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ENGINEERING FEASIBILITY ANALYSIS

FOR IN-SITU STABILIZATION OF

BURRELL TOWNSHIP SITE RESIDUES

November 1982

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1 Executive Summary

1.1 SCOPE AND OBJECTIVES

The Burrell Township site, located in western Pennsylvania, received approximately 11,600 tons of radioactively-contaminated material in late 1956 and early 1957 from the Vitro Manufacturing Company's operations in Canonsburg, Pennsylvania. WESTON was requested to conduct an engineering study to determine the feasibility of stabilizing the site in accordance with the U.S. Environmental Protection Agency's (EPA) interim and proposed standards (45 FR 27366-27368, April 22, 1980, and 46 FR 2556-2563, January 9, 1981). The scope of this study is limited to those alternatives that can be implemented on the site and will not require removal and offsite disposal of radioactively-contaminated material.

Four alternatives for control of the radioactive material at the Burrell site were considered and evaluated, as follows:

1. Site stabilization and closure.
2. Site control and containment.
3. Waste excavation and encapsulation.
4. Waste excavation, incineration, and encapsulation.

1.2 SITE CHARACTERIZATION

1.2.1 Introduction

The current conditions at the Burrell site have been characterized using published information and detailed field investigations to determine the site's radiological, hydrogeological, and water-quality conditions.

1.2.2 Site history

The Burrell site is located in western Pennsylvania approximately 40 miles east of Pittsburgh (Figure 1-1). The 49-acre site is situated within a bend of the Conemaugh River (Figure 1-2). During the 1950's, the Pennsylvania Railroad operated the site as a dump for a variety of wastes, including railroad ties. Radiological contamination of the site resulted from the disposal of 11,600 tons of residues during one time period, i.e., October 1956 to January 1957, from the Vitro Manufacturing Company operations in Canonsburg, Pennsylvania. The waste residues were generated under Atomic Energy Commission (AEC) contract AT-(30-1)-1683, and were reported to consist of pitchblende, carbonate cake, calcium fluoride, and magnesium fluoride (Leggett et al., 1979). These residues contained approximately 6000 tons of radioactive wastes, 4000 tons of water, and 1600 tons of possibly nonradiologically contaminated material.

1.2.3 Radiological characteristics of the site

A radiological survey of the Burrell site was conducted by Oak Ridge National Laboratory in late 1977 (Leggett et al., 1979). During this survey, measurements were taken of the following:

1. Beta-gamma dose rates.
2. Concentrations of radium-226 (Ra-226) and uranium-238 (U-238) in soils and subsurface water.
3. Gamma-radiation levels as a means of estimating radium-226 concentrations in bore holes.
4. Concentrations of radon-222 (Rn-222) and its daughters in ambient air.

These surveys indicated that radioactive residues containing an estimated 5.8 tons of 0.097-percent uranium oxide (approximately 1.5 curies of uranium-238) were transferred from the Canonsburg site and dumped at the Burrell site. Analyses of subsurface-soil samples for 76 holes augered on this site to depths of 50 feet revealed the general location of residues containing an estimated above-background total uranium-238 activity of 1.3 curies, and an estimated total radium-226 activity of 4 curies. It appeared that more than 75 percent of these residues were at least 10 feet beneath the surface (Figure 1-3). Radioactive residues were also scattered on the surface. At some points the surface soils showed radium-226 concentrations of several thousand picocuries per gram, uranium-238 soil concentrations of 360 picocuries per gram, external-gamma-radiation levels at 1 meter in excess of 600 microroentgens per hour, and beta-gamma dose rates at 1 centimeter from the surface in excess of 5 millirads per hour. Such measurements were not, however, representative of the entire area; at most sampling points radionuclide concentrations in surface soils and radiation levels at the surface and at 1 meter above the surface were less than 10 times background levels. Figure 1-4 depicts the surface radiation levels found at the site. The maximum concentrations of radioisotopes in onsite ground-water samples were 370 picocuries per liter for thorium-230, 10 picocuries per liter for radium-226, and 403 picocuries per liter for uranium-238. Analyses of water and sediment from drainage pathways from the site to the Conemaugh River indicated that these radionuclides were at or only slightly above background levels in these pathways off the site. Atmospheric radon levels were, with one exception, at background levels; radon-daughter-product concentrations were also at background levels.

During July 1981 and January and February 1982, WESTON conducted a limited radiological survey that included measurements of uranium-234, -235, and -238, and radium-226 in ground water and gamma-radiation levels at various depths in augered wells (Figure 1-5). This survey found very little radiation at the site. The external gamma-dose rates were essentially at the background level, and the radium and uranium levels in ground water were at or slightly above background. Very little radioactivity was present in soils near or below the

WELL 3

WELL 5

WELL 6

WELL 12

WELL 13

WELL 14

WELL 16

FIGURE 1-5
SOIL GAMMA ACTIVITY AS DETERMINED BY NATURAL GAMMA LOGGING
JULY 1981 —BURRELL TOWNSHIP SITE

surface. The highest uranium concentrations found in the ground water were 6.6 picocuries per liter of uranium-234, 0.22 picocuries per liter of uranium-235, and 5.3 picocuries per liter of uranium-238. The total uranium concentrations for wells in the known dump area ranged up to 12 picocuries per liter. The radium-226 levels in the ground water from all wells tested were found to be at background level. In 7 out of 28 wells gamma-radiation levels were found to be above background level, with most of the activity in these wells at depths less than 7 feet.

In March and April of 1982, Bendix Field Engineering Corporation performed a confirmatory survey of the Burrell site (Rarrick, 1982), including gamma-radiation levels and estimates of radium-226, magnetic susceptibilities, potassium, thorium, and total potassium-uranium-thorium in the wells. In 9 out of 28 wells the gamma-radiation levels were above background level, with most of the activity at depths less than 8 feet. The estimates of radium-226 concentrations in subsurface soils ranged from less than 1 picocurie per gram to 800 picocuries per gram. Only seven observations were documented in which radium activity was greater than 10 picocuries per gram.

In general, the Bendix survey results confirmed WESTON's conclusion that the levels of radioactivity in the contaminated zone at the site have declined since the 1977 survey by ORNL. This reduction is evidenced in Table 1-1 where the average radium-226 concentration in ground water decreased by a factor of approximately 3, and for uranium-238, by a factor of approximately 24.

The reduction of these radioactivity levels at the site may be due to the radionuclides leaching and migrating through various pathways, or the redistribution of activity throughout larger portions of the site. Regardless of the mechanism, it is clear that radioactivity at the site is currently at a very low level and does not warrant any extensive remedial action.

Table 1-1. Comparison of ground-water radioactivity (picocuries per liter)

Nuclide	1977 ORNL data		1981-1982 WESTON data		Proposed EPA standard
	Range	Average	Range	Average	
Ra-226	<0.5 - 10	3.6	<1.0 - 2.02	1.06	5 ^a
U-238	2.1 - 403	31.8	<0.10 - 5.73	1.33	10 ^b

^aIncludes Ra-226 and Ra-228.

^bTotal uranium.

1.2.4 Hydrogeological characteristics

The present hydrogeological environment at the Burrell site has been substantially affected by past site use as a borrow area (documented in 1949 aerial photographs). (The hydrogeological features and the water budget for the Burrell site are shown on Figure 1-6, and tabulated in Table 1-2.) The excavation of materials left a bowl-shaped pit with steep sides in the unconsolidated colluvium and alluvium. This bowl was subsequently filled with a variety of materials, including railroad ties, rubble, and low-level radioactive waste. The result is a high-permeability fill overlying low-permeability colluvium, alluvium, and bedrock. Ground-water pump-test data on the fill indicated a transmissivity of 4878 square feet per day, and a permeability of 245 feet per day. In the alluvium and colluvium the transmissivity was 35, and the permeability was 1.28. The difference in permeability between the fill and bedrock indicates that there is no significant recharge of ground water from the fill into the bedrock. Ground water exits the site as effluent to both the ponds and the river.

The ground-water quality at the site is only slightly affected by the waste material as compared to background conditions. Even though sulfate was found to be above Federal drinking-water standards in all samples, this and all other nonradiological above-standard values were within the range expected in the coal-containing bedrock underlying the site. The radiological water quality was within Federal drinking-water standards for most samples.

1.2.5 Remedial-action requirements

The latest radiological survey of the Burrell site, conducted in March and April 1982 by the Bendix Corporation (Rarrick, 1982), concluded that the current levels of radiation do not warrant extensive remedial action. However, because of the uncertainty about the final EPA standards (yet to be published), a conservative approach has been taken. The remedial action discussed in this report is based on current (stringent) EPA proposed requirements for cleanup of inactive uranium-mill-tailings sites and designated properties. Such standards would require removing the contaminated material that exceeds, on the average, 5 picocuries of radium-226 per gram, or stabilizing and containing the site to prohibit the release of radionuclides at unacceptable levels in various pathways into the environment for at least 1000 years.

Since the scope of this study is to investigate only the feasibility of onsite remedial-action alternatives, only those alternatives that do not require offsite disposal of contaminated material have been developed and evaluated.

**A. INFLOW TO POND D
(BASE FLOW CONDITION)**

**B. DIRECT SEEPAGE INTO RIVER FROM
THE SITE, EAST OF POND C**

TONED AREAS INDICATE SATURATED ZONE
 UNCONSOLIDATED MATERIAL
 GROUNDWATER FLOW DIRECTION
 NOTE: SEE TABLE 1-2 FOR FLOW NET CALCULATIONS
 50 0 50 (NO VERTICAL EXAGGERATION)
 SCALE IN FEET

**FIGURE 1-6
FLOW NET ANALYSIS OF SHALLOW
GROUNDWATER FLOW
BURRELL TOWNSHIP SITE**

Table 1-2. Flow-net calculations

Flow through unit cross-section:

$$q = K \Delta h \frac{n_f}{n_d} \cdot \frac{a}{b}$$

Where:

K = Hydraulic conductivity.

n_f = Number of flow channels.

a/b = Ratio of spacing of equipotential lines (a) to flow lines (b).

Δh = Change in potential (head) between two equipotential lines (h_1-h_2).

n_d = Equipotential units between h_1 and h_2 .

Refer to Figure 1-6(b).

Δh = Drop in head between W19 and W7.

K = 0.16 ft/min.

n_f = 2.

a/b = 0.1.

$$q = (0.16 \text{ ft/min.}) (942.2' - 937.9') \cdot \frac{2}{4.7} (0.1)$$

$$q = 0.029 \text{ ft}^3/\text{min.}$$

Total flow across 2000 ft. cross-section Q:

$$Q = 58 \text{ ft}^3/\text{min.} = 452 \text{ gpm.}$$

Refer to Figure 1-6(b).

Δh = Drop in head between edge of site and Pond D.

K = 0.16 ft/min.

n_f = 2.

a/b = 0.19.

$$q = K \Delta h \frac{n_f}{n_d} \cdot \frac{a}{b}$$

$$q = (0.16 \text{ ft/min.}) (950 - 937) \cdot \frac{2}{9} (0.19)$$

$$q = 0.089 \text{ ft}^3/\text{min.}$$

Total flow across 950 ft. cross-section:

$$Q = 39.1 \text{ ft}^3/\text{min.} = 305 \text{ gpm}$$

Outflow from Pond D = 200 gpm (field estimate).

$$\begin{array}{r} 305 \\ -200 \\ \hline 105 \text{ gpm -- direct seepage to river} \end{array}$$

Total direct seepage to river:

$$\begin{array}{r} 452 \\ +105 \\ \hline 557 \text{ gpm} \end{array}$$

1.3 REMEDIAL-ACTION ALTERNATIVES

1.3.1 Control requirements

Radiological monitoring and exploration at the site indicated only a few localized soil areas with radionuclide levels exceeding the EPA proposed standards and requiring some remedial action, with minimal radioactive contamination of ground water, and with a probable annual average radon flux, based on soil radium-226 content, which was essentially at background levels. However, the characteristics of the site create some uncertainty about possible future increases in radionuclide losses through any of several mechanisms. These characteristics include the following:

1. Pond topography -- As constituted, the ponds have side slopes of greater than a 1:1 slope. Erosion of the slopes on the north side could produce erosion channels that would cut into the contaminated zone and thus allow the direct release of radionuclides into runoff.
2. Surface permeability -- The materials currently on the surface of the filled area are quite porous; infiltration has been estimated as high as 85 percent. The leaching of radioisotopes has probably occurred in the past, but might increase from present levels if decomposition releases more soluble materials.
3. Landfill stability -- The fill material has substantial quantities of decomposable materials. As this material continues to degrade, subsidence in the ground surface will occur over an extended period of time. The resulting surface cracking may increase infiltration and leaching, and expose shallow radioactive zones.
4. Shallow burial -- Because of shallow burial of the material, the contaminated zone is sufficiently near the surface that penetration by burrowing animals or vegetative roots may expose contaminated buried material or damage a final cover system.

A series of alternatives for site remedial action were investigated. The overall objective for developing the remedial-action alternatives was to produce a range of alternatives from which an optimum plan could be formulated. The essential features of the four remedial-action alternatives are summarized in Table 1-3. The alternatives are the following:

1. Site stabilization and closure.
2. Site control and containment.
3. Waste excavation and encapsulation.
4. Waste excavation, incineration, and encapsulation of residues.

Table 1-3. Common features of onsite remedial-action alternatives

Alternative	Ground-water stabilization	Slope stability and erosion control	Infiltration control	Decomposition settlement	Root and animal pene- tration
1. Site stabilization and closure	Gravel underdrain at pond eleva- tion.	Fill ponds	Fill contaminated area to obtain 2 percent slope.	Slope con- trol only.	Stone layer.
2. Site control and con- tainment	Gravel underdrain at pond elevation and add exchange media to stone.	Fill ponds	Fill to obtain 4 percent slope plus clay cap.	Slope con- trol only.	Stone layer.
3. Waste excavation and encapsulation	Gravel underdrain at pond elevation.	Fill ^a ponds	Clay cap and liner. Use 3 percent slope.	Slope con- trol and compaction of wastes.	Stone layer.
4. Waste excavation, incineration, and encapsulation	Gravel underdrain at pond elevation.	Fill ^a ponds	Clay cap and liner. Use 2 percent slope.	Burn decom- posable ma- terials prior to placement.	Stone layer.

^aEncapsulation areas are partially located over the existing ponds.

The main factors addressed in all of these alternatives include the following:

1. Stabilization of contaminated material and control of ground water.
2. Reduction of slopes surrounding the ponds to minimize erosion.
3. Reduction of surface permeability to reduce infiltration.
4. Reduction of the consequences of decomposition and settlement.
5. Reduction of the potential for root and animal penetration.

The four alternatives are evaluated in subsection 1.3.6, relative to the following set of criteria:

1. General suitability -- The approach should be consistent with the problems identified, and should avoid overly complex remedial actions that are not clearly justified by site conditions.
2. Environmental effectiveness -- The plan should address the site characteristics in a direct manner and without the creation of secondary environmental and exposure impacts. The selected alternative should ensure continued compliance with all environmental standards pertaining to air, water, and soil quality.
3. Technical feasibility -- The recommended plan should incorporate proven technology and should be within the capabilities of conventional construction contractors.
4. Cost-effectiveness -- Increased levels of expenditure should produce recognizable gains in environmental protection appropriate to the level of expenditure.

1.3.2 Alternative 1: site stabilization and closure

The main features of this alternative (conceptually presented on Figure 1-7) include the following:

1. Reduction of infiltration (to approximately 20 percent of total annual precipitation) through the contaminated zone by placement of a two-layer surface-cover system consisting of the following:
 - a. A 12-inch stone and gravel layer covered by a geotextile layer.
 - b. An 18-inch soil layer covered by 6 inches of topsoil.
2. Reduction in the potential for animal and root penetration, as well as potential radon emanation, by placement of the two-layer cover components.

FIGURE 1-7
TYPICAL SECTION—SITE STABILIZATION AND CLOSURE
ALTERNATIVE 1—BURRELL TOWNSHIP SITE

3. Reduction of surface erosion by establishing a vegetation cover, improving the drainage pattern for the site by constructing swales and sedimentation ponds for storm-water control.
4. Stabilization of the side slopes in the contaminated zone by backfilling ponds B, C, and D.
5. Control of the ground-water elevation in the area of the contaminated zone by placing a gravel subdrain at the lower portion of ponds B, C, and D (as shown on Figure 1-5) to reduce the potential for water to rise into the waste materials.
6. Overall site management and improvement to prevent excessive erosion and potential exposure of contaminated material through environmental pathways.

The preliminary cost estimates for the major components of this site stabilization and closure alternative are summarized as follows:

Landfill surface cover and stabilization	\$ 597,000
Installation of subdrain, pond filling, and rehabilitation	\$ 1,134,000
Overall site management and improvements	\$ 349,000
Contingency, engineering, and management	\$ <u>700,000</u>
Total	\$ 2,780,000 (Approximately \$2.8 million)

It should be noted that these estimates are very conservative and are based on the stabilization and closure of large portions of the disposal site. It is probable that the appropriate level of remedial action may only require implementation of part of the site stabilization and closure plan. This would reduce the cost to below \$1 million.

1.3.3 Alternative 2: site control and containment

The main features of this concept are very similar to those described for Alternative 1, with the exception of the following:

1. Substantial reduction in the infiltration through the contaminated zone (to less than 1 percent of the total annual precipitation) by installing a multilayer cover system consisting of the following:
 - a. Earth fill to establish a 4-percent grade, with the addition of bentonite clay admixture in the top 6 inches of this layer.

- b. A 12-inch stone and gravel layer covered by a geotextile layer.
 - c. An 18-inch layer of soil covered by an 8-inch layer of topsoil.
2. Incorporation of an ion-exchange medium in the subdrain layer in the lower portion of ponds B, C, and D.

The preliminary construction cost estimates for the site control and containment alternative are as follows:

Multilayer cover and stabilization	\$ 1,517,000
Installation of subdrain and ion-exchange medium, pond filling, and rehabilitation	\$ 1,644,000
Overall site management and improvements	\$ 349,000
Contingency, engineering, and management	\$ 1,230,000
Total	\$ 4,740,000 (Approximately \$4.8 million)

1.3.4 Alternative 3: waste excavation and encapsulation

The main features of this concept consist of the following:

1. Excavating the waste material (approximately 213,000 cubic yards) from the contaminated zone and removing it to a staging area.
2. Placing a clay and soil liner in the excavation area after preparing the subgrade.
3. Installing a gravel subdrain, and backfilling and rehabilitating ponds C, and D (as described in Alternative 1).
4. Transferring the excavated material from the staging area, and placing and compacting the excavated waste and contaminated material in the lined area.
5. Placing a multilayer cover system (similar to the cover for Alternative 2) over the lined area to encapsulate the excavated waste.
6. Overall site management and improvements (similar to those discussed for Alternative 1).

The preliminary construction cost estimates for the major components of the waste excavation and encapsulation alternative are summarized as follows:

Installation of subdrain, pond filling, and rehabilitation	\$ 845,000
Material excavation and staging	\$ 1,705,000
Installation of clay liner, material placement, and encapsulation with a multilayer cover system	\$ 2,555,000
Overall site management and improvements	\$ 1,051,000
Contingency, engineering, and management	\$ <u>2,159,000</u>
Total	\$ 8,315,000 (Approximately \$8.3 million)

1.3.5 Alternative 4: waste excavation, incineration, and encapsulation

The main features of this concept are similar to those described for Alternative 3 with the following steps added between the waste removal and encapsulation activities:

1. Staging and sorting the excavated material followed by shredding the bulky combustible material (e.g., railroad ties) for size reduction.
2. Incineration of the combustible fraction of the excavated waste materials in two parallel rotary-kiln incineration lines.
3. Conditioning and cleaning flue gas from the incineration units using cooling chambers, a roughing filter, and high-efficiency particulate air filters.
4. Burial of the incinerator residues in the encapsulation area along with the other noncombustible waste materials.

The preliminary cost estimates for the major components of this alternative are summarized as follows:

Installation of subdrain, pond filling, and rehabilitation	\$ 845,000
Material excavation, staging, and sorting	\$ 1,705,000
Shredding and incineration of the combustible fraction	\$22,160,000
Installation of clay liner and encapsulation of waste and incinerator residues	\$ 1,500,000
Site management and improvements	\$ 1,051,000
Contingency, engineering, and management	<u>\$10,920,000</u>
Total	\$38,181,000 (Approximately \$38 million)

1.3.6 Evaluation of alternatives

A qualitative evaluation of the four onsite remediation alternatives has been performed. A summary of this analysis is presented in Table 1-4. It should be noted that each alternative can meet regulatory and environmental requirements. However, the selection of an optimum level of control is also a function of technical feasibility and cost-effectiveness.

Alternative 1, site stabilization and closure, meets all the environmental objectives and the technical feasibility and implementation requirements. This concept, in comparison to the other three approaches, ranks highest in terms of cost-effectiveness. The other alternatives do not substantially add to the environmental effectiveness, technical feasibility, or implementation of the remedial-action program in comparison with the additional construction costs associated with these alternatives.

Alternative 2, site control and containment, represents added control of infiltration through the contaminated zone. However, this reduction does not correspond to any additional environmental benefits, since even with the current levels of infiltration, the radiological limits of the Federal primary drinking water standards are not exceeded. Moreover, the complex multilayer cover system will complicate the implementation of the remedial action while raising questions about the effects of waste degradation and subsidence on long-term integrity. Similar concerns can also be raised about the need for and the cost-effectiveness of the ion-exchange barrier to be incorporated in the subdrain. Therefore, this concept is not recommended.

Table 1-4. Evaluation of remedial-action alternatives

	1	2	3	4
Evaluation criteria	Site stabilization and closure	Site control and containment	Waste excavation and encapsulation	Waste excavation, incineration, and encapsulation
<u>Environmental criteria</u>				
Air-quality impacts	Good	Good	Fair	Poor
Surface-water impacts	Fair	Fair	Fair	Fair
Ground-water impacts	Fair	Fair	Good	Good
Secondary impacts	Good	Good	Poor	Poor
Future land use	Poor	Poor	Poor	Fair
<u>Technical criteria</u>				
Technical feasibility	Good	Fair	Poor	Poor
Long-term stability	Fair	Fair	Good	Good
Implementation features	Good	Fair	Poor	Poor
<u>Economic criteria</u>				
Cost-effectiveness	Good (\$2.9 million)	Fair (\$4.6 million)	Poor (\$8.3 million)	Poor (\$38 million)
Impact on future UMTRA sites	Good	Fair	Poor	Poor

Alternative 3, waste excavation and encapsulation, is not recommended for the Burrell site because of its questionable technical feasibility and implementation, and the possible secondary environmental and exposure impacts from waste excavation and handling, and its poor cost-effectiveness.

Alternative 4, excavation, incineration, and encapsulation of residuals, is not recommended because of its questionable technical feasibility and implementation, and because of the possibility of secondary impacts from disturbing, handling, and incinerating the wastes. This concept is also not feasible because of its prohibitive cost (an order of magnitude higher than Alternative 1).

The conclusion drawn from this analysis is that Alternative 1 meets all of the environmental, technical, and cost-effectiveness criteria. Therefore, it is recommended that the feasibility of onsite remedial action be based on this approach (site stabilization and closure). Furthermore, this level of control should be considered an upper limit for the Burrell site, since recent radiological surveys suggest that the contamination level has declined. Partial implementation of the Alternative 1 control elements may reduce the cost of remedial action below \$1 million.

1.4 FEASIBILITY OF THE RECOMMENDED ACTION

1.4.1 Feasibility analysis

Ten criteria were established to evaluate the feasibility of the recommended engineering concept. These criteria are discussed in the paragraphs that follow.

1. Meeting regulatory requirements -- It is anticipated that the recommended concept will meet the proposed requirements for air and water quality; however, it is difficult to predict long-term compliance with extended life criteria (e.g., 1000 years) because of the anticipated differential subsidence of the waste material in the fill. The recommended concept should not, however, result in significant releases of radionuclides even if subsidence and settlement continue for the foreseeable future.
2. Environmental effectiveness -- The recommended concept will provide adequate protection of air, water, and land quality.
3. Cost-effectiveness -- The site stabilization and closure concept, Alternative 1, could cost as much as \$2.8 million. Partial stabilization and closure (e.g., not filling the ponds) could reduce the cost below \$1.0 million. Although Alternative 1 is less costly than other onsite or offsite alternatives, it is equally effective and superior in technical feasibility and implementation.

4. Use of demonstrated technology -- The recommended concept utilizes proven and demonstrated construction techniques and materials such as soil, gravel, and clay. The overall approach is very similar to rehabilitation and closure of inactive municipal, commercial, and industrial land-disposal sites.
5. Long-term stability -- The materials selected for site stabilization and closure are natural and durable materials that should maintain the integrity of the site for a long time. Because of the organic nature of the existing landfill materials, some level of long-term maintenance is required to prevent land subsidence and disruption of the closure integrity as the landfill materials continue to decompose.
6. Public acceptance -- During the scoping meeting held 3 July 1981 at Black Lick, the DOE received a petition favoring in-situ stabilization over other concepts that require excavating, removing, reprocessing, and hauling the waste materials because of secondary impacts and exposure that could occur.
7. Conductibility and schedule -- The site stabilization and closure activities can be achieved in approximately one year using conventional earthmoving equipment and will not require highly specialized construction equipment or skilled personnel.
8. Implementation and practicability -- The recommended concept can be implemented and is practical. However, detailed engineering analysis and design tasks must be performed before starting construction.
9. Flexibility of control elements -- The recommended concept is flexible and could be implemented partially or in phases for improved cost-effectiveness.
10. Impact on the UMTRA Project -- The Burrell site, a vicinity property, should be viewed, from a radiation point of view, as a lower priority property. Complete site stabilization and closure should be considered as an upper limit (cost \$2.8 million). Other means of cost reduction should be pursued further.

1.4.2 Implementation guidelines

The guidelines for implementing the recommended alternative are presented in the paragraphs that follow.

1. Final engineering design -- The recommended design for the site stabilization and closure alternative for the Burrell site (shown on Figure 1-8) is based on the following:
 - a. Using a two-layer cover system over the contaminated landfill zone.

FIGURE 1-8
FINAL GRADING PLAN—SITE STABILIZATION AND CLOSURE
ALTERNATIVE 1- WESTERN PART- BURRELL TOWNSHIP SITE

NOTE: 1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR UNION CARBIDE CORP. BY RICHARD G. BACH & ASSOC., ZELIENOPLE, PA. DATED 11/16/77

- b. Installing a subdrain and backfilling the pond areas contiguous to the contaminated zone.
- c. Overall site management to improve drainage and reduce infiltration.

Before the work can begin, a detailed engineering evaluation and design will be required to develop the following:

- a. Optimum level of remedial action and the need for cover and pond stabilization.
 - b. Swale elevation and pond-filling details.
 - c. Type and quantity of materials required for filling the ponds.
 - d. Provisions for draining pond A to lower the water table in the area (north of the railroad tracks).
- 2. Construction sequence -- The site stabilization and closure effort will require approximately one year to stabilize the ponds, cover the contaminated zone, and complete overall site improvements, as required. Before the construction activities, however, the access road and rail crossing must be improved to receive the construction materials (soil, gravel, clay, etc.).
 - 3. Material availability -- The construction materials required for full implementation will consist of large quantities of soil, gravel or stone, and clay (up to 250,000 cubic yards). These materials should be available close to the site. A smaller quantity of bentonite clay (500 tons) will be required for stabilizing the pond and may have to be imported from a considerable distance (e.g., Wyoming).
 - 4. Traffic patterns and control -- The access road to the site must be improved before construction activities begin. In addition, a rail-unloading facility will be required if it is feasible to transport the construction materials by rail. Traffic and rail-crossing controls will be required during the entire construction period.
 - 5. Environmental monitoring during construction -- A moderate level of radiation monitoring during construction is recommended to record the contamination levels at the site and to protect the health of the construction workers.

1.5 CONCLUSIONS

The conclusions reached from this project are as follows:

1. Radiological surveys performed by Oak Ridge National Laboratory, WESTON, and Bendix Corporation have shown the following:
 - a. Concentrations of airborne and ground-water radionuclides, for the most part, are below current NRC and proposed EPA guidelines and standards.
 - b. There is no significant measurable transport of radioactivity off the site.
 - c. Soil radiation levels are, on the average, below the EPA proposed standards; however, such limits are exceeded in a few localized areas.
2. Hydrogeological investigations indicate that the site has high transmissivity and permeability. This appears to have caused a redistribution or reduction of site radiation levels between the 1977 and 1982 radiological surveys. The ground water currently contains radiation levels below the Federal primary drinking-water standards. This decline in radionuclide concentrations is expected to continue.
3. An analysis of the site's radiological and hydrogeological conditions indicates that the Burrell site requires only a minimal level of remedial action.
4. Of the four alternatives for onsite remedial action evaluated, only one, site stabilization and closure, is technically and environmentally justified, and then only as an upper limit.
5. Partial implementation of the stabilization and closure alternative could alleviate the potential radioactivity problem based on the extent of the current site radiological conditions. This could reduce the remediation cost from \$2.9 million to less than \$1 million, particularly if selective site covering and/or nonfilling of the ponds is possible.
6. The base concept, site stabilization and closure, when implemented in full or in part, would meet the feasibility criteria set for this project (i.e., regulatory requirements, environmental protection, cost-effectiveness, technical feasibility, etc.).

2 Site Characterization

2.1 INTRODUCTION

The purpose of this section is to establish the Burrell Township site characteristics and the extent of environmental contamination. This is essential to determine the extent of the remedial action required. The site-characterization effort will primarily focus on problem definition as an aid in evaluating and selecting the appropriate level of control at the site.

The areas addressed in this section are as follows:

1. Site history.
2. Radiological conditions.
3. Hydrogeological conditions.
4. Remedial-action requirements.

2.2 SITE HISTORY

2.2.1 General description

The Burrell site is a 49-acre parcel of land located in western Pennsylvania approximately 40 miles east of Pittsburgh along the southern border of Indiana County (Figure 1-1). It is fully contained within Burrell Township, and lies about 1 mile east of the Town of Blairsville.

The Burrell site is situated within a bend of the Conemaugh River (Figure 1-2). A ConRail mainline borders the northern region of the site. The site is presently owned by the James Burrows Company. There are no structures on the property and, except for the ConRail right-of-way, no public thoroughfares. The most outstanding surface features are three steep-banked ponds located within the western part of the site.

2.2.2 Site history

Originally the Burrell site was a naturally-occurring plateau along the Conemaugh River and was cultivated for field crops and fruit production. Prior to 1949 it became a borrow site and most of its internal area was excavated for sand and gravel. The Pennsylvania Railroad acquired the property in the 1950's and used it as a railroad landfill. A mixture of railroad ties and industrial wastes were deposited on the site from the perimeter toward the excavated area (Figure 2-1). These dumping activities eventually raised the site elevation significantly above its previous elevation. (The current ponds

SOURCE: ORNL RECORD PHOTOGRAPH NO. 0323-79, 1957

FIGURE 2-1

RECORD PHOTOGRAPH, LOOKING DUE EAST, SHOWING GENERAL PIT LAYOUT
AND UNLOADING OPERATIONS - 1957 - BURRELL TOWNSHIP SITE

are a result of the filling operation.) In the early 1950's the U.S. Army Corps of Engineers constructed the Conemaugh Dam approximately 8 miles downstream from the site. As part of this project, a debris control dam was installed at the downstream edge of the Burrell site. Although the Burrell site is within the maximum flood pool of the Conemaugh River, the potential for flooding is believed to be minimal since Hurricane Agnes in 1972, considered to be a 1000-year storm, did not create a flood pool high enough to inundate the site. During that hurricane the onsite ponds did not completely fill.

The radiological contamination at the site is the result of a one-time disposal action. From October 1956 through January 1957 the Vitro Manufacturing Company received AEC and Pennsylvania Railroad approval to dispose of approximately 11,600 tons of residues from its Canonsburg facility at the Burrell landfill. This material was generated from AEC-contracted operations, and was reported to consist primarily of carbonate cake, pitchblende, calcium fluoride, and magnesium fluoride (Leggett et al., 1979).

The Canonsburg residues were transported by rail to the site where they were unloaded and stockpiled in a relatively small area between the spur and disposal pit, in the western portion of the site (known dump area). From there they were pushed by bulldozer over the pit edge (Figure 2-2). This type of disposal resulted in virtually all of the Vitro material being located on a small section of the site. The residues were then covered with an uneven layer of nonradiologically contaminated material.

2.3 RADIOLOGICAL CHARACTERIZATION

2.3.1 Survey by Oak Ridge National Laboratory

A radiological survey of the Burrell site was conducted by Oak Ridge National Laboratory from 11 November through 9 December 1977 (Leggett et al., 1979). This survey included measurements of the following:

1. Beta-gamma dose rates at 1 centimeter from the surface and external gamma-radiation levels at the surface and at 1 meter above the surface, throughout the site.
2. Concentrations of radium-226 and uranium-238 in surface and subsurface soils on the site.
3. Concentrations of radium-226, uranium-238, and lead-210 in surface and subsurface waters on the site.
4. Gamma-radiation levels at various depths in auger holes drilled on the site, as a means of estimating the radium-226 concentrations at these locations.
5. Concentrations of radon and its daughters in air on and near the site.

SOURCE: ORNL RECORD PHOTOGRAPH NO. 0320-79, 1957

FIGURE 2-2

RECORD PHOTOGRAPH SHOWING CANONSBURG/ VITRO WASTE
(CARBONATE CAKE) DUMPED - 1957 - BURRELL TOWNSHIP SITE

The measurements of gamma radiation in the western portion of the site at 1-meter heights above the surface noted a maximum of 630 microroentgens per hour with several measurements above 100 microroentgens per hour (Figure 1-4). The majority of these measurements, in both the eastern and western portions of the site, however, were at background levels, approximately 10 microroentgens per hour. The gamma measurements at the surface showed a similar pattern and peaked at 3100 microroentgens per hour. The beta-gamma measurements followed a similar pattern and peaked at 5.5 millirads per hour.

The concentrations of radium-226 and uranium-238 in surface-soil samples were as high as 5000 picocuries per gram and 360 picocuries per gram, respectively. Radium-226 concentrations in the area showing general surface contamination averaged 10 picocuries per gram. The average uranium-238 surface concentration in this same area was 3.9 picocuries per gram. The background levels for radium-226 and uranium-238 are approximately 1.9 and 0.9 picocuries per gram, respectively.

The subsurface-soil contamination (Figure 1-3) was determined by augering holes ranging to 50 feet in depth and subsequently analyzing both the soils removed in the augering process and the materials remaining in the ground. It was determined that the radioactive residues were widely scattered and were found at depths varying from the surface to 36 feet. Because of the sampling method used and the heterogeneity of the results, no estimate of maximum or average radium-226 or uranium-238 concentrations could be made. However, this technique, coupled with gamma logging of the bore holes, did permit an estimation of the total above-background radioactivity present. It was estimated that 4 curies of radium-226 and 1.3 curies of uranium-238 were buried at the site.

The concentrations of radium-226, thorium-230, and uranium-238 were determined in ground water taken from the auger holes. The maximum values found were 370 picocuries per liter for thorium-230, 10 picocuries per liter for radium-226, and 403 picocuries per liter for uranium-238. Analyses of water samples taken from drainage pathways to the Conemaugh River found thorium-230 and radium-226 at background concentrations, and lead-210 and uranium-238 at levels slightly above background. Typical background values for these radionuclides average 1 picocurie per liter. Analyses of sediments from these same locations showed similar results.

The average atmospheric-radon levels (1.82 picocuries per liter being the one exception) were no different from normal background levels, which are typically less than 1 picocurie per liter. All radon-daughter-product concentrations were at a normal outdoors background level of approximately 0.001 working level.

In summary, it appeared that radioactive residues containing an estimated 5.8 tons of uranium oxide (approximately 1.5 curies of uranium-238) were transferred from the Canonsburg site and dumped at the Burrell site. A combination of analyses of subsurface-soil samples for 76 holes augered on this site to depths to 50 feet revealed the general location of residues containing an estimated above-background total uranium-238 activity of 1.3 curies, and an estimated total radium-226 activity of 4 curies. It appeared

that more than 75 percent of the residues lie at least 10 feet beneath the surface. Radioactive residues were also scattered on the surface. At some points the surface soils showed radium-226 concentrations of several thousand picocuries per gram, uranium-238 soil concentrations of 360 picocuries per gram, and external-gamma-radiation levels at 1 meter in excess of 600 microroentgens per hour, and beta-gamma dose rates at 1 centimeter from the surface in excess of 5 millirads per hour. Such measurements were not, however, representative of the entire area; at most sampling points radionuclide concentrations in surface soils and radiation levels at the surface and at 1 meter above the surface were less than 10 times background levels.

2.3.2 Survey by Roy F. Weston, Inc. (WESTON)

A limited radiological survey of the Burrell site was performed by WESTON in July 1981 and in January and February 1982. These surveys included measurements of the following:

1. Concentrations of uranium-234, -235, and -238, and radium-226 in ground water.
2. Gamma-radiation levels at various depths in wells drilled on the site.

The highest uranium concentrations found in ground water were as follows:

1. Uranium-234 -- 6.6 picocuries per liter.
2. Uranium-235 -- 0.22 picocurie per liter.
3. Uranium-238 -- 5.3 picocuries per liter.

These levels were all found in a well approximately 1500 feet east of the known dump area. The uranium concentrations in ground water from wells in the known dump area were below the EPA proposed standard of 10 picocuries per liter with one exception of about 12 picocuries per liter. The radium-226 levels in all wells tested were at background level and below the EPA proposed standard of 5 picocuries per liter.

Gamma-radiation levels in 7 of 28 wells were above background activity (Figure 1-5). One well had an activity maximum at a depth of 21 feet, and one well showed maximum activity at a depth of 11 feet. The activity in the remaining wells was at depths less than 7 feet.

Table 2-1 is a tabulation of analyses of radionuclides in water samples from the site. Figure 2-3 illustrates uranium-238 concentrations in ground-water samples at the site. No water samples exceeded the Federal drinking-water standard for total radium (5 picocuries per liter). In three samples the detection limit obtained for gross-alpha activity exceeded the Federal drinking-water limit of 15 picocuries per liter, and one analysis detected 16 picocuries per liter -- all other samples were below that limit. Two of the samples exceeded the EPA proposed standard for total uranium of 10 picocuries per liter.

Table 2-1. Summary of radionuclide data in ground water-- Burrell site

Well number ^a	Ra-226 (pCi/l)	Gross alpha (pCi/l)	Gross beta (pCi/l)	U-234 (pCi/l)	U-235 (pCi/l)	U-238 (pCi/l)	Total uranium (pCi/l)
2	2.02	< 5	17.0	0.54	<0.05	0.52	1.11
3	1.00	10	17.0	1.81	<0.10	1.63	3.54
5	<1.00	<40	<40.0	3.56	0.12	3.28	6.96
6	<1.00	10	15.0	2.78	0.13	2.37	5.28
7	<1.00	5	25.0	1.17	<0.05	0.93	2.15
8	<1.00	10	18.0	0.60	<0.05	0.52	1.17
9	<1.28	<40	66.0	6.57	0.22	5.34	12.13
10	<1.00	5	3.5	0.30	<0.05	0.21	0.56
11	<1.00	10	<4.0	3.74	0.13	3.81	7.68
12	1.37	<6	6.1	0.56	<0.05	0.52	1.13
13	<1.00	16	21.0	5.87	0.40	5.73	12.00
14	<1.00	<10	5.2	3.51	0.16	2.86	6.53
15	<1.00	<4	4.0	0.13	<0.05	<0.10	0.28
16	<1.00	<4	4.3	1.79	<0.10	1.62	3.51
17	<1.00	<4	3.7	0.47	<0.05	0.42	0.94
18	1.34	<4	5.8	0.10	<0.05	<0.10	0.25
19	<1.00	<10	21.0	1.30	<0.05	1.27	2.62
20	1.00	<4	4.4	0.74	<0.05	0.77	1.56
21	<1.00	<30	<4.0	<0.10	<0.05	<0.10	0.25
22	<1.00	<7	13.0	<0.10	<0.05	<0.10	0.25
23	<1.00	<9	16.0	0.85	<0.05	0.67	1.57
24	<1.00	<5	3.7	0.30	<0.03	0.18	0.51
25	<1.00	<2	4.0	0.21	<0.02	0.13	0.36
26	<1.00	<2	8.1	1.30	<0.01	0.95	2.26
27	<1.00	<3	3.8	0.22	<0.02	0.16	0.40
28	<1.00	<4	2.0	0.55	0.068	0.16	0.78

Standards

EPA	5	15				10
DOE-NRC	30		4000	4000	600	600

^aWell locations are shown on Figure 1-2.

FIGURE 2-3
ISOPLETH MAP OF GROUNDWATER
URANIUM-238 CONCENTRATIONS
BURRELL TOWNSHIP SITE

- NOTE:
1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR UNION CARBIDE CORP. BY RICHARD G. BACH & ASSOC., ZENITH, PA., DATED 1/18/81.
 2. TOPOGRAPHICAL DETAIL FROM MAP, TEST HOLE LOCATIONS, FOR ROY F. WESTON INC. BY KURCH-HOUSLEY & ASSOC., PITTSBURGH, PA., DATED 11/6/81, REV. 3/2/82.
 3. ALL ELEVATIONS ARE TO USGS DATUM, BLAIRSVILLE, PA. AND ARE SHOWN IN FT/MSL. ELEVATION CHECK RUN BY K. SCH-HOUSLEY, PITTSBURGH, PA., DATED 6/11/82.

2.3.3 Survey by Bendix Corporation

In March and April of 1982 Bendix Field Engineering Corporation performed a radiological survey of the Burrell site (Rarrick, 1982). This survey included measurements of the following:

1. Gamma-radiation levels at various depths in wells drilled for the WESTON survey on the site.
2. Estimates of radium-226 concentrations and magnetic susceptibilities in the wells as a function of depth.
3. Estimates of potassium, thorium, and total potassium-uranium-thorium in these wells as a function of depth.

The gamma-radiation levels in 22 wells were above background in nine instances. In seven of these nine instances the activity maximum was within 8 feet of the ground surface. The other wells had maximum above-background activity at 12 feet and at 75 to 100 feet. This latter measurement was in bedrock and may not be related to the site's use as a dumping area.

The estimates of the radium-226 concentrations in subsurface soil ranged from less than 1 picocurie per gram up to 800 picocuries per gram with an estimated average of less than 5 picocuries per gram. There were seven instances in which the radium activity was greater than 10 picocuries per gram at depths corresponding to the increased gamma levels, with the exception of the bedrock.

The magnetic susceptibility readings noted divergent readings with respect to depth. These readings could indicate the presence of iron sulfides, a constituent of the mill-tailings wastes that had been deposited. There was no apparent correlation between the magnetic levels and gamma levels with respect to depth. A possible interpretation of this find is that the radioactive materials, being more water soluble than the iron, have been washed out.

2.3.4 Summary of radiological conditions

In 1977, surveys of the Burrell site noted levels of radioactivity in excess of the EPA proposed standards. Specifically, the radium content of surface and subsurface soils, and external gamma-radiation levels were above allowable limits. The radium and uranium content of ground water on the site (but not off the site) was well above naturally-occurring background levels. In addition, it was determined that the site contained above-background amounts of approximately 1.3 curies of uranium-238 and 4 curies of radium-226, with more than 75 percent of this material at depths greater than 10 feet. These results confirmed the historical record of the method of disposal, the quantity of radioactive materials deposited, and also indicated that all of the dumped materials were essentially stabilized on the site. Surveys performed in 1981 and 1982 noted very different site conditions. These surveys found very little radioactivity at the site. The external gamma-dose rates were essentially at background levels for the entire site, except for

one small area in the northwestern corner. The radium levels in the ground water were at background levels, and the uranium levels were only slightly above background. It was also determined that very little radioactivity was present in soils either below 10 feet or on the surface. Based on these results, there has been a change in the radioactivity levels of the site. This change probably occurred either through a redistribution of the materials on the site, or more likely, transportation of the materials off the site. In fact, the data suggest that the radioactive materials originally deposited at the site have been leached out. Regardless of the reason for the change, however, the need for remedial action is now minimal since there are only a few small contaminated areas remaining in need of clean up.

Based on the surveys performed by Oak Ridge National Laboratory, WESTON, and Bendix Corporation, the following conclusions were reached concerning the current conditions at the Burrell site:

1. The concentrations of airborne radionuclides are within NRC guidelines.
2. The concentrations of radionuclides in ground water are below the EPA proposed standards and the NRC guidelines.
3. The average radium-226 concentration in soil is less than the EPA proposed standard; there are, however, several localized areas with higher concentrations.
4. The average external-dose rate is within the NRC regulations; there is one small area with a higher dose rate than the NRC regulations.
5. Measured radioactivity levels in ground water and ambient air show that there is no current apparent significant transport of radioactivity off the site.

2.4 HYDROGEOLOGY OF THE BURRELL SITE

2.4.1 Objectives and background

The critical hydrogeological questions at the Burrell site are as follows:

1. Is ground water presently contaminated as a result of the tailings disposed of at the site?
2. What are the significant ground-water-bearing units on the site, and what are the hydraulic characteristics of those units?
3. Where does ground water flowing through the site discharge?
4. What is the quantity of ground water that moves through the site, and in what direction does it flow?

In order to answer these question, WESTON conducted a detailed field investigation including installation of 30 monitor wells, and performance of pump tests, percolation and infiltration tests on the soils, and water-quality analyses.

The historical use of the Burrell site is relevant to the present site hydrogeology. Figure 2-4 is a reconstruction of the site prepared from 1949 aerial photographs. It appears that prior to that year the site had been an active borrowing operation, mining the site for alluvial and colluvial sand and gravel deposits. As shown on Figure 2-4 there were steep cut faces along the present ConRail tracks and the river. A berm of alluvium was apparently left in place along the river. The pit was flat-floored with an apparent floor elevation at the river level. An examination of available photographs taken during 1957 shows that landfilling proceeded from the edge of the site toward the middle. Ponds B, C, and D exist because these areas were not filled.

The result of these activities is the present site configuration, which is a bowl made of alluvium and colluvium with railroad ties, rubble, ash, miscellaneous fill, and the Canonsburg material filling the bowl. The bowl sits on a base of shale and sandstone bedrock. Figure 2-5 is a cross-section of the site that shows the relationship of these materials.

2.4.2 Field investigation and results

The field investigation done by WESTON was conducted as an integrated effort to characterize all the components of the site including the soils, fill material, alluvium and colluvium, bedrock, and water quality. The methods that were used to obtain data were as follows:

1. Installation of wells.
2. Construction of soil-test pits.
3. Infiltration and percolation tests.
4. Aquifer tests.
5. Ground-water sampling.

2.4.2.1 Soils

The soils at the Burrell site have been severely disrupted during past excavation and landfilling operations. No original soil was found in any of the 12 test pits (Figure 1-2). (The test pits were excavated using a backhoe to characterize site soils. The pits were 2 feet wide by 6 feet deep and 6 to 10 feet long.) The permeability of surficial materials was determined by the standard percolation method. Soil infiltration rates were determined by the single-ring method within the upper 4 inches of soil; the tests were conducted at the ground surface and at depths of 32 to 84 inches. The percolation rate ranged from 6.60×10^{-4} inches per second to 2.81×10^{-3} inches per second. The infiltration rates ranged from 1.67×10^{-4} inches per second to 9.69×10^{-3} inches per second. The percolation rates are moderate to rapid,

FIGURE 2-4
SITE CONFIGURATION — 1949
BURRELL TOWNSHIP SITE

FROM HISTORICAL AERIAL PHOTOGRAPHY, USDA,
DATE: 10/13/49

NOTE: 1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR
UNION CARBIDE CORP. BY RICHARD G. BACH & ASSOC.,
ZELIENOPLE, PA-DATED 11/16/77

and the infiltration rates are slow to rapid, reflecting the variability of the surficial materials as well as the differences in compaction of this material. The results of the soil tests are presented in Table 2-2.

2.4.2.2 Geology

The onsite geology was determined from data collected while drilling the monitoring wells. The site is underlain by three separate materials: fill, unconsolidated sediments, and sedimentary rocks. The fill material is made up of ash, rubble, coal, and scrap metal. Used railroad ties are a significant component of the fill. The thickness of the fill is variable; the maximum thickness is approximately 50 feet. Unconsolidated sediments underlie the fill and include both colluvium (or talus) and alluvium. The colluvium is composed of unweathered but broken rocks, ranging widely in size, and has been eroded from the steep cliff face north of the site. The maximum thickness of the colluvium at the site is approximately 18 feet near the cliff. The alluvium is fine- to coarse-grained silty sand deposited by the Conemaugh River; its maximum thickness on the site is approximately 12 feet. The bedrock at the site is composed of alternating layers of shale, limestone, sandstone, siltstone, coal, coal under clays, and clay stone. These rocks belong to the Pennsylvania Age Casselman Formation, which is a member of the Conemaugh Group of coal-bearing formations. The bedding is well-defined; in most units the thickness ranges from 1 foot to 5 feet. Structurally, the local bedrock lies in a gently folded northeast-trending anticline.

2.4.3 Water quality

The ground-water chemistry at the Burrell Township site is based on a complex interaction among three chemically different components. The components are the following:

1. Combined flow from ground-water springs and storm-water runoff from the bluff north of the site.
2. Precipitation.
3. The mixture of landfill materials emplaced at the site.

Table 2-3 is a summary of water-quality analyses of the Burrell samples. The sample from well 21 provides an approximation of the water chemistry of the infiltration running off the bluff. This chemistry is characterized by a very acid pH, low dissolved chloride and high dissolved sulfate ions, a high oxidation-reduction potential (ORP), and low to nondetectable radionuclide concentrations.

Table 2-2. Percolation and infiltration rates for Burrell Township site

Test pit ^a	Percolation rate (in./sec)	Percolation test depth (in.)	Infiltration rate ^b (in./sec)
1A	2.59×10^{-3}	84	2.17×10^{-3}
1B	9.17×10^{-4}	40	8.34×10^{-4}
2A	2.44×10^{-3}	72	2.0×10^{-3}
2B	Flooded	0	7.32×10^{-3}
3A	6.65×10^{-4}	66	6.18×10^{-3}
3B	2.81×10^{-3}	32	9.69×10^{-3}
4A	1.22×10^{-3}	56	6.65×10^{-4}
4B	Flooded	0	2.16×10^{-3}
5A	8.35×10^{-4}	66	1.67×10^{-4}
5B	1.42×10^{-3}	48	1.5×10^{-3}
6A	1.19×10^{-3}	60	1.67×10^{-3}
6B	1.98×10^{-3}	48	9.17×10^{-3}
$\bar{X}$	7.79×10^{-4}	0	3.63×10^{-3}

^aTest pit locations are shown on Figure 1-2.

^bInfiltration tests are performed within the upper 4 inches of soil.

Table 2-3. Ground-water quality at the Burrell site

Well number	Date sampled	pH	Specific conductance (µmhos/cm)	Cl ⁻ (mg/L)	SO ₄ (mg/L)	NO ₃ N (mg/L)	Fe (mg/L)	Pb (mg/L)	Ba (mg/L)	B (mg/L)
1	Dry									
2	1-29-82	6.8	1100	20.8	91	NF	0.06	NF	0.07	0.63
3	1-29-82	6.9	1175	14	348	NF	0.22	NF	0.02	0.40
4	Dry									
5	Blocked									
6	2-4-82	7.2	1200	35.2	170	NF	0.10	NF	0.11	0.45
7	1-29-82	7.7	1300	59.8	200	NF	NF	NF	0.10	1.13
8	1-29-82	7.4	900	9.3	131	NF	NF	NF	0.04	0.59
9	1-29-82	8.8	4900	106	1590	6.5	142	NF	0.41	1.70
10	2-4-82	7.3	900	21.2	108	NF	0.07	NF	0.02	0.18
11	1-29-82	7.1	2000	795	NF	NF	NF	NF	NF	0.20
12	1-29-82	5.8	750	8.3	720	0.34	3.84	NF	NF	0.27
13	1-29-82	7.2	1975	24.3	300	NF	NF	NF	0.07	0.24
14	1-29-82	3.5	1825	23.4	880	1.62	50.1	0.52	NF	0.07
15	1-29-82	4.6	1250	17.8	680	0.33	0.40	NF	NF	0.06
16	2-4-82	6.7	1550	16.8	198	NF	0.06	NF	NF	0.22
17	2-4-82	6.8	1100	19.1	380	NF	NF	NF	0.02	0.24
18	2-2-82	7.0	570	9.1	112	0.23	1.62	NF	NF	0.17
19	1-29-82	6.9	1500	15.5	266	NF	0.07	NF	NF	0.94
20	2-4-82	6.6	1300	20.4	665	Inter- ference	NF	NF	0.03	0.07
21	1-29-82	3.7	---	5.6	891	0.32	0.72	NF	NF	NF
	2-2-82	3.3	1850	8.8	1120	0.73	3.7	NF	NF	0.10
22	2-4-82	5.2	1600	18	845	NF	NF	NF	NF	NF
23	2-2-82	6.9	1425	51.8	390	NF	NF	NF	NF	0.43
24	2-2-82	7.8	325	4.2	34.8	NF	0.49	NF	0.10	0.15
25	2-2-82	7.6	1200	24	169	NF	NF	NF	0.09	0.50
26	2-2-82	7.0	700	18.3	79	NF	0.14	NF	0.03	0.16
27	2-4-82	6.6	---	11	895	NF	13	NF	NF	0.12
28	2-4-82	7.5	350	7.0	9.6	NF	NF	NF	0.72	0.08
Pond A	2-4-82	7.0	1250	19.7	420	NF	NF	NF	0.02	0.76
Pond B	2-4-82	6.9	1200	20.2	290	NF	NF	NF	0.03	0.41
Pond C	2-4-82	5.7	12	22.3	440	0.72	NF	NF	NF	0.07

Note: Well locations are shown on Figure 1-2.
 NF = not found

Direct data are not available to characterize the rain-water chemistry. However, rain water in the greater Pittsburgh area would be expected to have an acid pH, moderate chloride and sulfate concentrations, a high oxidation-reduction potential, and low to nondetectable radionuclide concentrations. The bulk chemical composition of the fill material is undoubtedly highly variable. Since chemical interactions between the water and solid phases are dominated by solid surface effects and by the presence of readily soluble mineral phases, chemical analyses of the samples of fill materials would not be instructive. According to the water-chemistry analyses in Table 2-3 from wells on the site, the landfill materials may be characterized approximately as having a pH-buffered water in the mildly alkaline range, with significant amounts of readily soluble organic species, or slightly soluble reduced mineral species that result in water with a mildly reduced oxidation-reduction potential, very few remaining readily soluble chloride or sulfate salts, and very few remaining radionuclide salts of any solubility.

The result of the mixture and chemical interactions among these three components is a ground-water chemistry at the Burrell site that represents only a mildly degraded ground-water quality (Figures 2-6 and 2-7). Sulfate-ion concentrations exceed drinking-water standards (250 milligrams per liter) in all samples, but are not inconsistent with sulfate levels to be expected in ground waters contained in coal-containing bedrock in the site's general region. The chloride-ion level is well within the 250 milligrams per liter drinking-water standards in all wells at the site. The water pH over most of the site is within drinking-water standards, and where the pH is too acidic this departure from the standards would be typical of ground waters contained in coal-containing bedrock. All other dissolved nonradionuclide species analyzed were within drinking-water standards, with the exception of lead and iron. The lead analyses were run at a detection limit of 0.5 part per million, which is above the standard of 0.05 milligram per liter. Therefore, the absence of detectable lead does not assure that the standard is met. Iron exceeded the Federal drinking-water standard of 0.3 part per million in several samples, although the iron levels found are consistent with the concentrations expected.

2.4.4 Hydrogeology

The locations of the wells are shown on Figure 1-2. Most of the wells were screened to the total saturated thickness of the materials encountered. Six wells were completed in the fill or alluvium and colluvium. Figure 2-8 is a piezometric surface map representing base-flow conditions at the site. The map indicates only two areas of relatively steep water-table gradients; on the river side and on the north side adjacent to the bluff near pond A. Over the rest of the site the gradients are gentle. The flow lines on the contours show that ground water flows to two discharge areas: the ponds and the river bank.

NOTE: 1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR UNION CARBIDE CORP. BY RICHARD G. BACH & ASSOC. ZELLENOPLE, PA DATED 11/6/77
2. TOPOGRAPHICAL DETAIL FROM MAP TEST HOLE LOCATIONS FOR ROY E. WESTON INC. BY KURCH-HOUSLEY & ASSOC. PITTSBURGH, PA DATED 11/6/81, REV. 3/2/82
3. ALL ELEVATIONS ARE TO USGS DATUM, BLAIRSVILLE, PA, AND ARE SHOWN IN FT/MSL. ELEVATION CHECK RUN BY KURCH-HOUSLEY, PITTSBURGH, PA DATED 6/11/82

FIGURE 2-8
WATER TABLE MAP — 19 JANUARY 1982
BURRELL TOWNSHIP SITE

The permeability of the alluvium and the fill materials was determined by pump testing wells 21 and 27. According to these data the transmissivity in the alluvium at well 21 is 35 square feet per day. Adjusting this value for the saturated thickness of alluvium, the permeability is 1.28 feet per day. The pump-test results for well 27 were adjusted for the contribution of the alluvium below the fill. The resulting transmissivity for the fill material is 4878 square feet per day. The permeability of fill is 245 feet per day. A confirmation of this value was made by determining the inflow rate into the ponds that are entirely within the fill material. Assuming a porosity of 40 percent for the fill material, the permeability was calculated as 245 feet per day.

A water balance for the site assumed that the recharge to alluvium, colluvium, and bedrock below the fill is zero based on the large permeability differential between the fill and the underlying materials. This was calculated from a flow net for base-flow conditions of 556 gallons per minute flow through the site. The discharge through the ponds is 200 gallons per minute, and the discharge to the river is 356 gallons per minute.

Figure 2-9 is an isopach map of the unsaturated fill at the site; the average thickness is 29 feet. Using 40 percent as the porosity for the fill, the volume of water stored in the fill is 1.8×10^8 gallons. If recharge to the fill is 556 gallons per minute, then the annual throughput of water is 2.9×10^8 gallons. The resident time of water in the fill is seven months. If the radioactive wastes were emplaced in 1957, then there have been 40 pore volume changes since the wastes were emplaced.

3 Evaluation of Onsite Remedial-Action Alternatives

3.1 BACKGROUND

From the latest radiological survey by the Bendix Corporation of the Burrell site, it can be concluded that the current levels of radiation do not warrant extensive remedial action. However, because of the uncertainty of the final EPA standards (yet to be published), a conservative approach has been taken. The remedial action is assumed to be based on current (stringent) requirements for remediation of inactive uranium-mill-tailings sites and designated properties. Such standards would require removing the contaminated material that exceeds, on the average, a radium-226 content of five picocuries per gram, or stabilizing and containing the site to protect the environment from the release of radionuclides in various pathways for at least 1000 years. Since the scope of this study is to investigate the feasibility of onsite remedial-action alternatives, only those alternatives that do not require offsite disposal of contaminated material have been developed and evaluated.

Four levels of control were identified as potentially feasible and applicable to the Burrell Township site. The alternatives are the following:

1. Site stabilization and closure.
2. Site control and containment.
3. Waste excavation and encapsulation.
4. Waste excavation, incineration, and encapsulation of residues.

At the present time radionuclide releases from the site are below all applicable EPA proposed standards. Therefore, each of the plans developed emphasizes the prevention of a future rise in radionuclide release as opposed to achieving major reductions in the current rates of radionuclide release. The site is vulnerable to deterioration by natural processes with time. The reasons for this are as follows:

1. Slopes -- Very steep slopes adjacent to the ponds are subject to erosion, which not only adds to siltation, but raises the question of surface erosion eventually extending to the radioactive portion of the site. Erosion could be accelerated by failure of the slopes due to the poor shear strength of the refuse deposit.
2. Surface permeability -- The materials over the contaminated zone are highly permeable, with infiltration estimated at 85 percent. Leaching of radionuclides has been high and probably accounts for the low residual-attrition rates currently observed. Infiltration may be economically reduced by a number of techniques relating to slope and porosity modifications.

3. Landfill stability -- Test borings indicate substantial amounts of decomposable organic waste materials scattered randomly throughout the refuse deposit. With abundant infiltration, rapid decomposition is expected. Subsequent consolidation will produce differential surface settlement that will further increase infiltration by ponding any rainfall in settlement depressions on the surface. Since the current slopes are flat, the effect may appear rather quickly.

In establishing an array of possible remedial-action measures which might be appropriate to the site, priorities were established in the following order:

1. Stabilization of ground water.
2. Prevention of excessive erosion.
3. Reduction in infiltration.
4. Reduction of decomposition settlement.
5. Protection of buried material and cover system.

Four levels of remedial action were investigated, ranging from little more than basic stabilization of ground water and slopes, to a comprehensive program intended to address all possible site characteristics, which may lead to future increases in radionuclide-release rates. The essential features of the options selected are summarized in Table 3-1. Alternative 1 involves the smallest quantity of imported fill materials. Alternatives 2 and 3 require larger amounts of fill to establish steeper slopes and for encapsulation, while Alternative 4 requires substantial expenditures for excavation and incineration.

In the subsequent subsections of this chapter, engineering calculations are documented to provide a basis for evaluating the comparative costs of the selected options. Where feasible, the changes in variables affecting radionuclide-loss rates are also evaluated.

3.2 ALTERNATIVE 1: SITE STABILIZATION AND CLOSURE

3.2.1 Site-stabilization concept

The results of ambient air, surface soil, and ground-water monitoring, and radon flux calculations indicate that the current radionuclide releases from the site are within the EPA proposed standards. There may be hot spots on the site that may cause a future increase in such levels, but the high porosity of the refuse deposit makes such an event very unlikely. The most probable future changes that could affect radionuclide-loss rates are a possible rise or mounding of the ground-water table that would saturate the deposit, and the formation of surface-settlement depressions that would increase infiltration. The possibility of either occurrence can be significantly reduced by relatively straightforward and cost-effective procedures to be detailed fully in the discussion that follows. Protective measures should also incorporate a barrier against penetration by animals, and should result in final slopes that are conducive to the growth of a permanent vegetative cover, and which would minimize surface erosion.

Table 3-1. Summary of remedial-action alternatives

Function	Control alternative			
	1	2	3	4
	Site stabilization and closure	Site control and containment	Waste excavation and encapsulation	Waste excavation, incineration, and encapsulation
Ground-water stabilization	Gravel subdrain at pond level to prevent ground-water rise.	Same except add ion-exchange media to stone.	Gravel subdrain only.	Gravel subdrain only.
Slope stability and erosion control	Fill ponds to eliminate slopes.	Fill ponds to eliminate slopes.	Fill ponds to eliminate slopes. ^a	Fill ponds to eliminate slopes. ^a
Infiltration control	Grade to 2 percent slope over deposit.	Grade to 4 percent slope and treat with clay.	Excavate deposit and encapsulate in clay. Use 3 percent slope.	Excavate deposit and encapsulate in clay. Use 2 percent slope.
Decomposition settlement	Slope control only.	Slope control only.	Slope control and compaction of wastes.	Incinerate combustible fraction prior to placement to eliminate settlement.
Root and animal penetration	Stone layer.	Stone layer.	Stone layer.	Stone layer.

^aEncapsulation areas are partially located over the existing ponds.

The main features of this alternative are conceptually presented on Figure 3-1, and include the following:

1. Reduction of infiltration (to approximately 20 percent of the total annual precipitation) through the contaminated zone by placement of a two-layer surface-cover system consisting of the following:
 - a. A 12-inch stone layer covered by geotextile (fabrics developed for specialized field applications, such as filtering, load-bearing, etc.).
 - b. An 18-inch soil layer covered by 6 inches of topsoil.
2. Reduction in the potential for animal and root penetration, as well as potential radon emanation, by the two-layer cover components.
3. Reduction of surface erosion by establishing a vegetation cover, improving the drainage pattern for the site by constructing swales and sedimentation ponds.
4. Stabilization of the side slopes of the contaminated zone by backfilling ponds B, C, and D.
5. Control of the ground-water elevation in the contaminated area by placing a gravel subdrain in the lower portion of ponds B, C, and D (as shown on Figure 3-1) to preclude the potential for mounding into the waste materials.
6. Overall site management and improvements to prevent excessive erosion and potential exposure of contaminated material through environmental pathways.

The ground-water table is currently near the bottom of the waste deposit. The top of the ground-water table is contained within the bottom of the fill material and the alluvium and colluvium that underlie the site. The current subsurface-drainage pattern can be protected by establishing a gravel subdrain at the bottom of the pond prior to filling the ponds. The gravel subdrain will prevent the possibility of clogging the existing permeable layer by accumulating sediment in the ponds. The gravel layer will be extended westerly to a seepage area adjacent to the Conemaugh River.

Infiltration will be reduced primarily through enhancing runoff by establishing a 2-percent minimum surface slope over the radioactive area, and routing collected rain water to drainage swales leading to the river. The main drainage swale will be located over the existing ponds with a branch extending north to the railroad tracks. Both swales will be lined with low-porosity soil and will lead to a sedimentation basin to be established at the western end of the site.

FIGURE 3-1
SCHEMATIC PLAN OF SITE STABILIZATION AND CLOSURE —ALTERNATIVE 1
WESTERN PART— BURRELL TOWNSHIP SITE

NOTE: 1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR
UNION CARBIDE CORP., BY RICHARD G. BACH & ASSOC.,
ZELIENOPLE, PA-DATED 11/16/77

Erosion is currently pronounced on the steep slopes leading down to the pond level. Following the placement of a gravel underdrain at the pond elevation, a fine gravel and sand filter will be placed at the pond level, and earth fill will be used to bring the pond area up to grade. The earth fill will be capped with a bentonite-treated layer to form the drainage swale. The location of the swale (shown on Figure 3-1) over the ponds substantially reduces the fill required to bring the area up to a suitable grade.

General site-erosion protection will be provided by a 6-inch topsoil layer established over the entire disturbed surface and a grass cover. Once the ponds are filled, the entire contaminated area will be above the potential flood elevation. Therefore, no special flood-erosion measures will be required.

An 8-inch layer of 4-inch diameter stone, and a 4-inch layer of 3/4-inch diameter gravel are proposed over the contaminated area to prevent animals from burrowing and digging. The stone will be placed following rough filling and grading, and before the final earth fill and topsoil are placed. The stone layer will also serve as a subsurface drain to assist in removing infiltration from the upper soil layers.

3.2.2 Evaluation of hydrological effectiveness

1. Ground water -- The gravel subdrain is intended to minimize any future mounding of ground water. Therefore, no change is hypothesized in ground-water elevations in the contaminated zone.
2. Surface water -- No impervious surface barrier is proposed in conjunction with this alternative. However, the elimination of surface depressions, and providing surface slope and positive drainage of precipitation will reduce infiltration substantially. The existing and modified surface-water budgets obtained by hydrological modeling are shown on Figure 3-2. The EPA hydrologic simulation model for hazardous waste disposal sites (HSSWDS), was used for all computations. (See Appendix A for a detailed discussion of this model.)

The seepage analysis was based on average rainfall data for Pittsburgh, Pennsylvania, from 1974 through 1978. A schematic showing the projected rainfall distribution is included on Figure 3-2. Of approximately 40 inches of rainfall per year, 8.15 inches is expected to penetrate to the drainage layer. Since no impervious barrier is incorporated in this alternative, 7.79 inches would penetrate the underlying contaminated zone. This represents approximately 20 percent of applied rainfall. Given the current porous surface and presence of low-evapotranspirative vegetation, as much as 85 percent may currently be infiltrating. Thus, a reduction in percolation by a factor of four is expected to result from the surface improvements.

FIGURE 3-2
DISTRIBUTION OF PRECIPITATION THROUGH COVER SYSTEM
SITE STABILIZATION AND CLOSURE —ALTERNATIVE 1
BURRELL TOWNSHIP SITE

The reduction in infiltration obtained by surface modifications should be considered temporary in that decomposition and consolidation of the biodegradable fraction of the fill will cause future settlement that will alter grades and may reestablish surface depressions. Thus, the 75-percent reduction in net infiltration predicted should be taken as a factor of safety against infiltration becoming worse than it currently is, rather than as a true reduction. The extent of consolidation and settlement is impossible to predict from the data available, but it is estimated that the grades proposed are sufficient to keep infiltration under reasonable control for perhaps 50 years, at which time further filling and grading may be desirable.

3.2.3 Construction requirements

Construction requirements are discussed in the following subsections in the general sequence in which they may be scheduled.

1. Install subdrain and fill pond area -- The ponds must be drained before grading for the stone-drainage blanket. The grading requirements will consist of removing the existing sediment deposits and any debris or bulky objects to ensure high-permeability contact with the underlying porous strata. All of the earth removed (8000 cubic yards) will be deposited on the surface of the contaminated area as an adjunct to rough grading.

A 3-foot thick layer of 3/4-inch graded gravel will be compacted over the pond area and covered with 6 inches of pea gravel and 6 inches of coarse sand to serve as a filter. This drainage system will form a gravel subdrain. The area will then be brought up to 2 feet below final grade with fill to form a base for the impervious drainage swale. A typical cross-section is shown on Figure 3-3. The estimated quantities of materials required are as follows:

3/4-inch gravel	17,700 cubic yards
Pea gravel	1,800 cubic yards
Coarse sand	1,800 cubic yards

From a cost-effectiveness standpoint, it is proposed that slag or other readily available clean material be considered for fill over the subdrain. The ponds will then be filled to within 2 feet of the final grade. A 2-foot layer of earth cover will be placed over the fill material (or slag) to bring the surface up to grade, and an area 100-feet wide along the centerline of the swales will be treated with 5 pounds per square foot of bentonite, disced, and harrowed to a depth of 6 inches. The bentonite will minimize seepage of the runoff through the porous fill material. The quantities of materials required are as follows:

Fill material (slag)	145,200 cubic yards
Earth fill	28,900 cubic yards
Bentonite clay	530 tons

FIGURE 3-3
TYPICAL SECTION—SITE STABILIZATION AND CLOSURE
ALTERNATIVE 1—BURRELL TOWNSHIP SITE

2. Rough-grade surface of deposit -- The potential for reshaping the surface is regarded as somewhat limited because of the presence of heavy railroad ties buried near the surface. However, some shaping can be accomplished, and the materials removed from the ponds can be incorporated to yield a rough-grade contour. Considerable cutting will be required adjacent to the railroad to provide a basis for drainage. The total area affected will be approximately 10 acres.
3. Place fill for surface slope over contaminated area -- Approximately 31,100 cubic yards of clean fill must be placed and compacted to establish the basic 2-percent slope over the contaminated area. The contours of the site prior to placement of the two-layer final cover are shown on Figure 3-4.
4. Construct final cover over contaminated area -- The final cover consists of a two-layer system. The initial layer is a stone drainage blanket to be placed over the surface of the fill, followed by a second layer consisting of a soil cover. The initial stone drainage blanket layer consists of 8 inches of 4-inch diameter stone capped with 4 inches of 3/4-inch gravel that is covered by a single thickness of geotextile. This drainage blanket will serve the dual purpose of draining the surface-water infiltration and blocking possible animal penetration. The geotextile will serve to prevent the stone drain layer from clogging with sediment. The stone layer is required only over the contaminated zone, and the estimated quantities of materials are as follows:

4-inch stone	7,400 cubic yards
3/4-inch gravel	3,700 cubic yards
Geotextile	33,200 square yards

An 18-inch layer of clean earth cover will be applied over the drainage blanket and lightly compacted. This 18-inch soil layer will then be covered with a 6-inch layer of topsoil for a total final soil cover of 24 inches. The earth layer will absorb rain water, protect the drainage layer, and provide a reasonable root zone above the geotextile for vegetative growth. The total soil cover required is 21,400 cubic yards.

5. Grade, place topsoil over noncontaminated areas and seed -- The remaining area of the landfill should be graded to provide a gently sloping surface so that surface runoff is directed to the southern drainage swale. Up to 3000 cubic yards of fill may be needed to fill the surface depressions to obtain suitable grades. The total area affected is approximately 8 acres.

The western portion of the site will be given a 6-inch topsoil layer to permit the growth of vegetation as an erosion-resistant cover. This will require 20,400 cubic yards of topsoil. The final site elevations are shown on Figure 3-5.

FIGURE 3-4
ROUGH GRADING AND FILL PLAN
SITE STABILIZATION AND CLOSURE—ALTERNATIVE 1
WESTERN PART—BURRELL TOWNSHIP SITE

NOTE: 1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR
 UNION CARBIDE CORP. BY RICHARD G. BACH & ASSOC.
 ZELLENFLE, PA. DATED 11/16/77

6. Surface-drainage facilities -- In order to conserve fill materials in the pond area, the elevation of the main drainage swale was kept as low as possible without allowing the side slopes to exceed 12 percent. As a result, the branch swale slope is excessive. In order to avoid erosion in the branch swale, a 50-foot wide strip of 4-inch stone will be placed along the 500-foot centerline. This will require 310 cubic yards of stone. A sedimentation basin will also be constructed at the main swale outlet to contain any sediment eroded during construction, prior to the discharge of runoff into the river.
7. Equipment decontamination -- Vehicles and equipment that are only operating on the site may not have to be decontaminated until ready to leave the site. All onsite vehicles, however, will be monitored routinely to determine if the operator's cab or cab entry is contaminated. Decontamination of the vehicle-operator's cab and cab entry point will be carried out as needed. Vehicles or equipment preparing to leave the site will be monitored prior to leaving. If contamination is found, the equipment will be decontaminated by dry removal or washing, as required.

3.2.4 Effect on contaminant pathways

The basic level of control described in Alternative 1 is intended to ensure only that radionuclides will not rise to a higher level in the future through either gradual deterioration or catastrophic failure at the site. Improving the surface-drainage characteristics will reduce infiltration-associated leaching of contaminants to the ground water, but this effect will diminish with future general settlement of the area from underground decomposition. The benefits to be derived from the proposed site improvements may be summarized as follows:

1. Infiltration will be initially reduced and spread over a longer period of time, thus preventing a rise above current levels.
2. Ground-water levels will be maintained at a elevation below the contaminated zone.
3. The potential for slope failure adjacent to the ponds due to natural instability or river flooding will be eliminated by filling the pond depression. Filling will also eliminate the potential for bank erosion which might extend back into the contaminated zone.
4. The potential for penetration of the deposit by burrowing animals will be minimized.

3.2.5 Preliminary cost estimate

A preliminary estimate of the construction costs (approximately \$2.8 million) for Alternative 1 is shown in Table 3-2. For the initial evaluation, it was assumed that all materials required to fill the pond area would be obtained off the site. If it is readily available locally, slag may be the most economical fill material for this purpose.

If existing fill materials from the uncontaminated area to the south of the ponds could be employed as a bulk filler and for preliminary grading, a cost reduction in the range of \$300,000 to \$500,000 is possible. An evaluation of the feasibility of this substitution would require more extensive drillings than are currently planned. Partial implementation of selected features of this alternative could possibly reduce the cost of remedial action below \$1 million. Further evaluation is recommended during the final engineering design phase.

3.3 ALTERNATIVE 2: SITE CONTROL AND CONTAINMENT

3.3.1 Site-containment concept

The remedial actions under Alternative 1 are directed more toward the prevention of a potential rise in radionuclide releases rather than a substantial reduction from current levels. The Alternative 2 remedial-action approach is designed to achieve a reduction in radionuclide releases from current levels. Since the major radionuclide-loss route is through infiltration and ground-water seepage, the primary control objective of Alternative 2 is to further reduce infiltration and install a positive barrier to prevent ground-water losses. A schematic of the Alternative 2 plan is shown on Figure 3-6. The additional features may be summarized as follows:

1. The pond treatment is similar to Alternative 1, except an ion-exchange medium is added to the gravel-subdrain materials to provide a barrier to radionuclide loss through the ground-water route.
2. Surface slopes over the contaminated zone are increased to a minimum of 4 percent. This will delay any future infiltration increase due to general subsidence of the area.
3. A layer of bentonite-treated soil will be incorporated into a multilayer cover system to be placed over the contaminated zone. This will serve to further reduce infiltration through the contaminated deposit.

Table 3-2. Preliminary cost estimate for site stabilization and closure (Alternative 1)

Activity	Cost
<u>Landfill surface stabilization -- contaminated area</u>	
Construct earth fill for surface slope	\$ 180,000
Place stone-drainage blanket	81,000
Install geotextile	70,000
Install 18-inch earth cover	186,000
Apply topsoil and seed	<u>80,000</u>
Total	\$ 597,000
<u>Pond rehabilitation</u>	
Grade and install subdrain	\$ 183,000
Place fill material in pond area	435,000
Install 2-foot cover over fill material	146,000
Place bentonite in earth cover under swales	290,000
Apply topsoil and seed	80,000
Total	\$1,134,000
<u>Site management -- noncontaminated area</u>	
Lightly grade 8 acres and add fill	\$ 40,000
Apply topsoil on 10 acres and seed	80,000
Construct sedimentation basin and drainage	34,000
Construct access roads and install fencing	150,000
Set up workers' facilities	20,000
Demobilize and clean up	<u>25,000</u>
Total	\$ 349,000
Subtotal	\$2,080,000
Contingency	500,000
Construction and environmental management	<u>200,000</u>
Total	\$2,780,000 (Approximately \$2.8 million)

3.3.2 Evaluation of hydrological effectiveness

The HSSWDS model was used to determine the increased diversion of percolation that would be expected from an increase in ground slope from 2 to 4 percent and the addition of a bentonite-treated layer in the multilayer cover system. A schematic illustrating the projected distribution of precipitation is shown on Figure 3-7. Of the 8.15 inches of precipitation penetrating to the drain layer, 99 percent will be diverted away from the contaminated zone and only 0.12 inch will penetrate. As compared to Alternative 1, the bentonite layer will further reduce infiltration from an 80-percent reduction for Alternative 1 to as high as 99-percent reduction for Alternative 2. Insufficient data are available to correlate radionuclide leaching with the infiltration rate; however, a substantial reduction in the potential for leaching will obviously be achieved.

3.3.3 Construction requirements

The construction requirements are discussed in the following paragraphs in the general sequence in which they may be scheduled.

1. Install subdrain and fill pond area -- After the three ponds (A, B, and C) are drained, an estimated 8000 cubic yards of sediment and materials must be excavated and removed to the fill area over the contaminated zone. An estimated 17,700 cubic yards of 3/4-inch gravel will be required to establish a subdrain layer 4 feet thick. Ion-exchange media, such as natural clays with high cation, exchange capacity, or synthetic resins (zeolites, macro-reticular polymers, gels, etc.), constituting 2 percent of the stone volume can be incorporated by placing the stone and media in layers. The subdrain will require 6-inch layers of pea gravel and sand (1800 cubic yards each) to establish a filter surface.

Filling the pond depressions is required to reduce the side slopes to a point where erosion and the potential for slope failure can be controlled. In the feasibility design, the swale elevation was established to yield side slopes not exceeding 12 percent. At this elevation, 145,200 cubic yards of fill material will be required to establish an elevation 2 feet below the final grade. As discussed relative to Alternative 1, it is assumed that slag could be used for this purpose. However, if onsite materials prove to be suitable, a substantial cost reduction can be obtained.

The swale area will require 2 feet of clean earth fill to cap the fill material prior to the bentonite treatment. A total of 28,900 cubic yards will be required for the 12.6 acres affected. Bentonite will be admixed into the top 6 inches of soil in the same manner as discussed for Alternative 1.

FIGURE 3-7
DISTRIBUTION OF PRECIPITATION THROUGH COVER SYSTEM
SITE CONTROL AND CONTAINMENT —ALTERNATIVE 2
BURRELL TOWNSHIP SITE

2. Place fill for surface slope over contaminated area -- Earth fill will be required to establish the desired 4-percent surface slope over the contaminated area. Since the contaminated area is bisected by a branch swale, the filled portions are designated as the eastern and western mounds. Figure 3-8 shows a typical cross-section through the western mound. It is estimated that 59,000 cubic yards of fill will be required to establish the western mound and 5,100 cubic yards to establish the eastern mound.
3. Construct final cover over contaminated area -- The final cover over the contaminated area will use a multilayer cover similar to Alternative 1, but a clay layer will be added to further reduce infiltration. A layer of bentonite will be applied to the mound areas at a rate of 3 pounds per square foot. The material should be incorporated into the soil uniformly to a depth of 6 inches to form an impervious layer. The total bentonite requirements are 1650 tons.

The stone-drainage blanket is intended to divert infiltration away from the contaminated zone, and restrict access by burrowing animals. The layer will consist of 8 inches of 4-inch stone, 4 inches of 3/4-inch stone, covered by a single layer of geotextile. The material quantities for the drainage blanket are as follows:

4-inch stone	7,400 cubic yards
3/4-inch stone	3,700 cubic yards
Geotextile	33,200 square yards

An 18-inch layer of clean earth fill will be placed over the drainage blanket to provide a root zone for vegetation. Approximately 23,000 cubic yards of earth fill material will be required. This 18-inch soil layer will then be covered with a 6-inch layer of topsoil for a total final soil cover of 24 inches.

4. Grade and place topsoil over noncontaminated areas and seed -- A 6-inch layer of topsoil will be required over the noncontaminated area that has been disturbed. This will require 20,400 cubic yards of topsoil. A final grading plan for the site is shown on Figure 3-9.
5. Surface-drainage facilities -- Because of an excessive slope on the branch swale, a 50-foot by 500-foot layer of 4-inch stone will be required to reduce the velocity and control erosion. Approximately 310 cubic yards of stone will be required for this purpose. In addition, a sedimentation basin will be constructed at the swale-discharge point for sediment containment during the construction phase.
6. Equipment decontamination -- Vehicles and equipment that are only operating on the site may not have to be decontaminated until ready to leave the site. All onsite vehicles, however, will be monitored routinely to determine if the operator's cab or cab entry is contaminated. Decontamination of the vehicle-operator's cab and cab entry point will be carried out as needed. Vehicles or equipment preparing to leave the site will be monitored prior to leaving. If contamination is found, the equipment will be decontaminated by dry removal or washing, as required.

FIGURE 3-9
FINAL GRADING PLAN—SITE CONTROL AND CONTAINMENT
ALTERNATIVE 2— WESTERN PART—BURRELL TOWNSHIP SITE

NOTE: 1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR UNION CARBIDE CORP. BY RICHARD G. BACH & ASSOC., ZELLENOPLE, PA-DATED 11/16/77

3.3.4 Effect on contaminant pathways

The remedial actions described are expected to reduce levels of emissions below current values. Leaching of contaminants to the ground water due to infiltration should be reduced in approximate proportion to the decrease in infiltration; 99 percent of the precipitation impinging on the cover will be diverted. However, several years may be required for the full effect to be achieved. The ion-exchange subdrain in the pond area will provide further reduction, depending on the effectiveness of the ground-water interception. The high efficiency of the Alternative 2 control measures will not be maintained indefinitely since decomposition settlement will tend to crack the multilayer final cover, and the ion-exchange media will be saturated by ground-water cations. However, it is expected that ground-water emissions will remain below current levels for at least 100 years.

Radon-emission rates may be increased by drying out the contaminated area, but reduced by the additional earth fill over the contaminated area. Since current emissions are relatively low, no attempt has been made to define the exact overall impact, but a decrease is possible.

3.3.5 Preliminary cost estimate

A preliminary estimate of the construction cost (approximately \$4.8 million) is shown in Table 3-3. As discussed under Alternative 1, the substitution of onsite material for slag to fill the ponds would reduce the cost by \$300,000 to \$500,000. A further \$500,000 could be saved by eliminating the ion-exchange media without materially affecting the predicted reduction in ground-water percolation losses.

3.4 ALTERNATIVE 3: WASTE EXCAVATION AND ENCAPSULATION

3.4.1 Site-encapsulation concept

At this level of control, the contaminated materials are removed for encapsulation in place. The principal advantage will be that the resulting barrier will further reduce infiltration as compared with Alternative 2, and will provide an impervious clay layer (liner) under the waste and contaminated material.

As in the other alternatives, an underdrain is proposed at the current pond level to stabilize the ground-water level. However, only ponds B and C, will be filled with earth or slag. The contaminated materials will then be excavated and moved to the eastern portion of the site for temporary staging until the lined area is constructed. Since there is a large amount of railroad ties that cannot be removed or replaced easily with machinery, it is assumed that "hand" or piecemeal separation and stacking will be required. Once a sufficient area is excavated, the clay liner can be started for the encapsulation area and replacement of waste into the encapsulation area can proceed along with excavation.

Table 3-3. Preliminary cost estimate for site control and containment (Alternative 2)

Activity	Cost
<u>Landfill surface and stabilization -- contaminated area</u>	
Construct earth fill for surface slope	\$ 500,000
Place bentonite layer	600,000
Place stone-drainage blanket	81,000
Place geotextile	70,000
Install 18-inch earth cover	186,000
Spread topsoil and seed	<u>80,000</u>
Total	\$1,517,000
<u>Pond rehabilitation</u>	
Grade and install subdrain	\$ 183,000
Install ion-exchange media	500,000
Place fill material in pond area	435,000
Install 2-foot earth cover over fill material	146,000
Place bentonite in earth cover under swales	300,000
Apply topsoil and seed	<u>80,000</u>
Total	\$1,644,000
<u>Site management -- uncontaminated area</u>	
Lightly grade 8 acres and add fill	\$ 40,000
Apply topsoil and seed 7 acres	80,000
Construct sedimentation basin and drainage	34,000
Construct access road and install fencing	150,000
Set up workers' facilities	20,000
Demobilize and clean up	<u>25,000</u>
Total	<u>\$ 349,000</u>
Subtotal	\$3,510,000
Contingency	880,000
Construction and environmental management	<u>350,000</u>
Total	\$4,740,000 (Approximately \$4.8 million)

A typical cross-section of the proposed encapsulation area is shown on Figure 3-10. Construction will entail a 3-foot thick clay liner on which the contaminated material will be placed. Railroad ties will be individually placed in layers by hand and covered with the excavated material. The cap for the encapsulation area will consist of a 2-foot layer of clay topped with a stone drainage blanket, geotextile, earth, and topsoil cover similar to that for Alternative 2.

The excavated materials will be screened for radioactivity as excavation proceeds to obtain a clean-fill stockpile that can be used to fill disturbed areas outside the encapsulation zone. However, a substantial amount of earth fill and topsoil will still be required to produce an acceptable final grade on the site.

Throughout the construction period, proper environmental management of the site is essential. This includes handling contaminated waste water, treating it if necessary, and monitoring both the site and the people working on it. The need for waste-water treatment has not been fully documented, nor has the potential water quality been determined. To demonstrate the feasibility of the concept, however, provision for a waste-water treatment system has been included in this alternative.

The main functional features of this concept are illustrated on Figure 3-11 and consist of the following:

1. Excavating the waste material (approximately 213,000 cubic yards) from the contaminated zone and removing it to a staging area.
2. Placing a clay or soil liner in the excavation area after preparing the subgrade.
3. Installing a gravel subdrain, and backfilling and rehabilitating ponds B, C, and D (as described in Alternative 1).
4. Transferring the excavated material from the staging area, followed by placing and compacting the excavated waste and contaminated material in the lined area.
5. Placing a multilayer cover system (similar to the cover for Alternative 2) over the lined area to encapsulate the excavated waste.
6. Overall site management and improvements similar to those discussed in Alternative 1.

3.4.2 Evaluation of hydrological effectiveness

An analysis of surface-water penetration through the clay layer was performed using the HSSWDS model. The results are shown on Figure 3-12. Water reaching the radioactive mass is expected to drop from 7.76 to 0.178 inches per year. This represents a drop of 98 percent. At this penetration rate, the ion-exchange properties of the clay liner should control radionuclide loss through the liner for several hundred years. However, in this alternative the long-term integrity of the multilayer cover is questionable because of the inclusion of wood in the encapsulation area. Decomposition is expected to cause eventual settlement that may crack the clay cap and allow infiltration to increase. Water reaching the contaminated material, however, should stay substantially below current levels for an indefinite period.

3.4.3 Construction requirements

1. Install subdrain and fill pond area -- The treatment of the ponds is similar to that in Alternative 1. The ponds will be drained, sediment hauled to a temporary storage area, and a 4-foot thick underdrain installed. The gravel will be capped with 6 inches of pea gravel and 6 inches of sand. The estimated quantities of materials for this phase are as follows:

Sediment	8,000 cubic yards
3/4-inch gravel	18,000 cubic yards
Pea gravel	1,800 cubic yards
Sand	1,800 cubic yards

Approximately 115,000 cubic yards of earth fill will be required to fill ponds B and C which are east of the planned encapsulation area. The fill may consist entirely of earth or could be slag topped with a 2-foot layer of earth, as in the first two alternatives.

2. Excavation of contaminated materials -- Because of the presence of buried railroad ties, it is assumed that considerable hand or piecemeal sorting will be required. Ties will be stacked separately from the other materials removed. Although the volume of contaminated material is smaller, it is estimated that 213,000 cubic yards of total excavation will be required to completely remove hot spots and simultaneously establish a suitable contour to construct a liner for the encapsulation area. It is assumed that some of the material removed can be classified as "clean" for use as fill outside the encapsulation area.
3. Staging and separation of excavated material -- The staging area is located near the excavation area and consists of a lined area of approximately 8 acres, including storm-water runoff control and treatment.

The off-the-road trucks used to haul excavated material will dump the material in designated areas. Railroad ties will be separated with the aid of cherry pickers (light cranes), and front-end loaders will separate the ties from the other contaminated material. Some separation of railroad ties will undoubtedly have to be done manually.

4. Place liner and fill with contaminated material -- Liner placement and filling may proceed as soon as a sufficiently large section is excavated to provide a working area. Until this working area is established, the excavated material must be stored on a temporary basis in a staging area. A total clay volume of 30,600 cubic yards is estimated for the complete liner. Railroad ties should be individually placed in uniform layers to minimize subsequent differential settlement.
5. Construct final cover over encapsulation area -- All materials classified as radioactive plus any contaminated surface soil and liner material from the storage and staging area will be transferred to the encapsulation area. The placement of the final multilayer cover over the encapsulation area will require the following materials:

Clay cap (2 feet thick)	20,400 cubic yards
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4-inch stone (8 inches thick)	6,800 cubic yards
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3/4-inch stone (4 inches thick)	3,400 cubic yards
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Geotextile	30,600 square yards
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Earth cover (18 inches thick)	15,300 cubic yards
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Topsoil (6 inches thick)	5,100 cubic yards
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6. Grade and place topsoil over noncontaminated areas and seed -- Surface grading will be required in the noncontaminated area to establish suitable grades. The disturbed area of 25 acres will then receive a 6-inch topsoil layer (20,000 cubic yards) and be planted in grass.
7. Surface-drainage facilities -- As in the other alternatives, a sedimentation basin will also be required, at least during the construction phase.
8. Equipment decontamination -- Vehicles and equipment that are only operating on the site may not have to be decontaminated until ready to leave the site. All onsite vehicles, however, will be monitored routinely to determine if the operator's cab or cab entry is contaminated. Decontamination of the vehicle-operator's cab and cab

entry point will be carried out as needed. Vehicles or equipment preparing to leave the site will be monitored prior to leaving. If contamination is found, the equipment will be decontaminated by dry removal or washing, as required.

3.4.4 Effect on contaminant pathways

The combined effect of a clay cap and multilayer cover, plus a clay liner with ion-exchange properties is expected to substantially reduce radionuclide losses through the ground-water route. The exact extent of reduction cannot be defined precisely, but should exceed 90 percent for at least 100 years. Considering that radioactive decay is in progress, the emissions will probably never return to their current levels.

A liner system used with a cover has the additional benefit of providing waste encapsulation. By tying the cover and the liner systems together the buried low-level radioactive wastes can be completely sealed. Encapsulation allows more complete isolation of the disposed wastes, and therefore lessens any environmental impacts. The clay liner provides ion-exchange capability to reduce the contamination of any leachate that may pass through it.

The most serious potential environmental effect of any remedial approach involving excavation is that during movement of the material, some losses are inevitable. At least temporarily, small amounts of contaminated material will be transported by wind and rainfall. Some exposure of the workers on the site will also occur, particularly when sorting and handling the railroad ties. The site workers could wear special clothing and use special equipment for protection, if necessary, and dust-control measures will be followed to control possible exposure off the site. Site monitoring will also be initiated as a means of measuring exposure and ambient levels so that control action can be implemented, if necessary.

3.4.5 Preliminary cost estimate

The breakdown of approximate construction costs associated with the third alternative (approximately \$8.3 million) is listed in Table 3-4. The requirement for excavating and replacing the contaminated material substantially increases the estimated construction cost compared to Alternatives 1 and 2. Most of the cost differential can be attributed to the piecemeal work required in handling the railroad ties, and the requirements associated with using clay in the encapsulation activities.

Table 3-4. Preliminary cost estimate for waste excavation and encapsulation (Alternative 3)

Activity	Cost
<u>Pond rehabilitation</u>	
Grade and install subdrain	\$ 185,000
Place fill material in ponds B and C	580,000
Apply topsoil and seed	<u>80,000</u>
Total	\$ 845,000
<u>Material excavation and staging</u>	
Excavate 213,000 cubic yards of material	\$1,065,000
Haul and stage	300,000
Separate railroad ties	<u>340,000</u>
Total	\$1,705,000
<u>Encapsulate contaminated material</u>	
Install clay liner	\$ 455,000
Place railroad ties	700,000
Place contaminated material in encapsulation area	800,000
Place multilayer final cover	500,000
Final grade, apply topsoil and seed	<u>100,000</u>
Total	\$2,555,000
<u>Site management -- noncontaminated area</u>	
Temporary staging area and rehabilitation	\$ 270,000
Construct sedimentation basin and drainage	35,000
Construct access roads, etc., install fencing	180,000
Construct waste-water treatment plant and decontamination facilities	380,000
Set up workers' facilities	31,000
Lightly grade 10 acres	50,000
Apply topsoil and seed	80,000
Demobilize and clean up	<u>25,000</u>
Total	<u>\$1,051,000</u>
Subtotal	\$6,156,000
Contingency	\$1,539,000
Construction and environmental management	<u>620,000</u>
Total	\$8,315,000
	(Approximately \$8.3 million)

3.5 ALTERNATIVE 4: WASTE EXCAVATION, INCINERATION, AND ENCAPSULATION OF RESIDUES

3.5.1 Excavation, incineration, and encapsulation concept

The excavation, incineration, and encapsulation alternative will essentially follow Alternative 3 with the added separation and incineration of all combustible materials. This step will include manual separation and shredding of railroad ties.

By incinerating any combustible fraction in the contaminated materials, it is possible to minimize future settlement of the site. This treatment will enhance the long-term cover integrity and will also reduce the volume that is to be encapsulated.

A rough estimate of the combustible fraction (organics) of the contaminated material has been based on interpretation of the boring logs. Approximately 100,000 cubic yards of material will have to be incinerated. This material will not consist of pure organic material, but will be mixed with some inerts such as slag, earth, etc. that will not be destroyed in the combustion process. For that reason, it is estimated that thermal conditioning will result in a 70-percent reduction in volume of 100,000 cubic yards, or about 70,000 cubic yards. The total volume to be encapsulated will be 100,000 cubic yards of inorganics and 30,000 cubic yards of incinerator residues.

The excavation, staging, sorting, and encapsulation of materials greatly increases the potential for worker and offsite exposure, in addition to the loss of materials. All storm-water runoff and contaminated water will be captured and treated in a waste-water treatment plant to prevent contamination of the ground water or the river. Special air-pollution controls will be incorporated in the design of the incinerators to control air emissions.

Throughout the construction period, proper environmental management of the site is essential. This includes handling contaminated waste water, including treatment if necessary, and monitoring both the site and the people working on it. The need for waste-water treatment has not been fully documented, nor the potential water quality been determined. To demonstrate the feasibility of the concept, however, provision for a waste-water treatment system has been included in this alternative.

The main features of this concept are similar to those described in Alternative 3, with the following steps added between waste removal and encapsulation:

1. Staging and sorting the excavated material followed by shredding the bulky combustible material (e.g., railroad ties) for size reduction.
2. Incinerating the combustible fraction of the excavated waste materials in two parallel rotary-kiln incineration lines.
3. Conditioning and cleaning the flue gas from the incineration units using cooling chambers, roughing filters, and high-efficiency particulate air filters.

4. Burying the incinerator residues in the encapsulation area, along with the other noncombustible waste material.

3.5.2 Construction Requirements

The remedial activities under this alternative will be conducted in the following manner:

1. Install subdrain and fill pond area -- The treatment of the ponds is similar to that in Alternative 1. The ponds must be drained, sediment hauled to a temporary storage area, and a 4-foot thick underdrain installed. The gravel may be capped with 6 inches of pea gravel and 6 inches of sand. The estimated quantities of materials for this phase are as follows:

Sediment	8,000 cubic yards
3/4-inch gravel	18,000 cubic yards
Pea gravel	1,800 cubic yards
Sand	1,800 cubic yards

Approximately 115,000 cubic yards of earth fill will be required to fill ponds B, C, and D which are east of the planned encapsulation area. The fill may consist entirely of earth or could be slag topped with a 2-foot layer of earth, as in the first two alternatives.

2. Excavation of contaminated material -- All contaminated materials will be excavated from west to east across the contaminated areas in two passes by a team of two excavators. The first pass will excavate a layer of half the total depth of the contaminated material; the second pass will excavate the remaining contaminated material. Organic materials will be separated from inert material when possible.

The excavators will load the materials in off-the-road trucks that will haul the contaminated material to the eastern part of the site where it will be dumped on the staging area.

3. Staging and separation of excavated material -- The staging area is located next to the incineration facility and consists of a lined area of approximately 8 acres, including storm-water runoff control and treatment.

The off-the-road trucks will dump the excavated material in designated areas. Front-end loaders will then remove the organic (combustible) material and stack it near the charging hoppers of the incinerators as shown on Figure 3-13.

Railroad ties will be separated with the aid of cherry pickers (light cranes), and front-end loaders will carry the ties to the shredding area. Some separation of railroad ties will undoubtedly have to be done manually. The railroad ties will then be inspected and all metal

FIGURE 3-13
 SCHEMATIC OF EQUIPMENT FOR
 WASTE EXCAVATION, INCINERATION AND ENCAPSULATION
 ALTERNATIVE 4 — BURRELL TOWNSHIP SITE

parts, nails, etc. will be removed. All ties will then be shredded by a high torque, low-rpm shredder. This same shredder can also be used to grind tires. Shredding is required to facilitate feeding bulky materials through a hydraulic-ram-feed mechanism and into the incinerators. The shredded railroad ties will be burned together with the other combustible materials.

4. Incineration system -- The incineration of organics in the contaminated materials will result in considerable volume reduction. There are many designs available for solid-waste combustion. The rotary-kiln technology was selected because it produces the most sterile ash of all the types of incinerators now in operation for combustion of solid waste and because it can handle a wide range of solid-waste materials.

It is estimated that some 200,000 tons of waste material must be excavated, separated, treated, and then encapsulated. Of that quantity, about 100,000 tons will be fed to the incinerators.

Two incinerator "trains" or lines are proposed. These are sized to ensure that the material will be processed in a reasonable length of time. A relocatable plant was considered that could be used for other hazardous-waste applications. The term "relocatable plant" indicates incinerator units that are capable of being mechanically decontaminated, dismantled, and reassembled at other remote sites for future use.

The two incinerator trains (Figure 3-13) will each consist of the following:

- a. A hydraulic-ram feeder and a charge chute that will be fed by either a front-end loader or a crane.
- b. A 100-ton-per-day rotary-kiln incinerator equipped with auxiliary-fuel-firing capabilities and automatic controls.
- c. A secondary combustion chamber, refractory lined, and equipped with auxiliary-fuel-firing capabilities allowing elevated flue-gas-temperature controls.
- d. A residue-ash conveyor that will collect ash from both incinerator trains, and will deposit all of the collected ash in a roll-off bin for burial in the encapsulation area.
- e. A waste-heat boiler or gas conditioning chamber will cool the combustion gases from the secondary combustion chamber. This cooling is needed to protect the filter banks downstream. The steam generated in the waste-heat boiler will be condensed and cooled in fan-operated air-cooled condensers.

- f. A bank of prefilters or roughing filters followed by a bank of high-efficiency particulate air filters (HEPA) will remove particulates down to 0.3 micron in size, with an efficiency of 99.97 percent. These filters will be constructed of media, separators, and frames that can sustain temperatures of 250°F.
- g. An induced-draft fan sized to handle the flue-gas flow and system-pressure drop imposed by the various upstream components and the stack. The fan-discharge enters into a stack.
- h. A low-rotational-speed shredder will be located some distance from the incinerator installation on a vibration-absorbing pad. The shredder will be required to handle railroad ties and automobile tires and reduce them to a size suitable for incineration. The particle size will be approximately 4 inches square.

The incinerator will operate at 1400 to 1600°F in the rotary-kiln portion. This temperature will be maintained from the heating value of the contaminated waste and with auxiliary fuel firing, if required. The secondary chamber will maintain 1600°F for a minimum of 2-seconds retention time. The secondary chamber will also be equipped with auxiliary-fuel firing, if needed, to maintain 1600°F and with an air-to-air heat exchanger at the chamber discharge to preheat the combustion air, thus reducing the amount of auxiliary fuel required. The flue gas will be further cooled by a waste boiler to bring the combustion gases down to a temperature that will not damage the prefilters and the HEPA filters.

The residues leaving the rotary kiln and secondary combustion chamber will drop into the water-filled residue conveyors. The hot ash will cool in the conveyor trough and completely cool in the ash-collection container.

The collected ash will be reburied in the encapsulation area in the landfill, shown on Figure 3-14. The work force required for the incinerator plant will be a force of 16 personnel for operations 7 days per week, 350 days per year, over slightly less than 2 years. The force will consist of supervisory personnel, and a four-shift operating group, including mechanics.

- 5. Install liner and fill with contaminated material -- All contaminated combustible waste and shredded railroad ties and tires will be processed through the incinerators. It is understood that some inert materials will also pass through the incinerator as it will be extremely difficult to completely separate inert and organic matter. Since the inert material is not destroyed by the combustion process, there will be only a 70-percent volume reduction of the estimated 100,000 tons of material that will be incinerated. Nonorganic matter, such as slag, ashes, etc. will be buried in the encapsulation area after separation at the staging area. If any drums are uncovered, they will require testing to determine the nature of the contents, and, if the material is found to be safe to incinerate, their contents

FIGURE 3-14
 SCHEMATIC PLAN OF WASTE EXCAVATION, INCINERATION AND
 ENCAPSULATION — ALTERNATIVE 4 — WESTERN PART
 BURRELL TOWNSHIP SITE

NOTE: 1. PROPERTY LINE DATA FROM PLAN OF PROPERTY FOR
 UNION CARBIDE CORP. BY RICHARD G. BACH & ASSOC.,
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will be fed, along with the other waste stream. If the drum contents are found to be unsuitable for incineration, the drum will be re-buried in the encapsulation area.

6. Equipment decontamination -- Vehicles and equipment that are only operating on the site may not have to be decontaminated until ready to leave the site. All onsite vehicles, however, will be monitored routinely to determine if the operator's cab or cab entry is contaminated. Decontamination of the vehicle-operator's cab and cab entry point will be carried out as needed. Vehicles or equipment preparing to leave the site will be monitored prior to leaving. If contamination is found, the equipment will be decontaminated by dry removal or washing, as required.

3.5.3 Effect on contaminant pathways

The incineration alternative is intended to represent an ultimate remedial-action alternative that will reduce emissions to a near zero level over an indefinite life. All aspects are technically feasible, with the possible exception of shredding. There is considerable doubt as to the ability of any known commercial shredders to handle an excavated mass of timber, soil, steel, and organic debris without prohibitive maintenance or total hand separation. The increased effectiveness of this alternative is due to a reduction in the potential for differential settling and subsequent cap failure. This is a result of the volume reduction of organic wastes by shredding and incineration. The ash residues from incineration may still contain leachable constituents; therefore, secure disposal is required for the ash.

Assuming that shredding can be implemented, excavation will inevitably result in short-term increases in radionuclide losses to air and water, plus worker exposures. These short-term losses must be weighed against the long-term benefits to be gained by the reduction in emissions from current levels.

3.5.4 Preliminary cost estimate

A breakdown of the approximate construction costs associated with the excavation, incineration, and encapsulation alternative is shown in Table 3-5. The total cost is expected to be over four times as high as Alternative 3, primarily because of the incineration step.

Table 3-5. Preliminary cost estimate for excavation, incineration, and encapsulation (Alternative 4)

Activity	Cost
<u>Pond rehabilitation (see Alternative 3)</u>	\$ 845,000
<u>Material excavation and staging (see Alternative 3)</u>	1,705,000
<u>Incineration of combustible fraction</u>	
Incinerators (2), including air-pollution-control equipment	13,950,000 ^a
Shredder	1,000,000
Conveyors	650,000
Electricity and instrumentation	2,000,000
Building	400,000
Site preparation, support facilities and structures	800,000
Demolition and disassembly	1,000,000
Two-year operating cost (fuel, labor, supervision, etc.)	<u>2,360,000</u>
Total	\$ 22,160,000
<u>Encapsulate contaminated material and residue</u>	
Install clay liner	\$ 430,000
Place contaminated material	400,000
Place residue	120,000
Place multilayer final cover	470,000
Final grade, topsoil, and seed	<u>80,000</u>
Total	\$ 1,500,000
<u>Site management -- noncontaminated area (see Alternative 3)</u>	\$ 1,051,000
Subtotal	\$27,261,000
Contingency at 25 percent	\$ 6,820,000
Construction and environmental management at 15 percent	<u>4,100,000</u>
Total	\$38,181,000 (Approximately \$38 million)

^aDoes not include salvage or residual value.

3.6 EVALUATION OF ALTERNATIVES

3.6.1 Evaluation criteria

In comparing the alternatives, a no-action alternative must be implicitly incorporated as a possible choice. All data indicate that only relatively small quantities of radioactive waste are present on the site and that the current emissions to air and water are within acceptable limits. At the Burrell site, the no-action alternative has been rejected, primarily because of the presence of and geometry of the ponds. The very steep slopes adjacent to the ponds make erosion almost inevitable. Since the contaminated zone is near the surface and close to the ponds, it is expected that erosion will eventually expose contaminated material. Thus, it is concluded that elimination of the pond slope or stabilization is an absolute minimum requirement for this site.

Within the context of the desirability of some remedial action, the alternatives presented have been evaluated within a framework consisting of four desirable criteria for selection. The selected alternative should best meet the objectives of the four criteria. The criteria are as follows:

1. Environmental effectiveness -- The plan should address the problems identified in a direct manner and without creating secondary problems that do not presently exist. The emissions should meet all applicable criteria and standards.
2. Technical feasibility -- Any remedial action proposed must be based on existing technology and should be of proven effectiveness. Furthermore, it is desirable that the actions be within the capability of ordinary construction contractors.
3. Cost effectiveness -- Increased levels of expenditure should reduce radionuclide releases in keeping with the incremental cost.
4. General suitability -- The general approach should be consistent with the problems identified and should avoid overly elaborate and complex remedial actions unless these are clearly justified by the site conditions.

3.6.2 Alternative 1: site stabilization and closure

The first alternative will address all identified problems at a minimum level, as follows:

1. The potential erosion of the radioactive waste will be eliminated.
2. The potential for mounding ground water into the buried waste material will be minimized.

3. Infiltration will be reduced.
4. The radon flux will be reduced by adding cover and fill materials.
5. The potential access by burrowing animals will be decreased.
6. Secondary environmental exposure problems will be avoided by leaving the waste deposit undisturbed.

Any contractor capable of conventional earthwork can accomplish the essential tasks with no significant exposure of employees.

From the standpoint of environmental effectiveness, Alternative 1 addresses all of the potential problems identified, but at a level below the maximum attainable. Since with the exception of soil-contamination levels, all other applicable standards are not currently being violated, the minimum level of control is not necessarily an insufficient level of site closure. Thus, Alternative 1 has been assigned a "moderate" rating for environmental effectiveness.

The technical feasibility of Alternative 1 is ranked high since no unusual technology is incorporated. It is expected that a decrease in infiltration will reduce radionuclide losses to ground water, but no reliance is placed on a numerical correlation for this reduction. Similarly, cost-effectiveness is regarded as high because this is the base option.

Alternative 1 also ranks high in terms of general suitability. Since no exposure problem can be presently documented at the site, it is difficult to justify elaborate and expensive remedial measures.

3.6.3 Alternative 2: site control and containment

The second alternative differs from the first in the following ways:

1. A clay cap is incorporated into the final cover and is used to further reduce infiltration.
2. A steeper top surface is specified to delay the adverse effects of settlement.
3. An ion-exchange bed in the pond-area subdrain is proposed to reduce ground-water losses.

The combination of a clay cap and steeper slopes increases the cost of remedial action by approximately \$1.5 million. The benefits to be gained consist of a further reduction in infiltration and the potential leaching of contaminants to the ground water and the capability of maintaining the extremely low contaminant release rates for as much as 100 years. Considering

that the level of control in Alternative 1 is sufficient to prevent releases from increasing and that current ground-water losses are acceptable, the incremental cost of a larger safety factor is difficult to justify. Similarly, the \$500,000 cost of an ion-exchange medium in the subdrain with only limited effectiveness does not appear cost-effective when it addresses a problem that is of very low severity. Thus, Alternative 2 is rated as only moderately cost effective.

Alternative 2 can be rated high in environmental effectiveness and in technical feasibility for the same reasons as Alternative 1. The deposit will remain intact without dispersion, and no unusual or sophisticated construction techniques are proposed. The general suitability of the remedial measures will be acceptable if a large safety factor against any future problems is considered justified.

3.6.4 Alternative 3: waste excavation and encapsulation

Alternative 3, in which the waste deposit is excavated and encapsulated using a clay liner and multilayer final cover, is subject to criticism in several respects. The environmental consequences of excavation will inevitably entail short-term losses to air and water and exposure of contractor personnel. These are difficult to justify considering the very limited exposure potential currently prevailing at the site. Furthermore, the technical feasibility and cost-effectiveness of encapsulation is subject to criticism based on the limited life expectancy of the final cover system. The decomposition settlement will inevitably damage the final cover and reduce the effects of encapsulation within a relatively short period of time. The large cost increments of \$3.5 to 5.5 million relative to the first two alternatives will appear justifiable only if current or projected future releases of radionuclides from the site are excessive, which the data show is not the case.

3.6.5 Alternative 4: waste excavation, incineration, and encapsulation

This alternative was evaluated to determine the cost of ultimate control. There will be short-term increases in exposure because of excavation, but once incineration and encapsulation are accomplished, radiation losses will be effectively blocked for the foreseeable future. There are serious doubts as to the technical feasibility of shredding and incinerating excavated waste materials containing railroad ties and steel scrap; however, all other aspects have been proven feasible.

This alternative is rated very low in terms of cost-effectiveness because of the extremely high total cost of addressing a minor problem.

3.6.6 Recommended remedial action

As can be seen from the previous discussion and the summary of the alternatives given in Table 1-4, site stabilization and closure is a more superior and cost-effective approach for remediation of the Burrell site.

Since the site currently presents few environmental hazards, Alternative 1 is recommended as an upper limit on the level of control. All potential site problems are addressed in such a way that release rates are reduced somewhat from current levels. Although the life expectancies of the remedial actions are limited, the actual remaining radioactivity will decrease through radioactive decay. The alternative is suitable for rapid construction by a conventional earthmoving contractor without personnel exposure and at a reasonable cost. It should be noted, however, that further cost-reduction measures should be considered in the engineering and design phase to bring the cost of the remedial action in line with the minimal radiological levels that are currently present at the Burrell site.

4 Feasibility of the Recommended Action

4.1 FEASIBILITY ANALYSIS

4.1.1 Feasibility criteria

The feasibility of in-situ stabilization and closure as a remedial action for the Burrell site was evaluated against the following criteria:

1. Meeting regulatory requirements.
2. Environmental effectiveness.
3. Cost effectiveness.
4. Use of demonstrated technology.
5. Long-term stability.
6. Public acceptance.
7. Constructability and schedule.
8. Practicability.
9. Flexibility of control elements.
10. Impact on the UMTRA project.

The recommended remedial-action plan was evaluated in light of each of these criteria, and the approach was found to be feasible for control and stabilization of the Burrell site.

4.1.2 Meeting regulatory requirements

Air-related requirements (radon emanation) are not violated even without additional site controls. The recommended remedial action will result in further reduction of radon emanation due to the placement of a two-layer cover system.

The concentrations of the ground-water quality parameters at the site have been, for the most part, below the Federal primary drinking water standards and EPA proposed standards. Only a few radiological contaminants have exceeded these limits in the past. The latest sampling-program results indicate that all monitoring-well samples at the site are below the EPA proposed standards. It is, therefore, expected that even without additional site-remediation effort, the criterion for meeting the Federal radiological parameters at a distance of 1.0 kilometer from the site will be met. The proposed remedial action will result in a reduction of infiltration into the contaminated landfill areas and consequent reduction of contaminant migration potential in the ground water. This will ensure the continued protection of ground-water quality.

The proposed remedial action will also meet other proposed criteria including site stabilization using passive techniques, etc. However, the specific requirement for a 1000-year service life, which is not believed to apply to the Burrill site since it is a vicinity property, cannot be met because of expected long-term subsidence of the landfilled material and its effect on the proposed cover system. Low-level maintenance can, however, compensate for the possible deterioration of the cover integrity.

4.1.3 Environmental effectiveness

As discussed in the previous subsection, the major environmental objectives related to air and water quality can be met by minimal site improvements and closure. The recommended remedial action will also result in further environmental protection, specifically in the following areas:

1. Reduction of excessive erosion of the landfill surface and side slopes.
2. Attenuation of surface-radiation levels.
3. Reduction of excessive infiltration and potential migration of chemical and radioactive species.
4. Physical isolation of the contaminated material.
5. Reduction of long-term deterioration and potential exposure of contaminated material through wind and water erosion and by plant and wildlife penetration.

4.1.4 Cost effectiveness

Although the recommended remedial action represents the lowest-cost approach (out of the four levels of onsite remediation), it is equally effective and in some respects technically and environmentally superior to the other three alternatives. The preliminary cost estimate to achieve site stabilization and closure is approximately \$2.8 million (compared to \$4.8, \$8.3, and \$38 million for Alternatives 2, 3, and 4, respectively). Furthermore, it is believed that detailed engineering analysis of the remedial action can result in additional cost reduction while still meeting regulatory requirements. Cost-reduction measures can even be achieved by any of the following variations of the recommended concept:

1. Selective site grading and surface rehabilitation as the remedial-action approach. Cost -- \$400,000.
2. Surface stabilization and closure, but leaving the existing ponds. Cost -- \$1.0 million.

4.1.5 Use of demonstrated technology

The recommended remedial-action alternative uses demonstrated technology, materials, and construction methods. The use of innovative and state-of-the-art conceptual-evaluation techniques has shown that simple site-stabilization and closure techniques are adequate for the Burrell site.

The materials used in site stabilization consist of naturally occurring and durable substances such as soil, clay, gravel, crushed stone, and slag. Synthetic and less durable materials (e.g., plastics) have not been selected for the site cover and closure because of their questionable longevity and long-term integrity. It should be emphasized that the stabilization and closure techniques recommended for the Burrell site are similar to current engineering practices for closure of landfills and dumps that may have received industrial or hazardous substances during their operation.

4.1.6 Long-term stability

The use of naturally-occurring materials and low maintenance and passive structures will stabilize the site and reduce the leaching potential. Long-term stability problems, however, are anticipated because of differential subsidence of the waste material in the landfill itself. This will continue, but at a slower rate, for 20 to 30 more years because of consolidation and degradation of the waste and fill material in the landfill. The recommended concept for site closure will tolerate some degree of subsidence and settlement. However, low-level maintenance of the landfill surfaces may be required during the next 20 to 30 years until settlement and subsidence are stabilized.

4.1.7 Public acceptance

It is expected that the local public will favor onsite remedial action over removing and hauling away the contaminated material mixed with a wide variety of refuse and waste materials. Moreover, in-situ stabilization and closure will be more acceptable than other complex remedial-action approaches that involve excavating and handling large volumes of waste materials, longer construction periods, and possible secondary impacts (e.g., air emissions from the incinerator). The recommended concept will use earthmoving techniques and equipment, can be accomplished in a short period of time, and will not require disturbing or exposing buried waste materials.

4.1.8 Constructability and schedule

A detailed construction sequence is discussed and presented on Figure 4-1. The total duration of the construction activities will be approximately one year. However, this schedule can be shortened if alternative closure techniques, requiring importing lower quantities of materials, are considered. All of the construction activities can be performed by local general and earthmoving contractors without using highly specialized equipment.

4.1.9 Practicability

As previously stated, the recommended site stabilization and closure concept is implementable and practicable. However, there are several tasks which must be performed before the construction starts to ensure the practicality of the remedial action. These include the following:

1. Establishing the level of closure and the need for filling the ponds.
2. Performing a detailed engineering evaluation and design.
3. Optimizing the material requirements, types, and characteristics.
4. Identifying sources of materials including soil, clay, gravel, and slag.
5. Evaluating the possibility of using rail transportation instead of trucking the required materials.

4.1.10 Flexibility of control elements

The conceptual remedial action for the Burrell site is a flexible approach that can be altered to reduce the cost or to respond to changes in the regulatory climate. The actual stabilization and closure tasks can be implemented in part or in total and range from minimal site grading and cover rehabilitation (at a cost of \$400,000) to total rehabilitation and cover of the contaminated zone as well as the contiguous ponds (at a cost of \$2.8 million). Depending on the Federal and state regulatory climate, the former approach may prove to be the most flexible and cost-effective concept. This approach can also be implemented in phases, starting with the minimal requirements and adding more controls (e.g., cover, pond closure) if needed in later phases.

4.1.11 Impact on the UMTRA Project

From a radiation standpoint, the Burrell site is several orders of magnitude less contaminated than the Canonsburg site or other mill-tailings sites in the UMTRA Project. It is not necessary to "overinvest" in stabilizing and closing this site. The existing levels of contamination at the site may not technically require a remedial action; however, since the site has been designated as a "vicinity property," an appropriate level of site stabilization is required. It is, therefore, prudent to implement a remedial-action approach that is commensurate with existing and future impacts from the site.

The recommended concept for site stabilization and closure is considered an upper limit for a remedial action. It is recommended, however, that means of cost reduction be considered in the engineering design phase of this project. Meanwhile, it is believed that the site stabilization and closure approach is compatible with the overall mission of the UMTRA Project, and even if implemented in its entirety (at a cost of \$2.8 million), it will not have a negative impact on the project.

4.2 IMPLEMENTATION FEATURES AND GUIDELINES

4.2.1 Final engineering design

The recommended alternative for stabilizing and closing the Burrell Township site is based on the following construction elements:

1. Stabilizing the contaminated areas using a two-layer final cover system.
2. Placing a subsurface drain and backfilling the ponds contiguous to the contaminated area.
3. Overall site management to improve drainage and reduce erosion.

In subsection 3.1, the recommended remedial-action plan was developed in sufficient detail to allow an evaluation of the feasibility and to provide a basis for an order-of-magnitude estimate of the construction cost. However, several aspects of the plan require more detailed evaluation during development of a final engineering design. These aspects are discussed in the subsections that follow.

1. Swale elevation and pond fill -- The main drainage swale is positioned over the ponds to reduce the amount of fill material required in the pond area. The elevation and slope shown on the grading plans represent the lowest swale position consistent with the design objectives, as follows:
 - a. Not regrading the slopes adjacent to the ponds because of materials-handling problems in connection with railroad ties and other bulky materials in the landfill.

- b. Maintaining the swale side slopes under 12 percent to minimize slope-stability problems.

If the slopes adjacent to the ponds can be regraded and the material used for fill, the swale elevation can be lowered further and the quantity of pond fill materials needed will be reduced substantially. Further exploratory drilling is recommended before selecting the final design to evaluate the materials present in the banks, and whether they can reasonably be handled during regrading. In lowering the swale elevation, care should be taken to avoid steep grades that may cause the swales to erode. At the current elevation of the main swales, a velocity of approximately 5 feet per second is expected in the branch swale. Rip-rap will provide adequate protection at this velocity, but more elaborate measures may be necessary if the grade is steeper.

2. Pond fill material -- The preliminary plan proposes using slag as a bulk filler in the pond area. Slag is generally a low-cost material, but will likely require transportation by rail and construction of a new siding into the site. If fill can be taken from the nonradioactive area between the ponds and the river, the total project cost can be reduced substantially. Simultaneously, the swale side-slope problem may be alleviated, thus resulting in a lower fill requirement. Exploratory drilling to determine the suitability of the onsite-fill material is recommended as part of the final design. If onsite fill is used, the general site-grading requirements and quantities of imported topsoil will both increase with the increase in size of the disturbed area. However, the project cost may be reduced as much as \$500,000.
3. Pond A drainage -- The existing pond to the north of the railroad tracks is considerably below grade and receives substantial amounts of runoff. The pond has a drainage pipe, but its destination is unknown; it may empty into the southern ponds or directly into the river. If the outlet is destroyed during construction, flooding may occur. It is recommended that a dye test be performed to determine the route of this pipe so its function can be preserved, if necessary.

4.2.2 Construction sequence

The entrance road represents the greatest constraint on construction at this site. The access road must be improved, and a grade crossing must be constructed over the three-track rail line. Some roadwork will be needed on the site for bringing in gravel, fill, and topsoil, and a hardstand will be required for holding trucks. Temporary roads will be adequate on the site, but a substantial gravel base will be required to avoid problems with the compressible and unstable fill.

The construction sequence (shown in the preliminary construction schedule, (Figure 4-1) starts with draining and excavating the ponds for the subsurface drain. This is followed by filling the subsurface drain and depositing slag or fill in the pond area and on the upper mounded areas, as needed. The topsoil will be spread over all disturbed areas after bentonite (or clay) has been applied over the swales. Seeding the area and placing rip-rap in the swales will be the final construction activities.

4.2.3 Material availability

1. Fill and topsoil -- Conversations with a Pittsburgh contractor have indicated that soil for the final cover and fill are readily available in this area. The sites for borrow material and topsoil will generally be developed by the contractor as the need arises.

The pond fill material may be slag if this is cost-effective and poses no environmental problems. Approximately 200,000 cubic yards of fill or slag will be needed to fill the ponds and depressions in other areas and to provide mounds on the eastern and western portions of the site. As previously discussed, it is economically preferable that materials on the site be used for at least the bulk subsurface fill.

The top 6-inch layer of the final cover must be suitable for promoting the growth of grasses and other small vegetation. The top layer can be topsoil, if available, or soil suitable for revegetation. A total of 20,400 cubic yards will be required for this 6-inch soil layer.

Time-released herbicides are currently being researched by Pacific Northwest Laboratories, and could be used to provide a biological barrier to any deep-rooted vegetation if demonstration projects prove that this is feasible. The herbicides would be strategically placed in the upper soils to allow the growth of small vegetation, but exclude any deep-rooting vegetation. Since these herbicides are in the developmental stage, the application cost has not been included in this report. If the time-release herbicides do not prove cost-effective, then periodic mowing and maintenance of the site might be required to prevent deep-rooted vegetation from becoming established. (The major limitations of these herbicides are their enormous cost.)

2. Impermeable materials -- A mixture of clean fill and bentonite has been specified to provide impermeable layers under the swales and as pond liners to reduce infiltration. For this effort, 530 tons of bentonite will be required. Natural clay of the required permeability can be substituted if it is available locally at a competitive cost. Presently only one potential source for clay has been found (about 40 miles from the site, in Somerset, Pennsylvania).
3. Gravel and crushed stone -- Gravel and sand are required for several functions in the proposed remedial-action plan. Telephone inquiries have indicated that sand, natural gravel, and crushed stone are available in the area.

4.2.4 Traffic patterns and control

Before any work begins at the Burrell site, the access road to Strangford Road must be improved to accommodate truck traffic, and a grade crossing should be constructed across the ConRail tracks. During construction, a flagman from the railroad will be necessary to control traffic across the grade crossing. The intensity of rail traffic may influence the smooth movement of construction materials into the site. No estimate of rail traffic has been made, but it will be explored with ConRail once the details of the truck movements are known.

4.2.5 Environmental monitoring during construction

Under the selected remedial-action program, the contaminated material will not be disturbed. It is not expected that radionuclide releases to the environment will be significantly increased during construction. Other than periodic spot-check monitoring, no special program for air or water monitoring is planned until the project is completed. Post-construction verification of ground-water quality is recommended to direct any unexpected releases that might accompany alterations in infiltration and ground-water flow patterns.

Hot spots that were not detected in the initial radiation surveys may exist at the site. For this reason, it is recommended that a full-time radiation-health physicist, competent in radiation monitoring, be assigned to the site during construction. The radiation-health physicist can oversee a film badge program for the workers, check construction equipment for contamination, and check for hot spots wherever the original ground surface is disturbed.

4.2.6 Partial construction alternatives

In the event the full \$2.8 million cannot be obtained to accomplish the recommended level of construction, three closure-concept variations are available to partially improve site conditions. Light grading can be considered to improve surface slopes and promote drainage. Combined with a soil cover and revegetation and stabilization, a reduction in infiltration through the contaminated zone can be attained. Depending on the portion of the area improved, the total cost would range from \$200,000 to \$400,000.

At a higher cost, the ponds can be left as is, and a sloped cover established only over the contaminated zone. Assuming that 2-percent slope mounds with a drainage blanket and soil cover are selected, the order-of-magnitude project cost will not exceed \$1,000,000.

In the event that suitable fill materials for the pond area are available on the site, a cost reduction can be achieved for the total recommended remedial-action plan. With bulk materials obtained on the site but all other materials imported, the total project cost should not exceed \$300,000. In addition, construction time could be reduced by 3 months and substantial truck traffic eliminated on adjacent roads.

5 Conclusions and Recommendations

5.1 CONCLUSIONS

5.1.1 Radiological conditions

Based on the surveys performed by Oak Ridge National Laboratory, WESTON, and the Bendix Corporation, the conclusions presented in the following subsections were reached concerning the current conditions at the Burrell site.

1. The concentrations of airborne radionuclides are within the EPA proposed standards.
2. The concentrations of radionuclides in ground water are below the EPA proposed standards.
3. There is no apparent significant migration of radioactivity off the site through environmental pathways.
4. The average radium-226 concentration in soil is less than the EPA proposed standard of 5 picocuries per gram; however, there are several localized areas with higher concentrations.
5. The average external-dose rate is within the EPA proposed standards; there is one small area with a higher dose rate.

5.1.2 Hydrogeological conditions

Based on the examination and interpretation of data collected at the site, the following conclusions have been drawn:

1. The site hydrogeological environment is such that the ground water on the site flushes approximately every three years. This may account for the reduced concentration of radionuclides in the ground water at the Burrell site.
2. The ground water on the site is not significantly degraded as a result of the disposal of radioactive waste. The ground-water quality at the site is presently well within the required limits for existing sites.
3. There is no evidence that radiological contamination will increase in the future.

5.1.3 Remedial-action requirements

Based on the analysis of the site's radiological and hydrogeological characteristics, the following conclusions have been drawn:

1. Depending on the levels of allowable radioactivity on the site and through various pathways, specified in the EPA regulations (to be published in late 1982), the Burrell site may only require a minimal level of remediation and stabilization.
2. For the purpose of analysis, it is assumed that the site would have to be stabilized in a manner similar to inactive uranium-mill-tailings sites.

5.1.4 Alternatives for remedial action

Four different onsite remedial-action alternatives were conceptually developed and evaluated for environmental and technical feasibility and cost effectiveness. The results of the conceptual evaluation include the following:

1. Each of the four options may be considered environmentally acceptable and technically feasible.
2. The first alternative, site stabilization and closure, has been found to be the most cost-effective (\$2.8 million), technically feasible, and environmentally effective in meeting environmental requirements.
3. Partial implementation of Alternative 1 may be adequate to meet regulatory requirements. This could bring the cost of remedial action below \$1 million.
4. Alternative 2, site control and containment, provides a slight improvement over Alternative 1 by using a multilayer cap and cover system instead of a two-layer cover system. However, the added benefit of reducing infiltration is not required, and therefore the cost of this alternative (\$4.8 million) is not justifiable.
5. Alternative 3, waste excavation and encapsulation, provides some improvement over Alternatives 1 and 2, with regard to long-term stability, through excavation and recompaction prior to encapsulation. However, the excavation and handling of waste and contaminated material may create secondary impacts that outweigh the benefits of this concept. The cost of this alternative (\$8.3 million) is also prohibitive considering the true need for remediation of this site.

6. Alternative 4, waste excavation, incineration, and encapsulation of residuals, is even less attractive from environmental and technical-feasibility aspects than the other alternatives. Secondary impacts from excavating and handling contaminated materials and air emissions from the incineration operations outweigh the stability benefits derived from the volume reduction and thermal stabilization of the contaminated materials. The cost of this alternative (\$38 million) is extremely prohibitive considering the level of contamination of this site.

5.1.5 Feasibility of recommended alternative

The recommended concept, site stabilization and closure, should be viewed as an upper limit for remedial action of the Burrell site. Partial implementation may be justifiable, depending on the outcome of the final EPA standards when they are published. The following feasibility criteria for the base concept could be satisfied:

1. The regulatory requirements can be met even if the current stringent proposed EPA standards are enforced.
2. Environmental effectiveness can be established through protection of air, subsurface water, and surface-water pathways.
3. The stabilization and closure plan is cost-effective and can be partially implemented at a lower cost than the base concept.
4. The recommended concept will utilize demonstrated technology and proven materials.
5. The recommended remedial action is expected to be effective over a long period in spite of continued site subsidence.
6. Public acceptance of site stabilization and closure is expected to be more favorable than other onsite, or offsite, remedial-action approaches.
7. The remedial-action approach is constructable and can be implemented in a reasonable period of time (approximately one year).
8. The major elements of the program are implementable using conventional construction techniques, equipment, materials, and personnel.
9. The program elements are feasible and can be implemented in a phased approach or in part, depending on the final outcome of the EPA standards.

10. The base alternative, or a variation of it, is compatible with the project objectives and should not have a negative impact on the UMTRA Project.

5.1.6 Implementation guidelines

Before remedial action begins at the Burrell site, the following tasks must be completed:

1. The final EPA standards must be reviewed when they become available to determine the appropriate level of control required for the site.
2. A detailed engineering evaluation and design of the confirmed remedial action must be completed.
3. The source, type, quality, and quantity of materials required for onsite stabilization and closure must be confirmed.

5.2 RECOMMENDATIONS

As a result of the work accomplished for this project, the following recommendations are made:

1. The UMTRA project office and the TAC should continue to follow the status of the EPA regulatory requirements for inactive uranium-mill-tailings sites and vicinity properties. The current level of radiological contamination should be checked against the final EPA standards when they become available.
2. If the final EPA standards (to be published in late 1982) indicate that the radiological-contamination levels in soils, air, and water at the site are below or close to the levels requiring remedial action, the UMTRA and TAC project teams may elect to investigate the feasibility of requesting the application of supplemental standards for the Burrell site, based on its current insignificant levels of radioactivity and minimal potential environmental impacts. The Burrell site will not require a license from the NRC and the DOE is not required to own the site since it is a vicinity property. In addition, according to the proposed final EPA standards, approval by the NRC or other offices may not be needed to leave contaminated materials on vicinity properties.
3. If remedial action is required, it is recommended that the site stabilization and closure concept (Alternative 1) be considered the proposed action for establishing the feasibility of an onsite remedial-action program. This alternative should be viewed as an upper limit, since the radiological conditions of the site may preclude the necessity for remedial action under the EPA proposed

standards. If remedial action is required for the Burrell site, the means of reducing costs over the basic alternative should be investigated. These may include the following:

- a. Selective site improvements, partial cover, and closure.
 - b. Use of onsite materials for stabilizing the adjacent ponds.
4. After establishing the level of remedial action at the Burrell site that will be required to meet the regulatory and programmatic standards, the TAC should confirm the site conditions, establish the design requirements and parameters, and finish the preliminary design in preparation for the detailed design and construction work by the RAC.

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Appendix A

Evaluation Methodology for Containment and Encapsulation of Inactive Low-Level Radioactive Waste Disposal Sites

Appendix A

EVALUATION METHODOLOGY FOR CONTAINMENT AND ENCAPSULATION OF INACTIVE LOW-LEVEL RADIOACTIVE WASTE DISPOSAL SITES^a

INTRODUCTION

In order to securely contain low-level radioactive waste and contaminated soils, it was proposed that they be contained or placed in an encapsulation cell. In-situ containment could be accomplished by utilizing a cover system over the waste disposal site. Encapsulation could be accomplished by placing the waste in a cell consisting of an interconnected cover and liner which totally encapsulate the waste. The encapsulation and containment design was formulated to meet the EPA criteria for remedial action at inactive uranium-mill-tailings sites. Criteria of primary importance in the design of the cell included those regulating radon gas emission and groundwater contamination. The cover and liner configuration that was recommended for use is shown in Figure 1.

This appendix discusses state-of-the-art techniques for containment and encapsulation of hazardous waste disposal sites. Such techniques have been applied for remedial action of inactive hazardous waste disposal sites containing chemical, toxic, and low-level radioactive materials. The following discussion is based on a remedial action case history for a large site containing low-level radioactive waste. The technical approach, however, is applicable to other types of hazardous and/or toxic waste.

COVER SYSTEM

Background

The cover, as an element of the encapsulation cell, plays a very important role in protecting the environment and public health. A properly selected, designed, and constructed cover system will control potential releases of radioactivity through air diffusion, surface and subsurface migration, and other physical transport pathways.

The evaluation and selection of cover systems for low-level radioactive waste is a function of various performance criteria and cover materials. A successful cover system will provide effective control of surface-water infiltration and radon gas emission, and will remain effective with minimum maintenance for 1,000 years. The control of surface-water infiltration will minimize radionuclide leaching and subsequent transport.

^aPortions of this technical presentation are based on a feasibility study conducted by Roy F. Weston, Inc. for in-situ stabilization of the Canonsburg UMTAP site for Sandia National Laboratories (Contract No. 74-2738) for the U.S. Department of Energy's UMTRA project office in Albuquerque, New Mexico.

FIGURE 1

PROFILE OF RECOMMENDED ENCAPSULATION
AND COVER CONFIGURATION

Cover Material Evaluation

For the case history, 18 cover types were systematically evaluated based on 20 performance criteria. The covers were then ranked based on these criteria, and the best performer was identified. Six major classes of covers were evaluated, and were multilayer, asphalts, concrete, synthetics, natural soils, and soil admixtures.

Table 1 illustrates the evaluation process for the various cover materials. If a cover material was given a positive performance rating, a plus sign appears in that criteria column. If a negative performance rating was given, a minus sign appears in the criteria column. It is clearly seen that the multilayered cover system shows the best performance. The multilayer cover system for the low-level radioactive residues is shown in Figure 2. The system consists of the following:

1. Top layer of noncompacted soil which will support vegetation.
2. A middle layer of coarse gravel or crushed rock.
3. A bottom layer of clay.

Radon Attenuation in Cover System

A primary purpose of the cover system was to reduce radon fluxes at the surface of the covered remedial action case history disposal site to 2 picocuries per square meter per second or less. It was necessary to design the cover to accommodate the highest radon flux anticipated from the waste encapsulation area. The design cover thickness to reduce the design base flux to the 2 picocuries per square meter per second specification was computed using the following equation (RAECO, March 1981):

$$x_1 = -\ln\left(\frac{J_1}{J_0}\right) \frac{1}{\sqrt{\frac{\lambda p}{Dh}}} \quad (1)$$

Where:

x_1	= Required cover thickness.
J_1	= Radon flux rate from covered materials.
J_0	= Radon flux rate from uncovered materials.
λ	= Radon decay constant ($2.1 \times 10^{-6} \text{sec}^{-1}$).
p	= Porosity of the cover material.
D	= Effective radon diffusion coefficient for the cover material.
h	= Dimensionless coefficient (~ 1 when $J_1 \ll J_0$).

Table 1 Cover Material General Performance Criteria Evaluation

Cover material	Historical applications as a cover material	Permeability	Impede water percolation	Radon gas control	Erosion control	Aid surface runoff	Deacidation	Prevent/chew stability	Seismic stability	Rock resistance	Side-slope stability	Potential for side-slope seepage	Discourages rodent burrowing	Supports vegetation	Ease of construction	Probable 1000-year life	Cost of placement	Biological deterioration	Root penetration	Have radiation gamma penetration
Spray asphalt emulsion																				
Hydraulic asphalt																				
Synthetic -- CPG																				
Synthetic -- PVC																				
Synthetic -- neoprene																				
Synthetic -- CPG																				
Concrete																				
Low permeability native soils																				
Onsite soils																				
Soil admixtures (bentonite)																				
Bentonite																				
Well-graded gravel																				
Riprap																				
Silty-sand (soil)																				
Clayey-sand (soil)																				
Soil cement																				
Soil asphalt																				
Multilayered -- grass/topsoil/gravel/clay/soil

FIGURE 2 PROFILE OF RECOMMENDED ENCAPSULATION AND COVER CONFIGURATION

Analyses of the effects of various cover configurations on radon flux rates were conducted using a computer model developed by Rogers Associates Engineering Corporation (RAECO, March 1981). Pertinent results are displayed in Table 2. For instance, from this table it can be seen that a 1,500 picocuries per square meter per second flux rate from the encapsulation area can be controlled to the specified regulatory level of 2 picocuries per square meter per second with the use of a 10-foot multilayer cover system.

Table 2
Radon Attenuation by Various Covers

Cover	Base radon flux (pCi/m ² /s)			
	100	300	1000	1500
	Radon emanation through cover system (pCi/m ² /s)			
3 ft soil	14.25	70.55	140.9	211.3
6 ft soil	1.173	5.175	10.18	15.18
3 ft clay/1 ft gravel/2 ft soil	2.354	11.10	22.22	33.25
3 ft clay/1 ft gravel/6 ft soil	0.2363	0.4940	0.8162	1.138

Functional Components of the Cover System

A. Vegetation and Upper Soils

Vegetation controls erosion and encourages soil water loss by evapotranspiration. Otherwise, erosion will ultimately degrade the cover and seriously reduce its effectiveness. The effect of vegetation quality on resultant percolation through the topsoil and underlying noncompacted soil was examined. The results for good grasses as opposed to poor grasses are shown in Figure 3. They were computed using the Hydrologic Simulation and Solid Waste Disposal Sites (HSSWDS) model developed by the EPA with the U.S. Army Corps of Engineers (Perrier and Gibson, 1980). Greater attenuation of percolation through the upper soil layers is achieved with greater total thickness as shown in Figure 4 (an example calculation for a site in the Pittsburgh, Pennsylvania area). Note that there is a significant reduction in percolation as a function of increased total thickness. Water budget results for the drain and clay layers follow.

*1. Average Annual Value Precipitation for 1974 to 1978 (Inclusive) — 38.09 Inches /Year

*2. Top Soil—Silt Loam, Non-Compacted Soil—Clay
as per USDA Soils Textural Classification

FIGURE 3 COMPARATIVE WATER BUDGET RESULTS FOR VEGETATIVE COVERING USING 'GOOD' GRASS AND 'POOR' GRASS

1. Upper Soils Layer Consists of top soil (a constant thickness of 6 inches) and non-compacted soils
2. As per USDA Soils Textural Classification
Top Soil—Silt Loam
Non-Compacted Soil—Clay
3. Precipitation value (38.09 inches/ year) is the Average Annual Value Precipitation for 1974 to 1978 (inclusive).

FIGURE 4 GRAPH OF AMOUNT OF ANNUAL PRECIPITATION PERCOLATING THROUGH INCREASING THICKNESS OF UPPER SOILS LAYER

B. Drain Layer

The drain layer consists of crushed rock or coarse gravel having a relatively large permeability, K_s , of 1×10^{-1} cubic meter per second. A drain layer thickness of one foot was used. The thickness requirement is a function of: annual percolation rate, drain length, permeability, and drain slope.

An example of calculating flow through the drain layer is given in Figure 5 (Moore, 1980). This figure shows a drain layer of thickness $d(\text{cm})$ overlying a low permeability material. The drain layer extends over distance, L . The saturated permeability of the drain layer is given by K_s . The annual percolation rate, e , is the amount of water, annually, that impinges on the drain layer. It is assumed that the percolation rate is constant with time. This is a valid assumption since seepage fluxes do not change rapidly with respect to time.

The height of the saturated water surface for the limiting case when $\alpha = 0$ is given by (Moore, 1980), as follows:

$$h = \left(\frac{e}{K_s} (L-x) x \right)^{1/2} \quad (2)$$

The maximum height of water in the drain layer, $h_{\max}$, is given as:

$$h_{\max} = \left(\frac{eL^2}{4K_s} \right)^{1/2} \quad (3)$$

Setting the slope at some value greater than 0 ($\alpha > 0$) will accelerate the flow toward the collector system. $h_{\max}$ for $\alpha > 0$ is given by:

$$h_{\max} = \frac{L\sqrt{C}}{2} \left[\frac{\tan^2 \alpha}{C} + 1 - \frac{\tan \alpha}{C} \sqrt{\tan^2 \alpha + C} \right] \quad (4a)$$

Where:

$$C \equiv \frac{e}{K_s} \quad (4b)$$

Having a slope α , greater than zero is critical since in this case, if water were to cease impinging on the drain layer, the water would completely drain in a finite amount of time. If $\alpha = 0$ the drainage time is infinitely long.

FIGURE 5 **DIAGRAM OF ASSUMED WATER SURFACE PROFILE IN DRAIN LAYER.**

The results of a sensitivity analysis for the previously mentioned Pittsburgh, Pennsylvania area site, are given in Table 3 to examine the effects of percolation rate, drainage length and slope, and saturated permeability on the maximum height of water standing in the drain layer. Drain thickness requirements will increase as a function of an increase in annual percolation rate and decrease in permeability. Other parameters being equal, drain thickness requirements will decrease as a function of increasing slope.

The approach for estimating drain layer efficiency is based on saturated Darcy flow in both the drain layer and clay cap. The assumed geometry is given in Figure 6, at some time, t (Moore, 1980).

This approach postulates that at some initial time a rectangular slug of liquid is placed on the saturated liner to a depth, h_0 . The liquid flows both horizontally along the slope of the system, and vertically into the clay liner. The fraction of liquid moving into the collector drain system at time, t , is given (Moore, 1980), as follows:

$$\frac{S}{S_0} = 1 - \frac{t}{t_1} \quad (5)$$

and the fraction of liquid seeping into the clay liner is given by:

$$\frac{h}{h_0} = \left(1 + \frac{d}{h_0 \cos \alpha}\right) e^{-Ct/t_1} - \frac{d}{h_0 \cos \alpha} \quad 0 \leq t \leq t_1 \quad (6)$$

Where:

$$t_1 = \frac{S_0}{K_{s1} \sin \alpha} \quad (7)$$

$$C = \left(\frac{S_0}{d}\right) \left(\frac{K_{s2}}{K_{s1}}\right) \cot \alpha \quad (8)$$

and

S = Length of saturated volume at time, t (cm).

h = Thickness of saturated volume at time, t (cm).

S_0 = Initial length of saturated volume = $L/2$ sec (centimeters).

h_0 = Initial thickness of saturated volume (centimeters).

Table 3

Illustration of a Sensitivity Analysis
for the Pittsburgh, Pennsylvania Area Site

Drain layer length: 200 ft

$L = 2 \times \text{drainage length} = 400 \text{ ft} = 121.92 \text{ m}$

Vegetation cover: "Fair" grass

Upper soil thickness	Maximum annual percolation rate	Slope 10	5%	10%	15%
Drain layer thickness (in.)					
<hr/> (K = 1×10^{-1} cm/sec) <hr/> s <hr/>					
24 inches	11.64 in./yr 9.4×10^{-9} m/sec	3.76	3.68	3.68	3.68
72 inches	9.47 in./yr 7.6×10^{-9} m/sec	3.37	3.31	3.31	3.31
<hr/> (K = 1×10^{-2} cm/sec) <hr/> s <hr/>					
24 inches	11.64 in./yr 9.4×10^{-9} m/sec	13.54	11.74	11.66	11.65
72 inches	9.47 in./yr 7.6×10^{-9} m/sec	11.93	10.54	10.48	10.47

a GEOMETRY FOR CALCULATING
EFFICIENCY OF DRAIN LAYER

b DIAGRAM FOR COMPUTING
EFFICIENCY OF DRAIN LAYER

SOURCE: MOORE 1980

**FIGURE 6 ASSUMED GEOMETRY FOR COMPUTING
DRAIN LAYER EFFICIENCY**

- K_{s1} = Saturated permeability of the material above clay liner (centimeter per second).
- K_{s2} = Saturated permeability of the clay liner (centimeter per second).
- α = Slope angle of the system (degrees).
- d = Thickness of the clay liner (centimeters).

The efficiency of the liner is determined with reference to Figure 6(b) which plots h/h_0 versus S/S_0 and t/t_1 . Equations (5) and (6) can be solved parametrically in t/t_1 , to yield the line shown on the figure. (The line is actually a curve, however, for practical liner and drain layer configurations it can be approximated as a straight line.) In this case, the efficiency of the system is given by the area labelled "f." This area is most easily determined by calculating the value of h/h_0 when $t/t_1 = 1.0$ (or $S/S_0 = 0$). The term h/h_0 is set equal to n and can be obtained by solving equation (9) with $t/t_1 = 1.0$:

$$n = \left(1 + \frac{d}{h_0 \cos \alpha}\right) e^{-C} - \frac{d}{h_0 \cos \alpha} \quad (9)$$

The value of n can be either positive or negative, however, most efficient designs will have $n > 0$. The efficiency is given by either:

$$f = \frac{1+n}{2} \quad \text{for } n > 0 \quad (10a)$$

or

$$f = \frac{1}{2(1-n)} \quad \text{for } n < 0 \quad (10b)$$

Thus, the efficiency varies from 0 to 1.0.

C. Impermeable Barrier (Clay Cap)

The clay cap may be constructed either of one layer of compacted soil; or two layers, compacted soil overlaid by a compacted soil and bentonite mixture. The criterion for barrier selection is permeability. Permeabilities of 10^{-6} to 10^{-8} centimeters per second are required for attenuation of radon as well as reduction of seepage through contaminated materials.

In the early stages, the wetting process is described by equation (11) where the first term on the right side dominates, shown as follows:

$$\frac{\partial \tilde{\theta}}{\partial t} = D^* \frac{\partial^2 \tilde{\theta}}{\partial Z^2} - K^* \frac{\partial \theta}{\partial Z} \quad (11)$$

Thus,

$$\frac{\partial \tilde{\theta}}{\partial t} \approx D^* \frac{\partial^2 \theta}{\partial Z^2} \quad (12)$$

The D^* term represents capillary attraction. During this stage of the wetting process, gravitational forces are negligible as compared to capillary forces.

Imposing the following initial and boundary conditions:

Initial Condition

$$\tilde{\theta} = 0; \text{ for } Z > 0 \text{ and } t = 0$$

(Z is positive, downward)

At initial time ($t = 0$), assume that the moisture content is equal to θ , throughout the depth of the liner.

Boundary Condition

$$\theta = \theta_s \text{ for } Z = 0 \text{ and } t \geq 0$$

At all times at the boundary ($Z = 0$), the moisture content is held at the saturation moisture content, θ_s .

The solution of equation (12), having the initial and boundary conditions just given, is as follows:

$$\tilde{\theta} = \theta_i + (\theta_s - \theta_i) \operatorname{erfc} \frac{Z}{\sqrt{2 D^* t}} \quad (13)$$

The relationship for the cumulative amount of water entering the barrier soil at time, t , is as follows:

$$M_t = 2 (\theta_s - \theta_i) \sqrt{\frac{D^* t}{\pi}} \quad (14)$$

and the quantity of liquid required to saturate the barrier to a depth, d , is given by:

$$M_t = (\theta_s - \theta_i) d \quad (15)$$

Equating equations (14) and (15) yields:

$$t = \frac{\pi d^2}{4D\pi} \quad (16)$$

LINER SYSTEM

Background

The use of natural and synthetic materials of low permeability to line waste storage and disposal impoundments have been demonstrated to be a useful means of preventing leachate and waste liquid components from leaking and subsequently polluting ground and surface waters. These liner materials can also serve to prevent the migration of dangerous concentrations of radon and other gases from a waste containment site. Many liner materials are available from which the containment system for specific wastes may be chosen.

Two types of liner systems exist, active and passive. Active liner systems employ the use of leachate collection, and generally require considerable post-closure maintenance. An active liner system must also be constructed of highly impervious materials, and include a backup liner for quality assurance. Active liner systems have restricted life expectancies, and typically cannot be expected to provide a low maintenance 1,000-year life.

A significant amount of information exists regarding the water resistance of lining materials, regardless of whether they are soils, asphalts, or polymeric membranes. The contaminated materials may also contain other ingredients which could affect lining materials. It is, therefore, necessary to consider the totality of all constituents in a waste in assessing a liner material for a given application; the chemical composition of both the waste and the lining material must be considered.

This section, Liner System, will only consider passive liner systems because with their use, a low maintenance service life, can reasonably be expected. A variety of liner systems was considered for the encapsulation area, including asphalts, concrete, synthetics, natural soils, and soil admixtures. Table 4 illustrates the systematic performance evaluation of these materials. The natural soils with possible soil admixtures (bentonite clay) were again chosen based on past experience and long service life. They are also desirable for their ability to provide controlled hydraulic flux and radiological attenuation. The cost of placement and ease of construction are favorable characteristics.

Table 4

Liner Material General Performance Criteria Evaluation

<u>Liner material</u>	Permits hydraulic controlled flux	Historical application as liner material	Seismic stability (2)	Crack resistance (3)	Radionuclide attenuation (5)	Vegetation penetration	Potential for damage to liner during placement	Ease of construction	Probable 1000-year life	Biochemical deterioration	Cost of placement
Spray asphalt emulsion	+	+	+	+	+	+	+	+	+	+	+
Hydraulic asphalt	+	+	+	+	+	+	+	+	+	+	+
Synthetic -- Hypalon	+	+	+	+	+	+	+	+	+	+	+
Synthetic -- PVC	+	+	+	+	+	+	+	+	+	+	+
Synthetic -- Neoprene	+	+	+	+	+	+	+	+	+	+	+
Synthetic -- CPE	+	+	+	+	+	+	+	+	+	+	+
Concrete	+	+	+	+	+	+	+	+	+	+	+
Low permeability/native soils (1)	+	+	+	+	+	+	+	+	+	+	+
Soil admixtures (4) (bentonite)	+	+	+	+	+	+	+	+	+	+	+
Bentonite (4)	+	+	+	+	+	+	+	+	+	+	+
Soil cement	+	+	+	+	+	+	+	+	+	+	+
Soil asphalt	+	+	+	+	+	+	+	+	+	+	+

Functions of the Liner

The primary purpose and function of a liner system is to retard the physical movement of water into the natural environment. An optimal liner design would address the dual function of minimizing water (leachate) movement while passively treating any leachate that does migrate through the liner.

Water that permeates the clay cap will, in time, permeate the waste material and liner. The rate of water movement through the liner will, at saturation, equal that of the clay cap. Thus, water will not accumulate between the liner and the cap.

An ion-exchange barrier may be considered a means of controlling the migration of radionuclides in or into groundwater. This type of system could be constructed as follows:

1. A curtain or barrier designed to intercept the flow of groundwater from a contaminated area.
2. A liner to be placed under a waste area designed to intercept any leachate that may be generated.

Ion-exchange material may be comprised of natural soils (clays) or synthetic resins (zeolites, macroreticular polymers, gels, etc.).

The use of ion-exchange materials for control of radioactive wastes has been proposed in the literature (Benson, 1980, and Northrup, 1980). The performance of various natural materials, e.g., expandable clays and zeolites, for adsorbing specific radioactive species has been reported. A recent literature search (Benson, 1980) revealed 10 references to ion-exchange data associated with clays, zeolites, and basalt, 22 references to ion-exchange data on clays, 22 references for zeolites, and 6 references on basalt.

Nowak (1979) has proposed a model for radionuclide migration through an ion-exchange backfill barrier system. This type of modeling effort may also be applied to a liner. Nowak (1979) presented his model, beginning with its differential form, as follows:

$$\epsilon \frac{\partial C}{\partial t} + \frac{\partial S}{\partial t} + \epsilon v_g \frac{\partial C}{\partial x} - \epsilon D_L \frac{\partial^2 C}{\partial x^2} = 0 \quad (17)$$

- Where:
- C = Liquid phase concentration, quantity of sorbing species per unit volume of liquid.
 - S = Concentration of species sorbed on the solid phase (quantity of sorbed species per unit volume of bed liquid plus solid volumes).

- ϵ = Effective porosity of bed (fraction of bed volume containing flowing liquid).
- v_g = Average interstitial velocity of flowing liquid.
- x = Distance in bed along direction of flow and longitudinal diffusion.
- D_L = Coefficient of longitudinal dispersion and diffusion combined.
- t = Time.

For the boundary condition,

$$C = C_0, \quad x = 0, \quad T > 0$$

and for the initial condition,

$$C = 0, \quad x > 0, \quad T = 0,$$

Crank (1956) gives the solution for equation (17) as follows:

$$\frac{C}{C_0} = 1 - \operatorname{erf} \left\{ \frac{x}{2 \left(\frac{D_f t}{\sqrt{2R_f}} \right)^{1/2}} \right\} \quad (18)$$

Where: D_f = Liquid phase molecular diffusivity.

$$R_f = 1 + \rho \frac{BK_d}{\epsilon}$$

ρB = Bulk packing density of solid sorbent, mass of solid per unit bed volume.

K_d = Distribution coefficient for a linear-sorption isotherm, the ratio of quantity of sorbed species per unit mass of solids to quantity of mobile species in the liquid phase per unit volume of liquid.

Typical values for the parameters used in equation (18) are presented in Table 5. The time to "breakthrough" for barrier walls with various characteristics is given in Figure 7. In developing these estimates, "breakthrough" is defined as $C/C_0 = 0.01$. As Figure 7 indicates, for those parameter values used, a barrier thickness ranging from less than 1.0 foot to approximately 6.5 feet

FIGURE 7 GRAPH OF BREAKTHROUGH TIME AS A FUNCTION OF BARRIER WALL CHARACTERISTICS—HIGH AND LOW DIFFUSION RATES (D_1)

would be necessary to attain a 1,000-year design (i.e., at 1,000 years of barrier life, the breakthrough concentration ratio, C/C^0 would be less than or equal to 0.01.

Table 5

Typical Values of Physical and Chemical Properties
for the Ion-Exchange Barrier

K_d = 100 to 5,000 milliliters per gram

B = 2 grams per cubic centimeter

D_f = 10^{-4} to 10^{-6} square centimeters per second

ϵ = 0.25 to 0.40

X = 1 to 10 feet

The results for a clay barrier wall can be roughly applied to a clay liner system as well. A clay of the type to be used for the encapsulation-cell liner at the case-history site should have a K_d of about 500 milliliters per gram and a D_f of about 10^{-5} square centimeters per second.

Liner-System Description

Two to three feet is the recommended thickness for the clay liner. This choice was made for several reasons: constructability, long-term ion-exchange capacity, and compactability with waste and contaminated material.

Bentonite combined with natural soils to produce a mixture of low permeability, or a native clayey soil may be used. The specific liner material can only be selected once the native soils are tested for permeability and cationic exchange capacity.

It should be noted that standard bentonite is susceptible to deterioration in an excessively low pH environment (Crim, 1979; Morrison, 1981; and van Zyl, 1978). The pH effects can only be assessed once the low-level waste of concern is tested.

A liner system used with a cover has the additional benefit of providing waste encapsulation. By tying the cover and liner systems together the buried wastes can be completely sealed. Encapsulation allows more complete isolation of the disposed wastes, and therefore lessens any environmental impacts.

The attenuating capabilities and inherent long-term structural and physiochemical stability of soils are their outstanding characteristics. Relatively simple construction techniques, along with ready availability and accessibility, make soil an obvious choice as a liner material.

WASTE CONDITIONING

Waste conditioning is generally performed to meet one of the following three objectives:

1. To improve the handling and physical characteristics of the waste.
2. To limit the solubility of various contaminants within the waste.
3. To decrease the surface area across which transfer and loss of contained contaminants can occur.

A number of fixation and conditioning methodologies were considered for application including the following:

1. Cement-based techniques.
2. Lime-based techniques.
3. Thermoplastic techniques.
4. Thermosetting resins.
5. Encapsulation techniques.
6. Glass and ceramic-fixation techniques.
7. Thermal stabilization.
8. Extraction of contaminants.

These techniques are all chemical (as opposed to physical). They may be used in the event waste material is found to have a low pH, which could damage a liner or cap made of bentonite clay and soil. Of the conditioning techniques considered, the lime-based techniques are the most applicable to such material. Fixation techniques using lime-type products usually depend on the reaction of lime with a pozzolanic (silicate-type) material, water, and the waste to produce a concrete-type material. The most common pozzolanic materials used in waste fixation are cement-kiln dust, fly ash, and pulverized slag. The effectiveness of chemical fixation using this technique must also be demonstrated through bench-scale tests that simulate the actual process.

Waste conditioning may also imply physical conditioning to improve the physical properties (such as bearing strength, etc.) of the contaminated materials. This should result in a compactable material of optimum moisture content and density which is strong enough to support both the multilayered cover system and the temporary load of construction vehicles. Adequate support of the cover system from below is essential to promote long-term stability and integrity of the cover.

SUMMARY AND CONCLUSIONS

Containment and encapsulation of hazardous waste disposal sites could be achieved by utilizing a combination of the following:

- Cover system for waste isolation, gas control, and reduction of infiltration through waste material.
- When applicable, use of a liner system as a back-up for the cover system and as a means for attenuation of leachate from waste material.
- Ion-exchange media (as part of the liner system or barrier) for attenuation of groundwater contaminants.
- Use of passive hydrogeologic isolation techniques including low permeability covers, liners, slurry walls, and drainage channels.
- In situ grouping, conditioning, solidification, or fixation of waste material.
- Total management, surveillance, and monitoring of the site during and after remedial action activities.

In situ containment and encapsulation offers a technically feasible, cost-effective means for control of contaminant release from inactive hazardous and low-level radioactive sites. When applicable, this approach is as effective for removal and off-site disposal of waste and contaminated material. However, the cost of in situ management is often a fraction of the latter approach.

The use of computer simulation for environmental simulation and optimization of design features an encapsulation system and has proven to be an invaluable tool. Techniques for evaluation of cover, liner, and barriers are presented and illustrated in this paper.

It is preferred to utilize passive rather than active techniques for encapsulating waste-disposal sites. Multilayer cover systems, soil/clay liners, bentonite slurry walls, and ion-exchange barriers represent the basic elements of remedial action that does not require perpetual post-closure operations.

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