662984

DP-1366

60

STORING SOLID RADIOACTIVE WASTES AT THE SAVANNAH RIVER PLANT

J. H. HORTON
J. C. COREY

SAVANNAH RIVER LABORATORY
AIKEN, SOUTH CAROLINA 29801

PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION UNDER CONTRACT AT(07-2)-1

Printed in the United States of America

Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed Copy $4.00; Microfiche $2.25

DP-1366 ~~DWA~~ 104

Distribution Category: UC-70

STORING SOLID RADIOACTIVE WASTES AT THE SAVANNAH RIVER PLANT

by

J. H. Horton and J. C. Corey

Approved by

E. L. Albenesius, Research Manager
Environmental Effects Division

Publication Date: June 1976

E. I. DU PONT DE NEMOURS AND COMPANY
SAVANNAH RIVER LABORATORY
AIKEN, SOUTH CAROLINA 29801

PREPARED FOR THE U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION UNDER CONTRACT AT(07-2)-1

INTERNAL DISTRIBUTION

Copy No.

1-3. T. B. Niland, SR

4. J. D. Ellett, Wilm
5. H. F. Ring
6. F. E. Kruesi - J. F. Proctor
7. L. C. Evans - J. W. Croach

8. W File

9. L. F. Shafranek, Eng Dept

10. W. J. Mottel, SRP
11. R. Maher
12. S. Mirshak
13. J. L. Womack
14. J. N. Beatty
15. D. C. Nichols - E. J. O'Rourke
16. O. W. Mowry
17. Q. R. Harper
18. W. P. Martin
19. R. G. Garvin
20. C. M. Patterson
21. H. A. McClearen
22. J. S. Murdock
23. R. D. Caldwell
24. R. C. Cooley

25. C. H. Ice - L. H. Meyer, SRL
26. J. L. Crandall
27. E. L. Albenesius
28. T. V. Crawford
29. W. R. Jacobsen
30. W. L. Marter
31. W. C. Reinig
32. E. B. Sheldon
33. J. C. Corey
34. J. H. Horton, Jr.

35-59. TIS

60. TIS Record Copy

INTERNAL DISTRIBUTION

Copy No.

1-3. T. B. Niland, SR

4. J. D. Ellett, Wilm
5. H. F. Ring
6. F. E. Kruesi - J. F. Proctor
7. L. C. Evans - J. W. Croach

8. W File

9. L. F. Shafranek, Eng Dept

10. W. J. Mottel, SRP
11. R. Maher
12. S. Mirshak
13. J. L. Womack
14. J. N. Beatty
15. D. C. Nichols - E. J. O'Rourke
16. O. W. Mowry
17. Q. R. Harper
18. W. P. Martin
19. R. G. Garvin
20. C. M. Patterson
21. H. A. McClearen
22. J. S. Murdock
23. R. D. Caldwell
24. R. C. Cooley

25. C. H. Ice - L. H. Meyer, SRL
26. J. L. Crandall
27. E. L. Albenesius
28. T. V. Crawford
29. W. R. Jacobsen
30. W. L. Marter
31. W. C. Reinig
32. E. B. Sheldon
33. J. C. Corey
34. J. H. Horton, Jr.

35-59. TIS

60. TIS Record Copy

INTERNAL DISTRIBUTION

Copy No.	
1-3.	T. B. Niland, SR
4.	J. D. Ellett, Wilm
5.	H. F. Ring
6.	F. E. Kruesi - J. F. Proctor
7.	L. C. Evans - J. W. Croach
8.	W File
9.	L. F. Shafranek, Eng Dept
10.	W. J. Mottel, SRP
11.	R. Maher
12.	S. Mirshak
13.	J. L. Womack
14.	J. N. Beatty
15.	D. C. Nichols - E. J. O'Rourke
16.	O. W. Mowry
17.	Q. R. Harper
18.	W. P. Martin
19.	R. G. Garvin
20.	C. M. Patterson
21.	H. A. McClearen
22.	J. S. Murdock
23.	R. D. Caldwell
24.	R. C. Cooley
25.	C. H. Ice - L. H. Meyer, SRL
26.	J. L. Crandall
27.	E. L. Albenesius
28.	T. V. Crawford
29.	W. R. Jacobsen
30.	W. L. Marter
31.	W. C. Reinig
32.	E. B. Sheldon
33.	J. C. Corey
34.	J. H. Horton, Jr.
35-59.	TIS
60.	TIS Record Copy

INTERNAL DISTRIBUTION

Copy No.	
1-3.	T. B. Niland, SR
4.	J. D. Ellett, Wilm
5.	H. F. Ring
6.	F. E. Kruesi - J. F. Proctor
7.	L. C. Evans - J. W. Croach
8.	W File
9.	L. F. Shafranek, Eng Dept
10.	W. J. Mottel, SRP
11.	R. Maher
12.	S. Mirshak
13.	J. L. Womack
14.	J. N. Beatty
15.	D. C. Nichols - E. J. O'Rourke
16.	O. W. Mowry
17.	Q. R. Harper
18.	W. P. Martin
19.	R. G. Garvin
20.	C. M. Patterson
21.	H. A. McClearen
22.	J. S. Murdock
23.	R. D. Caldwell
24.	R. C. Cooley
25.	C. H. Ice - L. H. Meyer, SRL
26.	J. L. Crandall
27.	E. L. Albenesius
28.	T. V. Crawford
29.	W. R. Jacobsen
30.	W. L. Marter
31.	W. C. Reinig
32.	E. B. Sheldon
33.	J. C. Corey
34.	J. H. Horton, Jr.
35-59.	TIS
60.	TIS Record Copy

CONTENTS

LIST OF FIGURES

LIST OF TABLES

STORING RADIOACTIVE WASTES AT THE SAVANNAH RIVER PLANT

INTRODUCTION

The Savannah River Plant (SRP) occupies an approximately circular site in South Carolina of about 192,000 acres bounded on the southwest by the Savannah River and centered approximately 25 miles southeast of Augusta, Ga. Solid radioactive waste has been stored at one location at SRP since 1953. This report discusses SRP solid radioactive waste storage site facilities, describes the procedures used to segregate and the methods used to store radioactive waste materials, and summarizes monitoring results obtained from studies of the potential transport of radionuclides from buried wastes at SRP.

FACILITY DESCRIPTION

One centrally located solid radioactive waste storage site (Figure 1) is used to store all solid radioactive waste presently produced on the plant, as well as occasional special ERDA shipments from offsite. The original site of 76 acres, with 8-foot-high woven wire security fencing and lying between Road E and the F-Area railroad, was filled in 1972, and operations have shifted to a 119-acre site across the railroad tracks. The new site is partially enclosed with a similar 8-foot fence, and the remainder is enclosed with a barbed wire fence.

The solid radioactive waste storage site has a paved road to its entrance and has many secondary roads inside the fence for access to burial sites. Three railroad spurs permit trains to bring in heavy process equipment. The equipment and manpower assigned to operate the facility are listed in Table 1.

The solid radioactive waste storage site is principally for the managed storage of solid radioactive wastes in underground trenches or on covered pads on the surface. Examples of the materials handled to date are:

- Contaminated equipment: obsolete or failed tanks, pipes, and other process equipment.

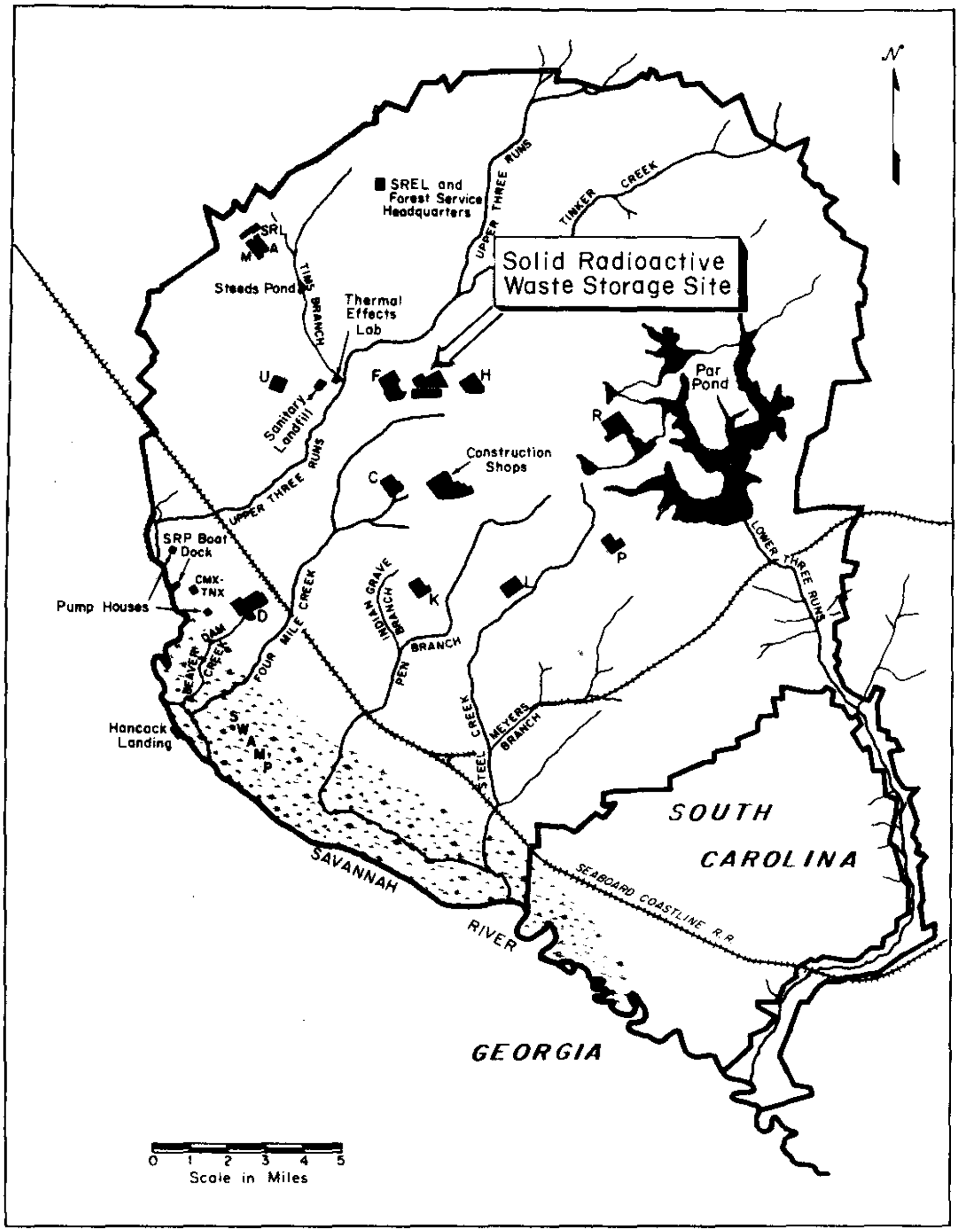


FIGURE 1. Solid Radioactive Waste Storage Site Location on SRP

TABLE 1

Solid Radioactive Waste Storage
Site Personnel and Equipment

Personnel	
1	Supervisor
1	Traffic and Transportation Foreman
1	Health Physics Inspector
1	Laborer
1	Heavy Equipment Operator
1	Crane Operator
2	Riggers
0.5	Dragline Operator

Equipment

Shielded Crawler Crane, with a 100-foot boom and a rating of 25 tons at 35 feet extension

3-ton Mobile Hydrocrane

Dragline

Crawler Crane with Bucket for backfilling transuranium alpha waste trenches

Bulldozer for backfilling trenches

Truck with Water Tank for firefighting and decontaminating recovered equipment

2 Pickup Trucks

1 Carryall Truck

25-ton Fork Lift

- Reactor and fuel hardware: fuel components and housings not containing fuel or products.

- Spent lithium-aluminum targets: the waste target alloy after tritium was extracted by melting the alloy.

- Oil from gas displacement pumps in the tritium facilities: prior to burial, the oil is placed in drums containing an absorbent material.

- Laboratory and operating waste: small equipment, clothes, analytical waste, decontamination residues, plastic sheeting, gloves, etc.

- Special shipments from offsite: tritiated waste from Mound Laboratory; ^{238}Pu process waste from Los Alamos Scientific Laboratory and Mound Laboratory; debris from 2 U.S. airplane accidents in foreign countries.

- Spent deionizer resins: from reactor use.

Several facilities and operations in the area are not directly related to the burial of solid waste. These include above-ground storage of process equipment that is to be returned to service (Figure 2), an organic solvent storage facility (Figure 3), a sandblasting facility for decontaminating equipment (Figure 4), and an equipment repair area (Figure 5). The solid radioactive waste storage site office and clothing change facilities are shown in Figure 6.

The solid radioactive waste storage site is divided into sections for transuranium alpha waste, low-level waste, and high-level waste (Figure 7).

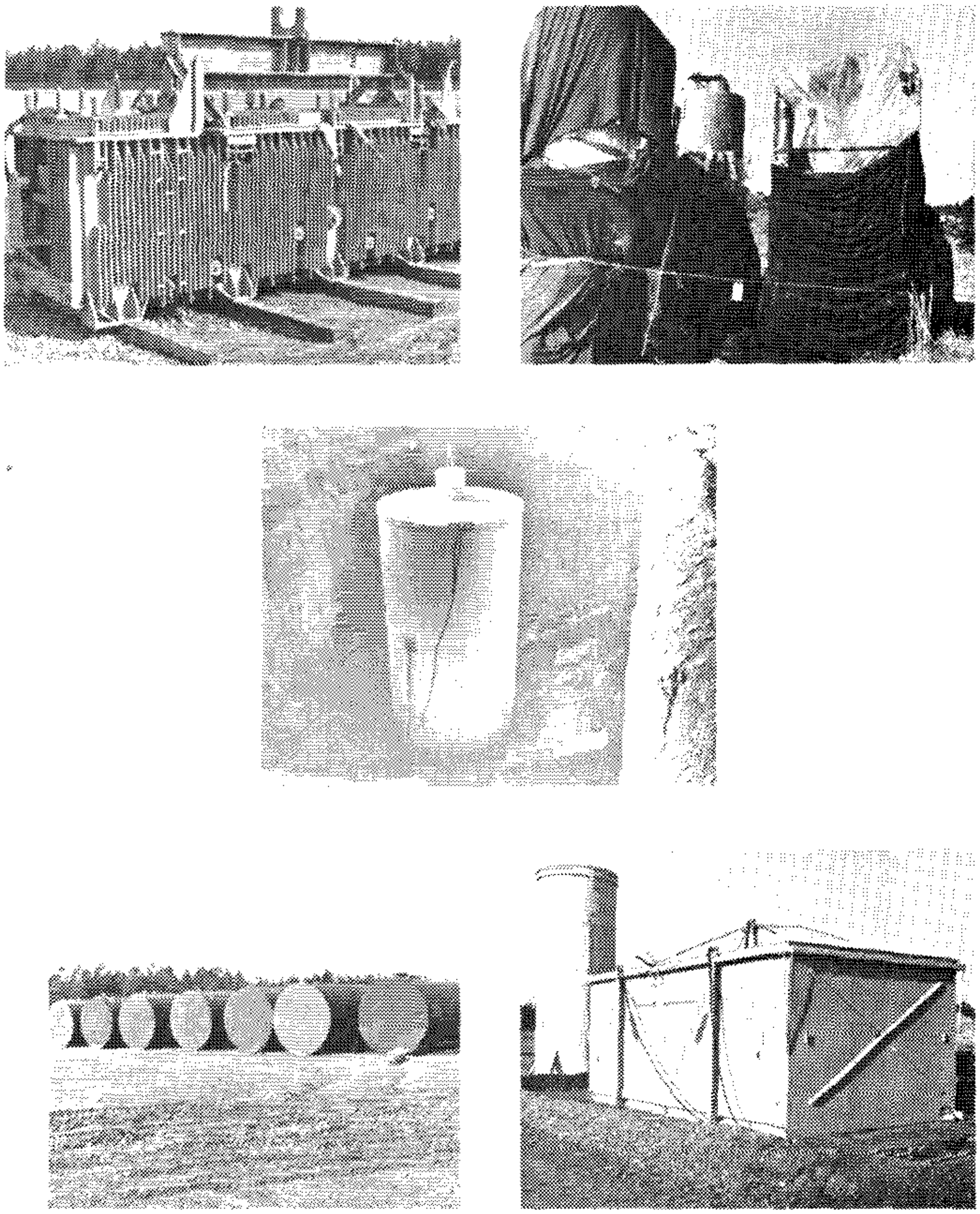
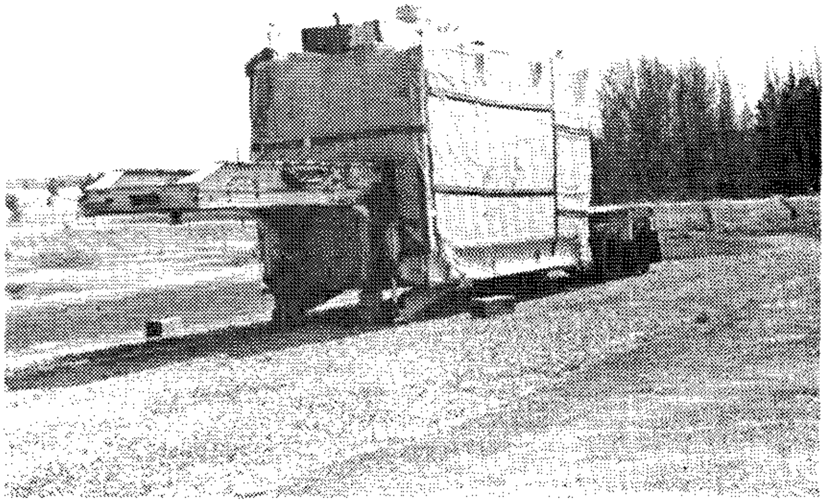
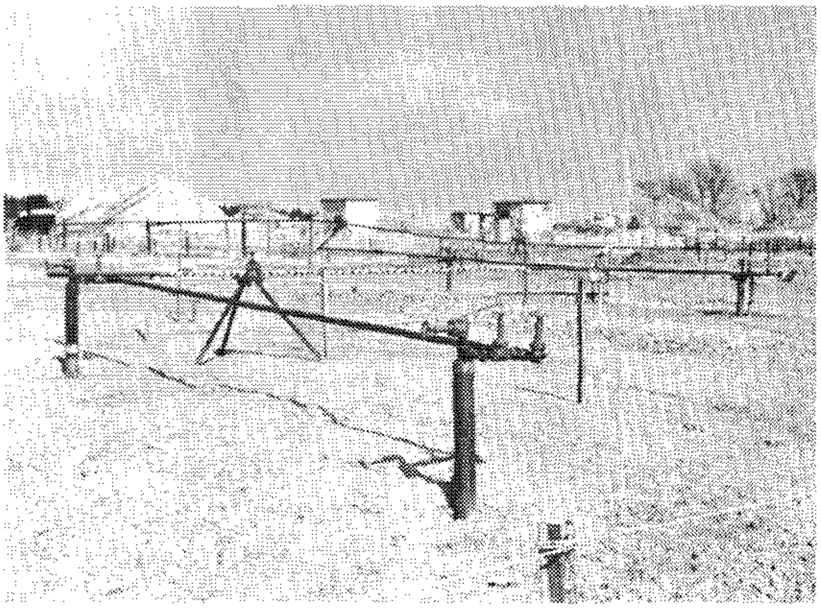


FIGURE 2. Above Ground and Bunker Storage

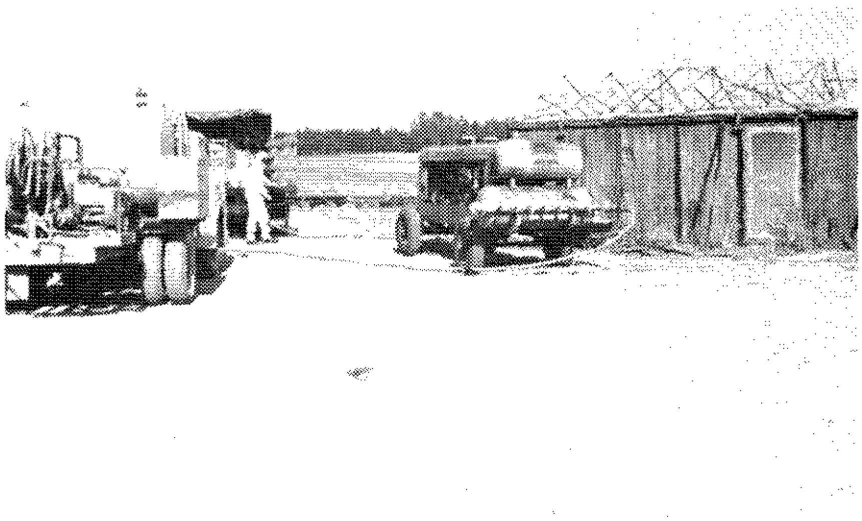


a. Solvent Trailer for Transporting Solvent from Separations Areas to Burial Ground

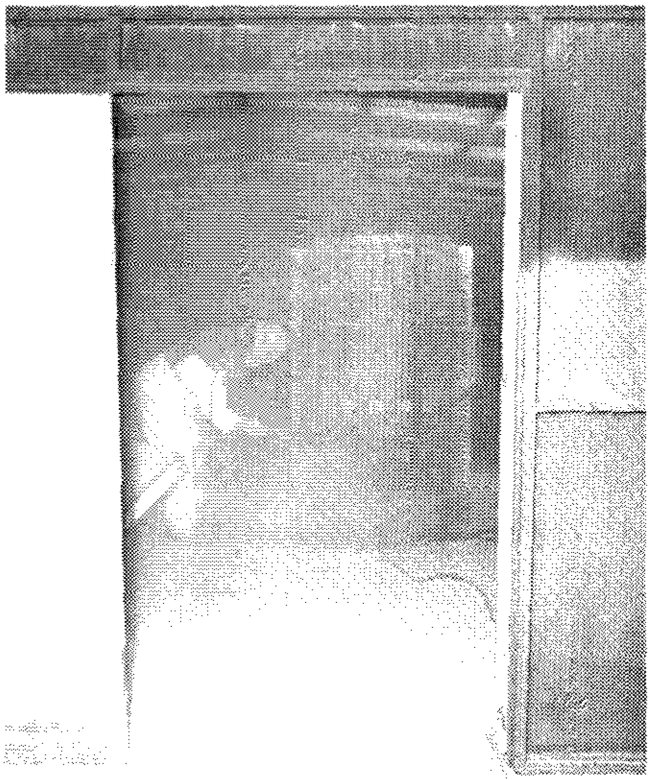


b. Underground Tank Storage Area

FIGURE 3. Solvent Storage Facility



a. Exterior View



b. Interior View

FIGURE 4. Sandblasting Facility

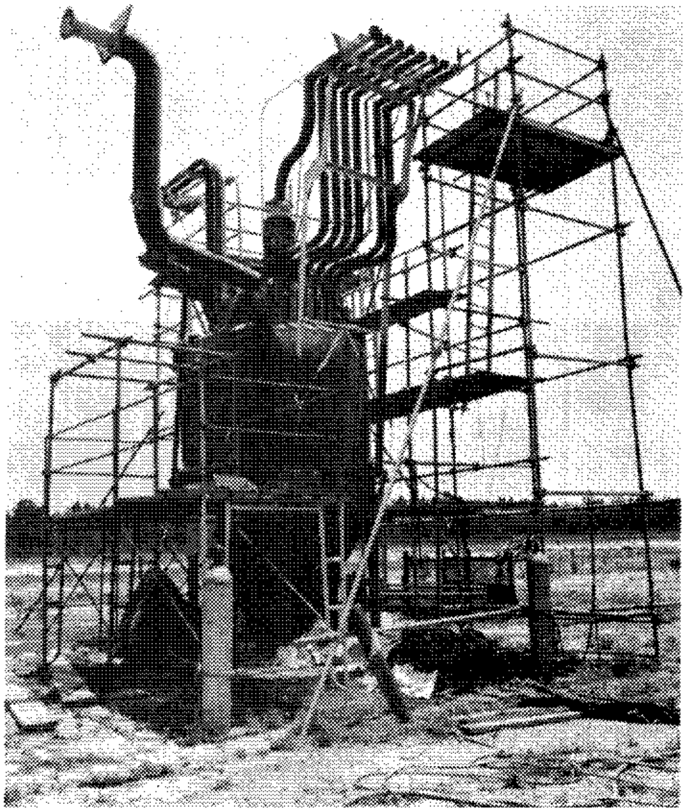


FIGURE 5. Equipment Repair Area

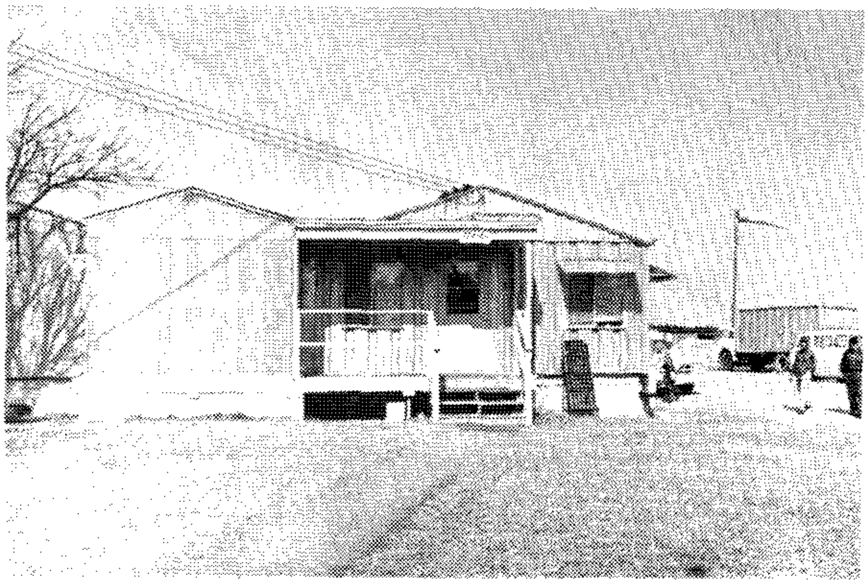


FIGURE 6. Building at Entrance to Solid Radioactive Waste Storage Site Containing Offices and Clothing Change Facilities

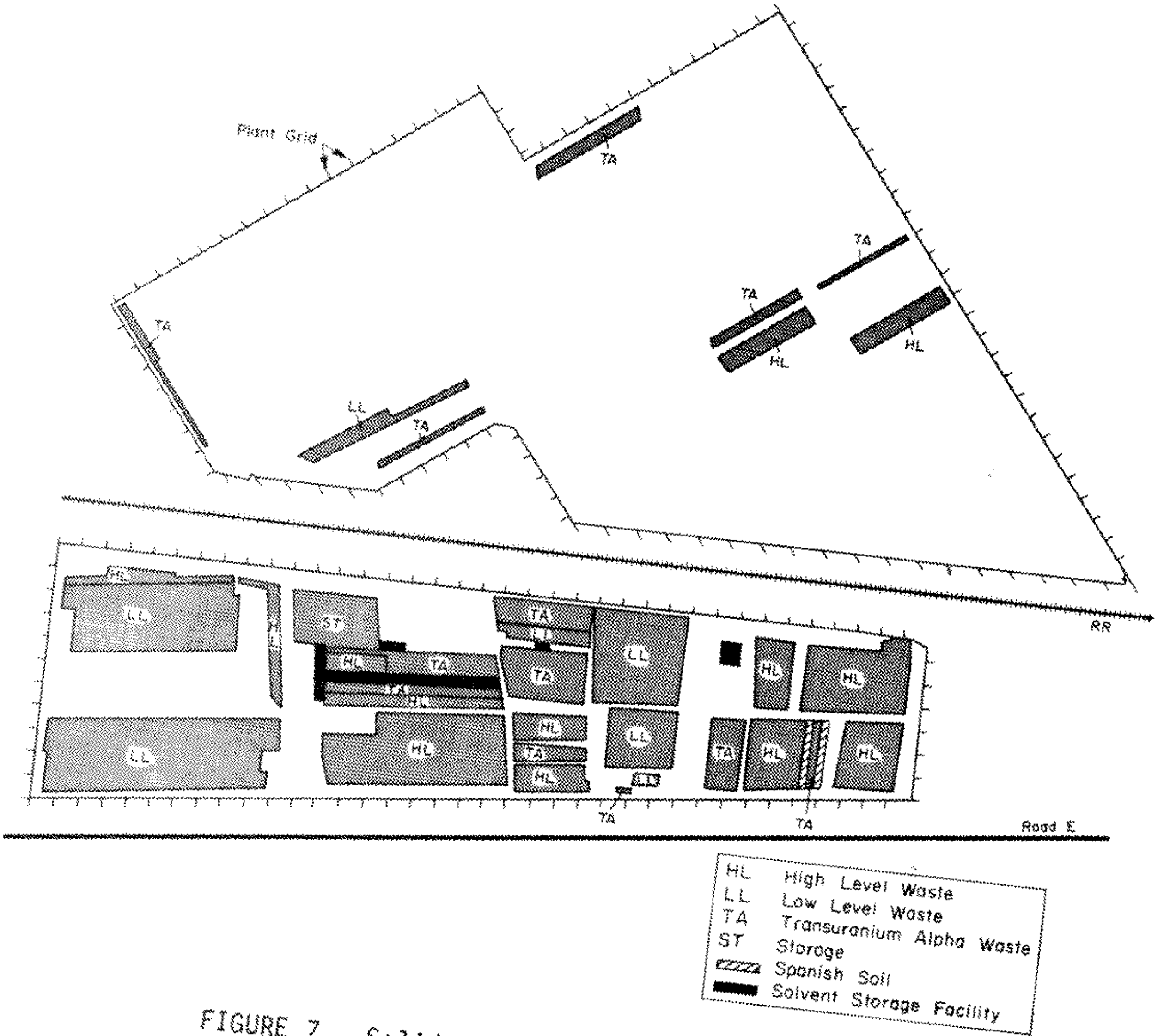


FIGURE 7. Solid Radioactive Waste Storage Site Map Showing Trenches and Grid Spacings

OPERATING PROCEDURES

Procedures and job plans are written prior to initiating storage of waste in order to achieve maximum protection from radiation and contamination to personnel and equipment. Coveralls, rubber shoe covers, gloves, eye protection, and hard hats are required for personnel assisting with waste handling operations (Figure 8). Only essential vehicles are permitted to enter the solid radioactive waste storage site. The vehicles are surveyed for contamination before leaving. A Health Physics inspector observes burial of high-level waste and makes routine surveys to determine ground surface or vegetation contamination.

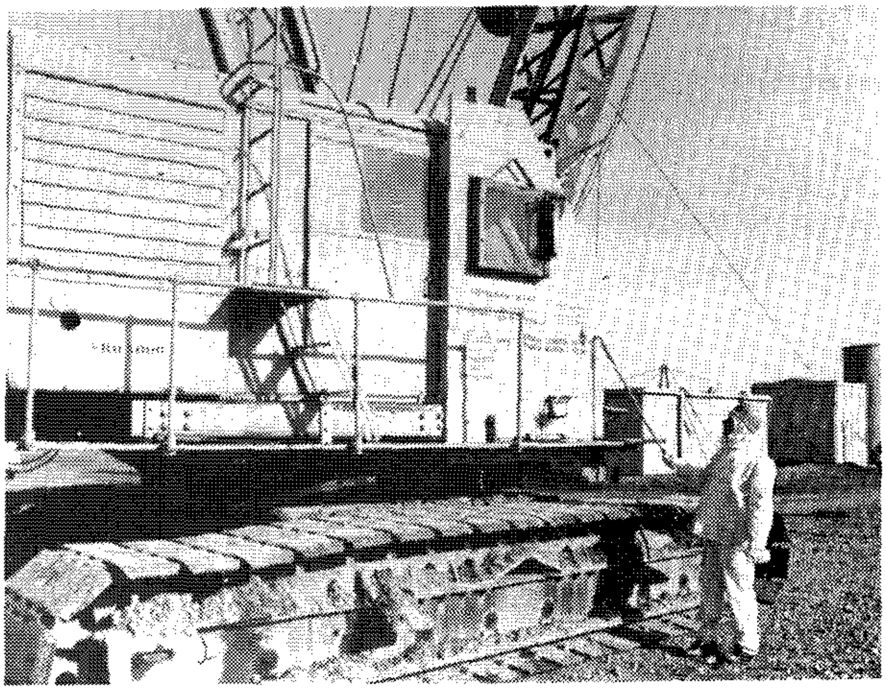
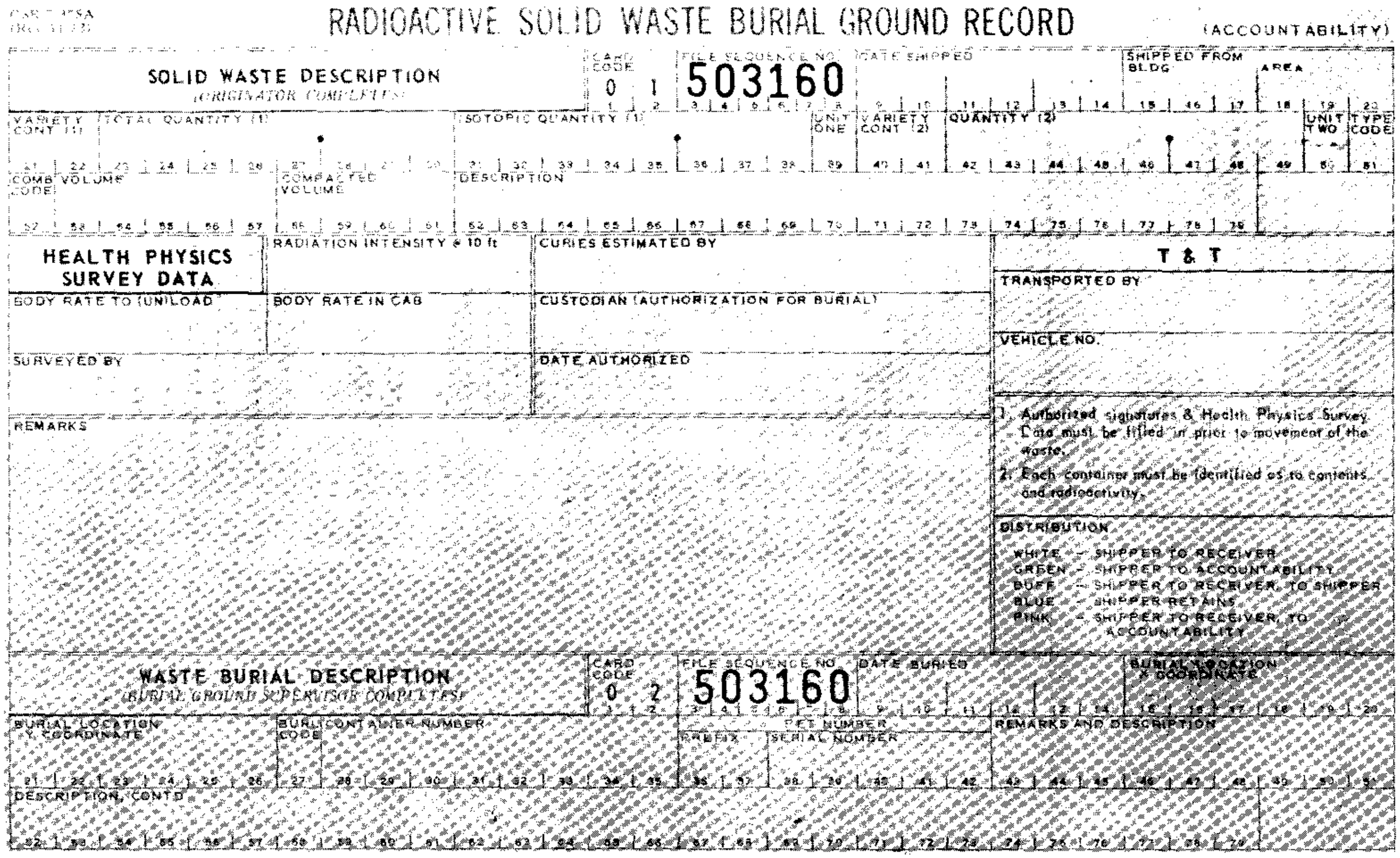


FIGURE 8. A Health Physics Inspector Checks the Shielded Crane for Smearable Radionuclides

The supervisor of the solid radioactive waste storage site keeps accurate records of the contents, radiation level, and burial location of each load received. Shipments are described and recorded on a Radioactive Solid Waste Record (Figure 9), and permanent computerized records are maintained on magnetic tape. The exact location of the trenches is defined by use of a 100-foot grid system laid out in 1960. The 100-foot grids are further divided into twenty-five 20-foot squares. Previous to 1960 the trenches were defined with concrete markers.



RADIOACTIVE SOLID WASTE BURIAL GROUND RECORD (ACCOUNTABILITY)

SOLID WASTE DESCRIPTION
(ORIGINATOR COMPLETES)

CARD CODE 0 1 | FILE SEQUENCE NO. 503160 | DATE SHIPPED | SHIPPED FROM BLDG. | AREA

VARIETY CONT (1) | TOTAL QUANTITY (1) | ISOTOPIC QUANTITY (1) | UNIT ONE | VARIETY CONT (2) | QUANTITY (2) | UNIT TWO | TYPE CODE

COMB CODE | VOLUME | COMPACTED VOLUME | DESCRIPTION

HEALTH PHYSICS SURVEY DATA

RADIATION INTENSITY @ 10 ft | CURIES ESTIMATED BY | T & T

BODY RATE TO (UN)LOAD | BODY RATE IN CAB | CUSTODIAN (AUTHORIZATION FOR BURIAL) | TRANSPORTED BY

VEHICLE NO.

SURVEYED BY | DATE AUTHORIZED

REMARKS

1. Authorized signatures & Health Physics Survey Data must be filled in prior to movement of the waste.
2. Each container must be identified as to contents and radioactivity.

DISTRIBUTION
WHITE — SHIPPER TO RECEIVER
GREEN — SHIPPER TO ACCOUNTABILITY
BUFF — SHIPPER TO RECEIVER, TO SHIPPER
BLUE — SHIPPER RETAINS
PINK — SHIPPER TO RECEIVER, TO ACCOUNTABILITY

WASTE BURIAL DESCRIPTION
(BURIAL GROUND SUPERVISOR COMPLETES)

CARD CODE 0 2 | FILE SEQUENCE NO. 503160 | DATE BURIED | BURIAL LOCATION X COORDINATE

BURIAL LOCATION Y COORDINATE | BURI. CODE | CONTAINER NUMBER | PET NUMBER PREFIX | SERIAL NUMBER | REMARKS AND DESCRIPTION

DESCRIPTION, CONT'D

a. Obverse Face

FIGURE 9. Radioactive Solid Waste Record

INSTRUCTIONS

01 CARD

SHIPPER'S ADDRESS

Enter 999 in Columns 15-17 for off-plant material received. Blanks and/or dashes should no precede letters or numbers used in Columns 18-20.

VARIETY OF CONTAMINATION – Use symbols as follows:

Columns 21-22, 40-41

10 – Depleted Uranium	70 – Uranium-233	CS – Cesium
20 – Enriched Uranium	81 – Normal Uranium	40 – Plutonium-242
44 – Americium-241	82 – Neptunium-237	SR – Strontium
45 – Americium-243	83 – Plutonium-238	IA – Induced Activity
46 – Curium-244	86 – Deuterium	FP – Fission Products
47 – Berkelium	87 – Tritium	OT – Other
48 – Californium	88 – Thorium	
50 – Plutonium (Weapons Grade)	CO – Cobalt	

RADIOACTIVE WASTE DESCRIPTION CODES

Columns 39 and 50

Unit C – Curies
G – Grams
K – Kilograms
M – Milligrams

Column 52

Combustion N – Noncombustible
C – Combustible

Column 51

Type 1 – Job control waste, including housekeeping waste and protective clothing
2 – Oil
3 – Irradiated metal scrap
4 – Naturally radioactive materials
5 – Capital equipment, must be accompanied by a Plant Equipment Transfer (PET)
6 – Resin
7 – Other

TOTAL ISOTOPIC QUANTITY

Columns 23-38, 40-49

Enter total and isotopic weights for all waste in milligrams, grams, or kilograms. Fissi Products and Induced Activity waste are reported in curies. The isotopic weight of Weapon Grade Plutonium is the sum of the 239 and 241 isotopic weights. The weight of Uranium-2 is the isotopic weight for depleted, enriched, and normal uranium.

VOLUME/COMPACTED VOLUME

Columns [illegible]

Enter volume before and after compaction. If waste is not compacted, leave compacted volum field blank.

02 CARD

BURIAL CODE

Column [illegible]

1 – Low Level Beta-Gamma Trench	5 – Concrete Pour
2 – High Level Beta-Gamma Trench	6 – Above Ground Storage
3 – Low Level Alpha Trench	7 – Other
4 – Burial Containers (Retrievable TRU)	

AUTHORIZATION FOR SHIPMENT

Requires signature of responsible supervisor who notes Health Physics survey requirement

b. Reverse Face

FIGURE 9. Continued

Burials are made in trenches that are 20 feet deep and 20 feet wide. Low-level waste is unloaded manually or emptied directly into trenches. Where the radiation dose rate is high, the waste is handled remotely. For the highest dose rates, a shielded crane is used. Waste is covered by soil soon after burial to reduce radiation, contamination, and the possibility of fire. The minimum soil cover is 4 feet, but must be sufficient to reduce surface radiation to 6 mR/hr or less.

PAST OPERATING PRACTICES

Routine Burials

Radioactive waste has always been segregated into transuranium alpha, low-level, and high-level waste categories. These are described below:

1. Transuranium Alpha Waste

From 1964 to 1974 this waste was segregated into two divisions:

- *Retrievable*

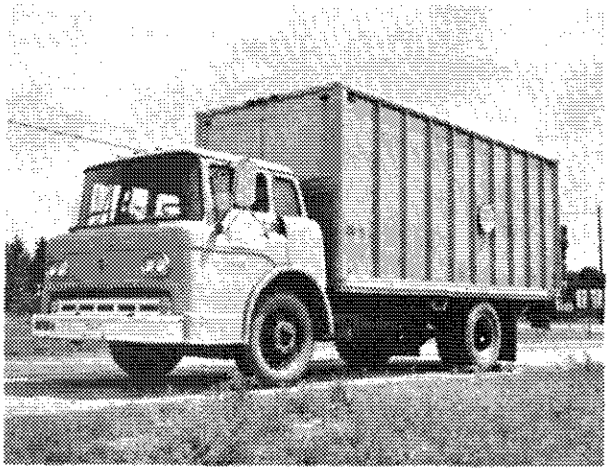
  Waste containing greater than 0.1 curie per package was placed in prefabricated concrete containers and then buried (Figure 10). These containers were 6 feet in diameter by 6.5 feet high. Waste that did not fit into the prefabricated concrete containers was encapsulated in concrete (Figure 11). Transuranium waste from the Savannah River Laboratory (SRL) was buried in square concrete containers (Figure 12). Prior to 1964, this waste was not placed into retrievable containers.

- *Nonretrievable*

  Waste containing less than 0.1 curie per package was buried in a low-level transuranium alpha trench.

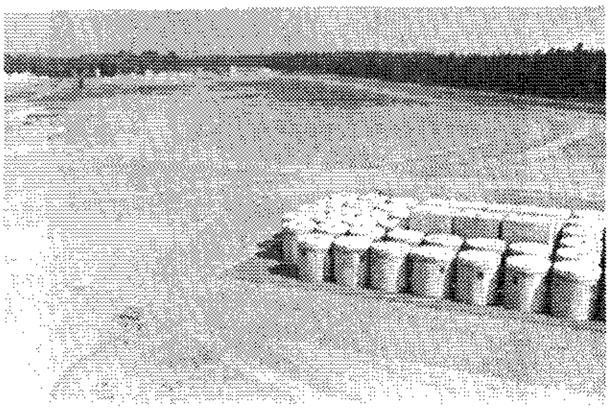
2. Low-Level Waste

Low-level waste (Figure 13) was defined as that measuring less than 50 mR/hr at 3 inches from an unshielded package, less than 50 mR/hr at 10 feet from the truck load, and less than 0.1 Ci of transuranic alpha activity per package. Full shipments of waste, e.g., skip pans or closed container dumpsters with radiation intensities to 50 mR/hr at 10 feet, were disposed of in low-level waste trenches. Scrap uranium from the fuel fabrication operation was also placed in these trenches.



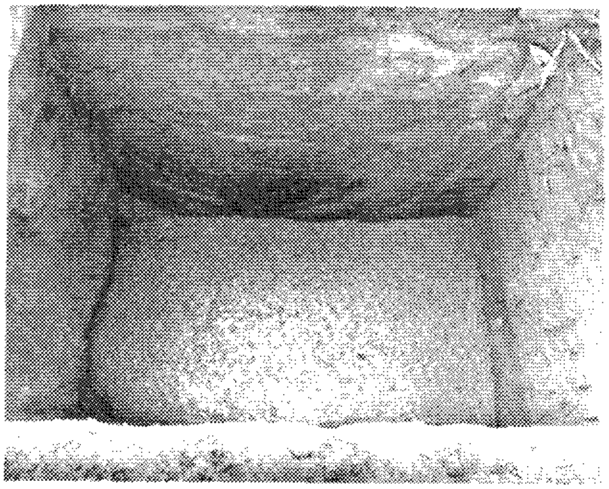
a. Transporting Vehicle

b. Interior View of Container.

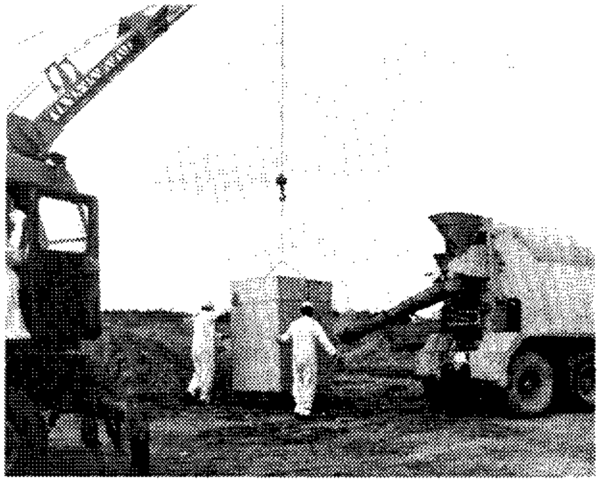


c. Assembled for Mound Burial

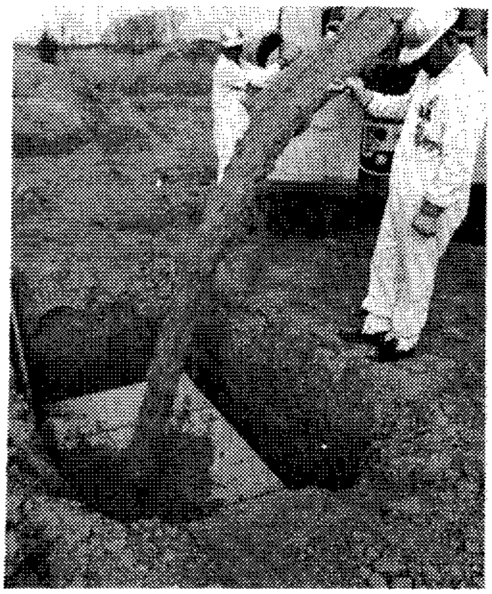
FIGURE 10. Concrete Containers for Transuranic Waste



a. Concrete in Bottom of Hole

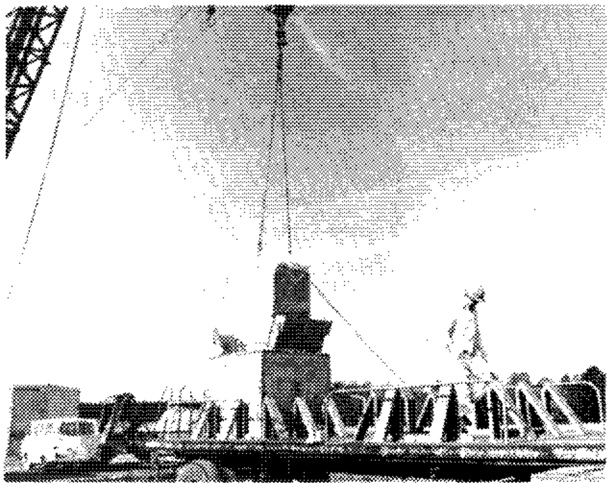


b. Placement of Equipment in Hole

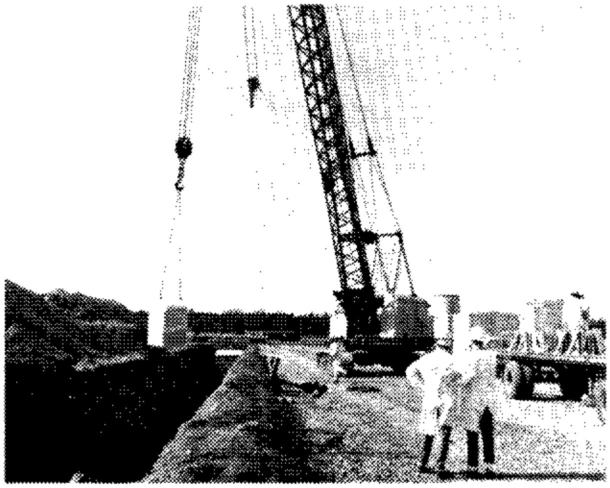


c. Pouring Concrete Around Sides of Box

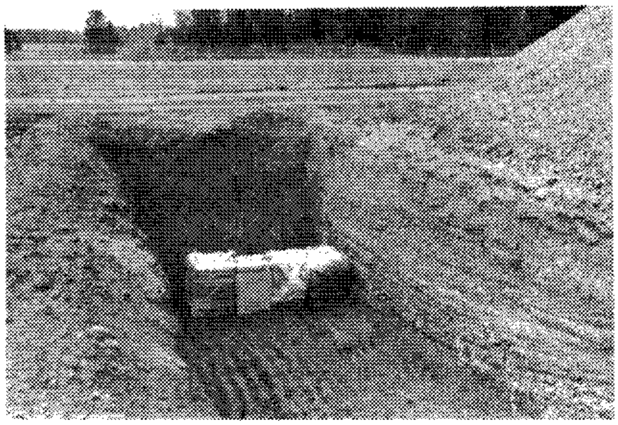
FIGURE 11. Concrete Encapsulation of Equipment too Large for Concrete Containers



a. Transfer Cask on Trailer



b. Concrete Box Being Placed in Trench



c. Waste Trench

FIGURE 12. Transuranic Waste in Concrete Containers Being Placed in Alpha Trench

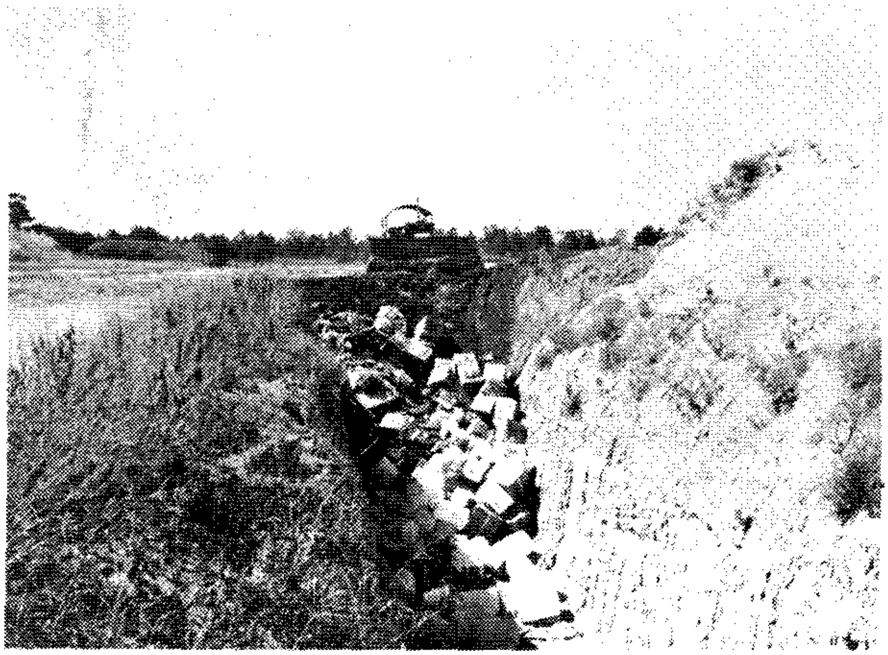


FIGURE 13. Low Level Trench Containing Boxed Paper and Laboratory Waste Being Refilled Using a Bulldozer

3. High-Level Waste

High-level waste was defined as that exceeding 50 mR/hr at 3 inches from an unshielded package. An example of a typical burial operation of high-level waste is shown in Figure 14.

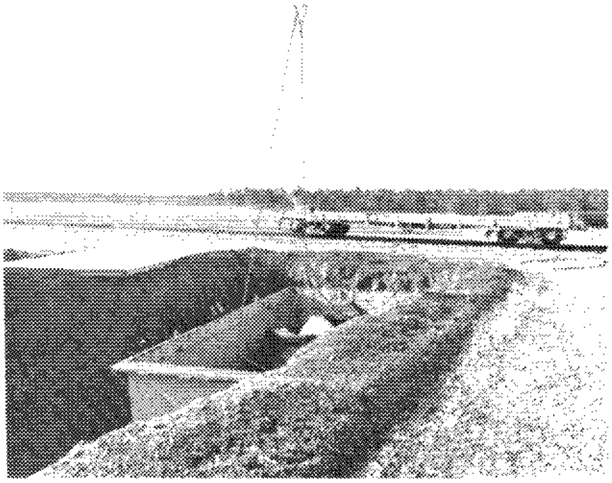
The volume and radioactivity content of waste buried in 1974 are listed in Table 2. The volume and radioactivity of waste buried since startup through 1974 are summarized in Table 3.

Special Burials

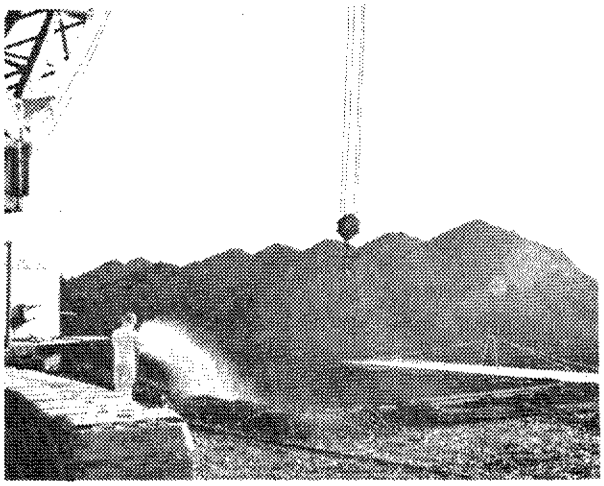
Occasionally shipments of classified wastes are received per ERDA request. Two such shipments occurred following crashes of airplanes.

a. *Spanish Soil*

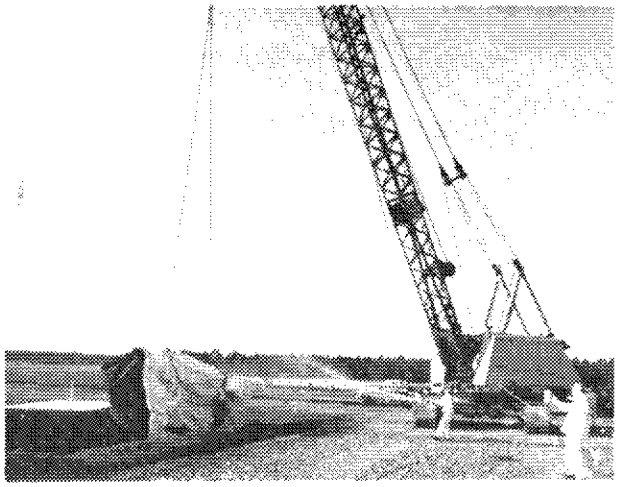
A collision during mid-air refueling on January 17, 1966, between a bomber carrying nuclear weapons and a refueling plane contaminated the ground at Palomares, Spain, with plutonium. Decontamination procedures produced



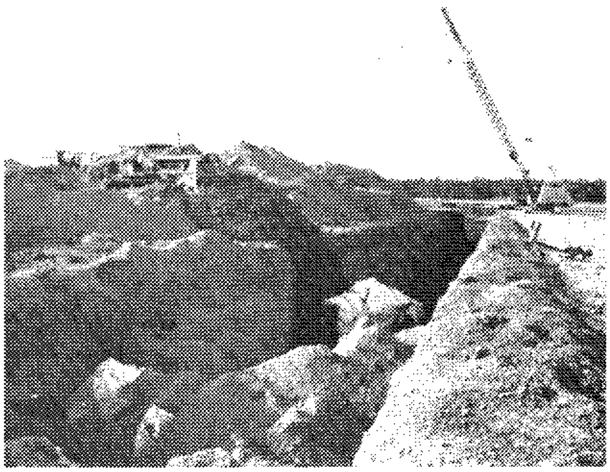
a. Box Containing Process Pipe From Separations Areas in Burial Ground Trench With Lid Removed



b. Spraying Box With Water to Reduce Airborne Contamination During Removal of Process Pipe From Transfer Box



c. Removing Process Pipe From Transfer Box



d. Covering Process Pipe With Earth

FIGURE 14. Process Pipe Burial in High Level Waste Trench

TABLE 2

Radioactive Waste Burials in 1974

Waste Classification	*Radioactivity Content, Ci*	*Volume, ft^3*
1. Transuranium Alpha Waste		
Retrievable	5,000	7,000
Nonretrievable	200	74,000
2. Low Level	5,000	280,000
3. High Level	280,000	42,000

TABLE 3

Radioactive Waste Burials From Startup Through 1974

Waste Classification	*Radioactivity Content, Ci*	*Volume, ft^3*
1. Transuranium Alpha Waste		
Retrievable	500,000	70,000
Nonretrievable	20,000	1,100,000
2. Low Level	3,200,000	6,700,000
3. High Level	4,100,000	700,000

4,827 55-gallon drums of soil and vegetation. These were placed in two separate trenches in 1966. The drums were buried 10 feet below the ground surface as a precaution against local infestation with plant and soil diseases from Spain (Figure 15).

b. *Greenland Ice*

On January 21, 1968, a bomber that carried nuclear weapons crashed in Greenland, producing large quantities of contaminated ice and aircraft parts.[1] Recovery activities required 535 containers with a storage

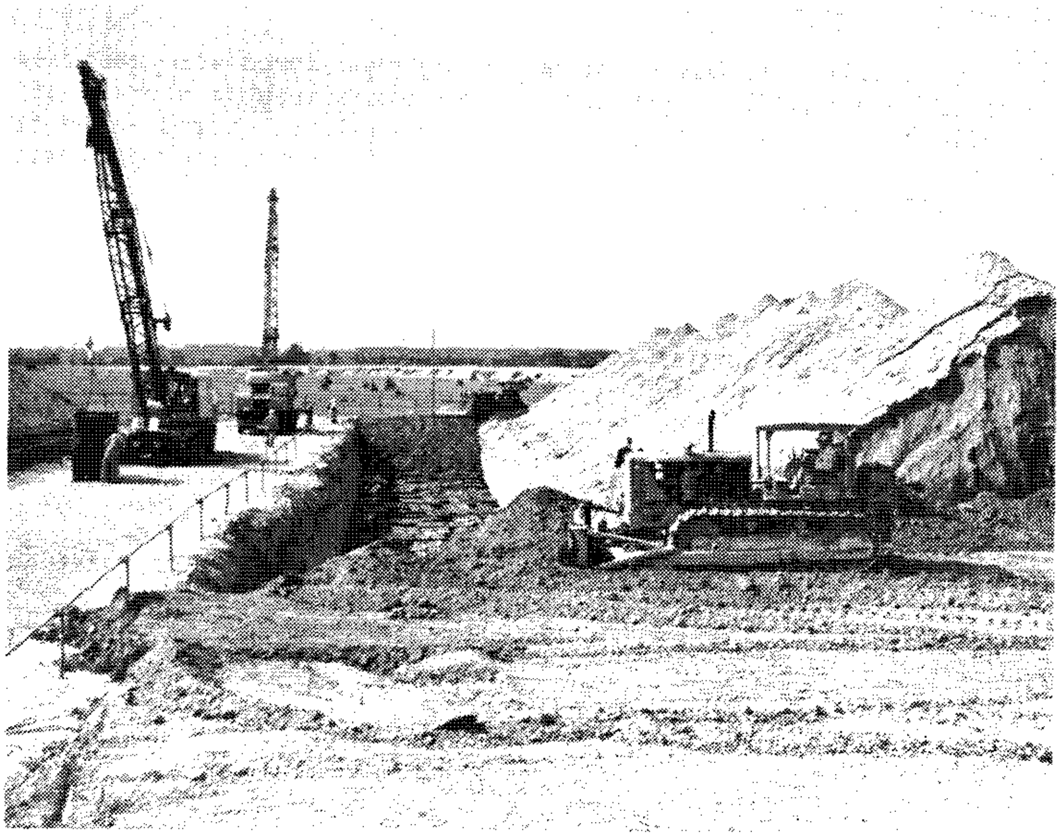


FIGURE 15. Spanish Soil Burial

volume of 120,000 cubic feet for aircraft parts and 680,000 gallons of water potentially contaminated with plutonium. The water was filtered, monitored, and sent to a seepage basin, except for a small fraction that was evaporated and its concentrates stored in the high level waste tanks. Aircraft parts and storage tanks have been buried in three separate trenches.

In addition to these several categories and examples of solid waste, degraded solvent is temporarily stored in the solid radioactive waste storage site in 20 underground tanks (150,000 gal in storage in 1975). The solvent contains residual transuranics and fission products that were not removable by washing procedures. The transuranics in 1975 totaled 45 Ci of alpha radioactivity, primarily ^{238}Pu and ^{239}Pu. Most of the fission product activity in the solvent is short-lived. A facility for incineration of this solvent inventory is being designed.

3. The SRP limits on the quantity of beta-gamma radioactivity emplaced each year at the solid radioactive waste storage site are the following:

^{137}Cs	500 Ci
^{90}Sr	500 Ci
^{60}Co	3×10^5 Ci
^{3}H	4×10^5 Ci
Other nuclides ($T_{\frac{1}{2}} > 10$ y)	1×10^3 Ci
Other nuclides ($T_{\frac{1}{2}} < 10$ y)	5×10^5 Ci

4. A comprehensive surveillance program shall be provided to monitor migration of radionuclides from their storage locations.

TRANSPORT OF RADIOACTIVITY

Stratigraphy of Area

Geological and hydrological characteristics of the SRP site favor the safe burial of radioactive solid wastes. SRP is in the Atlantic Coastal Plain physiographic province. At the solid waste storage site, the stratigraphic section consists of nearly a thousand feet of mostly unconsolidated sands, clayey sands, sandy clays, and clays (Table 4 and Reference 2). Downward flow of ground water into the prolific Tuscaloosa aquifer is prevented by a hydrostatic head reversal in the Congaree formation (Figure 16) that indicates flow is into the Congaree formation both from above and below. Thus, migration of radionuclides is confined to the direction of surface streams.

Water Movement in Soil

The highly favorable ground water hydrology compensates for the high annual rainfall, which averages 47 in./y.[3] Because of surface runoff and evaporation, only about 15 inches flows through the soil to the water table annually;[4] but this is sufficient to outweigh other mechanisms tending to move radionuclides through the soil. Therefore, migration is downward to the water table and then horizontally in the ground water to flowing surface streams. The average depth to the water table at the solid waste storage area is about 45 feet, and in the unsaturated soil above the water table, water flows at a rate of about 7 ft/y.[5,6] In the water saturated zone, water moves between 29 and 47 ft/y.[7] Because the shortest flow path from buried high level waste emplacements to Four Mile Creek is 0.5 mile, the travel time for subsurface water from the solid radioactive waste storage site to this stream is about 70 years.

TABLE 4

Sediments Beneath SRP[a]

System	Series	Formation	Lithology	Thickness, ft	Hydrology	Piezometric Head Below Water Table
Quaternary to Tertiary	Recent to Pliocene	Alluvium	Gravel, sand, silt, clay	0-30	Very little ground water	0
	Miocene	Hawthorn	Multicolored clays, sandy clays, and sands. Many clastic dikes	0-80	Small to moderate amounts of ground water	0
	Eocene	Barnwell	Multicolored fine-coarse sand and sandy clay	0-90	Ground water sufficient for home use	0
Tertiary	Eocene	McBean	Multicolored fine-coarse glauconitic sand and clay. Calcareous zone 0-80 ft thick, composed of limestone, marl, clay, and silicified shells	0-150	Ground water supply moderate to large in sandy portion; small in calcareous zone.	Ranges from 2-33 ft in Separations Areas
	Eocene	Congaree	Green sandy clay, silt, and thin hard sandstone and chert beds near top. Brown and green sandy clay, sand and silicified shells below	0-100	Ground water supply low to moderate	Ranges from 58-102 ft in Separations Areas
Upper Cretaceous		Ellenton	Dark gray to black sandy micaceous clay, sand and gypsum	0-100	Ground water supply moderate	Same as Tuscaloosa
		Tuscaloosa	Tan, buff, red, white cross-bedded coarse micaceous sand, clayey sand, and interbedded with red, brown, purple clay and white Kaolin	0-600	Large supplies of soft ground water. Yields up to 2000 gpm from 8 to 12-inch gravel packed wells.	Ranges from 26-91 ft in Separations Areas

a. Modified from Table 2, p 16 in Siple[2]

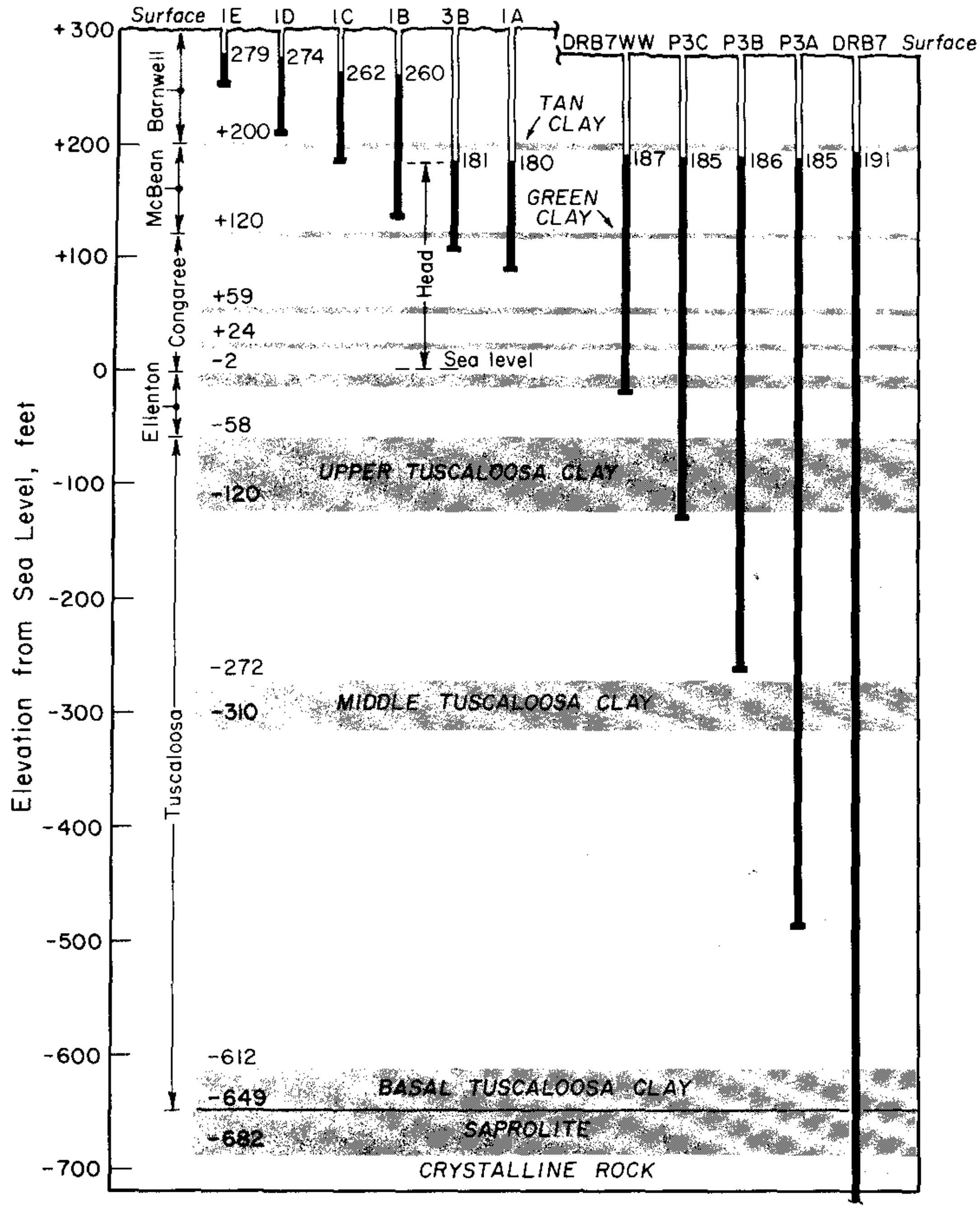


FIGURE 16. Hydrostatic Head in Ground Water Near Solid Radioactive Waste Storage Site

Transport of Nuclides through Soil

Ion exchange will increase the travel time for strontium by a factor of 16 and cesium by a factor of 200.[8] Thus, before emerging into Four Mile Creek, the ^{90}Sr and ^{137}Cs will have decayed to much less than 1 percent of the quantity placed into the ground.

Leaching of radionuclides from buried waste is minimized by the characteristics of water in unsaturated soil. Unless all soil pores are filled with water, the soil is unsaturated and the hydrostatic pressure is less than atmospheric. Under these conditions, water will not flow from water-filled pores to air-filled pores or into cavities in the soil. Many of the radionuclides are in cavities such as the interior of pipes or vessels. In such locations, radionuclides can only be leached if the waste is in perched ground water, i.e., water-saturated soil above the permanent water table. Because of the higher water permeability in backfilled than undisturbed soil, perched water does occur in the bottom of some trenches. Monitoring data from wells installed in backfilled trenches indicate only a small quantity (tens of millicuries) of radioactivity is present in the perched water.

Monitoring Program and Results

Monitoring for radionuclide leaching through the soil in the solid waste storage area began with the installation of 9 wells in 1956 (Figure 17). Two other wells, BG 12 and BG 18, were installed in 1962 after the direction of ground water flow was known to be in a southwesterly direction. Well BG 8 was destroyed in the construction of new waste trenches in 1965, and Well BG 5 was similarly damaged in 1968. The concentrations of alpha and non-volatile beta-emitting radionuclides measured in these 11 wells from 1956 through 1974 were at or near background levels. Tritium concentrations are similar to those found elsewhere in the vicinity of the chemical separations areas and are due to atmospheric releases. The maximum and average concentrations measured in the wells are summarized in Table 5.

To evaluate the extent and effect of perched water in the bottom of backfilled trenches, 24 wells were installed with 6-in.-long screens at the bottom of the trenches in 1969. The locations of the wells are shown in Figure 18. Weekly water-level measurements were made in these from August 1969 through July 1970. Only Wells 6, 7, 17, and 19 had more than a trace of water (Figure 19). Water from these wells has been analyzed for radioactivity every

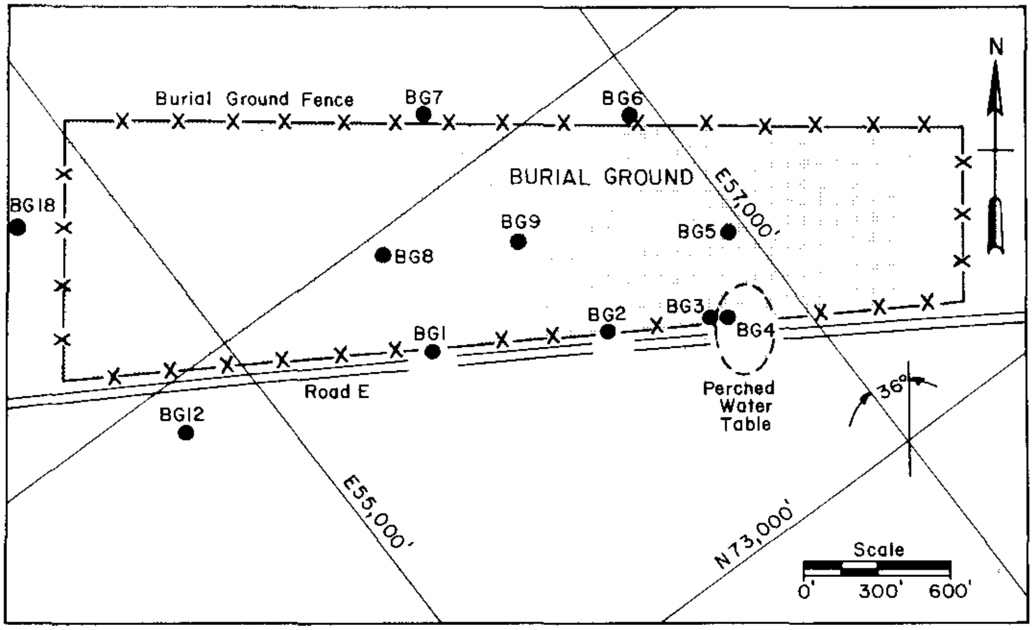


FIGURE 17. Solid Radioactive Waste Storage Site Wells Prior to 1973

TABLE 5

Radionuclide Concentrations in Solid Radioactive Waste Storage Site Monitoring Wells from 1956 Through 1974

	Concentration, pCi/liter					
	Alpha		*Nonvolatile Beta*		*Tritium*	
Well No.	*Max.*[a]	*Avg.*	*Max.*[a]	*Avg.*	*Max.*[a]	*Avg.*
BG 1	0.9	0.5	13	7	62,000	24,000
BG 2	0.7	0.4	11	8	140,000	49,000
BG 3	1.4	0.7	27	12	103,000	58,000
BG 4	1.8	1.0	13	10	860,000	187,000
BG 5[b]	0.7	0.5	13	9	261,000	109,000
BG 6	0.8	0.4	77	13	87,000	46,000
BG 7	0.9	0.5	40	12	62,000	32,000
BG 8[b]	1.1	1.0	15	11	33,000	19,000
BG 9	1.5	0.6	16	9	142,000	42,000
BG 12[b]	2.0	1.3	20	12	84,000	35,000
BG 18[b]	3.6	1.6	44	20	61,000	37,000

a. Maximum yearly average.

b. Well BG 8 was destroyed in 1965, Well BG 5 was destroyed in 1968, and Wells BG 12 and BG 18 were installed in 1962.

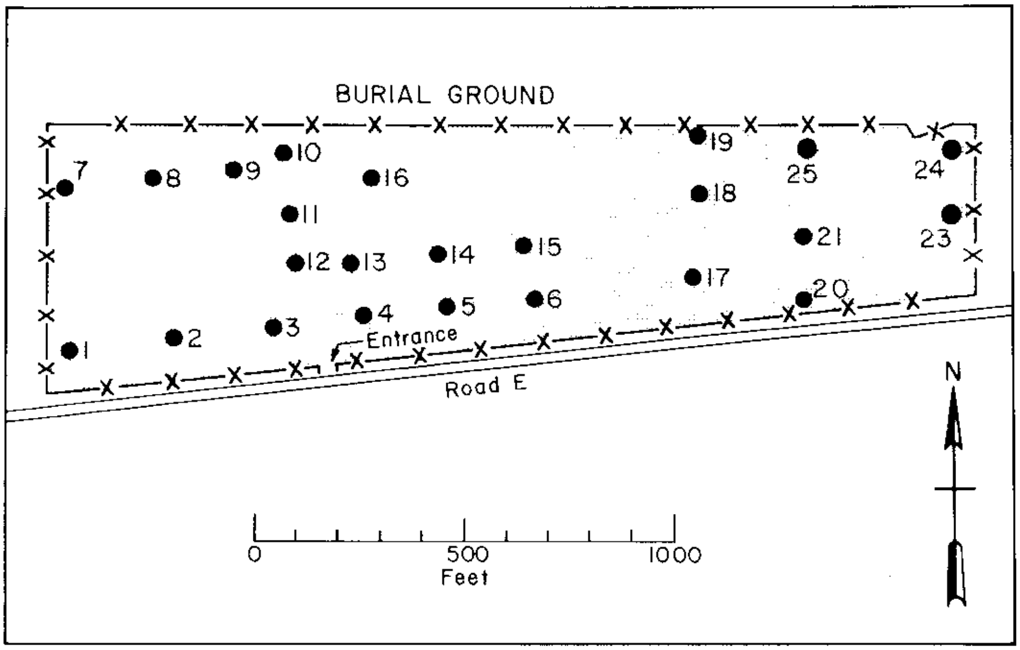


FIGURE 18. Wells Screened at Bottom of Burial Trenches in the SRP Solid Radioactive Waste Storage Site

two weeks since March 1970. The results (Table 6) show that the waters contain levels of nonvolatile beta-emitters above background levels. During April 1974, specific radionuclide analyses showed that ^{90}Sr was the primary component of the nonvolatile beta-emitters, and ^{137}Cs and ^{60}Co were also detectable in Well 9.

When most solid waste storage operations had shifted from the original 76-acre site in 1972, ground water monitoring was increased by installing monitoring wells in a grid pattern on 200-foot centers (Figure 20). The predominant radioactive isotope in the monitoring data (Table 7) is tritium from the burial of spent lithium-aluminum target melts. Approximately one-third of the wells contain tritium levels significantly above concentations recorded for rain in the vicinity of the solid waste storage site. Eight of the wells contain tritium concentrations above the radioactivity concentration guide (RCG) for uncontrolled areas (3000 pCi/ml). The average concentration in these eight wells is approximately 100 times the RCG, and the concentration in the maximum well is 800 times the RCG. The total inventory of tritium in the ground water underlying the old 76-acre sector of the storage site is ∿50,000 Ci. About 1000 Ci have migrated (via ground water movement) into an area of about 17 acres beyond the boundary fence southwest of the storage site. Because of the slow rate of travel of the ground water, most of the tritium will decay before outcropping in Four Mile Creek. When this tritium

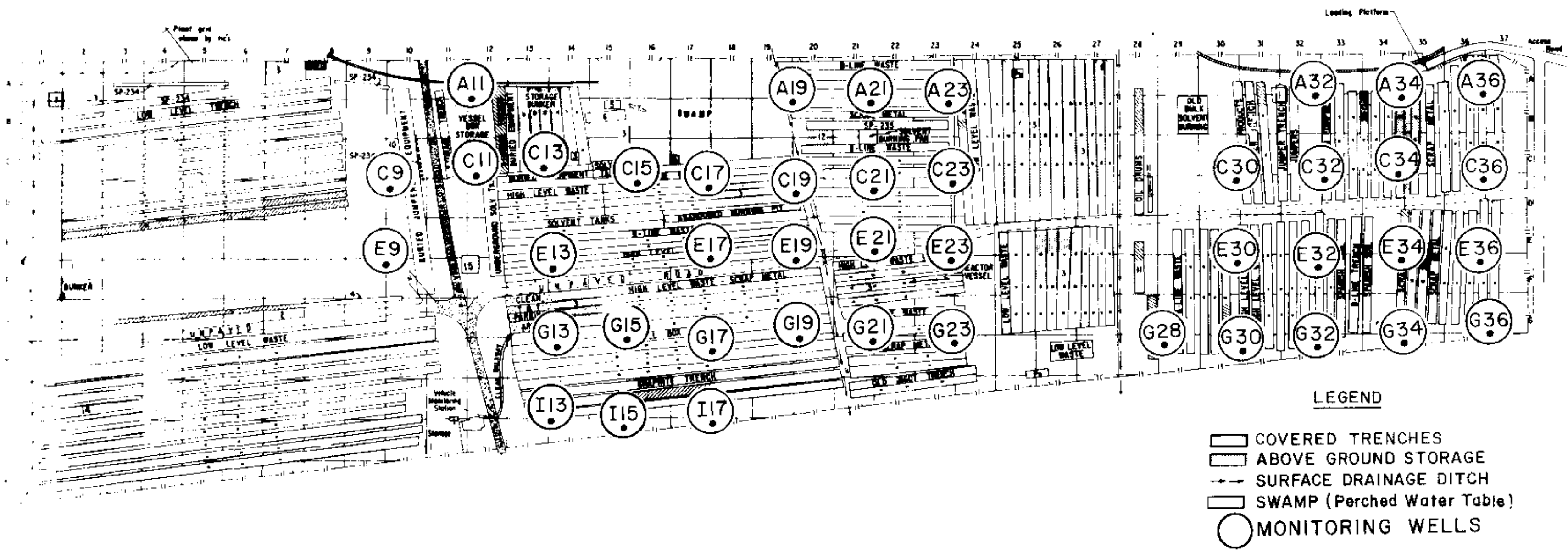


FIGURE 20. Monitoring Well Locations in Solid Radioactive Waste Storage Site in 1974

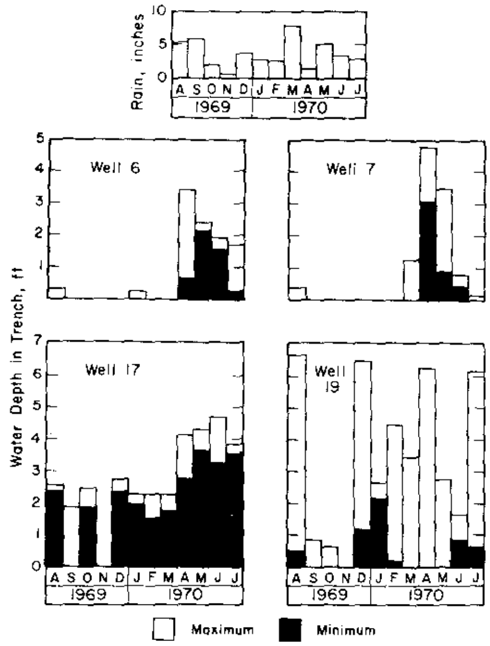


FIGURE 19. Water Levels in Backfilled Trenches

TABLE 6

Radionuclide Concentrations in Perched Water in the Bottom of Backfilled Trenches

	Alpha Emitters, pCi/liter											
Year	*Well 6*		*Well 7*		*Well 9*		*Well 17*		*Well 19*		*Well 23*	
	Max	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*
1970	0.8	0.6	0.5	0.5		*a*	1.7	0.6	1.5	1.0		*a*
1971	1.3	0.4	2.3	0.5		*a*	1.8	0.6	2.1	0.7		*a*
1972	0.6	0.3	1.1	0.3		*a*	2.3	0.7	1.6	0.8		*a*
1973	1.7	0.5	2.0	0.6	4.1	1.7	4.0	1.1	2.4	1.2	1.8	0.9
1974	5.4	1.5	1.0	0.4	7.4	2.4	11.0	5.0	4.0	2.2		*a*
1975	4.0	1.9	2.7	0.8	5.4	2.9	2.7	0.7	5.0	2.8		*a*

	Nonvolatile Beta Emitters, pCi/liter											
Year	*Well 6*		*Well 7*		*Well 9*		*Well 17*		*Well 19*		*Well 23*	
	Max	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*
1970	83	60	140	105		*a*	170	120	510	380		*a*
1971	1250	330	1600	730		*a*	620	190	740	340		*a*
1972	490	355	1260	950		*a*	390	150	930	290		*a*
1973	530	260	1560	910	3240	1280	450	150	840	350	1670	930
1974	1400	520	2000	1220	5960	2770	210	110	570	310		*a*
1975	80	180	1010	770	3580	2400	160	130	820	400		*a*

a. Well dry.

TABLE 7

Radionuclide Concentrations in Monitoring Wells (1975 data)

Well	*Alpha Emitters, pCi/l*		*Beta-Gamma Emitters, pCi/l*		*Tritium, pCi/ml*	
	Max	*Avg*	*Max*	*Avg*	*Max*	*Avg*
A-11	3	1	17	13	<50	<50
A-19	3	1	9	2	<50	<50
A-21	4	1	26	11	80	50
A-23	2	1	32	11	110	90
A-32	6	2	37	16	210	100
A-34	3	1	12	4	80	60
A-36	2	1	5	2	290	200
C-09	1	0	3	1	8000	6900
C-11	1	1	26	7	50	40
C-13	4	2	56	15	<50	<50
C-15	3	1	31	15	<50	<50
C-17	72	33	68	26	60	50
C-19	2	1	8	2	50	40
C-21	2	1	31	8	160	70
C-23	1	0	25	6	2000	1100
C-30	1	0	32	6	430	360
C-32	2	2	53	19	1600	1000
C-34	5	2	48	21	350	220
C-36	2	1	11	6	2800	1400
E-09	1	1	2	1	50	50
E-13	1	0	11	4	<50	<50
E-17	6	3	84	48	<50	<50
E-19	1	0	46	17	8400	6900
E-21	3	1	4	2	40	30
E-23	3	1	0	0	100	60
E-30	1	1	9	3	390	280
E-32	3	1	18	7	110	80
E-34	2	1	200	100	1000	480
E-36	3	1	27	11	260	130
G-13	19	5	44	14	57,000	40,000
G-15	2	1	6	2	12,000	9000
G-17	2	1	15	7	54,000	30,000
G-19	9	3	18	8	170	150
G-21	36	16	340	220	3,900,000	2,400,000
G-23	1	0	7	2	18,000	12,000
G-28	3	1	0	0	80	75
G-30	1	0	18	10	70	60
G-32	1	1	28	13	110,000	51,000
G-34	1	0	16	4	1100	470
G-36	1	0	7	2	1800	730
I-13	32	18	280	180	90	80
I-15	6	3	87	30	80	70
I-17	9	5	20	5	80	40

reaches Four Mile Creek, the maximum total dose-to-man will be 0.02 man-rem per year to a population of 70,000 people consuming Savannah River water.[9]

Small concentrations of alpha and nonvolatile beta-gamma radioactivities were detected in seven of the wells (C-17, E-17, E-34, G-13, G-21, I-13, and I-17). The alpha and nonvolatile beta-gamma radioactivities in two of these, Wells I-13 and I-17, are natural uranium and its decay products. The alpha and beta-gamma activities in four others (Wells C-17, E-17, G-13, and G-21) are not attributable to migration from solid waste storage, but appear to be residual low-level contamination from spills of spent solvent from storage and burning operations during the period 1955 to 1968. The spills are estimated to have contained approximately 8 mCi of plutonium and ~150 mCi of beta-gamma activity in about 600 gallons of solvent. The nonvolatile beta-gamma activity is primarily ^{60}Co in Well E-34.

UPTAKE OF RADIONUCLIDES BY VEGETATION

General Principles

Radioactivity on buried waste can be translocated to the ground surface by growing plants.[10] Radiostrontium is the radionuclide most readily absorbed when plants are grown on soil contaminated with long-lived mixed fission products. Cesium-137 is relatively unavailable for plant uptake because of its strong fixation by the soil. Romney, et al.[11] found that radiostrontium accounted for 50 to 80% of the beta activity transferred to above-ground plant parts from soil mixed with solutions of mixed fission products. Less than 10% was attributable to ^{106}Ru, ^{137}Cs, and ^{144}Ce. Similar results were found by Anderson.[12]

Plutonium is only slightly available to plants.[13,14] Cline[13] found that the plutonium activity per gram of oven-dried tissue divided by the plutonium activity per gram of oven-dried soil was 0.0002 for ^{239}Pu when barley was growing on Cinebar soil under greenhouse conditions. Studies at SRL of plants grown under field conditions, where both uptake by plant roots of plutonium from the soil and deposition on the plant of plutonium associated with re-suspended soil particles were potentially operable, gave values of 0.01 to 0.1 for the above activity ratio.

The depth at which the radionuclide is buried influences its uptake by vegetation.[15,16] In general, the greater the depth of burial, the smaller the uptake by plants. The maximum depth that roots of native vegetation reach is not known, and considerable efforts to determine this have been unsuccessful, but root depth of some native vegetation is thought to be several times greater than the depth that waste is buried.

SRP Experience

SRP experience has shown that vegetation can absorb significant amounts of radionuclides from buried radioactive waste. Vegetation radiating 2100 mrad/hr at 2 inches was detected growing over backfilled burial trenches during the summer of 1965. The radioactivity was due entirely to ^{90}Sr uptake from a buried evaporator vessel (77 μCi ^{90}Sr/g of soil) that was 2.2 feet beneath the soil surface. At another location in the same trench, radiation levels from vegetation were 210 mrad/hr, and the region of greatest soil contamination (76 μCi ^{90}Sr/g of soil) was at a depth of 4.5 feet. In both cases, the contaminated vegetation was removed and additional backfill added over the trench.

Additional radioactive vegetation was found in the waste storage site during June 1968 (Table 8). The maximum ^{90}Sr reported was only 0.01% of that in 1965 and was found in the same area of the trench as in 1965. Gamma activity in several of the samples was slightly higher than that found routinely on vegetation at the burial ground fence. Alpha activity was within the same range as vegetation exposed only to fallout (1 pCi/g max.).

Controlling Vegetation Uptake

Dispersal of radionuclides through vegetation uptake will negate the purpose of the radioactive waste storage site to contain radionuclides. Thus, deep-rooted vegetation should not be permitted to grow over the waste trenches. Continuing studies are evaluating both shallow-rooted grasses and several nonvegetative soil covers (Table 9 and Figure 21). Other alternatives include chemical and mechanical means of vegetation control.

TABLE 8

Radioactivity in 1968 Vegetation

	Concentration, pCi/g					
	Solid Radioactive Waste Storage Site				*General, F and H Areas*	
	Within Site		*At Fence*			
Isotope	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*
^{144}Ce	17	75	6.0	10.1	5.4	6.4
^{137}Cs	12	140	2.0	3.1	1.5	1.8
^{106}Ru	16	84	9.8	32.0	3.5	4.2
^{95}Zr-^{95}Nb	3	17	1.9	2.6	1.6	2.3
^{90}Sr	120	790	4.6	7.9	*a*	*a*
^{54}Mn	25	260	0.6	0.6	0.6	0.6

a. No analysis

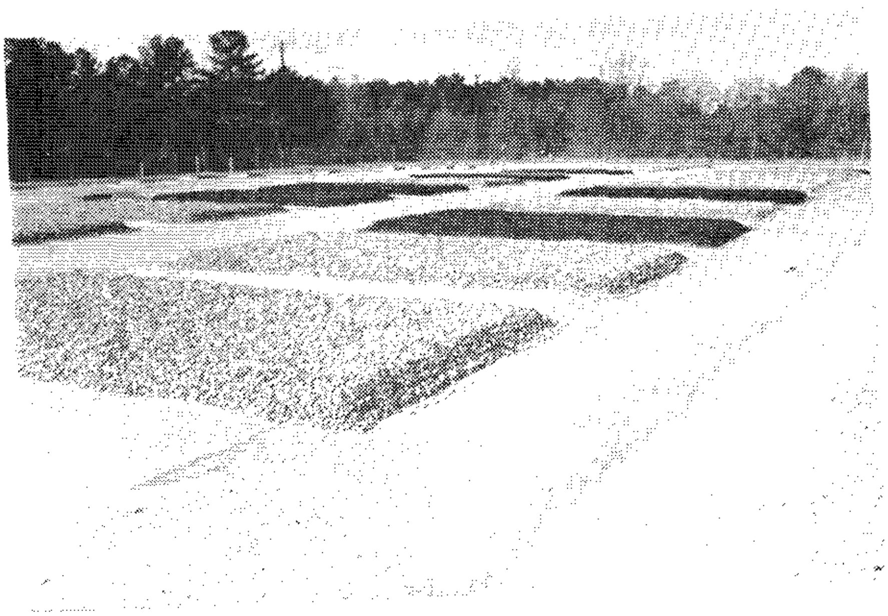
TABLE 9

Surface Covers Currently being Evaluated

1. Herbicide, *Hypalon*[a] sheet, asphalt, crushed stone
2. Herbicide, crushed stone
3. Herbicide, polyethylene sheet, asphalt, crushed stone
4. Herbicide, soil cement
5. Herbicide, polyethylene sheet, crushed stone, asphalt
6. Herbicide, *Tedlar*[a] sheet, crushed stone
7. Herbicide, *Hypalon*[a] sheet, crushed stone, asphalt
8. Herbicide, *Hypalon*[a] sheet, crushed stone, asphalt
9. Herbicide, polyethylene sheet, crushed stone
10. Herbicide, asphalt, crushed stone
11. Crushed stone

a. Trademarks, E. I. du Pont de Nemours and Co., Wilmington, Delaware.

a. Vegetative



b. Nonvegetative

FIGURE 21. Test Plots for Evaluating Soil Covers for Burial Trenches

CONCLUSIONS

Radioactive waste management policies in the United States are undergoing continual revision. These changes necessitate a solid waste management program that not only meets present standards, but is also adaptable to future requirements. The SRP waste management procedures satisfy these criteria.

With the attention currently given to monitoring and control of migration, the solid wastes can remain safely in their present location for as long as is necessary for a national policy to be established for their eventual disposal. Leaching of fission product, activation product, and transuranium nuclides has been negligible. However, tritium is leaching from buried wastes. Because of the low movement rate of ground water, the dose-to-man projection from tritium leaching from the inventory in the burial trenches is estimated to be less than 0.02 man-rem per year. Uptake of radionuclides by vegetation growing over buried waste has shown that deep-rooted vegetation should not be permitted to grow over the waste. Thus, long-term (100 to 200 years) managment will primarily require vegetation and erosion control.

SRP waste management procedures for transuranium wastes are compatible with recovery and removal of buried solid wastes if national policy should so dictate. Segregation of waste according to source and radiation levels permits minimum management for much of the area and permits recovery of any one type of waste. Transuranium alpha emitters buried in concrete can be recovered without including soil. Detailed records of waste burial locations will facilitate recovery of wastes.

REFERENCES

1. *Project Crested Ice*. Danish Atomic Energy Commission Report RISO 213, Research Establishment, Riso, Denmark (1970). 'Also published in: *USAF Nuclear Safety 65*, No. 1 (Part 2), special edition (Jan/Feb/Mar 1970).

2. G. E. Siple. *Geology and Ground Water of the Savannah River Plant and Vicinity, South Carolina*. U. S. Geological Survey Water-Supply Paper 1841, U. S. Government Printing Office, Washington, DC (1967).

3. T. M. Langley and W. L. Marter. *The Savannah River Plant Site*. USAEC Report DP-1323, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina (1973).

4. R. H. Hawkins and J. H. Horton. "Bentonite as a Protective Cover for Buried Radioactive Waste." *Health Phys. 13*, 287-292 (1967).

5. C. C. Haskell and R. H. Hawkins. "D_2O - Na^{24} Method for Tracing Soil Moisture Movement in the Field." *Soil Sci. Soc. Amer. Proceed. 28*, 725-728 (1964).

6. J. H. Horton and R. H. Hawkins. "Flow Path of Rain From the Soil Surface to the Water Table." *Soil Sci. 100*, 377-383 (1965).

7. J. W. Fenimore. "Land Burial of Solid Radioactive Waste During a Ten-Year Period." *Health Phys. 10*, 229 (1964).

8. W. E. Prout. "Adsorption of Radioactive Wastes by Savannah River Plant Soil." *Soil Sci. 86*, 13-17 (1958).

9. R. H. Hawkins. "Migration of Tritium From a Nuclear Waste Burial Site." Presented at the *Third ERDA Environmental Protection Conference, Chicago, Illinois*, September 23-25, 1975.

10. A. C. Schuffelsen. "On the Radioactive Contamination of Soils and Crops." *Agricultural and Public Health Aspects of Radioactive Contamination in Normal and Emergency Situations*. FAO Atomic Energy Series No. 5, pp 68-91, Food and Agriculture Organization of the United Nations, Rome (1964).

11. E. M. Romney, H. Nishita, J. H. Olafson, and K. H. Larson. "Root Transfer of Fission Products From Contaminated Soil." *Soil Sci. Soc. Amer. Proceed. 27*, 383-385 (1963).

12. A. J. Andersen *Investigations on the Plant Uptake of Fission Products From Contaminated Soils. I. Influence of Plant Species and Soil Types on the Uptake of Radioactive Strontium and Cesium.* Danish Atomic Energy Commission Report RISO 170, Research Establishment, Riso, Denmark (1967).

13. J. F. Cline. *Uptake of ^{241}Am and ^{239}Pu by Plants.* USAEC Report BNWL-714, p 8.24, Battelle Memorial Institute, Battelle Northwest Laboratory, Richland, Washington (1968).

14. J. H. Olafson and K. H. Larson. "Plutonium, Its Biology and Environmental Persistence," pp 633-639. V. Schultz and A. W. Klement, Jr., eds. *Radioecology.* Reinhold, New York (1963).

15. A. J. Andersen *Investigations on the Plant Uptake of Fission Products From Contaminated Soils. II. The Uptake of Radioactive Strontium Placed at Different Depths in the Soil.* Danish Atomic Energy Commission Report RISO 174, Research Establishment, Riso, Denmark (1967).

16. A. Troughton. *The Underground Organs of Herbage Grasses.* Bull. No. 44, Commonwealth Agricultural Bureau, England (1957).