SECTION 5
CUTOFF WALL
EVALUATION
INTRODUCTION

This section presents the engineering evaluation for the selection of cutoff wall construction method, materials of construction, and wall alignment.

As mentioned in Section 4, the cutoff wall is an integral part of the proposed containment system consisting of a cover system seepage cutoff wall, gas venting system, monitoring wells and possibly leachate collection and treatment and additional monitoring wells.

The general objectives are to reduce seepage of contaminated ground water into Rabbit Run and Chestnut Branch, reduce migration of contaminants through the Kirkwood Clay layer and provide an approximate 50 year design service life. The reduction of groundwater seepage is achieved by providing a barrier to the flow of contaminated groundwater from the site and diverting the flow of upgradient groundwater around the site. The effects of the cutoff wall permeabilities are shown in Section 3.

DESIGN CRITERIA AND ASSUMPTIONS

To make the cutoff wall evaluations, certain design criteria had to be established and assumptions had to be made. These criteria and assumptions are based on information obtained from evaluating available existing data previously generated for the site, on engineering judgment based on literature reviews, experience with similar projects and the objectives of the design.
The following is a list of the design criteria and assumptions made for this evaluation.

1. The cutoff wall shall encircle the contaminated area with a 360-degree enclosure.

2. The cutoff wall shall enclose all areas on the site reported to date to contain buried wastes.

3. The cutoff wall shall enclose as much of the area of known contamination downgradient of the buried wastes as is practical. Wall alignment shall be similar to that proposed by R.E. Wright Associates in a previous study.

4. The cutoff wall shall extend from the cover system to a minimum of two feet into a clay layer which occurs at an elevation of about 80 to 92 feet (mean sea level).

5. The native soils at the site above the clay layer consist of fine to medium sands with less than 25 percent fines and with occasional gravel.

6. Existing groundwater table elevations range from a high of about elevation 117 feet (msl) at the western boundary of the site to a low of about 105 feet (msl) at Chestnut Branch.

7. The groundwater levels outside the cutoff wall will eventually be higher than the groundwater level inside the wall. The maximum expected differential groundwater level will be about 25 feet.
8. Equilibrium seepage conditions into and out of the enclosed area are significantly affected by the characteristics of the cutoff wall (See Section 3).

9. The cutoff wall shall have an equivalent permeability equal to or less than a 2-foot thick soil barrier having a permeability of $1 \times 10^{-7}$ cm/sec.

10. No underground utilities or sewer lines are known to exist within the proposed wall alignment. Buried drums or other wastes may be encountered, but are reported to exist only in the area delineated by R.E. Wright Associates in a previous report.

11. Along most of the cutoff wall alignment, groundwater that contacts the wall will be highly contaminated.

12. Soil materials from the trench excavation below the groundwater table may be highly contaminated, posing a potential air quality and health hazard. Contaminated soil materials may be disposed of on-site beneath the proposed cover.

13. The maximum expected frost depth is 36 inches.

14. Surface-applied vehicular loads should be experienced only near the entrance gate after construction. However, the system will be designed for inadvertent vehicular loads due to future construction and maintenance.

15. No leachate collection or treatment system will be constructed at this time. Therefore at this time water levels within the encapsulated area will not be controlled by pumping from wells.
METHODS OF CUTOFF WALL CONSTRUCTION

Two methods of vertical cutoff wall construction are addressed in this section, the slurry trench method and the vibrated beam method. Other methods for providing a vertical cutoff wall include sheet piling and open-trench excavations. Sheet piling are not considered to provide a sufficient degree of impermeability, and are much more expensive than other wall systems. Open trench excavations are not considered feasible to the depths required at the site. Therefore, these other methods were not considered further.

Slurry Trench Method

This method involves excavating a narrow trench and backfilling the trench with a slurry mixture. The trench is kept full of bentonite slurry during the excavation and backfilling process to stabilize the sides of the trench and thereby permit vertical side walls. The slurry is mixed and stored in ponds or containments and pumped to and from the trench as it is excavated and backfilled to maintain a constant level. Because of the fluid nature of the slurry, the trench surface must be level and changes in grade are made in steps.

The trench is backfilled with a slurry that can be made up of such mixtures as soil-bentonite (SB), cement-bentonite (CB), emulsified asphalt or concrete.

The primary advantage of the slurry trench method is that the thickness of the wall and the trenching method of construction ensure wall integrity or continuity. The method is also a conventional, proven technology. The depth of the clay layer can be ascertained by visual inspection of the excavated material, assuring the proper keying of the wall into the clay layer.
The disadvantages of the slurry trenching method is the site work necessary to handle the trenching slurry and the proper handling and disposal of the contaminated excavated material.

Soils excavated from below the groundwater table will be highly contaminated. These soils should not be used as backfill, but should be disposed of onsite in a trench or pit beneath the proposed cover, for the following reasons:

1. Exposed contaminated soils pose a potential hazard to air quality caused by the volatile organic constituents, or a health threat during mixing operations.

2. Organic contaminants in the soil could adversely affect the swelling potential and permeability of the soil-bentonite backfill.

3. The trench or pit will avoid surface water runoff from the contaminated soils, provide a source of borrow materials to be used as backfill for the slurry trench, and will limit exposure of the soils to the wind.

The potential air pollution problems caused by slurry trenching will be addressed in the Health and Safety Plan.

"Vibrated Beam" Method

This is a propriety method of cutoff wall construction developed by Slurry Systems, Inc., Gary, Indiana. A two- to six-inch thick wall is constructed by driving an H-pile to the required cutoff wall depth and injecting a slurry material into the void left by the H-pile as the pile is extracted.
Slurry materials include CB and an asphalt-based emulsion called "Aspemix", developed by Slurry Systems.

The vibrated beam cutoff wall has the advantages of rapid construction, and no requirement for handling excavated contaminated material. The vibrated beam method can be used on steeper slopes than slurry trench method since the slurries are more viscous, so that site grading in preparation for the wall placement requires less earth movement.

The primary disadvantage of the vibrated beam method is that the continuity of the wall between adjacent wall panels is impossible to ensure. Similar to pile driving operations, it is difficult to maintain the plumbness of the wall to within 1%; this would result in a horizontal deviation of the tip of the beam of 6 inches at the bottom of a 50-foot deep wall. Since the wall is nominally only 4 inches wide, a gap in the wall could easily result. Gravels, large roots, or buried trash will tend to force the beam to deviate from its intended vertical alignment. It is also difficult to ascertain at what depth the clay layer is encountered, so that it is possible for a gap to be left at the bottom of the wall.

The thin nature of the wall is also a disadvantage. Any necking-in or collapse of the sides of the wall during wall placement will result in a very thin spot or a gap in the wall. A differential hydraulic head of between 20 and 25 feet across the wall is anticipated.

**MATERIALS OF CUTOFF WALL CONSTRUCTION**

A review of available data indicates that samples of the Lipari Landfill leachate have been collected and analyzed by several investigators. The most comprehensive testing was
completed by the U.S. EPA and by Lawler, Matusky and Skelly Engineers and presented in a previous report by R.E. Wright Associates. The chemical constituents of the leachate that are considered the most influential to the deterioration of various cutoff wall materials are summarized in Table 1. This data was used to evaluate the effect of the Lipari Landfill leachate on the cutoff wall materials.

**Slurry Trench**

One of the most commonly used slurry wall backfill materials is a soil-bentonite (sodium montmorillonite) mixture. The primary advantages of a soil-bentonite backfill are conventional practice, successful experience with this type of installation, and low material costs. The primary disadvantages are potential increased permeability with time caused by chemical interactions between the leachate and the bentonite, and inability to support surface wheel loads. Damage due to freezing and thawing, desiccation, burrowing animals, or tree root penetration is not considered significant at the Lipari site because the water table is generally located more than 10 feet below the ground surface.

Potential chemical interactions between the Lipari leachate and a soil-bentonite backfill are as follows:

1. **Ion exchange effect.** Calcium, potassium, or iron can undergo ion exchange with the sodium in the bentonite crystal structure and thereby reduce the swelling characteristics of the clay. However, the concentrations of these ions in the Lipari leachate are not great enough to cause significant change in the permeability of the bentonite.

2. **Acidic reaction.** The pH of the Lipari leachate is slightly acidic, but not low enough to cause a severe
reaction with the alkaline-rich sodium bentonite. A slow reaction is possible, but with a wall thickness of approximately 3 feet, the effect is minimal.

3. Chemical desiccation. Chemical desiccation is the loss of loosely bound water from a clay mineral due to the presence of a polar organic compound that has an affinity for water. This loss of water results in a decrease in the swelling of the clay and a corresponding increase in the clay permeability. Sodium montmorillonite is particularly susceptible to chemical desiccation. The only known polar organic compound found on the Lipari leachate is phenol which is present in concentrations ranging from about 1 to 5 ppm.

4. Organic chemical absorption. Since the swelling of sodium bentonite is a surface reaction, the absorption of non-polar organic chemicals on the surface of the bentonite surface can occur. This organic chemical absorption will decrease the water absorption and will limit the swelling of the bentonite material. The Lipari leachate contains high concentrations of non-polar organic chemicals including benzene, toluene and Bis (2-chloroethylether) which can absorb on the bentonite particles.

Both chemical desiccation and organic chemical absorption are reversible processes; that is, the swelling characteristics of the clay are restored upon introduction of uncontaminated water. This is particularly important in areas where uncontaminated groundwater on the outside of the wall is located at a higher elevation than contaminated groundwater inside the wall.

The potential exists, therefore, for a decrease in the swelling of the bentonite and a corresponding increase in the
permeability of the soil-bentonite backfill. However, the
degree of deterioration of the soil-bentonite backfill de­
pends on the concentrations of the organic compounds and is
difficult to predict. Tests have been conducted by American
Colloid Co. (1981) and International Minerals and Chemical
Corp. (1981) on samples of their respective bentonite products
that were mixed with various soil types and permeated with
Lipari leachate. These tests were conducted on samples of a
compacted soil-bentonite mixture, not a slurry backfill.
Permeabilities both above and below $10^{-7}$ cm/sec were reported.

Review of studies conducted at other sites with similar leac­
hate by D'Appolonia (1980) and Goldberg-Zoino and Associates
(1981) suggest that the permeability of the soil-bentonite
backfill is greatly affected by the percentage of fines
(material smaller than the No. 200 sieve) and the percentage
of bentonite. Leachates have been shown to cause an increase
in the permeability of the backfill by a factor of about 3
to 10; yet permeabilities less than $1 \times 10^{-7}$ cm/sec have
been attainable.

It is therefore anticipated that a suitable mixture of ben­
tonite, native site soils, and imported fine materials can
be prepared that will result in a backfill having a per­
meability of less than $1 \times 10^{-7}$ cm/sec under long-term
exposure to Lipari Landfill leachate. No tests have been
conducted to determine the optimum proportions of the various
components or to verify the permeabilities attainable.

Asphalt emulsions, primarily "Aspemix", a proprietary material
developed by Slurry Systems, Inc., are also occasionally
used for slurry trench backfills. Aspemix is a mixture of
asphalt emulsion, cement, flyash, and water and has a rela­
tively high shear strength to support surface loads, has low
permeability, and a high resistance to chemical attack.
Tests conducted by Brenneman Co. for Slurry Systems, Inc. (1981) using Lipari leachate as permeant indicated a permeability of $2 \times 10^{-8}$ cm/sec. This permeability reportedly decreases with time; after 50 days, the permeability was reported to be $5 \times 10^{-9}$ cm/sec. The primary disadvantages of Aspemix are excessively high costs for the volume of trench backfill needed, and the relative lack of experience in the use of asphalt emulsions as slurry trench backfill. The long term chemical resistance of an asphalt emulsion is questionable since asphalt is soluble in many organic solvents. High concentrations of benzene, toluene, and Bis present in the Lipari leachate may eventually lead to dissolution of the asphalt. With a 3-foot nominal wall thickness, however, dissolution is not expected to result in substantial loss of asphalt or failure of the wall.

Other types of slurry trench backfill materials that are commonly used include cement-bentonite and concrete. Cement-bentonite has the advantage of hardening as it cures, so that support can be given to surface loadings (vehicular traffic). However, reported permeabilities of cement-bentonite are commonly higher than the desired $1 \times 10^{-7}$ cm/sec; cement-bentonite was therefore dropped from further consideration. Concrete has a sufficiently low permeability ($1 \times 10^{-10}$ cm/sec) and can readily support surface loads. Placement of concrete to depths of 50 feet must be done cautiously to prevent segregation of aggregate and cement or the formation of voids. It would be difficult to ensure impermeable joints between adjacent pours, or to prevent excessive crack development at depths of 50 feet. The chemical resistance of concrete to organic chemicals is generally good. The resistance of concrete to acids is poor, however the Lipari leachate is not highly acidic. The primary disadvantage of concrete is the fact that it is more costly than
soil-bentonite mixtures and is not warranted because the low permeability \((1 \times 10^{-10} \text{ cm/sec})\) is not necessary at this site.

**Vibrated Beam**

Two types of slurry materials are available for the vibrated beam method of construction. They are asphalt emulsion and cement-bentonite, both of which are described in the preceding paragraphs. Cement-bentonite has a permeability of more than \(10^{-7} \text{ cm/sec}\), which is unacceptable for the 4-inch wall. This leaves only the asphalt emulsion as an acceptable slurry wall material with the vibrated beam method. Dissolution of the asphalt by organic solvents in the leachate could result in a significant long-term reduction in wall thickness and integrity.

**CONCLUSIONS AND RECOMMENDATIONS**

**Method of Construction**

The vibrated beam method is not advisable in this application since it will be difficult to ensure continuity of the wall due to tilting, necking or insufficient penetration.

The slurry trench method of construction is recommended even though it presents a greater potential for air pollution during construction, because it offers a high degree of reliability in regard to continuity of the wall. The potential for air pollution during construction can be controlled by air monitoring and disposal in pits and daily covering of excavated contaminated material. The excavated trench materials may be mixed with soil or peat for stabilization prior to covering.
Materials of Construction

Based on the alternatives discussed above, the slurry trench cutoff wall should consist of a trench at least 30-inches wide backfilled with a soil-bentonite mixture. The soil-bentonite mixture was selected because it is a conventional, proven technology, and provides a low permeability backfill at low cost. To improve the permeability characteristics of the backfill, a minimum of 20% fines should be added to the native site soils prior to mixing with bentonite slurry. The minimum bentonite content should be 6% of the dry weight of the backfill.

Additional Testing

The permeability of the soil-bentonite backfill has not been adequately tested. Our review of existing available information has indicated that permeabilities below $1 \times 10^{-7}$ cm/sec may be achieved for an extensive period depending on the actual mix proportions of bentonite, native sand, and imported plastic fines. It is imperative that the actual backfill permeability be verified both prior to and following the wall construction because:

1. None of the tests conducted to date has been performed using a slurry trench backfill mixture.

2. None of the tests conducted to date has been performed using native sand and imported plastic fines as the soil admixture.

3. None of the tests conducted to date has been performed using the design mix to verify that a permeability of $10^{-7}$ cm/sec can be achieved at the Lipari site.
4. A change of 2% in the proportion of bentonite represents a savings of about $51,000.00; a change of 5% in the proportion of imported plastic fines represents a savings of about $5,000.00. The cost of additional testing is estimated at about $2,500.00.

A laboratory testing program is recommended for immediate implementation that consists of permeability measurements on four representative soil-bentonite slurry mixes using leachate from the Lipari Landfill as the permeating fluid. The tests should be conducted for two different percentages of bentonite, 4 and 6%; and for two different soil mixes, one consisting of native site material and the other consisting of native site material mixed with 20% plastic fines. Measurements of the permeability should be taken daily until the rate of increase in the permeability stabilizes, which is estimated at about 3 weeks. Continuous saturation of the sample with leachate should be maintained. These tests should ultimately be used to evaluate and/or verify the design mix proportions and material specifications of the soil-bentonite backfill. These tests will not determine long-term effects of the leachate on the backfill permeability.

Monitoring Wells

Monitoring wells must be installed to monitor the concentrations of leachate on both sides of the wall to determine changes in permeability of the wall. This is the only way to determine the long-term effects of the leachate on the in-place slurry cutoff wall.

Wall Alignment

Information available to date does not indicate that industrial wastes have been buried outside of the area designated
by R.E. Wright Associates in a previous report. The wall alignment should therefore remain similar to the alignment shown by R.E. Wright Associates.

The configuration of the wall should accommodate trenching operations by limiting the number of turns required and by providing a minimum turning radius of about 150 feet. The centerline of the wall should be located no closer than 10 feet from the edge of a fill slope, and 5 feet from the toe of an excavation slope.

Along the western boundary of the site, the cutoff wall should be placed about 10 feet from the property line in order to enclose the area designated as containing buried wastes. To allow the backhoe or clam shell to pivot around, the fence must be positioned no closer than 15 feet from the trench. It will therefore be necessary to obtain a temporary easement for a 5 to 10 foot-wide strip along the western boundary; this area is currently a dirt road. A temporary fence should be placed along the edge of the easement and relocated following completion of the cover.

Proposed changes in the wall alignment from that shown by R.E. Wright Associates are relatively minor and include:

1. Rounding corners to 150- to 300-foot radii.

2. Filling a portion of the swale on the eastern side of the site to allow the wall to be straight.

3. Making the wall parallel to the property line along the western boundaries and directly east–west along the northern and southern sections.
Selected Cutoff Wall System

The selected cutoff wall system is a soil-bentonite cutoff wall placed by the slurry trench method. The wall system consists of site grading, 30-inch wide slurry trench excavation, disposal of excavated contaminated soil on-site, and backfill consisting of a mixture of bentonite powder, bentonite slurry, native sands, and imported plastic fines.

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Table 5-1
CHEMICAL POLLUTANTS IN LIPARI LEACHATE