2. RADIOACTIVE SOLID WASTE BURIAL GROUND

This section describes postulated deviations from normal operation of the burial ground and potential consequences. As for the tank farms discussed in the previous section, the safety of the operation is evaluated for two sets of conditions:

- *Abnormal Operating Conditions.* Operational incidents that are a result of equipment malfunction or operator error. These events could cause a release of several curies of radioactivity, but no offsite effects would be expected.

- *Accidents.* Low probability events with potential for offsite consequences. These events are selected as significant examples for purposes of analysis of consequences.

ABNORMAL OPERATIONS

During 20 years of operations there have been 111 radioactive waste incidents in the burial ground. The incidents are summarized in Table III-41 and are discussed below.

Airborne Contamination

There have been 75 incidents which resulted in release of radioactivity to the atmosphere. These involved burials of contaminated equipment, sand blasting to decontaminate equipment, burning contaminated organic solvent, and accidental fires. Contaminated areas resulting from these incidents ranged up to 2 acres in extent. Radiation intensities ranged to 5 rad/hr at 3 inches. In each case, the areas were cleaned by removing the contaminated soil and burying it. Of these 75 incidents, three resulted in minor contamination outside the burial ground fence. The contaminated soil was removed and buried. Improved operating procedures have greatly decreased the frequency of abnormal incidents in recent years.

Waterborne Contamination

Large-scale release of activity by flooding of the burial ground is highly unlikely. As discussed for the tank farms, the postulated highest flood level of the Savannah River is 141 ft above mean sea level, compared to the normal level of 84 ft at a flow of 10,000 cfs. The elevation of the burial ground is a minimum of 270 ft above mean sea level, and the normal water table is a minimum of 230 ft above mean sea level.

TABLE III-41

Burial Ground Radioactive Waste Incidents

Type	*Pre-1960*	*1960-1964*	*1965-1969*	*1970-1975*	*All*
Airborne Contamination					
Equipment Burial	14	17	12	0	43
Sandblasting	4	2	0	0	6
Solvent Burning	0	14	4	0	18
Fire	2	3	2	1	8
Waterborne Contamination					
Flood	0	0	1	1	2
Migration Through Soil					
Solvent Spills	4	3	2	0	9
Water Spills	0	1	0	1	2
Vegetation Uptake	0	0	4	6	10
Unintentional Exhumation or Burial					
Unintentional Exhumation	1	2	0	0	3
Unintentional Burial	6	1	1	2	10
All	31	43	26	11	111

Only two flooding incidents have been reported in the burial ground. In 1965, a trench containing rain water was backfilled with soil. The soil displaced the contaminated rain water and caused it to overflow the trench, resulting in contamination of the adjacent ground area. In 1973, rain water filled an open trench and overflowed and caused low-level contamination of about 3000 ft^2 of ground. The contamination included a small area outside the burial ground fence. In these two incidents, the contaminated soil was removed and buried.

Migration of Activity Through Soil

Liquid Spills

A total of 11 spills of radioactive liquid have occurred in the burial ground. Contamination resulting from the spills has ranged in area from 2 to 1000 ft^2. Radiation intensities from the contaminated soil ranged from 5 mr/hr at 3 in. to 5 rad/hr at 18 in. In each case, the contaminated soil was removed and buried.

Vegetation Uptake

A total of 10 incidents of radioactive vegetation are documented in the burial ground. Routine surveillance included perimeter monitoring until 1965 when interior monitoring was added. In 1965, vegetation emitting 2100 mrad/hr at 2 in. was detected growing over backfilled trenches at the burial ground. The radioactivity was due entirely to ^{90}Sr uptake from soil contamination (77 μCi ^{90}Sr/g of soil) from a buried evaporator vessel that was 2.2 ft beneath the soil surface. The vegetation contained up to 7.4 μCi ^{90}Sr/g. 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 soil) was at a depth of 4.5 ft. The contaminated vegetation was removed and additional backfill was added over the trench to cover the waste to a minimum depth of 4 ft. The other instances of contamination of vegetation resulted in ^{90}Sr content ranging from 790 pCi/g to 0.3 μCi/g. In each case, the contaminated vegetation was removed and buried. Long root vegetation has been destroyed and short root grasses such as Bahia are used to control soil erosion. The last incident (Table III-41) occurred in 1972 and several in 1970-1975 were only marginally radioactive.

Unintentional Exhumation or Burial

Three incidents of unintential exhumation have occurred at the burial ground, all minor. In one incident trench backfill settled and exposed the open top of a buried vessel. The vessel was covered and no radioactivity was released. The other two incidents involved bulldozers. In one, a bulldozer accidentally cut into a high-level waste trench, contaminating about 1/10 acre of the burial ground. In the other, a bulldozer accidentally cut into a shallow-buried drum of burned solvent residue, contaminating a small area in the burial ground. The contaminated soil was recovered and re-buried.

Ten incidents are documented of unintentional burials between 1955 and 1972. No releases of radioactivity occurred in any unintentional burial. On two occasions (in 1964 and in 1965), several irradiated fuel elements that had undergone examination in shielded laboratory facilities were dumped into trenches along with waste from the facilities. These elements were recovered for processing in the 200 Areas. Radiation levels were as high as 200 rad/hr at 1 ft from the elements, but no contamination was released to the soil.

ACCIDENTS

The accidents in the burial ground believed to offer the greatest potential for offsite consequences are fire, explosion, wind storm, and aircraft crash. Accidents described in this section are judged to be very low probability events. No attempt is made to give a detailed description of these accidents; instead, it is assumed for the purposes of analysis that the accident occurs. The potential consequences of each accident are estimated as follows:

- Estimate the total quantity of hazardous isotopes involved in the accident (Table III-42).
- Estimate the maximum fraction of this material that could conceivably be released to the atmosphere.
- Calculate the potential intake and resulting dose for an individual at the nearest plant boundary, assuming that this individual is at the point of maximum ground-level concentration during the entire release.
- Compare this dose with established accident guidelines.

Fire

Several fires and explosions in drums containing pyrophoric waste materials have occurred at commercial and government burial grounds.[43] Most of the loose material buried in the SRP trenches could conceivably ignite because it consists of a mixture of combustible waste such as paper, cardboard boxes, wooden boxes, plastic bags, rubber scrap, and rags. Combustible transuranium waste was not generally separated from noncombustible waste until 1973. Before then, approximately 45,000 ft^3 of transuranium-contaminated waste and approximately 200,000 ft^3 of nontransuranium-contaminated waste were buried at SRP annually.[44]

TABLE III-42

Maximum Quantities of Burial Ground Radionuclides Stored at Single Locations

Isotope	*Condition*	*Maximum Quantity, Ci*	*Basis*
^{238}Pu	High-level transuranium cabinet waste in lined, steel drums. Fourteen drums are placed in a concrete container. Container is open prior to sealing.	2000 per concrete container (550 per drum)	Heat-load limits for above-grade TRU storage
^{239}Pu	Same as above	23 per concrete container (12 per drum)	Criticality considerations
^{244}Cm	High-level transuranium waste from SRL in lined steel drums. Fourteen drums are placed in a concrete container. Container is open prior to sealing.	1800 per concrete container (500 per drum)	Heat-load limits for above-grade TRU storage
^{3}H	Contaminated pump parts near other combustible waste before covering with earth	∿10,000	Estimated maximum quantity that has been placed in a container

There have been fewer than a dozen small fires in the trenches at SRP, and no dispersion of radioactivity was observed.

Fraction Released. Radionuclides can be released from a fire as solid particulate matter or as a gas or vapor (as in the case of tritium). The nuclides that present the greatest potential hazard from fire in the SRP burial ground would be released only as solid particulate matter, and therefore the radioactive material would remain largely in the ashes.[44]

To determine the quantities of radioactivity that might be released from burial ground fires and reach the plant boundary, the sizes of the released particles must be estimated. Table III-42 gives estimates of the percent of activity and the particle size range of material released from various types of fires.

The information compiled in Table III-43 indicates that releases in excess of 1% contain large (>10 μm) particles. Particles of less than ∿10 μm in diameter represent the greatest hazard with respect to off-site uptake. A maximum of 1% of the total amount of activity involved in a fire in an open trench or concrete container containing typical waste is estimated to be released to the atmosphere.

Atmospheric Dispersion. The pessimistic assumption is made that all of the released material is released at ground level and is dispersed only by meteorological conditions uninfluenced by particle settling. The uptake fraction at the 95th percentile is 1.1×10^{-9} as previously determined.

Consequences. The consequences of a fire were analyzed using the quantities of material given in Table III-42. Under the conditions described in the preceding sections, 1.1×10^{-9} of the total material released (or 1.1×10^{-11} of the total quantity of material given in Table III-42) could be inhaled by an individual located at the nearest plant boundary at the point of maximum ground-level concentration during the entire period required for the activity to pass by this point. The dose commitments calculated for the conditions of Table III-42 are compared to the recommended guidelines accident doses in Table III-44.

Table III-44 shows that the maximum potential consequence occurs for a fire in a concrete container with the largest expected quantity of ^{238}Pu (before sealing). Two scenarios for this type of accident are considered.

The first is the breaching by fire of all 14 drums in the concrete container and the loss of 1% of the maximum amount of ^{238}Pu in the container. This accident would result in a potential

TABLE III-43

Activity Release from Fires

Type of Particle	*Percent Release*	*Particle Size Range, μm*	*Basis for Estimate of % Release*
Oil smoke	<0.1	0.03-1[42]	Open pan burning of solvent at SRP[46]
Burning plutonium metal	0.0045 0.033	3-15[45]	Reference 47
Aerosol from plutonium oxalate heated to 1000°C	0.9	-	Reference 47
Fly ash from incineration of typical waste	5	0.01-200[42]	Incineration of typical wastes at Harwell, England[44]
	1	<8[44]	Performance of off-gas cleaning system on Harwell incineration[44]

TABLE III-44

Potential Consequences of Fire in Burial Ground

Isotope	*Condition*	*Dose Commitment, rem*[a] *Body*	*Bone*	*Percent of Guideline Accident Dose*[b] *Body*	*Bone*
^{238}Pu	High-level transuranium cabinet waste in lined, steel drums. Fourteen drums are placed in a concrete container. Container is open prior to sealing.	4.0[c] 1.1[d]	161[c] 44[d]	16[c] 4.4[d]	107[c] 29[d]
^{239}Pu	Same as above	0.06[c] 0.03[d]	2.3[c] 1.2[d]	0.2[c] 0.1[d]	1.5[c] 0.8[d]
^{244}Cm	High-level transuranium waste from SRL in lined steel drums. Fourteen drums are placed in a concrete container. Container is open prior to sealing.	1.6[c] 0.4[d]	27.0[c] 7.5[d]	6.4[c] 1.6[d]	18.0[c] 5.0[e]
^{3}H	Contaminated pump parts near other combustible waste before covering over with earth.	0.0005[e]	-	0.002	-

a. Based on 95th percentile estimates.

b. For all of the transuranium isotopes the guideline accident dose to the bone is 150 rem in 70 years. For ^{3}H, it is based on 25 rem to the whole body.[17]

c. Assumes the fire breached all 14 drums in the concrete container and 1% of the maximum amount in the container were released, a highly unlikely occurrence.

d. Assumes only one drum to be breached and 1% of the maximum amount in a drum to be released.

e. Assumes 10% released as gas.

offsite bone dose commitment of about 161 rem or 1.1 times the guideline accident dose.[38] Drums containing transuranium alpha waste are loaded and sealed at the waste generating station. When the drums are received at the burial ground, those to be stored in concrete containers are placed directly into a container, and the lid of the container is replaced. The container is not uncovered except during the loading of drums. A fire in a concrete container of sufficient intensity to breach all of the drums could be caused by an aircraft crash directly into the face of the TRU storage pad. Aircraft crashes and their probability are discussed in a later section.

The other scenario is the loss by fire of the maximum contents of one drum. Such an accident would result in a potential offsite bone dose of about 44 rem or approximately 29% of the guideline accident dose. The only fires that have occurred at SRP were in the low-level waste trenches. Current regulations for transuranium alpha waste permit only waste contaminated to less than 10 nCi/g be buried directly in earthen trenches. The potential consequence of this type of fire is a dose commitment of much less than 1% of the guideline dose.

The consequences due to a fire in removal and relocation operations are approximately the same as those given in Table III-44 assuming that approximately the same quantities of waste could be "re-exposed" during such operations.

Explosion

Analysis of an explosion occurring in any of the conditions given in Tables III-42 and III-43 indicates that the consequences of such an accident would be no more severe than for the fires postulated above, because explosions produce significantly greater dispersions as well as larger particles than fire. The small (<10 μm) particles produced by combustion[42] would not be generated by an explosion. Explosions are significant primarily as a means of breaching containment.

Wind Storms and Tornadoes

A wind storm could disperse waste which was not yet buried, but the consequences of a wind storm would be less severe than for the fires analyzed previously. Most of the activity would be in the form of large particles, and the conditions of a wind storm (high mean wind speed usually accompanied by unstable conditions) lead to maximum dispersion of the activity as it travels to the nearest plant boundary.

A characteristic tornado[48] could be expected to have rotational (tangential) and vertical wind speeds on the order of 200 mph, and move at a translational velocity of 30 mph. Under these conditions, the material would be dispersed from an effective height of up to several miles, and dilution factors would be much greater at the plant boundary than for stable conditions, just as in the case of a wind storm with no overall rotational motion. The probability of a tornado at a single point in the area of the Savannah River Plant is estimated to be less than 10^{-5} per year.

Nuclear Excursions

A nuclear excursion is considered unlikely in the burial ground because of the limits on fissile materials in the above-ground storage modes for alpha waste and because of the very low concentrations of ^{239}Pu in waste that is buried in trenches. A nuclear excursion would be no worse than an explosion with respect to the dispersal of particulate matter and in this respect the offsite consequences would be less severe than for fires. However, gaseous isotopes would be produced as a result of the nuclear reaction. Assuming that a single burst of 10^{19} fissions occurs and that the critical concentration is dispersed by the burst and does not recur, then the most hazardous gaseous isotopes produced would be $^{131-135}I$. The following quantities would be produced: 8 Ci of ^{131}I, 1,000 Ci of ^{132}I, 160 Ci of ^{133}I, 4,800 Ci of ^{134}I, and 500 Ci of ^{135}I.

Approximately 90% of this iodine would be produced within a 24-hour period. The total integrated dose to an individual at the nearest plant boundary for a 24-hour period was estimated from Savannah River Plant meteorological data where ground level release was assumed. The maximum calculated estimate based on these data is 1.55 rem or 0.5% of the thyroid dose limit. Based on more likely meteorological conditions, the dose is estimated to be 0.015 rem (5×10^{-3}% of the 10-CFR-100 limit) with a probability of 95% that the dose would not exceed this amount.

Earthquakes

An earthquake could conceivably rupture the underground tanks in which degraded solvent is stored. The total quantity of radioactivity is about 45 Ci of alpha activity (^{238}Pu, ^{239}Pu and ^{244}Cm) and about 50 Ci of beta-gamma activity in 150,000 gallons of solvent. This activity could leak out into the ground but it would remain in the vicinity of the burial site for an extended period of time and would not present a potential offsite hazard of the magnitude discussed in the previous categories.[4]

Aircraft Crashes

The estimated probability of an aircraft crash at SRP is $\sim 5 \times 10^{-7}$ per square mile per year. Consequences of an aircraft crash that does not involve fire would be no worse than an explosion with respect to dispersal of particulate matter. An aircraft crash that causes a fire at the working face of the TRU storage pad may result in the maximum consequence (discussed previously). The probability of an airplane crashing into the face of the TRU pad is estimated to be about 10^{-12} per year.