduced to 0.01 percent of precipitation. As shown in Appendix B, for all site alternatives involving deed restrictions (Alternatives 2 through 9), the pathway for ground water ingestion at the site would be broken for the most probable exposure scenario. Thus, there would be little additional public health benefit, under the most probable scenario, from reducing infiltration values.

If well-maintained, this alternative would be effective and reliable for at least 20 years, after which minimal reconstruction of damaged sections may be necessary. There would be virtually no long-term threat to public health and the environment.

4.2.8.5 Implementability

Before construction of the cap, a suitable borrow source of clay would have to be located nearby, as described in Site Alternative 4. In addition, a suitable synthetic material would have to be selected. This would probably be either PVC or HDPE. The synthetic material would be installed in sheets, seamed together, to provide a continuous layer over the landfill. It would take approximately 10 months to implement this alternative, after which the operation and maintenance would be the same as for Site Alternative 6.

4.2.8.6 Cost

The initial capital costs for this site alternative are estimated at $6.2 million. Operating and maintenance costs for ground water monitoring, maintenance of the fence, and leachate collection and removal are estimated at $247,000 per year. At a discounted rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $8.6 million. Table 14 presents supporting information for these estimates.

4.2.8.7 Overall Protection of Human Health and the Environment

As under Site Alternatives 4, 5, and 6, there would remain one area of the site where people could be exposed to elevated levels of contaminants under a worst case scenario. As under Site Alternatives 2 and 3, the presence of a secure fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent use of the land and the ground water.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B in Table B-10.

Exposure risk scenarios are the same as for Site Alternative 4. The most probable exposure scenario would result in both a carcinogenic risk and a hazard index of zero. The

worst case exposure scenario would result in an insignificant carcinogenic risk of 4.38 x 10^{-8} and a hazard index of 0.241. A hazard index of greater than unity represents a potential noncarcinogenic risk.

4.2.9 Site Alternative 9

- **Ground water monitoring (4.2.2)**
- **Deed and site restrictions (4.2.2)**
- **Management of surface debris (4.2.3)**
- **Improvements to landfill side slopes**
- **Erosion control and drainage improvements (4.2.3)**
- **Natural clay cover on landfill top**

A natural clay cover, consisting of 24 inches of topsoil over 24 inches of compacted natural clay, would be placed over the existing landfill top to reduce and retard infiltration, and minimize the migration of liquid through the waste. Site Alternative 9 would be the same as Site Alternative 4, but the natural clay cover would be placed over the landfill top only, and the sides would be repaired where necessary. The following discussions evaluate only these additions.

4.2.9.1 Compliance with ARARs

Current State of Ohio solid waste landfill closure standards as outlined in OAC 3745-27-10, Closure of Sanitary Landfills, are not applicable. Portions may be relevant and appropriate. The clay cover over the landfill top would attain the standard of OAC 3745-27-09(F)(4), and would have a low permeability to water, good compactability, and relatively uniform texture. Depending upon the present depth of cover on the side slopes, the type of material, and the extent of repairs, the slopes may or may not meet the standards of OAC 3745-27.

The landfill side slopes would be improved where necessary in areas of high erosion, at localized areas where stability is a concern, and at areas where ponding occurs. These improvements would be carried out with the objectives of providing continuously sloping surfaces, having a maximum horizontal to vertical ratio of 2 to 1, that would drain water off the side slopes. The repairs to the landfill cover would improve erosion protection, improve surface runoff, prevent ponding, and result in some reduction of infiltration.

Field information shows that a portion of the side slopes may have a depth of cover of 2 feet. The preliminary site investigation of the existing cover showed that a majority of the side slopes is covered by at least 1 foot of material, and in several locations showed a depth of cover of 2 feet. A more detailed investigation of the existing cover soils on the side slopes would be carried out during the predesign phase of the project. The depth of soil on the side slopes would be measured at discrete points through the side slopes laid out on a grid system throughout the area where waste was disposed. The results of this detailed cover investigation, together with a survey of drainage patterns and areas of erosion and potential erosion, would be used to determine where the depth of cover would need to be improved. Improvements would be made with the objectives of improving erosion protection, improving surface runoff, and reducing infiltration. For the intent of this feasibility study, it has been assumed (based upon the site evaluation) that approximately 2000 cubic yards of soil would be used for the repairs to the toe of the east side slope. This basis assumes that 25% of the east side slope would require repairs. Also, approximately 10% of the remaining side slopes would also require improvements for drainage, resulting in an additional soil requirement of 2,200 cubic yards of soil. The resulting soil coverage after completion of these improvements may or may not meet the standards of OAC 3745-27.

The preliminary site investigation showed that the probable soil classification of the side slopes is a sandy loam or loam. These soils are included in those soil classifications listed in OAC 3745-27-09(F)(4). Where improvements are required to the side slopes, additions would be made using material in accordance with this regulation.

The alternative would provide erosion protection of the side slopes. Preliminary slope stability calculations (Appendix D) show the side slopes would be stable. This analysis was based upon soil samples collected from the side slopes, published data on relevant soil properties, together with a review of the slope configuration detailed on the existing topographic map for Site Alternative 9 (Drawing 15). These calculations do not take into account the beneficial effects of the existing highly stable ecosystem on the side slopes. The broad diversity of vegetation provides a root system which, on the slopes of the landfill, gives both surficial and deep stabilization and protects against erosion from precipitation and periodic flooding. Furthermore, the diversity of plant species that have developed naturally at the site indicates that they are likely to maintain their domination of the site and provide continued stability. These conclusions would be rechecked during the

design phase based upon the results of a more detailed site topographic survey and additional soil sampling data. Slopes deemed unstable would be regraded by adding soil and compacting to give stable slopes, and revegetating. Repairs to the landfill side slopes, together with erosion control at areas that may be exposed to high river velocities, would further improve erosion protection.

Improvements to the landfill top, including addition of a drainage control berm around the perimeter, would be effective in significantly reducing infiltration and in reducing sheet runoff over the landfill side slopes that could cause erosion. Significant reduction in infiltration would be achieved by repairs to the side slopes and improvements to the landfill top. The natural clay cover would reduce and retard infiltration by precipitation. The runoff control berms around the perimeter of the top cover would collect and redirect runoff through several discharge chutes thus reducing both sheet surface flow and potential infiltration through the side slopes. The present diverse vegetative cover on the side slopes results in greater evapotranspirative withdrawal from surficial soils than would occur with shallow-rooted grasses. Repairs to the side slopes to attain continuous sloping surfaces and subsequent covering would reduce ponding and further reduce infiltration.

Results from the HELP model using field data from the preliminary site investigation show that approximately 34.3 percent of precipitation infiltrates the existing landfill cover. After completion of the improvements, predicted infiltration into the landfill top cover and side slopes would be reduced to approximately 15.8 percent of precipitation. There is no evidence of an upward trend in chemical concentrations measured in the ground water and thus this reduction in infiltration would provide additional protection against future releases. A carefully designed ground water monitoring program would ensure detection of any change in ground water contaminant levels before significant offsite migration occurs.

Effective control of releases to the environment from waste in the landfill would be achieved by these actions.

4.2.9.2 Reduction in Toxicity, Mobility, or Volume

This alternative would not reduce the toxicity, mobility, or volume of the waste (with the exception of the small volume of surface debris that would be removed). However, the addition of a natural clay cover over the landfill top would reduce the potential for migration of the waste because of the reduced infiltration. Local repairs to the existing side slopes would also achieve some reduction in infiltration. This reduction would result because those areas having inadequate cover would be repaired with natural clay soil, and the improved cover would allow less precipitation to percolate through the waste. It is estimated that these improvements would result in reduction of infiltration into the landfill to 15.8 percent of precipitation.

4.2.9.3 Short-Term Effectiveness

There would be no unusual short-term risks to the community or to workers during the implementation of this alternative, if properly managed. The alternative would involve short-term construction-related safety concerns similar to those described in Site Alternative 3. This alternative would involve greater construction activity than Site Alternative 3, and thus safety concerns would be proportionately increased.

It may occasionally be necessary to remove partially buried trash from the side slopes, with the resulting potential of exposing workers to contaminated waste. Surface debris would be removed by personnel wearing appropriate protective equipment. Removal of vegetation and construction of the clay cap over the landfill top would be carried out under an appropriate health and safety plan to ensure minimal onsite and offsite exposure.

Safety risks imposed on the local community from truck traffic would be increased over Site Alternative 3 by the extra haulage required to remove the vegetation on the landfill top and install the natural clay cover. It is estimated that up to approximately 5,200 truckloads would be required to implement this alternative. Approximately 32,000 cubic yards of clay would be imported if the clay from the field to the west were not used, and 34,000 cubic yards of topsoil would be imported. This would involve approximately 4,500 truckloads. In addition, between 100 and 300 truckloads of vegetation would be hauled offsite for disposal, and 375 truckloads of riprap would be required.

4.2.9.4 Long-Term Effectiveness and Permanence

Implementation of Site Alternative 9 would be protective over the long term, and the risks of exposure following implementation would be reduced. A natural clay layer on the landfill top would be an effective means of reducing infiltration, would enhance surface runoff, and would provide protection to the existing landfill slopes from erosion and wear. Considerations are as described under Site Alternative 4. Installation of a cover on the landfill top and repairs to the side slopes would provide a continuous soil cover over the landfill and would eliminate the potential for contact with the exposed waste. Filling of the open gullies and erosion rifts, as well as elimination of surface depressions, would reduce the amount of liquid that penetrates the landfill surface. Infiltration that moves laterally through the landfill would be reduced by the evapotranspirative withdrawal from the surficial soils by the trees at the toe of the landfill.

The existing site vegetation is a highly stable ecosystem that is effective in protecting against erosion (Appendix A). The addition of riprap adjacent to the main river channel and drainage control berms on the landfill perimeter would further enhance the stabilization. In general, stabilization and erosion control are similar to Site Alternative 3 for the side slopes.

Maintenance of the landfill side slopes would be as described in Site Alternative 3, while maintenance of the natural clay cover would be as described under Site Alternative 4.

4.2.9.5 Implementability

A natural clay cover on the landfill top would not require any unusual construction practices. Removal of visible waste and removal of trees on the landfill top would probably be carried out before the repairs to the side slopes. This would improve access to the side slopes. Installation of the clay cover would be as described in Site Alternative 4.

Improvements to the landfill side slopes would commence with mobilizing personnel to walk the site and manually remove trash. Larger items would be handled by small front-end loaders. These machines could be operated on areas of the side slopes,

depending upon steepness. The machines could be maneuvered among the trees on certain areas of the slopes. For inaccessible areas, the machines would be equipped with cables and could be operated from the landfill top or from the adjacent field area to remove material.

After surface debris had been removed, tree cover over the side slopes would be thinned in accordance with the maintenance plan. Trees would be cut down at grade level. Handling and disposal of the affected vegetation would be carried out in the same manner as for material removed from the landfill top.

The integrity of the east side slope is questionable. Improvements would be made by working from the bottom and top of the side slopes. To gain access from below, the drainage ditch would be dewatered to the extent possible, and a construction access road would be built along the west side of the ditch at the landfill.

Repair of areas where erosion or localized stability is a concern would be carried out mainly from the top. Soil used for repairs would be brought from the adjacent field areas or from offsite. Alternatively, areas near the base of the side slopes could be repaired by earthmoving equipment located on the construction access road. Compacting may be achieved by using portable mechanical equipment. Where compacting is not practical, riprap would be placed on the filled area. Repairs to the bottom of the slope, at the areas of contact with the east ditch, would be made after the improvements to the side slopes. These repairs may involve stabilizing limited portions of the landfill base with sheet pile or riprap placed along the toe of the berm.

Improvements to the other side slopes involving repairs to areas where erosion and localized stability is a concern, together with improvements to the terraced areas, would be carried out using the same general techniques. Accessibility should be improved, and areas requiring additional slope repairs are expected to be limited.

Improvements to the drainage patterns around the base of the landfill would be implemented next. These improvements are described under Site Alternative 3 and would involve providing drainage flow through the ditch on the west side of the landfill, regrading the ditch on the west side of the landfill to give a continuously draining flow path, and regrading the area of the field to the north adjacent to the east ditch to improve drainage.

Installation of the natural clay cover over the landfill top would be implemented after the above improvements had been completed and would not involve any unusual construction practices. Installation of the clay cover would be, in general, as described under Site Alternative 4 and would commence with removal of the vegetative cover. Erosion control measures on the landfill north and south tips would be carried out during this phase. Seeding and revegetation of the landfill top and side slopes would be the final operation.

It is anticipated that the whole operation would be carried out using conventional equipment. It is estimated that implementation time for this alternative would be 8 months, and that the operation would be carried out so as to avoid construction activities during potential flood stage periods.

4.2.9.6 Cost

Initial capital costs for this site alternative are estimated at $2.5 million. Operating and maintenance costs for ground water monitoring, maintenance of the fence, erosion control, and drainage improvements are estimated at $101,000 per year. At a discounted rate of 10 percent, over a period of 30 years, the total present worth is estimated at approximately $3.4 million. Table 15 presents supporting information for these estimates.

4.2.9.7 Overall Protection of Human Health and the Environment

Under Site Alternative 9, visible landfill surface debris would be removed, a new cover would be constructed over the landfill top, and repairs would be made to the landfill slopes. This action would both reduce migration of contaminants by reducing surface water infiltration into the landfill and contain most of the contaminated soils of the landfill. As under Site Alternatives 2 and 3, the presence of a secure fence around the site would prevent virtually all contact with contaminated soils. A deed restriction would prevent use of the land and the ground water.

The assumptions used in this public health evaluation are discussed at length in Appendix B. A detailed exposure scenario is presented in Appendix B in Table B-11.

Exposure risk scenarios are the same as for Site Alternative 2, with the exception that the placement of a cover over the landfill top would enclose some of the areas of lead contamination above background. The most probable exposure scenario would result in a carcinogenic risk of zero as well as a hazard index of zero. The worst case exposure scenario assumes that some people would enter the site, despite the fence, and come into contact with the soils; deed restrictions would still prevent use of ground water. Exposure to such soils would result in a carcinogenic risk of 4.58×10^{-7} and a hazard index of 0.277. A hazard index greater than unity represents a potential noncarcinogenic risk.

4.3 SENSITIVITY ANALYSIS

Tables 16 and 17 present a sensitivity analysis assessing the effect of variations in specific assumptions on the overall present worth of the costs of each alternative. Table 16 shows the effects of a variation of minus 30 percent or plus 50 percent on the cost of each alternative, holding all other variables constant. The table shows that the capital-intensive alternatives, such as Site Alternatives 6 and 7, which include a flood protection dike, are most sensitive to variations in capital cost.

Table 17 shows the effect of utilizing a discount rate of 5 or 15 percent for determining the present worth of operating and maintenance costs over a term of 30 years. The effect of a variable discount rate would have the greatest effect on alternatives, such as 6 and 7, that have high operation and maintenance costs associated with long-term maintenance of site restrictions and the flood protection dike.

5.0 SUMMARY OF SITE ALTERNATIVES

5.1 INTRODUCTION

This chapter presents a summary of the nine remedial alternatives that were subjected to detailed evaluation in Section 4.0. This summary of alternatives is a key step to enable the decision maker, in accordance with CERCLA and the NCP, to select the most cost-effective which is fully protective of public health and the environment. Table 18 summarizes the most important information to consider in the selection of a remedy. By consolidating all pertinent information in this section, the alternatives may be easily compared. The table highlights differences among alternatives developed and analyzed in Sections 3.0 and 4.0. With the exception of Site Alternatives 1 and 2, all alternatives involve source control actions. The precision of the information in this summary is consistent with the present level and extent of knowledge concerning the environmental issues at the site.

The following considerations are summarized in Table 18 for each remedial alternative:

- **Compliance with ARARs.** The table references ARARs discussed in Chapter 4.
- **Reduction of Toxicity, Mobility, and Volume.** The table indicates the degree to which alternatives employ treatment to reduce toxicity, mobility, or volume of contaminants.
- **Short-Term Effectiveness.** Alternatives are assessed on the basis of reduction of existing risks and the short-term risks involved in implementation.
- **Long-Term Effectiveness.** Alternatives are assessed on the basis of residual risks following implementation, long-term management requirements, and the reliability of the controls.
- **Implementability.** Alternatives are assessed on the basis of construction time and such technical issues as performance and reliability.
- **Cost Evaluation.** The net present worth of the alternative is listed together with the associated capital and operating and maintenance requirements.
- **Overall Protection of Human Health and the Environment.** The alternatives are assessed for their impact on human health after implementation and the extent to which they effectively mitigate or minimize damage to public health.

This information, presented in summary form, is used as reference for a discussion in which alternatives are compared with one another. This comparison is made in light of the following two regulatory considerations. Firstly, NCP Section 300.68, paragraph (i), states that the appropriate remedy shall be determined by the lead agency's selection of a cost-effective remedial alternative that effectively mitigates and minimizes threat to and provides adequate protection of public health, welfare, and the environment. Secondly, Section 121 of SARA states that:

> Remedial action in which treatment permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants, as a principal element is to be preferred over remedial actions not involving such treatment. The offsite transport and disposal of hazardous substances or contaminated materials without such treatment should be the least favored alternative remedial action where practicable treatment technologies are available.

5.2 COMPARISON OF SITE ALTERNATIVES

The following is a comparative analysis describing the strengths and weaknesses of the alternatives relative to one another. Table 19 shows each component of the site alternatives in a matrix form, together with economic information.

5.2.1 Alternatives that Require No Action (One Alternative)

5.2.1.1 Site Alternative 1
•No action

There would be no reduction in toxicity, mobility, or volume; potential infiltration would be approximately 34 percent of precipitation. The present stable vegetative cover would remain, would protect against erosion (except immediately adjacent to the river), and would result in greater evapotranspirative withdrawal by the moisture-loving tree species than would occur with shallow-rooted species. There are no costs associated with this alternative.

No remedial action would be taken to remove, control migration from, or minimize exposure to chemicals. Visible surface debris would remain, and areas of erosion and ponding would not be repaired. Public health risks are due to contaminants identified in the EA are as follows:

	Most Probable	Worst Case
Carcinogenic risk	1.05×10^{-6}	1.23×10^{-5}
Hazard index	0.34	4.64

Carcinogenic risks within 10^{-4} to 10^{-7} are within the target risk range. A hazard index of greater than unity represents a potential noncarcinogenic risk.

5.2.2 Alternatives that Involve Containment of Waste with Little or No Treatment, but Provide Protection of Human Health and the Environment Primarily by Preventing Potential Exposure or Reducing the Mobility of the Waste (Eight Alternatives)

5.2.2.1 Site Alternative 2
- **Ground water monitoring**
- **Deed and site restrictions**

Under Site Alternative 2, deed and site restrictions would be imposed, and a ground water monitoring program would be operated at the site. Deed restrictions would be effective in preventing use of the site for extraction of ground water downgradient of the landfill. Access restrictions would be effective in preventing unauthorized access to the site and would restrict direct contact with exposed waste material in the landfill, or with contaminated soils. The fence would enclose all soils at the site that were found to be contaminated above background levels. The ground water monitoring program would detect any increase in contaminant levels. If concentrations should show a generally upward trend, as characterized by a statistically significant increase in concentrations, then a protective action would be triggered.

There would be no reduction in toxicity, mobility, or volume. No remedial action would be taken to control migration of or exposure to chemicals. As with Site Alternative 1, the current stable vegetative cover would remain; visible surface debris would remain; and areas of erosion and ponding would not be repaired.

Implementation time is estimated at 1 month. Light construction equipment would be used; no abnormal maintenance is expected.

Public health risks are as follows:

	Most Probable	Worst Case
Carcinogenic risk	0	4.58×10^{-7}
Hazard index	0	0.277

Public health risks are reduced when compared to Site Alternative 1 by imposition of deed restrictions which break the potential pathway of ground water ingestion downgradient of the landfill. Risks are also reduced by site access restrictions which prevent access by all persons except those who may scale the fence.

Under the worst case scenario, the carcinogenic risk is within the target risk range and in fact the lower end of risk range. The hazard index does not represent a noncarcinogenic risk.

This site alternative has a present worth of $0.5 million.

5.2.2.2 Site Alternative 3

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Local repairs to existing landfill cover**
- **Erosion control and drainage improvements**

Site Alternative 3 combines the monitoring and deed restriction features of Site Alternative 2 with management of surface debris on the landfill surface, local repairs to the existing landfill cover, installation of riprap and other erosion control measures at landfill areas exposed to high river velocity, and improvement of site and landfill drainage to minimize surface water ponding.

Portions of State of Ohio Department of Health Rule HE-24 for licensed solid waste landfills may be "relevant and appropriate" to closure of the landfill. Under HE-24-09, the "cover shall be of earth....prevent...unsightly appearance, will permit minimal percolation of water." The final cover shall "...be graded to serve its intended purpose..." Portions of current State of Ohio solid waste landfill closure standards may be "relevant and appropriate" to certain categories of remedial actions to the landfill. The appearance of the current stable and diverse vegetative cover, more than 20 years after ceasing landfilling, would be improved by removal of surface debris and by surface repairs. Management of

the diverse vegetation to sustain development of moisture-loving tree species would result in removal of greater amounts of moisture from surficial soils than would occur with dry soil species. Repairs to the landfill cover and regrading would improve surface runoff, reducing ponding and infiltration. Erosion control at areas that may be exposed to high river velocities would further improve erosion protection. The natural diversity of plant species indicates they should maintain their dominance of the site, result in continued stability, and be effective in controlling significant releases to the environment.

There would be no reduction in toxicity, mobility or volume; there would be some reduction in the potential for migration because of the reduction in infiltration.

Implementation time is estimated at 3 months; standard earth-moving equipment would be used. Approximately 1,225 truckloads to transport surface debris, clay for landfill repairs, and riprap for erosion protection may be required to implement this site alternative. This may have a short term impact in the locality.

Public health risks are as follows:

	Most Probable	**Worst Case**
Carcinogenic risk	0	4.58×10^{-7}
Hazard index	0	0.277

Public health risks are the same as for Site Alternative 2; however, Site Alternative 2 has no provision for improvements to the landfill surface. The integrity and stability of the cover for this site alternative would be maintained by landfill repairs and management of the vegetative cover.

Deed and site restrictions would be effective in preventing ground water ingestion and limiting exposure to contaminated soils. The repairs to the landfill cover and erosion protection, together with an ongoing maintenance plan for the landfill surface and vegetative cover, should result in continued control of significant releases to the environment. Under the ground water monitoring program, if concentrations show a statistically significant upward trend, then a protective action would be triggered.

This site alternative has a present worth of $2.2 million. Site Alternative 3 represents a cost-effective alternative that should continue to be protective of the public health and environment by continued control of significant releases to the environment.

5.2.2.3 Site Alternative 4

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Natural clay cover over landfill**

Site Alternative 4 involves the same features as Site Alternative 3, but instead of repairing the existing cover, the present vegetative cover would be removed and a natural clay cover would be installed. All subsequent site alternatives involve removal of the existing vegetative cover.

The landfill would be covered using the standards in OAC 3745-27-10, *Closure of Sanitary Landfills*. The natural clay cover would enclose essentially all areas of elevated lead concentration in the soils.

There would be no reduction in toxicity, mobility or volume; potential migration would be less than under Site Alternative 3 since infiltration would be reduced to an estimated 9.8 percent of precipitation.

Implementation time is estimated at approximately 10 months and would use conventional heavy earthmoving equipment. Vegetation would be removed, and broadleaf herbicides would be applied to systemically kill woody species remaining. If clay is available onsite for cover material, approximately 700 truckloads of imported materials would be required; otherwise 8,200 truckloads would be required to transport surface debris, clay for landfill repairs, and riprap for erosion protection. These numbers are substantially greater than those for Site Alternative 3.

Mowing of the grass cover, together with inspection and repair of the cap, is required to ensure long-term effectiveness.

Public health risks are as follows:

	Most Probable	Worst Case
Carcinogenic risk	0	4.38×10^{-8}
Hazard index	0	0.241

Public health risks under the worst case scenario are slightly lower than for Site Alternative 3 because installing the cap would cover the most potentially contaminated soils.

This site alternative has a present worth of $4.3 million. It is not cost-effective in reducing public health risks when compared to Site Alternatives 2, 3 or 9, which have present worths of $0.5 million, $2.2 million and $3.4 million, respectively, and are protective of public health and the environment.

5.2.2.4 Site Alternative 5

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Natural clay cover over landfill**
- **Gas venting system and leachate collection system**

Site Alternative 5 incorporates the features of Site Alternative 4, with the addition of a gas venting system and a leachate collection system.

The landfill would be covered in accordance with OAC 3745-27-10, *Closure of Sanitary Landfills*. The landfill is expected to be essentially inert after 20 years of inactivity, particularly considering that the majority of the waste material was residential refuse, which readily biodegrades. Also there have been no reports of cracking of the surface or release of gas bubbles from ponded water. There may, however, be small quantities of gas generated under the cap from decaying plant material. There is no evidence that gas venting is necessary.

During the RI there was very little evidence of seeps or leachate. Thus, there is no confirming evidence that leachate collection is necessary.

There would be no reduction in toxicity, mobility, or volume; potential migration would be reduced over Site Alternative 3.

Implementation time is estimated at approximately 10 months. Approximately 1,250 truckloads of gravel for the gas venting and leachate collection systems would be needed over and above the requirements for Site Alternative 4. This would be substantially more than for Site Alternative 3, and somewhat more than for Site Alternative 9.

Maintenance requirements would be similar to those for Site Alternative 4. Based on the assumption that essentially all surface water that infiltrates is removed as leachate, approximately 300 truckloads per year of leachate would be disposed of at an offsite treatment unit.

Public health risks would be the same as for Site Alternative 4.

This site alternative has a present worth of $6.7 million. It is not cost-effective in reducing public health risks when compared to Site Alternatives 2, 3 or 9, which have present worths of $0.5 million, $2.2 million and $3.4 million, respectively, and are protective of public health and the environment.

5.2.2.5 Site Alternative 6

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Drainage improvements**
- **Natural clay cover over landfill**
- **Gas venting system**
- **Leachate collection system**
- **Flood protection dike**

This site alternative includes the features of Site Alternative 5, with the addition of a flood protection dike.

Under this alternative, State of Ohio solid waste closure standards would be exceeded.

There would be no reduction in toxicity, mobility or volume; potential migration would be reduced over Site Alternatives 3, 4, 5, and 9 by the addition of a flood protection dike.

Implementation time is estimated at 18 months, which could be lengthened by delays due to flood events. If clay is not used from the field to the west, approximately 12,000 truckloads of material to construct the flood protection dike would be needed over and above the requirements for Site Alternative 5. This is also substantially more than for Site Alternatives 3, 4, 7, and 9.

Maintenance requirements for the cap would be the same as for Site Alternative 5. Regular maintenance of the flood protection dike should ensure that it provides effective long-term protection.

Public health risks are the same as for Site Alternatives 4 and 5.

This site alternative has a present worth of $12.2 million. Approximately 50 percent of this amount is associated with the flood protection dike. There is no evidence of an upward trend in chemical concentration measured in the ground water, even though in an average year, the field to the west of the landfill is under water for 29 days. Except for the ends adjacent to the river, there is no evidence of erosion of the landfill as a result of flooding. Since these ends will be protected by riprap, there is no evidence that a flood protection dike would be cost-effective.

5.2.2.6 Site Alternative 7

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Drainage improvements**
- **Gas venting system**
- **Leachate collection system**
- **Flood protection dike**
- **Synthetic membrane cap over landfill**

This site alternative includes the features of Site Alternative 6, except that a synthetic membrane over the landfill would be used in addition to a clay cap as the primary impervious barrier to moisture entering the landfill.

State of Ohio solid waste landfill closure standards would be exceeded by the installation of a cap typically used for closure of operating hazardous waste landfills.

There would be no reduction in toxicity, mobility, or volume; potential migration would be reduced over Site Alternatives 3, 4, 5, and 9 by the addition of a flood protection

dike and synthetic membrane cap. For Site Alternative 6, potential migration would be reduced by the addition of a synthetic membrane cap, and for Site Alternative 8 by the addition of a flood protection dike. The synthetic membrane cap is estimated to reduce infiltration to 0.01 percent of precipitation compared to 9.8 percent through the clay cover. This percolation assumes zero leakage from possible mechanical penetrations through the synthetic membrane in addition to the assumptions listed in Appendix C.

Implementation time is estimated at 18 months, which could be lengthened by flood events. Trucking and maintenance requirements would be similar to those for Site Alternative 6.

Public health risks are the same as for Site Alternatives 4, 5, and 6.

This site alternative has a present worth of $13.8 million. The addition of the synthetic membrane accounts for $1.7 million. This additional expenditure is not cost-effective compared to Site Alternative 6, since the change in concentrations measured in ground water show no evidence of an upward trend.

5.2.2.7 Site Alternative 8

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Gas venting system**
- **Leachate collection system**
- **Synthetic membrane cap over landfill**

This site alternative includes the features of Site Alternative 5, with the addition of a synthetic membrane cap over the low-permeability clay cover.

The landfill would be closed in accordance with hazardous waste landfill closure standards and State of Ohio solid waste closure standards would be exceeded.

There would be no reduction in toxicity, mobility, or volume. Potential migration would be reduced over Site Alternatives 3, 4, 5, and 9 by the addition of a synthetic membrane cap. The synthetic membrane cap is estimated to reduce infiltration to 0.01 percent of precipitation compared to 9.8 percent through the clay cover. This percolation

assumes zero leakage from possible mechanical penetrations through the synthetic membrane in addition to the assumptions listed in Appendix C.

Implementation time is estimated at 10 months, which could be lengthened by delays due to flood events. Trucking and maintenance requirements would be similar to those for Site Alternative 5.

Public health risks are the same as for Site Alternatives 4, 5, 6, and 7.

This site alternative has a present worth of $8.6 million. The addition of the synthetic membrane accounts for $1.7 million. This additional expenditure is not cost-effective compared to Site Alternative 5, since the concentrations measured in ground water show no evidence of an upward trend.

5.2.2.8 Site Alternative 9

- **Ground water monitoring**
- **Deed and site restrictions**
- **Management of surface debris**
- **Erosion control and drainage improvements**
- **Local repairs to landfill side slopes**
- **Natural clay cover over landfill cap**

Site Alternative 9 combines the benefits of a natural clay cover on the landfill top, of the type described under Site Alternative 4, with the improvements to the side slopes of Site Alternative 3.

The landfill top would be covered in accordance with the standards of OAC 3745-27-10, Closure of Sanitary Landfills. The landfill side slopes would be repaired where necessary to provide erosion protection, improve surface runoff, prevent ponding, and result in some reduction of infiltration.

The alternative would provide erosion protection of the side slopes. Preliminary slope stability calculations show the side slopes to be stable without accounting for the beneficial effects of the highly stable ecosystem on the slopes. Repairs to the side slopes, together with erosion control at areas that may be exposed to high river velocities, would further improve erosion protection.

Improvements to the landfill top, including addition of a drainage control berm around the perimeter, would be effective at reducing sheet runoff over the landfill side slopes that could cause erosion and infiltration.

There would be no reduction in toxicity, mobility, or volume. Potential infiltration is estimated to be 15.8 percent of precipitation compared to 9.8 percent for Site Alternative 4.

Implementation time is estimated at 8 months. Approximately 5,200 truckloads of clay for the landfill and riprap for erosion protection may be required to implement this site alternative, and this may have a short-term impact in the locality. This number is intermediate between Site Alternative 3 and Site Alternative 4.

Public health risks are the same as for Site Alternative 3, with the exception that placement of the cover over the landfill top would enclose much of the area of lead contamination above background.

This site alternative has a present worth of $3.4 million. Site Alternative 9, representing a combination of the benefits of a natural clay cover over the landfill top and improvements to the existing highly stable ecosystem on the slopes, is a cost-effective alternative that should continue to be protective of the public health and environment by continued control of significant releases to the environment.

5.2.3 Treatment Alternatives for Source Control that Would Eliminate the Need for Long-Term Management (including monitoring)

No alternatives.

5.2.4 Alternatives Involving Treatment as a Principal Element to Reduce the Toxicity, Mobility, or Volume of Site Waste.

No alternatives.

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TABLE 1

SUMMARY OF WASTE CATEGORIES REPORTED IN ECKHARDT SURVEY BY DUPONT AND PPG BOWERS LANDFILL - CIRCLEVILLE, OHIO

Generator	Composition of Waste
E.I. DuPont de Nemours & Company	Heavy metals and trace metals (bonded organically and inorganically) Arsenic, selenium, and antimony Iron, magnesium, and manganese Zinc, cadmium, copper, and chromium Organics Amides, amines, and imides Resins Elastomers Solvents, polar (except water) Halogenated aliphatics Acrylates and latex emulsions Solvents, halogenated aliphatic Oils and oil sludges Esters and ethers Alcohols Ketones and aldehydes Inorganics Salts Paints and pigments Asbestos
PPG Industries Incorporated	Organics Halogenated aliphatics Halogenated aromatics Acrylates and latex emulsions Amides, amines, and imides Plasticizers Resins Elastomers Solvents, polar (except water) Trichloroethylene Other solvents nonpolar Solvents, halogenated aliphatic Oils and soil sludges Esters and ethers Alcohols Inorganics Salts Mercaptans Wastes with flash point below 100°F

Source: Bowers Consent Order, 1985.

TABLE 2

GENERAL RESPONSE ACTIONS AND OBJECTIVES

Action	Objective
A. No action	Established baseline level for comparison.
B. Land use restrictions	Limits present and future use.
C. Containment	Isolates contaminants from environment.
D. Remove and treat	Removes contaminants for onsite or offsite treatment.
E. Treat in-situ	Onsite treatment without removal.
F. Dispose	Removes contaminants for onsite or offsite isolation or treatment by others.
G. Surface water controls	Controls natural water flows to support other measures.

TABLE 3

TECHNOLOGY SCREENING
BOWERS LANDFILL

	Landfill	Surface Soils	Ground Water	Comments
A. No Action	Yes	Yes	Yes	Must be fully evaluated per 40 CFR 300.68.
B. Land Use Restrictions				
• Restrict site access	Yes	Yes	NA	Will prevent direct contact with surface soils and landfill.
• Deed restrictions	Yes	Yes	Yes	Will prohibit future site development, excavation, installation of ground water wells.
• Zoning restrictions	NA	NA	NA	Not applicable since no evidence of contamination offsite.
C. Containment				
• Management of surface debris	Yes	NA	NA	Removal of surface waste is the first step to any landfill action.
• Capping				
-single layer cap				
-clay	Yes	NA	NA	Existing State of Ohio approved capping material for closure of sanitary landfills. Soils contamination is at or in the immediate vicinity of the landfill, and thus capping actions for the landfill would address the majority of these soils. Not practical to cap remaining soils due to the sparse distribution of contaminants.
-asphalt	No	NA	NA	May require substantial maintenance to ensure integrity. Freeze thaw fractures likely. Asphalt is a possible source of PAHs.
-concrete	No	NA	NA	May require substantial maintenance to ensure integrity. Freeze thaw fractures likely.
-multi-layer cap				
-synthetic membrane	Yes	NA	NA	Typically used for closure of hazardous waste landfill.
•Repairs to cover	Yes	NA	NA	Appropriate action to improve landfill cover to meet standards in effect at time of closure.
• Drains	Yes	NA	NA	Effective technique for leachate collection.
• Sumps	Yes	NA	NA	Effective technique for leachate collection.
• Monitoring	Yes	No	Yes	Effective at detecting migrating contaminants. Not feasible for surface soils due the sparse distribution, and relatively immobile nature, of contaminants.

TABLE 3

TECHNOLOGY SCREENING
BOWERS LANDFILL

	Landfill	Surface Soils	Ground Water	Comments
D. Remove and Treat				
• Excavation	No	Yes	NA	Excavation of landfill may involve significant worker exposure to contaminants. Excavation of soils is feasible.
• Wells	NA	NA	Yes	Effective technique for extraction of ground water from aquifer.
• Incinerate	No	No	No	Not effective for inorganics (eg lead). Not practical for contents of landfill because of lack of large scale incinerator capacity, long implementation time, large volume of non-combustibles, and large volume of ash. Ash and residuals may require additional treatment or disposal
• Biological methods	No	No	No	Inappropriate for landfill waste mix. Inorganic compounds in soils and ground water may be toxic to bacteria. Contaminant levels generally too low to maintain biological reaction.
• Physical methods				
-solvent extraction	NA	No	No	Not suitable for surface soils, landfill, and ground water due to low contaminant concentrations.
-chelation	NA	No	No	Usually an in-situ treatment for soils. Not suitable due to low contaminant levels. Not applicable to ground water.
-stabilization/solidification	No	Yes	NA	Appropriate for treating small volumes of contaminated soil. Not suitable for ground water.
-carbon adsorption	NA	NA	Yes	Applicable to fluid systems only. Removes organics.
• Chemical methods				
-precipitation	NA	NA	Yes	Applicable to aqueous systems only. Removes metals.
E. Treat In-Situ				
• Chelation	NA	No	NA	Requires intimate contact of contaminants and chelating agents. Due to low concentration of metals in soils, achieving this contact would be difficult. There is an uneven distribution of contaminants across the site, making chelating agent application impractical

TABLE 3

TECHNOLOGY SCREENING
BOWERS LANDFILL

	Landfill	Surface Soils	Ground Water	Comments
• Flushing	NA	No	No	A form of ion exchange. Metallic ions would be exchanged for ions of less harmful metals which would be applied to the soils as a salt solution through a sprinkler system. Metals would be flushed into ground water formation
• Vitrify	No	No	NA	Not practical for low contaminant levels in soil, unproven for landfill application.
• Gas venting	Yes	No	NA	Effective technique for managing future potential vapor production.
• Biological	No	No	No	Remediation time is very slow for landfill and soils. Unsuitable for ground water due to low contaminant levels.
• Solvent extraction	NA	No	No	Not practical for low contaminant levels present.
F. Dispose				
• Landfill	No	No	No	Placement of contaminated soils on landfill not allowed under State of Ohio solid waste regulations. Landfilling free liquids without treatment is prohibited. Space limitations make ground water disposal impractical.
• Discharge to Scioto River	NA	NA	Yes	Not applicable to solids. Ground water could be extracted from the aquifer and discharged to the Scioto River, following treatment.
• Offsite	NA	Yes	Yes	Soils may be excavated for offsite disposal, however it is EPA's policy to minimize the use of land disposal in accordance with the direction taken by Congress in amending RCRA. Ground water could be discharged to local POTW.
G. Surface Water Controls				
• Flood Protection	Yes	No	NA	Applicable on floodplain. Soils contamination is at or in the immediate vicinity of the landfill, and thus flood protection actions for the landfill would address the majority of these soils.
• Channels and waterways	Yes	No	NA	Controls surface water flow to assist other remedial technologies. May be appropriate to prevent surface water running onto landfill.

TABLE 4

LIST OF APPLICABLE REMEDIAL TECHNOLOGIES

General Response Action	Technology	Comments
1. Surface Soils		
A. No action	-	Must be fully evaluated per 40 CFR 300.68
B. Land use restrictions	Restrict site access	Will prevent contact with surface soils
	Deed restrictions	Will prohibit future site development or excavation
C. Containment	None	
D. Remove and treat	Excavation	Soils may be excavated for treatment or offsite disposal
	Stabilization/Solidification	Appropriate for treating small volumes of contaminated soils
E. Treat in-situ	None	
F. Dispose	Offsite	May be appropriate to small volumes
G. Surface water controls	None	
2. Landfill		
A. No action	-	Must be fully evaluated per 40 CFR 300.68
B. Land use restrictions	Restrict site access	Will prevent contact with exposed waste
	Deed restrictions	Will prohibit future excavation of landfill
C. Containment	Management of surface debris	Removal of surface waste is the first step in any landfill action
	Single layer clay cap	Existing State of Ohio approved capping material for closure of sanitary landfills
	Multilayer synthetic membrane cap	Normally implemented with multimedia gravel/soil cover
	Repairs to cover	Appropriate action to improve landfill cover to meet standards in effect at time of closure
	Drains	Effective technique for leachate collection

TABLE 4 (continued)

General Response Action	Technology	Comments
	Sumps	Effective technique for leachate collection
	Monitoring	Effective at detecting migrating contaminants
D. Remove and treat	None	
E. Treat in-situ	Gas venting	Effective technique for managing future potential gas production
F. Dispose	None	
G. Surface water controls	Flood protection Channels and waterways	Applicable on floodplain Control surface water flow to assist other remedial technologies. May be appropriate to prevent runon
3. Ground Water		
A. No action		Must be fully evaluated per 40 CFR 300.68
B. Land use restrictions	Deed restrictions	Will prohibit installation of ground water wells
C. Containment	Monitoring	Effective at detecting migrating contaminants
D. Remove and treat	Wells	Feasible technique for ground water extraction
	Carbon adsorption	Removes organics
	Precipitation	Removes metals
E. Treat in-situ	None	
F. Dispose	Discharge to Scioto River Offsite	Feasible technology Ground water could be discharged to a local POTW
G. Surface water controls	None	

TABLE 5

LIST OF POTENTIAL FEDERAL ACTION-SPECIFIC ARARs FOR REMEDIAL ALTERNATIVES

1. **20 CFR 1910.120 Hazardous Waste Operations and Emergency Response**

   Occupational Safety and Health Administration (OSHA) regulations applicable to employee health and safety during hazardous waste site operations

   Alternatives: Applicable to all alternatives except no action alternatives.

2. **40 CFR 122 National Pollutant Discharge Elimination System**

   Requirements for discharge of pollutants from any point source into surface waters of the United States

   Alternatives: May be applicable to soils treatment by stabilization/solidification and any significant earthmoving operations with need for erosion and sedimentation control.

3. **40 CFR 125 Criteria and Standards for the National Pollutant Discharge Elimination System**

   Establishes criteria and standards for determining technology-based treatment requirements and effluent limitations for discharge of pollutants to surface waters

   Alternatives: Applicable to discharges related to soils treatment by stabilization/solidification and any significant earthmoving operations with need for erosion and sedimentation control.

4. **40 CFR 264 Subpart F Releases from Solid Waste Management Units**

   Contains ground water protection and ground water monitoring requirements for solid waste management units permitted under RCRA

   Alternatives: May be appropriate for soil excavation and treatment by stabilization/solidification. May be appropriate to all alternatives for landfill.

5. **40 CFR 264 Subpart G Closure and Post-Closure**

   Includes technical performance standards for closure of RCRA-regulated hazardous waste management facilities; also includes requirements for care of facilities after closure

   Alternatives: May be appropriate for all alternatives for landfill.

6. **40 CFR 264 Subpart H Financial Requirements**

   Identifies financial requirements to be met by owners and operators who close RCRA-regulated hazardous waste management facilities

   Alternatives: May be appropriate for soil treatment and alternatives for landfill.

7. **40 CFR 264 Subpart L Waste Piles**

Identifies design, operating, closure, and post-closure requirements for storage of hazardous waste in piles.

Alternative: May be relevant to soil excavation and removal to offsite landfill and to soil treatment.

8. **40 CFR 264 Subpart N Landfills**

Identifies design, operating, closure, and post-closure requirements for hazardous waste landfills permitted under RCRA.

Alternatives: May be relevant to alternatives for landfill.

8. **40 CFR 403 General Pretreatment Regulations for Existing and New Sources of Pollution**

Identifies treatment requirements for liquid waste streams before these streams can be discharged to a publicly owned treatment works (POTW)

Alternatives: May be relevant to landfill leachate offsite treatment or disposal.

9. **40 CFR 761 Subpart G Polychlorinated Biphenyls (PCB) Spill Cleanup Policy**

Describes cleanup standards for spills of PCBs and PCB-contaminated materials in restricted access and non-restricted access areas.

Alternatives: May be relevant to alternatives for soil excavation and removal and to soils treatment by stabilization/solidification.

TABLE 6

LIST OF POTENTIAL STATE ARARs FOR REMEDIAL ALTERNATIVES

Alternative	Citation*	Comment
SURFACE SOILS		
•No Action	N/A	
•Deed and Site Restrictions	N/A	
•Excavate and Treat by Immobilization	3745-50 to -69	These regulations govern the identification, handling, and disposal of hazardous waste (if the soils are a hazardous waste).
	3745-27	Placement on the Bowers Landfill of the solidified soil for purpose of disposal is not allowed under state solid waste regulations.
•Excavate Surface Soils and Dispose of Offsite	3745-50 to -69	These regulations govern the identification, handling, and disposal of hazardous waste (if the soils are a hazardous waste).
	43745-27	These regulations govern the identification, handling, and disposal of solid waste (if the soils are a solid waste).
LANDFILL		
•No Action	N/A	
•Deed and Site Restrictions	N/A	
•Landfill capping actions	3745-55	Closure and Post-Closure Requirements for a hazardous waste facility.
	3745-27-10	Closure of sanitary landfills.
	3745-54-92 to -97	Ground water protection standards for a hazardous waste facility.
	3734.041 ORC	Gas monitoring is required for a sanitary landfill if a residence or other occupied structure is located within 1,000 feet of the exterior boundary of the landfill.

TABLE 6 (continued)

Alternative	Citation*	Comment
GROUND WATER		
•No Action	N/A	
•Deed Restriction	N/A	
•Pump and Treat; Discharge to River	3754-50 to 3745-69	These regulations govern the identification, handling and disposal of hazardous wastes (if the sludge and spent activated carbon are a hazardous waste).
	3745-27	These regulations govern the identification, handling and disposal of solid waste (if the sludge and spent activated carbon are a solid waste).
	3745-31-05(A)(3)	Treatment of ground water before discharge must employ best available technology.
	3745-33-04(B)(1)(a) (i) through (v)	Authorized Discharge Levels - Final Limitations.
	3745-1-09	Scioto River Water Quality Standards (warm water habitat; agricultural and industrial usage, primary contact).
	3745-54-92 to 54-97	Ground water protection standards for a hazardous waste facility.
Pump and Discharge to POTW	3745-3-04	Industrial discharges to a publicly owned treatment works (Pretreatment Rules).
	3745-54-92 to 54-97	Ground water protection standards for a hazardous waste facility.

* Unless otherwise indicated, citations are from the Ohio Administrative Code (OAC).

TABLE 7

INDICATOR CHEMICALS CONCENTRATIONS IN SITE MEDIA
(Note 1)

INDICATOR CHEMICAL	SITE MEDIUM		MAXIMUM CONCENTRATION (mg/kg)	GEOMETRIC MEAN CONCENTRATION (mg/kg) (Note 2)
Barium	Ground water	(Note 3)	2.070	0.330
	Scioto River	(Note 4)	0.060	0.054
	Drainage ditch		0.199	0.101
	River sediment	(Note 5)	312	106
	Ditch sediment		227	128
	Surface soils	(Note 6)	279	189
Lead	Ground water	(Note 3)	0.007	0.001
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		0.009	0.001
	River sediment	(Note 5)	39	34
	Ditch sediment		104	39
	Surface soils	(Note 6)	179	78
Mercury	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	0.0002	0.00013
	Drainage ditch		0.00027	0.00012
	River sediment	(Note 5)	0.590	0.480
	Ditch sediment		1.400	0.140
	Surface soils	(Note 6)	0.430	0.270
Benzene	Ground water	(Note 3)	0.006	0.001
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	ND	ND
	Ditch sediment		ND	ND
	Surface soils	(Note 6)	ND	ND
Chlordane	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	0.200	0.067
	Ditch sediment		0.140	0.055
	Surface soils	(Note 6)	0.210	0.015

TABLE 7 (cont.)

INDICATOR CHEMICAL	SITE MEDIUM		MAXIMUM CONCENTRATION (mg/kg)	GEOMETRIC MEAN CONCENTRATION (mg/kg) (Note 2)
4-methyl phenol	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	8.600	0.036
	Ditch sediment		8.100	0.091
	Surface soils	(Note 6)	ND	ND
PCBs	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		0.003	0.001
	River sediment	(Note 5)	ND	ND
	Ditch sediment		2.300	0.105
	Surface soils	(Note 6)	3.600	0.238
PAHs	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	5.580	1.305
	Ditch sediment		2.872	0.457
	Surface soils	(Note 6)	25.960	0.667
Tetrachloroethene	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	0.001	0.001
	Drainage ditch		ND	ND
	River sediment	(Note 5)	ND	ND
	Ditch sediment		ND	ND
	Surface soils	(Note 6)	ND	ND

ND -- contaminant was not detected in medium

Note 1 Source: Tables 3-3, 3-6, 3-7, 3-9 from EA

Note 2 From EA

Note 3 Presents data from wells downgradient of landfill

Note 4 Presents data from locations downstream of landfill

Note 5 Presents data from locations downstream of landfill

Note 6 Presents data from locations on or adjacent to the landfill

LEGEND FOR TABLES 8 THROUGH 15

LS	Lump Sum
LF	Linear Feet
EA	Each
CY	Cubic Yard
FT	Feet
GAL	Gallons
SF	Square Feet

TABLE 8

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 2

- Ground Water Monitoring
- Deed and Site Restrictions

Description		Unit Cost		Quantity	Cost($)
I Capital Cost					
Ground Water Monitoring		0		0	0
Deed Restrictions-Legal Fees		15,000	LS	1	**15,000**
Site Restrictions					
Industrial chain link fence		10.30	/LF	7,500	77,300
Bracing for fence along river		27	EA	450	12,200
Corner posts		75	EA	10	800
30' wide (pair) swinging gate		3,150	EA	1	3,200
Subtotal (fencing costs)					**93,500**
Subtotal					**108,500**
	Engineering	15%			16,300
	Miscellaneous	10%			10,900
	Contingency	25%			27,100
	Inspection	10%			10,900
Total Capital Cost					**173,700**
II Operating Cost					
Ground Water Monitoring					
Labor for collecting ground water samples		2,000	/Visit	2	4,000
Analyses of ground water samples		1,700	/Well	8	13,600
General Maintenance					
Fence maintenance		5%	capital	93,500	4,700
Subtotal					**22,300**
	Miscellaneous	20%			4,500
	Contingency	20%			4,500
Annual Operating Cost					**31,300**
Present Worth Operating Cost		**30**	**Years**	**@10%**	**295,100**
III Present Worth of Site Alternative 2					
Capital Cost					173,700
Operating Cost					295,100
Total Present Worth					**468,800**

TABLE 9

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 3

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Local Repair of Existing Landfill Cover**
- **Erosion Control & Drainage Improvements**

Description	Unit Cost		Quantity	Cost($)
I Capital Cost				
Ground Water Monitoring	0		0	**0**
Deed Restrictions-Legal Fees	15,000	LS	1	**15,000**
Site Restrictions				
Industrial chain link fence	10.30	/LF	7,500	77,300
Bracing for fence along river	27	EA	450	12,200
Corner posts	75	EA	10	800
30' wide (pair) swinging gate	3150	EA	1	3,200
Subtotal (fencing costs)				**93,500**
Management of Surface Debris				
Clear trees & brush	2,000	/acre	3	6,000
Clear drums,appliances,plastic,etc.	5,000	LS	1	5,000
Subtotal (surface improvements)				**11,000**
Drainage Improvements				
Grading of landfill	3	/cy	2,200	6,600
65 x 100' culvert intake apron	150	/cy	120.4	18,100
Culvert headwall	1,800	LS	1	1,800
48" tunnel excavation for pipe	400	/ft	200	80,000
Remediation of boring pits	250	/cy	93	23,300
36" CMP drainage discharge pipe	58	/ft	200	11,600
36" diameter discharge check valve	11,000	LS	1	11,000
Subtotal (drainage improvements)				**152,400**
Side Slope Improvements				
Reduce water level in east ditch	540	/day	60	32,400
Construction of temporary access road	9	/cy	1400	12,600
Place random fill to repair side slopes	12	/cy	2000	24,000
Reconstruct slopes and provide stabilization	40	/cy	200	8,000
Subtotal (Side Slope Improvements)				**77,000**
Repair & Seeding of Landfill Cover				
Repair of existing cover	3	/cy	9,550	28,700
Mulch,fertilize, & seed	2,500	/acre	3	7,500
Subtotal (repairs to landfill cover)				**36,200**
Erosion Control on Landfill				
Sheet piling at landfill ends	271.3	/ft	1,500	407,000
Riprap on landfill	40	/cy	2,500	100,000
Subtotal (erosion control)				**507,000**
Subtotal				**892,100**
Engineering	15%			133,800
Miscellaneous	10%			89,200
Contingency	25%			223,000
Inspection	10%			89,200
Total Capital Cost				**1,427,300**
II Operating Cost				
Ground Water Monitoring				

TABLE 9

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 3

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Local Repair of Existing Landfill Cover**
- **Erosion Control & Drainage Improvements**

Description	Unit Cost		Quantity	Cost($)
Labor for collecting ground water samples	2,000	/Visit	2	4,000
Analyses of ground water samples	1,700	/Well	8	13,600
General Maintenance				
Fence maintenance	5%	capital	93,500	4,700
Erosion and drainage maintenance	5%	capital	659,400	33,000
Landfill maintenance	2.5%	capital	36,200	900
Subtotal				**56,200**
Miscellaneous	20%			11,200
Contingency	20%			11,200
Annual Operating Cost				**78,600**
Present Worth Operating Cost	**30**	**Years**	**@10%**	**741,000**
III Present Worth of Site Alternative 3				
Capital Cost				1,427,300
Operating Cost				741,000
Total Present Worth				**2,168,300**

TABLE 10

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 4

- •Ground Water Monitoring
- •Deed and Site Restrictions
- •Management of Surface Debris
- •Erosion Control & Drainage Improvements
- •Local Repairs To Existing Landfill Sides
- •Natural Clay Cover Over Landfill

Description	Unit Cost		Quantity	Cost($)
I Capital Cost				
Ground Water Monitoring	0		0	0
Deed Restrictions-Legal Fees	15,000	LS	1	**15,000**
Site Restrictions				
Industrial chain link fence	10.30	/LF	7,500	77,300
Bracing for fence along river	27	EA	450	12,200
Corner posts	75	EA	10	800
30' wide (pair) swinging gate	3,150	EA	1	3,200
Subtotal (fencing costs)				**93,500**
Management of Surface Debris				
Clear trees and brush	2,000	/acre	14	28,000
Clear drums, appliances, plastic, etc.	5,000	LS	1	5,000
Subtotal (surface improvements)				**33,000**
Drainage Improvements				
Grading of landfill	3	/cy	2,200	6,600
65 x 100' culvert intake apron	150	/cy	120.4	18,100
Culvert headwall	1,800	LS	1	1,800
48" tunnel excavation for pipe	400	/ft	200	80,000
Remediation of boring pits	250	/cy	93	23,300
36" CMP drainage discharge pipe	58	/ft	200	11,600
36" diameter discharge check valve	11,000	LS	1	11,000
Subtotal (drainage improvements)				**152,400**
Side Slope Improvements				
Reduce water level in east ditch	540	/day	60	32,400
Construction of temporary access road	9	/cy	1400	12,600
Place random fill to repair side slopes	12	/cy	2000	24,000
Reconstruct slopes and provide stabilization	40	/cy	200	8,000
Subtotal (Side Slope Improvements)				**77,000**
Construction of natural clay cover over landfill				
Regrading of existing cover	3	/cy	3,400	10,200
Clay cover, 24" thick	12	/cy	52,000	624,000
Topsoil vegetative layer	8	/cy	54,500	436,000
Mulch, fertilize, & seed	2500	/acre	14	35,000
Subtotal (clay cover)				**1,105,200**
Erosion control on landfill				
Sheet piling at landfill ends	271.3	/ft	1,500	407,000
Riprap on landfill	40	/cy	2,500	100,000
Subtotal (erosion control)				**507,000**
Subtotal				**1,983,100**
Engineering	15%			297,500
Miscellaneous	10%			198,300
Contingency	25%			495,800
Inspection	10%			198,300
Total Capital Cost				**3,173,000**

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 4

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control & Drainage Improvements**
- **Local Repairs To Existing Landfill Sides**
- **Natural Clay Cover Over Landfill**

Description	Unit Cost		Quantity	Cost($)
II Operating Cost				
Ground Water Monitoring				
Labor for collecting ground water samples	2,000	/Visit	2	4,000
Analyses of ground water samples	1,700	/Well	8	13,600
General Maintenance				
Fence maintenance	5%	capital	93,500	4,700
Erosion and drainage maintenance	5%	capital	659,400	33,000
Landfill maintenance	2.5%	capital	1,105,200	27,600
Subtotal				**82,900**
Miscellaneous	20%			16,600
Contingency	20%			16,600
Annual Operating Cost				**116,100**
Present Worth Operating Cost	**30**	**Years**	**@10%**	**1,094,500**
III Present Worth of Site Alternative 4				
Capital Cost				3,173,000
Operating Cost				1,094,500
Total Present Worth				**4,267,500**

TABLE 11

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 5

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control and Drainage Improvements**
- **Natural Clay Cover Over Landfill**
- **Gas Venting System**
- **Leachate Collection System**

Description	Unit Cost		Quantity	Cost($)
I Capital Cost				
Ground Water Monitoring	0		0	**0**
Deed Restrictions-Legal Fees	15,000	LS	1	**15,000**
Site Restrictions				
Industrial chain link fence	10.30	/LF	7,500	77,300
Bracing for fence along river	27	EA	450	12,200
Corner posts	75	EA	10	800
30' wide (pair) swinging gate	3150	EA	1	3,200
Subtotal (fencing costs)				**93,500**
Management of Surface Debris				
Clear trees & brush	2,000	/acre	14	28,000
Clear drums, appliances, plastic, etc.	5,000	LS	1	5,000
Subtotal (surface improvements)				**33,000**
Drainage Improvements				
Grading of landfill	3	/cy	2,200	6,600
65 x 100' culvert intake apron	150	/cy	120.4	18,100
Culvert headwall	1,800	LS	1	1,800
48" tunnel excavation for pipe	400	/ft	200	80,000
Remediation of boring pits	250	/cy	93	23,300
36" CMP drainage discharge pipe	58	/ft	200	11,600
36" diameter discharge check valve	11,000	LS	1	11,000
Subtotal (drainage improvements)				**152,400**
Side Slope Improvements				
Reduce water level in east ditch	540	/day	60	32,400
Construction of temporary access road	9	/cy	1400	12,600
Place random fill to repair side slopes	12	/cy	2000	24,000
Reconstruct slopes and provide stabilization	40	/cy	200	8,000
Subtotal (Side Slope Improvements)				**77,000**
Erosion Control on Landfill				
Sheet piling at landfill ends	271.3	/ft	1,500	407,000
Riprap on landfill	40	/cy	2,500	100,000
Subtotal (erosion control)				**507,000**
Construction of Natural Clay Cover over Landfill				
Regrade existing surface	3	/cy	3,400	10,200
Coarse gravel collection layer	20	/cy	25,000	500,000
Gas vent piping	3	/ft	7,000	21,000
Leachate collection trench	0.45	/ft	8,500	3,800
Granular material in leachate trench	20	/cy	630	12,600
Leachate collection piping	2	/ft	8,500	17,000
Leachate pump & tank	5,000	LS	1	5,000
Geo-fabric between gravel & clay	0.25	/sf	683,000	170,800
Clay cover, 24" thick	12	/cy	52,000	624,000
Topsoil vegetative layer	8	/cy	54,500	436,000
Mulch, fertilize, & seed	2,500	/acre	14	35,000
Subtotal (clay cover)				**1,835,400**
Subtotal				**2,713,300**
Engineering	15%			407,000

TABLE 11

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 5

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control and Drainage Improvements**
- **Natural Clay Cover Over Landfill**
- **Gas Venting System**
- **Leachate Collection System**

Description	Unit Cost		Quantity	Cost($)
Miscellaneous	10%			271,300
Contingency	25%			678,300
Inspection.	10%			271,300
Total Capital Cost				**4,341,200**
II Operating Cost				
Ground Water Monitoring				
Labor for collecting ground water samples	2,000	/Visit	2	4,000
Analyses on ground water samples	1,700	/Well	8	13,600
General Maintenance				
Fence maintenance	5%	capital	93,500	4,700
Erosion and drainage maintenance	5%	capital	659,400	33,000
Landfill maintenance	2.5%	capital	1,835,400	45,900
Leachate collection and disposal				
Truck rental	20,400	/Year	1	20,400
Labor	20,000	/Year	1	20,000
Transportation to discharge point	2.00	/Load	264	500
Discharge fee	2.54	/Load	264	700
Treatment costs at POTW	0.0281	/Gal	1,320,000	37,100
Subtotal				**179,900**
Miscellaneous	20%			36,000
Contingency	20%			36,000
Annual Operating Cost				**251,900**
Present Worth Operating Cost	**30**	**Years**	**@10%**	**2,374,600**
III Present Worth of Site Alternative 5				
Capital Cost				4,341,200
Operating Cost				2,374,600
Total Present Worth				**6,715,800**

TABLE 12

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 6

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Natural Clay Cover Over Landfill**
- **Gas Venting System**
- **Leachate Collection System**
- **Flood Protection Dike**

Description	Unit Cost		Quantity	Cost($)
I Capital Cost				
Ground Water Monitoring	0		0	**0**
Deed Restrictions-Legal Fees	15,000	LS	1	**15,000**
Site Restrictions				
Industrial chain link fence	10.30	/LF	7,500	77,300
Bracing for fence along river	27	EA	450	12,200
Corner posts	75	EA	10	800
30' wide (pair) swinging gate	3,150	EA	1	3,200
Subtotal (fencing costs)				**93,500**
Management of Surface Debris				
Clear trees & brush	2,000	/acre	14	28,000
Clear drums, appliances, plastic, etc.	5,000	LS	1	5,000
Subtotal (surface improvements)				**33,000**
Drainage Improvements				
Grading of landfill	3	/cy	2,200	6,600
65 x 100' culvert intake apron	150	/cy	120.4	18,100
Culvert headwall	1,800	LS	1	1,800
48" tunnel excavation for pipe	400	/ft	200	80,000
Remediation of boring pits	250	/cy	93	23,300
36" CMP drainage discharge pipe	58	/ft	200	11,600
36" diameter discharge check valve	11,000	LS	1	11,000
Subtotal (drainage improvements)				**152,400**
Side Slope Improvements				
Reduce water level in east ditch	540	/day	60	32,400
Construction of temporary access road	9	/cy	1400	12,600
Place random fill to repair side slopes	12	/cy	2000	24,000
Reconstruct slopes and provide stabilization	40	/cy	200	8,000
Subtotal (Side Slope Improvements)				**77,000**
Construction of Natural Clay Cover over Landfill				
Regrade existing surface	3	/cy	3,400	10,200
Coarse gravel collection layer	20	/cy	25,000	500,000
Gas vent piping	3	/ft	7,000	21,000
Leachate collection trench	0.45	/ft	8,500	3,800
Granular material in leachate trench	20	/cy	630	12,600
Leachate collection piping	2	/ft	8,500	17,000
Leachate pump & tank	5,000	LS	1	5,000
Geo-fabric between gravel & clay	0.25	/sf	683,000	170,800
Clay cover, 24" thick	12	/cy	52,000	624,000
Topsoil vegetative layer	8	/cy	54,500	436,000
Mulch, fertilize, & seed	2,500	/acre	14	35,000
Subtotal (clay cover)				**1,835,400**
Construction of Flood Protection Dike				
Excavate & place clay core	12	/cy	93,133	1,117,600
Borrow material	8	/cy	82,867	662,900

TABLE 12

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 6

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Natural Clay Cover Over Landfill**
- **Gas Venting System**
- **Leachate Collection System**
- **Flood Protection Dike**

Description	Unit Cost		Quantity	Cost($)
Excavate for dike core	4.20	/cy	2,933	12,300
Piling	17.15	/ft	3,120	53,500
Tie rods & channel irons	1,400	EA	272	380,800
Rock fill material	20	/cy	38,333	766,700
Stormwater discharge stations (Pre-fab)	50,000	EA	2	100,000
Subtotal (flood dike capital costs)				**3,093,800**
Construction of Concrete Flood Protection Wall				
Excavate for concrete wall continuous footing	4.20	/cy	780	3,300
Forms, rebar, concrete in continuous footing	21.45	/ft	1,400	30,000
Forms, rebar, concrete for flood wall	250	/ft	1,400	350,000
Backfill concrete flood wall	1.42	/cy	380	500
Subtotal (flood wall capital costs)				**383,800**
Subtotal				**5,683,900**
Engineering	15%			852,600
Miscellaneous	10%			568,400
Contingency	25%			1,421,000
Inspection	10%			568,400
Total Capital Cost				**9,094,300**
II Operating Cost				
Ground Water Monitoring				
Labor for collecting ground water samples	2,000	/Visit	2	4,000
Analyses on ground water samples	1,700	/Wells	8	13,600
General Maintenance				
Fence maintenance	5%	capital	93,500	4,700
Flood dike maintenance	2.5%	capital	3,093,800	77,300
Landfill maintenance	2.5%	capital	1,835,400	45,900
Drainage maintenance	5%	capital	152,400	7,600
Leachate collection and disposal				
Truck rental	20,400	/Year	1	20,400
Labor	20,000	/Year	1	20,000
Transportation to discharge point	2.00	/Load	264	500
Discharge fee	2.54	/Load	264	700
Treatment costs at POTW	0.0281	/Gal	1,320,000	37,100
Subtotal				**231,800**
Miscellaneous	20%			46,400
Contingency	20%			46,400
Annual Operating Cost				**324,600**
Present Worth Operating Cost	**30**	**Years**	**@10%**	**3,060,000**
III Present Worth of Site Alternative 6				
Capital Cost				9,094,300

TABLE 12

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 6

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Natural Clay Cover Over Landfill**
- **Gas Venting System**
- **Leachate Collection System**
- **Flood Protection Dike**

Description	Unit Cost	Quantity	Cost($)
Operating Cost			3,060,000
Total Present Worth			**12,154,300**

TABLE 13

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 7

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Flood Protection Dike**
- **Gas Venting System**
- **Leachate Collection System**
- **Synthetic Membrane Cap over Landfill**

Description			Quantity	Cost($)
I Capital Cost				
Ground Water Monitoring	0		0	**0**
Deed Restrictions-Legal Fees	15,000	LS	1	**15,000**
Site Restrictions				
Industrial chain link fence	10.30	/LF	7,500	77,300
Bracing for fence along river	27	EA	450	12,200
Corner posts	75	EA	10	800
30' wide (pair) swinging gate	3,150	EA	1	3,200
Subtotal (fencing costs)				**93,500**
Management of Surface Debris				
Clear trees & brush	2,000	/acre	14	28,000
Clear drums, appliances,plastic, etc.	5,000	LS	1	5,000
Subtotal (surface improvements)				**33,000**
Drainage Improvements				
Grading of landfill	3	/cy	2,200	6,600
65 x 100' culvert intake apron	150	/cy	120.4	18,100
Culvert headwall	1,800	LS	1	1,800
48" tunnel excavation for pipe	400	/ft	200	80,000
Remediation of boring pits	250	/cy	93	23,300
36" CMP drainage discharge pipe	58	/ft	200	11,600
36" diameter discharge check valve	11,000	LS	1	11,000
Subtotal (drainage improvements)				**152,400**
Side Slope Improvements				
Reduce water level in east ditch	540	/day	60	32,400
Construction of temporary access road	9	/cy	1400	12,600
Place random fill to repair side slopes	12	/cy	2000	24,000
Reconstruct slopes and provide stabilization	40	/cy	200	8,000
Subtotal (Side Slope Improvements)				**77,000**
Construction of Flood Protection Dike				
Excavate & place clay core	12	/cy	93,133	1,117,600
Excavate and place random fill	8	/cy	82,867	662,900
Excavate for dike core	4.20	/cy	2,933	12,300
Piling	17.15	/ft	3,120	53,500
Tie rods & channel irons	1,400	EA	272	380,800
Rock fill material	20	/cy	38,333	766,700
Stormwater discharge stations (pre-fab)	50,000	EA	2	100,000
Subtotal (flood dike capital costs)				**3,093,800**
Construction of Concrete Flood Protection Wall				
Excavate for concrete wall continuous footing	4.20	/cy	780	3,300
Forms, rebar, concrete in continuous footing	21.45	/ft	1,400	30,000
Forms, rebar, concrete for flood wall	250	/ft	1,400	350,000
Backfill concrete flood wall	1.42	/cy	380	500
Subtotal (flood wall capital costs)				**383,800**
Construct Synthetic Membrane Cap over Landfill with Gas Venting & Leachate Collection Systems				
Regrade existing landfill	3	/cy	3,400	10,200
Coarse gravel collection layer	20	/cy	25,000	500,000

TABLE 13

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 7

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Flood Protection Dike**
- **Gas Venting System**
- **Leachate Collection System**
- **Synthetic Membrane Cap over Landfill**

Description			Quantity	Cost($)
Gas vent piping	3	/ft	7,000	21,000
Leachate collection trench	0.45	/ft	8,500	3,800
Granular material in leachate trench	20	/cy	630	12,600
Leachate collection piping	2	/ft	8,500	17,000
Leachate pump & tank	5,000	LS	1	5,000
Geo-fabric between gravel & clay	0.25	/sf	683,000	170,800
Clay cover, 24" thick	12	/cy	52,000	624,000
20-mil synthetic liner	1	/sf	683,000	683,000
Drainage layer	20	/cy	25,000	500,000
Topsoil vegetative layer	8	/cy	54,500	436,000
Mulch, fertilize, & seed	2,500	/acre	12.6	31,500
Subtotal (synthetic membrane cap costs)				**3,014,900**
Subtotal				**6,479,600**
Engineering	15%			971,900
Miscellaneous	10%			648,000
Contingency	25%			1,619,900
Inspection	10%			648,000
Total Capital Cost				**10,367,400**
II Operating Cost				
Ground Water Monitoring				
Labor for collecting ground water samples	2,000	/Visit	2	4,000
Analyses on ground water samples	1,700	/Well	8	13,600
General Maintenance				
Fence maintenance	5%	capital	93,500	4,700
Flood dike maintenance	2.5%	capital	3,093,800	77,300
Drainage maintenance	5%	capital	152,400	7,600
Landfill maintenance	2.5%	capital	3,014,900	75,400
Leachate collection and disposal				
Truck rental	20,400	/Year	1	20,400
Labor	20,000	/Year	1	20,000
Transportation to discharge point	2.00	/Load	264	500
Discharge fee	2.54	/Load	264	700
Treatment costs at POTW	0.0281	/Gal	1,320,000	37,100
Subtotal				**261,300**
Miscellaneous	20%			52,300
Contingency	20%			52,300
Annual Operating Cost				**365,900**
Present Worth Operating Cost	**30**	**Years**	**@10%**	**3,449,300**

III Present Worth of Site Alternative 7

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 7

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Flood Protection Dike**
- **Gas Venting System**
- **Leachate Collection System**
- **Synthetic Membrane Cap over Landfill**

Description	Quantity	Cost($)
Capital Cost		10,367,400
Operating Cost		3,449,300
Total Present Worth		**13,816,700**

TABLE 14

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 8

- •Ground Water Monitoring
- •Deed and Site Restrictions
- •Management of Surface Debris
- •Erosion Control And Drainage Improvements
- •Gas Venting System
- •Leachate Collection System
- •Synthetic Membrane Cap over Landfill

Description			Quantity	Cost($)
I Capital Cost				
Ground Water Monitoring	0		0	0
Deed Restrictions-Legal Fees	15,000	LS	1	**15,000**
Site Restrictions				
Industrial chain link fence	10.30	/LF	7,500	77,300
Bracing for fence along river	27	EA	450	12,200
Corner posts	75	EA	10	800
30' wide (pair) swinging gate	3,150	EA	1	3,200
Subtotal (fencing costs)				**93,500**
Management of Surface Debris				
Clear trees & brush	2,000	/acre	14	28,000
Clear drums, appliances,plastic, etc.	5,000	LS	1	5,000
Subtotal (surface improvements)				**33,000**
Drainage Improvements				
Grading of landfill	3	/cy	2,200	6,600
65 x 100' culvert intake apron	150	/cy	120.4	18,100
Culvert headwall	1,800	LS	1	1,800
48" tunnel excavation for pipe	400	/ft	200	80,000
Remediation of boring pits	250	/cy	93	23,300
36" CMP drainage discharge pipe	58	/ft	200	11,600
36" diameter discharge check valve	11,000	LS	1	11,000
Subtotal (drainage improvements)				**152,400**
Side Slope Improvements				
Reduce water level in east ditch	540	/day	60	32,400
Construction of temporary access road	9	/cy	1400	12,600
Place random fill to repair side slopes	12	/cy	2000	24,000
Reconstruct slopes and provide stabilization	40	/cy	200	8,000
Subtotal (Side Slope Improvements)				**77,000**
Erosion Control on Landfill				
Sheet piling at landfill ends	271.3	/ft	1500	407,000
Riprap on landfill	40	/cy	2500	100,000
Subtotal (erosion control)				**507,000**
Construct Synthetic Membrane Cap over Landfill with Gas Venting & Leachate Collection Systems				
Regrade existing landfill	3	/cy	3,400	10,200
Coarse gravel collection layer	20	/cy	25,000	500,000
Gas vent piping	3	/ft	7,000	21,000
Leachate collection trench	0.45	/ft	8,500	3,800
Granular material in leachate trench	20	/cy	630	12,600
Leachate collection piping	2	/ft	8,500	17,000
Leachate pump & tank	5,000	LS	1	5,000
Geo-fabric between gravel & clay	0.25	/sf	683,000	170,800
Clay cover, 24" thick	12	/cy	52,000	624,000
20-mil synthetic liner	1	/sf	683,000	683,000
Drainage layer	20	/cy	25,000	500,000
Topsoil vegetative layer	8	/cy	54,500	436,000
Mulch, fertilize, & seed	2,500	/acre	12.6	31,500
Subtotal (synthetic membrane cap costs)				**3,014,900**

TABLE 14

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 8

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control And Drainage Improvements**
- **Gas Venting System**
- **Leachate Collection System**
- **Synthetic Membrane Cap over Landfill**

Description				Quantity	Cost($)
Subtotal					**3,892,800**
	Engineering	15%			583,900
	Miscellaneous	10%			389,300
	Contingency	25%			973,200
	Inspection	10%			389,300
Total Capital Cost					**6,228,500**
II Operating Cost					
Ground Water Monitoring					
Labor for collecting ground water samples		2,000	/Visit	2	4,000
Analyses on ground water samples		1,700	/Well	8	13,600
General Maintenance					
Fence maintenance		5%	capital	93,500	4,700
Erosion and drainage maintenance		5%	capital	659,400	33,000
Landfill maintenance		2.5%	capital	3,014,900	75,400
Leachate collection and disposal					
Truck rental		20,400	/Year	1	20,400
Labor		20,000	/Year	1	20,000
Transportation to discharge point		2.00	/Load	264	500
Discharge fee		2.54	/Load	264	700
Treatment costs at POTW		0.0281	/Gal	1,320,000	37,100
Subtotal					**176,400**
	Miscellaneous	20%			35,300
	Contingency	20%			35,300
Annual Operating Cost					**247,000**
Present Worth Operating Cost		**30**	**Years**	**@10%**	**2,328,400**
III Present Worth of Site Alternative 8					
Capital Cost					6,228,500
Operating Cost					2,328,400
Total Present Worth					**8,556,900**

TABLE 15

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 9

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control & Drainage Improvements**
- **Improvements To Landfill Side Slopes**
- **Natural Clay Cover Over Landfill Top**

Description	Unit Cost		Quantity	Cost($)
I Capital Cost				
Ground Water Monitoring	0		0	**0**
Deed Restrictions-Legal Fees	15,000	LS	1	**15,000**
Site Restrictions				
Industrial chain link fence	10.30	/LF	7,500	77,300
Bracing for fence along river	27	EA	450	12,200
Corner posts	75	EA	10	800
30' wide (pair) swinging gate	3,150	EA	1	3,200
Subtotal (fencing costs)				**93,500**
Management of Surface Debris				
Clear trees and brush	2,000	/acre	8.6	17,200
Clear drums, appliances, plastic, etc.	5,000	LS	1	5,000
Subtotal (surface improvements)				**22,200**
Drainage Improvements				
Grading of landfill	3	/cy	2,200	6,600
65 x 100' culvert intake apron	150	/cy	120.4	18,100
Culvert headwall	1,800	LS	1	1,800
48" tunnel excavation for pipe	400	/ft	200	80,000
Remediation of boring pits	250	/cy	93	23,300
36" CMP drainage discharge pipe	58	/ft	200	11,600
36" diameter discharge check valve	11,000	LS	1	11,000
Subtotal (drainage improvements)				**152,400**
Side Slope Improvements				
Reduce water level in east ditch	540	/day	60	32,400
Construction of temporary access road	9	/cy	1400	12,600
Place random fill to repair side slopes	12	/cy	2000	24,000
Reconstruct slopes and provide stabilization	40	/cy	200	8,000
Subtotal (Side Slope Improvements)				**77,000**
Construction of natural clay cover over landfill				
Regrading of existing cover	3	/cy	2,100	6,300
Clay cover, 24" thick	12	/cy	32,240	386,900
Topsoil vegetative layer	8	/cy	33,800	270,400
Mulch, fertilize, & seed	2500	/acre	8.6	21,500
Subtotal (clay cover)				**685,100**
Erosion control on landfill				
Sheet piling at landfill ends	271.3	/ft	1,500	407,000
Riprap on landfill	40	/cy	2,500	100,000
Subtotal (erosion control)				**507,000**
Subtotal				**1,552,200**
Engineering	15%			232,800
Miscellaneous	10%			155,200
Contingency	25%			388,100
Inspection	10%			155,200
Total Capital Cost				**2,483,500**

TABLE 15

PRESENT WORTH ANALYSIS OF SITE ALTERNATIVE 9

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control & Drainage Improvements**
- **Improvements To Landfill Side Slopes**
- **Natural Clay Cover Over Landfill Top**

Description	Unit Cost		Quantity	Cost($)
II Operating Cost				
Ground Water Monitoring				
Labor for collecting ground water samples	2,000	/Visit	2	4,000
Analyses of ground water samples	1,700	/Well	8	13,600
General Maintenance				
Fence maintenance	5%	capital	93,500	4,700
Erosion and drainage maintenance	5%	capital	659,400	33,000
Landfill maintenance	2.5%	capital	685,100	17,100
Subtotal				**72,400**
Miscellaneous	20%			14,500
Contingency	20%			14,500
Annual Operating Cost				**101,400**
Present Worth Operating Cost	**30**	**Years**	**@10%**	**955,900**
III Present Worth of Site Alternative 9				
Capital Cost				2,483,500
Operating Cost				955,900
Total Present Worth				**3,439,400**

TABLE 16

PRESENT WORTH SENSITIVITY ANALYSIS

SENSITIVITY OF VARIATION IN COST

SITE ALTERNATIVE	ORIGINAL PRESENT WORTH ($)	NEW PRESENT WORTH			
		Reduce Capital Cost by 30% ($)	Increase Capital Cost by 50% ($)	Reduce O & M Cost by 30% ($)	Increase O & M Cost by 50% ($)
1	0	0	0	0	0
2	468,800	416,700	555,700	380,300	616,400
3	2,168,300	1,740,100	2,882,000	1,946,000	2,538,800
4	4,267,500	3,315,600	5,854,000	3,939,200	4,814,800
5	6,715,800	5,413,400	8,886,400	6,003,400	7,903,100
6	12,154,300	9,426,000	16,701,500	11,236,300	13,684,300
7	13,816,700	10,706,500	19,000,400	12,781,900	15,541,400
8	8,556,900	6,688,400	11,671,200	7,858,400	9,721,100
9	3,439,400	2,694,400	4,681,200	3,152,600	3,917,400

TABLE 17

PRESENT WORTH SENSITIVITY ANALYSIS

SENSITIVITY OF VARIATION IN INTEREST RATE

SITE ALTERNATIVE	ORIGINAL PRESENT WORTH (10% I.R.) ($)	NEW PRESENT WORTH	
		Reduce Interest Rate to 5% ($)	Increase Interest Rate to 15% ($)
1	0	0	0
2	468,800	654,900	379,200
3	2,168,300	2,635,600	1,943,400
4	4,267,500	4,957,700	3,935,300
5	6,715,800	8,213,500	5,995,200
6	12,154,300	14,084,200	11,225,600
7	13,816,700	15,992,200	12,769,900
8	8,556,900	10,025,500	7,850,300
9	3,439,400	4,042,300	3,149,300

TABLE 18

SUMMARY OF SITE ALTERNATIVES

Alternatives	Compliance with ARARs	Reduction of Toxicity, Mobility and Volume	Short-term Effectiveness	Long-term Effectiveness	Implementability	Total Present Worth ($MM)	Capital Cost ($MM)	Annual Operating and Maintenance Cost ($MM/year)	Overall Protection of Human Health and the Environment
Site Alternative 1 • No action	See 4.2.1.1	No remedial actions at site; no reduction in toxicity, mobility or volume	No reduction of existing low risks	No remedial action to remove or control contaminant migration Existing cover reduces infiltration to approximately 34% of precipitation	Not applicable	0.000	0.000	0.000	Risks would remain at current levels. No exposure pathways using worst case concentrations give significant risks, except lead. CDC, however, cites health risk data only at concentrations above worst case lead concentrations. PAHs and PCBs were also detected in soils within the target risk range of 10E-4 to 10E-7.
Site Alternative 2 • Ground water monitoring • Deed and site restrictions	See 4.2.2.1	No remedial actions at site; no reduction in toxicity, mobility or volume	No exposure to increased risks in excess of normal construction risks	Deed restrictions would be effective in preventing site development. Site access restrictions would substantially reduce direct contact with contaminants	Legal work required for deed restriction. A security fence would be constructed in several months	0.469	0.174	0.031	Under the worst case scenario, the hazard index would be 0.277 and the carcinogenic risk would be within the target range. Under the most probable scenario, risks would be zero.
Site Alternative 3 • Ground water monitoring • Deed and site restrictions • Management of surface debris • Local repairs to existing landfill cover • Erosion control and drainage improvements	See 4.2.3.1	Potential for leachate generation reduced	No exposure to increased risks in excess of normal construction risks	Improvements to landfill surface would be effective and reliable at preventing erosion. The diverse vegetation should result in increased evapo-transpirative withdrawal over shallow-rooted grasses. Regular maintenance required to retain effectiveness	Normal earthmoving and construction techniques would be used. Construction time would be 3 months. Extensive truck traffic on local roads would result	2.168	1.427	0.079	Under the worst case scenario, the hazard index would be 0.277 and the carcinogenic risk would be within the target range. Under the most probable scenario, risks would be zero.

TABLE 18 (continued)

Alternatives	Compliance with ARARs	Reduction of Toxicity, Mobility and Volume	Short-term Effectiveness	Long-term Effectiveness	Implementability	Total Present Worth ($MM)	Capital Cost ($MM)	Annual Operating and Maintenance Cost ($MM/year)	Overall Protection of Human Health and the Environment
Site Alternative 4 • Ground water monitoring • Deed and site restrictions • Management of surface debris • Erosion control and drainage improvements • Natural clay cover over landfill	See 4.2.4.1	Potential for leachate generation reduced	Risks due to exposure to waste would be mitigated by a health and safety plan	Effective and reliable method to reduce infiltration of moisture into the landfill and to prevent erosion. Clay cover would reduce infiltration to 9.8% of precipitation. Regular maintenance required to retain effectiveness in the future	Normal earthmoving and construction techniques would be used. Construction time would be 3 months. Extensive truck traffic on local roads would result. Clay may be obtainable locally	4.268	3.173	0.116	Under the worst case scenario, the hazard index would be 0.241 and the carcinogenic risk would be insignificant. Under the most probable case scenario, risks would be zero.
Site Alternative 5 • Ground water monitoring • Deed and site restrictions • Management of surface debris • Erosion control and drainage improvements • Natural clay cover over landfill • Gas venting system • Leachate collection system	See 4.2.5.1	Potential for leachate generation reduced	Risks due to exposure to waste would be mitigated by a health and safety plan	Effective and reliable method to reduce infiltration of moisture into the landfill. There appears to be no evidence that gas venting and leachate collection is necessary. Regular maintenance required to retain effectiveness	Normal earthmoving and construction techniques would be used. Construction time, involving extensive construction activities, would be 10 months. Extensive truck traffic on local roads would result. Clay may be obtainable locally	6.716	4.341	0.252	Under the worst case scenario, the hazard index would be 0.241 and the carcinogenic risk would be insignificant. Under the most probable case scenario, risks would be zero.
Site Alternative 6 • Ground water monitoring • Deed and site restrictions • Management of surface debris • Natural clay cover over landfill • Drainage improvements • Gas venting system • Leachate collection system • Flood protection dike	See 4.2.6.1	Potential for leachate generation reduced	Risks due to exposure to waste would be mitigated by a health and safety plan	Protection of landfill from flooding may further reduce infiltration. There appears to be no evidence that gas venting and leachate collection is necessary. Regular maintenance required to retain future effectiveness	Normal earthmoving and construction techniques would be used. Construction time, involving extensive construction activities, would be 18 months. Extensive truck traffic on local roads would result. Clay may be obtainable locally	12.154	9.094	0.325	Under the worst case scenario, the hazard index would be 0.241 and the carcinogenic risk would be insignificant. Under the most probable case scenario, risks would be zero.

TABLE 18 (continued)

Alternatives	Compliance with ARARs	Reduction of Toxicity, Mobility and Volume	Short-term Effectiveness	Long-term Effectiveness	Implementability	Total Present Worth ($MM)	Capital Cost ($MM)	Annual Operating and Maintenance Cost ($MM/year)	Overall Protection of Human Health and the Environment
Site Alternative 7 • Ground water monitoring • Deed and site restrictions • Management of surface debris • Synthetic membrane cap over landfill • Drainage improvements • Gas venting system • Leachate collection system • Flood protection dike	See 4.2.7.1	Potential for leachate generation reduced	Risks due to exposure to waste would be mitigated by a health and safety plan	Synthetic membrane liner on cap would reduce infiltration to 0.01% of precipitation. There appears to be no evidence that gas venting and leachate collection is necessary. Regular maintenance required to retain effectiveness in future	Normal earthmoving and construction techniques would be used. Construction time, involving extensive construction activities, would be 18 months. Extensive truck traffic on local roads would result. Clay may be obtainable locally. Synthetic membrane would be stitched in place	13.817	10.367	0.366	Under the worst case scenario, the hazard index would be 0.241 and the carcinogenic risk would be insignificant. Under the most probable case scenario, risks would be zero.
Site Alternative 8 • Ground water monitoring • Deed and site restrictions • Management of surface debris • Synthetic membrane cap over landfill • Erosion control and drainage improvements • Gas venting system • Leachate collection system	See 4.2.8.1	Potential for leachate generation reduced	Risks due to exposure to waste would be mitigated by a health and safety plan	Synthetic membrane liner on cap would reduce infiltration to 0.01% of precipitation. There appears to be no evidence that gas venting and leachate collection is necessary. Regular maintenance required to retain effectiveness in future	Normal earthmoving and construction techniques would be used. Construction time, involving extensive construction activities, would be 10 months. Extensive truck traffic on local roads would result. Clay may be obtainable locally. Synthetic membrane would be stitched in place	8.557	6.229	0.247	Under the worst case scenario, the hazard index would be 0.241 and the carcinogenic risk would be insignificant. Under the most probable case scenario, risks would be zero.

TABLE 18 (continued)

Alternatives	Compliance with ARARs	Reduction of Toxicity, Mobility and Volume	Short-term Effectiveness	Long-term Effectiveness	Implementability	Total Present Worth ($MM)	Capital Cost ($MM)	Annual Operating and Maintenance Cost ($MM/year)	Overall Protection of Human Health and the Environment
Site Alternative 9 • Ground water monitoring • Deed and site restrictions • Management of surface debris • Erosion control and drainage improvements • Improvements to landfill side slopes • Natural clay cover over landfill top	See 4.2.9.1	Potential for leachate generation reduced	Risks due to exposure to waste would be mitigated by a health and safety plan	Effective and reliable method to reduce infiltration of moisture into the landfill top and to prevent erosion. Improvements to landfill sides would be effective at preventing erosion. Would reduce infiltration to 15.8% of precipitation. Regular maintenance required to retain effectiveness in the future	Normal earthmoving and construction techniques would be used. Construction time would be 8 months. Extensive truck traffic on local roads would result. Clay may be obtainable locally.	3.439	2.484	0.101	Under the worst case scenario, the hazard index would be 0.277 and the carcinogenic risk would be insignificant. Under the most probable case scenario, risks would be zero.

TABLE 19
SUMMARY MATRIX
BOWERS LANDFILL SITE ALTERNATIVES

Remedial Action	1	2	3	4	5	6	7	8	9
•No action	x								
•Ground water monitoring		x	x	x	x	x	x	x	x
•Deed and site restrictions		x	x	x	x	x	x	x	x
•Management of surface debris			x	x	x	x	x	x	x
•Improvements to landfill side slopes									x
•Local repairs to existing landfill cover			x						
•Erosion control and drainage improvements			x	x	x	x	x	x	x
•Natural clay cover over landfill				x	x	x			
•Natural clay cover over landfill top									x
•Gas venting system					x	x	x	x	
•Leachate collection system					x	x	x	x	
•Flood protection dike						x	x		
•Synthetic membrane cap over landfill							x	x	
Total Present Worth ($ million)	0.0	0.5	2.2	4.3	6.7	12.2	13.8	8.6	3.4

APPENDICES

APPENDIX A

TECHNICAL MEMORANDUM

BOWERS LANDFILL VEGETATION EVALUATION

A1.0 INTRODUCTION

On July 26, 1988, a field investigation was conducted at the Bowers Landfill, located north of Circleville, Ohio. This field program was conducted to acquire additional information to address questions concerning the applicability of selected alternative closure options for the site. Information collected during the field program supplements data already presented as part of the "Technical Memorandum - Biological Study, Remedial Investigation/Feasibility Study - Bowers Landfill, Circleville, Ohio."

The objectives of this investigation were to:

- Evalute the integrity and stability of the existing natural vegetation cover on the disposal site

- Detail a suggested long-term monitoring and management plan for the site that would be effective in maintaining the site integrity

- Evaluate erosion conditions on the land at the west end of the berm adjacent to the Scioto River

The following discussion describes the current conditions of the site, including the existing successional levels, details the current vegetation structure, presents a monitoring and maintenance plan, and details erosion conditions at the landfill site. A glossary of terms used in the text is provided in Section A7.0 of the appendix.

A2.0 SITE DESCRIPTION

At the time of the field investigation (July 1988), the vegetation of the Bowers Landfill site was in full foliar development. In spite of stress from the recent regional drought affecting the Midwest, the site did not evidence abnormal foliar losses, necrotic foliage, discoloration of the vegetation, cupping or curling, or premature leaf shedding.

During the field survey, photographs were taken of the berm area of the landfill to document the condition and strata of the vegetation present. The current drought stress level from April 1 to July 22 for central Ohio, including the landfill site, is 4.5 inches below the normal level of precipitation for the growing season (National Weather Service, personal communication, July 27, 1988).

The berm area, used in the past for waste disposal, is L-shaped and is elevated above the surrounding land by 6 to over 15 feet. The landfill berm has been undisturbed for a number of years and, as a result, has developed a substantial vegetation cover that includes ground cover, understory, and overstory tree species. These are endemic species from the surrounding fields and woodlands that have reinvaded the landfill site (Photographs 1 to 10).

A2.1 EXISTING VEGETATION STRUCTURE

The existing vegetation of the berm area on the site includes a diverse combination of plant types, with overstory tree species including: box elder, silver maple, red maple, hackberry, sycamore, cottonwood, American elm, red elm, and black locust. In general, the larger trees are located at the toe of the berm; trees in this location show the greatest diameter and height development on the landfill site, with diameters at breast height (dbh) ranging from 14 to 21 inches.

Understory woody vegetation on the berm includes representatives of red maple, silver maple, yellow buckeye, ailanthus, hackberry, redbud, honey locust, black locust, osage orange, wild apple, red mulberry, sycamore, cottonwood, red oak, smooth sumac, sandbar willow, American elm, and red elm. In general, the understory vegetation on the berm is of dbh less than 5 inches. The ground cover vegetation is highly variable in distribution and composition on the berm. In areas with dense overstory and understory development, the ground cover is sparse; however, at the edges of wooded portions of the berm where there is a break in the tree canopy, the ground cover becomes very dense and forms thickets. A list of the vegetation recorded at the site during the first site survey is presented in Table A-1. A schematic representation of this vegetation is presented in Figure A-1.

A2.2 BERM VEGETATION SUCCESSION

Successional development on the berm portion of the site was very apparent during both field surveys. In general, the berm has followed a well-established pattern of successional development. The pattern, here as elsewhere, can be altered by such factors as previous use of the site, soil conditions, erosion potential, moisture availability, microclimate, and other features that compose the local ecology. Over the approximately 30-year period that the berm has existed on the site, several distinct phases of successional development have occurred. The generalized oldfield successional pattern at the landfill site was developed in the following specific phases:

- **First Year**: The dominant vegetation of the site, while reflecting the last grown crop, includes primarily low-value grass species such as panic grasses, crab grasses, composites; common ragweed, fleabane, several legumes; trailing wild bean, and other species, including plantain and horseweed.

- **Second Year**: The second-year field largely supports a number of the species previously found in the first-year field. During the midsummer period, however, various goldenrods and asters assume a more dominant position.

- **Third Year**: Compositional change alters abruptly from the previous year. The formerly dominant annual grasses and composites evidence a decline. An increase in perennial species is noted, with goldenrods, asters, and broomsedge showing up in greater numbers.

- **Fourth Year**: Perennial species have become well established by this time. The plant community becomes a relatively stable system dominated by mixed grass and composite species. Some development of a shrub layer is seen. By this time, the important species of the first and second year are almost totally absent.

- **Fifth Year**: The vegetation composition attained at the 5-year period remains almost in equilibrium, experiencing only minor changes. Subtle additions include the development of blackberry/raspberry, cinquefoil, legumes, and broomsedge. The presence of woody species as a shrub layer increases.

Competition between shade-tolerant and shade-intolerant species occurs and continues from this period forward.

- **Ten Years**: No dramatic changes occur in the 10-year field since the establishment of the 5-year field. Fewer herbaceous species are found in the 10-year field, especially those species exhibiting high frequency and cover compositional values. Shrub species are more commonly found on the periphery of the berm. The 10-year field is similar to the 5-year field, except for the greater predominance of shrubs and woody species.

- **Fifteen Years**: At the 15-year point, in areas where the land has remained open, grass species have become the dominant cover species. Goldenrods, greenbriers, honeysuckle, and wild rose are found. The herbaceous species are in general decline in the open areas. Within the margins of the berm, the shrubby-woody species have increased in number over the previous stage of development, and a division between understory and overstory is beginning to develop.

- **Twenty to Twenty-Five Years**: The grass species found in the open areas of the berm continue to maintain their position against the increased encroachment of the shrub layer. At this time, the shrub layer has definitely developed a woody species component. The amount of surface erosion taking place greatly influences the vegetation composition. Although the dominant grasses of the open areas can be found in any site having this stage of successional development, the shrub and tree species have lower densities, basal areas, and are shorter in areas having extensive erosion. This condition was not noted at the Bowers site.

- **Thirty Years and Beyond**: The importance of shade-tolerant species is clearly evident in the 30-plus-year field such as represented by the berm. In areas having tree or shrub thickets, goldenrod and other composites are found, while grasses occupy open sites. Tree species are common and are beginning to dominate the site. Many mature tree species are starting to produce viable seed, thus actively regenerating the overstory species (especially noted for maple, sycamore, elm, hackberry, and box elder species at the site). This woody species regeneration represents the beginning establishment of a climax

vegetation on the site. Subsequent to the 30-year successional level, the predominant woody species begin to expand progressively further into the clear grass-covered areas, developing a more complete canopy closure as the development progresses.

Based on this outline of the successional development currently occurring at the Bowers landfill berm site, it is evident that the berm is covered by a mature, highly developed and advanced vegetation composition, the result of over 20 years of progressive structural development. The stability and diversity of this system are noteworthy; there are no indications that the site represents an environment restrictive to the development of either herbaceous or woody vegetation species.

A schematic cross sections of the vegetation on the berm site is provided in Figure A-1. The schematic is not drawn to scale, but represents the type of woody plant development on the sideslopes and crest of the berm, with dominance of understory and ground cover as one progresses from the lower levels up along the slopes of the berm. At the top of the berm are wide areas of grassland vegetation where there were formerly open spaces. The grassland vegetation generally parallels the access road that was located in the middle portion of the berm. Tree species are gradually expanding onto the upper portions of the berm, reducing the total amount of clear area as woody understory species advance into the open space. Figure A-1 graphically illustrate this observed condition.

A2.3 EDAPHIC FACTORS

The surficial soils of the berm provide adequate nutrient and mineral constituents to promote rapid and complete vegetation cover over the surface of the site. Even in circumstances where coarse gravel fill materials or compaction of the access road were noted, there was ample vegetation cover over the berm area to prevent surface erosion. This vegetative cover serves to stabilize the surface materials against erosion during seasonal precipitation.

The presence of large-diameter hydrophytic tree species (i.e., sycamore, cottonwood, boxelder, and silver maple) on the east and west slopes of the berm indicate (by their dominance in the overstory) that they are growing in a favorable environment for continued development and expansion on the berm site.

A3.0 ENVIRONMENTAL CONSIDERATIONS, VEGETATION COVER

At the Bowers Landfill site, the vegetation on the berm has developed over a period of more than 20 years. This vegetation cover represents a highly stable environment, and any alternative for closure of the site should consider the following environmental aspects related to the vegetation cover on the berm.

A3.1 VEGETATIVE SPECIES SITE ADAPTABILITY

The high density and species diversity of the existing landfill vegetation result from the ability of the species to adapt to a significantly wider range of site conditions (i.e., soil, moisture, slope, and topography) than could the conventional grass or grass-legume ground vegetation generally recommended for landfill cover.

A3.2 HYDROPHYTIC VEGETATION AND MOISTURE WITHDRAWAL

The presence of numerous deep-rooted vegetation species (woody and non-woody) on the landfill results in greater evapotranspirative withdrawal from the surficial and deep subsoil areas of the berm than would be possible with grass or grass-legume cover vegetation. In part, this relates to the multi-strata structure of the existing vegetation, with overstory, understory, and ground cover vegetation occupying the same surface area and drawing moisture from the soil at various depths. Additionally, the vascular transport of moisture occurs in greater volume in large woody species than it would in an equivalent surface area covered with monotypic grass or legume species, which are inherently shallow rooted (i.e., >24 inches). The existing vegetative cover on the landfill site consists of endemic species common to the area. This endemic vegetation consists of hydrophytic species adapted to a broad range of moisture conditions not requiring surficial soils saturation to enable the vegetation to fluorish. Hydrophytes (moisture-loving species) are species that can uptake greater amounts of moisture than dry soil adapted species (mesophytes or xerophytes). As a result, the vegetation at the site removes a larger volume of water from the surficial soil than would occur with a grass or grass-legume ground cover vegetation. This enhanced moisture removal results in less potential for subsurface water (leachate) to move out of the landfill berm.

A3.3 SURFICIAL AND SUBSURFACE BIOTECHNICAL EROSION CONTROL

In much the same manner as previously described for the removal of subsurface moisture, the root system of the existing vegetative cover on the site represents an incrementally greater surface and subsurface stabilizing capability against flooding and erosion than would occur with a grass cover alone. The shallow fibrous root network of the understory and ground cover vegetation on the berm prevents surface sheet erosion caused by periodic storm events, while the deeply rooted woody tree species provide additional stabilization against the forceful effects of flooding of the Scioto River.

A3.4 ENDEMIC SPECIES SITE ADAPTATION

The natural invasion of the site by endemic plant species from the surrounding area is a positive biological indication that the site is capable of providing essential growth requirements for a broad range of native plant species. This condition is contrasted with the requirement for detailed cultivation procedures (i.e., soil placement, disking, soil amendments, and dragging) when establishing a non-endemic, grass-type ground cover. In addition, use of a monotypic (single species) or very limited number of grass and legume species can result in a high potential for revegetation failure, particularly if growing conditions are unfavorable, as they have been in the recent drought conditions.

A3.5 INTEGRITY OF LANDFILL VEGETATION

The existing vegetation on the berm represents a complete, stable plant cover. This current condition presents the least potential for surface erosion and/or migration of material from the berm. Any modification of the surface, such as grading, disking, or other earthwork activities, will result in increased levels of erosion and sedimentation to downslope areas. Because containment and stability are important criteria for the landfill, the existing vegetation cover provides effective protection against erosion and sedimentation at the present time.

A3.6 ADDITIONAL ECOLOGICAL BENEFITS OF EXISTING VEGETATION

In addition to the extensive site cover provided by the native vegetation (due to the diverse complement of species present), the site is a useful habitat for a range of wildlife

species common to the region. The dense vegetation provides many concealment and cover opportunities to terrestrial and avian species. In addition, the range of fruit- and seed-bearing plants provides forage resources to a number of resident wildlife species. This resource would not be available to any significant degree if a grass or grass-legume ground cover were used on the landfill berm instead of the existing native vegetation.

It is possible, however, that hunters and their families may ingest terrestrial animals and birds contaminated by releases at the site. No tissue samples were taken during the RI, however, the EA concluded that any exposure by this pathway is expected to be very limited.

A3.7 SITE STABILITY WITH EXISTING ADVANCED SUCCESSIONAL CONDITIONS

As detailed previously in the section describing vegetation succession, the landfill site is in an advanced stage of plant development, with a broad range of mature woody tree species present. The advanced development means that the site vegetation is very stable, with little overall change occurring other than continued development toward a tree-dominated cover type. Replacement of this vegetation with a cover composed of a single or small number of grass species will result in a need for careful monitoring of the plant community during its early growth stages to assure that a stable vegetation type is achieved.

A3.8 ADVANTAGE OF NUMEROUS ENDEMIC SPECIES AT SITE

If left intact, the existing vegetation will maintain its domination of the site by virtue of the large numbers of mature overstory species present. This will be a direct extension of the current successional stability of the site. In addition, it is doubtful that pest or pathogen infestations would reduce the woody species domination, because there are a large number of species present in the overstory. This would not necessarily be the case if the site were dominated with a grass cover composed of only one or several species. Also, other conditions, such as the recent drought, could severely reduce the extent and effectiveness of a shallow rooted grass and legume ground cover.

A3.9 SITE MODIFICATION AND POTENTIAL DISPOSAL PROBLEMS

If the site were to be cleared and graded prior to establishing a new vegetative cover, the clearing effort would be substantial, requiring cutting, chipping, and clearing of the extensive woody species. Disposing of the cleared materials may also be problematic. If placed in the existing landfill and covered over, this material would undergo progressive biodegradation that is likely to cause significant deformation of the surface as the subsurface organic materials are reduced in volume over time. In fact, the mere removal of the vegetation from the surface of the site will probably result in increased potential for subsurface leachate movement due to lack of evapotranspirative withdrawal from the berm.

The bare exposed soil would require several applications of broadleaf herbicides to systemically kill the woody species root stocks and prevent tree growth over the landfill cap. The use of herbicides in this manner is disadvantageous, because it reduces grass cover vigor at the outset of planting the protective vegetation by way of accumulating in the soil of "carryover" herbicides. Use of herbicides to kill deep-rooted species will lead to increased surface erosion potential by chemically killing or retarding the growth of a stabilizing ground cover.

A3.10 MAINTENANCE REQUIREMENTS FOR EXISTING SITE VEGETATION

The existing site vegetation will require multiple stratum management for greatest effectiveness. Ground cover vegetation will need to be mowed to provide a usable access road to the site monitoring wells. Brush clearing will be needed on the edges of wooded areas to permit the tree species to develop. Selective cutting will be needed to provide "release" for overstory species if close growing conditions result in too close spacing of the trees.

A4.0 SITE CLOSURE UTILIZING EXISTING VEGETATION

In general, hazardous waste landfill sites are developed with a grass or grass-legume vegetation cover over the liner or cap. Traditionally, the use of deep-rooted vegetation has been avoided for these sites because deeply rooted species provide a potential pathway for passage of water into the leachate zone, potentially resulting in increased quantities of leachate that would require remediation. In addition, because most hazardous waste landfill sites are designed with an impervious clay liner or cap, use of

deep-rooted plant species would be counterproductive to the containment effort. This reasoning, when applied to a new landfill, is sound and represents the current technology in hazardous waste containment.

The Bowers landfill represents a unique situation, in which an old landfill was used, closed, and then left unused for over 20 years. The vegetation currently flourishing on the landfill site represents both shallow and deeply rooted species and includes a variety of native vegetation common to the surrounding region. The existing deep-rooted vegetation on the site does not indicate any contaminant effects ascribable to the landfill (i.e., toxic leachate) and can thus be effectively used as a "bio-indicator" for the presence of toxic material in the surficial ground water regime. If a significant concentration of toxic substance were released into the ground water, the deep-rooted vegetation in the immediate area surrounding such a leak would exhibit observable physiological changes, such as stunted growth, leaf loss, etiolation, leaf necrosis, marginal scorching, leaf blotching, chlorosis, mottling, discoloration, cupping, curling, or premature leaf shedding. In addition to the physiological evidence of toxic stress, only the vegetation in close proximity to the leachate material would be so affected. The location of the woody vegetation on the outslopes of the berm could be used as a bio-indicator for monitoring of any lateral migration of contaminated leachate. This method could be used in conjunction with other monitoring techniques to assess the landfill for potential contaminant migration.

There is no evidence that any future contaminant migration is likely. The existing berm area has progressed vegetatively for more than 20 years, indicating that the existing site is in a very stable condition. If no modifications to the site are made, it is likely that the stability of the site will be maintained by the existing vegetation. In support of this projection, the current site vegetation exists as a bio-indicator along the full extent of the berm and in the future can serve as an indicator if any subtle site changes occur that could affect contaminant release. There are many advantages in utilizing the existing site vegetation to its maximum extent in this practical, effective, and efficient form of site containment and monitoring. Any modification of the existing site conditions would serve to destabilize the existing system. The most significant destabilizing factors would include clearing of the existing cover, increasing erosion potential and percolation and thus contaminant migration potential, and reducing the structural stability of the berm in the surficial and subsoil layers. The existing site configuration, with a practical maintenance and management plan, is the most effective site control option available.

A5.0 MITIGATION METHODS FOR EXISTING SITE CONDITIONS

The existing landfill berm at the Bowers site can be improved by implementation of the following actions.

A5.1 LOCATE SURFACE TRASH AND REMOVE

This activity will include the location of all of the old tires, truck and car chassis, old appliances, drums and surface papers, metal, and other debris on the site. Once located, this material will be removed from the site by truck and disposed of in a permitted sanitary or hazardous waste landfill. Based on detailed site inspection, most of the material can be removed with a truck and a front-end loader or back hoe and a small crew of workers. Subsequent to removal of debris and trash, the areas would be scarified, amended, and seeded with a rapidly growing grass or legume mixture to prevent surface erosion.

A5.2 CLEAR OUT AND TRIM UNDERSTORY

In various locations on the site, principally in the vicinity of the access road, it will be necessary to clear out the understory where this material has developed sufficiently to prevent passage of an inspection vehicle. In the areas where the understory is removed, there will be ground cover vegetation that should be left in place. The understory vegetation consisting of shrubs and woody vines can be chipped and deposited on the site as a surface mulch where needed. Removal of this understory vegetation will promote the development of a denser ground cover and enhance development of larger tree species which provide root stabilization to the side slopes.

A5.3 MAINTAIN A NARROW ACCESS ROAD

Periodic site inspections will require that a narrow access road be kept clear. Because of the desire to limit access to the site, the access road should be maintained north of the existing chain link fence enclosure area on the site. Maintenance north of this location will prevent observation of the access road directly from the highway. The access road can be maintained once clearing and trimming of the understory have been accomplished by the use of a bushhog two or three times during the active growing season.

Additionally, as required, a powered brush cutter can be used to clean and maintain the access path.

A6.0 MANAGEMENT AND MONITORING PLAN FOR SITE VEGETATION

A6.1 MANAGEMENT

A6.1.1 Mixed Vegetation Strata Management Strategy

The mixed overstory, understory, and ground cover vegetation management strategy consists of encouraging the development of plant communities dominated by mixtures of tall-growing, woody species, a woody understory, and dense ground cover. The overstory vegetation is dominated by the woodland species common to the region. The woody understory includes species capable of withstanding partial shade and competition provided by the overstory vegetation. The herbaceous plants of the site will vary in competition depending on whether they are growing under shaded conditions on the edges of wooded areas or in open areas that are not woody species-dominated.

Management of the landfill area will include periodic cutting of the ground cover, selective thinning of the understory, including brush removal, and selective thinning of the overstory vegetation to maintain plant density without stagnant overmature overstory development. Maintaining the overstory at a sub-mature stage of development is most desirable for the landfill site.

A6.1.2 Advantages

The mixed vegetation management strategy will provide an excellent vegetation cover capable of providing continued stabilization of the berm slopes. While the overstory vegetation should be prevented from becoming overmature, the height, spacing, density, and species composition can be manipulated at the site to obtain the desired composition and age stratum. In addition, as noted previously, the use of multiple species as bio-indicators along the entire length of the landfill berm on both outslopes provides a level of in situ monitoring unique to this site.

A6.1.3 Disadvantages

The principal disadvantage of use of this strategy at the landfill site is that it will require periodic monitoring due to large numbers of tall-growing species present and the need to conduct visual inspections of the vegetation to determine if physiological stress is occurring. In addition, maintenance of the access road is a requirement that is, in part, the result of the multiple strata of vegetation present at the site. This disadvantage can be effectively handled through a system in which the site is divided into small management units so that, on a rotational basis, clearing and thinning of selected areas can be efficiently accomplished, eliminating large-scale full site thinning or clearing operations.

A6.1.4 Implementation

For management of the site in the future, the approximate 25-acre site will be divided into small "management units" grouped by similar vegetation types or site conditions. A program of maintenance will be developed for each of these separate areas to maximize effective control and management of the vegetation. Predominantly open areas will be managed to encourage woody species development while maintaining a dense ground cover. Wooded sites will be managed by thinning the understory to permit the development of woody species and to maintain an effective ground cover vegetation.

The following activities will be performed as part of an annual program at the site:

Mowing - Mowing will be performed with a bushhog for the purpose of maintaining the access road for inspection vehicles. This activity will be limited to those portions of the berm area that consist of grass and herbaceous ground cover.

Selective Brush Removal - The removal of woody vines and other low-growth species will be performed where needed on the berm. Areas where the brush removal will be most effective are those at the margins of more wooded areas. Brush developed in these areas consists of bush honeysuckle, Japanese honeysuckle, wild grape, poison ivy, and a variety of other species that choke the developing woody understory and prevent significant ground cover development. These species would be removed with a brush cutter and chipped as mulch for use elsewhere on the berm.

Selective Thinning - Selective thinning will be performed on an individual "management unit" basis. Where the density of overstory or understory is excessive, the number of woody species will be reduced by selective thinning. In general, because the site represents an advanced stage of successional development, there will be a low number of areas where selective thinning will be required. Selective thinning will be performed only in the management units at the site, on the basis of density calculations performed as part of the site management program. The objective of the selective thinning program will be to enhance the overstory tree species development while maintaining some openings in the canopy to permit the development and maintenance of a stabilizing ground cover vegetation.

Maintenance Schedule - To provide effective site management, the berm area should be observed on a semiannual basis to be sure that the desired objectives are achieved. The inspection monitoring plan provides for a spring site inspection, at which time the activities required on the individual "management units" will be developed. Subsequent to the spring inspection, a late summer-early fall inspection will be conducted to determine the need for additional site maintenance during the active growing season. Using the two-inspection approach, site maintenance is provided at the beginning and conclusion of the active growing season of each year. Unless indicated by unusual site conditions, additional inspections are considered unnecessary under the outlined management program.

A6.2 MONITORING

As described previously, the existing native vegetation can be used as a sensitive "bio-indicator" of the site subsurface conditions. As planned, the berm vegetation will be inspected concurrently with the semiannual maintenance inspection to evaluate if there is any physical evidence of plant physiological stress on the site.

A7.0 GLOSSARY

Associations, vegetation	Any assemblage of plants living in a prescribed area or physical habitat. The vegetation association may have sharply defined limits, but more frequently they blend gradually into one another.
Basal area	The area of the cross section of a tree stem near its base, generally at 4.5 feet from the ground (breast height) and inclusive of the bark.
Dominant species	The concept that one or several species in a site due to its numbers or extent of coverage is the major or predominant component of the vegetation association found within an area. The dominant species may under various circumstances be either a ground cover, understory, or overstory species. The dominant species in an area is generally the most successful at exploiting the resources of the area and is the most well-established species found in the area.
Edaphic factors	Those parameters associated with the soils of a site. These can be either physical, such as soil texture, permeability, density, grain size distribution, or friability; or they may be chemical properties such as soil reaction (pH), macronutrient concentration, micronutrient concentration, cation exchange capacity, or sodium absorption ratio. The edaphic factors of a given site have a significant influence on the type and extent of vegetation growth that a particular site is capable of producing.
Etiolation	Blanching, whitening, and/or generally becoming puny or sickly.
Ground cover	A stratum of vegetation found in close proximity to the soil. Ground cover vegetation is generally non-woody and is less than 20 inches in height. The ground cover vegetation of a site generally is the most diverse stratum, with a representation of annual, biennial, and perennial species commonly found.
Hydrophytic	In relation to plants and vegetation, the term refers to species that are moisture-loving. In reference to a site, hydrophytic describes a habitat characterized by wet or moist conditions.
Mesic	Refers to vegetation that is moderate in moisture requirements between dry and wet or saturated conditions. Most species that are not specifically

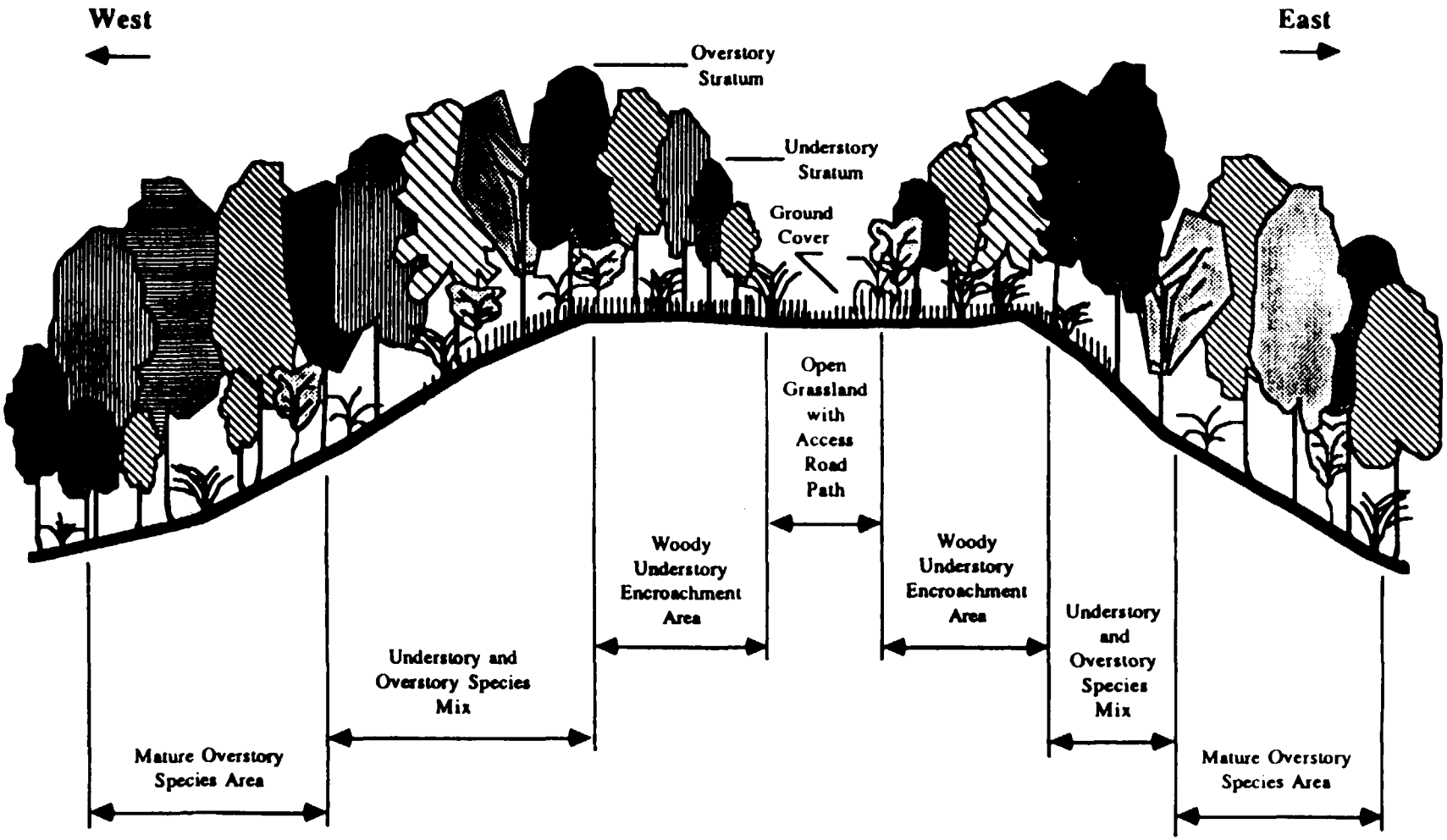
	adapted to either very dry or very wet conditions are characterized as mesic. A site described as mesic refers to the same condition in regard to moisture availability.
Mesophytic	Refers specifically to vegetation that is moderately moisture-loving. See mesic.
Overstory	Refers specifically to vegetation in the upper canopy or canopies of plants. Usually refers to trees.
Relative density	Refers specifically to the number of individuals of a species per unit area. The density is directly the relative closeness of individuals to one another. Relative density is the expression of this relationship as a percentage (0 to 100 percent).
Relative dominance	Relative dominance for plant species is a measure of their number, coverage, or size that have considerable influence or control over the conditions of existence of associated species. Relative dominance is expressed as a percentage (0 to 100 percent).
Relative frequency	A quantitative expression of the presence or absence of individuals of a species in a population; i.e., the ratio between the number of sample units that contain a species and the total number of sampled units. Relative frequency is the expression of this relationship as a percentage (0 to 100 percent).
Species diversity	The number of species found to occur within a measured area. In general, the higher the diversity of an area, the "younger" the area is in terms of its successional development.
Stratification	The structural relationship between the different strata of vegetation existing on a site. The strata normally include the overstory, understory, and ground cover. Differences in the various strata or the lack of a given stratum may relate directly to the development of a specific stand on a site.
Successional trend	The future projected condition of a specific site's vegetation, based on the present condition, structural development, and composition of the vegetation.
Understory	The stratum of vegetation found beneath the overstory or canopy vegetation on a site. Understory vegetation consists of woody species

with diameters at breast height (dbh) less than 5 inches and heights greater than 20 inches.

Xeric	Refers to the moisture condition of a site, specifically to a dry condition. Xeric or xerophytic is also used in reference to vegetation that thrives in a dry site.

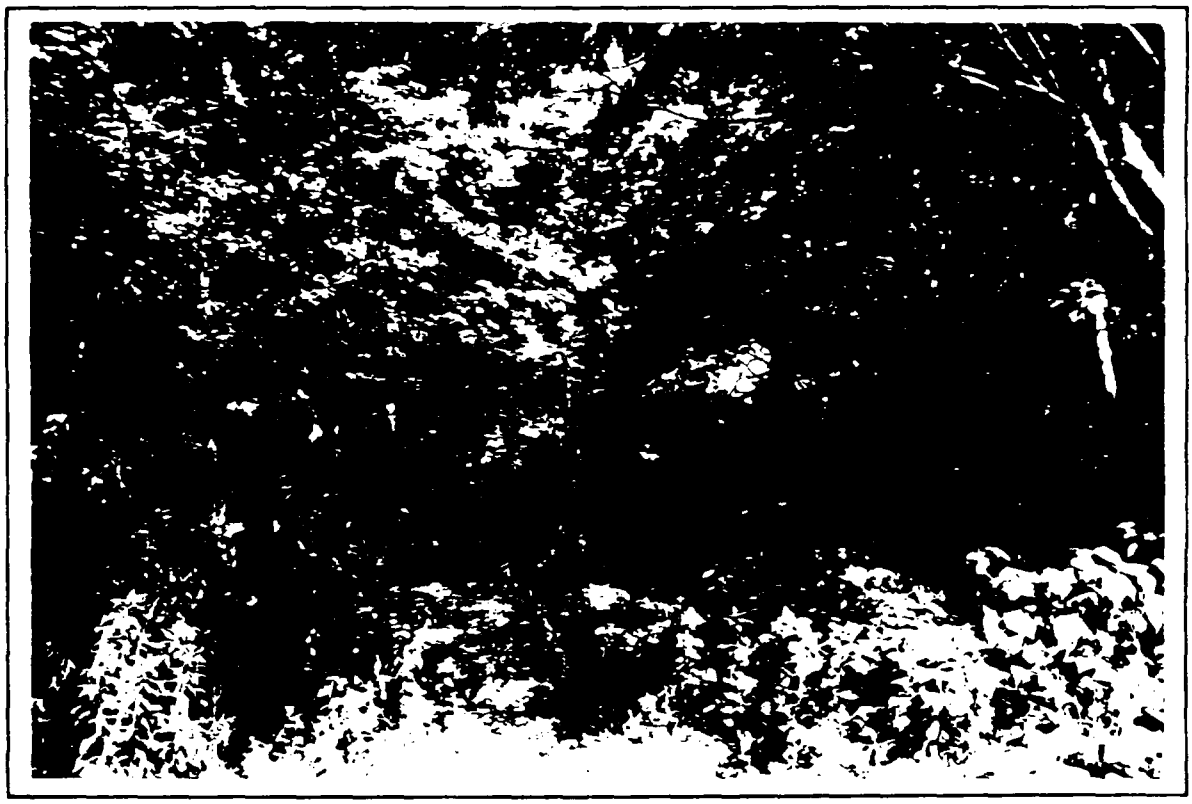
FIGURE A-1

SCHEMATIC REPRESENTATION OF
LANDFILL VEGETATION CROSS SECTION
NORTHERN WOODED AREA (82%)



Not to Scale

Photograph 1. West site of landfill berm showing slope angle and size of Silver Maple (Acer saccharinum)



Photograph 2. Access road north of chain link enclosure showing extent of ground cover and understory vegetation development.

Photograph 3. Landfill berm access road showing density of understory and ground cover vegetation.

Photograph 4. Open portion of berm showing ground cover vegetation and in background, understory and overstory trees.

Photograph 5. Detail of woody shrub understory developing at the edge of an open grass cover area. Note the density of the cover.

Photograph 6. A view near the north end of the berm looking to the south showing the tree cover adjacent to the path.

Photograph 7. A view of the landfill berm from the soybean field immediately to the west of the site. Note the tree height.

Photograph 8. Typical view along the access road showing the dense understory and ground cover development.

Photograph 9. View of the berm vegetation including all developed strata. Compare with Photograph 10. below.

Photograph 10. View of a grass field directly north of the berm site. Note the lack of understory and overstory development.

APPENDIX B

PUBLIC HEALTH EVALUATION

B.1.0 CONTAMINANT IDENTIFICATION

Data from laboratory analysis of environmental samples from various media were used to identify chemicals present at the site. During the Remedial Investigation (RI), samples were collected from the following media:

- Ground water
- Surface soil
- Surface water
- Sediment

The site plan in Drawing 2 shows most of the sampling locations. During the RI, samples of ground water were collected from 20 monitoring wells and four offsite residential wells. Samples of surface water and sediment were collected from the Scioto River and other bodies of water. Surface soil samples were collected from the perimeter of the landfill, at exposed or eroded areas, from the field to the north of the landfill, from the field between the landfill and the river, and from the agricultural field on the west side of the river.

A detailed discussion of sample collection procedures, analytical results, and quality assurance and quality control is presented in the RI report.

Numerous chemicals were identified as present at the site. Because of the large number of chemicals, it was technically impractical to completely evaluate the potential impacts associated with each chemical. Therefore, indicator chemicals were selected for the site. Indicator chemicals were selected based on the following criteria:

- Representative concentrations
- Medium-specific and chemical-specific toxicity constants
- Estimated potential mobility
- Persistence

The following nine indicator chemicals were selected for the site:

1. Barium
2. Lead
3. Mercury
4. Benzene
5. Chlordane

6. 4-methyl phenol
7. Polychlorinated biphenyls (PCBs)
8. Polynuclear aromatic hydrocarbons (PAHs)
9. Tetrachloroethene

A detailed discussion concerning the indicator chemical selection process, including the derivation of representative concentrations, is presented in the Endangerment Assessment (EA). The maximum and geometric mean concentrations of the indicator chemicals in each exposure medium are shown on Table B-1. This table summarizes portions of Tables 3-3, 3-6, 3-7, and 3-9 from the EA. For ground water, only wells hydraulically downgradient of the landfill were used; for the Scioto River and river sediment, only sampling points downstream of the landfill were included; for soils, only sampling locations on or adjacent to the landfill were included.

B.2.0 EXPOSURE/RISK EVALUATION

An exposure pathway is considered complete, only if it consists of four necessary elements:

- A source and mechanism of chemical release to the environment
- An environmental transport medium--ground water, surface water, or soils
- A point of potential human contact with the contaminated medium (exposure point)
- A human exposure route (e.g., ground water ingestion) at the exposure point

If any element of the exposure pathway is missing under both current use and future use exposure scenarios, the pathway was deemed unlikely to be complete and was not considered to warrant further consideration.

Data gathered during the RI were used to evaluate the complete exposure routes of site releases to potential receptors. The EA was conducted to assess potential human health effects that may result from exposure to site releases in the absence of any site remediation. Physical, chemical, demographic, and geographic factors were evaluated to assess the extent, if any, of potential harm to the public.

The EA presented potential risks associated with noncarcinogenic chemicals as the Hazard Index (HI). The HI is the ratio of the daily dose for a chemical to the acceptable chronic intake level (AIC) for that chemical. The AICs are based on long term exposure studies and are designed to protect sensitive populations. If the HI for an exposure scenario exceeds one (that is, if the daily dose exceeds the AIC), there is a potential risk from that exposure. Potential risks from carcinogenic chemicals were presented as incremental

cancer risks (ICR). ICRs were evaluated in the EA using carcinogenic potency factor. The incremental risk of developing cancer is the product of the carcinogenic potency factor and the average lifetime dose of the chemical in question. The ICR is presented as a probability (for example, 10^{-6}, or 1 cancer per million people exposed). Recent U.S. EPA guidance indicates that the target carcinogenic risks resulting from exposures at a Superfund site may range between 10^{-4} and 10^{-7}. Using this range as a baseline, a risk level greater than 10^{-4} is considered to present a significant risk, and levels smaller than 10^{-7} are considered insignificant. Risk levels between 10^{-4} and 10^{-7} are within the target range.

The FS addresses remediation of surface soil and the landfill because they pose potentially unacceptable health risks. It has identified nine remedial alternatives for the site, as follows:

1. No action
2. Ground water monitoring; deed and site restrictions
3. Ground water monitoring; deed and site restrictions; management of surface debris; local repair of existing landfill cover; erosion control and drainage improvements
4. Ground water monitoring; deed and site restrictions; management of surface debris; natural clay cover over landfill; erosion control and drainage improvements
5. Ground water monitoring; deed and site restrictions; management of surface debris; natural clay cover over landfill; erosion control and drainage improvements; gas venting system; leachate collection system
6. Ground water monitoring; deed and site restrictions; management of surface debris; natural clay cover over landfill; erosion control and drainage improvements; gas venting system; leachate collection system; construct flood protection dike
7. Ground water monitoring; deed and site restrictions; management of surface debris; synthetic membrane cap over landfill; erosion control and drainage improvements; gas venting system; leachate collection system; construct flood protection dike
8. Ground water monitoring; deed and site restrictions; management of surface debris; synthetic membrane cap over landfill; erosion control and drainage improvements; gas venting system; leachate collection system
9. Ground water monitoring; deed and site restrictions; management of surface debris; erosion control and drainage improvements; improvements to landfill side slopes; natural clay cover over landfill top

A discussion of exposure pathway analyses and assumptions and a detailed exposure evaluation of the the No Action Alternative (Site Alternative 1) are presented in the EA. The exposure assumptions from the EA, together with assumptions on ingestion of soils by teenagers--the group considered to be most at risk-- are summarized on Table B-2. A summary of the effect of each alternative on the exposure media for the site, under a most probable exposure scenario, is shown below. Where the exposure pathway is complete, the table indicates "Yes." Where the exposure pathway is incomplete, the table indicates "No." "No" is a desirable situation. The chart demonstrates only the most probable exposure scenario. A fundamental assumption of this scenario is that a fence around the site would deter people from entering, and hence would break the pathway for soils ingestion.

	Site Alternative (Most Probable Case)								
Pathway	1	2	3	4	5	6	7	8	9
1. Ground water	Yes	No	No	No	No	No	No	No	No
2. Surface soil	Yes	No	No	No	No	No	No	No	No

B.2.1 EXPOSURE ASSUMPTIONS

The EA determined that human intake of the indicator chemicals by the dermal and inhalation pathways were insignificant compared with direct ingestion; therefore, the risks associated with such pathways were not calculated. Absorption factors for human intake of the indicator chemicals by ingestion were estimated in the EA to be 100 percent absorption for ingestion of ground water and 50 percent absorption for ingestion of soils.

The exposure scenarios and estimated frequency and duration of exposures are based on knowledge of the site and surrounding area. Detailed discussions of each exposure scenario for Site Alternative 1 are presented in the EA. The exposure and risk evaluations for the complete pathways for the other eight remedial alternatives are based on assumptions from Site Alternative 1 and are derived as shown in the following sections.

B.2.1.1 Ground Water

The concentration of contaminants and rates of drinking water ingestion and domestic water use are assumed to be the same as for Site Alternative 1 described in the EA. The estimated chemical concentrations used to evaluate Site Alternative 1 are described in the EA.

Under Site Alternative 1, the estimated worst case health risk associated with potential exposure to ground water is within the target risk range of 10^{-4} to 10^{-7}.

B.2.1.2 Surface Soil

The frequency, duration, and degree of exposure to surface soil for Site Alternatives 2 through 9 are derived from the most probable exposures for Site Alternative 1. By erecting a secure fence around the site, the exposure pathway for surface soils would be broken. In Site Alternatives 2 through 9, the fence would act as a barrier between the receptors and the exposure point. Therefore, for the most probable exposure scenario, there would be no intake of contaminants, hence no risk.

The worst case exposure scenario assumes that there would be unauthorized access to the site, despite the fence. Under Site Alternative 1, it was assumed that receptors were small children who purposely ingest 100 mg of soil per visit, with 10 visits per year for 3 years. However, after construction of a secure fence, it is assumed that the only receptors would be teenagers, who are the only group of people likely to scale a secure fence and ignore warning signs. Adults, although physically capable of scaling a fence, would most likely heed the warning signs. It is assumed that the receptors would visit the site 10 times a year for 5 years and would ingest 200 mg of soils per exposure event. Applying the above assumptions, the risk to teenagers in Site Alternatives 2 - 9 would be considerably lower than to children in Site Alternative 1. It should be noted that there exists very little data in the Superfund Public Health Evaluation Manual (SPHEM) to support the above assumptions for ingestion of soils by teenagers. The amount of soil ingested was assumed to be 20 percent of the value listed in the SPHEM for children, since soils ingestion, in this case, would not be intentional.

Potential exposure to surface soil would be controlled by using one or more of the following technologies:

- Restrict site access
- Cover the landfill top with natural clay
- Cover the landfill with either natural clay, a clay cap, or a synthetic membrane cap

Restricting access would preclude exposure for the most probable case and would limit the worst case exposure. Covering the landfill top with natural clay would preclude exposure of much of the contaminated soils, but those samples taken on or adjacent to the side slopes during the RI would not be covered; thus no credit is taken for these areas of

elevated lead concentration. Covering the landfill would preclude exposure to all but one area of elevated lead contamination, SO-44, which has lower levels of contaminants than the maximums used in all other worst case exposures.

With restricted access only, the estimated worst case carcinogenic risk associated with potential exposure to surface soil would be within the target risk range at 4.58×10^{-7}. The hazard index would be 0.277, hence there would be little potential risk from direct contact with noncarcinogenic chemicals. Despite the lack of soils ingestion data, the assumptions made may result in an overestimate of actual risks because they are calculated using conservative assumptions, such as ingesting the maximum soil concentration together with the maximum soil ingestion rate.

B.3.0 PUBLIC HEALTH EVALUATION OF EACH SITE ALTERNATIVE

Each alternative was evaluated for potential public health risks for the assumed most probable and worst case exposure scenarios. Detailed presentations of estimated potential health risks by chemical, exposure route, and pathway for each alternative are contained in Tables B-3 through B-11 in this appendix.

All alternatives except for Site Alternative 1, worst case, reduce the potential cumulative health risk to a target risk level or an insignificant risk level.

B.3.1 SITE ALTERNATIVE 1

Site Alternative 1 would allow the site to remain as it currently exists. The most probable scenario results in an estimated total carcinogenic risk that is within the target range of 10^{-4} to 10^{-7} and a hazard index for non-carcinogens at less than unity. The worst case scenario would result in a carcinogenic risk within the target range of 10^{-4} to 10^{-7}, and a hazard index of 4.641. Maximum and mean concentrations of each contaminant are derived from the EA and are presented in Table B-1.

The scenario assumes that the area would be developed in the future to include drinking water supply wells.

Detailed exposure scenarios are presented on Table B-3.

B.3.2 SITE ALTERNATIVE 2

Site Alternative 2 would prevent ground water use and adjacent residential development, and restrict site access. Under the most probable exposure scenario, the pathway of indicator chemicals to receptor would be incomplete. Hence, both the hazard index and the incremental carcinogenic risk would be zero.

Under the worst case scenario, it is assumed that teenagers would scale the security fence and come into contact with the soils. However, the hazard index for such an exposure would be 0.277 and the incremental carcinogenic risk would be within the target range. Maximum and mean concentrations of each contaminant are derived from the EA and are presented in Table B-1.

A detailed exposure scenario is presented on Table B-4.

B.3.3 SITE ALTERNATIVE 3

Under Site Alternative 3, ground water use and residential development would be prevented and access to the site would be restricted. Surface debris would be removed from the landfill, the cover would be repaired and regraded to assist drainage and control erosion. Under the most probable exposure scenario, the pathway of indicator chemicals would be incomplete. Hence, both the hazard index and the incremental carcinogenic risk would be zero.

The worst case exposure scenario is the same as for Site Alternative 2 -- the hazard index would be acceptable at 0.277 and the incremental carcinogenic risk would be within the target risk range. Maximum and mean concentrations of each contaminant are derived from the EA and are presented in Table B-1.

A detailed exposure scenario is presented on Table B-5.

B.3.4 SITE ALTERNATIVE 4

Site Alternative 4 would be similar to Site Alternative 3 with the exception that the landfill would be covered with natural clay. The clay would cover all of the contaminated soil, with the exception of one location, SO-44. Under the most probable exposure scenario, the security fence would prevent access to the site and the deed restriction would

prevent use of the ground water. Therefore, both the hazard index and the incremental carcinogenic risk would be zero.

Under the worst case scenario, as with Site Alternatives 2 and 3, it is assumed that teenagers would scale the fence. The only contaminated soil which they could come into contact with would be those that were not covered by the clay. The hazard index associated with this exposure would be 0.244 and the incremental carcinogenic risk would be insignificant at 4.38×10^{-8}. The maximum concentration, used in the evaluation of this alternative, for each indicator chemical is presented on Table B-11, together with the sampling location. Data for this table was obtained from the RI, and consists of the maximum concentration of each contaminant that would be detected in soils borings or grab samples from within the proposed fenced area, but not immediately adjacent to the landfill.

A detailed exposure scenario is presented on Table B-6.

B.3.5 SITE ALTERNATIVES 5, 6, 7, AND 8

The remaining alternatives would protect public health to the same extent as Site Alternative 4. The exposure pathway in the most probable case would be incomplete due to site access and deed restrictions. Under the worst case scenario, exposure to contaminated soils would be minimized by covering the landfill.

A detailed exposure scenario for each alternative is presented on Tables B-7 to B-10.

B.3.5 SITE ALTERNATIVE 9

Site Alternative 9 would be similar to Site Alternative 4 with the exception that the landfill top would be covered with natural clay and the improvements to the side slopes would be as described under Site Alternative 3. The clay would cover much of the contaminated soil. Those areas on or adjacent to the landfill side slopes would not be covered; thus no credit is taken for covering these areas of elevated lead concentration. Thus, exposure scenarios are calculated using the same basis as Site Alternative 3.

A detailed exposure scenario is presented on Table B-11. Table B-12 presents the concentrations of the indicator chemicals in the uncovered soils.

TABLE B-1

INDICATOR CHEMICALS CONCENTRATION IN SITE MEDIA
(Note 1)

INDICATOR CHEMICAL	SITE MEDIUM		MAXIMUM CONCENTRATION (mg/kg)	GEOMETRIC MEAN CONCENTRATION (mg/kg) (Note 2)
Barium	Ground water	(Note 3)	2.070	0.330
	Scioto River	(Note 4)	0.060	0.054
	Drainage ditch		0.199	0.101
	River sediment	(Note 5)	312	106
	Ditch sediment		227	128
	Surface soils	(Note 6)	279	189
Lead	Ground water	(Note 3)	0.007	0.001
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		0.009	0.001
	River sediment	(Note 5)	39	34
	Ditch sediment		104	39
	Surface soils	(Note 6)	179	78
Mercury	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	0.0002	0.00013
	Drainage ditch		0.00027	0.00012
	River sediment	(Note 5)	0.590	0.480
	Ditch sediment		1.400	0.140
	Surface soils	(Note 6)	0.430	0.270
Benzene	Ground water	(Note 3)	0.006	0.001
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	ND	ND
	Ditch sediment		ND	ND
	Surface soils	(Note 6)	ND	ND
Chlordane	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	0.200	0.067
	Ditch sediment		0.140	0.055
	Surface soils	(Note 6)	0.210	0.015

TABLE B-1 (cont.)

INDICATOR CHEMICAL	SITE MEDIUM		MAXIMUM CONCENTRATION (mg/kg)	GEOMETRIC MEAN CONCENTRATION (mg/kg) (Note 2)
4-methyl phenol	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	8.600	0.036
	Ditch sediment		8.100	0.091
	Surface soils	(Note 6)	ND	ND
PCBs	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		0.003	0.001
	River sediment	(Note 5)	ND	ND
	Ditch sediment		2.300	0.105
	Surface soils	(Note 6)	3.600	0.238
PAHs	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	ND	ND
	Drainage ditch		ND	ND
	River sediment	(Note 5)	5.580	1.305
	Ditch sediment		2.872	0.457
	Surface soils	(Note 6)	25.960	0.667
Tetrachloroethene	Ground water	(Note 3)	ND	ND
	Scioto River	(Note 4)	0.001	0.001
	Drainage ditch		ND	ND
	River sediment	(Note 5)	ND	ND
	Ditch sediment		ND	ND
	Surface soils	(Note 6)	ND	ND

ND -- contaminant was not detected in medium
Note 1 Source: Tables 3-3, 3-6, 3-7, 3-9 from EA
Note 2 From EA
Note 3 Presents data from wells downgradient of landfill
Note 4 Presents data from locations downstream of landfill
Note 5 Presents data from locations downstream of landfill
Note 6 Presents data from locations on or adjacent to the landfill

TABLE B-2
SUMMARY OF ASSUMPTIONS

ADSORPTION FACTORS
(Note 1)

Ground Water	100%
Surface Soils	50%

INGESTION BY CHILD

(Note 1)	Most Probable Exposure	Worst Case Exposure
Body Weight	20 kg	20 kg
Intake of Soils per Event	100 mg	1 g
Frequency of Exposure Events	10 /year	10 /year
Exposure Period	3 years	3 years

INGESTION BY TEENAGER

Body Weight	50 kg	50 kg
Intake of Soils per Event	0 mg	200 mg
Frequency of Exposure Events	0 /year	10 /year
Exposure Period	0 years	5 years

INGESTION BY ADULT (Note 1)

Body Weight	70 kg	70 kg
Intake of Ground Water per Event	2 l	2 l
Frequency of Exposure Events	365 /year	365 /year
Exposure Period	70 years	70 years

CARCINOGENIC POTENCY FACTORS
(kg.day/mg)
(Note 1)

Benzene	0.052
Chlordane	1.3
PCBs	7
Benzo[a]anthracene	0.115
Benzo[a]pyrene	11.5
Benzo[b]fluoranthene	3.45
Chrysene	0.115
Dibenzo[a,h]anthracene	11.5
Indeno[1,2,3,c,d]pyrene	0.115

ACCEPTABLE DAILY INTAKES
(mg/kg/day)
(Note 1)

Barium	0.057
Lead	0.0014
Mercury	0.0003
Chlordane	0.00005
4-methyl phenol	0.05
Tetrachloroethene	0.02

For non-carcinogens
Daily Dose (mg/kg/day) = Amount of media ingested per day * chemical concentration in media/body weight

Hazard = Daily dose/acceptable daily intake

For carcinogens
Daily Dose (mg/kg/day) = Amount of media ingested per day * chemical concentration in media/body weight * frequency/365 * exposure period/70

Carcinogenic Risk = Daily dose * carcinogenic potency factor

Note 1: From EA

TABLE B-3
RISK ASSESSMENT FOR ALTERNATIVE 1

• **No Action**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	4.73E-04	8.30E-03	9.43E-03	1.65E-01	1.74E-01
Lead	1.95E-04	1.39E-01	3.43E-05	2.45E-02	1.64E-01
Mercury	6.75E-07	2.25E-03	0.00E+00	0.00E+00	2.25E-03
Chlordane	3.75E-08	7.50E-04	0.00E+00	0.00E+00	7.50E-04
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.151**	**Total**	**0.190**	**0.341**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	2.00E-05	1.04E-06	1.04E-06
Chlordane	4.40E-11	5.72E-11	0.00E+00	0.00E+00	5.72E-11
PCBs	6.99E-10	4.89E-09	0.00E+00	0.00E+00	4.89E-09
Benzo[a]anthracene	3.41E-10	3.92E-11	0.00E+00	0.00E+00	3.92E-11
Benzo[a]pyrene	3.38E-10	3.89E-09	0.00E+00	0.00E+00	3.89E-09
Benzo[b]fluoranthene	5.23E-10	1.80E-09	0.00E+00	0.00E+00	1.80E-09
Chrysene	4.96E-10	5.70E-11	0.00E+00	0.00E+00	5.70E-11
Dibenzo[a,h]anthracene	7.63E-11	8.77E-10	0.00E+00	0.00E+00	8.77E-10
Indeno[1,2,3,c,d]pyrene	2.14E-10	2.46E-11	0.00E+00	0.00E+00	2.46E-11
	Total	**1.16E-08**	**Total**	**1.04E-06**	**1.05E-06**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	6.98E-03	1.22E-01	5.91E-02	1.04E+00	1.16E+00
Lead	4.48E-03	3.20E+00	1.97E-04	1.41E-01	3.34E+00
Mercury	1.08E-05	3.60E-02	0.00E+00	0.00E+00	3.60E-02
Chlordane	5.25E-06	1.05E-01	0.00E+00	0.00E+00	1.05E-01
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**3.463**	**Total**	**1.178**	**4.641**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	1.71E-04	8.89E-06	8.89E-06
Chlordane	6.16E-09	8.01E-09	0.00E+00	0.00E+00	8.01E-09
PCBs	1.06E-07	7.42E-07	0.00E+00	0.00E+00	7.42E-07
Benzo[a]anthracene	1.26E-07	1.45E-08	0.00E+00	0.00E+00	1.45E-08
Benzo[a]pyrene	1.26E-07	1.45E-06	0.00E+00	0.00E+00	1.45E-06
Benzo[b]fluoranthene	2.52E-07	8.69E-07	0.00E+00	0.00E+00	8.69E-07
Chrysene	1.53E-07	1.76E-08	0.00E+00	0.00E+00	1.76E-08
Dibenzo[a,h]anthracene	2.82E-08	3.24E-07	0.00E+00	0.00E+00	3.24E-07
Indeno[1,2,3,c,d]pyrene	7.63E-08	8.77E-09	0.00E+00	0.00E+00	8.77E-09
	Total	**3.43E-06**	**Total**	**8.89E-06**	**1.23E-05**

TABLE B-4
RISK ASSESSMENT FOR ALTERNATIVE 2

- **Ground Water Monitoring**
- **Deed and Site Restrictions**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	5.58E-04	9.79E-03	0.00E+00	0.00E+00	9.79E-03
Lead	3.58E-04	2.56E-01	0.00E+00	0.00E+00	2.56E-01
Mercury	8.60E-07	2.87E-03	0.00E+00	0.00E+00	2.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.277**	**Total**	**0.000**	**0.277**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.22E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	1.41E-08	9.87E-08	0.00E+00	0.00E+00	9.87E-08
Benzo[a]anthracene	1.68E-08	1.93E-09	0.00E+00	0.00E+00	1.93E-09
Benzo[a]pyrene	1.68E-08	1.93E-07	0.00E+00	0.00E+00	1.93E-07
Benzo[b]fluoranthene	3.37E-08	1.16E-07	0.00E+00	0.00E+00	1.16E-07
Chrysene	2.04E-08	2.35E-09	0.00E+00	0.00E+00	2.35E-09
Dibenzo[a,h]anthracene	3.76E-09	4.32E-08	0.00E+00	0.00E+00	4.32E-08
Indeno[1,2,3,c,d]pyrene	1.02E-08	1.17E-09	0.00E+00	0.00E+00	1.17E-09
	Total	**4.58E-07**	**Total**	**0.00E+00**	**4.58E-07**

TABLE B-5
RISK ASSESSMENT FOR ALTERNATIVE 3

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control and Drainage Improvements**
- **Local Repair of Existing Landfill Cover**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	5.58E-04	9.79E-03	0.00E+00	0.00E+00	9.79E-03
Lead	3.58E-04	2.56E-01	0.00E+00	0.00E+00	2.56E-01
Mercury	8.60E-07	2.87E-03	0.00E+00	0.00E+00	2.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.277**	**Total**	**0.000**	**0.277**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.22E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	1.41E-08	9.87E-08	0.00E+00	0.00E+00	9.87E-08
Benzo[a]anthracene	1.68E-08	1.93E-09	0.00E+00	0.00E+00	1.93E-09
Benzo[a]pyrene	1.68E-08	1.93E-07	0.00E+00	0.00E+00	1.93E-07
Benzo[b]fluoranthene	3.37E-08	1.16E-07	0.00E+00	0.00E+00	1.16E-07
Chrysene	2.04E-08	2.35E-09	0.00E+00	0.00E+00	2.35E-09
Dibenzo[a,h]anthracene	3.76E-09	4.32E-08	0.00E+00	0.00E+00	4.32E-08
Indeno[1,2,3,c,d]pyrene	1.02E-08	1.17E-09	0.00E+00	0.00E+00	1.17E-09
	Total	**4.58E-07**	**Total**	**0.00E+00**	**4.58E-07**

TABLE B-6
RISK ASSESSMENT FOR ALTERNATIVE 4

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control and Drainage Improvements**
- **Natural Clay Cover over Landfill**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	3.96E-04	6.95E-03	0.00E+00	0.00E+00	6.95E-03
Lead	3.10E-04	2.21E-01	0.00E+00	0.00E+00	2.21E-01
Mercury	1.16E-06	3.87E-03	0.00E+00	0.00E+00	3.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.241**	**Total**	**0.000**	**0.241**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.23E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	9.39E-10	6.57E-09	0.00E+00	0.00E+00	6.57E-09
Benzo[a]anthracene	2.08E-09	2.39E-10	0.00E+00	0.00E+00	2.39E-10
Benzo[a]pyrene	1.96E-09	2.25E-08	0.00E+00	0.00E+00	2.25E-08
Benzo[b]fluoranthene	3.76E-09	1.30E-08	0.00E+00	0.00E+00	1.30E-08
Chrysene	2.70E-09	3.11E-10	0.00E+00	0.00E+00	3.11E-10
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	1.02E-09	1.17E-10	0.00E+00	0.00E+00	1.17E-10
	Total	**4.38E-08**	**Total**	**0.00E+00**	**4.38E-08**

TABLE B-7
RISK ASSESSMENT FOR ALTERNATIVE 5

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control and Drainage Improvements**
- **Natural Clay Cover over Landfill**
- **Gas Venting System**
- **Leachate Collection System**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	3.96E-04	6.95E-03	0.00E+00	0.00E+00	6.95E-03
Lead	3.10E-04	2.21E-01	0.00E+00	0.00E+00	2.21E-01
Mercury	1.16E-06	3.87E-03	0.00E+00	0.00E+00	3.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.100	**Total**	**0.241**	**Total**	**0.000**	**0.241**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.23E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	9.39E-10	6.57E-09	0.00E+00	0.00E+00	6.57E-09
Benzo[a]anthracene	2.08E-09	2.39E-10	0.00E+00	0.00E+00	2.39E-10
Benzo[a]pyrene	1.96E-09	2.25E-08	0.00E+00	0.00E+00	2.25E-08
Benzo[b]fluoranthene	3.76E-09	1.30E-08	0.00E+00	0.00E+00	1.30E-08
Chrysene	2.70E-09	3.11E-10	0.00E+00	0.00E+00	3.11E-10
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	1.02E-09	1.17E-10	0.00E+00	0.00E+00	1.17E-10
	Total	**4.38E-08**	**Total**	**0.00E+00**	**4.38E-08**

TABLE B-8
RISK ASSESSMENT FOR ALTERNATIVE 6

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Natural Clay Cover over Landfill**
- **Gas Venting System**
- **Leachate Collection System**
- **Flood Protection Dike**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	3.96E-04	6.95E-03	0.00E+00	0.00E+00	6.95E-03
Lead	3.10E-04	2.21E-01	0.00E+00	0.00E+00	2.21E-01
Mercury	1.16E-06	3.87E-03	0.00E+00	0.00E+00	3.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.241**	**Total**	**0.000**	**0.241**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.23E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	9.39E-10	6.57E-09	0.00E+00	0.00E+00	6.57E-09
Benzo[a]anthracene	2.08E-09	2.39E-10	0.00E+00	0.00E+00	2.39E-10
Benzo[a]pyrene	1.96E-09	2.25E-08	0.00E+00	0.00E+00	2.25E-08
Benzo[b]fluoranthene	3.76E-09	1.30E-08	0.00E+00	0.00E+00	1.30E-08
Chrysene	2.70E-09	3.11E-10	0.00E+00	0.00E+00	3.11E-10
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	1.02E-09	1.17E-10	0.00E+00	0.00E+00	1.17E-10
	Total	**4.38E-08**	**Total**	**0.00E+00**	**4.38E-08**

TABLE B-9
RISK ASSESSMENT FOR ALTERNATIVE 7

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Drainage Improvements**
- **Gas Venting System**
- **Leachate Collection System**
- **Flood Protection Dike**
- **Synthetic Membrane Cap Over Landfill**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	3.96E-04	6.95E-03	0.00E+00	0.00E+00	6.95E-03
Lead	3.10E-04	2.21E-01	0.00E+00	0.00E+00	2.21E-01
Mercury	1.16E-06	3.87E-03	0.00E+00	0.00E+00	3.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.241**	**Total**	**0.000**	**0.241**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.23E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	9.39E-10	6.57E-09	0.00E+00	0.00E+00	6.57E-09
Benzo[a]anthracene	2.08E-09	2.39E-10	0.00E+00	0.00E+00	2.39E-10
Benzo[a]pyrene	1.96E-09	2.25E-08	0.00E+00	0.00E+00	2.25E-08
Benzo[b]fluoranthene	3.76E-09	1.30E-08	0.00E+00	0.00E+00	1.30E-08
Chrysene	2.70E-09	3.11E-10	0.00E+00	0.00E+00	3.11E-10
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	1.02E-09	1.17E-10	0.00E+00	0.00E+00	1.17E-10
	Total	**4.38E-08**	**Total**	**0.00E+00**	**4.38E-08**

TABLE B-10
RISK ASSESSMENT FOR ALTERNATIVE 8

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Erosion Control and Drainage Improvements**
- **Gas Venting System**
- **Leachate Collection System**
- **Synthetic Membrane Cap Over Landfill**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	3.96E-04	6.95E-03	0.00E+00	0.00E+00	6.95E-03
Lead	3.10E-04	2.21E-01	0.00E+00	0.00E+00	2.21E-01
Mercury	1.16E-06	3.87E-03	0.00E+00	0.00E+00	3.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.241**	**Total**	**0.000**	**0.241**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.23E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	9.39E-10	6.57E-09	0.00E+00	0.00E+00	6.57E-09
Benzo[a]anthracene	2.08E-09	2.39E-10	0.00E+00	0.00E+00	2.39E-10
Benzo[a]pyrene	1.96E-09	2.25E-08	0.00E+00	0.00E+00	2.25E-08
Benzo[b]fluoranthene	3.76E-09	1.30E-08	0.00E+00	0.00E+00	1.30E-08
Chrysene	2.70E-09	3.11E-10	0.00E+00	0.00E+00	3.11E-10
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	1.02E-09	1.17E-10	0.00E+00	0.00E+00	1.17E-10
	Total	**4.38E-08**	**Total**	**0.00E+00**	**4.38E-08**

TABLE B-11
RISK ASSESSMENT FOR ALTERNATIVE 9

- **Ground Water Monitoring**
- **Deed and Site Restrictions**
- **Management of Surface Debris**
- **Natural Clay Cover Over Landfill Top**
- **Local Repair to Landfill Side Slopes**
- **Erosion Control and Drainage Improvements**

Most Probable Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.000**	**Total**	**0.000**	**0.000**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCBs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[a]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo[b]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenzo[a,h]anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno[1,2,3,c,d]pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.00E+00**	**Total**	**0.00E+00**	**0.00E+00**

Worst Case

	Daily Dose	Hazard Index	Daily Dose	Hazard Index	Total Hazard Index
Barium	5.58E-04	9.79E-03	0.00E+00	0.00E+00	9.79E-03
Lead	3.58E-04	2.56E-01	0.00E+00	0.00E+00	2.56E-01
Mercury	8.60E-07	2.87E-03	0.00E+00	0.00E+00	2.87E-03
Chlordane	4.20E-07	8.40E-03	0.00E+00	0.00E+00	8.40E-03
4-methyl phenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	**0.277**	**Total**	**0.000**	**0.277**

	Chronic Intake	Carcinogenic Risk	Chronic Intake	Carcinogenic Risk	Carcinogenic Risk
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlordane	8.22E-10	1.07E-09	0.00E+00	0.00E+00	1.07E-09
PCBs	1.41E-08	9.87E-08	0.00E+00	0.00E+00	9.87E-08
Benzo[a]anthracene	1.68E-08	1.93E-09	0.00E+00	0.00E+00	1.93E-09
Benzo[a]pyrene	1.68E-08	1.93E-07	0.00E+00	0.00E+00	1.93E-07
Benzo[b]fluoranthene	3.37E-08	1.16E-07	0.00E+00	0.00E+00	1.16E-07
Chrysene	2.04E-08	2.35E-09	0.00E+00	0.00E+00	2.35E-09
Dibenzo[a,h]anthracene	3.76E-09	4.32E-08	0.00E+00	0.00E+00	4.32E-08
Indeno[1,2,3,c,d]pyrene	1.02E-08	1.17E-09	0.00E+00	0.00E+00	1.17E-09
	Total	**4.58E-07**	**Total**	**0.00E+00**	**4.58E-07**

TABLE B-12

MAXIMUM CONCENTRATIONS OF INDICATOR CHEMICALS IN EXPOSED SOILS FOR ALTERNATIVES 4, 5, 6, 7, AND 8

INDICATOR CHEMICAL	MAXIMUM CONCENTRATION (mg/kg)	LOCATION
Barium	198	S0-06
Lead	155	SO-44
Mercury	0.58	SO-43
Chlordane	0.21	SO-11
4-Methyl phenol	ND	-
Tetrachloroethane	ND	-
Benzene	ND	-
PCBs	0.24	SO-42
PAHs:		
Benzo[a]anthracene	0.53	SO-44
Benzo[a]pyrene	0.5	SO-44
Benzo[b]fluoranthene	0.96	SO-44
Chrysene	0.69	SO-44
Dibenzo[a,h]anthracene	ND	-
Indeno[1,2,3,c,d]pyrene	0.26	SO-44

ND: Contaminant not detected in soils to remain uncovered

Source: Endangerment Assessment

APPENDIX C

HYDROLOGICAL EVALUATION OF LANDFILL ALTERNATIVES PERFORMANCE MODEL

Alternatives involving a cover for the Bowers Landfill include the following four cases:

- Case 1 Existing cover (Alternatives 1 and 2)
- Case 2 Construction of a natural clay cover (Alternatives 4, 5, and 6)
- Case 3 Construction of a RCRA cap (Alternatives 7 and 8)
- Case 4 Construction of a natural clay cover on top of landfill and repair of side slopes (Alternative 9)

These cases were evaluated using The Hydraulic Evaluation of Landfill Performance (HELP) Version 1 written by Paul R. Schroeder of the Water Resources Engineering Group Environmental Laboratory, Vicksburg, Mississippi.

The HELP Model computer program is a quasi-two-dimensional hydrological model of water movement across, into, through, and out of landfills. The model accepts climatological, soil, and design data, and utilizes a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. Landfill systems including various combinations of vegetation, cover soils, waste cells, special drainage layers, and relatively impermeable barrier soils, as well as synthetic membrane covers and liners, may be modeled. The program was developed to facilitate rapid estimation of the amounts of runoff, drainage, and leachate that may be expected to result from the operation of a wide variety of landfill designs.

The system contains 22 types of soil with various characteristics that can be modified in the program to match the soil at a particular site. The system also contains precipitation information and runoff curves for various cities throughout the United States.

For the Bowers feasibility study, an analysis of the following cases was performed to show the relative performance of each proposed improvement. A summary of the

performance evaluation is presented in Table C-1. Tables C-2, C-3, C-4, and C-5 present the data input and results.

Climatological data for Columbus, Ohio (1974 through 1978) were used as precipitation input, since Columbus is the nearest city for which the program had information available.

CASE 1 (ALTERNATIVES 1 AND 2)

A preliminary site investigation of the existing cover soils and side slopes was performed. This involved measuring the depths of the cover soils with the use of a hand auger. The soil samples were classified by the means of laboratory tests and visual examinations. Laboratory tests used in this preliminary geotechnical investigation were the ASTM D-1140-54, Amount of Material in Soils Finer than the No. 200 Sieve, and a visual inspection. Samples collected at the locations shown on Drawing 15 indicated cover soil depths ranging from 8 inches to more than 2 feet. Due to the consistency of the cover material and the nature of this preliminary investigation, only two samples were analyzed with the ASTM D-1140-54. Results of the preliminary investigation are shown below:

Sample Number	Total Depth of Cover	Percent Finer Than a No. 200 Sieve (less than 0.08 mm)	Probable Soil Classification by Soil Conservation Service (SCS)	Location
1	2 ft	29.2	sandy loam	slope
2	1.5 ft	55.5	sandy loam, loam	slope
The remaining samples were visually analyzed:				
3	1.5 ft		sandy loam	slope
4	1.0 ft		sandy loam	top
5	8 in		sandy loam	top
6	1.0 ft		sandy loam	top
7	2.0 ft		sandy loam	slope
8	1.0 ft		sandy loam	top
9	1.5 ft		sandy loam	slope
10	1.5 ft		sandy loam	slope
11	1.5 ft		sandy loam	top
12	1.0 ft		sandy loam	slope

According to the Soil Conservation Service (SCS), the percent finer than a No. 200 sieve and the percent of silt and clay in the sample are approximately equivalent. SCS soil definitions are as follows:

> **Sandy loam** - Soil material that contains either 20 percent clay or less, and the percentage of silt plus twice the percentage of clay exceed 30, and 52 percent or more sand.
>
> **Loam** - Soil material that contains 7 to 27 percent clay, 28 to 50 percent silt and less than 52 percent sand.

Based upon this information, a 6-inch thickness was assumed for the cover on the landfill top, and a 12-inch thickness was assumed for the cover on the side slopes. A soil texture classification number 8, equivalent to a sandy loam, was used to represent the characteristics of the material. The percolation from base to cover was determined using a ratio of top cover to sides of 62 to 38 from Drawing 15. Based upon the site investigation, a maximum of 5 percent of the existing cover was assumed to be exposed; this number is assigned as unrestricted percolation.

The HELP model for the existing conditions yielded 45,665 cf/acre passing through the top cover (Table C-2) and 33,507 cf/acre passing through the side slopes, (Table C-3). Precipitation is 131,021 cf/acre. The following weighted equation was used to determine the percolation through the existing cover:

Case 1 (Alternative 1)

percolation = [(% of top cover) 45,665 + (% of side slopes) 33,507] x % covered + (% exposed) 131,021

= [(0.62) (44,665) + (0.38) (33,507)] x 0.95 + 0.05 x 131021

= 44,955 cf/acre

No estimate was made for Site Alternative 3 for percolation through the cover. It would, however, be less than Case 1, after removing the 5 percent allowance for unrestricted percolation. This further unquantified reduction would be due to the improvements in the cover.

CASE 2 (ALTERNATIVES 4, 5, AND 6)

The second cover alternative involves a two-layer cap, the first a vertical percolation (topsoil) layer, and the second, a barrier (clay) layer. The first layer was assumed to be topsoil from the surrounding fields, which is typically a silty clay material. Soil texture classification number 15 was used to represent the characteristics of the topsoil. The second layer was assumed to be the underlying clay material from the surrounding field. The barrier soil classification number 20 was modified to represent a 1×10^{-6} cm/sec permeability. A permeability of 1×10^{-6} cm/sec was assumed for the clay material based upon soil samples taken and statements made in Section 5.2.3 of the RI. (See Appendix E of the RI for permeability analyses performed on soil samples SO-8 and SO-9.) Each layer will be 24 inches thick.

The percolation through the cover was calculated to be 12, 841 cf/acre (Table C-4).

CASE 3 (ALTERNATIVES 7, 8)

The third alternative involves three layers, a vertical percolation (topsoil) layer, a granular drainage layer, and a barrier layer comprising a synthetic liner and 1×10^{-7} cm/sec permeability clay. All but the vertical percolation layer was assumed to be specified material from offsite sources. Pending results from the borrow investigation, clay material availability in the floodplain and its characteristics can be determined. The vertical percolation layer was assumed to be made up of 24 inches of the same silty clay as the previous case. The granular drainage layer would be 12 inches thick, with the underlying barrier soil 24 inches thick.

The percolation through the cover was calculated to be 9 cf/acre (Table C-5).

CASE 4 (ALTERNATIVE 9)

The fourth case involves a combination of Case 2 and estimates of the existing cover material on the side slopes as discussed in Case 1.

The HELP model result for percolation through the landfill top (Case 2) was 12,841 cf/acre, and the result for percolation through the side slopes (Case 1) was 33,507 cf/acre. The following weighted equation was used to determine the percolation through the cover:

Case 4 (Alternative 9) percolation = (% of clay cover) 12,841 cf/acre + (% of sides) 33,507cf/acre

$$= .62\ (12{,}841) + .38\ (33{,}507)$$

$$= 20{,}694 \text{ cf/acre}$$

TABLE C-1

HELP MODEL RESULTS

Case	Annual Precipitation (cf/acre)/inches	Percolation from Base of Cover (cf/acre)/inches	Percolation Passing Through Cover (percent)	Comparative Improvement by Case (percent)
1	131,021/36.1	44,955/12.4	34.3	---
2	131,021/36.1	12,841/3.5	9.8	24.5
3	131,021/36.1	9/0.002	0.01	34.29
4	131,021/36.1	20,694/5.7	15.8	18.5

Table C-2

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BOWER' S LANDFILL CASE 1 (TOP COVER)
CIRCLEVILLE, OHIO
11/29/88

****
****

FAIR GRASS

LAYER 1 Sandy Loam (8)

THICKNESS	=	6.00 inches
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2365 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0021600001492 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	68.71
TOTAL AREA OF COVER	=	43,560.00 SQ FT
EVAPORATIVE ZONE DEPTH	=	18.00 INCHES
UPPER LIMIT VER. STORAGE	=	2.7180 INCHES
INITIAL VEG. STORAGE	=	1.4413 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM

AVERAGE ANNUAL TOTALS FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)	(PERCENT)
PRECIPITATION	36.09	131021.	100.00
RUNOFF	0.012	45.	0.03
EVAPOTRANSPIRATION	23.564	85538.	65.29
PERCOLATION FROM LAYER 1	12.5798	45665.	34.85
CHANGE IN WATER STORAGE	-0.062	-227.	-0.17

Table C-2 Cont.

PEAK DAILY VALUES FOR YEARS 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	2.32	8421.6
RUNOFF	0.062	226.7
PERCOLATION FROM LAYER 1	1.8154	6589.9
SNOW WATER	1.49	5419.2

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3359
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0768

Table C-3

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BOWER' S LANDFILL CASE 1 (SIDE SLOPES)
CIRCLEVILLE, OHIO
11/29/88

****
****

FAIR GRASS

LAYER 1 Sandy Loam (8)

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2346 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0021600001492 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	68.71
TOTAL AREA OF COVER	=	43,560.00 SQ FT
EVAPORATIVE ZONE DEPTH	=	18.00 INCHES
UPPER LIMIT VER. STORAGE	=	5.4360 INCHES
INITIAL VEG. STORAGE	=	2.8420 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM

AVERAGE ANNUAL TOTALS FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)	(PERCENT)
PRECIPITATION	36.09	131021.	100.00
RUNOFF	0.018	66.	0.05
EVAPOTRANSPIRATION	26.936	97777.	74.63
PERCOLATION FROM LAYER 1	9.2306	33507.	25.57
CHANGE IN WATER STORAGE	-0.091	-329.	-0.25

Table C-3 Cont.

PEAK DAILY VALUES FOR YEARS 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	2.32	8421.6
RUNOFF	0.091	329.9
PERCOLATION FROM LAYER 1	1.7563	6375.4
SNOW WATER	1.49	5416.3

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3289
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0812

Table C-4

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BOWER' S LANDFILL IMPROVEMENTS CASE 2
CIRCLEVILLE, OHIO
7/25/88

****
****

GOOD GRASS

LAYER 1 SILTY CLAY TOPSOIL LAYER (15)

VERTICAL PERCOLATION LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	4.200 MM/DAY**0.5
POROSITY	=	0.5880 VOL/VOL
FIELD CAPACITY	=	0.5040 VOL/VOL
WILTING POINT	=	0.3550 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	0.17219996 INCHES/HR

LAYER 2 CLAY SOIL LAYER OF 1 X 10-6

BARRIER SOIL LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	3.100 MM/DAY**0.05
POROSITY	=	0.5200 VOL/VOL
FIELD CAPACITY	=	0.4800 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	0.00142000 INCHES/HR

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	81.43
TOTAL AREA OF COVER	=	43560. SQ. FT.
EVAPORATIVE ZONE DEPTH	=	18.00 INCHES
EFFECTIVE EVAPORATION COEFFICIENT	=	4.200 MM/DAY**0.5
UPPER LIMIT VEG. STORAGE	=	10.5840 INCHES
INITIAL VEG. STORAGE	=	7.7310 INCHES

CLIMATOLOGIC DATA FOR COLUMBUS, OHIO

Table C-4 Cont.

AVERAGE ANNUAL TOTALS FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)	(PERCENT)
PRECIPITATION	36.09	131019.	100.00
RUNOFF	1.832	6649.	5.07
EVAPOTRANSPIRATION	30.436	110483.	84.33
PERCOLATION FROM BASE OF COVER	3.5375	12841.	9.80
DRAINAGE FROM BASE OF COVER	0.0	0.	0.0

PEAK DAILY VALUES FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	2.32	8421.6
RUNOFF	1.213	4402.2
PERCOLAITON FROM BASE OF COVER	0.0816	296.3
DRAINAGE FROM BASE OF COVER	0.0	0.0
HEAD ON BASE OF COVER	23.8	
SNOW WATER	5.00	18165.2
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.5880	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.3550	

Table C-5

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BOWER' S LANDFILL IMPROVEMENTS CASE 3
CIRCLEVILLE, OHIO
7/25/88

****
****

GOOD GRASS

LAYER 1 SILTY CLAY TOPSOIL LAYER (15)

VERTICAL PERCOLATION LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	4.200 MM/DAY**0.5
POROSITY	=	0.5880 VOL/VOL
FIELD CAPACITY	=	0.5040 VOL/VOL
WILTING POINT	=	0.3550 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	0.17219996 INCHES/HR

LAYER 2 GRANULAR MATERIAL 1 X 10-3

LATERAL DRAINAGE LAYER		
SLOPE	=	4.00 PERCENT
DRAINAGE LENGTH	=	150.0 FEET
THICKNESS	=	12.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	0.3760 VOL/VOL
FIELD CAPACITY	=	0.2180 VOL/VOL
WILTING POINT	=	0.1310 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	7.09000015 INCHES/HR

LAYER 3 CLAY LAYER WITH SYNTHETIC MEMBRANE

BARRIER SOIL LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	3.100 MM/DAY**0.05
POROSITY	=	0.5200 VOL/VOL
FIELD CAPACITY	=	0.4500 VOL/VOL
WILTING POINT	=	0.3600 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	0.00014200 INCHES/HR

Table C-5 Cont.

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	81.43
TOTAL AREA OF COVER	=	43560. SQ. FT.
EVAPORATIVE ZONE DEPTH	=	18.00 INCHES
LINER LEAKAGE FRACTION	=	0.002000
EFFECTIVE EVAPORATION COEFFICIENT	=	4.200 MM/DAY**0.5
UPPER LIMIT VEG. STORAGE	=	10.5840 INCHES
INITIAL VEG. STORAGE	=	7.7310 INCHES

CLIMATOLOGIC DATA FOR COLUMBUS, OHIO

AVERAGE ANNUAL TOTALS FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)	(PERCENT)
PRECIPITATION	36.09	131019.	100.00
RUNOFF	1.230	4465.	3.41
EVAPOTRANSPIRATION	30.364	110222.	84.13
PERCOLATION FROM BASE OF COVER	0.0025	9.	0.01
DRAINAGE FROM BASE OF COVER	4.169	15135.	11.55

PEAK DAILY VALUES FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	2.32	8421.6
RUNOFF	0.932	3384.8
PERCOLAITON FROM BASE OF COVER	0.0001	0.3
DRAINAGE FROM BASE OF COVER	0.108	391.0
HEAD ON BASE OF COVER	32.7	
SNOW WATER	5.00	18165.2

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.5735
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.3550

APPENDIX D

SLOPE STABILITY ANALYSIS

1.0 PRELIMINARY STABILITY ANALYSIS OF SIDE SLOPES

In the following paragraphs, preliminary stability analyses are presented for the landfill side slopes. Two cases are considered. In the first, the stability of the existing side slopes are evaluated after repair, and in the second, the landfill side slopes are evaluated after installation of a clay cover. These cases can be summarized as follows:

- Case 1, existing side slopes after repair (Site Alternatives 3 and 9)

- Case 2, improved side slopes with clay cover (Site Alternatives 4, 5, 6, 7, and 8)

Calculations presented in this appendix are preliminary and reflect current estimates of soil parameters and slope data. Changes to the estimate may cause the design slopes to be flatter or steeper to meet the stability requirements discussed below.

1.1 CASE 1, EXISTING SIDE SLOPES AFTER REPAIR (SITE ALTERNATIVES 3 AND 9)

A preliminary analysis of the stability of the side slopes around the Bowers Landfill after repair is shown in the following stability calculations. The calculated minimum factor of safety against failure was 1.5, which equals the recommended[1] factor of safety of 1.5 (for non-seismic conditions where the uncertainty of soil strength measurements is large and there is no imminent danger to human life). Therefore, based on this analysis, the slope is considered adequate.

Soil information for the analysis was based on soil samples collected from the side slopes (as discussed in Appendix C). The material was characterized as a sandy loam. The soil parameters--unit weight, cohesion, and friction angle--were estimated based on

1 United States Environmental Protection Agency, *Permit Applicants' Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities; final Draft*, May, 1984, EPA 530 sw-84-004).

published literature[2] for compacted sandy loam. The values obtained from published literature were reduced to account for the lower-strength refuse which lies beneath the sandy loam cover material. The soil parameters assumed are significantly lower than minimum values generally assigned to mineral soil, and are considered to adequately represent the strength characteristics of the landfill cover and materials for this preliminary analysis. Prior to final design, a geotechnical investigation should be performed to quantify the strength characteristics of the existing soil. The investigation may involve field sampling, laboratory testing, in-situ strength tests, and/or estimating soil parameters by comparison with parameters established for similar soil. The strength from tree roots was neglected.

The slope configuration was based upon the existing topographic map (Drawing 15) and the landfill cross section (Drawing 16). These drawings show that the most critical slope from the edge of the landfill cover is 2 to 1 (horizontal to vertical) over a vertical height of 7 feet. There currently are steeper sections of the side slopes, but these will be improved to a 2 to 1 slope or flatter. Similarly, there are sections of the side slopes which are higher than 7 feet. However, these sections have significantly flatter slopes than 2:1, therefore they were not considered to be as critical as the slope analyzed.

The stability of the landfill side slopes was estimated using the Spencer method described in *Foundation Engineering Handbook,* (Winterkorn, H.F. and Fang, H.Y., von Nostrand Reinhold Co., 1975, p. 363-364). The Spencer method assumes a cylindrical failure surface, and divides the earth mass inside the failure surface into small vertical slices. This method satisfies equilibrium equations for forces and moments. It was chosen because it analyzes the slope on the basis of effective stress which is applicable to slopes which have been in place for more than a few months. The analysis was performed for the estimated critical side slope, depicted in Section A on Drawing 15, and assumed the following:

1. The critical side slope is 7 feet high and is sloped at approximately 27 degrees (2 horizontal to 1 vertical). This height was determined based upon a review of topographic data at the landfill, as shown on Drawing 15.

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2 *Foundations and Earth Structures, Design Manual 7.2,* Naval Facility Engineering Command (NAVFAC), May, 1982, p. 7.2-39.

2. The potential stabilizing effect of existing vegetation is ignored.

3. Worst-case stability conditions assume the slope is fully saturated (i.e., such as following an extended flood event) and water has drained from the floodplain. This corresponds to a pore pressure ratio (r_u) of approximately 0.5. Pore pressures in excess of this amount are not expected to develop because they will dissipate as the floodwaters slowly recede. Normal stability conditions assume a dry slope, r_u=0.0.

4. As previously described, existing landfill cover and materials are estimated to have the following physical properties:

   Total unit weight (g), 125 pounds per cubic foot
   Effective cohesion (c'), 125 pounds per square foot
   Effective friction angle (ø'), 20°

5. The landfill subgrade is assumed to be native, undisturbed, mineral soil having similar, or better, shear strength characteristics (ø, c) than the existing landfill cover and materials.

Normal Conditions

Estimate stability under dry conditions (r_u = 0.0) from Figure 10.13, *Foundation Engineering Handbook* (Winterkorn and Fang, p. 364).

$$F = C^1/N_s\, g\, H$$

Where:

F	=	Factor Of Safety
C^1	=	Effective Cohesion = 125 psf
N_s	=	Stability Factor
g	=	Unit Weight Of Soil = 125 pcf
H	=	Height of Slope = 7 feet

Assume F = 2.0

$$\phi^1 m = \tan^{-1}\left(\frac{\tan \phi^1}{F}\right)$$

Where: $\phi^1 m$ = Mobilized Friction Angle

ϕ^1 = Effective Friction Angle = 20°

$$\phi^1 m = \tan^{-1}\left(\frac{\tan 20^\circ}{2.0}\right) = 10^\circ$$

From Figure 10.13 with a 2:1 slope

Ns = 0.066

$$F = \frac{C^1}{N_s g H} = \frac{125 \text{ psf}}{(0.066)(125\text{pcf})(7\text{ft})} = 2.2 \text{ Close to 2.0 (assumed)}$$

F = 2.0

Worst Case Conditions

Estimate stability under fully saturated conditions (r_u = 0.5) from Figure 10.13, *Foundation Engineering Handbook* (Winterkorn and Fang, p. 364).

Assume F = 1.5

$$\phi^1 m = \tan^{-1}\left(\frac{\tan 20^\circ}{1.5}\right) = 14^\circ$$

From Figure 10.13, 2:1 Slope

Ns = 0.093

$$F = \frac{C^1}{N_s g H} = \frac{125 \text{ psf}}{(0.093)(125\text{pcf})(7\text{ ft})} = 1.5 \quad \text{Same as 1.5 (assumed)}$$

F = 1.5

1.2 CASE 2, IMPROVED SIDE SLOPES WITH CLAY COVER (SITE ALTERNATIVES 4, 5, 6, 7, AND 8)

A preliminary analysis of the stability of the final cover slopes is shown in the following stability calculations. The preliminary analysis of Case 1 was modified to reflect an increased slope height of 12 feet and different soil conditions. The slope configuration was based upon the existing topography map (Drawing 15) and the landfill cross section after improvement (Drawing 17). The physical properties--unit weight, cohesion, and friction angle--of the final cover soil were estimated based on published literature[3] for compacted sandy loam. These values were not reduced to account for the lower-strength refuse, as they were in the analysis for Case 1, because the final cover soils comprise a significant portion of the completed slope. In addition, compaction efforts for the final cover soil is likely to increase the density of the existing materials in place, furthering strengthening the slope.

The calculated minimum factor of safety for the cover extended down a 2 to 1 slope is 2.8 under normal conditions, and 1.8 under fully saturated conditions (worst case condition following an extended period of flooding). These values exceed the recommended factor of safety of 1.5 (for non-seismic conditions where the uncertainty of soil strength measurements is large and there is no imminent danger to human life). Therefore, based on this analysis, the slope is considered adequate.

The following calculations present the slope stability analysis for 2 to 1 slopes:

2 TO 1 SLOPE STABILITY CALCULATION

Normal Conditions

Estimate stability under dry conditions (r_u = 0.0) from Figure 10.13, *Foundation*

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3 See Reference 2.

Engineering Handbook (Winterkorn and Fang, p. 364) use the following soil properties:

$$C^1 = 230 \text{ psf}$$

$$\phi^1 = 31^\circ$$

$$g = 125 \text{ pcf}$$

$$H = 12 \text{ ft}$$

Assume F = 3.0

$$\phi^1 m = \tan^{-1}\left(\frac{\tan 31^\circ}{3.0}\right) = 11^\circ$$

From Figure 10.13, 2:1 Slope

$$N_s = 0.060$$

$$F = \frac{C^1}{N_s g H} = \frac{230 \text{ psf}}{(0.060)(125 \text{ pcf})(12 \text{ ft}} = 2.9 \text{ Close to } 2.8$$

$$F = 2.8$$

Worst Case Condition

Estimate stability under fully saturated conditions ($r_u = 0.5$) from Figure 10.13, *Foundation Engineering Handbook* (Winterkorn and Fang, p. 364).

Assume F = 2.0

$$\phi^1 m = \tan^{-1}\left(\frac{\tan 31^\circ}{2.0}\right) = 17$$

From Figure 10.13, 2:1 Slope

$$N_s = 0.083$$

$$F = \frac{C^1}{N_s g H} = \frac{230 \text{ psf}}{(0.083)(125 \text{ pcf})(12 \text{ ft})} = 1.8 \text{ Close to } 2.0 \text{ (Assumed)}$$

$$F = 1.8$$

2.0 PRELIMINARY EROSION PROTECTION ANALYSIS

The landfill lies within the 100-year floodplain of the Scioto River, and flooding may erode the cover materials. The existing landfill cover has, however, successfully withstood numerous periodic flooding events, except at the tips of the landfill adjacent to the river. Additional protection could be provided to this cover by placing armour protection on exposed faces or by providing a flood protection dike to completely isolate the landfill from floodwaters.

No additional flood protection would be provided under Site Alternatives 1 and 2. Under Site Alternatives 3, 4, 5, 8, and 9, riprap would be provided on certain exposed areas of the landfill. Under Site Alternatives 6 and 7, the landfill would be protected by a flood control dike. In the following paragraphs, several design considerations are discussed that may dictate the use of riprap over certain areas of the landfill. These conditions address protection requirements for Site Alternatives 4, 5, and 8. Under these site alternatives, the natural erosion protection of the existing vegetative cover would be removed and replaced with a natural clay cap or a synthetic membrane cap, each overlain with a vegetated top cover.

Site Alternatives 3 and 9 are not addressed in the following discussion. Under both these site alternatives, the existing vegetative cover would remain on the side slopes, and erosion protection requirements are readily identified based upon current limited evidence of erosion after 20 years of exposure to flood events.

The primary consideration for erosion protection is to design the landfill structure to withstand the scouring effects of floodwaters during flood events. This scouring could be caused by the sweeping actions of the floodwaters against the landfill side slopes. For the landfill side slopes to resist the scouring effects of floodwaters, the water velocity at the side slopes must be low enough to prevent surface loss, or armour protection must be provided. This is determined by relating the flow to the permissible velocity, which will prevent erosion in a channel if maintained for a reasonable length of time. The maximum permissible velocity that is used in the design of grass surfaced slopes[4] is 6.0 ft/sec for Bermuda grass. This velocity is applicable where the water flow is parallel to the surface

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[4] USEPA, 1985. *Handbook Remedial Action at Waste Disposal Sites*

as is the case for floodwaters flowing beside the side slopes. This permissible velocity is that which will not cause damage exceeding normal maintenance from flood scouring actions.

2.1 PRELIMINARY DETERMINATION OF EROSION PROTECTION FROM SCOURING

Erosion protection requirements from scouring based on floodwater velocities relate to the velocities expected at the landfill and the maximum permissible velocity. A preliminary evaluation of flow parameters in the floodplain is necessary to estimate flow velocities at the landfill.

The 100 year flood elevation for the Scioto River in the vicinity of the site may be expected to be 672.8 feet, msl (recent unpublished data, U.S. Army Corps of Engineers, 1986). The floodplain geometry allows for a significant increase in the areal extent of the river (Drawing 18). Both sides of the river will flood. To the west of the river, the land will flood until constrained by the highway embankment; the land to the east of the river will flood until constrained by the esker. Floodwater will flow downstream across this area, around and, occasionally, over the landfill. The area of the floodplain at the vicinity of the site gradually reduces as the highway nears the bridge immediately to the south of the landfill.

Section XX[1] shown on Drawing 18 represents a typical cross section across the floodplain. Drawing 19 presents this section for the 100 year flood event. After allowing for a 4-foot thick cap over the existing landfill (equivalent to Site Alternatives 4, 5, and 8), the cross sectional area of the floodplain is calculated to be 26,800 square feet. This assumes the Scioto River is approximately 8 feet deep under normal conditions. The 100 year flow is 157,900 cubic feet per second (U.S. Army Corps of Engineers, 1986), and thus the average velocity across the section is 5.9 feet per second.

Flows at the periphery of an open channel are substantially lower than average values[5] . Thus, the velocity at the landfill at Section XX[1] is expected to be considerably below 5.9 feet per second. This is because of the presence of the large and irregular free

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[5] *Open Channel Hydraulics*, V.T. Chow, 1959, p.25

surface creating significant frictional effects in the shallow areas of water near the landfill. Typical curves of equal velocity in irregular channel sections show that velocities at the vicinity of the landfill surface may be approximately 50% of average velocities.[6]

These preliminary calculations for Section XX[1] indicate that average velocities at the landfill during the 100 year flood event are below the maximum permissible velocity. Furthermore, the surface velocities at the landfill may be approximately 50% of the maximum permissible velocity. For points on the landfill north/south leg, to the north of Section XX[1], velocities will be even lower, and erosion protection would not be required in this region for Site Alternatives 4, 5, and 8. For points south of Section XX[1], further calculations will be necessary during the remedial design phase to more closely estimate velocities and determine the extent of armour protection required.

At the northern end of the landfill, the landfill axis runs perpendicular to the floodwaters. During flood events, the waters will be diverted around the landfill and over the top, causing the potential scouring action, especially at the northwest corner of the landfill. Flow patterns and velocities will be complicated in this area, but velocities will not necessarily be greater than the average velocity for the entire flood event of 5.9 ft/sec, because the available area in the floodplain is increased (over Section XX[1]). Thus, for Site Alternatives 4, 5, and 8, armour protection is expected to be required at areas in the vicinity of the river. Further calculations will be necessary during the remedial design phase to more closely evaluate the need for armour protection.

2.2 ADDITIONAL EROSION PROTECTION CONSIDERATIONS

Wave action during flood events has the potential of creating erosive conditions.

Wave height is estimated from wind speed and the distance over water where wind speed and direction is relatively constant (fetch). The longest fetch, from the north is approximately 3,000 feet. The fastest wind speed with a recurrence interval of 50 years is 70 miles per hour[7]. Applying these factors in the following equation[8] gives a wave height (H) of 2 feet, 8 inches:

---

6 See Reference 5.

7 *The Ohio Basic Building Code*, Building Officials and Code Administrators International, Inc., 1982, p. 204.

$$H = 0.17\,(UF)^{0.5} + 2.5 - (F)^{0.25}$$

where U = wind speed (mph) = 70 mph

F = fetch, (miles) = $\frac{3000}{5280}$ = 0.568 miles

Substituting,

$$H = 0.17\,[70(0.568)]^{0.5} + 2.5 - (0.568)^{0.25}$$

$$H = 2.7 \text{ feet}$$

The above equation is based upon work carried out by the American Society of Civil Engineers in 1934 to determine wave height for inland lakes having a fetch of less than 20 miles. The values 0.17 and 0.25 are constants determined from this program.

This predicted wave height is modified down for several reasons. The waves are generated by blowing over shallow water. Therefore, the calculated wave height is not expected to be reached because of frictional effects from the floodplain. In addition, the likelihood of the design wind occurring at the critical flood stage is small. Finally, fetch and wind velocity estimates are conservative.

The existing landfill cover shows no sign of erosion from wave action. This lack of evidence of erosion from wave action, together with its limited frequency (i.e. flood event, together with high winds) indicates that these conditions would not warrant additional erosion protection.

2.3 SUMMARY OF EROSION PROTECTION REQUIREMENTS FOR SITE ALTERNATIVES 4, 5, AND 8

In the following, erosion protection requirements for each landfill face are summarized. Drawing 18 denotes the areas discussed.

---

8 *Standard Handbook for Civil Engineers*, F. S. Merritt, 1976, p. 23-5

Landfill Tips

The portions of the landfill adjacent to the river at the northern and southern tips, currently show signs of erosion from flooding. These areas would be protected from erosion by riprap.

Northern Side Slope (Upstream Side)

The upstream side slopes of the northern face of the landfill would be exposed to erosive effects as the floodwaters are diverted by the berm. Average flows at this face may exceed the maximum permissible velocity in the vicinity of the river. Some riprap protection is expected to be required at areas in the vicinity of the river.

Northern Side Slope (Downstream Side)

The downstream side slopes of the northern face of the landfill would not be exposed to scouring effects of the floodwaters against the landfill. This is because velocities on this downstream side are expected to be protected from high floodwater velocities by the berm. This side my be exposed to the limited effect of occasional wave actions during periods where there is a combination of high wind and flooding. No riprap protection is recommended.

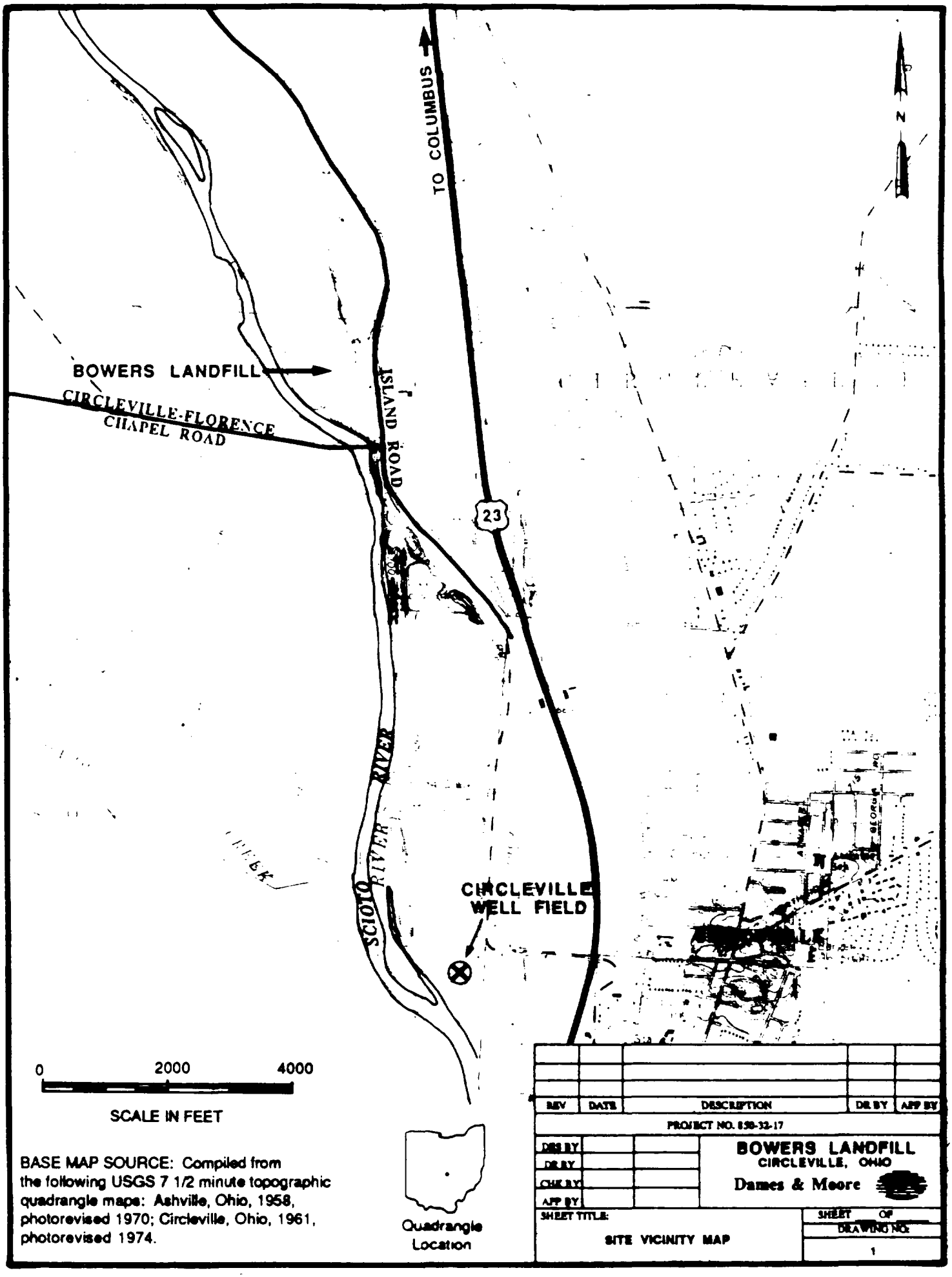
Western Side Slope

The western side slope of the main north/south region of the landfill is expected to be exposed to scouring effects and may also be exposed to occasional wave actions during flood events. Points south of Section XX[1] on Drawing 18 may require erosion protection. Further calculations will be necessary during the remedial design phase to more closely estimate velocities and determine the extent of protection required.

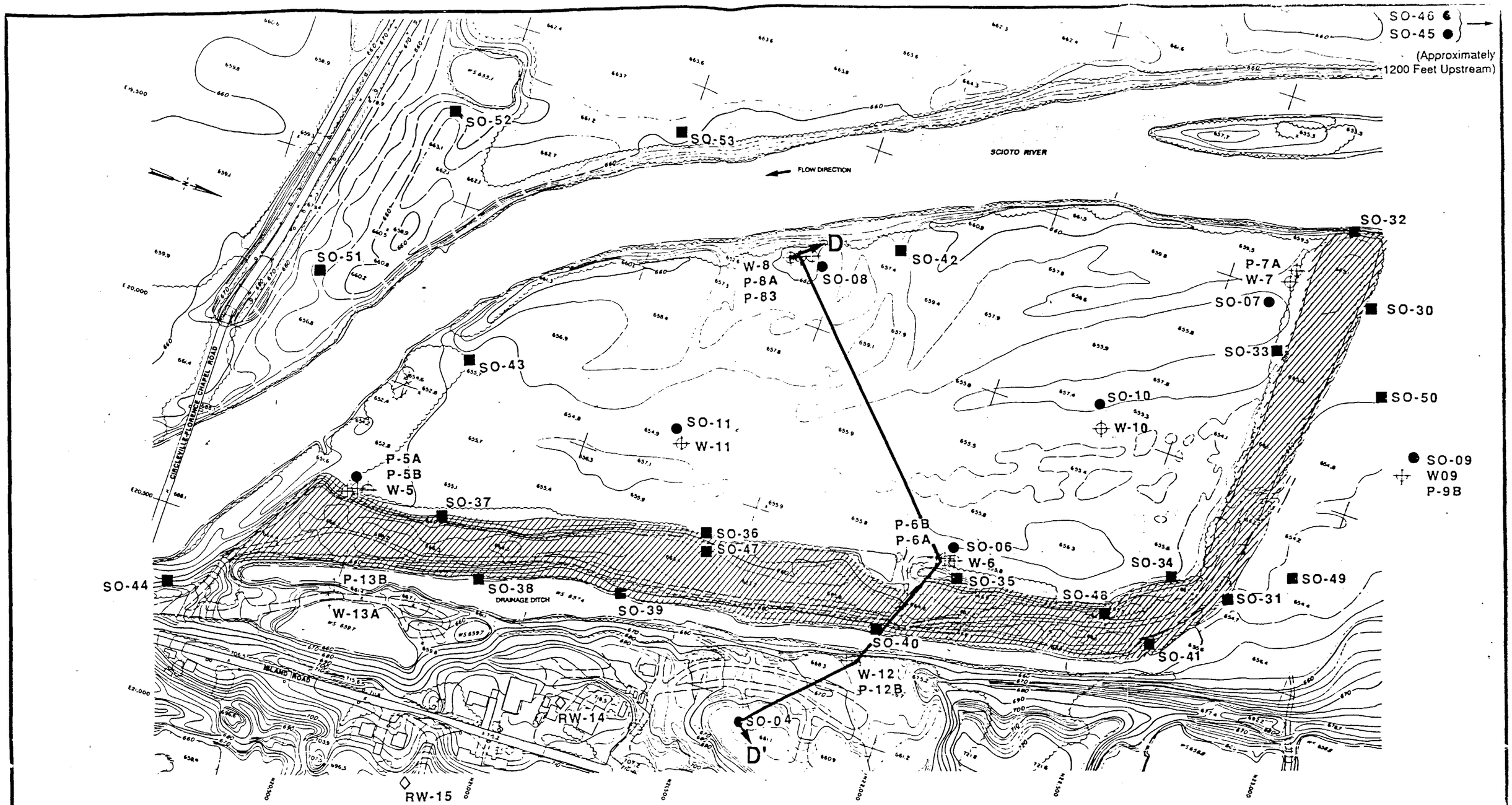
Eastern Side Slope

The eastern side slope of the main north/south region of the landfill is not expected to be exposed to either scouring effects or wave actions during minor flood events. This is because significant flow along this side slope is prevented by the banked area at the south

of the ditch that connects the landfill tip and the esker. During flooding, the ditch will fill as the flood stage rises, but outflow will be prevented by this banked area. Thus, it will not be possible for high channel flows to develop in the ditch while floodwaters are rising. Occasionally, the landfill will be overtopped, resulting in some potential for scouring. Velocities on the eastern side slope should, however, be lower than the western side because of its proximity to the edge of the floodplain. Frequency of occurrence should also be reduced because this situation would only occur at times when the landfill is overtopped. Furthermore, wave actions will not be a consideration because of the short fetch. Thus, riprap requirements are expected to be less than for the western side slope.



BASE MAP SOURCE: Compiled from the following USGS 7 1/2 minute topographic quadrangle maps: Ashville, Ohio, 1958, photorevised 1970; Circleville, Ohio, 1961, photorevised 1974.



LEGEND:

- EXISTING LANDFILL
- BORING/MONITORING WELL LOCATION
- RESIDENTIAL WELL LOCATION
- SOIL SAMPLE (SHELBY TUBE)
- SURFACE SOIL SAMPLE
- LINE OF CROSS SECTION (DRAWING 3)

W-4

0 300
SCALE IN FEET

CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984

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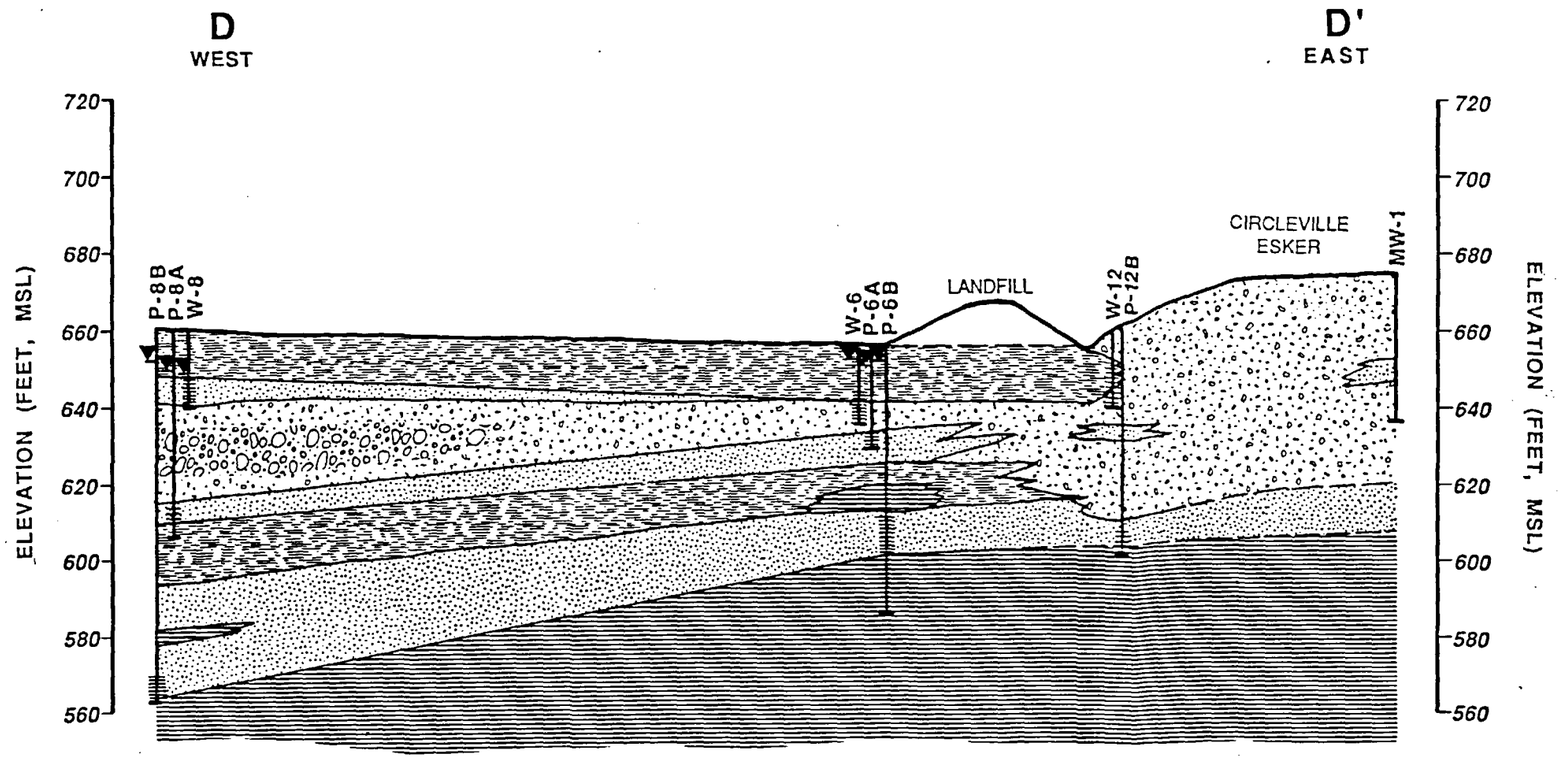
DES BY	W.W.	BOWERS LANDFILL
DR BY	A.G.	CIRCLEVILLE, OHIO
CHK BY		Dames & Moore
APP BY		

SHEET TITLE: SITE PLAN

SHEET ___ OF ___

DRAWING NO: 2



HYDROGEOLOGIC CROSS SECTION LEGEND:

- SILT AND CLAY
- SAND
- GRAVEL
- SAND AND GRAVEL
- SHALE
- UNIT CONTACT
- INFERRED UNIT CONTACT
- W-6 BORING/MONITORING WELL LOCATION WITH CORRESPONDING WATER LEVEL, SCREEN INTERVAL, AND BORING DEPTH

NOTES:

- The depth and thickness of the soil strata indicated on the subsurface section were obtained by interpolating between test borings. Information on actual subsurface conditions exists only at the locations of the test borings and it is possible that conditions may vary from those indicated.
- For location of cross section, see Drawing 2
- Water levels measured on 3/12/87.

40
0
0 200
SCALE IN FEET
VERTICAL EXAGGERATION=5x

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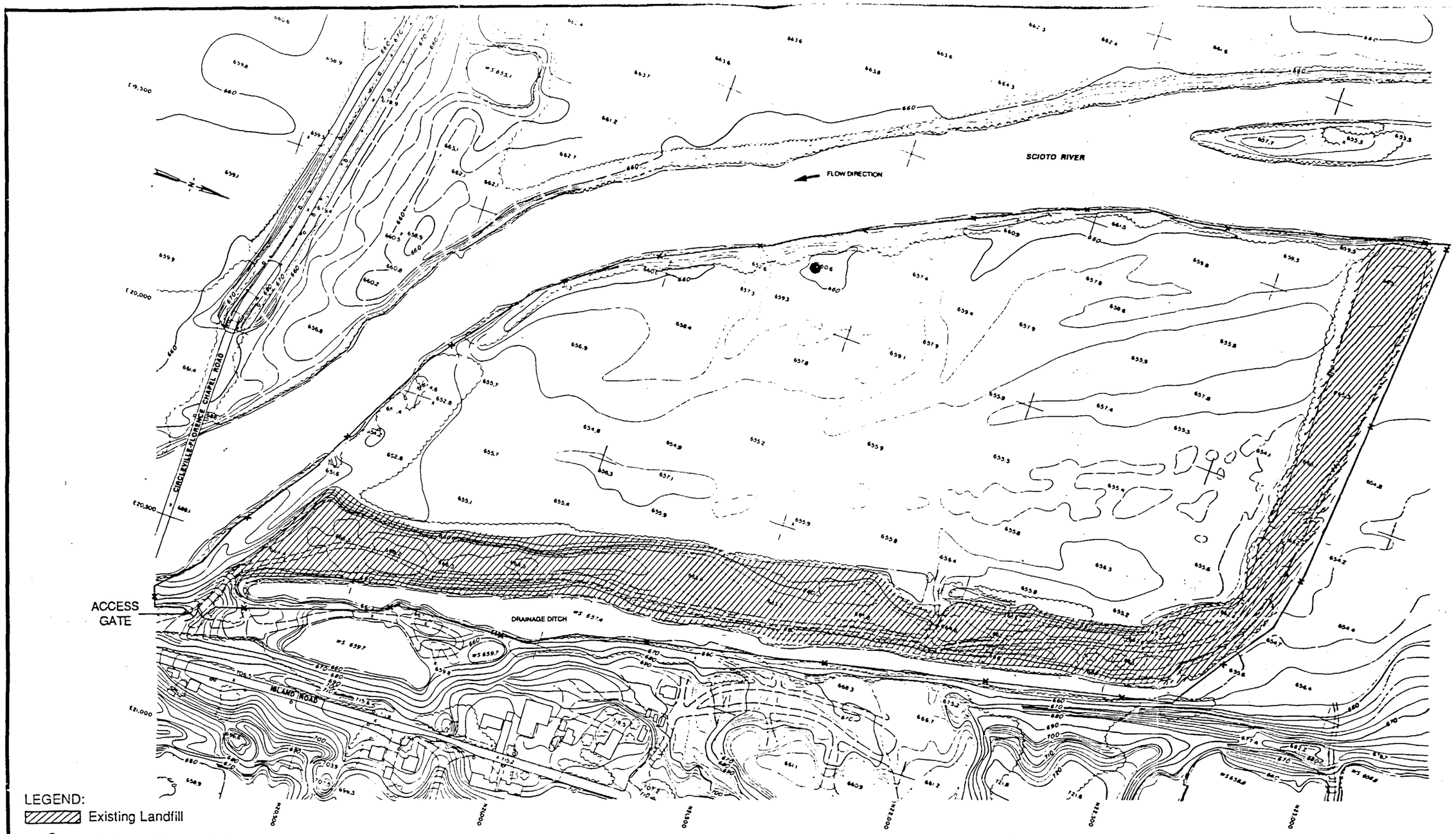
SHEET TITLE:
HYDROGEOLOGIC CROSS-SECTION D-D'

SHEET ___ OF ___
DRAWING NO: 3



LEGEND:

- Existing Landfill
- Monitoring Well (typical)
- Perimeter Fence

SITE ALTERNATIVE 2:

- Ground Water Monitoring
- Deed and Site Restrictions

0 300
SCALE IN FEET

CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984

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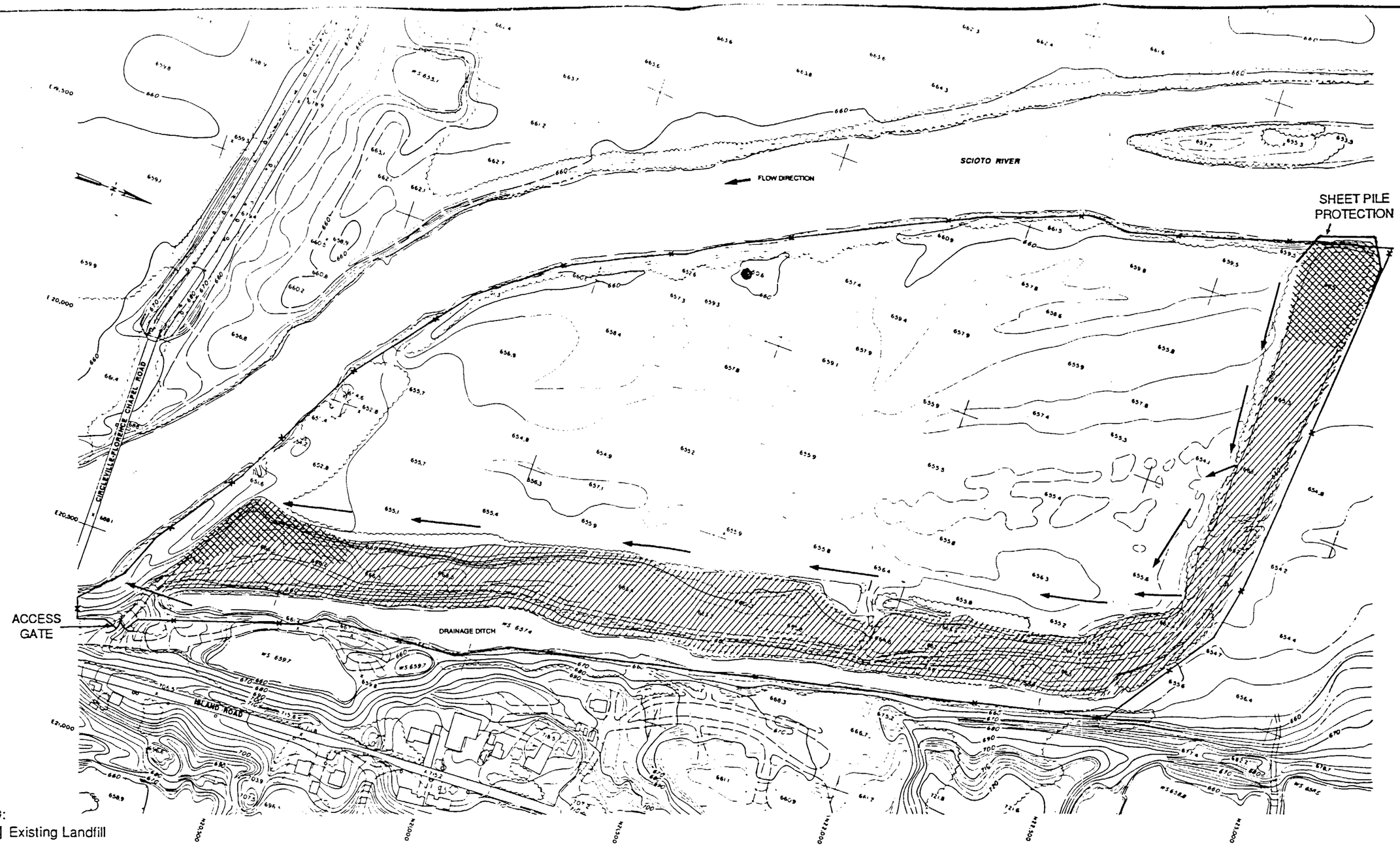
SHEET TITLE: SITE ALTERNATIVE 2

SHEET ___ OF ___
DRAWING NO: 4



LEGEND:

- Existing Landfill
- Monitoring Well (typical)
- Perimeter Fence
- Rip-Rap
- Drainage Improvement

SITE ALTERNATIVE 3:

- Ground Water Monitoring
- Deed and Site Restrictions
- Removal of Visible Landfill Waste
- Local Repair to Existing Landfill Cover
- Erosion Control and Drainage Improvements

0 300
SCALE IN FEET

CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984

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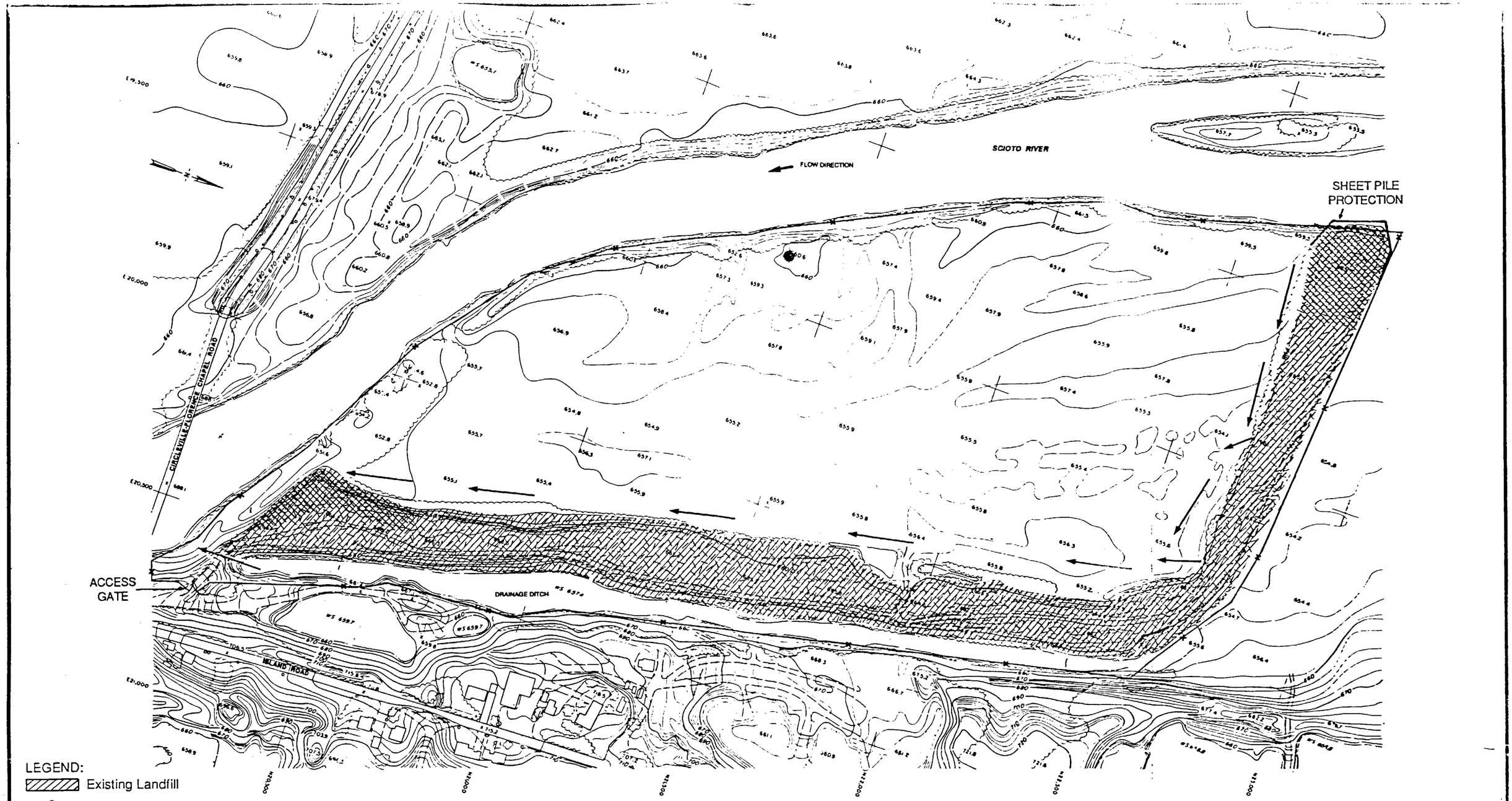
SHEET TITLE: SITE ALTERNATIVE 3

SHEET ___ OF ___
DRAWING NO: 5


SCIOTO RIVER
FLOW DIRECTION
SHEET PILE PROTECTION
ACCESS GATE
DRAINAGE DITCH
CIRCLEVILLE-FLORENCE CHAPEL ROAD
HILLIARD ROAD
LEGEND:
Existing Landfill
Monitoring Well (typical)
Perimeter Fence
Rip-Rap
Drainage Improvement
Natural Clay Cover
SITE ALTERNATIVE 4:
• Ground Water Monitoring
• Deed and Site Restrictions
• Management of Surface Debris
• Erosion Control and Drainage Improvements
• Natural Clay Cover Over Landfill
0 300
SCALE IN FEET
CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984
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DES BY
DR BY
CHK BY
APP BY
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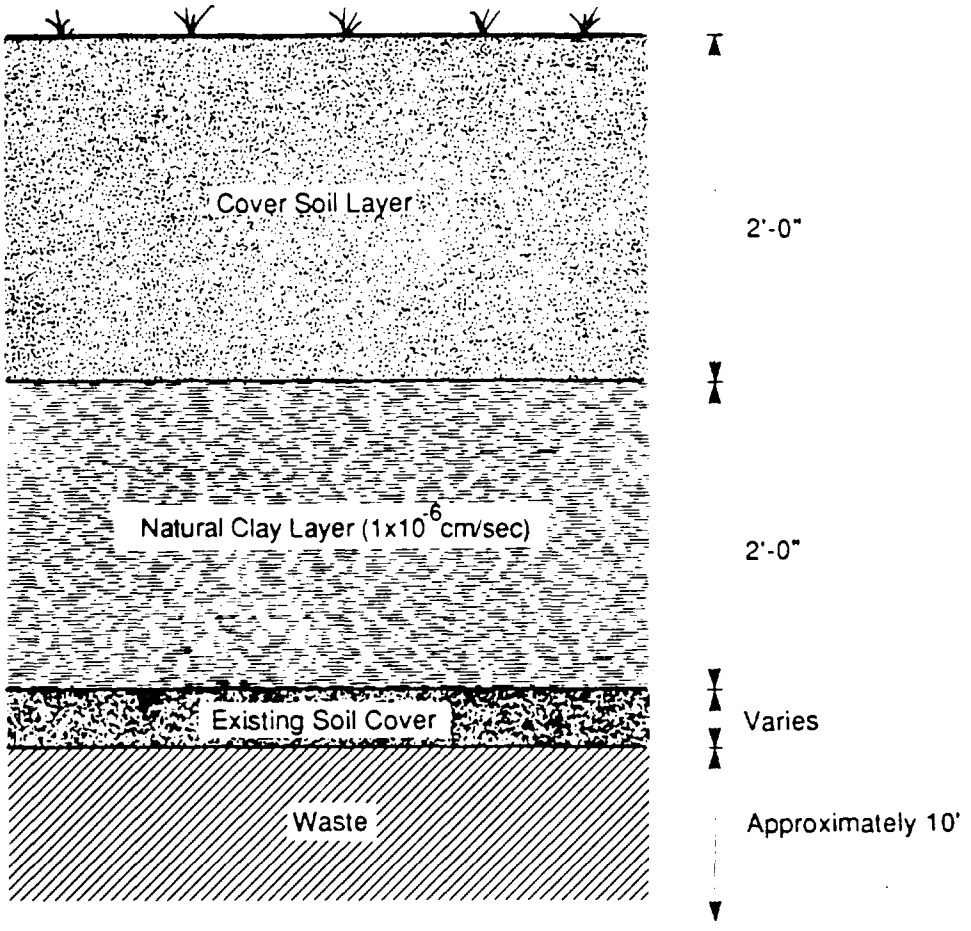
SHEET TITLE:
SITE ALTERNATIVE 4
SHEET ___ OF ___
DRAWING NO.
6



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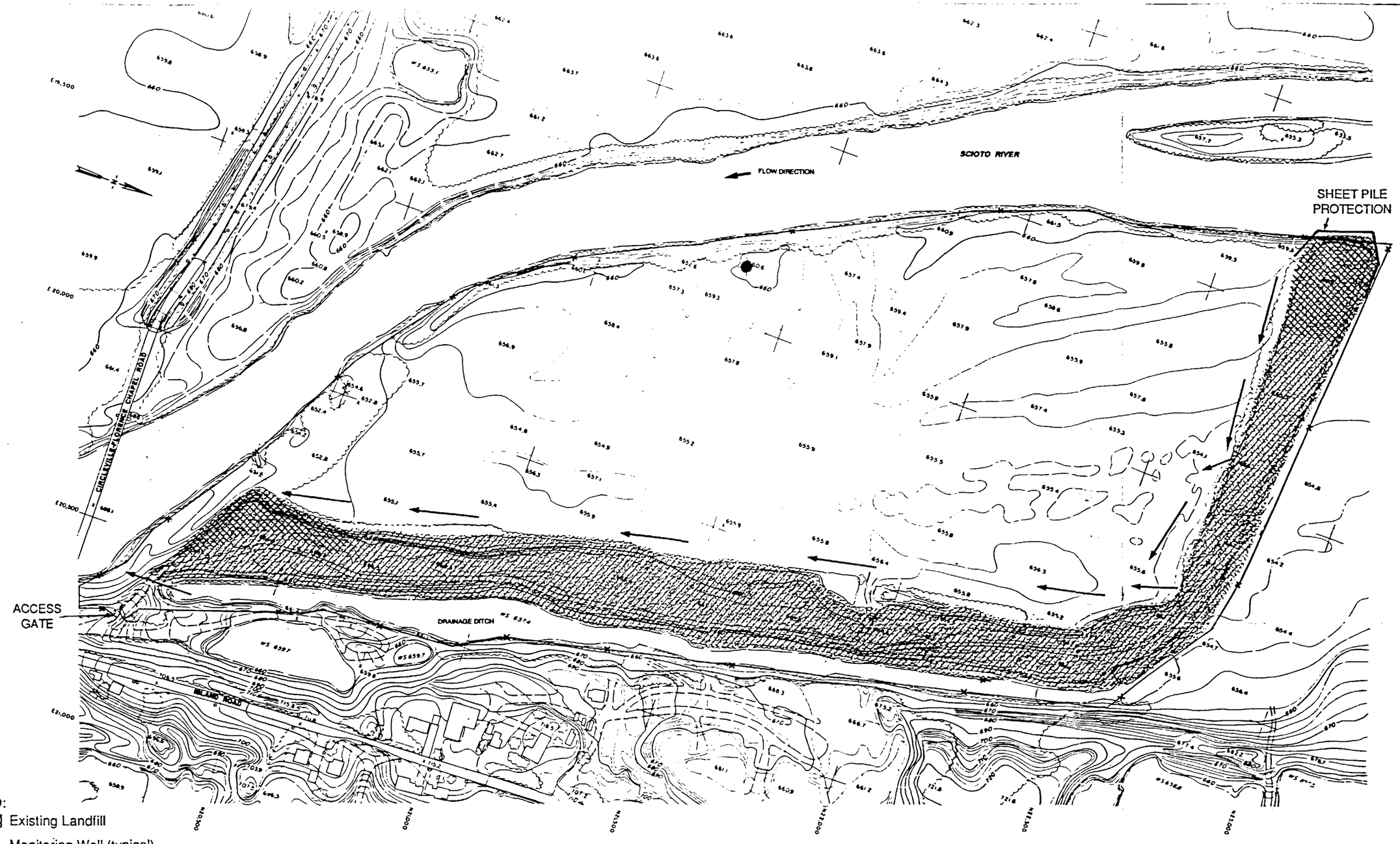
SHEET TITLE:
DETAIL OF NATURAL CLAY COVER

SHEET ___ OF ___

DRAWING NO:
7



LEGEND:

- Existing Landfill
- Monitoring Well (typical)
- Perimeter Fence
- Rip-Rap
- Drainage Improvement
- Natural Clay Cover With Gas Venting System and Leachate Collection System

SITE ALTERNATIVE 5:

- Ground Water Monitoring
- Deed and Site Restrictions
- Management of Surface Debris
- Erosion Control and Drainage Improvements
- Construct Natural Clay Cover Over Landfill
- Install Gas Venting System
- Install Leachate Collection System

0 300
SCALE IN FEET

CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984

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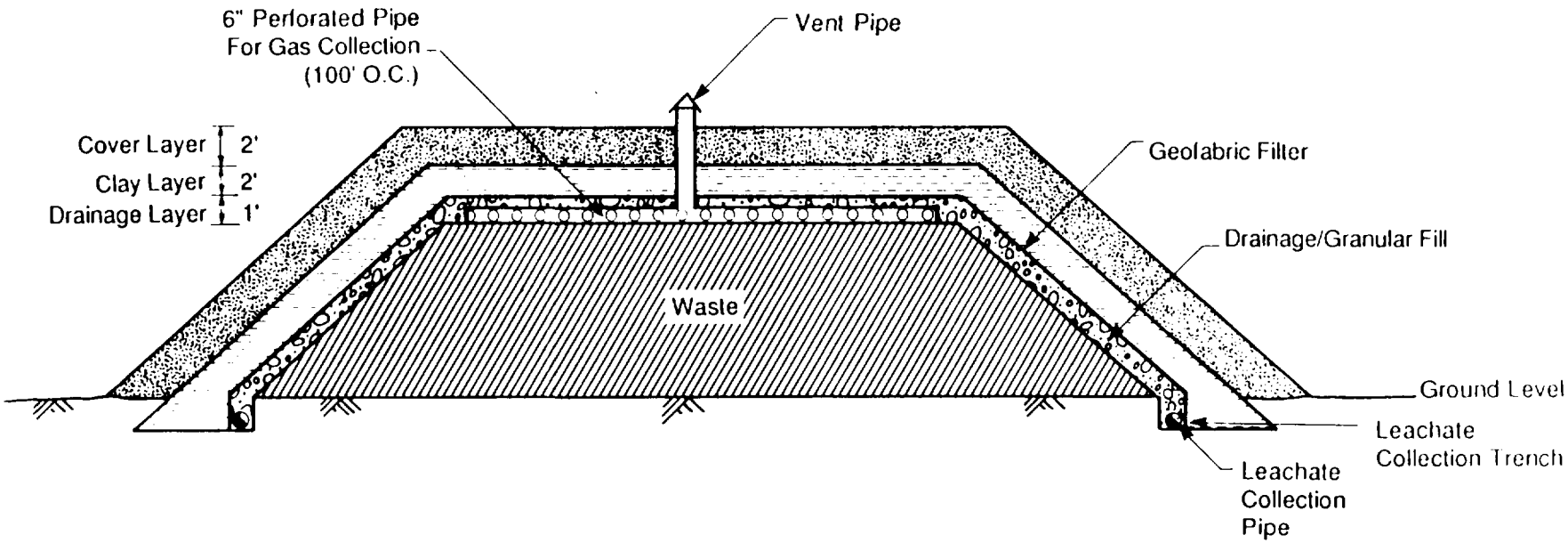
SHEET TITLE:
SITE ALTERNATIVE 5

SHEET ___ OF ___
DRAWING NO: 8



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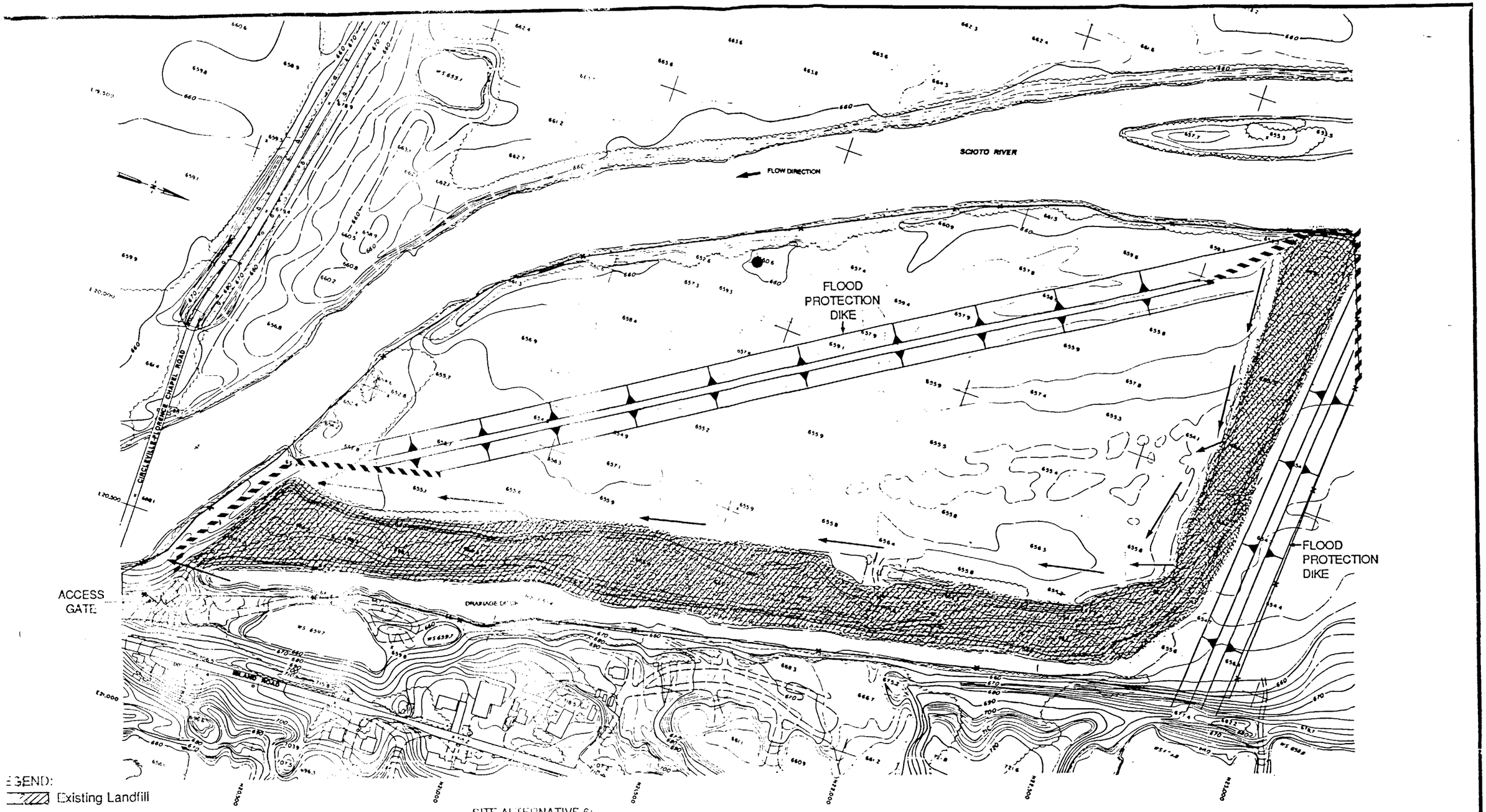
SHEET TITLE: TYPICAL CROSS-SECTION OF LANDFILL WITH CLAY CAP AND LEACHATE COLLECTION SYSTEM AND GAS VENTING SYSTEM

SHEET OF

DRAWING NO

9



LEGEND:

- Existing Landfill
- Monitoring Well (typical)
- Perimeter Fence
- Drainage Improvement
- Natural Clay Cover With Gas Venting System and Leachate Collection System
- Concrete Floodwall

SITE ALTERNATIVE 6:

- Ground Water Monitoring
- Deed and Site Restrictions
- Management of Surface Debris
- Drainage Improvements
- Construct Natural Clay Cover Over Landfill With Gas Venting System and Leachate Collection System
- Construct Flood Protection Dike

0 300
SCALE IN FEET

CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984

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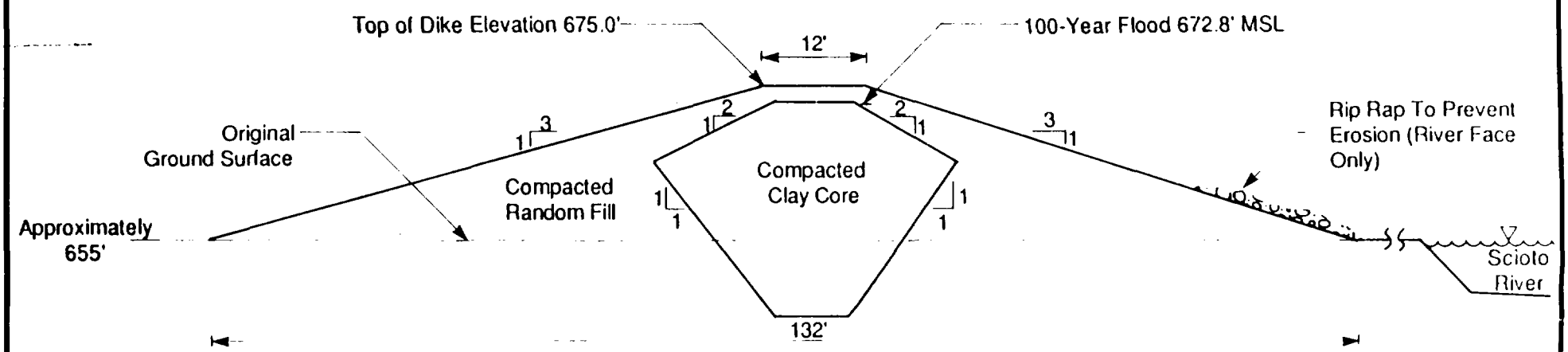
SHEET TITLE: SITE ALTERNATIVE 6

SHEET OF
DRAWING NO: 10



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DES BY
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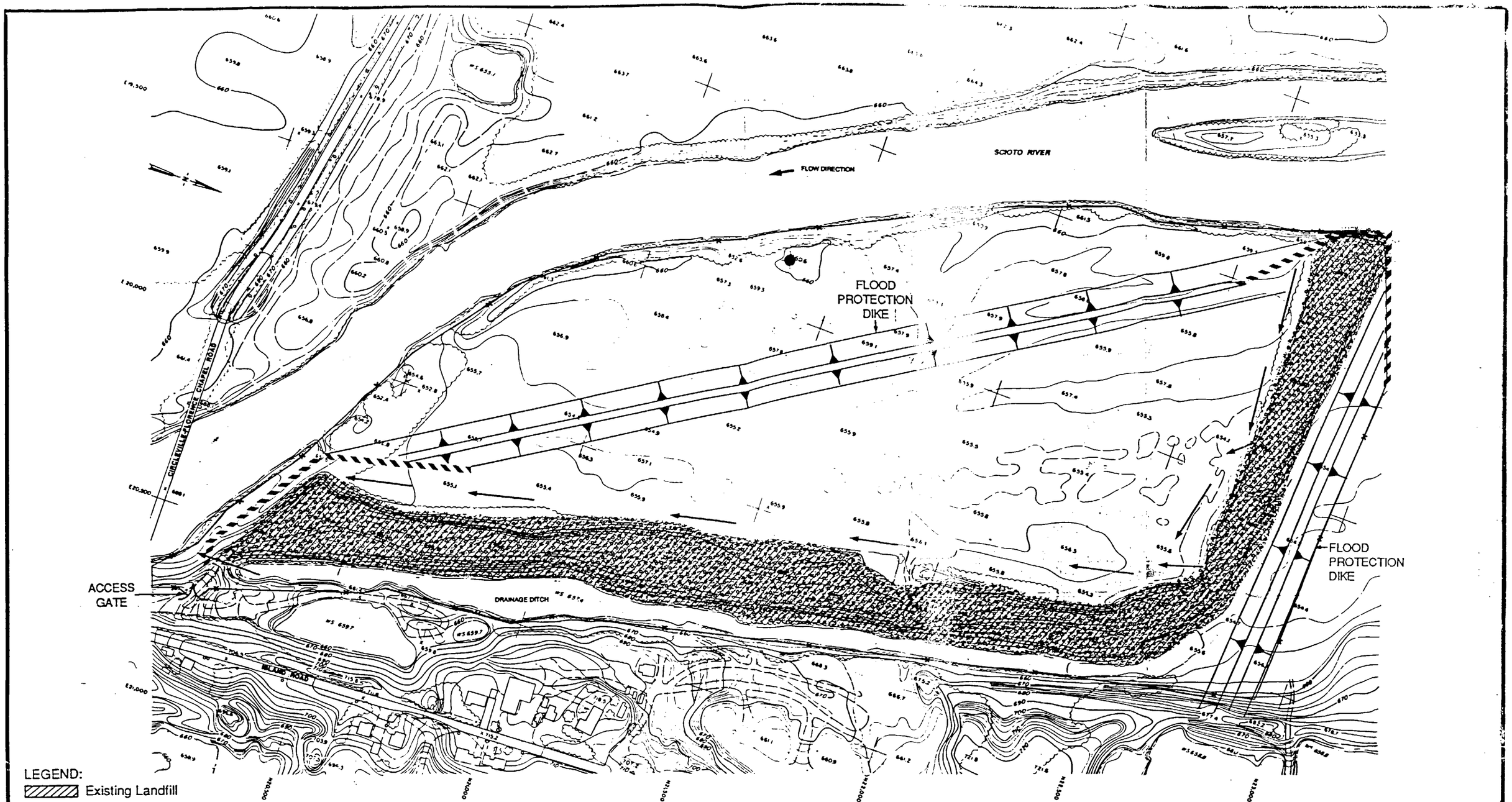
SHEET TITLE:
CROSS-SECTION OF THE
FLOOD PROTECTION DIKE

SHEET OF

DRAWING NO

11



LEGEND:

- Existing Landfill
- Monitoring Well (typical)
- Perimeter Fence
- Drainage Improvement
- Synthetic Membrane Cap Over Landfill with Gas Venting System and Leachate Collection System
- Concrete Floodwall

SITE ALTERNATIVE 7:

- Ground Water Monitoring
- Deed and Site Restrictions
- Management of Surface Debris
- Drainage Improvements
- Gas Venting System
- Leachate Collection System
- Flood Protection Dike
- Construct Synthetic Membrane Cap Over Landfill

0 300
SCALE IN FEET

CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984

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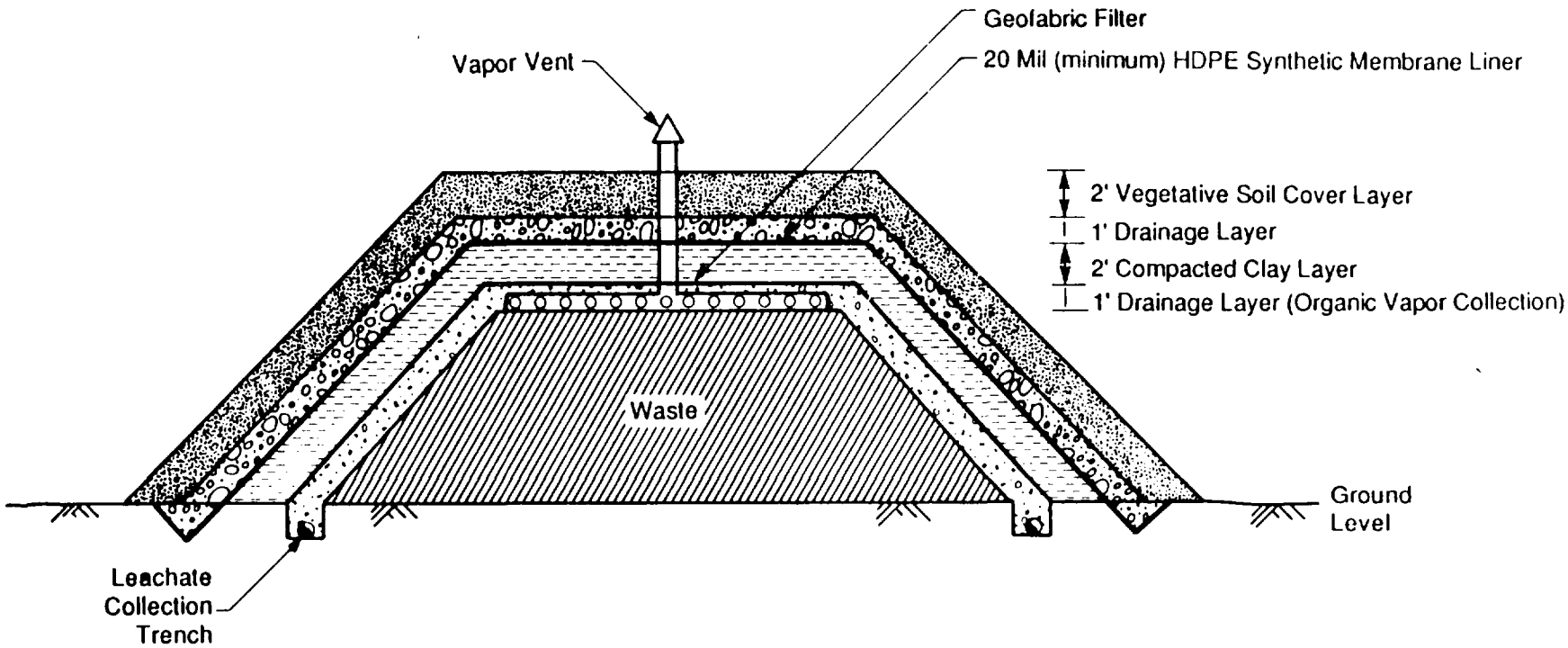
SHEET TITLE:
SITE ALTERNATIVE 7

SHEET OF
DRAWING NO.
12



REV	DATE	DESCRIPTION	DR BY	APP BY

PROJECT NO. 850-32-17

DES BY
DR BY
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APP BY

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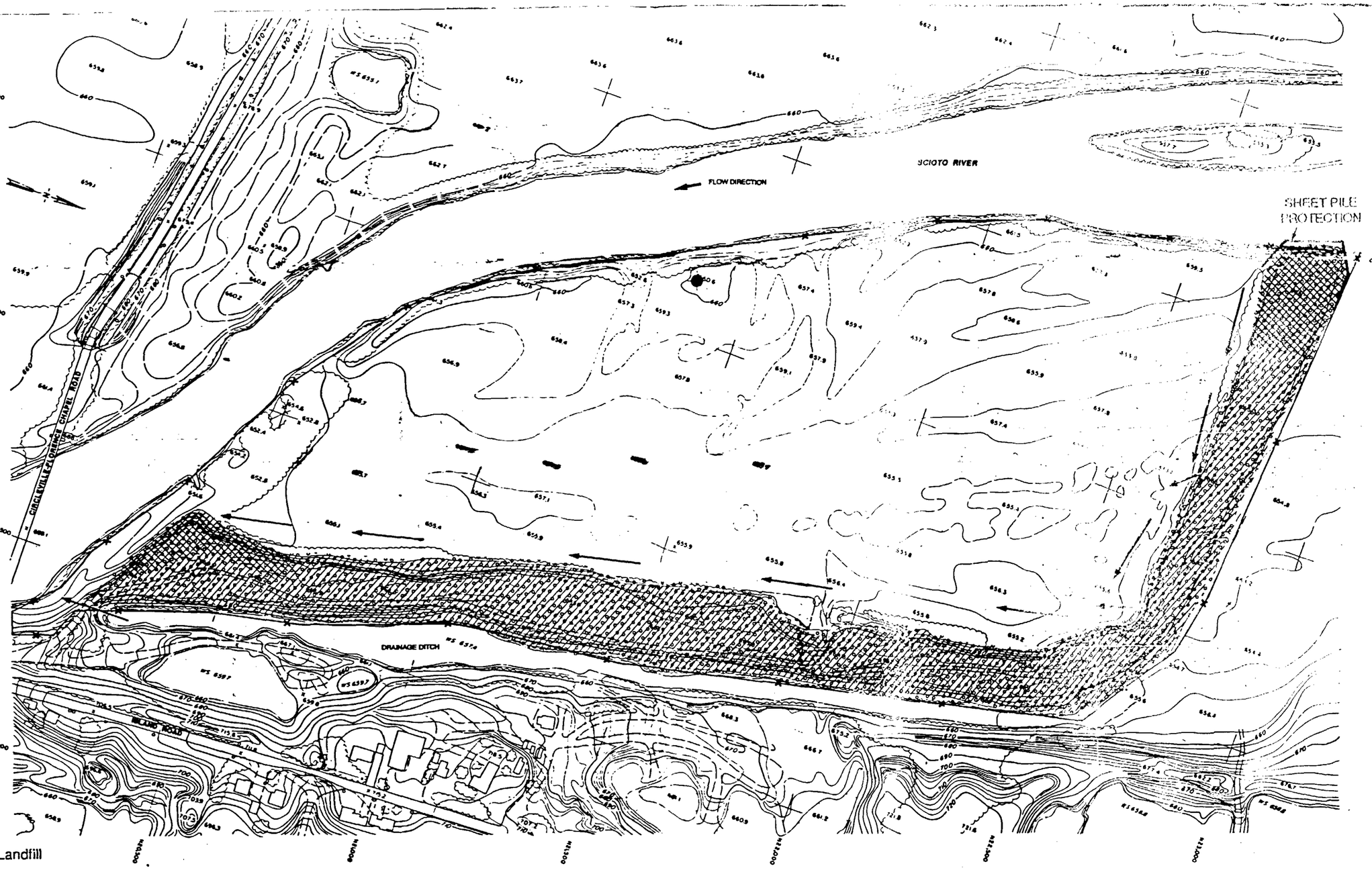
SHEET TITLE: TYPICAL CROSS-SECTION LANDFILL WITH SYNTHETIC MEMBRANE CAP AND LEACHATE COLLECTION SYSTEM AND GAS VENTING SYSTEM

SHEET OF

DRAWING NO.

13



LEGEND:

- Existing Landfill
- Monitoring Well (typical)
- Perimeter Fence
- Rip-Rap
- Synthetic Membrane Cap Over Landfill with Gas Venting System and Leachate Collection System
- Drainage Improvement

SITE ALTERNATIVE 8:

- Ground Water Monitoring
- Deed and Site Restrictions
- Management of Surface Debris
- Erosion Control and Drainage Improvements
- Install Gas Venting System
- Install Leachate Collection System
- Construct Synthetic Membrane Cap Over Landfill

0 200
SCALE IN FEET

CONTOUR INTERVAL: 2 FEET
DATE OF AERIAL PHOTOGRAPH: MAY 1, 1984

REV	DATE	DESCRIPTION	DR BY	APP BY

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DES BY
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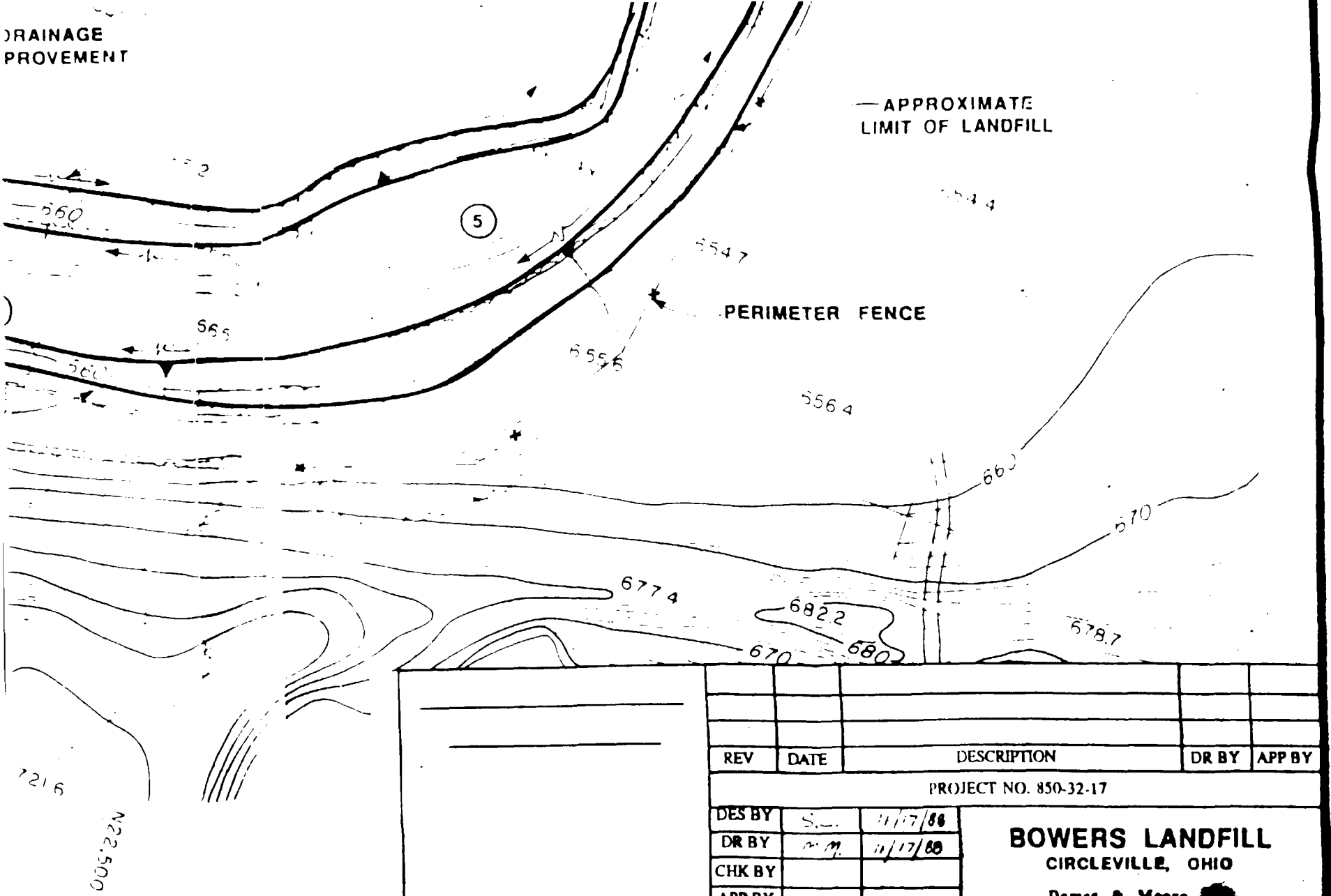
SHEET TITLE: SITE ALTERNATIVE 8

SHEET OF
DRAWING NO. 14



CONTOUR INTERVAL = 2 FEET

DATE OF AERIAL PHOTOGRAPHY: MAY 1, 1984

REV	DATE	DESCRIPTION	DR BY	APP BY

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DES BY	S.	11/17/88
DR BY	[illegible]	11/17/88
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APP BY		

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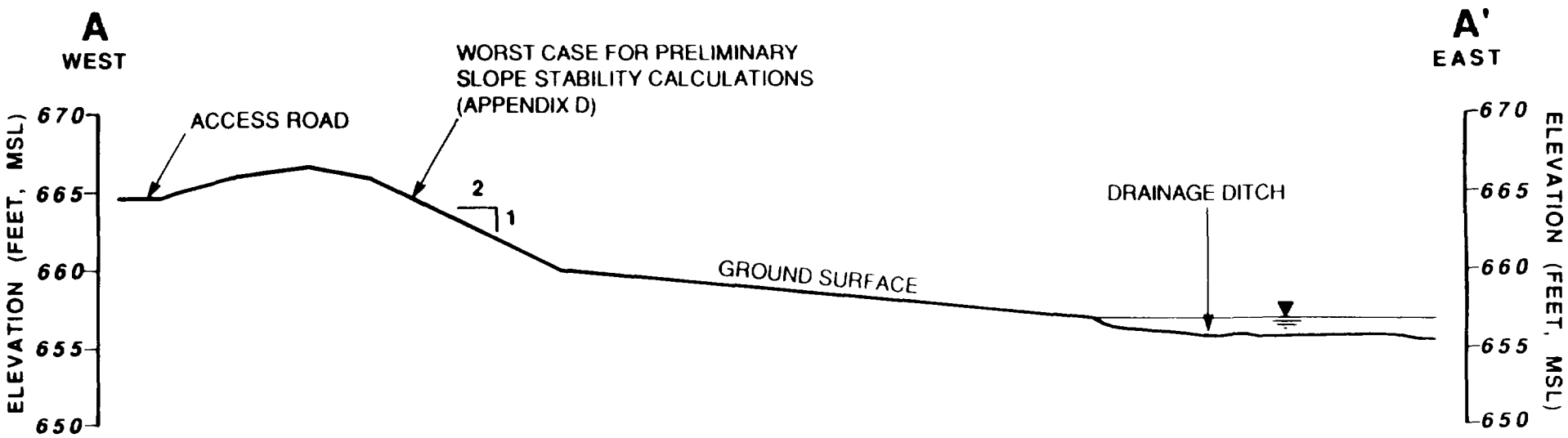
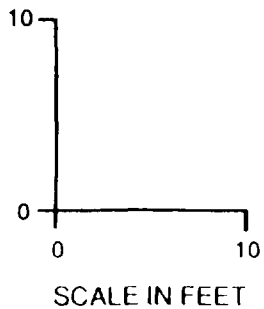
SHEET TITLE:
SITE ALTERNATIVE 8

SHEET ___ OF ___
DRAWING NO.
15





NOTE: Ground surface and ditch water surface denotes terrain based on aerial photography: May 1, 1984

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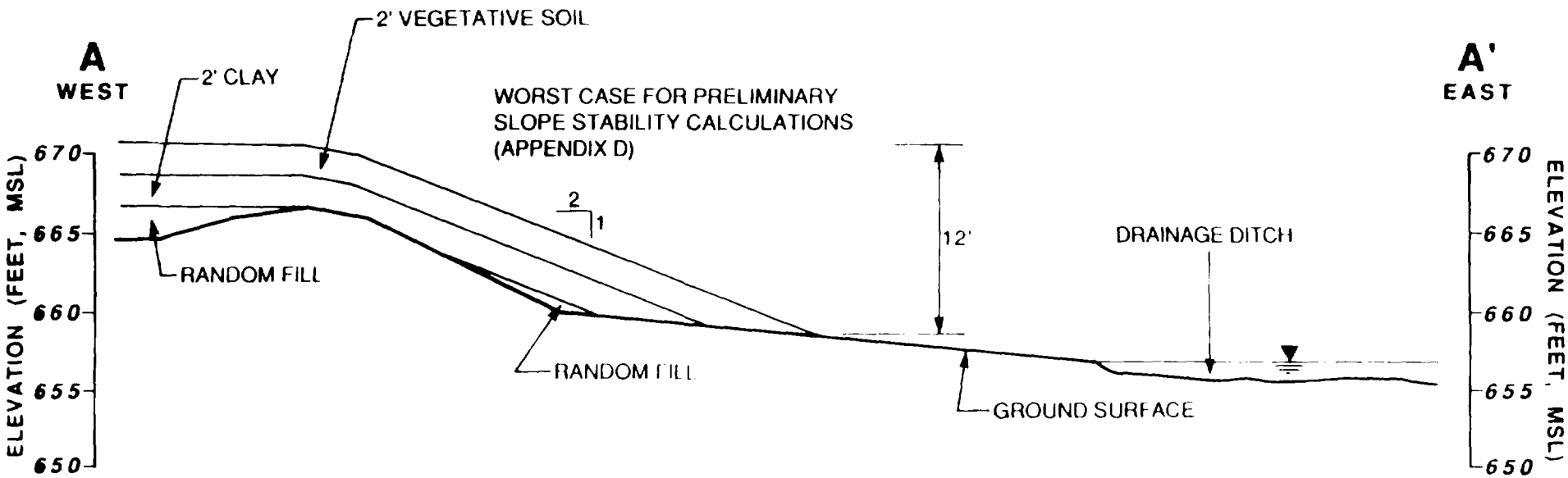
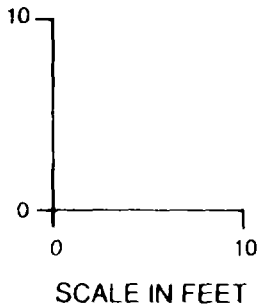
SHEET TITLE
SITE ALTERNATIVE 9
SECTION A-A' EAST SLOPE

SHEET OF
DRAWING NO.





NOTE. Ground surface and ditch water surface denotes terrain based on aerial photography: May 1, 1984

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SHEET TITLE:
SITE ALTERNATIVES 4,5,6,7,& 8
SECTION A-A' EAST SLOPE

SHEET OF
DRAWING NO
17