Department of Energy
Washington, DC 20585

September 17, 2002

MEMORANDUM FOR DISTRIBUTION

FROM: JESSIE HILL ROBERSON
ASSISTANT SECRETARY FOR
ENVIRONMENTAL MANAGEMENT

SUBJECT: Hazard Categorization of EM Inactive Waste Sites as Less Than Hazard Category 3

Environmental Management (EM) is responsible for a large number of inactive waste sites. These inactive waste sites exist primarily at the following Department of Energy (DOE) sites: Fernald, Hanford-RL, INEEL, Nevada Test Site, Oak Ridge, and Savannah River. Other sites that have, or will have, inactive waste sites as a result of decommissioning include Hanford-Office of River Protection, Rocky Flats, and some of the DOE national laboratories.

The nuclear safety rules in 10 CFR Part 830, Subpart B require hazard category 1, 2, and 3 DOE nuclear facilities to have a safety basis. Contractors responsible for such facilities are required to perform work in accordance with the safety basis and the hazard controls to ensure adequate protection of workers, the public, and the environment. DOE nuclear facilities categorized as less than category 3 are not subject to the safety basis requirements. A facility, activity, or operation can be categorized as less than hazard category 3 if it has no potential for significant off-site, on-site, or local consequences consistent with the standard DOE-STD-1027-92, Change Notice 1, as required by 10 CFR 830.202(b)(3). The standard describes a methodology for categorizing a facility, activity, or operation based on a hazard analysis that considers material inventories, material form, dispersibility, and interaction with energy sources.

At an EM workshop near the Rocky Flats Site on April 23-25, 2002, DOE and contractor representatives from EM sites studied EM's current inactive waste sites in light of the criteria for hazard categorization in accordance with the standard. The workshop participants developed a definition of an inactive waste site proposed for use in hazard categorization (Attachment 1) and described the physical features and controls common to EM inactive waste sites (Attachment 2). The workshop participants concluded that in light of their similar safety features, operational characteristics, and minimal hazard potential, most EM inactive waste sites could qualify to be categorized as less than hazard category 3. The basis for the proposed final hazard categorization is presented in Enclosure 3 and the supporting calculations and assumptions for Hanford site used to derive dose consequences are shown in Attachment 4. These attachments may only be used for the purposes of the hazard categorization in this memorandum, using site-specific assumptions in Attachment 4.

Based on the analysis from the workshop and in accordance with Section 9.3.2 of DOE M 411.1-1B, *Safety Management Functions, Responsibilities, and Authorities Manual*, which assigns the responsibility to approve the final hazard categorization to the Cognizant Secretarial Officer, I hereby categorize EM inactive waste sites as below hazard category 3 nuclear facilities provided that the following terms and conditions are verified and documented:

1) The site must meet the definition of an inactive waste site in Attachment 1;
2) The site must be regulated under currently-binding RCRA permits, orders, or agreements pertaining to mixed waste, and/or currently-binding CERCLA regulations and agreements;
3) The site must have in place hazard controls that are identified in Attachment 2;
4) The site must not have identified hazards or conditions that exceed the hazard analysis assumptions presented in Attachment 3 and 4.

The hazard categorization package developed to verify and document the above terms and conditions must be approved by you. By December 15, 2002, please notify me which of your inactive waste sites were categorized and approved according to this memorandum. The Office of Safety, Health and Security (EM-5) will work with your safety basis points of contact to provide the format for your notification.

If you have any questions, please contact me or Ms. Sandra Johnson at (202) 586-0651.

Attachments

Distribution

Warren E. Bergholz, Jr., Acting Manager, Idaho Operations Office (ID)
Jack R. Craig, Deputy Manager, Ohio Field Office (OH)
Keith A. Klein, Manager, Richland Operations Office (RL)
Roy J. Schepens, Manager, Office of River Protection (ORP)
Eugene C. Schmitt, Manager, Rocky Flats Field Office (RF)
Jeffrey M. Allison, Acting Manager, Savannah River Operations Office (SR)
Dr. Inés Triay, Manager, Carlsbad Field Office (CBFO)
William E. Murphie, Manager, Portsmouth/Paducah Field Office (PPFO)

cc:
W. John Arthur, III, Manager, Albuquerque Operations Office (AL)
Marvin E. Gunn, Jr., Manager, Chicago Operations Office (CH)
Kathleen Carlson, Manager, Nevada Operations Office (NV)
Camille Yuan-Soo Hoo, Manager, Oakland Operations Office (OAK)
Michael Holland, Acting Manager, Oak Ridge Operations Office (OR)
Rita Bajura, Director, National Energy Technology Laboratory (NETL)
Jack Tillman, Director, Office of Environmental Management, Albuquerque Operations Office (AL)
Anibal Taboas, Assistant Manager for Environmental Management, Chicago Operations Office (CH)
Carl Gertz, Assistant Manager for Environmental Management, Nevada Operations Office (NV)
Roger Liddle, Acting Assistant Manager for Environmental Management, Oakland Operations Office (OAK)
Gerald Boyd, Assistant Manager for Environmental Management, Oak Ridge Operations Office (OR)
Celinda Crawford, Acting Associate Director for Environmental Management and Defense Programs, National Energy Technology Laboratory (NETL)

bcc:
Dr. Robert Kuckuck, Acting Principal Deputy Administrator, NA-2
Milton Johnson, Chief Operating Officer, SC-3
Paul Golan, Chief Operating Officer, EM-3
Sandra Johnson, Director, EM-5
Jay Rhoderick, Director, EM-6
Dr. Barbara Male, Director, EM-7
Roger Butler, Deputy Assistant Secretary, EM-10
Patrice M. Bubar, Associate Deputy Assistant Secretary, EM-20
Mark Frei, Deputy Assistant Secretary, EM-30
Mark Frei, Acting Deputy Assistant Secretary, EM-40
James M. Owendoff, Deputy Assistant Secretary, EM-50

September 17, 2002 (2:31PM)

Inactive Waste Site Definition

For the purpose of this attachment, "inactive waste sites" are sites covered with a soil or other engineered barrier as required by RCRA[1] and/or CERCLA requirements and subject to physical access as required by HAZWOPER and 10 CFR 835. Hazardous or radioactive materials may be in a general soil matrix as a result of liquid discharge or spill, legacy burial grounds, or in areas that contain contaminated equipment, pipes, or other items disposed of at the waste site. Physical features preclude the introduction of an energy source capable of dispersing the radioactive material.

Intrinsic to this description are the passive and administrative features, described in Attachment 2, that preclude intrusive activities, control access, and provide barriers to the release of radioactive material to the above-ground environment. Once environmental remediation activities commence or other intrusive activities are initiated, the waste site no longer meets the description of an inactive waste site.

The following items are specifically *not* included in the definition of inactive waste sites:

1. Above ground structures or containers.
2. Below-grade facilities/structures with human access or active provision of services (e.g., electricity, ventilation, steam), including tanks.
3. Any intrusive activity of the waste site (e.g., waste sampling, acceptance or retrieval activities).
4. Above-ground remediation activities for an inactive waste site (e.g., pump and treat facilities adjacent to an inactive waste site).
5. Evaporation ponds and sludges.
6. Waste sites that could contain fissile such that there is a potential for a criticality hazard because of water intrusion or material rearrangement (see supporting rationale in Attachment 3).
7. Waste sites that could contain explosives, or chemicals that might react with sufficient energy to cause a significant release (see supporting rationale in Attachment 3), and
8. Unvented tanks, unless demonstrated that there is no potential to exceed tank bursting limits from overpressurization (see supporting rationale in Attachment 3).

[1] While it is recognized that RCRA does not statutorily apply to radiological constituents of hazardous mixed wastes, RCRA controls applied to the regulated hazardous constituents provide the same controls for co-located radiological hazards. Therefore RCRA regulation is included as an alternative regulation in the definition of inactive waste sites. It is appropriate to consider either regulation under RCRA or CERCLA as a condition of inactive waste site.

Inherent Physical Features and Controls Provided at Inactive Waste Sites

Inactive waste sites (IWSs) are subject to physical features and controls that afford protection to workers, the public and environment. These protective measures are already in place for IWSs, as mandated through various statutory and regulatory requirements. As listed below, provisions include passive safety features as required by CERCLA/RCRA; safety oversight and review of proposed risk management strategies that are applied to IWSs as required by EPA and local/state regulatory agencies; worker safety controls and physical access requirements as required by 29 CFR 1910.120 (HAZWOPER); and radiation protection controls such as work permits, posting and monitoring that is required by 10 CFR 835.

1. Inherent Physical Features

The soil overburden physical characteristic of an IWS provides an inherent control from release of hazardous materials. The soil overburden either exists naturally or as an engineered barrier. Engineered barriers may consist of differing soil types (i.e., clay or sand), riprap, an asphalt or cement cap, or a combination of these features. Depending on the site, RCRA or CERCLA may indicate the need for an engineered barrier designed to protect against water or biota intrusion. These forms of cover provide the following protective measures for the public, workers, and environment.

- **Shielding.** Radiation dose reduction due to shielding. Soil overburden prevents most, if not all, significant exposure to nearby workers. Additionally, 10 CFR 835 provides a regulatory mechanism to ensure any needed additional level of protection is identified and appropriate measures taken.
- **Intrusion Barrier.** Protection from external energy sources. The wastes in the IWS are protected from impact by energy sources commonly considered for above ground structures, e.g., facility fires, electrical, hot work, range fires, local flooding, impact due to common carriers (vehicles, trains, planes), or falling objects. To expel significant levels of waste, sources of energy would need to act below the soil overburden rather than merely impacting the soil cover. The soil overburden also provides a barrier against unintentional intrusive activities. These waste sites are clearly marked. Intentional excavation is required to defeat the barrier. In addition, if an engineered barrier exists, this provides additional protection that requires extensive effort to penetrate.
- **Containment.** The soil cover provides a level of containment to prevent surface release. Normal dispersive mechanisms are not significant concerns. Wind transport is precluded and water runoff is precluded or reduced from affecting the hazardous radiological inventory.

- **Confinement**. If an accident condition is possible, the soil overburden provides a smothering effect on any dispersive events as well as filtration of gases and particulates.
- **Passive Barrier.** Soil overburden is passive. By definition, no external energy such as electrical, pneumatic, or hydraulic is required to maintain the barrier. Although this is a key feature, no worker actions are required for it to be fully effective. There is no mechanism to easily remove or distribute hazardous radiological inventory without intentional intrusive activities specifically designed to defeat the barrier. Potential migration of the waste inventory through environmental transport is addressed by RCRA/CERCLA.

2. Site Level Institutional Programs

Inactive waste sites are located on DOE property and are not readily accessible to the public. They are also subject to physical access controls as required by 29 CFR 1910.120 (HAZWOPER) and 10 CFR 835. Both regulations require identification and control of safe work zones (e.g., based on levels of hazardous/radioactive materials present). These measures provide additional buffers against potential disturbances or unauthorized intrusive activities that are required to gain access to radiological or hazardous materials.

3. Work Control Process

Workers are precluded from conducting activities that may disturb an IWS through mechanisms provided by established work control systems. These include processes for work authorization and the development and implementation of hazard controls in accordance with integrated safety management system requirements (i.e., as required by 48 CFR 970.5223-1). Using the Integrated Safety Management System, work activities (i.e., routine surveillance and maintenance) must be planned prior to personnel access, worker hazards must be identified and appropriate protective measures must be established. Additionally, work control measures invoked by 29 CFR 1910.120, 29 CFR 1926.65 and 10 CFR 835, ensure that hazardous/radiological material controls will be established to minimize potential personnel exposure, minimize the potential for release of materials to uncontrolled areas, provide for appropriate training (i.e., radiological and HAZWOPER) to personnel, and ensure that monitoring for any changes to IWS hazards is accomplished.

4. Radiation Protection Programs

The Occupational Radiation Protection Final Rule, 10 CFR 835, provides requirements and program requirements for protecting individuals from ionizing radiation resulting from the conduct of DOE activities. Standards are established for personnel monitoring, area posting, entry control, radioactive contamination control, and training of personnel. These requirements and standards are implemented through management and administrative processes that control potential access and work activities within areas that meet the criteria established by 10 CFR 835. Inactive areas are posted with the identified radiological hazard using the criteria of 10 CFR 835, Subpart G, Posting and Labeling, and periodically monitored to verify radiological conditions during inactive periods. All personnel entering a Radiological Control Area receive minimum training on the potential presence of radiological conditions and basic training on radiological hazards and posting that may be present. Entry into Radiological Areas requires additional training commensurate with the radiological hazards.

Requirements that are particularly relevant to an IWS are as follows:

- Individual and area monitoring where necessary (Sections 835.402 and 835.403)
- Entry control for radiological areas (Subpart F)
- Posting and labeling requirements (Subpart G)
- Proper creation, maintenance, and final disposition of monitoring and administrative records (Subpart H)
- Training (Subpart J)
- Design and workplace controls to maintain doses ALARA (Subpart K, especially Section 835.1003)
- Requirement for routine internal audits (Section 835.102)
- Occupational dose limits (Sections 835.202, 835.206, 835.207, and 835.208)

In addition, self-discovery and reporting of potential violations of 10 CFR 835, and timely implementation of corrective actions, are prompted by Price-Anderson Amendments Act considerations in the same manner as for 10 CFR 830, since violations of 10 CFR 835 are also considered violations of nuclear safety rules.

5. RCRA/CERCLA Controls and Risk Assessment Process

The Resource Conservation and Recovery Act (RCRA) and corresponding state laws regulate the treatment, storage and disposal of listed and characteristically hazardous wastes and hazardous wastes mixed with radioactive components ("mixed wastes"). In addition, RCRA establishes "Corrective Action" requirements to respond to releases of hazardous/mixed wastes from solid waste management units. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) establishes requirements for response to releases of hazardous substances, which include radioactive wastes. Independent regulatory oversight, that includes extensive state/EPA/local agencies, as well as public involvement, is inherent to RCRA as well as CERCLA.

Inactive waste sites as discussed herein, are subject to requirements imposed by RCRA, RCRA corrective action, and/or CERCLA. These requirements will be imposed at various stages in the life of the inactive waste site and, in general, will include the following attributes in accordance with the particular disposal or contamination circumstances of the individual site:

- ♦ Surface water monitoring;
- ♦ Ground water monitoring;
- ♦ Operation, surveillance, and maintenance of passive features such as caps, vegetative cover, slurry walls for containment, etc.

- Institutional controls to limit public access to the site and/or to limit use of the contaminated resource.

These requirements are formalized in legal commitments and agreements between the DOE facility and regulators (in some instances the contractor). These may take the form of:

- RCRA permit terms and conditions;
- RCRA corrective action orders and/or Corrective Action Decisions;
- CERCLA Records of Decision (RODs);
- Regulatory approvals of intermediate actions; and/or
- Federal Facility Compliance Agreements.

In addition, CERCLA Sec. 121(b) requires that, among other factors, both the short-term and long-term health and environmental risks be considered prior to selecting a remedy such as a long-term storage of radiological material in an inactive waste site as defined herein. This risk assessment evaluates risks to workers, the public and the environment and must include an evaluation of the threat posed by hazardous substances remaining on a site and the adequacy and reliability of any engineering or institutional control used to manage risks. (For additional detail, see the DOE Information Brief: *Assessment of Short-Term and Long-Term Risks for Remedy Selection,*" U. S. Department of Energy, CERCLA Information Brief, Office of Environmental Policy and Assistance, DOE/EH-413/9708 (August 1997).

As addressed in EPA guidance, "*Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Parts A, B and C)*," EPA/540/1-89/002, December 1989, the risk assessment process addresses potential pathways, quantification of potential radiation exposures, and quantification of risks. Such an assessment involves the identification of environmental media concern, the types of radionuclides expected at a site, areas of concern, and potential routes of radionuclide transport through the environment.

Finally, periodic reviews of the adequacy of RCRA/CERCLA controls are required. RCRA permits must be reviewed every five years. CERCLA also requires a reexamination of the selected remedy (including institutional controls) every five years.

Final Hazard Categorization Summary for Inactive Waste Sites

1. Introduction

10 CFR 830, Subpart B requires that facilities with radiological inventory perform a hazard categorization in accordance with DOE-STD-1027. The standard prescribes an initial hazard categorization that is based on gross inventory comparisons to threshold quantities of Table A.1. A final hazard categorization is also permitted for refining hazard categorization results based on a hazard analysis that considers material form, dispersibility, and interaction with energy sources, but not consideration of engineered safety features (ventilation system, fire suppression, etc.)

Section 4 of DOE-STD-1027 addresses various considerations for an acceptable hazard analysis. Per the standard's guidelines for applying a graded approach, facilities that are low in complexity typically warrant simplistic, qualitative hazard analysis methods and techniques. The standard cites waste storage as a low-complexity operation for which release mechanisms are "intuitive or straightforward."

Based on these DOE-STD-1027 guidelines, a semi-quantitative hazard analysis has been developed for categorizing inactive waste sites (IWSs). Common safety features, operational characteristics, and hazard potential among inactive waste sites justifies the use of singular hazard categorization approach for inactive waste sites across the DOE complex, provided they meet the criteria of Attachments 1 and 2.

This document provides the basis for a complex-wide final hazard categorization for an inactive waste site. Supporting calculations and assumptions used to derive dose consequences are contained in Attachment 4.

2. Hazard Identification

Hazardous materials stored at inactive waste sites vary among DOE sites, but consist primarily of contaminated soils and low-level wastes (e.g., contaminated personnel protective equipment, machine parts, residuals, sludges). For the purposes of this final hazard categorization, bounding values of plutonium are estimated in some accident scenarios based on the highest concentrations that would be expected at the Hanford site. These values are much greater than that expected at the vast majority of inactive waste sites at other DOE sites. The hazard analysis results show that bounding assumptions used for radiological inventories provide a sufficient basis for determining a final hazard categorization.

3. Hazard Analysis Discussion

10 CFR 830, Subpart B provides the basic definition for a Hazard Category 3 (HC3) facility as having the potential for only "significant localized consequences." DOE-STD-1027 provides further interpretation of HC3 as "facilities that cannot have a significant radiological impact outside of the facility."

An inactive waste site is not technically a facility. However, for purposes of hazard categorization, impacts "outside" of an inactive waste site facility is interpreted to mean an event that has the capability to exhume and disperse materials above the ground. Dispersion of waste materials could conceivably be postulated through several pathways including ingestion (e.g., contamination of groundwater or vegetation), inhalation or direct exposure (e.g., where protective overburden is breached). In defining a "significant localized consequence" for Hazard Category 3 facilities, DOE-STD-1027-92 reflects these three pathways within the EPA model used to calculate threshold quantities. However, given the short-time duration (i.e., 24 hours) over which consequences are estimated, the inhalation dose typically bounds other pathways and gives the highest consequences. Therefore, this final hazard categorization document focuses primarily on those events that have potential to uncover buried wastes and disperse materials to potential receptors above ground.

In order to create a radiological release of any significance at an inactive waste site (i.e., 10 rem at 30 meters as defined for HC3), an accident event would have to take place that possesses the following characteristics:

(1) An initiator would need to be of sufficient magnitude to penetrate into the ground to a depth necessary to impact a radiological source;
(2) A significant amount of energy would need to be imparted to a highly concentrated radiological inventory; and
(3) The radiological source would need to be dispersed in a sufficient amount that results in a significant localized consequence.

Given that inactive waste sites are "inactive" and no intrusive remedial activities are being conducted, there are no operational or process-related initiators of concern that would breach the protective overburden and expose hazardous/radioactive materials. Rather, initiators are limited to a small set of internal initiators and external man-made and natural phenomena events. A summary of the categories of hazards considered is presented in Table 1.

Table 1- Consideration of Hazardous Events

Categories of Hazards	Specific Events	Considerations
Internal/Operational	Criticality due to water intrusion or contamination movement	**Not Plausible** – Concentrations of fissile materials necessary for a criticality are not found at inactive waste sites. This event is analyzed in order to establish concentration limits that can be used to support inactive waste site definitions.
	Pressurization (e.g., from explosives)	**Not Plausible –** Explosives are typically not found at an inactive waste site. This event is analyzed in order to establish limits that can be used to support IWS definitions.
	Over-pressurization of storage tanks (e.g., gas generation)	**Not Plausible** – Hazardous tanks of this nature are typically not found at an inactive waste site. This event is analyzed in order to establish limits that can be used to support inactive waste site definitions.
	Fire	**Low consequence** –Material is below surface and there is a lack of oxygen to support combustion. Major forest and brush fires have occurred at inactive waste sites throughout the complex with no appreciable impacts on contaminated waste materials
	Loss of confinement	**Low Consequence**- No process initiators. Additionally, the consequences of this event would be bounded by aircraft impact or inadvertent penetration event.
External (Man-Made)	Aircraft Impact	**Low Consequence-** General aviation aircraft crash would be the only credible event. Typical ground penetration for GAA crash is three feet or less (see discussion). This is an analyzed event.
	Inadvertent Penetration of Surface (e.g., Digging)	**Low Consequence**- Event requires excavation of significant quantity of highly concentrated waste material followed by wind dispersion of exhumed materials. This is an analyzed event.
	Vehicle Impact	**Low Consequence**- Vehicle would have to significantly penetrate surface and result in a fire. The consequences of this event would be bounded by an aircraft crash, which has more velocity and greater impact angle for penetrating ground.
Natural Phenomena	High Wind/Tornado	**Not Plausible** – Material is below the surface. Significant crater would have to be created.
	Seismic	**Not Plausible-** Event would have to create large surface void and introduce fire ignition source. The consequences of such an event are bounded by "inadvertent penetration" event.

Bounding hazardous events presented in Table 1 are discussed below.

3.1 Criticality

The potential for a criticality involving fissile or fissionable materials in a soil matrix is driven by several factors including water content in soil, density of soil, and soil type. Based on various references or studies[1] performed for both uranium and plutonium, and assuming optimum conditions for these factors, ^{239}Pu concentration in soil above 2.5 g/L can be shown to present criticality concern. For ^{235}U, this concentration threshold is approximately 1.8 g/L. Studies have shown that calculations involving just ^{239}Pu or ^{235}U are conservative relative to typical mixtures of plutonium and/or uranium isotopes from reactor fuel processing. Concentrations of this magnitude are not expected at inactive waste sites. For example, as shown in the discussion below on inadvertent ground penetration, the ^{239}Pu concentrations (i.e., 0.7 g/L) associated with that scenario is below the critical concentrations shown above.

Another criticality hazard that must be considered is the potential for a concentrated mass that could potentially occur as a result of material rearrangement (i.e., seismic event or loss of integrity of containers) or water migration within the soil. Criticality mass limits are referenced in DOE-STD-1027 that provide thresholds for various fissile materials (i.e., 700 grams for ^{235}U, 450 grams for ^{239}Pu, and 500 grams for ^{233}U). Criticality would be of concern where there is a potential to actually concentrate fissile material into a critical mass that challenges the threshold quantities (i.e., as opposed to simply considering gross inventory over a relatively large area associated with an inactive waste site).

It is not expected that fissile materials within inactive waste sites could be sufficiently concentrated into a critical mass under conceivable phenomena that would be necessary to transport the materials from their stored locations. The relative immobility of plutonium and uranium species in a soil matrix precludes concentration due simply to migration resulting from water intrusion. For example, sampling of cribs at the Hanford facility's Plutonium Finishing Plant has shown that very little plutonium migration into the soil has occurred over time, even with almost continual water washing over it. Additionally, criticality safety evaluations for plutonium and/or uranium mixtures that are to be buried show that the waste remains subcritical even with optimum water moderation and reflection (e.g., water intrusion) and with no credit taken for the drum iron (e.g., loss of integrity). The analysis is performed to show that the double contingency principle is met.

The potential for fissile or fissionable materials to exceed the above assumptions for material rearrangement/water intrusion or concentration, as cited, should be used as a basis for inactive waste site definitions of Attachment 1. This includes the potential for assembling a critical mass or fissile or fissionable materials (e.g., ^{239}PU, ^{241}Pu, ^{238}Pu,

[1] Hanford memo of July 11, 1977 (Roecker to Elgert dealing with 241-Z-361 Tank criticality safety issue) indicates maximum subcritical concentrations of Pu in dry soil as low as 2.5 g/L. A study provided in the Proceedings of the Topical Meeting of the Nuclear Criticality Safety Division, "Criticality Safety Challenges in the Next Decade," September 7-11, 1997 indicate minimum critical concentrations of U^{235} in dry soil can be as low as 1.8 g/L (Calvin Hopper and Cecil Parks).

^{244}Cm, ^{233}U, ^{235}U, etc.). For conservatism, spent reactor fuel rods or assemblies should also be excluded in the inactive waste sites definition.

3.2 Internal pressurization

It is conceivable, but unlikely that inactive waste sites contain explosives or chemicals that could react rapidly creating a rapid pressure increase within the soil, and suspend contamination. Equations 5.23 and 5.24 of DOE/TIC-11268, *A Manual for the Prediction of Blast and Fragment Loading on Structures* show that, at 5 ft beneath the surface, it takes the ignition of 10 lbs of explosives to create a crater. Ignition of less than 10 lbs of explosives forms a camouflet (a below grade void) with little environmental release. Figure 5.15 of the stated DOE manual shows that 10 lbs of explosive ignited 5 ft below the surface results in a crater having a volume of 125 ft^3. The ignition of 40 lbs of explosive yields a crater having a volume of 400 ft^3.

The respirable release quantity is given by DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* as 0.2 times the quantity of TNT involved in the accident or 2 lbs of TNT in this case. The respirable release fraction is given by:

$$RRF = (0.2*10 \text{ lbs}) / (125 \text{ ft}^3)(106 \text{ lb/ft}^3) = 1.5 \times 10^{-4}$$

where 106 lb/ft^3 is the soil density (based on 1700 kg/m^3). While not all of the respirable release is contaminated material, the quantity released is greater than that from inadvertent excavation to be shown later. Therefore, to be conservative an inactive waste site that might have as much as 5 lbs of explosives or chemicals that might react so as to yield similar releases as 5 lbs of TNT equivalent should be excluded from consideration as an inactive waste site defined in Attachment 1.

3.3 Storage Tank Overpressurization

It is conceivable that an IWS may contain buried tanks with waste that could be generating gas. If these tanks are not ventilated, the pressure might build up to the point that the tank ruptures. It is also possible that, if the gas is flammable, an ignition source might develop and ignite the gas, causing the tank to rupture. It was shown above that the equivalent of 10 lbs of TNT ignited 5 ft below the surface could create a crater and a large respirable release. There are well known methods to determine the TNT equivalent for bursting vessels (see Section 6.3.3.1 of *Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires and BLEVEs)*. The equations require knowledge of the tank volume and burst pressure (which is a function of the volume, the wall thickness, and tank shape). Tanks that are vented will not pressurize to the point of bursting. Therefore non-vented tanks that have the potential to burst at conditions that generate the equivalent of 5 lbs of TNT (using similar assumptions as discussed in the internal pressurization event) should be excluded from consideration as an IWS defined in Attachment 1.

3.4 Aircraft Crash Evaluation

An aircraft crash that has the capability to penetrate an inactive waste protective overburden, create a sizeable crater, and disperse a high-octane gasoline that results in a fire is one of the most damaging events that can be postulated for an inactive waste sites. Such an event would need to involve an aircraft that has large enough mass, velocity and high impact angle to inflict significant damage.

With the exception of Rocky Flats Environmental Technology Site[2], EM's inactive waste sites are not located near airports, and therefore crashes from airport operations (i.e., takeoffs and landings) are not considered credible. For non-airport operations, Table B-15 of DOE-STD-3014-96, *Accident Analysis for Aircraft Crush into Hazardous Facilities* lists the probabilities per unit area of an air carrier, air taxi, large military craft, and small military crashes (i.e., high mass or high velocity aircraft). These values are presented for all DOE sites. The most restrictive value of any aircraft at the worst case DOE site is 2 E-06 crashes/mi^2/year. Inactive waste sites can cover large areas, so a value of 20 acres (0.03124 mi^2) was considered to be a reasonable bounding size of an inactive waste site. Multiplying this area by the crash probabilities per unit area indicates the annual probability of commercial and military crashes from non-airport operations is 6.2 E-8, and therefore is considered credible.

DOE-STD-3014-96 lists the maximum probability for a general aviation aircraft (GAA) crash per unit area for non-airport operations at a DOE site as 3 E-3 crashes/mi^2/year. These aircraft have relatively low mass and velocity when compared to commercial or military aircraft. Using the area of 20 acres, this would place the annual probability at 9.4 E-5. Therefore, this event was considered a credible, though extremely unlikely, event for an inactive waste site.

A GAA crash would have to penetrate an inactive waste site protective overburden in order to impact and disperse underground waste materials. Empirical studies or test data could not be found for modeling or predicting GAA crash damage. However, a search of the National Transportation Safety Board (NTSB) accident analysis database[3] was performed for GAA crashes involving fatalities. A sample of accidents for the five-year period between 1997 to 2002 showed that roughly 60% of GAA crashes resulted in impact craters that were one foot in depth or less. Another 33% were two feet or less and 7% of crash impacts were three feet or less. No impacts into soil were found beyond three feet in depth.

---

[2] Since RFETS is near Jeffco Airport, the frequency of an aircraft crash from airport operations is higher than other sites. The only inactive waste site located at RFETS is Pad 903 (asphalted contaminated soil with Pu machining oils) which is 100 m by 100m. Using a crash rate of 1.0E-3/mi^2/yr (based on Kaiser-Hill recalculating the data for the Denver metro area), the crash rate probability is 3.2E-6/yr.

[3] NOTE: Data was based on search of GAA accidents involving a fatality for specified five-year period using search word "crater." A total of 150 accidents were identified and results were compiled from those investigations in which crater specifications were given (about 62% of accidents reported).

Inactive waste sites that meet the definitions and criteria of Attachments 1 and 2 have inherent physical barriers such as soil overburden or engineered caps which have to meet pedigrees established by CERCLA or RCRA. These features must be established in order to reduce hazardous material risks (public, environment, and workers) to acceptable levels as negotiated with EPA and local/state regulators. The depth of protective overburden/caps provided at DOE sites varies depending on risks presented by waste materials and regulatory specifications. As an illustration:

- The Savannah River Site must provide overburden protection of around six feet to ensure their caps can resist wildlife intrusion.
- The Nevada Test site must have protective overburden of between 8 to 10 feet.
- Hanford site is in the range of five feet or greater of overburden.
- Oak Ridge site is in the range of five feet or greater of overburden.

Using the general assumption that protective overburden is at a sufficient depth that meets regulatory risk goals, and assuming a maximum size crater of around three feet deep that could be created by a GAA crash, it is not expected that such an event would inflict sufficient energy on soil terrain to disperse underground waste materials. Therefore, consequences from this event are considered negligible.

3.5 Inadvertent Penetration of Ground Surface

Consideration was given to an inadvertent ground penetration associated with two possible events. For each event, scenarios were postulated for three separate contamination areas that included (1) a highly contaminated crib; (2) a large spill site (e.g., leakage from a transfer line at Hanford Tank Farms); (3) a small concentrated spill site (e.g., drum spill). The crib inventory bounds that expected from a large or small spill site and is therefore carried forward in this evaluation.

The first accident initiator considered is wind blown erosion over a contaminated site. In this accident, the site either was uncovered by some mechanism or was inadvertently not covered when the contamination occurred. The resuspension is assumed to continue for 24 hours. The large waste site and small waste site are covered by this accident. The contaminated portion of a crib is typically around 1.5 meters below the soil surface. Therefore, it is not considered credible for a crib to become entirely uncovered by wind erosion.

The second accident is inadvertent digging of a test pit into a crib for soil characterization. It should be noted that this is not an allowed activity under the definition of an inactive waste site. It is included here to provide perspective on a worst case situation. This event would typically be controlled through a new safety evaluation and associated safety basis document. However, for the purposes of this hazard categorization it is assumed that this inadvertently occurs at an inactive waste site. The pit is assumed to be 2 m in diameter and 6 m deep (typical size). The contamination starts 1.5 m below the surface and extends to 6 m. The volume of contaminated soil is

14 m^3 or 18 yd^3. The excavated material is assumed to be placed in a layer 1 m deep all around the pit. The total amount of soil brought to the surface is 19 m^3. The ring of soil is 5.3 m in diameter (22 m^2). The number of loads dumped is 18. It is assumed that the bucket of the backhoe has a 1 cubic yard capacity. [Note: typical excavation of this volume associated with a test pit would take several weeks because of regulatory oversight restrictions].

In order to determine a bounding material at risk for Scenario 2, the soil is assumed to be contaminated at a similar level to the Hanford Z-1A Crib. This represents the highest expected plutonium concentrations for inactive waste site at the Hanford site. Information from the Z-1A crib shows that the greatest concentration of ^{239} Pu was 24,000 n Ci/g at 10 ft below the surface (data from PNNL-11978, *Results of the 1998 Spectral Gamma-Ray Monitoring of Boreholes at the 216-Z-1A Tile Field, 216-Z-9 Trench and 216-Z-12 Crib*). This value equates to 4×10^{-4} g Pu/g soil, using a specific activity of 0.062 Ci/g or 0.66 g Pu per liter of soil using 1700 g/L as the soil density. Since this value is similar to that from the Z-9 crib, a concentration of 0.7 g Pu per liter (assumes 6% ^{240}Pu) of soil will be used in the analysis for re-suspension off of or dumping of soil excavated from a crib.

This concentration is reasonable for a crib that received waste from fuel reprocessing plants. It is overly conservative for waste sites that involved spills. By comparison, RPP-10773, *Compressed Gas Accident Parametric Consequence Analysis*, Table 3-8 (page 3-32) provides a dose factor of 1 rem/g of soil or 1700 rem/L of soil based on the worst case documented Tank Farm spill (using a soil density of 1700 g/L). That soil had a concentration of ^{239}Pu of 3300 pCi/g or 10^{-4} g/L of soil.

Using these material inventory concentrations, dose consequences were calculated using analysis assumptions built into the EPA model that is used in DOE-STD-1027 HC3 thresholds. This includes a dose receptor distance of 30 meters, 1 m/s wind speed with D stability, X/Q value of 0.07 s/m^3 (receptor is in center line of plume), and resuspension of materials over a 24 hour period.

Release fractions were adjusted using Equation 4-5 of DOE-HDBK-3010-94, which provides a correlation for ARF based on drop height, mass, and density. The soil is assumed to spill from a height of 1 m. The average value of ARF for TiO_2 (a closer surrogate for soil than UO_2) was selected and is 10^{-4} for spills from 1 m. The corresponding value for RF is 0.6. Using these assumptions, the adjusted release fraction (ARF*RF) is 6×10^{-5}. This value is for a very dry oxide and is inconsistent with typical soil conditions, which, even for an arid climate such as Hanford's, ranges from 3-5% moisture content. DOE/RL/12074-30-2, *Dust Mitigation Study for the Environmental Restoration Disposal Facility*, p. 27 and AP-42, *Compilation of Air Pollutant Emission Factors, Fifth Edition*, Section 13.2.4.3 provides data for releases due to dumping soil containing moisture. Using emission rates provided in this study provides for an adjusted conservative value of 10^{-6}. This value is more appropriate for this application as it accounts for soil moisture and does not include surface contamination nor intensive remediation or decommissioning activities, which are precluded from the scope of this analysis. Similarly, use of Equation 4-6 was deemed appropriate for this scenario as it represents either pneumatic transfers or spills of minute quantities of soil during earth moving operations. Dumping bulk quantities of soil would not provide similar energetics or physical phenomenon. These values and assumptions have been peer reviewed and validated, based on discussions with Jofu Mishima.

Using the above conservative assumptions, maximum expected dose consequences are approximately 7 rem at 30 meters. This value is below DOE-STD-1027 HC3 values.

4. Conclusion

The inadvertent penetration event is the bounding event analyzed for inactive waste sites. Although consequences are approaching the general range of DOE-STD-1027 for Hazard Category 3, assumptions used in the postulation of this event were extremely conservative. These assumptions include defeating physical barriers or access controls that would be in place as a result of CERCLA/RCRA, HAZWOPER and 10 CFR 835 requirements; ignoring postings, work controls and permitting requirements of 10 CFR 835; excavation of a significant amount of material in a period of time that is much shorter than standard practices; and high conservatism within dose consequence estimates.

The ^{239}Pu concentrations that are postulated in the hazard analysis are considered the highest that would be expected at the Hanford site. Additionally, these values are much greater than that expected at the vast majority of inactive waste sites at other DOE sites. Further, although the bounding scenario only looked at ^{239}Pu, this is still conservative for the types of material that would commonly be expected at various inactive waste sites. For example, the threshold quantities for ^{239}Pu stated in DOE-STD-1027 for Hazard Category 3 are 2 E+5 greater than U^{235}. Other isotopes with higher specific activity than ^{239}Pu may be encountered, but not in the quantities evaluated in the inadvertent penetration scenario.

Therefore, it can be reasonably and conservatively assumed that DOE inactive waste sites do not present a significant localized consequence as defined by HC3 thresholds.

Final Hazard Categorization Basis for Inactive Waste Sites for Inadvertent Ground Penetration Scenario

R. W. Marusich, Flour Hanford Incorporated
A. L. Ramble, Flour Hanford Incorporated
M. W. Jackson, DOE Richland Operations Office
W. J. Woody, Link Management Solutions

[Note: This attachment is specific to hazards and conditions found at the Hanford site and is provided to give a perspective on maximally expected consequences associated with a ground penetration event. The event as postulated requires a series of activities that are extremely conservative, beyond currently accepted practices, and in violation of the definition of work permitted at an inactive waste site.]

1. Introduction and Summary

This report presents the final hazard categorization for inactive waste sites. Inactive waste sites include cribs, surface contamination areas, and below-grade contamination areas (e.g., transfer line leak). Work is not typically performed in these areas. Any intentional intrusion will be performed under an approved safety document. Waste sites undergoing active remediation and characterization efforts are not covered by this report.

These sites are contaminated with radioactive material. However, the radioactive material itself comprises a very small fraction of the contaminated area. The rest is soil. As a result, the wind entrainment (or resuspension) models are those used by the U.S. Environmental Protection Agency for similar sites. To be comprehensive, the wind entrainment models of DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, are also considered. Because the radioactive material has been present for a long time, much of it has been relocated to below grade by environmental factors or due to administrative procedures. As a result, the average concentration of radionuclides in soil is used. However, these averages were taken from bounding events.

Table 1 provides a summary of the results of the final hazard categorization of an inactive waste site. The data used in this analysis are shown in Table 2. The worst-case events involve digging a test pit into a crib.

Table 1. Summary of the Results.

Scenario Number and Description	Wind Speed, m/s	Exposure Duration, h	Site	Dose Factor, rem/L, soil	Dose at 30 m, rem
1. Wind over a contaminated site	1.0 1.0	24 24	Large Small	2×10^4 2×10^7	0.006 0.08
2. Test pit dug into a crib	1.0	24	Crib	2×10^7	7.0

Several conservatisms have been employed during this analysis:

- Dose conversion factors are based on ICRP 30 for consistency with past analyses. Use of the currently approved ICRP 68/71 values would reduce postulated doses by a factor of at least three.
- To account for uncertainty, the release fraction used has been rounded to the next nearest order of magnitude. This bounds uncertainties such as wind speed, shovel volume, and moisture content. This results in a factor of nine increase from the calculated value.
- Conservative resuspension rates are used from DOE-HDBK-3010 relative to those provided using EPA models. This results in a resuspension rate that is more than an order of magnitude greater.
- The scenarios do not address any of the features that are in place under separate regulation to prevent inadvertent intrusion, and when intrusion occurs, it is assumed that the intrusion occurs in bounding locations.
- The test pit scenario assumes that the dig was completed in one day. Test pits are normally dug over a several day period, and may take weeks to complete due to characterization data quality objectives.

Table 2. Data Used in Dose Calculations.

• Dose factors	
Crib	2×10^{7} rem/L of soil
Large contaminated site	2×10^{4} rem/L of soil
Small contaminated site	2×10^{7} rem/L of soil
• ARF*RF due to dumping[a]	10^{-6}
• Resuspension[a]	4×10^{-3} g/m^2-h
• X/Q at 30 m	
X/Q based on Pasquill D meteorology per DOE-STD-1027-92[b]	
Dumping	X/Q = 0.07 s/m^3 based on 1.0 m/s wind
Resuspension	
Large site	0.02 based on 1.0 m/s wind
Small site	0.07 based on 1.0 m/s wind
Test pit	0.07 based on 1.0 m/s wind
• Site size	
Large site	800 m^2
Small site	7.3 m^2
Test pit	22 m^2
• Number of 1 yd^3 loads that are dumped	
Test pit dug into crib	18
• Receptor present for 24 hours according to DOE-STD-1027-92.[b]	

[a]DOE-STD-1027-92 allows use of U.S. Environmental Protection Agency models for ARF*RF and for resuspension.

[b]DOE-STD-1027-92, 1992, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C.

2. Hazards

During the hazard identification phase, three types of contamination areas and two accident scenarios were identified. These scenarios address inadvertent intrusion or release of materials. The contamination areas are identified as a crib, a large spill waste site (e.g., like that from a large spill from a transfer line at the tank farms), and a small spill waste site (e.g., a drum spill).

The accident scenarios include contaminated soil dispersal from:

- Entrainment by the wind
- Inadvertent excavation for characterization (e.g., digging in the wrong place)

These last two events represent those ground penetration scenarios with the greatest likelihood of occurring. Radioactive material releases and the resulting dose consequences will be determined for these two scenarios for the three types of waste contamination.

The first accident type is wind-blown erosion over a contaminated site. In this accident, the site either was uncovered by some mechanism or was inadvertently not covered when the contamination occurred. The resuspension is assumed to continue for 24 hours. The large waste site and small waste site are covered by this accident. The contaminated portion of a crib is typically 5 ft below the soil surface. It is not considered credible for a crib to become entirely uncovered. Scenario 2 will cover the partial uncovering of a crib.

The second accident involves a test pit dug into the soil for characterization. The pit is assumed to be dug into a crib. The pit is assumed to be 2 m in diameter and 6 m deep. The contamination starts 1.5 m below the surface and extends to 6 m. The volume of contaminated soil is 14 m^3 or 18 yd^3. The excavated material is assumed to be placed in a layer 1 m deep all around the pit. The total amount of soil brought to the surface is 19 m^3. The ring of soil is 5.3 m in diameter (22 m^2). The area of contamination, assuming the top of the ring of soil that had been removed is covered with contaminated soil.

Scenario 2 also bounds a test well or borehole inadvertently sunk through contaminated soil. Assuming the well is 12 in. in diameter, the extent of contamination would have to be exceptionally long for the volume dumped by well drilling to exceed that discussed in Scenario 2.

3. Soil Contamination and Dose Factors

For the analysis involving the crib, the soil is assumed to be contaminated to the same extent as was the Z-9 Crib. The Z-9 Crib was the most highly contaminated crib, in terms of plutonium concentration, on the Hanford Site. ARH-2207, *216-Z-9 Crib History and Safety Analysis*, provides information regarding the Z-9 Crib. Liquid waste containing plutonium was discharged into this crib. Table 2 of ARH-2207 (p. 23) shows that the plutonium existed within the upper 2 to 3 ft of the soil. The maximum concentration was 25.4 g/L of soil. Below the upper 2 to 3 ft of soil, concentrations are much less (i.e., 0.06 to 1 g/L). The large concentrations of plutonium were removed from this crib, leaving soil with an average concentration of about 0.5 g Pu/L.

Information from the Z-1A Crib shows that the greatest concentration of ^{239}Pu was 24,000 nCi/g at 10 ft below the surface (data from PNNL-11978, *Results of 1998 Spectral Gamma-Ray Monitoring of Boreholes at the 216-Z-1A Tile Field, 216-Z-9 Trench and 216-Z-12 Crib*). This value equates to 4×10^{-4} g Pu/g soil using a specific activity of 0.062 Ci/g, or 0.066 g Pu/L of soil using 1700 g/L as the soil density. This value is similar to that from the Z-9 Crib. Therefore, a concentration of 0.7 g Pu/L of soil will be used in the analysis for resuspension off of or dumping of soil excavated from a crib.

The isotopic mix for weapons grade plutonium is taken from HNF-SD-CP-SAR-021, *Plutonium Finishing Plant Final Safety Analysis Report*. The data take into account americium buildup, which yields the following:

Isotope	Weapons-grade 6% ^{240}Pu	rem/ g (Class Y)
^{238}Pu	0.01	4.93×10^9
^{239}Pu	93.77	1.91×10^7
^{240}Pu	6.0	6.99×10^7
^{241}Pu	0.2	5.11×10^8
^{241}Am	0.14	1.52×10^9

The dose factor for weapons-grade plutonium (6% ^{240}Pu) is 2.6×10^7 rem/g.

Weapons-grade plutonium is used in this analysis. The reason is two-fold. The data provided in HNF-SD-CP-021, Table 9-43 shows that 70% of the plutonium stored at the Plutonium Finishing Plant at Hanford is weapons-grade plutonium. This is indicative of the process history. The discharges to the crib also reflect that process history. Therefore, it is expected that the isotopic mix of plutonium in the crib is predominantly weapons-grade plutonium. Second, fuels-grade plutonium campaigns occurred later in the history of the facility. It would be expected that process improvements and increased environmental awareness would have resulted in relatively smaller discharges than would have been the case earlier in the history of the facility. This would result in the isotopic mix being even more reflective of weapons-grade plutonium. In addition, because of the conservatisms in the site size, plutonium concentration in the soil, and in the choice of ARF, the choice of a greater-than-average, but less-than-bounding, isotopic mix is reasonable.

The dose factor for cribs is found as follows:

$$\frac{0.7\,\text{g / Pu}}{\text{L, soil}}\left(\frac{2.6 \text{ x } 10^7 \text{ rem}}{\text{g, Pu}}\right) = 1.8 \text{x} 10^7 \text{ rem / L of soil}$$

This value will be rounded up to 2×10^7 rem/L of soil.

The concentrations above are reasonable for a crib that received waste from fuel reprocessing plants; however, they are overly conservative for waste sites that involved spills. By comparison, RPP-10773, *Compressed Gas Accident Parametric Consequence Analysis*, Table 3-8 (p. 3-32) provides a dose factor of 1 rem/g of soil or 1700 rem/L of soil (using a soil density of 1700 g/L) based on the worst-case documented tank farm spill. The soil had a concentration of ^{239}Pu of 3300 pCi/g or 10^{-4} g/L of soil. This will be increased by a factor of 10 and rounded up to 2 x 10^4 rem/L of soil to bound large contaminated waste sites that do not resemble cribs. This dose factor will be used for larger contamination sites.

Smaller contamination sites could be formed. In this case, it is assumed that 200 g of plutonium (maximum allowed in a 55-gal drum) are scattered over a 10-ft-diameter area (equivalent to 55 gal of waste spread about 1 in. thick). The plutonium is assumed to be mixed in with 6 in. of soil (1:6 dilution). The plutonium concentration is

$$200 \text{ g}/[(\pi/4)\ (10 \text{ ft})^2\ (0.5 \text{ ft})\ (28.3 \text{ L/ft}^3)] = 0.2 \text{ gPu/L}$$

Using the crib data, the dose factor is

$$\frac{0.2\ \text{g/Pu}}{\text{L, soil}}\left(\frac{7\ \text{x}\ 10^7\ \text{rem}}{\text{g, Pu}}\right) = 2\ \text{x}\ 10^7\ \text{rem/L of soil (rounded up)}$$

where 7 x 10^7 rem/g is the average dose factor for all plutonium stored at PFP at the time of writing HNF-SD-CP-SAR-021 (data are from Table 9-45 of the reference).

A summary of the dose factors follows:

- Crib and like sites — 2 x 10^7 rem/L of soil
- Small contaminated sites — 2 x 10^7 rem/L of soil
- Large contaminated sites — 2 x 10^4 rem/L of soil

4. Respirable Release Due To Dumping

The respirable release is found by multiplying the mass of soil dumped by the ARF and respirable fraction (RF). ARF and RF are found in Section 4.4.3.1.2 of DOE-HDBK-3010-94. The soil is assumed to spill from a height of 1 m. While the bucket can be raised to at least 2 m and possibly more, there is no reason to believe that the operator will drop the material from more than 1 m. The average value of ARF for TiO_2 (a closer surrogate for soil than UO_2) is about 10^{-4} for spills from 1 m. The corresponding value for RF is 0.6. Equation 4-5 of the reference provides a correlation for ARF based on drop height, mass, and density. The bulk density of soil is typically 1700 kg/m^3. The mass of soil in 1 yd^3 is 1300 kg. ARF is given by

$$ARF = 0.1064(M)^{0.125}\ H^{2.37}/\rho^{1.02}$$

where

M = mass, kg
= 1300 kg
H = drop height, m
= 1.0 m
ρ = bulk density, kg/m^3
= 1700 kg/m^3.

Solving for ARF yields 1.3×10^{-4}. RF is taken to be 0.6. The value of ARF*RF is 8×10^{-5}. If 0.1 yd^3 is dropped from 1 m, ARF is 10^{-4} and the ARF*RF is 6×10^{-5}.

This value is based on very dry oxide. The contaminated soil, however, is not very dry oxide. It contains moisture, which changes the dynamics of resuspension due to dumping. DOE/RL/12074-30-2, *Dust Mitigation Study for the Environmental Restoration Disposal Facility*, p. 27 and AP-42, *Compilation of Air Pollutant Emission Factors, Fifth Edition*, Section 13.2.4.3 provides data for releases due to dumping soil containing moisture. The equation is

$$e = k(0.0016)(u/2.2)^{1.3}/(M/2)^{1.4}$$

where

- e = the 10 µm particle release fraction, kg/tonne
- k = 0.35 when 10 µm particles are of concern (according to AP-42)
- u = mean wind speed, m/s
- M = moisture content, %.

The moisture content for Hanford Site soils is 3 to 5 percent (p. 31 of DOE/RL/12074-30-2). Using a moisture content of 3 percent, the release fraction (e from above equation) for 10 µm particles for a 1 m/s wind speed is 1.1×10^{-4} kg/tonne. A wind speed of 1 m/s is used in this calculation because it is the wind speed used in DOE-STD-1027-92 to determine the threshold quantities for Category 3 facilities. Because the calculation in this report is being performed for final hazard categorization purposes, it is judged that consistency with DOE-STD-1027-92 is important.

The values of the release fraction will be rounded up to the nearest order of magnitude to bound uncertainties such as wind speed, shovel volume, and moisture content. The value used in the analysis is then 10^{-6}.

The fraction of material suspended using the EPA model is about 100 times less than that found in DOE-HDBK-3010-94. The reason is two-fold. First, the mass spilled and the equation for ARF in DOE-HDBK-3010-94 show a functional dependence on mass. However, when a large volume is dropped, the main contribution to ARF is from the edges of the volume. The material in the inner section is not subjected to stresses while falling. At impact, particles are resuspended; however, most do not escape the volume due to interception by the mass further to the outside. That is, a damage ratio should be applied to large volume drops. The second reason is moisture. The powders used in the DOE-HDBK-3010-94 experiment were drier then soil. Even a moisture percentage difference of a factor of 5 yields a factor of 10 in ARF according to the DOE dust model. As a result, the ARF*RF from DOE-HDBK-3010-94 with an appropriate damage ratio yields results similar to the equation from AP-42. Therefore, a value of 10^{-6} will be used for ARF*RF.

5. Release Rate Due To Resuspension

The release rate due to resuspension is based on data in EPA/600, *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites*, p. 34. The equation comes from studies involving highly erodible soils. It is assumed that the site fits this description. The equation is:

$$E_{10} = 0.036(1-V)(u/u_t)^3\, F(x)$$

where

E_{10} = annual average emission factor for <10 μm particles, g/m^2-h
V = fraction of site covered by vegetation
= 0 (assumed)
u = wind speed, m/s
u_t = threshold value of wind, m/s (see below)
x = 0.886 (u_t/u)
$F(x)$ = function if x>2, $F(x) = 0.18(8x^3 + 12x) * \exp(-x^2)$. For 0<x<2 see Figure 4-3 of the reference.

To find u_t,

1. Obtain mode of particle size distribution. Assume 500 μm, in accordance with the example on p. 69 of the reference.
2. Use Figure 3-4 of the reference to obtain a threshold friction velocity of 50 cm/s.
3. Obtain surface roughness from Figure 3-6 (Z_o) of the reference. Assume 1.0 cm.
4. Use Figure 4-1 of the reference to obtain u_t/friction velocity.
5. u_t/friction velocity = 16.5
6. Solve for u_t = 16.5 (50 cm) = 8.25 m/s.

Using the above data and equation:

$$\text{For 1.0 m/s winds, } E_{10} = 0.036\left(\frac{1.0}{8.25}\right)^3 F(x)$$

$x = 7.3$ $F(x) = 4 \times 10^{-21}$
$E_{10} = 2.6 \times 10^{-25}$ g/m^2–h or zero

According to p. 38 of the reference:

$$R_{10} = yE_{10}\,A$$

where

R_{10} = emission rate for <10 μm particles
y = fraction of contaminant in soil (in E_{10})
= 1.0 here
A = area, m^2
= 1 m^2 (assumption).

DOE-HDBK-3010-94 provides the results of a test in which oxide and uranyl nitrate hexahydrate were spread over smooth sandy soil. The airborne resuspension rate over 24 hours for 1 m/s is as follows:

	1 m/s
UO_2	2×10^{-5}/h
Air-dried uranyl nitrate hexahydrate	3×10^{-6}/h
Uranyl nitrate hexahydrate	5×10^{-6}/h

In each of the above cases, about 50 g of the contaminant were sprinkled over the sandy soil held in a 23-in.-diameter tray. The tray area is 2.88 ft^2 or 0.27 m^2.

To compare the resuspension rates from DOE-HDBK-3010-94 to those from EPA/600 above, they must be multiplied by 50 g and divided by 0.27 m^2:

- 1 m/s wind 4×10^{-3} g/m^2-h to 6×10^{-4} g/m^2-h

The resuspension rate for 1 m/s winds from EPA/600 is much less than the values in DOE-HDBK-3010-94. There are many reasons why the EPA/600 values might be less, including upwind topography, age of deposit, particle shape, and soil particle size distribution. However, for conservatism, the resuspension rate of 4×10^{-3} g/m^2-h from DOE-HDBK-3010-94 will be used in the analysis, which, as was stated above, will use a 1 m/s wind speed.

6. Atmospheric Dispersion

The atmospheric dispersion factor is based on the equations within the GXQ code as documented in WHC-SD-GN-SWD-30002, *GXQ Program Users Guide*. The onsite individual is assumed to be 30 m from the edge of the contaminated site or operation and on the centerline of the plume. The value of X/Q for ground-level releases is given as follows:

$$X/Q = [\theta_y \theta_z u]^{-1} f(y)$$

where

θ_y = horizontal diffusion coefficient, m
= 3.17 m for Pasquill D conditions at 30 m (data from Table 1 of the reference) Pasquill D is used on p. A-7 of DOE-STD-1027-92.
θ_z = 1.58 m (same rationale as for θ_y)
u = 1.0 m/s according to DOE-STD-1027-92
$f(y)$ = $\exp[-0.5 (y/\theta_y)^2]$ where y = 0 if centerline values are wanted.

For scenarios involving dumping, f(y) is set equal to 1.0 (i.e., y = 0). The value of X/Q is 0.07 s/m^3. This is consistent with EPA model X/Q that provides 8.4x10^{-13} day/cm^3, which equals 0.07 s/m^3. This value also is used for the test pit. The reason is that the test pit has a small areas where the wind blows along the axis of the test pit.

For wind entrainment from a large area, it is conservative to assume that the receptor is on the centerline of the plume, downwind from one end of a long rectangle with a width small enough that most of the entrained material can affect the receptor. To determine the width of this rectangle, consider horizontal distances from the centerline of a plume from a small source. The value of f(y) is 0.5 when this small source is 3.7 m from the centerline and 30 m upwind from the individual. At 8 m from the centerline, f(y) equals 0.04. Because f(y) is small, X/Q is small as compared to that evaluated on the centerline. Therefore, for horizontal distances the plume extends about 8 m on either side of the centerline. This value will set the width of the contamination that will affect the onsite individual.

Based on the above, the large (800 m^2) waste site is considered to be an area source with a width of 16 m (from 2 times the 8 m width found above). Section 4.2.2 of WHC-SD-GN-SWD-30002 shows that for area sources the virtual source is located up wind such that

$$\theta_y = W/4.3$$

where

W = width of source
   = 16 m in this case.

Solving for θ_y yields 3.72 m. Using Table 1 of the reference, θ_y equals 3.72 m at 36 m. The virtual source is located

$$30 + 36 = 66 \text{ m upwind of the individual}$$

At 66 m, θ_z equals 3.17 m and θ_y equals 6.47 m. The value of X/Q is found as above, but with the new values for θ_y and θ_z. The value of X/Q is 0.02 s/m^3 for a wind speed of 1.0 m/s.

The small site is 3 m in width. No area source correction will be performed. The X/Q is 0.07 s/m^3.

The receptor is assumed to remain for 24 hours in keeping with DOE-STD-1027-92.

7. Site Area

The site sizes are as follows:

- Small site -- 7.3 m^2 (based on a 10-ft-diameter area discussed in Section 3.0)
- Large site -- 800 m^2 (based on a 16 m wide area, from Section 6.0; assumed 50 m long)

8. Consequence Calculations

Data used in the calculations below are found in Table 2.

8.1 Scenario 1 – Wind Over a Contaminated Site

- Dose rate equation

Dose rate = (resuspension rate)(site area) (L/1700 g) (X/Q) (3.3×10^{-4} m^3/s) (dose factor)

Where:

3.3×10^{-4} m^3/s = breathing rate. Notably, this is conservative to the EPA model, which uses a breathing rate of 2.3×10^{-4} m^3/s.

- Consequences

Large site	2.5×10^{-4} rem/h or 6×10^{-3} rem over 24 hours
Small site	3.4×10^{-3} rem/h or 0.08 rem over 24 hours.

8.2 Scenario 2 – Test Pit Dug into a Crib

Resuspension 0.024 rem/h or 0.6 rem over 24 hours

- Dumping

Dose = (1 yd^3) (ARF*RF) (765 L/yd^3) (# dumps) (X/Q) (3.3×10^{-4}) (dose factor)
=6.4 rem.

9. Analytical Conservatism

Several analytical conservatisms have been used during the preparation of this analysis:

- Dose conversion factors are based on ICRP 30 for consistency with past analyses. However, use of the currently approved ICRP 68/71 values would reduce postulated doses by a factor of at least three.
- To account for uncertainty, the release fraction used has been rounded to the next nearest order of magnitude. This bounds uncertainties such as wind speed, shovel volume, and moisture content. This results in a factor of nine increases from the calculated value.

- Conservative resuspension rates are used from DOE-HDBK-3010 relative to those provided by EPA models. This results in a resupsension rate that is more than an order of magnitude greater.
- The scenarios do not address any of the features that are in place under separate regulation to prevent inadvertent intrusion, and when intrusion occurs it is assumed that the intrusion occurs in bounding locations.
- The test pit scenario assumes that the dig was completed in one day. Test pits are normally dug over a several day period, and may take weeks to complete due to characterization data quality objectives.

10. References

AP-42, 1998, *Compilation of Air Pollutant Emission Factors, Fifth Edition*, Vol. 1, U.S. Environmental Protection Agency, Washington, D.C.

ARH-2207, 1971, *216-Z-9 Crib History and Safety Analysis*, Atlantic Richfield Hanford Company, Richland, Washington.

DOE-STD-1027-92, 1992, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C.

DOE-HDBK-3010-94, 1994, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, U.S. Department of Energy, Washington, D.C.

DOE/RL/12074-30-2, 1994, *Dust Mitigation Study for the Environmental Restoration Disposal Facility*, Department of the Army, Walla Walla, Washington.

DOE/TIC-11268, 1980, *A Manual for the Prediction of Blast and Fragment Loadings for Structures*, U. S. Department of Energy, Amarillo, TX.

EPA/600, 1985, *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites*, U.S. Environmental Protection Agency, Washington, D.C.

Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires and BLEVEs, 1994, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY.

HNF-SD-CP-SAR-021, 2001, *Plutonium Finishing Plant Final Safety Analysis Report*, Rev. 3, Fluor Hanford, Inc., Richland, Washington.

PNNL-11978, 1998, *Results of 1998 Spectral Gamma-Ray Monitoring of Boreholes at the 216-Z-1A Tile Field, 216-Z-9 Trench and 216-Z-12 Crib*, Pacific Northwest National Laboratory, Richland, Washington.

RPP-10773, 2002, *Compressed Gas Accident Parametric Consequence Analysis*, Rev. 0, Fluor Hanford, Richland, Washington.

WHC-SD-GN-SWD-30002, 1995, *GXQ Program Users Guide*, Rev. 1, Westinghouse Hanford Company, Richland, Washington.