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Evaluation of Soil and Buried Transuranic Waste Retrieval Technologies for Operable Unit 7-13/14

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December 2002

Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC

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ABSTRACT

The U.S. Department of Energy, to satisfy the requirements of the Federal Facilities Agreement and Consent Order with the State of Idaho and the U.S. Environmental Protection Agency, is conducting the Waste Area Group (WAG) 7 Operable Unit 13/14 Comprehensive Remedial Investigation/ Feasibility Study at the Idaho National Engineering and Environmental Laboratory. The Comprehensive Environmental Response, Compensation, and Liability Act governs these activities, which involve assessments of contaminants of concern, risk factors, and potential technologies for remediating the site.

This report describes the technologies for retrieving soil and buried transuranic waste at the Subsurface Disposal Area within WAG 7 at the Idaho National Engineering and Environmental Laboratory and presents specific technologies that can be used in this process. The technologies are evaluated for their applicability to the SDA. In addition, effectiveness, implementability, and cost are discussed.

In the attached appendix, several case studies are presented. These case studies were selected for evaluation on the basis of their similarities to conditions or issues presented by the SDA.

The document presents currently available technology performance information and serves as a subtier reference document in the pending WAG 7 Feasibility Study.

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ACRONYMS

AEC	Atomic Energy Commission
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
HEPA	high efficiency particulate air
INEEL	Idaho National Engineering and Environmental Laboratory
LDR	land disposal restriction
NRTS	National Reactor Testing Station
RAO	remedial action objective
RFP	Rocky Flats Plant
RI/FS	Remedial Investigation/Feasibility Study
SDA	Subsurface Disposal Area
TRU	transuranic
UXO	unexploded ordnance
VOC	volatile organic compound
WAG	waste area group

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1. INTRODUCTION

The Subsurface Disposal Area (SDA) in Waste Area Group (WAG) 7 at the Idaho National Engineering and Environmental Laboratory (INEEL) has accepted radioactive mixed waste since 1952. SDA pits, trenches, and soil vaults were filled with drums, boxes, cartons, trash, tanks, and other miscellaneous debris that contain transuranic (TRU), low-level radioactive, irradiated fuel materials, and mixed wastes. When full, a disposal unit was covered with several feet of clean soil.

Since December 1991, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation/Feasibility Study (RI/FS) process has been ongoing at WAG 7 to address the wastes buried at the SDA. With that process currently moving into the feasibility study phase, evaluations of retrieval options for the soil and buried waste at the SDA are needed for the feasibility study to progress. This report has been prepared to research and explore retrieval alternatives of the TRU waste in the SDA, with the goals of:

1. Describing the buried waste at the SDA

2. Identifying technologies that may be used to retrieve soil and buried TRU waste

3. Identifying retrieval technologies at other sites that may apply to the SDA

4. Identifying issues for the effectiveness and implementability of retrieval actions at the SDA.

1.1 Description of Buried Wastes

The following information describes the disposal practices at the SDA. The interval definitions described below are based on descriptions of disposal practices and waste received during the period. The information was derived from the WAG 7 *Preliminary Evaluation of Remedial Alternatives* report (INEEL 2002).

1.1.1 Disposals from 1952 to 1959

The original National Reactor Testing Station (NRTS) Burial Ground, now known as the SDA, was established for disposal of solid waste in 1952. The facility was managed and operated by the U.S. Atomic Energy Commission (AEC) Site Survey Branch. Trenches 1 through 10, excavated between 1952 and 1957, average 1.8 m (6 ft) wide, 900 ft (274.3 m) long, and 13 ft (3.7 m) deep. In 1957, Pit 1 was excavated to dispose of large bulky items. The facility was expanded in 1958 to its current size.

Disposal practices at the SDA classified waste as either routine or nonroutine. Routine solid waste, defined as waste with exposure rates within daily occupational limits, was packaged in cardboard boxes and typically consisted of paper, laboratory glassware, filters, metal pipe fittings, and other items contaminated by mixed fission products. The boxes were taped shut and collected in dumpsters that eventually were emptied into the trenches in the burial ground. Nonroutine waste, defined as waste that could exceed personnel exposure limits, was placed either in wooden boxes or in garbage cans. Special transport containers and vehicles hauled the waste to the disposal site. Before 1957, the radiation level was not limited for any disposal and items registering up to 12,000 R/hr were buried. Both routine and nonroutine waste was covered with soil; nonroutine waste was covered immediately, but routine waste boxes could be left exposed until the end of an operating week.

From 1954 to 1957, the SDA also accepted waste shipments for permanent disposal from the Rocky Flats Plant (RFP) under the authorization of the AEC. The RFP TRU waste, packaged in drums or wooden crates, was stacked horizontally in pits and trenches along with INEEL generated low-level mixed fission product waste.

1.1.2 Disposals from 1960 to 1963

From 1960, the SDA accepted approved shipments from off-Site generators, in addition to the RFP and INEEL waste for disposal. From 1960 to 1963 when the Interim Burial Ground Program was active, Trenches 16 through 25 and Pits 2 through 5 were open for waste disposal. The trenches received some mixture of stacked or dumped RFP TRU waste, INEEL waste, and off-Site waste. Beginning in November 1963 and continuing until 1969, drums from the RFP were dumped into pits rather than stacked to reduce labor costs and personnel exposures.

1.1.3 Disposals from 1964 to 1969

By the mid-1960s, concern about the environmental impacts of waste disposal significantly influenced waste management practices. Modifications to procedures for permanent interment included increasing the minimum trench depth from 0.9 to 1.5 m (3 to 5 ft), lining the bottoms of the trenches with at least 0.6 m (2 ft) of soil underburden, compacting the waste by dropping a heavy steel plate on the waste dumped in trenches, and increasing the cover over each disposal area from a minimum soil cover of 0.6 to 0.9 m (2 to 3 ft). These modifications were implemented between 1964 and 1970. In addition, TRU disposal was discontinued in 1969. Instead of burying TRU waste, the containers were retrievably stored by stacking them aboveground.

To facilitate the evaluation of retrieval technologies, generic cross-sections of the waste types buried in the pits, trenches, soil vault rows, Acid Pit, and Pad A are presented in Figure 1. Figures 2 and 3 show the practices during the 1960s of wastes being placed in the trenches and pits.

1.2 Retrieval Action General Considerations

As a remedial action, retrieving low-level radioactive and hazardous soil and buried waste from a site offers a number of benefits. For some sites, retrieval may be the only technology available that can achieve the goals established for remediation. Removing the waste from a site allows treatment to reduce the toxicity and mobility of many chemicals and reduce the volume of waste. Once removed, the material can be repackaged into safe, approved containers and managed in accordance with regulatory requirements. Consequently, retrieval at best removes the residual risk from the site (when the material can be disposed off-Site or treated to destroy or stabilize hazardous constituents) and at least reduces the magnitude of risk by implementing engineered controls. Typically, after retrieval is complete, the site can be backfilled with clean soil and returned to use by human and ecological users.

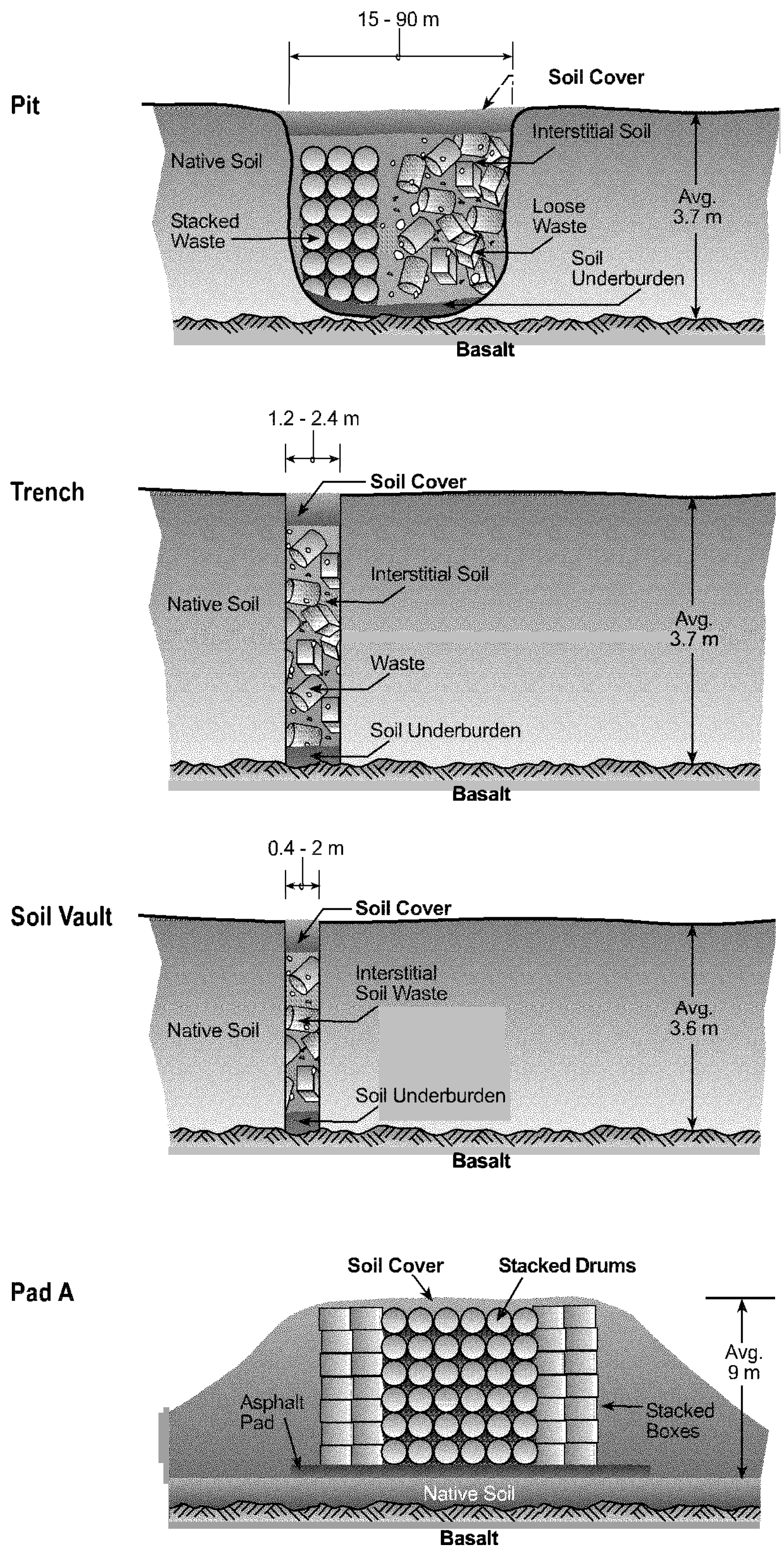

Figure 1. Generic cross section of waste sites.

Figure 2. Trench disposal practices.

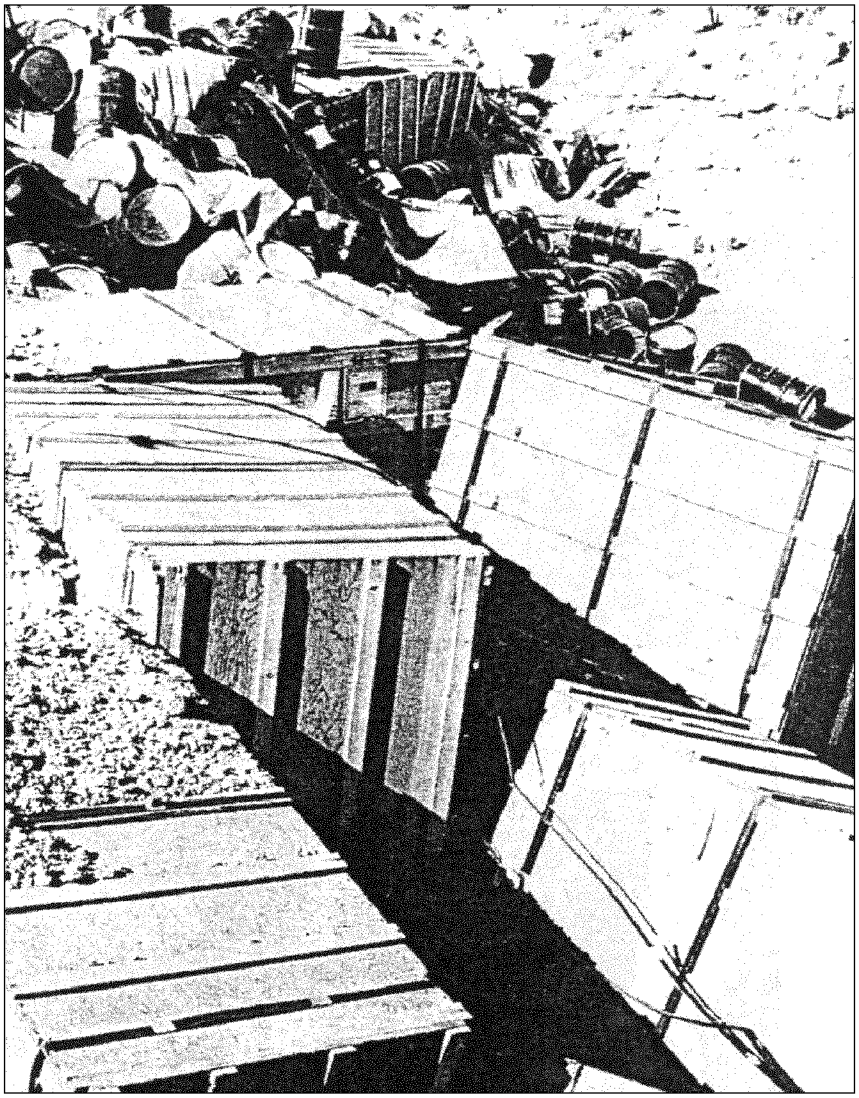

Figure 3. Pit disposal practices at Pit 10.

The design and construction of a retrieval system would be multifaceted and would have to account for the numerous controls required to mitigate the threat of exposure and release. Several systems designed for highly contaminated environments have been demonstrated and are available. Methods of contamination control include Moducon structures, strippable coatings, aerosol fogs, and ventilation systems. Technologies that may be applied to the excavation procedures include pressurized air cabins, shielded equipment, and remotely operated vehicles. Though individual technologies designed for highly contaminated areas are available, the design and construction of the system would have to be comprehensive and may require small retrieval tests before full-scale operations.

For large-scale excavations in radioactive environments, the process of retrieving the wastes will be affected and slowed by specific safety requirements. In the case of TRU wastes in particular, the multiple controls required to protect workers and treatments to dispose of the material can significantly slow progress. A typical process flow diagram for retrieval of TRU waste in the SDA, presented in

Figure 4, shows the numerous activities required during retrieval actions. Many of these activities take time to accomplish, and preparing an excavated item for disposal can take days to months. For the duration of the retrieval activities, the risk of exposure and contamination spread must be mitigated and controlled.

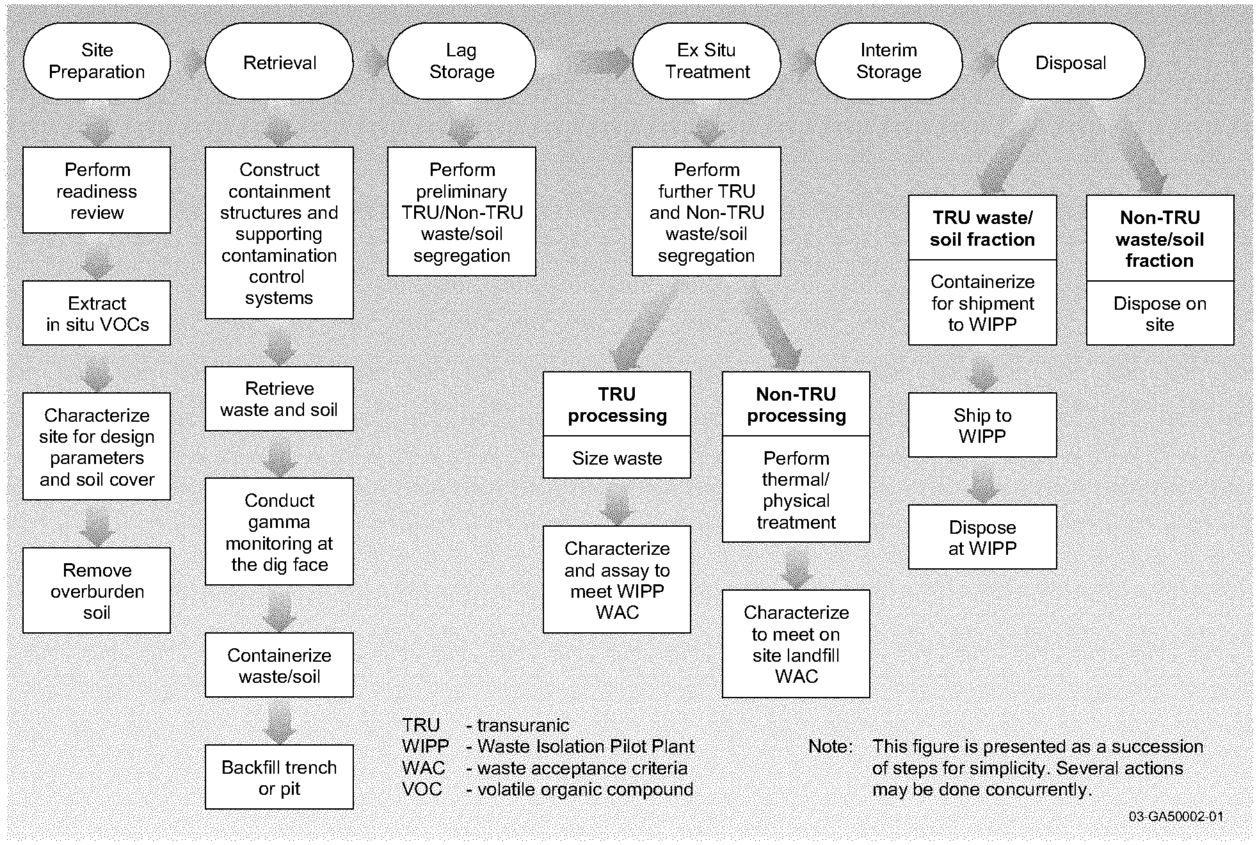

Figure 4. Waste retrieval, treatment, and disposal process flow diagram.

Both TRU and non-TRU waste could be generated from a retrieval action at the SDA. TRU material would be shipped off-Site and consideration should be given to the amount of characterization required to meet applicable Waste Acceptance Criteria (WAC), the number of shipments on the highways or railroads, and the capacity of the disposal site. Transporting the waste to a disposal facility increases the potential for human exposure and spread of contamination, though this risk can be managed. In the case of large-scale excavations involving TRU waste, the cost to characterize, package, and transport all retrieved waste for off-Site disposal may be significant. To reduce costs, on-Site treatment and disposal of non-TRU waste in a specially constructed engineered facility is anticipated.

2. TECHNOLOGY DESCRIPTION

A number of technologies can be used to retrieve soil and buried waste, including conventional heavy excavation equipment, hermetically sealed manually operated heavy excavation equipment (e.g., with a sealed and pressurized cabin with either supplied or filtered air), and remote-operated equipment and controls. Standard heavy construction equipment comprises most of the equipment used for excavation of soil and buried waste. This equipment has been proven at hazardous and radioactive wastes sites across the nation. Therefore, this report focuses on excavation equipment and remote technologies that may be required for waste retrieval actions at the SDA.

The radioactive and chemical materials present in the SDA pose a significant potential for airborne release and exposure to remediation workers Additionally, past retrieval efforts indicate these materials are difficult to control during retrieval actions. Of primary concern is the retrieval of TRU, reactive, and hazardous waste.

Table 1 describes some conventional heavy excavation equipment and remote technologies and their potential applicability to the SDA. This list is not meant to be all-inclusive and other equipment may be available. More detailed descriptions of the technologies in Table 1 can be found in *Survey of Materials-Handling Technologies Used at Hazardous Waste Sites* (EPA 1991), *Hot Spot Removal System, System Description* (INEEL 1997), and *Technical Alternatives Baseline Report* (BHI 2000).

Table 1. Description of waste retrieval equipment.

Technology	Description	Applicability to SDA
Standard Construction Equipment		
Backhoe	Crawler-mounted or tire-mounted subsurface excavators capable of digging small areas, with a typical bucket size of 1.5 m^3 (2 yd^3). Auxiliary equipment can include a clamshell bucket, drum grapplers, dippers, loader buckets, and hammers.	Useful for trench digging and area excavation up to 13.7 m (45 ft) depth; linear reach less than 30.5 m (100 ft).
Front-End Loader	Crawler-mounted or tire-mounted excavators capable of digging, lifting, dumping, and hauling materials. Bucket size is up to 15 m^3 (20 yd^3).	Applicable for excavating large areas with short travel distance requirements (less than 91 m (300 ft).
Bulldozers	Crawler-mounted tractor with a blade and bucket for surface work.	Applicable for removing surface layers, clearing surface debris, and general earth moving. Not useful for buried waste retrieval.
Trencher	Wheeled excavator capable of excavating and grading. Commonly referred to as a ditch witch; can be accessorized with a backhoe, backfill blade, auger, and remote handling devices.	Applicable for small-scale digging.
Vacuum/Soft Trencher	Vacuum removal of soil without disturbing large debris. Can use jetted air to loosen soil before vacuum removal.	May be used to remove loose soil at the digface. Not effective in retrieving buried waste.

Table 1. (continued).

Technology	Description	Applicability to SDA
Soil Skimmer	Removal of thin layers of soil in a controlled manner.	Applicable for removing thin layers. Not effective in retrieving buried waste.
Skid-Steer Loader	Excavator similar to a front-end loader, but usually smaller in size. Commonly referred to as a Bobcat.	Applicable for small-scale excavation, drum loading and transport, material handling, and site preparation. Not useful for buried waste retrieval.
Remote Excavators		
Brokk	Remote-controlled excavator with telescoping arm capable of full articulation. Available with several different end-effectors that could be used for hammering, cutting, and scooping wastes. The largest Brokk can reach approximately 4 m (13 ft) below ground surface (bgs).	Applicable for soil and buried waste at the SDA. Demonstrated and used at Hanford for remote retrieval of high-dose debris from the F Reactor fuel storage bin and at INEEL for demolition projects.
Kiebler Thompson	Remote-controlled excavator with telescopic boom capable of moving in three dimensions. Available with several end-effectors. The largest Keibler Thompson machine can reach approximately 5 m (16 ft) bgs.	Applicable for soil and buried waste at the SDA; similar to the Brokk.
Remote-Operated Excavator	Excavator mounted on a wheeled undercarriage that was developed to retrieve unexploded ordnance. A television provides images for remote excavation. The only such excavator is currently used at an Air Force base.	Though this excavator may not be available for use at the SDA, the concept and design may be applied.
T-Rex (front shovel excavator that would require modification for use)	A tele-operated, heavy-lift, long-reach excavator designed to retrieve boxes, drums, and containers with a front shovel excavator. Controls can be operated up to 381 m (1,250 ft) from the excavator.	Applicable to SDA buried waste that can be removed by front shovel excavators. Modifications would be necessary for backhoe end-effector operation. Developed at INEEL.
Front-End Loader (with a 2.75 yd^3 bucket)	Remote control developed for use on a front-end loader. Provides 3-dimensional color video/audio feedback that can be controlled from 457 m (1,500 ft) away. System could be modified for use on excavators.	Applicable to front-end load operations. May be modified for backhoe excavators, though this adaptation has not yet been developed.
Teleoperated Excavator (using T-Rex Remote Control Kit)	Remote-controlled excavator (bucket and thumb) adapted for hazardous environments such as unexploded ordnance (UXO) using sensors, controllers, and hydraulic components.	Applicable to the SDA buried waste; can be used to dig, trench, and cut.
Automated Ordnance Excavator	Remote-controlled excavator with extended reach capability, developed for UXO removal. Can grasp objects such as drums and boxes.	Applicable for soil and buried waste at the SDA.
Small Emplacement Excavator	Military tractor with front-end loader and backhoe remote operation for retrieving buried waste and soil. System can be controlled from 0.8 Km (0.5 mile) away.	Applicable for soil and buried waste at the SDA.

Table 1. (continued).

Technology	Description	Applicability to SDA
Remote Excavator, Hitachi Excavator, Innovative End-Effector (IEE), and Self-Guided Transport Vehicle	Standard excavator with end-effectors (such as buckets, rippers, and breakers) used for buried waste retrieval. System can be controlled inside cab, via a remote tether or from 762 m (2,500 ft) away.	Applicable for soil and buried waste at the SDA. Demonstrated at INEEL.
Modified Bobcat	Remote-controlled skid steer loader with a Bobcat vehicle base with barrel grapple, sweeper, and bucket attachments. Modified for hazardous environments, remote kit for other excavators.	Small excavator capable of retrieving soil and buried waste at the SDA. Control system can be applied to larger excavation equipment.
Standard Construction Equipment With Modifications		
Sealed and Pressurized Cabin, with Filtered Air Intakes and Extracts	Standard construction equipment with modifications made to the cabins. The sealed and pressurized cabin utilizes filtered air (through high-efficiency particulate air [HEPA] filtration).	Applicable for soil and buried waste at the SDA, especially in the TRU environments where worker protection from the source material is necessary.
Sealed and Pressurized Cabin, with Supplied Air	Standard construction equipment with modifications made to the cabins. The sealed and pressurized cabin utilizes supplied air.	Applicable for soil and buried waste at the SDA, especially in the TRU environments where worker protection from the source material is necessary.
Remote Controllers		
Remote Control Kit for Gantry Crane or Excavator	Remote control technology that can operate any track-size mounted excavator or gantry crane at a distance of 1.6 Km (1 mile) away.	Applicability is related to excavation equipment selected for retrieval.
Compact Remote Operator Console	Fully functional control system that can operate remote equipment. Adaptable to a variety of robotic and remote systems.	Applicability is related to excavation equipment selected for retrieval. Has been deployed at INEEL.
Coordinated Motion Control	Control system for hydraulic equipment such as excavators and backhoes.	Applicability is related to excavation equipment selected for retrieval.
Remote Kit for Excavators (developed and implemented on dozer)	Remote control technology that was developed to control the end-effectors and driving functions of a dozer. Not field tested.	May be applicable to excavation equipment, but is not proven.
Remote Cranes		
Cooperative Telerobotics Retrieval System	System consists of an 24.4 m (80-ft)-wide girder, two trolley assemblies with vertically telescoping masts, two manipulators, trolley, and a 5-ton hoist that operates remotely.	Unit is at the INEEL.
RoboCrane	Cable-driven platform for a parallel link manipulator. Provides load control via teleoperative, graphic off-line programming, and hybrid control modes.	In advanced development stage.
Swing Free Technology for Controlling Cranes	Operation of a gantry crane without large swinging motions.	Proven on a 30-ton crane. Unknown adaptability on other crane sizes.

Table 1. (continued).

Technology	Description	Applicability to SDA
Remote End-Effectors		
Safe Excavation	High-pressure probe dislodges compacted soil, other hardened materials using an air-jet/vacuum end-effector system. Vacuums up soil.	Usable system to break up and remove soil.
2-Armed, Tethered Hydraulically Powered Interstitial Conveyance System	Crane-deployed with two excavators and vacuums designed for low-level radiation fields. Maximum pickup load of 317 Kg (700 lb).	Used in conjunction with a gantry crane for selective retrieval.
Tentacle, Highly Manipulative	Teleoperated manipulator and bellows actuator.	Used with a crane and manipulator. Limited load capabilities (less than 1814 Kg (4,000 lb).
Hydraulic Impact End-Effector	Water cannon for tank applications attached to a robotic manipulator arm and used to break up monolithic hard cake forming around risers in tanks.	Used for tanks; resulting mud/sludge is not separable. More design work is needed.
Schilling Tital II	Manipulators deployed by crane for selective retrieval. Basic components include hydraulic system, positioning system, electronics module, and mechanical interface.	Must be deployed from a crane. Manipulators used for retrieval of barrels from soil.
Mineclaw	Manipulator with strong electromagnet to pick up barrels. Custom grapple with a several hundred pound payload and an electromagnet to retrieve metals.	Must be deployed from a crane. Used for barrel retrieval. Not usable on soil; not able to lift 1814 Kg 4,000-lb load.
Confined Sluicing End-Effector	Water-jet designed for waste tank cleanout. Uses high-pressure water-jets to cut material into small pieces and evacuates with a vacuum jet pump. Captures slurry water.	Water-jet would create additional waste. Other units capable of removing soil without additional waste.
Soil Skimmer	Skimmer removes soil overburden in 3-, 4-, and 6-in. increments. Adjustable depth controls the depth of cut without disturbing soil underneath.	Used for removal of overburden. Can be used with other excavators.
IEE	Consisting of three assemblies—a thumb, an attachable/detachable integrated transfer module, and a shovel assembly—capable of soil retrieval and dust-free waste dumping.	Viable method of retrieval for the soil. Use of soil stabilizers would control dust upon dumping.
Couplers, Quick-Change	Available in manual and hydraulic versions. Used on a variety of buckets, rakes, clamps, rippers, and other end-effectors.	May require the use of sizing equipment and end-effectors. Allows for remote changeouts.
Vacuum Systems	Nuclear-grade vacuum systems for contamination control and retrieval of soil with HEPA filtration and critically safe waste-containers.	Usable to extract dust/debris, but not for large areas.

HEPA= high-efficiency particulate air
IEE= Innovative End-Effector
INEEL=Idaho National Engineering and Environmental Laboratory
SDA=Subsurface Disposal Area
TRU=transuranic

2.1 Selection of Retrieval Technologies

The selection of retrieval technology will depend on the remediation requirements established at the site. Each piece of equipment has unique characteristics that make one more desirable than another for certain applications. Table 2 lists the general issues and related factors to be considered in the selection of technologies for the SDA.

Table 2. Factors in the selection of retrieval technologies.

Issue	Factors
Site Specific	Debris characteristics (debris type—metals, plastic, construction, boxes, drums, tanks, pipes, etc.; size—length, width, etc.)
	Waste characteristics (solid, liquid, sludge, chemicals, and associated hazards)
	Weight bearing capacity of the waste
	Extent and rate of waste decomposition
	Density of the waste site
	Extent of excavation (area and depth)
Equipment Specific	Purpose of equipment
	Weight of equipment
	Transportation requirements
	Available attachments, end-effectors
	Ability to inspect, maintain, service equipment
	Availability of equipment (lease, purchase, or design-construct)
	Production rate requirements
	Cost
Specific to the Determination of Selecting Remote Technology	Exposure potential to equipment operators and site workers
	Potential for explosion
	Potential for criticality
	Potential for fire
	Potential for spread of contamination
	Unknown conditions

The use of conventional construction equipment has proven reliable in the past during the retrieval of radioactive materials. However, the type of equipment selected must correspond to the needs of the project. The Equipment Selection Cold Test, a technology development project funded by the U.S. Department of Energy (DOE) and coordinated by the Buried Waste Integrated Demonstration Project, illustrates the process used to select conventional types of equipment. This study focused on the performance of field tests to determine the effectiveness of employing conventional construction equipment to retrieve buried TRU wastes (Valentich 1993). The test evaluated six pieces of equipment to select the most applicable technology for buried waste retrieval and consisted of a 841 m^3 (1,100 yd^3) cold (nonhazardous and nonradioactive) test pit constructed at the Caterpillar, Inc. Edwards Training Center near Peoria, Illinois. The pit was filled with containers packed with simulated waste (e.g., metals, plastics, wood, concrete, and sludge) and large objects such as truck beds, tanks, vaults, pipes, and beams like those disposed at the SDA. A series of commercially available excavators and loaders outfitted with different end-effectors were used to retrieve the simulated buried waste. Table 3 summarizes key goals and findings of the test.

Table 3. Objectives and conclusions of the 1993 equipment selection cold test.

Objective	Conclusion
Evaluate the effectiveness of the full-scale equipment and end-effectors chosen for retrieving buried waste forms typical of buried TRU wastes at the INEEL and other DOE sites.	Full-scale equipment is effective in retrieving buried wastes in forms that are typical at INEEL.
Retrieve an average of 61 m^3 (80 yd^3) per day of simulated buried waste.	The average production rate was nearly 306 m^3 (400 yd^3) per day, but if the equipment was remotized, retrieval rates could be reduced by 50% (153 m^3 or 200 yd^3 per day). Remotization was not field-tested.
Minimize the spread of dust during excavation.	Dust generation was minimal since the soils were fairly moist. Using the thumb end-effector to control/grip material would also help to minimize dust generation.
Determine whether removal of buried waste from belowgrade or abovegrade is more productive.	Both positions were equally productive, but operators preferred the belowgrade position because of enhanced visibility, less risk of digface collapse, and increased safety and feasibility when large objects were removed.
Determine volume rate of retrieval for different waste orientations.	Rates of retrieval were presented in the report.
Determine the correct suite of end-effectors to retrieve buried waste.	The Balderson thumb end-effector on the 325L excavator was preferred over other end-effectors.
Determine how well the technology lends itself to remotization.	Technology to remotize the 325L excavator is currently available.
Produce a rough order-of-magnitude cost to remotize equipment.	The 325L excavator could be remotized in 1993 for a cost of $1,000,000.
Determine whether the use of a closed-circuit television could enhance and improve operator views in the work area.	Information gathered during the test could be used to develop this technology.

Overall, this test proved that buried waste could be retrieved using conventional equipment and end-effectors, and also indicated that such equipment could be remotized. Further tests using personnel-operated equipment were not conducted, and focus was later put on developing remote control technologies.

3. SUBSURFACE DISPOSAL AREA RETRIEVAL EVALUATION

Many sites have used remote excavators and end-effectors when explosion hazards exist or when the condition of the buried waste containers or sources is unknown. Other sites have modified standard equipment so a person in a sealed environment can operate the equipment. Of the retrieval case studies available, 13 demonstrations, studies, and applications performed at different facilities were selected for evaluation based on their similarities to conditions or issues presented by the SDA. These include:

- The Los Alamos Area P Material Disposal Area Retrieval: An activity conducted for a site at the Los Alamos National Laboratory that used remote equipment to retrieve various types of waste, including high explosives-contaminated equipment and materials, uranium, metals, volatile organic compounds (VOCs), and semivolatile organic compounds.

- The Sandia Landfill: A retrieval action at the Sandia National Laboratory for radioactive and weapons-generated waste materials conducted remotely with a combination of conventional and remote equipment.

- Rocky Flats Trench 1: A retrieval activity at the RFP for soils, drums, and debris contaminated with uranium and uranium products performed with conventional equipment.

- Hanford 618-4: Partial remedial activity for a single pit at Hanford, with uranium from unknown origin identified as the primary contaminant.

- Fernald Waste Pits: A retrieval action at the former uranium-processing facility for low-level radioactive waste containing uranium, thorium, and other contaminants.

- The INEEL Solid Radioactive Waste Retrieval Test: A test performed, in part, to determine the techniques required and costs incurred to retrieve contaminated waste containers.

- The INEEL Initial Drum Removal: A demonstration of retrieval, repackaging, and interim storage placement methods for pits containing radioactive waste in stacked drums.

- The INEEL Early Waste Retrieval: A project implemented to retrieve the oldest buried waste at the SDA, with all retrieval operations conducted from an operating area confinement structure.

- INEEL Full-Scale Design to Retrieve Waste at the SDA (Early OU 7-10 Staged Interim Action Project Design): In the late 1980s a group of EG&G and DOE-ID personnel prepared a design for retrieval of Pit 9 (Schofield 2002). After approximately 2 to 3 years, funding was withdrawn. The project was in the preliminary design phase at the time the project ended.

- The INEEL OU 7-10 Staged Interim Action Project Design: A three-stage remediation plan designed to retrieve a small volume of waste (stage II requires retrieval of 200 yd^3 of buried waste and Stage III requires the retrieval of an entire pit) from a TRU and hazardous waste environment.

- Maralinga Rehabilitation Project: This project was implemented from 1996 to 2000 to remediate soils contaminated with plutonium, americium, uranium, beryllium, and other radioactive materials. Remediation activities primarily consisted of removing contaminated topsoil and burying it at depth on-Site. Cabin and engine compartment modifications (sealed and pressurized, with filtered air) to all the soil removal and monitoring equipment were made.

- Calvert City Project: A project that involved soil and sludge remediation of pits containing vinyl chloride. Because of the hazardous characteristics of vinyl chloride, the excavation equipment (large trackhoes) were modified to provide better protection to the operators. This modification included sealing and pressurizing the cabins and supplying them with air from tanks attached to the equipment.

- Weldon Spring Quarry: A retrieval of bulk waste, including radioactive contaminants remaining from the operation of the former uranium materials plant.

Descriptions of these case studies can be found in Appendix A, which also includes a summary table of technologies used in each of the case studies. The information provided by these case studies reflects a limited experience with excavating buried TRU waste, yet indicates that progress is being made in technology application.

3.1 Effectiveness

Retrieving soil and buried waste at the SDA would be effective in achieving remedial action objectives (RAO) and providing for the long-term protection of human health and the environment. However, implementation of the retrieval action itself has the potential to significantly impact human health and the environment. For this remedial action to be effective, several technologies and controls will need to be implemented. Based on a review of demonstrated retrieval actions (summarized in Appendix A), many of the retrieval technologies that will be needed are available. Before some of these technologies can be evaluated for effectiveness in excavation of SDA waste, field tests, mock tests, and/or a small retrieval test may be required before full-scale retrieval is undertaken. Careful consideration should be given to the protection of workers, the public, and the environment because of the potentially significant impacts on human health and the environment. As described in Section 1.2, waste retrieval could pose a risk from inhalation of radioactive and hazardous substances. Controls will be required to prevent inhalation of wastes and radiation exposure to personnel.

Most of the required equipment or technologies to perform a retrieval action have been proven in highly contaminated environments. For example, remote excavators have been proven successful in waste retrieval simulations and have been used at DOE facilities for decontamination and decommissioning . In addition, shielded excavators also have been successfully used at Hanford, and hermetically sealed vehicles have been used at Maralinga. Risks to the maintenance personnel who regularly enter the contaminated work area to work on the retrieval equipment (Sykes 2001) must be controlled. Technologies and designs are available that allow retrieval equipment to be driven into a maintenance area, which could provide a more protected environment. Entrance into the contaminated work area for the retrieval equipment should be limited to nonroutine activities to control this risk. Hermetically sealed retrieval equipment has been proven reliable in highly contaminated environments and, when compared to remote equipment, they are generally less expensive, have fewer maintenance issues, dig more precisely, and can be operated faster (Sykes 2001). In some instances within the SDA, shielding would be required on the equipment, such as Lexan windows with protective film layers, to protect the worker from beta and low energy gamma radiation being emitted from the source. Filtered or supplied air can also be added to the equipment to protect the operator. This has been proven at many sites, including Maralinga and Calvert City. These types of systems may be needed to achieve a production rate that meets the RAOs. Several factors that decrease the production rate of retrieval equipment include the following (Sykes 2001):

1. Remote technologies
2. One piece of equipment to dig, size, and sort
3. Unexpected conditions.

Several factors that increase the production rate of the retrieval equipment are (Sykes 2001):

1. Larger bucket sizes
2. End-effectors readily available for changing operations
3. More than one retrieval operation in progress
4. Second piece of equipment for sizing and sorting.

To meet the RAOs, several types of equipment may be used at the digface, such as an excavator to dig the waste, a sizer/sorter/cutter, and a front-end loader to scrape soil and move material. The amount of segregation and sizing performed at the digface should be weighed against the need to minimize material handling, thereby controlling contamination spread and protecting the worker. Large-sized objects, such as tanks, trucks, and casks, can be sized using large size cutters or plasma arc. If this type of action is not desirable at the excavation, these objects can be moved to the side, worked around, or stabilized, or contamination can be fixated until the object can be handled.

3.2 Implementability

Retrieval technologies are readily implementable at the SDA—they are available, reliable, and proven in hazardous environments. Effort would be required to obtain agreement among necessary parties to retrieve, treat, transport, and dispose of the waste because an administrative process has not yet been established. However, public records show agency and stakeholder preference for retrieval of the SDA waste. Presently, it is not known if there will be adequate capacity at an off-Site facility to dispose of the TRU waste generated in a retrieval action. This would be better defined when waste streams from a retrieval action are determined, technologies are further developed, and treatment performance is known. A retrieval action may need to include provisions for long-term on-Site storage until treatments are developed to handle the material to meet WAC or until a disposal facility is available to accept the waste.

In all likelihood, the equipment required for a retrieval action would have to be modified for this project, given the nature of the waste and site conditions. Examples of the necessary equipment include remote or hermetically sealed devices, containment structures, ventilation systems, contamination control devices, treatment units, and packaging facilities. Examples of modifications to retrieval equipment include adding HEPA filtration to an engine for contamination control or supplied air to the cab of the equipment for personnel protection. Training the workers would be required to implement this alternative; however, it is expected that the equipment and training would be readily available.

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Appendix A

Detailed Retrieval Case Histories

Appendix A

Detailed Retrieval Case Histories

Remote retrieval technologies have been demonstrated under hazardous conditions at numerous sites across the U.S. However, there is no reported experience with remote retrieval of transuranic (TRU) and radioactive buried waste, especially under conditions similar to those within the Subsurface Disposal Area (SDA) at the Idaho National Engineering and Environmental Laboratory (INEEL). Thus far, buried radioactive waste retrieval has been accomplished with manually operated construction equipment, some of which has been modified to protect the operator.

The following case studies summarize the work done to date with different excavator equipment to retrieve buried radioactive waste. Descriptions of the contamination control devices used in these studies are presented if available. In addition, Table A-1 compares the technology applications at each site.

Los Alamos Retrieval

The Area P Material Disposal Area (MDA-P) in Technical Area 16 (TA-16) is located in the southwest corner of the Los Alamos National Laboratory in New Mexico. The land has acquired by the Department of Army for the Manhattan Project in 1943.

The MDA-P was in operation from 1950 to 1984, receiving materials from the burning of high explosives (HE), HE-contaminated equipment and material, barium, nitrate, construction debris from Manhattan-era buildings, as well as empty drums, miscellaneous containers, trash, and vehicles. Chemicals of concern at this site include various types of HE, HE impurities and degradation products, uranium, metals (especially barium), volatile organic compounds, semivolatile organic compounds, and cyanide. Waste retrieval at the MDA-P is completed.

To mitigate the dangers of a detonation during the landfill excavation, all initial excavation operations were mandated to be performed remotely. Boissiere Engineering and Applied Robotics (BEAR) Inc. developed and deployed a Hybrid Remote Robotic Manipulation and Excavation System (HERMES) for the landfill excavation.

HERMES consisted of a 62,000-lb computer-controlled tracked excavator coupled with a hydraulic manipulator. The configuration allowed the excavator to remotely execute conventional excavation operations such as overburden and debris removal in the landfill. The excavator was controlled from a remote operator console that received and transmitted data to and from the system via multiple communication channels. Multiple on-board cameras were used to facilitate remote operations, including excavation and robot manipulation. Containment structures were not used—the primary threat to human health during construction was from external radiation exposure and explosive detonation (rather than from contamination spread like that of the SDA). These controls were adequate for operation, and the remote excavator successfully retrieved the buried waste.

Table A-1. Retrieval technologies implemented for case histories.

Technologies		Site Case History												Proposed
		Fernald	Maralinga	Calvert City	Rocky Flats	Sandia Chemical Waste Landfill	Sandia Classified Waste Landfill	Sandia Radioactive Waste Landfill	Initial Drum Retrieval	Los Alamos	Early Waste Retrieval	618-4 Burial Ground	618-10 Burial Ground	WAG 7 Retrieval
Contamination Control	**Pre-Treatment**						Unknown to be completed in 2003						Paraffin injection system	VOC extraction
	Dust Suppression **Source Control**	Water, Con Cover	Water, monitored wind direction		Water				Weather shield		Water	Water	Water	wetting agents fogger absorbent material wetting agents
	Decontamination	Water, Truck Wash			HEPA Filter System	Power wash			Air support		HEPA filter system	Crusting agent	Wetting agents	strippable coatings Water Fixatives
	Containment structures	NA			Tenting	Plastic sheet covering over pit Tent for separation and sorting area			Peda Guard II Sealant Absorbent		Bonding Agent Operating Area Confinement Fabric blanket Absorbent Rug	Frisking Tent	Spray on Covering Grout Inflatable building Plastic barrier sheets Vacuum systems Sealants Staytex (prefabricated bid) Fabric covered building	Spray on covering double containment moveable barriers air locks sealants
Retrieval Equipment	**Excavator**	Excavator, dump trucks, back hoes, bull dozers	Scrapers and bull dozers with pressurized and sealed cabins and filtered air	Large track hoes with pressurized and sealed cabins and supplied air	Track mounted excavator Back Hoe Front End Loader	Excavator Track Hoe Bucket Front End Loader	Excavator Back Hoe Robotic Arm on a Back Hoe	Excavator Track Hoe Robotic Arm on a Back Hoe	Scraper Bull Dozer Drott Excavator	HERMES (Hybrid Remote Robotic Manipulation and Excavation System)	Earth Scraper Back Hoe	Grizzly Apparatus Excavator Bucket Toothless Excavation Bucket Front End Loader Track Hoe w/ thumb	Track Excavator Back Hoe Sonsub (soil skimmer) Track Hoe w/thumb	Manned Backhoe Numerous end-effectors dozer gantry crane
Physical Treatment	**Sizing**										Waste Compactor			cutting, grapple
	Sorting	Sorting, crushing, shredding			Sorting	Mechanical Sorting Screen	Sorting Separating				Hydraulic Cutter	Sorting		sort soil from debris via end-effectors
Characterization	**In situ character.**													Soil cover for release
	Sample collection	Sample collection, lab analyses				Sample collection, on site lab								At treatment facility
	Non destruction analysis													TRU NDA at storage
Packaging	**Container**	Placed straight into rr cars, boxed and drummed waste included into rr car.			55 gallon drums	55 gallon drums 85-gallon drums 20-gallon poly tote					Plastic bags	55 gallon drums		temp. in soil bags 55-gallon drums waste bins

Sandia Landfill

The Radioactive Waste Landfill (RWL) ER Site 1 and Chemical Disposal Pits (CDP) Environmental Restoration (ER) Site 3 are located in the eastern portion of Technical Area II (TA-II) at the Sandia National Laboratory in New Mexico.

From 1949 to 1959, three pits and three trenches in the RWL received low-level radioactive waste. The unlined RWL pits were approximately 12 ft wide by 20 ft long by 25 ft deep, with no leachate detection or collection systems. Waste material disposed in the RWL mainly consisted of solids such as weapons components, irradiated and neutron-activated material, neutron generator parts, irradiated material from nuclear rocket tests, radium-beryllium neutron sources, thermal batteries, radioactive sources, laboratory-generated waste, and low-level waste material from nuclear reactor studies. The weapons components and waste material contained depleted uranium, thorium, tritium, cobalt, cesium, americium, and plutonium.

Small amounts of liquid waste were also present in the RWL. Chemical waste material included lead, thermal batteries, and nitric acid. Additional reported disposals included a Sandia Pulsed Reactor and tritiated waste from booster cylinders.

Reportedly, most of the waste was not contained before disposal, and the pits and trenches were covered with native soil and capped with 3 ft of concrete. Allegedly, a separate facility received all radioactive waste after March 1959, but one item removed from the landfill was dated 1978, contradicting this assertion.

The CDP was in use throughout the late 1940s and 1950s for disposal of chemical waste. The disposal pit was approximately 10 ft by 30 ft wide with an unknown depth. Unlined pits were not constructed with leachate containment or monitoring devices, and there were no records maintained of the pit locations, types and volumes of chemicals disposed, procedure of disposal, excavation of pits, or the exact length of time the pits were used.

In June 1995, the RWL and CDP combined to form one landfill site. Records show that an estimated 11,110 ft^3 of radioactive waste, with an estimated total activity of 2,847 curies, was buried in the landfill. This estimate does not include the native soil backfill.

In late 1996, voluntary remediation of the site commenced, as shown in the photograph of the excavation in progress in Figure A-1. The excavation removed roughly 9,400 yd^3 of soil; the retrieved waste included mixed and radioactive debris and radioactive soil. The tools and methods applied to the retrieval action included an excavator and a trackhoe, and sprung containment structures for fire and wind protection were used on-site.

A robotic arm, camera, and radiological meter were attached to the end of the operated backhoe when operators handled unknown radioactive material, not to excavate the material but to determine the radioactive concentrations. Once the site conditions were known, the manually operated excavator retrieved the waste. The site is currently awaiting approval to be backfilled.

Figure A-1. Sandia Landfill excavation.

Rocky Flats Plant, Trench 1

Operations at the RFP where the Trench 1 (T-1) burial ground is located, were involved with plutonium, depleted uranium, enriched uranium, beryllium, and stainless steel operations. The plant manufactured triggers for use in nuclear weapons and produced purified plutonium. The main source of waste deposited at T-1 consisted of depleted uranium chips. A photograph of the trench is shown in Figure A-2.

Conventional excavation techniques were used to remove the soil, drums, debris, and contaminated soils at T-1 (Kaiser-Hill 1999). Excavation equipment consisted of a track-mounted excavator, backhoe, and/or front-end loader. When drums containing depleted uranium were handled, an excavator bucket equipped to minimize spark-potential was employed.

To minimize exposure, the drums were removed one at a time, and site controls were instituted for both intact and nonintact drums. Located immediately adjacent to the excavation area, standard fire prevention and suppression techniques for pyrophoric-depleted uranium chips stood ready for use. A temporary structure designed to shed snow and withstand high winds and hail in accordance with applicable building codes and standards (e.g., Sprung Instant Structure) provided a weather shelter and sealed environment for operators performing excavation and treatment operations. The structure was constructed of flame retardant materials, with secondary containment for spill control, and was equipped with a high-efficiency particulate air (HEPA) filter system to control potential airborne contaminants.

The proposed accelerated action entailed excavating drums that contained depleted uranium chips in lathe coolant, associated soils with radionuclide activity that met or exceeded action levels, and other waste and debris from T-1. Materials were initially segregated as they were removed from the trench, and further segregated for potential pyrophoric content. Depleted uranium chips were stabilized by encapsulation in mineral oil or soil to address their potential pyrophoricity before shipment for off-Site treatment. Associated radiological contaminated soils above action levels were excavated, treated if necessary, and staged for off-Site disposal.

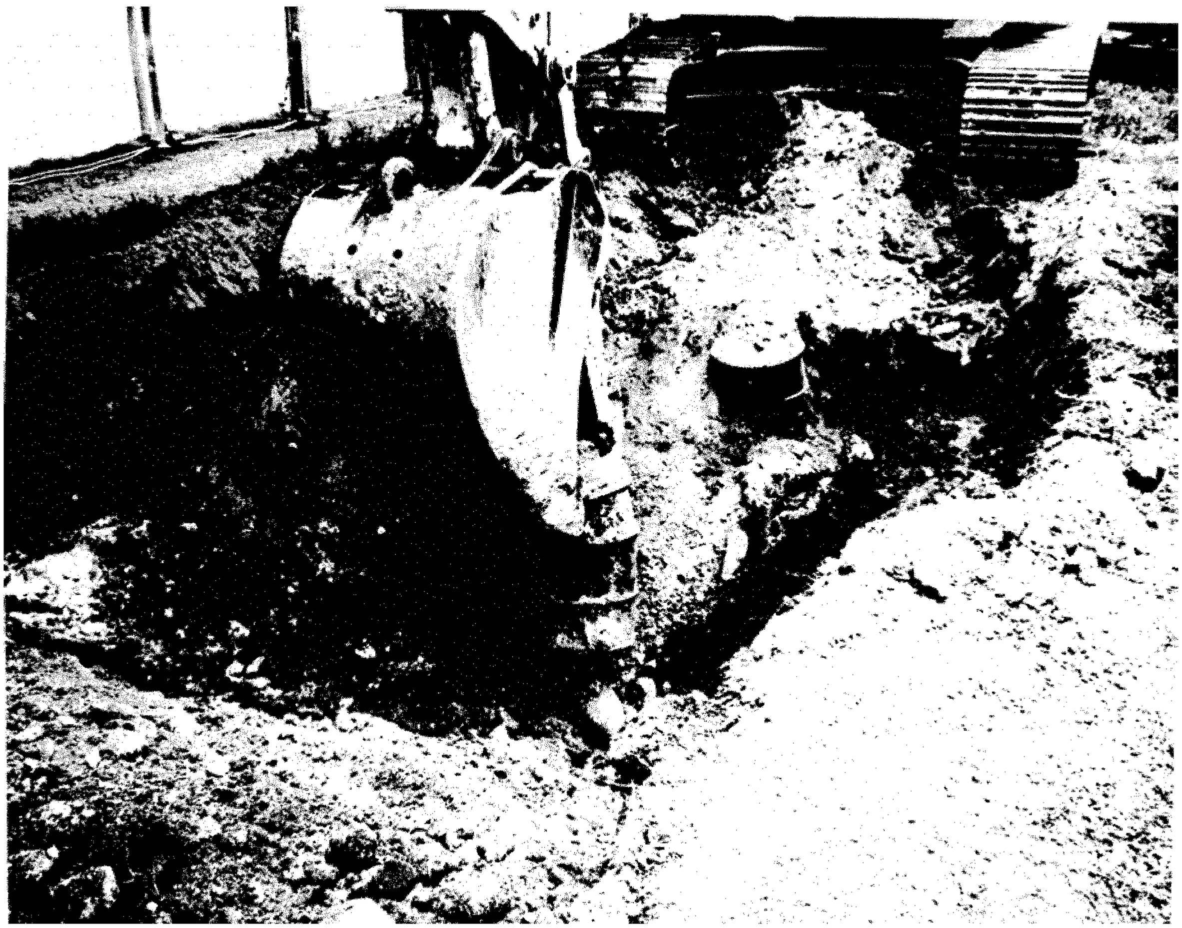

Figure A-2. Rocky Flats excavation.

Hanford 618-4

The 618-4 Burial Ground, located approximately 1 mile north of Richland, Washington, and 1,100 ft west of the Columbia River, is part of the remedial action activities at the Hanford 300 Area. Photographs of the excavation appear in Figures A-3 and A-4.

The 618-4 Burial Ground, a single disposal pit measuring approximately 105 ft by 525 ft, was believed to have operated as an official burial ground from 1955 through 1961. Test pit sample results identified uranium as the primary contaminant, consistent with available 300 Area process history, but little information exists to confirm the inventory and the source of waste deposited in the pit (BHI 1998). Investigations identified:

- Large amount of ferrous waste materials (based on geophysical surveys)
- Detectable concentrations of volatile organic compounds in soil gas samples
- Miscellaneous debris (e.g., contaminated pipe, scrap metal, salt-bath precipitate, rubber, pipe insulation, burnt wood, melted glass, asbestos, lead bricks) mixed with sand and gravel fill (observed during test pit excavation).

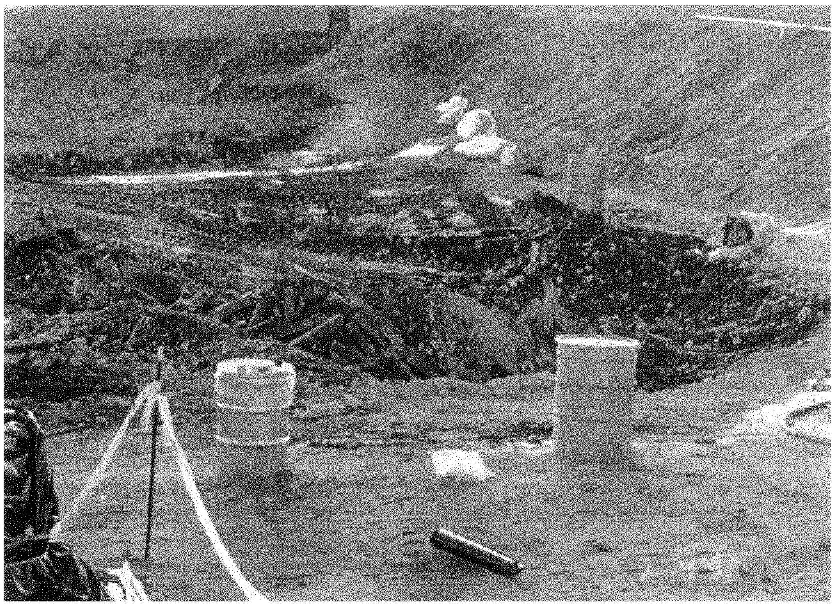

Figure A-3. Hanford 618-4 waste.

Figure A-4. Hanford 618-4 drums.

The 618-4 Burial Ground waste retrieval is not complete, as indicated by the photographs. Remedial action activities included removing the cover (topsoil and overburden) materials and retrieving the buried waste (BHI 1998).

A large number of drums were excavated from a central portion of the burial ground before activities ceased. To provide dust control during the period of inactivity, a crusting agent was applied to all of the soil surfaces and stockpiles (i.e., lead-contaminated soil, barium-contaminated soil, and lead debris) within the burial ground. Dust suppression during work operations typically involved applying water to the excavation areas using overland piping and a water truck. Efforts were made to minimize the amount of water necessary to maintain dust control and prevent the formation of puddles on applied surfaces.

A grizzly apparatus was initially used to sort waste material during the excavation process, but a field demonstration showed that alternate sorting methods were more effective and efficient.

The excavation employed a large excavator/bucket and a toothless (straight-edged) excavation bucket. The large excavator/bucket combination generally excavated material at a rate that exceeded the front-end loader capacity to fill haul containers. This enabled stockpiles to be made and screened before the load operation, and further permitted release/hold determinations to be made on each stockpile without affecting productivity. The toothless excavation bucket worked well to reduce the chances of tearing or puncturing anomalous waste items and containers. Additional excavation equipment included a John Deere front-end loader and trackhoe excavator with a thumb.

The presence of large quantities of anomalous waste materials postponed the remediation project. Equipment and personnel were demobilized from the site pending the disposition of the anomalous waste, and the excavation operations moved to another disposal site in May 1998. Demobilization was completed on May 5, 1998. Partial remediation of the 618-4 Burial Ground was performed safely without any lost-time injuries, though the cost of remediation was significantly greater than the original projection. The cost to complete the project was estimated at $1.9 M—approximately $3.04 M was spent to excavate 42% of the material projected in the initial design.

The primary lesson learned was that the project team had not anticipated the quantity and/or type of anomalous waste materials that were unearthed. A secondary lesson learned involved the inefficiency of the grizzly apparatus originally selected to sort waste material during the excavation process. Production time was also slowed when remediation of the burial ground was suspended on two occasions. The unexpected excavation of anomalous liquid waste material with unknown chemical hazards prompted the first suspension. On the second occasion, high winds that prevented the appropriate control of dust stopped excavation activities.

Fernald Waste Pits

The Fernald Environmental Management Project is a former uranium processing facility undergoing environmental remediation. The plant was in operation from 1951 to 1989. The 1,050-acre site is located about 18 miles northwest of Cincinnati, Ohio. Early in the cleanup process, management divided the site into five sections, known as operable units, to organize cleanup planning efforts and address site contamination. The operable units were divided based on physical location on-site and the potential for similar technologies to be used during cleanup. The operable units are the Waste Pits Remedial Action Project, On-Site Disposal Facility and Soil Characterization and Excavation Project, Decontamination and Dismantlement, Silos Project, and Aquifer Restoration and Wastewater Project.

The Fernald Waste Pits Remedial Action Project is part of Operable Unit 1. The 37-acre waste pit area in the northwest portion of the site includes six waste pits, a burn pit, clearwell, miscellaneous structures, facilities, and soil. The pits range in size from 1 to 5 acres and vary in depth from 10 to 40 ft. The waste pit area contains approximately 1 million tons of low-level radioactive waste from Fernald's uranium production operations. The waste contains uranium, thorium, and other contaminants.

On March 1, 1995, DOE and EPA signed a Record of Decision identifying the cleanup plan for the project. In 1999, the Waste Pits Project team initiated waste pit excavation. Soil was excavated with excavators, backhoes, and bulldozers. The excavated soil was then sampled and screened and moisture content and radiological levels were determined to decide if the waste needed to be treated. If treatable, the material was blended or treated using two indirect thermal dryers to remove the excess moisture. Excessively moist excavated soil could not be shipped to the commercial disposal facility, Envirocare, without treatment. Typically, most of the waste pit material did not require treatment and could be loaded directly into gondola railcars and shipped to Envirocare in Clive, Utah.

By the close of 2000, the project excavated approximately 30 % of waste from Pits 1 and 3 and shipped 32 railcars containing 194,000 tons of material to Envirocare. The Waste Pits Project is scheduled to complete waste excavation, processing, and railcar loading operation in 2004, and decontamination/dismantlement of equipment and facilities in 2005.

INEEL Solid Radioactive Waste Retrieval Test

During 1971 and 1972, a Solid Waste Radioactive Retrieval Test was performed on waste stored in Pits 2, 5, 10, and 11 in the SDA at the INEEL (Thompson 1972). The purpose of the test was to determine the condition of the waste and waste containers, the extent of plutonium migration in soil, the techniques required to minimize the spread of contamination, and from that information, determine the costs of retrieval.

Pit 2 was selected for the test portion that evaluated relatively old and stacked drums. Six barrels considered to be in the poorest condition (compared to those in other pits) were removed from the pit.

Pit 5 was selected for the portion of the test that determines the effect of the aging process on dumped drums. One barrel of Rocky Flats waste from Pit 10 also was targeted for retrieval, but was never excavated because of the random condition of the barrels that resulted from dumping.

Pit 11 was selected for the retrieval test to provide the best possible representative sampling of stacked waste containers that were in good condition. Two barrels of Rocky Flats waste also were targeted for retrieval, but only one barrel could be found, probably because of the complicated circumstances that existed at the time the barrel was buried. Five other barrels were removed without complication. These barrels had been stacked and exhibited low radiation levels, which contributed to the ease of their removal.

Excavation equipment included a backhoe with a bucket for dirt removal, a road grader, and a bulldozer with earth scraper for large volume dirt removal. A crane or backhoe with a standard barrel chain-lifting device lifted and removed barrels from the excavation. The crane offered some advantages over the backhoe, allowing for the use of multiple chain-lifting devices and permitting a larger area to be covered.

The nature of the waste, however, greatly complicated the retrieval and slowed digging operations. The discovery of many seriously damaged barrels necessitated hand digging and lifting. Therefore, during this test, hand digging was used extensively in conjunction with a backhoe to prevent rupturing of drums. Barrels damaged by equipment and ring closures that were hooked by the backhoe further slowed the retrieval efforts. Leaking sludge was also troublesome at the excavation, requiring surveys, contamination control measures, and repackaging before movement.

During Pit 5 retrieval, several filters exhibited radiation levels of 20 mR/hr at 3 ft away. As handling equipment was deemed inadequate to contain potential contamination spread and prevent unnecessary exposure to personnel, the filters were left in place. At Pit 2, a sludge drum was left in the pit because it was leaking a clear liquid.

Contamination control measures applied to this retrieval included plastic sheeting over excavated sites, the application of water to control dust, and a tent. Initial excavations were conducted in wind speeds of 10 mph or less. The hot cell operation was conducted under a sealed plastic tent in conjunction with the use of HEPA filters. Protective equipment included full protective clothing, full face masks, cotton overalls, plastic booties, latex boots, cotton hoods, gloves, and dust respirators. The respirators and frequent changes of protective clothing made working conditions difficult.

The test concluded that, given the large quantities of material to be retrieved, mass excavation techniques should be studied. The study recognized that the main problem inherent in mass techniques is achieving contamination control in areas where cardboard cartons and wooden boxes are buried and interspersed with barrels.

INEEL Initial Drum Removal

In 1974, the Initial Drum Retrieval (IDR) program was established for the primary purpose of demonstrating the safe retrieval, repackaging, and interim storage placement of drums containing TRU waste buried at INEEL (EG&G 1978a). The program followed the Solid Waste Radioactive Retrieval Test, and was limited to a portion of Pits 11 and 12 to avoid areas where drums were in poor condition. The pits contained radioactive waste in stacked drums that are included in the current scope of the SDA Feasibility Study.

The waste was retrieved with a scraper and/or dozer to remove the soil overburden to within 45 cm of the buried waste. The remaining soil overburden was removed with a Drott excavator, which was also used to remove drums and soil from the pit until a working face was formed. A photograph of the IDR site is shown in Figure A-5.

The drums were removed from the stacks, rigged out of the pit, and removed to a separate area for surveying and packaging. Breached drums were wrapped in plastic and placed in DOT 7A metal boxes. Drums with free liquids were placed over a drip pan containing absorbent material, then wrapped in plastic and boxed once the liquid was expelled. About 6% of the drums exhibited external alpha contamination up to 120,000 counts per minute (cpm). Roughly 155 drums contained free liquids with alpha contamination up to 40,000 cpm. Radiation levels on the drums were less than 10 mr/hr, with the highest reading at 120 mr/hr. Workers wore full sets of anticontamination clothing—coveralls, shoe covers, gloves, hard hat, and safety glasses—and carried respirators in case of an airborne release, though the respirators were never needed or used.

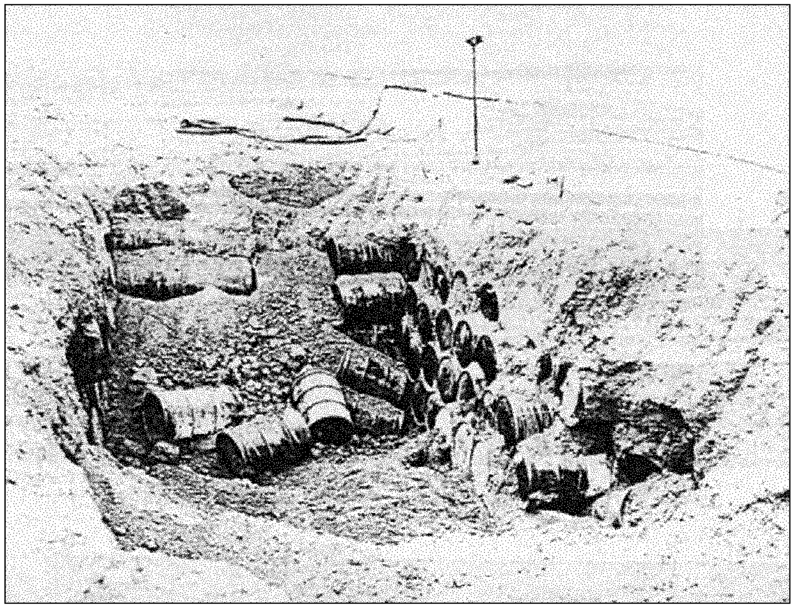

Figure A-5. IDR retrieval effort.

After removal techniques were optimized, these operations retrieved an average of 750 drums per month. Contamination controls included an air support weather shield (a reinforced fabric structure) over the work area. Cargo containers, floors, and the area extending 30 cm up the sidewalls were waterproofed with a sealant and absorbent material. The sealant and absorbent material precluded the spread of contaminated water from the cargo container in the event drums in the cargo container leaked.

The initial drum retrieval of Pit 11 was complete on June 20, 1977; Pit 12 was completed on June 12, 1978. The efforts safely retrieved 20,262 drums at a total cost of $1,614,820. Overall, the retrieval was successful, with no serious injuries of personnel and no traces of contamination spread into the environment.

The report concluded that drums stacked in an orderly fashion and buried in the ground for less than 10 years could be retrieved in a manner similar to that of the IDR. However, the types of waste within the SDA are not similar to most of the waste in the retrieval test (stacked drums versus dumped loose drums, boxes, tanks, and debris). Consequently, current health and safety standards would not allow this type of waste handling.

Probing performed at Pit 6 indicated that the waste was intermixed drums, plywood boxes, and loose waste with removable alpha contamination up to 1,000,000 cpm, and the IDR report concluded that "the levels of loose alpha contamination are not conducive to IDR type operations." Similarly, the report probed waste in Pit 9 and concluded that "the condition of intermixed waste creates a high risk of contamination spread for IDR operations." The same conclusion was drawn for Pit 10 and the further pursuit of the IDR program was not recommended.

INEEL Early Waste Retrieval

Following the IDR test, the Early Waste Retrieval (EWR) project was implemented in November 1974 to retrieve the oldest of the buried waste at the SDA, which lies in Pits 1 and 2 (EG&G 1978; EG&G 1979). Both pits contain TRU and mixed fission product waste in containers that were stacked in an orderly fashion.

All retrieval activities for EWR were performed inside of an Operating Area Confinement (OAC). The OAC was a self-supporting metal building constructed of lightweight metal panels that prevented the spread of contamination to the environment and provided operational safety to personnel. An air-supported reinforced fabric structure designed to withstand wind and snow provided weather protection for the OAC, while a propane-fired furnace supplied heat to allow for an all-weather operation. The exhausted air was filtered through a HEPA filter and constantly monitored to detect any airborne activity during retrieval operations. Retrieval personnel wore full anticontamination clothing and a totally enclosed bubble suit with fresh air supply.

The excavation efforts removed the overburden with an earth scraper to within 45 cm of the buried waste. After the OAC was in position, a backhoe was placed inside and used to remove the remaining soil cover. Any remaining soil around the waste containers was carefully removed by manual labor. Available photographs of the buried drums uncovered during the EWR project show the retrieved waste containers in various stages of deterioration.

Removable alpha contamination was measured up to 2,000,000 cpm. All loose waste was removed by hand or shovel and placed into large plastic bags, which were taped shut and removed from the excavation when full. Drums, removed with vertical lift slings attached to the bucket of a backhoe, were placed into bags that were also taped shut. About one-third of operating time was spent packaging the waste. A waste compactor was procured to compact waste generated during the excavation, and a hydraulic cutter was used to size some retrieved items.

As the retrieval progressed, dust and loss of liquid from drums became major problems. Several contamination control measures were applied to mitigate the problem. A soil stabilization blanket that provided a strong fabric resistant to tear, chemicals, temperature changes, and moisture was used. The fabric prevented the migration of particles larger than 5 microns in size, which reduced the amount of contamination to the underlying soil. An additional oil absorbent rug was placed under the fabric for absorption of any liquid that may have passed through the fabric blanket. A combination of water and a bonding agent was used to control dust, and plastic strip curtains were installed to control air flow.

This retrieval effort handled and repackaged a total of 170.6 m^3 of retrieved waste, contaminated soil, and waste generated from retrieval operations without spreading any contamination to the environment. The total cost for the project was $1,202,705.

The experience gained from retrieval operations supports the concept of using mechanized retrieval equipment to obtain the retrieval rates necessary for possible production-scale retrieval. The project concluded that the retrieval equipment should be electronically operated rather than manually operated, and that retrieval personnel should be isolated as much as possible from waste to minimize personnel hazards and risks during retrieval, though the personnel on this project performed the hand retrieval. In addition, further studies and tests were recommended for sizing odd-shaped and large items.

1.1 Maralinga Rehabilitation Project

Maralinga is located in the southern Australian Outback near the edge of the Great Victorian Desert. From 1955 to 1963, nuclear weapons development trials were conducted. These trials included seven “major nuclear trials” involving atomic explosions and numerous “minor trials” designed to investigate the performances of various components of a nuclear device, which dispersed radioactive materials over small areas (Australian Department of Health and Ageing, 2001). Radioactive and nonradioactive waste was buried in burial pits located at Maralinga.

The area within and surrounding Maralinga was highly contaminated with a variety of radioactive materials, activation products, and fused sand (containing trapped radioactive materials). Today, the principal neutron activation products remaining in the soil are cobalt-60 and europium-152, and the principal remaining fallout components are strontium-90, cesium-137, and europium-155. There are also other portions of the site (Taranki, Wewak, TM100/101, Kuli, TM50, and other minor trial areas) that are highly contaminated with plutonium, beryllium, or uranium (or a combination of all three), all of which pose inhalation hazards. Of these highly contaminated sites, Taranki is the most contaminated,, primarily due to the 22 kg of plutonium that was explosively dispersed in a sector of several hundred hectares. Uranium-235 and beryllium were also dispersed in the trials performed at Taranki (ARPANSA, 2001a).

Many of the minor trial areas have already been sufficiently cleaned up or the radioactive materials had sufficiently short half-lives that they are no longer detectable. However, major trial areas and areas mentioned above as highly contaminated with plutonium, uranium, or beryllium required remediation.

To address the need for remediation, the Maralinga Rehabilitation Project was implemented (ARPANSA, 2001b). From 1996 to 2000, remediation at the Project primarily consisted of scraping up the contaminated soil and burying it at depth on-site. The top 1 ft of surface soil was removed and buried in trenches.

Due to extreme inhalation hazards associated with plutonium and the associated americium, uranium, and beryllium, modifications were made to the cabin and engine compartments of the soil removal and monitoring equipment. This equipment included scrapers and bulldozers for soil removal and jeeps for radiological surveys. The cabins were modified to allow operators to work in sealed and pressurized cabins, with filtered air intakes and extracts and minimal personal protective equipment (PPE). HEPA filters supplied clean air to the cabin and the engine compartments. There were provisions for emergency escape that proved successful during an engine failure caused by extreme heat, which forced an emergency evacuation. All personnel were safely evacuated (phone conversations with Dan Glenn 12/11/2001 and Bill Bordern 12/12/2001, both CH2MHILL consultants who were involved in the project).

In addition to the cabin modifications, soils were kept moist and wind direction was monitored to keep contamination under control. These contamination controls, combined with careful work habits, were found to be very effective at this site. Work was completed successfully without any instances of plutonium migration.

Calvert City

In the mid- to late-1980s, BF Goodrich performed soil and sludge remediation of pits containing vinyl chloride as the main chemical of concern for the Calvert City Project in Kentucky (Davis-Smith 2001[a]). Due to the hazardous characteristics of vinyl chloride, the excavation equipment (large trackhoes) was modified to provide better protection to the operators. This modification included sealing and pressurizing the cabins and supplying them with air from tanks attached to the equipment. HEPA filtration was not applicable in this situation because vinyl chloride quickly clogs filters. In addition to the air that supplied the cabins, operators were on separate supplied air lines and were in Level A PPE. The

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a. Davis-Smith, 2001. Telephone conversation with Clay Morgan Davis/CH2MHILL at Separation Pilot Research Unit, New York, December 12, 2001.

air inside of the cab also was monitored to ensure a clean and safe environment. The equipment performed the required function and the operators were kept safe. Further details of this project are not available at this time due to the length of time since the project was implemented.

INEEL Full-Scale Design to Retrieve Waste at the SDA

In the late 1980s, a group of EG&G and DOE-ID personnel prepared a design for retrieval of Pit 9 (Schofield 2001). The retrieval structure consisted of a primary and secondary containment with the control room located in a separate auxiliary building. The primary containment was further divided into smaller areas by hanging curtains to reduce the size of the excavation area and to better control the spread of contamination. The HVAC design placed the primary containment at negative pressure to the secondary containment, whereby the air flow was directed up the face to HEPAs located directly above the dig face. The excavator was to be remote controlled with associated monitoring equipment attached.

Waste was to be retrieved, ground up, and mixed with burden and interstitial soils as the dig face progressed down the pit. The composite soil-waste was then transported to a hopper and placed in B-25 bins for segregation, characterization, and treatment. Intact drums were to be overpacked into larger containers at the hopper station. Higher activity sources were to be shielded and dealt with on a case-by-case basis. Larger metallic pieces (e.g. trucks, vessels, cranes, etc.) were to be left in place. Decontamination activities were completed on a routine cycle to maintain contamination at minimal levels.

Funding was pulled after approximately 2 to 3 years. At that time the project was in the preliminary design phase and the project ended.

INEEL Pit 9 Design

The three stage OU7-10 plan (INEEL 2000) was developed to remediate 200 yd^3 of buried waste in Pit 9 for treatability tests at the SDA to meet the objectives of the Record of Decision Declaration for Pit 9 at the Radioactive Waste Management Complex (RWMC) SDA at INEEL (Valentich 1993). This design project is currently being reviewed and modified. For this project, the three stages included:

1. Stage I: Subsurface exploration to obtain material for bench-scale treatability studies and to allow for material characterization

2. Stage II: Limited retrieval/excavation in select areas of Pit 9 to obtain materials for pilot-scale treatability studies, in situ and ex situ treatment tests, and characterization of the waste and soils

3. Stage III: Full-scale remediation.

Stage I employed nonintrusive downhole logging (essentially a casing equipped with inner sampling equipment that collects no material but is placed within the waste) to locate areas of concentrated TRU waste in the area to be excavated in Stage II. Completed for a total cost of $12 million, this stage of the project was considered successful because historical records and the results from the characterization coincided.[b] Future characterization conducted with the logging tool will cost significantly less because evaluation and planning have been completed. The program is now in the field and operating.

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b. McConnel, C., Telephone communication with Kira Sykes, March 28, 2001.

Stage II was taken to the design phase; EPA and the State of Idaho received a 90% complete design package in June of 2000. The retrieval system included the following performance characteristics:

1. Overburden will be removed to expose the waste.
2. Waste with TRU constituents less than or equal to 10 nCi/g containing 1,1,1-trichloroethane, tricholorethylene, percholorethylene, and carbon tetrachloride will be removed.
3. The reactor vessel and steel vault will not be removed.
4. Waste with TRU constituents less than or equal to 10 nCi/g may remain in the pit.
5. Contaminated underburden will be removed.
6. Waste with TRU concentrations greater than 10 nCi/g will be treated according to the Record of Decision:
    a. Waste to be returned to Pit 9 will be treated to remove hazardous components.
    b. Treatment residuals with TRU concentrations greater than 10 nCi/g that are to be disposed in sites subject to LDRs will be treated to the levels specified in the ROD.
    c. On-site treatment of materials containing TRU constituents greater than 10 nCi/g will not produce residuals with TRU concentrations between 10 nCi/g and 100 nCi/g.
7. Clean soil will be returned to the pit.
8. Low-level waste (less than or equal to 100 nCi/g for TRUs) will be either returned to Pit 9 following treatment or managed according to the Record of Decision.
9. Mixed low-level waste will be stored on-site if TRU concentrations are less than 100 nCi/g and LDRs are not met.
10. TRUs will be packaged for disposal at WIPP, but stored on-Site until receiving WIPP acceptance.

Because this design project involved a treatability test rather than a retrieval effort (with a goal of risk reduction), the design requirements for returning waste back into the pit may be modified if the design was applied to a full-scale retrieval. Additionally, provisions for retrieval of large debris would be included.

These performance characteristics resulted in a number of considerations for implementability in the system design:

- The retrieval facility will house equipment that can retrieve belowgrade waste containing TRU, low-level, mixed, and hazardous material
- The retrieval equipment will retrieve both intact and deteriorated waste containers
- The retrieval facility will have double confinement and may be a modular structure

- All the Stage II facilities and equipment will be relocatable for completion of Stage II operations and functions

- Retrieval equipment will be remotely operated for human factors.

- Individual worker radiation dose shall be less than 5 rem per year.

To date, the cost of performing this portion of Stage II is more than $15 M and the project is now in a review cycle.[c] The design package for this small-scale retrieval is comprehensive and includes design elements for 10 systems (structures, closure facilities, storage buildings, shoring, utilities, material handling and vacuum centers, secondary footings, data management, instrumentation, and equipment). The design project documentation comprises 27 binders that include plans, specifications, engineering design files, trade studies, data quality objectives, sampling plans, system requirements, functional requirements, safety requirements, reliability studies, performance requirements, schedules, costs, etc. The design package for a full-scale retrieval would be at least this exhaustive, and would add designs for treatment, packaging, transportation, and disposal systems.

The estimate to complete Stage II through retrieval and storage was $117.5 M, which includes the retrieval and storage of the material, but does not include potentially significant costs associated with characterization, treatment, or disposal. This stage is scheduled to be completed in 2009 (DOE 2000).

Though the Pit 9 design is not directly applicable to a full-scale retrieval action at the SDA (modifications and additional facilities would have to be added), a significant amount of knowledge was gained concerning the design of a retrieval system in a TRU, hazardous, and pyrophoric environment. Many of the facilities (such as storage facilities) and engineering evaluations (such as reliability of equipment) are directly applicable. Key functional requirements that resulted from this process give light to the magnitude of the issues associated with removing these types of buried waste.

The implementation of this project would provide valuable information on the effectiveness, implementability, and cost of full-scale retrieval of the SDA. However, the DOE currently does not have the funding to implement this project, and it is not known when Stage II will be completed.

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c. McConnel, C., Telephone communication with Kira Sykes, March 28, 2001.

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