Closure Plan for Active Low-Level Burial Grounds

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

**United States
Department of Energy**
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EXECUTIVE SUMMARY

This plan has been prepared in response to direction from the U.S. Department of Energy. The purpose of the plan is to define approaches that will be implemented to ensure protection of the public and the environment when active Low-Level Burial Grounds (LLBGs) at the Hanford Site are closed.

Performance assessments for active burial grounds in the 200 East and West 200 Areas provide current estimates of potential environmental contamination and doses to the "maximum exposed individual" from burial ground operation and closure and compare dose estimates to performance objective dose limits for the facilities. This is an Operational Closure Plan. The intent of the guidance in DOE Order 435.1 is that this plan will be a living document, like the facility performance assessments, and will be revised periodically through the operational life of the LLBGs to reflect updated information on waste inventory, management practices, facility transition planning, schedule dates, assessments of post-closure performance, and environmental consequences. Out year dates identified in this plan are tentative. A Final Closure Plan will be prepared in the future when the timing and extent of closure-related activities for LLBGs can be established with greater certainty.

After current operations at the LLBGs are concluded, this plan proposes transitioning of these facilities to the Environmental Restoration Program. This action will enable the Environmental Restoration Program to design and implement consistent and coordinated final remedial actions for active and inactive LLBGs. Active and inactive burial grounds in the 200 West and 200 East Areas are commingled.

This plan describes approaches that will be implemented during Interim Closure, Final Closure, and Institutional Control Periods to prepare LLBGs for surface barriers, and the construction of barriers, as well as the scope of inspection, monitoring and maintenance practices that will be performed during and after closure. Environmental monitoring is briefly discussed in this plan. However, a more comprehensive discussion of monitoring issues is provided in a separate performance assessment monitoring plan for LLBGs. Supporting information is provided regarding the geography, climate, hydrogeology, geochemistry and land-use practices of adjacent land areas.

During the Final Closure period, engineered surface barriers will be constructed over the LLBGs. A conceptual cover design, which is a development of the Hanford Site Environmental Restoration Program, is discussed as the current planning basis for capping LLBGs. This barrier meets all applicable federal and state requirements for covers over sites with Category 3 low-level waste (LLW) and/or hazardous/dangerous waste constituents. Attributes of this design are discussed in the context of ensuring the integrity of the closed facility and the cover system, preventing long-term degradation of the cover, ensuring structural stability, limiting infiltration, minimizing maintenance, limiting consequences of human intrusion, and achieving compliance with facility performance objectives.

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ACRONYMS/ABBREVIATIONS

1		
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4	ARAR	Applicable or Relevant & Appropriate Requirement (EPA)
5		
6	CERCLA	Comprehensive Environmental Response, Compensation & Liability Act of 1980
7	CH	Contact-Handle
8		
9	DOE	Department of Energy
10	DOE-RL	Department of Energy - Richland Operations Office
11		
12	EIS	Environmental Impact Statement
13	EPA	U.S. Environmental Protection Agency
14	ER	Environmental Restoration
15		
16	FFS	Focused Feasibility Study
17		
18	GTCC	Greater Than Class C (LLW)
19		
20	HDW-EIS	Hanford Defense Waste Environmental Impact Statement
21	HELP	Hydrologic Evaluation of Landfill Performance
22	HFSUWG	Hanford Future Site Uses Working Group
23	HIC	High-Integrity Container
24	HMS	Hanford Meteorological Station
25		
26	ILAW	Immobilized Low Activity Waste
27		
28	LDR	Land-Disposal Restricted
29	LLBG	Low-Level Burial Ground
30	LLW	Low-Level Waste
31		
32	MLLW	Low-Level Mixed Waste
33		
34	NRC	Nuclear Regulatory Commission
35		
36	PA	Performance Assessment
37		
38	RCRA	Resource Conservation & Recovery Act of 1976
39	RH	Remote-Handle
40		
41	SAR	Safety Analysis Report
42	SW-EIS	Hanford Site Solid Waste Program Environmental Impact Statement
43	SWITS	Solid Waste Inventory Tracking System
44		
45	TRU	Transuranic (Waste)
46		
47	WAC	Washington Administrative Code
48	WHC	Westinghouse Hanford Company
49	WIPP	Waste Isolation Pilot Plant
50	WNP-2	Washington Nuclear Plant 2 (Supply System)
51	WRAP	Waste Receiving & Packaging
52		

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1.0 INTRODUCTION

Future tense (e.g., "will") is used in discussions of Interim Closure, Final Closure and Institutional Control activities in this plan. The intent of this usage is to simplify discussion and to convey the sense that current visions and assessments of activities under discussion are futuristic. It is not intended to imply that the Solid Waste Storage and Disposal Program has made specific decisions and/or commitments regarding details of activities that are 30 to 40 years in the future.

1.1 GENERAL FACILITY DESCRIPTION

Active LLBGs in the 200 West and 200 East Areas cover a combined (but non-contiguous) area of 560 hectares (1,400 acres). Active LLBGs began accepting waste in the early 1960s from processing operations on the Hanford Site and are anticipated to continue to receive waste from on-site and off-site generators until approximately 2045. Other, older LLBGs, which were inactive in 1994 when the Hanford Site Environmental Restoration (ER) Contract was implemented, were assigned to the ER Contractor for surveillance and maintenance and final remediation at that time. As of January 1, 1999, approximately 274,000 m³ (358,000 yd³) of LLW and 9,200 m³ (12,000 yd³) of low-level mixed waste (MLLW) had been disposed in active LLBGs in various containers including drums and boxes made of steel, wood, and cardboard. Bulk contaminated equipment and soils have also been disposed in LLBG trenches. Containerized waste is typically stacked in the bottom of each trench using either cranes or forklifts. Bulk soils and debris are typically dumped from the trench lip down a working face for disposal. A minimum of 2.4 m (8 ft) of backfill is currently placed over disposed waste. Early operations placed as little as 0.6 m (2 ft) of soil over filled waste trenches but found through experience that 2.4 m (8ft) was required to minimize biointrusion concerns. Category 3 waste and waste containing certain mobile radionuclides are currently stabilized by placement in concrete vaults/high-integrity containers (HIC) or encasement in concrete. Mixed waste is disposed in Resource Conservation and Recovery Act of 1976 (RCRA) compliant lined trenches.

After all trenches in a burial ground have been filled with waste, the facility will be turned over to the ER Program for final remediation in a manner that will be integrated with adjacent sites. During Interim and Final Closure, measures will be taken to improve the bearing capacity of trench fills to support the weight of a final cover and a cover will be constructed over the site. Cover construction will be coordinated with remediation of adjacent facilities, including inactive LLBGs. The cover will limit water infiltration and inadvertent intrusion to meet performance objectives as described in the facility performance assessments (PAs). Land use adjacent to the burial grounds is currently limited to Hanford operations. In the region surrounding the Hanford Site, land use is typically agricultural.

1.2 GENERAL APPROACH TO CLOSURE

In Section 3.0 of this closure plan, a two-phase approach to closure of active LLBGs is presented. The two key elements of the approach are as follows:

- Increase the bearing capacity of trench fills (consisting of disposed waste and cover soil) to support the weight of a closure cover without excessive long-term settlement or subsidence
- Construct engineered covers as final remedial actions over active LLBGs. Covers will be designed specifically to minimize moisture infiltration, resist natural degradation processes, minimize maintenance, and control releases of radionuclides for a period of at least 500 years after closure.

Measures will be implemented to improve the bearing capacity of trench fills during the Interim Closure period. Trench fills will be stabilized by applying a number of sub-grade modification methods to compact trench fill materials, eliminate large voids (either by compaction or by void-fill grouting), and/or bond larger volumes of trench contents together by cement grouting. Sub-grade modification may be performed once or several times as necessary to achieve an adequate bearing capacity value within trench fills to support the distributed weight of cover materials over the closed facility.

During the Final Closure period, engineered surface barriers will be constructed over LLBGs. A generic conceptual cover design, which is a development of the ER Program at the Hanford Site, is described in this plan as the current planning basis for capping LLBGs. The Modified RCRA Subtitle C Barrier conforms to all applicable state and Federal regulatory requirements for landfill closure of sites containing Category 3 LLW and hazardous/dangerous waste. This design also is assumed as the final cover treatment over LLBGs for evaluation of future waste management alternatives in the Hanford Site Solid (Radioactive and Hazardous) Waste Environmental Impact Statement (SW-EIS) (DOE 2000). The planning basis may change in the future to reflect barrier design developments and remediation strategies for inactive LLBGs within the ER Program.

The Modified RCRA Subtitle C barrier design will be effective in controlling releases of radionuclides from the facilities after closure. The barrier will control releases of radionuclides by (1) minimizing infiltration of precipitation into and through disposed waste, (2) preventing biointrusion into buried waste, and (3) minimizing adverse consequences of inadvertent human intrusion in the future if there is a loss of active institutional control. The proposed cover system is designed to eliminate virtually all moisture infiltration by evapotranspiration. Biointrusion will be prevented by incorporation of a low-permeability layer that cannot be penetrated by plant roots or burrowing animals. Buried waste will be covered with at least 5 m (16.7 ft) of layered soil, rock and asphaltic materials. The overall thickness of material and the low-permeability layer will effectively isolate buried waste from inadvertent intrusion.

The cover design incorporates two independent strategies for elimination of soil moisture. The design includes a two-layer topsoil treatment. Compaction of the lower topsoil layer and a capillary barrier at the interface between the topsoil and underlying materials will retard moisture migration through the topsoil, increasing the time available for removal of moisture by evapotranspiration. The thickness of the two topsoil layers is designed to support a healthy stand of perennial vegetation. Moisture that infiltrates through the topsoil system will be eliminated by lateral drainage.

The Modified RCRA Subtitle C barrier system will be constructed of durable materials and includes design features that will minimize susceptibility to erosion of the topsoil surface. The upper topsoil layer includes a pea gravel admix treatment that will limit erosion by forming a surface armoring layer during any extended periods of wind erosion. The cover surface will be sloped at 2 percent, which is sufficient to induce runoff during severe storm events, but low enough to limit susceptibility to erosion by wind. Established cover vegetation, consisting of a mix of perennial grass species, should limit topsoil losses to an acceptably low value. In combination, these strategies should enable the cover to remain functional with minimum active maintenance for a performance period of at least 500 years.

The design is tailored to the Hanford Site's semiarid climate conditions and the local availability of suitable materials of construction. The capillary barrier feature, the compacted topsoil layer, and the selection of perennial grasses as cover vegetation are all treatments designed to maintain successful vegetative cover at a semiarid site. The pea gravel admix treatment, low surface slope, and cultivation of vegetative cover are designed to minimize soil losses from wind erosion.

1.3 CLOSURE SCHEDULE

The final closure schedule for each of the burial grounds is dependant upon several related activities. Current policy based on the Record of Decision for the Hanford Defense Waste Environmental Impact Statement (HDW-EIS) is that all stored transuranic (TRU) waste will be retrieved from LLBGs before they are closed. Trenches that are currently used for storage of TRU may be reused for LLW disposal, or they may be refilled with native soil in advance of closure. In the current Hanford Site Solid Waste Program Environmental Impact Statement (SW-EIS) a sub-alternative is being studied that would involve leaving TRU in place (i.e., changing the policy established by the HDW-EIS). After TRU retrieval (assuming no change to the current policy), the trench contents must be compacted to provide a stable base for the final closure cover, before the final closure cover can be constructed. The closure schedule in Section 4.0 of this plan assumes that all TRU waste must will be retrieved before 2030. A trench filling sequence has been developed in the "Low Level Burial Grounds Disposal Plan" (Pratt 2000) by allocating all LLW in the forecast to future trenches in the burial grounds. The filling sequence shows trenches receiving waste up until 2030. Once all TRU waste has been retrieved and the trenches have been filled with LLW, the burial ground will transition into an Interim Closure period where the bearing capacity of trench fills will be increased to support the final closure cover. This is planned to take from 1 to 6 years per burial ground. To cycle through all of the burial grounds and construct final covers will take until 2056. Construction of the final cover will require transporting massive quantities of construction materials and will take from 1 to 5 years per burial ground. If the final covers are constructed directly after the end of the Interim Closure period for each active LLBG, the last one will be complete in 2057. The schedules assume an Institutional Control period of at least 100 years beyond Final Closure.

1.4 RELATED ACTIVITIES

1.4.1 Final Remediation of Inactive LLBGs

Inactive LLBGs at the Hanford Site were assigned to the ER Contractor in 1994 when the Site's ER Contract was implemented. Inactive LLBGs will undergo final remediation following the Comprehensive Environmental Response, Compensation & Liability Act of 1980 (CERCLA) process. This plan proposes transitioning active LLBGs to the ER Program after conclusion of operations, so that final remediation of inactive and active LLBGs can be accomplished in an integrated manner under a single site contractor.

1.4.2 Canyon Disposition Initiative Project

The Canyon Disposition Initiative is a collaborative effort to evaluate the feasibility of using the five chemical processing facilities (canyon buildings) in the 200 Areas for waste disposal in conjunction with final remediation. A Canyon Task Team, consisting of personnel from DOE-RL, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology, is evaluating a number of technical alternatives for dispositioning these facilities. Some alternatives under consideration would involve constructing engineered surface barriers over these facilities as final remedial actions. Covers over canyon buildings could be large enough (in terms of areal extent) to impact designs of covers over nearby LLBGs.

1.4.3 Environmental Impact Evaluation of Alternatives for Future Solid Waste Management at the Hanford Site

The SW-EIS (DOE 2000) is being prepared to evaluate the environmental consequences of three alternatives for managing solid waste streams at the Hanford Site in the future. The evaluation involves newly generated TRU, MLLW, LLW, and contaminated equipment, retrievably stored TRU in LLBGs, new and existing facilities for characterization, treatment and storage of solid waste streams, and disposal options for various streams. Selection of the No-Action Alternative would eliminate plans for construction of some new treatment facilities, TRU retrieval from LLBGs and off-site disposal of TRU waste. The Baseline Alternative is generally consistent with the Hanford Site's current planning baseline. Most wastes that are currently in storage would be processed and prepared for disposal over the next 10 years, and the need for significant storage facilities gradually would be reduced over that time. Wastes would be treated in Waste Receiving & Packaging (WRAP) facility, T Plant, the M-91 Treatment Facility, and/or commercial facilities. Suitable treatment options would be made available for all solid waste streams. TRU waste would be shipped to the Waste Isolation Pilot Plant (WIPP) repository. A sub-alternative of the Baseline Alternative would involve leaving some TRU in place (i.e., potentially altering the policy on TRU retrieval and disposal established by the HDW-EIS). The Regional Alternative would create the same new treatment facilities and implement the same management processes and activities as the Baseline Alternative. It would also involve receipt, processing and on-site disposal at Hanford of additional volumes of LLW and MLLW from other DOE sites. The Regional Alternative would increase the inventories of LLW and MLLW disposed in LLBGs.

1.4.4 TRU Retrieval from Active LLBGs

Based on the Record of Decision for the HDW-EIS, all stored TRU waste will be retrieved from LLBGs before they are closed. Most active LLBGs include trenches containing retrievably stored TRU waste. Several active LLBGs (e.g., 218-W-3A, 218-W-4B and 218-E-10) could be closed when TRU retrieval is completed unless the trench space freed up by TRU retrieval is reallocated for LLW disposal. Schedule information for TRU retrieval is included in Section 4.0 of this plan. As noted above, a sub-alternative under consideration in the SW-EIS would involve leaving TRU waste in place.

1.4.5 Dangerous Waste Facility Permit

Several active LLBGs contain LLW with dangerous waste constituents (i.e., MLLW) that was disposed on or after August 19, 1987, which is the date that Hanford-generated waste streams became subject to regulation under WAC 173-303 by the State of Washington. A single site-wide Treatment, Storage and Disposal Facility Permit has been issued to the Hanford Site by the Washington State Department of Ecology. Negotiations are ongoing between DOE-RL and the Department of Ecology regarding inclusion of specific permit conditions for active LLBGs in the site-wide permit. MLLW currently is being disposed in a RCRA-compliant trench (Trench 34) in 218-W-5 Burial Ground. The Navy Reactor Compartment Trench (Trench 94) in 218-E-12B also is subject to dangerous waste regulations, although that trench is not lined. Near-future MLLW disposal is planned for Trench 31 in 218-W-5 Burial Ground. A third (larger) MLLW trench is planned for 218-E-12B at a later date (Pratt 2000).

1.4.6 Proposed Dedicated Trench for Immobilized Low Activity Waste (ILAW) Facility Waste

Solid Waste Storage and Disposal Operations has proposed to construct and operate a new, special-purpose trench in the northwest corner of 218-E-12B Burial Ground for disposal of contaminated equipment (e.g., failed melters) from the ILAW Facility. The proposed trench could also receive small

volumes of LLW and MLLW from the ILAW process operation. This trench would be designed and operated as a RCRA-compliant facility (i.e., with a double liner and a leachate collection system) and subject to the State of Washington's dangerous waste regulations (WAC 173-303). Design requirements and waste acceptance criteria for this trench have not been fully determined. If DOE elects to proceed with this plan, closure requirements and schedule data for the 218-E-12B Burial Ground would be impacted.

1.4.7 Monitoring Plan for LLBGs

A separate plan for monitoring of environmental media at active LLBGs was prepared recently by Chou et al. (DOE/RL-2000-72). The purpose of ongoing environmental monitoring is to acquire the necessary data to evaluate conformance of LLBGs to assumptions and performance predictions identified in the facility PAs and the Composite Analysis for the 200 Areas (Kincaid et al. 1998). Insofar as groundwater is regarded to be the most significant long-term exposure pathway in all of these assessments, it is the principal focus of the plan. The intent of DOE Order 435.1 is that any significant findings from environmental monitoring will be addressed in revisions to the facility closure plan and PAs.

1.5 KEY ASSUMPTIONS

1.5.1 Key Assumptions from Facility PAs

The current PAs for 200 East and West Area LLBGs rely on the following key assumptions:

- No major changes will occur in current land uses of areas adjacent to active LLBGs.
- There will be no significant changes in site conditions (i.e., climate, hydrogeology) through the period of interest for PAs.
- There will be no easing of the current waste acceptance criteria for LLBG operations between the present time and the time that LLBGs are closed (i.e., assumptions applied in the PAs regarding concentration limits, isolation of wastes containing mobile radionuclides, and waste stabilization, which are based on current waste acceptance criteria, will remain valid).

Any changes that impact these assumptions will be addressed in revisions to the PAs. Potential impacts to the current closure strategy for LLBG facilities will be addressed in future revisions of this plan.

1.5.2 Key Assumptions Relating to Future Waste Inventory

Three alternatives for management of solid waste streams (including LLBGs) at the Hanford Site are currently being evaluated in the SW-EIS (DOE 2000). These alternatives affect future waste inventory projections for LLBGs as described in Section 2.3 of this closure plan and as evaluated in the facility PAs (Wood et al. 1995, Wood et al. 1996). Uncertainties relating to future inventory additions will be reduced when a Record of Decision is published identifying the selected alternative. Current waste inventories of active LLBGs and future inventory projections will be updated in revisions to this document and the PAs.

1.5.3 Key Assumptions Relating to Interim Closure and Final Closure

Some proof-of-principle testing has been conducted of proposed sub-grade modification methods as discussed in Section 3.2.2. However, a pilot program will be needed to determine specifically how the proposed methods can best be utilized to achieve sub-grade stabilization objectives for Interim Closure.

A key assumption for this closure plan is that the proposed cover design will perform in a manner consistent with numerical simulation results. The ER Contractor plans to construct a prototype of the Modified RCRA Subtitle C Barrier in the 200 Areas within the next few years. After construction, the barrier will undergo a multi-year period of performance monitoring and evaluation. From the prototype, it is expected that an adequate performance information basis will be available to proceed with closure of LLBGs by the time operations are concluded.

1.5.4 Key Schedule Assumptions

Schedule information presented in Section 4.0 of this closure plan relies on the following assumptions:

- Availability of contractors and equipment for sub-grade modification is currently limited, because of the specialty nature of the work and limited demand for these services. It is envisioned that this constraint will continue into the future. Therefore, it is assumed that only one LLBG will undergo sub-grade modification at any given time.
- Aside from the constraint on sub-grade modification, there will be no other constraints on labor, equipment or materials. For scheduling purposes, it has been assumed that individual LLBGs will proceed directly from TRU retrieval into Interim Closure, Final Closure, and Institutional Control without schedule gaps. Schedule delays could occur in conjunction with facility transition.

2.0 DISPOSAL FACILITY CHARACTERISTICS

2.1 SITE CHARACTERISTICS

In this section, the environmental conditions that characterize the 200 East and West Area LLBGs are summarized. A detailed discussion will not be provided because these topics have been discussed at length in other publications [e.g., the HDW-EIS (DOE 1987) and SW-EIS (DOE 2000)] and numerous Safety Analysis Reports (SAR)). Environmental characteristics discussed include regional geography and demography, regional and site-specific geology, regional and site-specific hydrology, climatology, meteorology, and ecology.

2.1.1 Site Geography and Demography

The 200 Area LLBGs are located on the Hanford Site in the southeast corner of Washington State (Figure 2-1). The Hanford Site is located in a structural and topographic depression of the Columbia Plateau called the Pasco Basin. The northern and eastern boundaries of the site generally follow the Columbia River. The western margin of the site is generally bounded by the Rattlesnake Hills. The southern boundary of the site is approximated by the ridgeline of Rattlesnake Mountain and the Yakima River. The Hanford Site covers an area of about 1,500 km² (580 mi²). With the exception of a few natural basalt hills (e.g., Gable Butte and Gable Mountain), the central area of the site is relatively flat (Figure 2-2), with a topographic low at the Columbia River [about 100 to 120 m (300 to 390 ft) above sea level] and a gradual increase in elevation toward the north-central part of the site. The 200 Area LLBGs are located in this region, commonly referred to as the 200 Area Plateau. The elevation of the burial grounds is about 225 m (738 ft).

The nearest population center consists of three small cities (Richland, Kennewick, and Pasco) that are situated to the southeast of the site on the Columbia River. The population living within 80 km (50 mi) of the burial grounds is about 375,000 (Kincaid, et al 1993).

2.1.2 Site Climatology and Meteorology

Meteorological data has been collected at the Hanford Meteorology Station (HMS) since the year 1945. The HMS is located between the 200 East Area and the 200 West Area. Temperature and precipitation data have been recorded in the region since 1912. Generally, the Hanford Site climate is classified as semiarid with an average rainfall of about 16 cm/yr (6.3 in/yr), nearly half of which occurs in the winter months of November through January.

The prevailing winds of the area are from the northwest and secondarily from the southeast. Average wind speeds are about 10 to 15 km/h (6 to 9 mi/hr). The area is subjected to occasional high winds (e.g., a peak gust of wind of 130 km/h (80 mi/h) was recorded at the HMS in 1972).

2.1.3 Site Ecology

Site ecology is thoroughly summarized in the HDW-EIS (DOE 1987) and SW-EIS (DOE 2000). Dominant vegetation at the Hanford Site includes sagebrush, rabbit brush, and a variety of grasses, including cheat grass and, bunchgrass. Common mammals on the site include mule deer, elk, jack and cottontail rabbits, coyotes, badgers, raccoons, and a variety of rodents. Common birds on site include

grouse, doves, falcons, hawks, owls geese, and ducks. A wide variety of fish inhabit the Columbia River including salmon, trout, shad, bass, whitefish, sturgeon, and catfish.

Endangered, threatened, or candidate species have been identified onsite. However, a review based on information from the Fish and Wildlife Service for the Department of Interior suggests that these species are not directly at risk from waste management activities in the 200 Areas (DOE 1987).

2.1.3.1 Regional and Site-Specific Land Use

In the region surrounding the Hanford Site, commercial land use is typically agricultural which relies on irrigation to grow crops. The sources of irrigation are generally the Columbia and Yakima Rivers and confined aquifers (sediment layers between upper basalt flows). Several nuclear facilities are in operation on or adjacent to the Hanford Site including the Columbia Generating Station formerly known as Washington Nuclear Plant No. 2 (WNP-2), a commercial nuclear reactor operated by Energy Northwest, and the Siemens Nuclear Power Corporation Fuel Fabrication Plant. In addition, a commercial LLW disposal facility operated by U.S. Ecology is located adjacent to the 200 East Area on the central plateau of the Hanford Site.

On the Hanford Site, a large number of facilities including reactors and processing plants have been operated to produce nuclear materials. None of these facilities (except T Plant, which has been converted to support waste management operations) are currently operational and permanent shutdown is planned. The Solid Waste Storage and Disposal Complex is operating for management of LLW. The complex consists of a number of active and inactive burial sites (shallow land trenches), storage buildings (primarily for mixed waste), and administrative buildings.

2.1.3.2 Seismology

The Hanford Site is in an area of low seismicity (Figure 2-3). Earthquakes typically occur at shallow depths [focal depth less than 6 km (Caggiano and Duncan 1983)] as multiple events or swarms at magnitudes of less than 3.5. Two moderate-size earthquakes have been recorded near the site, one in 1936 in the Milton-Freewater area (Modified Mercallie intensity VII) about 40 mi southeast of the Hanford Site and another in Corfu in 1918 (Modified Mercallie intensity IV to VI) about 118 mi north of the site. The Corfu earthquake is estimated to have produced peak ground accelerations of 0.01 to 0.03 g onsite. The epicenters of recorded earthquakes occur somewhat randomly and are not strongly associated with any geologic structural features.

2.1.4 Hydrogeology

The Hanford Site is located on a geologic province referred to as the Columbia Plateau. The Columbia Plateau covers much of eastern Washington, eastern Oregon, and parts of Idaho. It was formed by a massive upwelling of basalt magma. The Hanford Site is located in the Pasco Basin, which is a structural depression within the Columbia Basin Plateau. About 3,000 m (10,000 ft) of flow basalts underlie sedimentary units of variable thickness within the Pasco Basin. The major supra-basalt sediments are the Ringold Formation and the Hanford formation. The Ringold Formation overlies the uppermost basalt flow and was deposited by various erosional processes. The Hanford formation overlies the Ringold Formation and was deposited in a series of catastrophic floods associated with glacial melting.

The hydrology of the Pasco Basin is characterized by a number of surface sources and aquifers. Groundwater occurs both within the upper unconfined aquifer system and within a system of deeper confined to semi-confined aquifers in the basalt flow tops, flow bottom zones, and sedimentary interbeds (DOE 1988b, vol. 2, p. 3.6-1). The confined aquifers are intercalated with aquitards, consisting of basalt

1 flow interiors (colonnades and entablatures). The uppermost aquifer system occurs within the suprabasalt
2 sediments. This aquifer is regionally unconfined.

3
4 Surface water enters the Pasco Basin from several adjacent basins (Figure 2-4), including the Yakima
5 River Basin, Horse Heaven Basin, Walla Walla River Basin, Palouse/Snake Basin, and Big Bend Basin.
6 Within the Pasco Basin, major tributaries including the Yakima, Snake, and Walla Walla rivers join the
7 Columbia River. Two intermittent streams, Cold Creek and Dry Creek, cut through the Hanford Site.
8 These drainages contain flowing water during the wetter winter and spring months.

9
10 Total annual precipitation over the Pasco Basin averages less than 16 cm (6.3 in. per year). Mean annual
11 runoff is estimated to be less than 2.5×10^4 acre-ft per year, or approximately 3 percent of the total
12 precipitation. The remaining precipitation is assumed to be lost through evapotranspiration, with a small
13 component (perhaps less than 1 percent) contributing to recharging of the groundwater system (DOE
14 1988b, vol. 2, p. 3.1-6).

15
16 The general direction of groundwater flow is from the natural recharge areas along the west edge of the
17 Hanford Site to discharge areas along the Columbia River. Recharge of the confined basalt aquifers
18 occurs through infiltration on the anticlinal ridges bounding the Pasco Basin and from westward flow in
19 basalt aquifers beneath the Columbia Plateau. Sources of natural recharge to the uppermost (unconfined)
20 aquifer system are infiltration and runoff of precipitation and runoff on the reaches of the Yakima and
21 Columbia Rivers. Cold Creek and Dry Creek, which are located between the Rattlesnake Hills and
22 Umtanum Ridge, drain the western slopes of the Pasco Basin, losing water to the subsurface as they
23 spread across the lower valley plains.

24
25 The 200 Areas are 90 m (300 ft) or more above the normal surface level of the Columbia River, which is
26 well beyond the area that would be affected by the 500-year flood or the probable maximum flood event.
27 The most likely source of flooding in the vicinity of the 200 Areas is Cold Creek, which is an ephemeral
28 stream. The projected maximum flood on Cold Creek would reach the southwest corner of 200 West
29 Area, but would not come within 0.8 km (0.5 mi) of any active LLBG.

30
31 Infiltration of precipitation through the vadose zone has been studied at several locations on the Hanford
32 Site (Gee 1987; Routson and Johnson 1990; Rockhold et al. 1990; Fayer et al. 1991). The general
33 conclusion is that very little, if any, infiltration occurs in areas where the surface soils are relatively
34 fine-grained and deep-rooted vegetation is present. In other areas where soils are coarse and vegetation is
35 shallow rooted or not present, infiltration may exceed 50 percent of annual precipitation.

36
37 Artificial recharge to the unconfined aquifer occurs at the Hanford Site from wastewater disposal
38 operations, mainly in the 200 Areas. Recharge from the 200 Areas wastewater disposal facilities was
39 estimated to be approximately 10 times the natural recharge rate at the Hanford Site by Graham et al.
40 (1981). More recently, Fayer and Walters (1995) have estimated that the total volume of natural recharge
41 over the Hanford Site in 1992 was about 8.47×10^6 m³/yr, (2.24×10^9 gal/yr). This value is of the same
42 order of magnitude as the artificial recharge to 200 Areas wastewater disposal facilities during 1992 and
43 is about half the volume that was being discharged in 1979. Liquid wastewater disposal is now regulated,
44 it is decreasing significantly from year to year, and will eventually cease, leading to falling groundwater
45 levels.

46 47 **2.1.4.1 Hydrogeology of the 200 West LLBG**

48 The sources of data described in this section are (1) a detailed summary of the hydrogeology of the 200
49 West Area by Connelly et al. (1992) and (2) a detailed characterization of Burial Ground 218-W-5 by
50 Bjornstad (1990). These reports represent the most recent synthesis of available data that have been used
51 to characterize the primary features of the vadose zone and unconfined aquifer that influence groundwater

1 movement. Typical soil characterization data taken from the soil samples include particle size
2 distribution, ambient moisture content, calcium carbonate content and gross gamma radiation counts as a
3 function of depth below the surface. The database shows that Hanford Site soils are predominantly sandy
4 with ambient moisture content in the range of 3 to 15 volume percent. Calcium carbonate is generally
5 present in sufficient quantity to control the pH of the groundwater solution.

6
7 Isopach maps (Connelly et al. 1992) of the major soil column units underlying the 200 West Area are
8 shown in Wood et al. 1995. A generalized cross-section of the stratigraphic units is shown in Figure 2-5.
9 Also, several cross sections (Bjornstad 1990) across Burial Ground 218-W-5 are included in Appendix A
10 of Wood et al. 1995. These drawings illustrate the spatial distribution of the major vadose zone units in a
11 three-dimensional fashion. The bulk of the thickness of the vadose zone consists of Hanford formation
12 and underlying Ringold Formation. The Ringold Formation consists of fluvial and lacustrine sediments
13 while the Hanford formation consists of catastrophic flood deposits. The total thickness of the vadose
14 zone and the relative thicknesses of the two main formations vary depending on the location of interest on
15 the Hanford Site.

16
17 Beneath the 200 West Area LLBG, four distinct subunits of the Ringold Formation have been described
18 (Bjornstad 1990). The water table occurs within the middle Ringold subunit. Between the Ringold and
19 Hanford formations is a thin erosional layer (the Plio-Pleistocene layer), which appears to be mostly
20 continuous across the burial grounds. The Plio-Pleistocene layer is a fine-grained sandy mud that has
21 been reworked by plant and animal activity and is variably cemented with calcite. The early Palouse soil,
22 which is an unconsolidated, muddy sand layer that may have been deposited by wind erosion and then
23 reworked by animal burrowing and root growth, is developed in the upper part of the Plio-Pleistocene
24 unit. The Hanford formation consists of a variety of facies ranging from coarse gravels in areas of
25 high-energy deposition to fine-grained silts in low-energy environments. Numerous cycles of flooding
26 apparently occurred, leading to a chaotic distribution of subfacies units. As indicated by Figure 2-6, a
27 secondary channel is indicated along the east side of the burial grounds by high-energy deposits of coarse
28 gravelly sand in Burial Grounds 218-W-3A and 218-W-3AE. In contrast, the burial grounds to the south
29 and west (218-W-5 and 218-W-4C) are considered to be moderate energy depositional environments as
30 indicated by a larger component of finer sands and less gravel. The formation thickens from northeast
31 (about 18m/60 ft) to southwest (about 43m/140 ft). The characterization of soil samples from wells in
32 the vicinity indicated that small lenses of fine-grained material are interspersed in the Hanford formation
33 that appear to be no more than 3 to 6 m (10 to 20 ft) thick, with a lateral extent of hundreds of meters or
34 less.

35
36 Hydrologic flow patterns across the 200 West Area burial grounds were also estimated based on hydraulic
37 conductivity data from site-wide soil samples and hydraulic head data from wells in the vicinity of the
38 burial ground. As with the geologic interpretation, the hydrologic flow patterns were estimated in the
39 context of the current understanding of the Hanford Site hydrologic regime.

40
41 The present direction of groundwater flow in the vicinity of the 200 West Area is highly influenced by a
42 groundwater mound associated with past artificial recharge at 216-U-10 Pond (U Pond) and with current
43 recharge to the 126-U-14 Ditch, which lies just east of U Pond (Bjornstad 1990). The influence of the U
44 Pond mound on groundwater flow beneath 200 West Area Burial Grounds is demonstrated on a regional
45 water table map that also indicates generalized groundwater flow direction (Figure 2-7). Artificial
46 recharge at U Pond raised the level of the unconfined aquifer 17 m (55 ft) between 1944, before the
47 construction of U Pond, and 1987. Based on water-level measurements collected at well 299-W15-2, it
48 appears that the water table has fluctuated as much as 5 m (15 ft) over a 36-yr time period (Bjornstad
49 1990). The fluctuations are probably the result of varied volumes of process water being delivered to U
50 Pond.

Even though U Pond was decommissioned in 1985, the groundwater mound is expected to continue to gradually decline for a number of years. Since about the time U Pond was decommissioned, water levels have in general declined, having fallen a total of about 2 m (7 ft) in the last 6 yr at Monitoring Well 299-W15-2. Hydrographs from the other wells located within 1,000 ft of 218-W-5 corroborate a general drop in water levels relative to those measured since the water levels have been measured at the site (Bjornstad 1990). As the groundwater mound dissipates, the direction of groundwater flow beneath 218-W-5 and the contiguous burial grounds will likely swing to the east, perhaps returning to the due-east regional groundwater flow direction recorded in 1944 (Figure 2-8).

The gradient across the burial ground is very slight (Figure 2-7). The general direction of flow is currently to the north-northeast. Saturated hydraulic conductivity data reported in the document show a reduction in hydraulic conductivity in the soils as a function of depth from 10^{-3} to 10^{-4} cm/s in the Ringold Formation. This trend is presumably the result of compaction by the soil column.

2.1.4.2 Hydrogeology of the 200 East Area LLBG

The sources of the data described in this section are a detailed summary of the hydrogeology of the 200 East Area by Connelly et al. (1992) and a detailed characterization of the 200 East Area Burial Grounds by Lindsey et al. (1994). These reports represent the most recent synthesis of available data that have been used to characterize the primary features of the vadose zone and unconfined aquifer.

The principal source of geologic and hydrologic information in the 200 East Area is borehole data. A generalized view of the suprabasalt sediment facies of 200 East Area is provided in Figure 2-5. The 200 East Area lies on the Cold Creek bar, a geomorphic remnant of the cataclysmic floods of the Pleistocene (Figure 2-6). As floodwater raced across the lowlands of the Pasco Basin and Hanford Site, energy was dissipated and deposits of gravels were left behind. The entire 200 Area Plateau is one of the most prominent of these deposits. In the northern half of the 200 East Area the water table is situated within gravel- to sand-dominated facies of the Hanford formation. To the south and east, it more commonly is found within gravels of Ringold units A and E and silts of the lower mud unit. Transmissivity and hydraulic conductivity data are summarized in Connelly et al. 1992. The vadose zone beneath the 200 East Area LLBG consists primarily of Hanford formation sediments.

2.1.4.2.1 Description of the Soil Column Underlying the 218-E-12B Burial Ground

Suprabasalt sediments beneath this burial ground consist entirely of Hanford formation sediments (refer to Appendix A, Figures A-1, A-2, A-3, and A-4 of Wood et al. 1996). The uppermost unit, Unit 1, is variable in thickness and distribution. It ranges from 11 to 37 m (35 to 120 ft) thick, and is predominantly a gravel facies. The unit is thinnest in the southwestern part of the burial ground and thickens to the north and east. The contact between Unit 1 and underlying strata generally is very irregular. The sands that make up Unit 2 are thickest [up to 55 m (180 ft)] in the southwestern part of the burial ground and pinch out toward the east and north. Silty beds and horizons within this unit have the potential to form perched water conditions. Unit 2a represents a transitional unit between Units 2 and 3, and exhibits increased gravel content. Unit 2a is locally well developed, especially to the east where Unit 2 pinches out and interfingers with Units 1 and 3. Unit 3, which is characterized by predominant gravel content, thickens to the north and northeast, from 12 to 45 m (40 to 150 ft) thick. Interbeds of sand and silt are present throughout Unit 3. Due to these interbeds, perched water conditions may also occur within Unit 3.

2.1.4.2.2 Description of the Soil Column Underlying the 218-E-10 Burial Ground

Hanford formation Units 1, 2, 2a, and 3 are all present beneath the 218-E-10 Burial Ground. Boreholes adjacent to the BX-BY Tank Farms encountered a thin sequence of Ringold-like sediments suggestive of the lower mud unit. However, Ringold Formation deposits are not present beneath the 218-E-10 Burial

Ground. Unit 1 ranges from 12 to 33.5 m (40 to 110 ft) thick. It consists predominantly of gravel with interbedded sands. The unit is thickest to the northwest and thins to the east and south. Sands of Unit 2 range from 27 to 40 m (90 to 130 ft) thick, generally thickening to the south and west over the burial ground area. Several gravel intervals 3 to 5 m (10 to 15 ft) thick occur in the middle part of Unit 2. The lower part of Unit 2 (referred to as Unit 2a) also exhibits increased gravel content and is up to 15 m (50 ft) thick. As much as 34 m (110 ft) of gravelly strata assigned to Unit 3 occur beneath the 218-E-10 Burial Ground. Data from boreholes that reached the top of basalt indicate the strata dip to the west and south beneath the burial ground. This is consistent with regional data.

2.1.4.3 Characteristics of the Uppermost Aquifer System Underlying the 200 East and 200 West LLBGs

A water table contour map of the uppermost aquifer for the Hanford Site, based on 1993 data, is shown in Figure 2-7. The position of the water table in the western portion of the Hanford Site generally occurs within Ringold Unit E gravels. The water table in the eastern portion of the Hanford Site generally occurs within Hanford formation sediments. The gradient across the burial grounds is very slight (Figure 2-7). The general direction of flow is currently east to west under the 200 East Area LLBG. The primary driving force is the groundwater mound underneath B Pond, situated to the east of the LLBG.

Recharge to the uppermost aquifer occurs primarily from wastewater disposal practices at surface ponds, ditches, and various cribs in the 200 East and 200 West Areas. Three large recharge mounds have developed at the Hanford Site: U Pond in the 200 West Area, B Pond east of the 200 East Area, and Gable Mountain Pond north of the 200 East Area. Under U Pond, which was decommissioned in 1985, the water table had risen more than 17 m (55 ft) since the start of wastewater disposal operations there. The mound under B Pond has risen more than 9 m (30 ft) (Graham et al. 1981). Underneath the 200 East Area LLBG, the depth to the water table is about 66 m (215 ft). The projected post-Hanford depth is about 69 m (225 ft). As these groundwater mounds dissipate, the direction of groundwater flow beneath the 200 East and West Area burial grounds is likely to return to the easterly regional groundwater flow direction estimated to exist before Hanford Site operations began (Figure 2-8).

2.1.5 Geochemistry

The general geochemical characteristics of the soil column are very consistent in the suprabasalt sediments across the Hanford Site. The soil phases are predominantly feldspar and quartz with minor quantities of smectite clay, hydrous oxides, and calcium carbonate that are consistently present. Measured quantities of soil phases from 218-W-5 Burial Ground (Serne et al. 1993) were about 31 percent feldspar, about 43 percent quartz, about 3 percent smectite clay, about 1 percent hydrous oxides, and about 2 percent calcium carbonate. Many analyses of the unconfined aquifer groundwater have been completed at the Hanford Site. Again, the data are very consistent. The groundwater is characterized as moderately alkaline (pH about 7.8 to 8.4), and oxidizing (Eh about 280 to 380 mv) with moderate concentrations of aqueous species (about 5 meq/L). Analyses of moisture from vadose zone sediments (Serne et al. 1993) show essentially the same chemical characteristics.

2.1.6 Natural Resources

The Central Plateau of the Hanford Site has no important natural resources other than industrial minerals (i.e., sand and gravel). No major mining operations exist in the vicinity of the Hanford Site. Oil and gas exploration has occurred in the region; however, no economically viable accumulations of either have been found. Some local gravel processing is performed in the area.

2.2 FACILITY CHARACTERISTICS

2.2.1 Facility Description

Active LLBGs are classified as a landfill facility and cover a noncontiguous combined area of about 570 hectares (1,400 acres) (DOE 1990, p. 2-5). The facility is located in the 200 East and 200 West Areas of the Hanford Site. It is divided into eight active burial grounds with various size trenches, currently including 167 unlined trenches for the disposal of low level waste, two RCRA compliant lined trenches for the disposal of MLLW and one large unlined trench for disposal of U.S. Navy reactor compartments.

2.2.1.1 Low-Level Waste Disposal Trenches

LLW generally is received packaged in 208-L (55-gal) steel drums and wood or steel boxes, although concrete burial vaults, other accepted burial containers, and inherently stable waste packages and bulk waste may also be disposed. Concrete drag-off boxes formerly were used for disposing of wastes that exceeded 200 mrem/h surface radiation dose rate. The boxes, which are approximately 61.5 m³ (2,170 ft³) in volume, were transported to a trench by a flatbed railroad car or truck. Drag-off boxes are no longer used in LLBG operations. LLW with hazardous/dangerous waste constituents was disposed in unlined trenches prior to August 19, 1987. Dangerous waste regulations were applied to LLW on that date.

Flat-bottom trenches nominally range from 5.2 m (17 ft) to 20 m (65 ft) deep. An engineering analysis is performed for trenches over 6.1 m (20 ft) deep to ensure stable slopes during the operational life. Bottom dimensions range from 4.9 m (16 ft) to over 30 m (100 ft) wide. Trench slopes are normally 1.5H:1V to avoid sloughing of the trench walls. Modifications are made to these trench designs as needed to accommodate a variety of waste packages. Trench bottoms are stabilized to the extent necessary to ensure sound bearing for waste handling equipment. The flat-bottom trenches are routinely backfilled with approximately 2.4 m (8 ft) of soil.

DOE has directed that waste disposal operations should maximize the use of the remaining LLBG area, by widening existing trenches and by constructing new deeper trenches in areas currently occupied by shallow unused trenches. The Disposal Plan (Pratt 2000) assumes that future trenches for contact-handled (CH) Category 1 LLW in drums and boxes and CH Category 3 LLW will be deep trenches. Trench depth will vary depending on location and the proposed stacking arrangement. Special-purpose trenches will be constructed for disposal of CH Category 1 LLW in drums and boxes in multiple tiers. These trenches may be as deep as 21 m (70 ft). Drums will be treated with dynamic compaction every fourth tier. Boxes will be stacked to a height of 5 m (16 ft) and covered with 1.2 m (4 ft) of soil; each layer of boxes will be treated with dynamic compaction before placement of the next layer. The final tier will be covered with 2.4 m (8 ft) of soil to bring the trench back to grade.

Currently, remote-handled (RH) LLW (i.e., LLW with dose rates greater than 200 mrem/h measured at the waste container surface) is disposed in single layers in V-trenches. Small quantities of RH LLW also have been disposed in covered caissons. All caissons in the LLBG are located in trench 14 of the 218-W-4B burial ground. Caissons for disposal of RH LLW are referred to as beta-gamma caissons.

2.2.1.2 Mixed Waste Disposal Trenches

The current MLLW disposal trenches receive waste that meets the applicable land disposal restrictions/requirements. MLLW trenches can also be permitted for greater-than-90-day storage prior to going to the disposal mode. Waste forms are containerized, inherently stable, and/or bulk waste. If approved by the LLBG operating contractor, nonstandard waste packages and miscellaneous equipment

waste may also be placed in a MLLW disposal trench. Less than 5 percent of MLLW is expected to be RH material. RH MLLW will be shielded or backfilled to minimize worker exposure. Lined MLLW trenches will be filled in balanced layers to ensure the liner is not differentially loaded to the point it is damaged.

The following is a general description of a lined MLLW trench. Future trenches are likely to vary in size, shape, and other design details. However, from a safety standpoint, they will be identical in that they will be in compliance with the applicable regulations. Geomembranes incorporated in the design primarily function in this application as a protective barrier to prevent leachate from reaching the environment. Water infiltration is anticipated to be very low, as discussed in this section under water infiltration. Lined MLLW disposal trenches have a liner system that consists of bentonite-enriched soil, geosynthetic liner materials, and the leachate drainage system. This liner system will prevent the release of leachate to the environment and prevent migration of any hazardous constituents through the liner during the operational life of the landfill and the post-closure period. The leachate collection system is capable of collecting and removing leachate such that a nominal hydraulic head on the liner is not exceeded. A low-capacity pump will handle the normal, average leachate flow. When adverse precipitation conditions require a higher capacity, such as for the assumed worst-case precipitation event, a high-capacity pump is available. The pumps and associated piping are resistant to leachate corrosion.

2.2.1.3 Navy Reactor Compartment (RC) Disposal Trench

The RC is the section of a submarine or surface vessel containing the sealed and defueled reactor compartment, associated components, bulkheads, and hull sections. Once placed, RCs are managed in the same manner as any other LLW. Because of its structural characteristics, the RC waste package is impervious to wind, rain, dust, fire, etc. RCs are placed on structural supports that have been designed in accordance with applicable earthquake standards for the Hanford Site.

The Navy RC disposal trench is designated Trench 94 in the 218-E-12B Burial Ground. This trench is located in the northeast corner of the 200 East Area. Trench 94 is managed as a MLLW disposal unit by agreement with the Washington State Department of Ecology.

RCs are classified as state-only regulated hazardous waste due to the presence of shielding lead. The waste package is classified as a bulk waste with the characteristics of a U.S. Department of Transportation Type B container carrying highway route controlled quantities of radioactive material (49 CFR 173.403). The Department of the Navy has obtained a certificate of compliance (NRC 1989) with the Type B packaging criteria. This compliance provides a high level of confidence that the RC waste will not represent a hazard to personnel or the environment.

2.2.1.4 LLBG Overview

The facility is comprised of eight burial grounds as described below. Most trenches that received waste prior to 1987 contain some waste with constituents that are currently regulated by the State of Washington as dangerous wastes.

218-W-3A -- This facility extends over an area of approximately 20 hectares (50 acres) and contains a total of 57 trenches. The oldest trench (trench 11) was opened in 1970 and filled in 1971. The last trench to receive waste (trench 49) was filled in 1998. A number of different trench designs (depth, width, and cross-section area) were constructed (see H-2-34880). A few of the oldest trenches (opened in 1972 and earlier) probably contain only 1.2 m (4 ft) of operational soil cover. In 1972, LLBG operating practices were modified to increase the thickness of operational cover to 8 ft to eliminate biointrusion problems. This burial ground received both Category 1 and Category 3 wastes. The two LLW categories were not

segregated. Two trenches contain post-August 19, 1987 RCRA and state-only designated mixed waste. Twelve trenches contain retrievable TRU.

218-W-3AE -- This facility extends over an area of approximately 20 hectares (49 acres) and currently contains a total of eight trenches. Three additional trenches are planned (Pratt 2000). This burial ground first received waste in 1981. A number of different trench designs (cross-sections) have been constructed. All filled trenches are believed to contain at least 2.4 m (8 ft) of operational soil cover. The facility contains both Category 1 and Category 3 wastes (unsegregated). Two trenches (trenches 5 and 10) contain post-August 19, 1987 RCRA and state-only designated MLLW. Waste disposed in this burial ground does not include any waste classified as retrievable TRU. A stabilized liquid effluent disposal site (216-T-4 Pond) is situated inside the facility boundary.

218-W-4B -- This facility extends over an area of approximately 3.5 hectares (8.6 acres) and contains a total of 13 trenches. The two oldest trenches (1 and 5) were filled in 1967. Trench 7 was the last trench to be filled (in 1983). Twelve below-grade caissons at the south end of the facility contain RH LLW and retrievable TRU. Waste disposal in caissons occurred between 1969 and 1990. Two trenches (7 and 11) contain retrievable TRU. Waste disposed in trenches other than trenches 7 and 11 was not segregated, and includes Category 1 and Category 3 LLW. Most trenches in this facility (other than trenches 7 and 11) were opened and filled prior to 1972 and likely have only 1.2 m (4 ft) of operational cover. No post-August 19, 1987 RCRA and state-only designated MLLW was disposed at this facility.

218-W-4C -- This burial ground is approximately 20 hectares (49 acres) in size and currently contains a total of 15 trenches. Five additional trenches are planned (Pratt 2000). The facility first received waste in 1978. Therefore, all filled trenches should have at least 2.4 m (8 ft) of operational soil cover. A number of different trench designs (cross-sections) have been constructed in this burial ground. The facility contains both Category 1 and Category 3 wastes (unsegregated). Trench NC, Trench 14, and Trench 58 contain post-August 19, 1987 RCRA and state-regulated mixed waste. Seven trenches contain TRU that will be retrieved. An adjoining 8.8-acre area at the southeast corner of this burial ground is included in the facility description. However, the adjoining area currently is unused, and no future utilization for LLW disposal is envisioned (Pratt 2000).

218-W-5 -- This burial ground is approximately 37.2 hectares (91.9 acres) in size and currently contains a total of thirteen trenches. Five additional trenches are planned (Pratt 2000). The first waste receipts were in 1986. Several different trench designs (cross-sections) have been constructed in this burial ground. Trenches 31 and 34 at the south end of the facility are RCRA-compliant trenches with liner and leachate collection systems for disposal of MLLW. The facility has received both Category 1 and Category 3 wastes (unsegregated). Trenches 22 and 24 contain post-August 19, 1987 RCRA and state-regulated MLLW. There is no retrievable TRU in this burial ground.

218-W-6 -- This burial ground is approximately 16 hectares (40 acres) in size. No trenches have been opened and no waste has been received. The site is reserved for future LLW and/or MLLW disposal. However, the current disposal plan (Pratt 2000) indicates that it will remain unused.

218-E-10 -- This facility extends over an area of approximately 36.1 hectares (89.2 acres), which is divided into two areas (labeled as northern portion and a southern portion). The northern portion is unused. The southern portion currently contains a total of 14 trenches with a north-south orientation and two other stub trenches at the southeast corner with an east-west orientation. This burial ground first received waste in 1960. Waste was unsegregated and included both Category 1 and Category 3 LLW. This burial ground does not contain any retrievable TRU. Trench 9 contains post-August 19, 1987 RCRA and state-regulated MLLW. No additional trenches are planned. The northern portion could be used for future MLLW disposal trenches. However, the current disposal plan (Pratt, 2000) envisions that it will remain unused.

1
2 **218-E-12B** -- This facility extends over an area of approximately 68 hectares (168 acres) and began
3 receiving waste in 1967. This facility currently contains a total of 40 trenches. One additional trench is
4 planned, which will be a large RCRA-compliant landfill trench with liner and leachate collection system
5 for MLLW disposal (Pratt 2000). This burial ground includes another large, special-purpose trench
6 (Trench 94) for disposal of RCs from decommissioned U.S. Navy submarines and surface vessels.
7 Trench 94 is a relatively wide and deep excavation. When RC disposal activities are concluded in
8 Trench 94, a separate engineering design will be necessary to ensure that fill is placed and compacted in
9 an adequate manner to prepare this trench for closure. Disposed RCs are regulated as mixed waste. The
10 majority of the waste volume in the 218-E-12B burial ground was disposed prior to 1987 (except for
11 disposal activities in Trench 94). Trenches contain unsegregated Category 1 and Category 3 LLW.
12 Retrievable TRU residues in portions of three trenches. There is a limited amount of unused disposal
13 capacity in existing trenches.
14

15 16 **2.2.2 Features of the Cover System that will Minimize Water Infiltration**

17 The current planning basis cover system for closure of active LLBGs (described in Section 3.3.2)
18 incorporates two independent water management strategies to minimize infiltration. The primary strategy
19 makes use of the high evapotranspiration potential at the Hanford Site, which reflects the Site's semiarid
20 climate. The cover design includes two topsoil layers. The upper layer consists of silt loam soil placed in
21 a relatively loose (non-compacted) condition. The lower topsoil layer will be placed in a relatively dense
22 (compacted) condition. A capillary barrier will be present at the base of the compacted topsoil layer,
23 which will tend to prevent drainage of soil moisture out of the topsoil layers. The capillary barrier and the
24 compacted condition of the lower topsoil layer will tend to retard vertical moisture migration and increase
25 retention time, increasing the amount of time available for moisture to be eliminated from the system by
26 evaporation and transpiration processes.
27

28 The second strategy is to provide a lateral drainage path so that any moisture that does drain below the
29 topsoil layers can be eliminated. At a lower level within the cover, moisture will be intercepted by a thick
30 layer of low-permeability asphalt (i.e., a double-tar asphaltic material with in-field permeability values of
31 between 10^{-7} and 10^{-9} cm/s). The asphalt layer will be constructed with a 2 percent slope toward the
32 perimeter of the covered area. The material placed directly above the asphalt will be clean, screened
33 aggregate material with a hydraulic conductivity of at least 1 cm/s. These properties ensure that the
34 material will be free draining and that hydraulic head (standing water) cannot accumulate within the
35 drainage media.
36

37 PAs for LLBGs indicate that long-term performance goals will be achieved if engineered surface barriers
38 limit deep infiltration into/through the waste layer to 0.5 cm/yr or less. Numerical simulations of cover
39 performance indicate that the proposed final cover treatment will eliminate more than 99 percent of
40 annual precipitation by evapotranspiration and will limit deep infiltration to about 0.1 cm/yr (0.2 in/yr).
41 The need for external drainage controls (e.g., surface run-on and runoff controls, perimeter drainage
42 collection and routing) will be evaluated as aspects of definitive design.
43

44 45 **2.2.3 Features that will Assure Integrity of the Cover System**

46 The current planning basis cover system for closure of active LLBGs will be constructed of materials that
47 are highly resistant to natural degradation processes. With the exception of the asphalt layer, the cover
48 system is designed entirely of natural soil and rock materials that will provide appropriate long-term
49 resistance to chemical and physical weathering. The ER Program is evaluating long-term durability of

asphalt materials. Preliminary indications are that asphalt materials in cover systems will have adequate durability to maintain function for post-closure periods of 500 to 1,000 years (Waugh et al. 1994).

The cover system is designed to require minimal maintenance during its design life. The silt loam topsoil in the surface layer will contain a 15 weight percent pea gravel admixture. As silt particles are removed from the topsoil surface by wind erosion, the pea gravel will concentrate into a lag deposit that will tend to protect the surface from further erosion. The surface slope of the cover has been specified at 2 percent to limit susceptibility to wind erosion. Perennial vegetation will be cultivated on the cover surface to minimize soil losses to wind and water erosion. Straw mulch will be crimped into the soil when seeding is performed to limit wind erosion during the first year, while vegetation is becoming established. The intent of these design strategies is to maximize the physical integrity of the cover and to minimize the need for ongoing maintenance. Sample calculations (which do not consider the beneficial effect of the pea gravel admixture) indicate that topsoil losses from the proposed cover system should be less than two tons per acre per year. Two tons per acre per year is the Environmental Protection Agency's (EPA) recommended performance guideline (EPA 1989).

2.2.4 Features that will Ensure Structural Stability of Closed LLBG Facilities

During the Interim Closure period, extensive sub-grade modification measures will be applied to densify and stabilize trench fills and to eliminate void volumes in containers in preparation for construction of final covers over LLBGs. Bearing capacity and tolerable settlement criteria for trench fill materials will be developed as an aspect of definitive design of the cover system. Sub-grade modification methods are described in Section 3.2, together with geophysical survey methods that may be used to evaluate the adequacy of sub-grade stabilization efforts.

The PAs do not require waste form stabilization for disposal of Category 1 LLW. Stabilization of Category 1 LLW will be accomplished solely by sub-grade modification. However, for Category 3 LLW, stabilization is required. Currently, Category 3 LLW is being stabilized by placement in concrete vaults or by encasement in concrete monoliths in trenches at the time of disposal.

As noted above, the cover system will be constructed of materials that are highly resistant to natural degradation processes (i.e., chemical and physical weathering).

2.2.5 Inadvertent Intruder Barrier

Human habitation of surfaces over closed LLBG facilities is the most potentially adverse inadvertent intrusion scenario considered in PAs (Wood et al. 1995, Wood et al. 1996). For closure of facilities with Class C LLW (comparable DOE Category 3 LLW), Nuclear Regulatory Commission (NRC) requires (10 CFR 61.52(a)(2)) that either the top of the waste must be a minimum of 5 m (16.4 ft) below final grade, or the waste must be covered with a surface barrier designed to protect against inadvertent human intrusion for at least 500 years. Criteria applied to the conceptual design of the proposed cover system were to:

1. Design a cover with a functional life of 500 years
2. Ensure that the top of the waste is at least 5 m (16.4 ft) below final grade or include appropriate design provisions to limit inadvertent human intrusion.

PAs for LLBGs with Category 3 LLW indicate that dose consequences to inadvertent intruders who take up residence 100 to 500 years after closure will not exceed the performance objective for intruder

protection (continuous exposure limit of 100 mrem/year) if the cover system conforms to the provisions in 10 CFR 61.52(a)(2).

The Modified RCRA Subtitle C cover is designed to withstand soil losses from wind and water erosion for a functional performance period of 500 years. The cover system (Layers 1 through 7) is 1.7 m (5.7 ft) thick. Filled trenches generally have been covered with 2.4 m (8 ft) of operational cover soil. The 5-m cover requirement will be met by placing a minimum 0.9 m (3 ft) of grading fill over each facility as an aspect of establishing grading slopes for the engineered cover layers. Grading plans will be developed during definitive design of the cover system.

The 15-cm (6 in.) thick low-permeability asphalt layer (Layer 6) of the proposed cover system represents a substantial barrier to inadvertent human intrusion. This layer will be impenetrable by hand excavation, and can only be breached with mechanized equipment. Absent other overt indications, this layer should serve to communicate to an intruder that the asphalt layer is part of an engineered structure. Any additional requirements that may be imposed on the design for intrusion prevention (e.g., surface warning markers) will be evaluated during definitive design.

2.3 WASTE CHARACTERISTICS

2.3.1 Current Waste Inventory

According to the draft SW-EIS, as of January 1, 1999, the Hanford Site Solid Waste Storage and Disposal Program inventory included a total volume of approximately 298,000 m³ (390,000 yd³) of LLW, TRU waste, MLLW, and minor volumes of elemental metals. Of this total, approximately 296,000 m³ had been disposed in active LLBGs, and the remainder was undergoing treatment or storage in preparation for disposal.

2.3.2 Future Additions To Waste Inventory

The SW-EIS considers three separate management alternatives for solid waste streams at the Hanford Site:

- A No-Action Alternative: Under this alternative, LLW and LDR-compliant MLLW would continue to be disposed in LLBGs. Additional shallow LLBG trenches would be constructed as necessary to support ongoing operations. TRU in burial grounds would not be retrieved; Hanford generated TRU wastes would not be shipped to WIPP for disposal off site. Existing waste treatment operations at WRAP (certification and repackaging) and T Plant (decontamination) would continue. However, no new treatment facilities would be constructed on site. Wastes would continue to be accepted from off-site generators who currently ship waste to the Hanford Site.
- A Proposed Baseline Alternative: With this alternative, new facilities will be constructed at the Hanford Site for storage, inspection, treatment and final disposal or shipment off-site for all waste streams currently managed by the Solid Waste Storage and Disposal Program. It assumes the same sources, waste streams and volumes as the No Action Alternative. Most wastes currently in storage would be removed, treated as required, and disposed over the next 10 years. TRU waste in LLBGs would be retrieved, treated as necessary, packaged, and shipped to WIPP for final disposal. Wastes would continue to be accepted from off-site generators who currently ship waste to the Hanford Site. Capping and final closure of active LLBGs, including MLLW trenches, are considered under this alternative.

A sub-alternative considered under this alternative is to leave TRU waste in LLBGs in place as part of the site inventory at final closure.

- A Proposed Regional Alternative: This alternative is similar to the Baseline Alternative in terms of waste management activities and processes and plans for new waste handling facilities. It differs from the Baseline Alternative in that additional volumes of LLW and MLLW would be shipped to the Hanford Site from other DOE sites. This alternative results in greater volumes of LLW and MLLW being managed and disposed at the Hanford Site, as well as inspecting and preparing additional TRU for shipment to the WIPP repository. Capping and final closure of active LLBGs, including MLLW trenches, are considered under this alternative.

Table 2.1, which is a summary of information presented in Table B.1 of the draft SW-EIS, provides a listing of the waste inventory in LLBGs, as well as a forecast of future inventory volumes for the No-Action and Proposed Baseline Alternatives. Table 2.2, which is a summary from Table B.2 of the EIS, gives current and future inventory data for the Proposed Regional Alternative. The values in these tables are from the current draft of the EIS and may change after this Closure Plan is issued and before the EIS becomes final.

2.3.3 Radiological Inventory

Table 2.3 provides a listing of current radiological inventories in active LLBGs based on records in Solid Waste Inventory Tracking System (SWITS). PAs for active LLBGs consider only the inventories of waste disposed since September 26, 1988 with emphasis on the projected and final inventories of radionuclides in LLBGs that are regarded to be mobile in groundwater or contribute towards potential inadvertent intruder dose. Projected inventory additions to be disposed in LLBG are summarized in Table 2.4 (from Wood, 1999).

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Figure 2.1. Map Showing Locations of the Hanford Site and the 200 Areas.

Figure 2.2. Topography of the Hanford Site.

Figure 2.3. Historical Seismicity of the Columbia Plateau and Surrounding Areas.

Figure 2.4. Hydrologic Basins Designated for the Washington State Portion of the Columbia Plateau.

H9312003.1a

Figure 2.5. Centralized Stratigraphy of Suprabasalt Sediments on the Hanford Site.

Figure 2.6. Geomorphic Features in the West-Central Portion of the Hanford Site.

Figure 2.7. Water Table Map for the 200 Areas, December 1987.

Figure 2.8. Hanford Site Water Table Map, January 1944.

Table 2.1. Waste Inventory and Forecast Volumes for Active LLBGs for the Baseline Alternative Described in the SW-EIS (DOE 2000)(a)

Waste Categories (i)	Inventory in LLBGs as of January 1, 1999 (in m ³)	Future Additions to Inventory (in m ³)	Cumulative Future Inventory (in m ³)
CAT 1 LLW	274,029 (b)	98,784 (c)	412,765
CAT 3 LLW		39,952 (d)	
TRU in Trenches and Caissons	14,825 (e)	57,189 (f)	72,014
MLLW	9,169 (g)	59,681 (h)	68,850

- (a) Based on information presented in Table B.1 of the SW-EIS
(b) Sum of Streams 6, 19 and 20 in Table B.1
(c) Stream 1
(d) Stream 2
(e) Sum of Streams 4 and 5
(f) Sum of Streams 8, 9, 10, 16 and 17
(g) Sum of current inventories in Streams 11, 12, 13, 14 and 15
(h) Sum of future inventory additions in Streams 11, 12, 13, 14 and 15
(i) Waste Volumes in Streams 3 and 18 of Table B.1 are not included.

Table 2.2. Waste Inventory and Forecast Volumes for Active LLBGs for the Regional Alternative Described in the SW-EIS (DOE 2000)(a)

Waste Categories (i)	Inventory in LLBGs as of January 1, 1999 (in m ³)	Future Additions to Inventory (in m ³)	Cumulative Future Inventory (in m ³)
CAT 1 LLW	274,029 (b)	278,031 (c)	611,611
CAT 3 LLW		59,551 (d)	
TRU in Trenches and Caissons	14,825 (e)	63,492 (f)	78,317
MLLW	9,169 (g)	200,018 (h)	209,187

- (a) Based on information presented in Table B.2 of the SW-EIS
(b) Sum of Streams 6, 19 and 20 in Table B.2
(c) Stream 1
(d) Stream 2
(e) Sum of Streams 4 and 5
(f) Sum of Streams 8, 9, 10, 16 and 17
(g) Sum of current inventories in Streams 11, 12, 13, 14 and 15
(h) Sum of future inventory additions in Streams 11, 12, 13, 14 and 15
(i) Waste Volumes in Streams 3 and 18 of Table B.2 are not included.

Table 2.3. Current Inventories of Radionuclides In LLBG (in Ci)

ISOTOPE	218-W-3A	218-W-3AE	218-W-4B	218-W-4C	218-W-5	218-E10	218-E-12B
²⁷⁷ Ac		8.00E-04		1.01E-06	6.15E-04		
²²⁸ Ac		3.58E-03		5.15E-04	1.51E-04		
¹⁰⁸ Ag	9.10E-06	2.70E-05			2.84E-03		
^{110M} Ag-- ¹¹⁰ Ag	3.07E+00	1.17E-05		2.84E-05	3.14E-04		
²⁸ Al					3.40E-05		
²⁴¹ Am	7.93E+01	5.94E+01	4.16E+00	5.63E+02	3.33E+00	1.46E-03	1.67E+00
^{242M} Am	6.20E-03	1.86E-01		3.15E-04	4.35E-03		2.05E-06
²⁴³ Am	2.44E-02	8.01E-02		1.06E+01	1.69E-02		4.32E-06
³⁹ Ar					2.30E-03		
¹⁹⁵ Au		9.25E-05			4.78E-05		
¹³³ Ba	1.59E-04	1.36E-02		6.95E-03	6.76E-02		
¹³⁴ Ba					1.33E-07		
¹⁴⁰ Ba				1.00E-03	1.38E-04		
¹⁰ Be	6.92E-10	4.60E-11		5.66E-05	1.06E-05		1.28E-06
⁷ Be	1.75E-01	3.98E-02		6.04E-03	1.38E+00		1.30E-09
²⁰⁷ Bi	2.70E-03	1.12E-03		1.20E-02	1.22E-02		
²¹² Bi		9.17E-02		4.35E-04	7.04E-03		
²¹⁴ Bi	3.48E-05	6.75E-05		3.40E-04	7.21E-04		
¹⁴ Bi	1.74E+00	1.39E+01		2.63E+00	5.28E+00		1.31E+02
¹⁴ C ACTIV.		2.01E+01		7.60E+01	3.51E-04		1.42E+02
METAL							
⁴⁵ Ca	1.00E-04	3.01E+00		1.99E+00	1.79E-02		
¹⁰⁹ Cd	5.10E-04	2.38E-04		2.26E-03	2.03E-02		
^{113M} Cd	3.61E-05	1.46E-03		1.57E-05	3.64E-04		
¹⁴¹ Ce	1.75E+02	2.85E+00		1.19E-04	1.21E-03		4.01E-01
¹⁴⁴ Ce -- ¹⁴⁴ Pr	5.75E+04	1.16E+00	8.42E+01	1.67E+03	6.93E+00	9.67E-07	3.48E+01
²⁴⁹ Cf					1.67E-03		
²⁵⁰ Cf					2.38E-03		
²⁵¹ Cf		1.05E-02			2.96E-06		
²⁵² Cf	2.01E-05	1.38E-04		1.08E+03	1.29E+01		
³⁶ Cl	2.00E-04	1.35E-03		1.61E-05	2.04E-03		5.56E-03
²⁴² Cm	1.04E-02	6.34E-02		3.70E-03	1.61E+01		2.94E-03
²⁴³ Cm	3.92E-04	2.62E-01		2.43E-05	3.69E-03		5.11E-07
²⁴⁴ Cm	4.81E-01	1.66E+01		4.23E+01	4.81E-01		3.12E-04
²⁴⁵ Cm		2.04E-04		1.41E+00	3.95E-05		
²⁴⁶ Cm		1.99E-04			3.10E-05		
²⁴⁷ Cm		4.18E-07					
²⁴⁸ Cm		8.54E-06		7.00E-07	5.25E-05		
²⁵⁰ Cm					3.83E-21		
⁵⁶ Co	2.78E-05	2.87E+00		1.57E-04	5.28E-01		
⁵⁷ Co	2.83E-03	1.01E+01		2.57E-04	6.19E-01	3.78E-04	1.28E-03
⁵⁸ Co	2.53E+01	3.93E+02		1.96E+03	1.45E+00		2.08E+04
⁵⁹ Co					4.00E-06		
⁶⁰ Co	4.98E+04	1.14E+05	2.09E+04	1.02E+06	7.17E+03	3.80E+03	1.08E+06
⁶⁰ Co ACTIV.		9.80E+00			3.36E-01	1.12E-02	7.60E+04
METAL							
⁵¹ Cr	9.96E-03	3.53E-01	1.00E-01	8.95E+02	4.48E+00		3.61E+02

Table 2.3. Current Inventories of Radionuclides In LLBG (in Ci)

ISOTOPE	218-W-3A	218-W-3AE	218-W-4B	218-W-4C	218-W-5	218-E10	218-E-12B
^{133m} Cs					2.80E-03		
¹³⁴ Cs	1.73E+04	1.94E+02	3.00E-01	1.79E+03	1.90E+00	1.61E-06	1.06E-01
¹³⁵ Cs	1.10E-06	3.80E-07		4.80E-07	1.31E-07		
¹³⁷ Cs-- ^{137m} Ba	3.14E+05	6.16E+04	3.55E+02	5.75E+04	3.06E+03	1.02E+06	2.69E+04
^{65m} Cu					7.02E-03		
²⁵⁴ Es		6.30E-09			1.15E-04		
¹⁵² Eu	2.29E+00	1.32E+03		2.10E+01	1.73E+00	2.01E-06	2.45E-05
^{153m} Eu		1.00E-09		6.37E+02			
¹⁵⁴ Eu	1.73E+00	2.10E+03	2.20E-01	4.75E+02	1.28E+02	4.43E-07	1.96E-06
¹⁵⁵ Eu	3.84E+01	5.29E+02		2.52E+04	1.27E+01	2.27E-06	
⁵⁵ Fe	1.71E+00	2.46E+04		1.11E+04	1.04E+03	1.12E+00	9.27E+05
⁵⁹ Fe	3.33E-01	1.49E+02	2.05E+00		3.70E+00		7.14E+01
⁶⁸ Ga				2.20E-08	6.21E-02		
¹⁵² Gd	3.39E-03				8.47E-02		
¹⁵³ Gd				1.00E-05	6.48E-04		
¹⁵⁴ Gd	2.31E-03	1.25E-05			4.42E-02		
⁶⁸ Ge	2.40E-02	1.12E-03		1.70E-05	6.19E-01		
³ H	4.44E+05	6.58E+04	2.31E+05	3.29E+04	5.32E+04	8.00E-08	1.12E+03
¹⁷⁵ Hf		1.00E-03			1.00E-06		
¹⁸¹ Hf		1.07E-02			3.36E-06		2.32E+00
²⁰³ Hg		1.20E-06		6.00E-07	2.17E-04		
¹²³ I					5.61E-04		
¹²⁵ I	1.51E-02	4.11E-02		1.21E-01	1.57E-01		
¹²⁹ I	1.44E-02	4.01E-04	5.00E-01	1.46E-03	3.44E-02		2.94E-03
¹³¹ I	1.37E-03	2.12E-04		1.00E-05	1.28E-02		
⁴⁰ K	2.02E-04	6.05E-02		2.00E-04	1.53E-02	3.96E-04	9.27E-03
⁸⁵ Kr	3.73E+03	1.31E+01		2.48E+01	8.80E+00		
¹⁴⁰ La				1.20E-06			
⁵⁴ Mn	4.36E+00	8.71E+03	3.62E+00	4.10E+02	9.66E+00	8.32E-04	1.12E+04
⁹³ Mo		5.60E-02		2.29E+00	1.33E+00		6.90E-02
²² Na	6.64E+00	6.65E+00		5.73E-02	1.42E+01		
⁹¹ Nb		5.78E-02			4.41E-01		
^{93m} Nb	7.43E-05	1.64E-02		9.08E-05	2.61E-02		5.61E-01
⁹⁴ Nb	2.14E-04	1.08E+00		1.38E+01	2.77E-01		1.50E+01
^{94m} Nb ACTIV.							1.45E+01
METAL							
⁹⁵		2.09E+03		7.35E-05	1.04E-01		1.35E+03
¹⁴⁷ Nd					2.41E-06		
⁵⁹ Ni	8.78E-04	5.24E+02		9.77E+01	8.54E+01		5.12E+03
⁶⁰ Ni	2.98E-01	1.80E+03		2.25E-01	3.23E+00		
⁶³ Ni	3.89E+00	6.28E+04		1.27E+04	9.93E+03		9.56E+05
⁶³ Ni ACTIV.		1.21E+01					4.32E+05
METAL							
²³⁷ Np	2.21E-02	6.69E-02	1.51E-01	1.02E-01	2.81E-02	1.05E-03	1.56E-08
³² P	4.71E-02	3.22E+00		1.90E-01	1.45E+00		
³³ P		4.81E-01					
²³¹ Pa		6.36E-03		2.32E-06	7.74E-01		
^{208m} Pb					9.20E-08		

Table 2.3. Current Inventories of Radionuclides In LLBG (in Ci)

ISOTOPE	218-W-3A	218-W-3AE	218-W-4B	218-W-4C	218-W-5	218-E10	218-E-12B
²¹⁰ Pb		5.96E-04		3.60E-04	3.16E-02		
²¹² Pb		2.24E-03		5.76E-03	3.34E-03		
²¹⁴ Pb	4.25E-05	7.03E-05		3.41E-04	2.59E-04		
¹⁰⁷ Pd					1.62E-08		
Pe-Ci	3.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
¹⁴⁷ Pm	4.02E+04	2.22E+00	9.59E+03	3.88E+03	3.71E+00		3.00E+00
²¹⁰ Po		1.18E-02	7.00E+00	1.14E-04	4.79E-03		
^{195M} Pt					9.00E-10		
Pu	1.91E+04	7.98E+01	4.33E+04	2.40E+05	1.09E+02	3.23E+03	1.01E+03
²³⁶ Pu		1.99E-09					
²³⁸ Pu	9.19E+00	8.86E+00	2.45E+01	8.98E+04	5.88E+00	1.51E-04	1.89E+00
²³⁹ Pu	4.41E-01	1.53E+01		2.22E+02	7.67E+00	2.57E-03	1.59E-01
²⁴⁰ Pu	2.95E-01	7.67E+00		1.23E+02	1.37E+02	1.37E-03	1.15E-01
²⁴¹ Pu	2.95E+01	3.21E+02		2.15E+04	1.13E+02	3.36E-02	4.52E+01
²⁴² Pu	1.32E-04	5.05E-03		8.13E-02	6.85E-04		4.05E-07
²⁴⁴ Pu		1.10E-05		1.83E-12	2.99E-06		
²³⁹ Pu FSL GR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
EQUIV							
²²⁴ Ra		9.19E+02		2.27E+02	5.61E+02		
²²⁶ Ra	2.57E+00	2.35E-02		3.52E-02	2.89E+00		
²²⁸ Ra		7.80E-04		4.54E-04	1.31E-03		
^{85M} Rd					3.00E-06		
⁸⁶ Rb	5.02E-03	1.00E-04			6.61E-03		
¹⁸⁷ Re	2.00E-04	1.21E-09		5.07E-09	3.00E-06		
¹⁰³ Ru-- ^{103M} Rh		1.00E-06	1.24E+00	2.00E-06	1.43E-01	1.21E-07	
¹⁰⁶ Ru-- ¹⁰⁶ Rh	6.80E+03	5.18E+02		3.23E+03	4.21E+00	1.15E-06	1.07E+00
³⁵ S	4.24E-02	2.35E-02		2.18E-02	1.82E-01		
¹²² Sb	3.00E-07				6.62E-06		
¹²⁴ Sb		4.30E-04		9.58E-07	1.85E-04		
¹²⁵ Sb	1.49E+03	9.05E+03	2.00E-02	5.14E+02	2.53E-01	4.08E-07	1.21E+04
¹²⁶ Sb	3.99E+00	7.20E-08		9.00E-08	2.50E-04		
⁴⁶ Sc	2.87E-04	1.27E+00		2.23E-02	5.21E-02		
⁷⁵ Se	8.60E-05	1.13E-02		5.00E-08	3.54E-03		
⁷⁹ Se	1.12E-04	9.77E-03		2.71E-05	5.00E-03		2.31E-05
³¹ Si	1.50E-05				1.00E-04		
¹⁴⁷ Sm	2.00E-04				7.86E-13		
¹⁵¹ Sm	9.98E-04	8.17E-03		3.07E+02	8.26E-01		4.44E-01
¹¹³ Sn		1.01E-05		4.30E-06	5.92E-01	1.42E-07	
^{119M} Sn		1.28E+04			4.64E-19		7.28E+03
^{121M} Sn	2.87E-07	1.60E+01		1.25E-07	3.30E-07		4.98E+01
^{123M} Sn		1.08E+02			2.00E-05		
¹²⁶ Sn-- ^{126M} Sb	1.05E-03	3.78E-02			1.03E-03		
⁸² Sr				2.00E-06	4.33E-04		
⁸⁵ Sr	2.88E-03	1.07E-02		2.02E-03	8.68E-02		
⁸⁹ Sr		1.28E-04		1.91E-05	2.46E+00		
⁹⁰ Sr-- ⁹⁰ Y	9.11E+04	5.32E+04	2.88E+02	7.33E+03	2.08E+03	8.53E+05	2.69E+04
¹⁸² Ta	1.27E-03	1.24E+02		2.56E-01	2.52E-01		1.00E-03

Table 2.3. Current Inventories of Radionuclides In LLBG (in Ci)

ISOTOPE	218-W-3A	218-W-3AE	218-W-4B	218-W-4C	218-W-5	218-E10	218-E-12B
¹⁸³ Ta		9.00E-01					
⁹⁹ Tc	2.88E-01	9.80E+00		1.64E+01	3.95E-01	5.07E-03	8.08E-01
⁹⁹ Tc ACTIV.		1.00E-07					
METAL							
¹²¹ Te					1.00E-04		
^{123M} Te	3.39E+02	1.92E+03		5.21E-04	4.15E-04		1.40E+03
^{127M} Te					5.02E-34		
^{129M} Te					1.00E-07		
²²⁸ Th	1.24E-04	6.32E+05		3.95E-01	1.53E+02	1.90E-05	
²²⁹ Th		1.84E-04		1.13E-04	3.26E-04		
²³⁰ Th	1.18E-03	5.04E-03		9.73E-04	1.90E+00		
²³² Th	1.23E-01	7.61E-02	7.35E-02	1.38E-02	2.52E-01	9.73E-06	2.20E-11
²³⁴ Th	1.20E-02	1.95E+04		2.96E+00	1.34E+03	1.04E-02	4.18E-03
²⁰⁴ Th	5.00E-10	4.02E-01		1.00E-05	8.65E-04		
²⁰⁸ Th		6.76E-04		4.32E-01	2.12E-03		
¹⁷⁰ Th	2.00E-04	2.00E-06			6.90E-07		
TOTAL	1.69E+06	5.78E+05	5.07E+05	1.84E+06	1.86E+07	4.70E+06	1.10E+07
BETA/GAMMA							
TOTAL-ALPHA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
²³² U	3.32E-09	5.29E+01		1.86E-02	5.71E+00		
²³³ U	1.96E+00	1.07E-01	7.33E+01	8.08E+00	4.75E-02		
²³⁴ U	6.49E-03	8.53E+00		2.17E+01	1.49E-01	9.54E-02	1.02E-02
²³⁵ U	2.17E-03	8.41E-01		7.50E-01	2.88E-02	2.78E-03	3.97E-04
²³⁶ U	1.69E-04	2.60E+00		1.22E+00	1.47E-03	6.09E-13	
²³⁷ U				5.31E+07			
²³⁸ U	1.11E-01	6.22E+01		4.01E+01	6.66E-01	1.14E-02	4.68E-03
URANIUM-DEPLE	2.48E+01	8.83E+00	1.63E+00	2.09E+00	6.61E+00		8.45E-02
TED							
URANIUM-ENRIC	9.86E-01	1.17E+00	8.66E-01	6.11E-01	1.40E+00		3.86E-04
HED							
URANIUM-NATU	3.08E-01	2.57E-01	2.87E-01	1.10E+00	2.41E+00	2.80E-01	2.67E-03
RAL							
⁴⁹ V	4.00E-08	3.83E-09		1.70E-01	1.65E+00		
^{131M} Xe		2.75E-05			4.35E-07		
^{183M} W					5.77E-06		
¹⁸⁵ W				6.10E-09	2.12E-05		
⁸⁷ W				2.40E-03			
⁸⁷ W					3.53E-03		
⁸⁸ Y	1.40E+00	1.10E-02		2.80E-01	9.47E-05		
⁶⁵ Zn	3.98E+01	2.12E+00		7.62E-02	2.08E+00	2.26E-07	3.32E-01
⁹³ Zr	1.83E-05	2.00E+00		5.70E-04	1.01E-03		5.61E-01
⁹⁵ Zr-- ^{95M} Nb	3.84E-06	9.77E+02	3.00E+01	4.51E-05	1.14E-02		3.94E+00

Table 2.4. Projected LLW and MLLW Inventory to be Disposed in LLBG from 1998 to Closure (Wood, 1999)

Radionuclide	Predicted Inventory (Ci)	Current Inventory (Ci)	Predicted Total Inventory at Closure (Ci)
H-3	3.80 E+05	8.20 E+05	1.20 E+06
C-14	6.14 E+01	2.66 E+02	3.27 E+02
Cl-36	4.99 E-05	7.15 E-03	7.20 E-03
Co-60	4.23 E+05	2.26 E+06	2.68 E+06
Se-79	5.44 E-04	5.21 E-03	5.75 E-03
Sr-90	3.86 E+07	1.02 E+06	3.96 E+07
Tc-99	1.57 E+01	1.82 E+01	3.39 E+01
I-129	2.64 E+00	5.54 E-01	3.19 E+00
Cs-137	3.85 E+07	1.47 E+06	4.00 E+07
Np-237	1.51 E+00	3.28 E-01	1.84 E+00
Pu-241	1.10 E+03	2.19 E+04	2.30 E+04
Pu	2.69 E+03	4.19 E+05	4.22 E+05
Am	260 E+03	6.75 E+02	3.28 E+03
U-233	1.84 E+00	8.35 E+01	8.53 E+01
U-234	3.18 E-01	3.00 E+01	3.03 E+01
U-235	1.43 E+00	1.60 E+00	3.03 E+00
U-238	1.03 E+00	1.01 E+02	1.02 E+02
U Total	4.61 E+00	2.16 E+02	2.21 E+02
Other	1.04 E+02	1.54 E+07	1.54 E+07
Total	7.79 E+07	2.14 E+07	9.93 E+07

*Tritium activities are those identified at the time of disposal and do not account for radioactive decay.

**53.48 Ci are present in activated metal and 7.92 Ci are associated with unconsolidated waste.

3.0 TECHNICAL APPROACH TO CLOSURE

After operations are concluded at individual LLBGs, they will enter into a process of closure consistent with requirements identified in DOE Order 435.1 or subsequent orders or regulations. During an initial period (termed Interim Closure), below ground modification methods will be applied to concentrate and stabilize waste and operational cover soil within individual trenches. These measures will be necessary to prepare each trench for construction of an engineered surface barrier, which is the anticipated final remedial action. It is envisioned that administrative control of individual LLBGs will be transferred from the Waste Management contractor to the ER contractor at some point during the Interim Closure period. Construction of surface barriers will occur during the Final Closure period. Information is presented in this section regarding the anticipated scope and extent of activities to be performed during Interim Closure, Final Closure and the Institutional Control Period following closure.

3.1 FACILITY TRANSITION

Currently, the Hanford Site Waste Management contractor has the prime responsibility for operation of active LLBGs. The site ER contractor has responsibility for remediation of radioactive waste burial grounds in the 200 Areas that were "inactive" when the ER contract was implemented at the Hanford Site in 1994. Active and inactive burial grounds are located in the 200 East and West Areas. In the ER contractor's remedial action planning documents for the 200 areas (e.g., DOE/RL-98-28), active and inactive burial grounds are identified together in a single process-based waste site operable unit (200-SW-2, "Radioactive Landfills and Dumps Group").

Prior to terminating operations at active LLBGs, a Facility Transition Plan will be developed for transfer of the active LLBGs for final remediation. End-point turnover criteria will be prepared for use as acceptance criteria for facility transition. These criteria will be documented in the transition plan. The transition plan will delineate respective roles and responsibilities during the transition period and will identify a specific point in time or set of conditions when turnover and transition from active to inactive status will occur.

3.2 OPERATIONAL/INTERIM CLOSURE

3.2.1 Background/Introduction

This plan specifically addresses closure of the eight active LLBGs at the Hanford Site. However, the intent of transitioning active LLBGs to the ER program for final remedial action (i.e., Final Closure) is to facilitate remediation of active and inactive LLBGs in a manner that will be integrated to the maximum practical extent. Therefore, it is anticipated that the following discussion of proposed approaches for closure of active LLBGs would be applicable to inactive LLBGs as well. The oldest active facility (218-E-10) first received LLW in 1960. Over the past 40 years, waste disposal practices at LLBGs have evolved in response to lessons learned, administrative changes, changes in DOE policy regarding classification and management of radioactive waste, and the imposition of new state and federal regulations.

Trench designs (i.e., trench lengths, depths, widths and cross-sections) vary within individual burial grounds, in response to factors such as packaging, external dose rates, unloading methods, and environmental considerations. All active burial grounds have accepted some quantity of bulk waste (e.g., contaminated vegetation and contaminated equipment) as well as packaged waste. Packaging has

included steel drums and boxes, wood pallets, plywood and cardboard boxes, and reinforced concrete high-integrity containers (HICs) for stabilization of Category 3 waste. Drummed and boxed wastes were intermingled in many trenches. In some cases, trenches have been used exclusively to dispose of CH or RH wastes. However, historical operating practices have not included a procedural requirement to segregate Category 1 and Category 3 LLW. Consequently, all active LLBGs contain significant quantities of Category 3 LLW. Operations at all active LLBGs (excluding 218-W-6, which is unused) predate implementation of the State of Washington's dangerous waste regulations (WAC-173-303) at the Hanford Site.

Disposed waste in trenches is covered with soil to minimize or prevent worker exposures, environmental releases of contaminants, and biointrusion. Prior to 1972, the prevailing operating practice was to construct trenches so that by covering the waste with 1.2 m (4 ft) of soil, the surface would be restored to the surrounding grade. An assessment in 1972 concluded that 1.2 m (4 ft) of cover was not always sufficient to prevent biointrusion, and procedures were modified at that time increasing the thickness of operational cover to 2.4 m (8 ft).

No systematic or specific efforts have been made during burial grounds operations to compact trench fills. Deterioration of packaging in covered trenches is the source of an ongoing problem with localized subsidence, requiring weekly inspection and maintenance. Low bulk density and the ongoing decomposition of waste packaging in trench fills present significant long-term stability issues that must be resolved before final site remediation (i.e., final closure) can be implemented.

3.2.2 Sub-grade Modification

The principal objectives of sub-grade modification activities performed during the Interim Closure Period will be to:

1. Densify and stabilize trench fill materials to minimize or eliminate sources of long-term settlement and subsidence.
2. Develop sufficient bearing capacity to support the weight of an engineered surface barrier over the site (i.e., the anticipated final remedial action).

Potential sub-grade modification methods are listed and briefly described below. Implementation of these methods is 30 years in the future and new ground-modification technologies may become available within this time frame. However, the necessary objectives could be met using methods and equipment that are available now.

- **Deep Dynamic Compaction:** The technique involves dropping heavy (e.g., 4.5 to 18.1 metric ton, 5 to 20-ton) steel or concrete blocks onto the ground surface 6 to 30 m (20 to 100 ft). A grid pattern is marked off over the surface area to be treated. Each grid point receives several (two to ten) blows in one or several passes. The drop block typically is raised and dropped by a crane with appropriate capacity and rigging for the activity. Limited performance tests at the Hanford Site (Phillips and Gilbert 1985) have shown that multiple blows with impact energies of $4.0 \times 10^5 \text{ J/m}^2$ (or about 27,000 lb ft/ft²) give adequate compaction of waste fills to a depth of 3.0 m (10 ft).
- **Vibroflotation:** Vibroflotation is a technique that has been in use since the 1930s for compacting granular soils to considerable depths [6 m (20 ft) or more]. A tool string is vibrated into the ground, with or without assistance of a water spray jet. Soil is compacted in a radial direction outward from the centerline of the tool string. Effective compaction of soil is achieved to a radial distance of about 1.5 m (5 ft).

- **Compaction Grouting:** This technique is included as an alternative to mechanical methods and involves injecting a very stiff mortar-like grout into the soil mass. The grout is designed to stay together in a homogeneous mass that displaces and compacts the surrounding soil (Bandimere 1993). Displacement of the soil increases its in-place density and bearing capacity. Specially designed equipment is required for mixing and pumping the stiff and abrasive grout mix used in this method.
- **Permeation Grouting:** A highly flowable grout material is injected into the soil mass under low pressure, displacing air and filling the void volume in the soil. Chemical grouts or micro-fine cement grouts with moderate to high water to cement ratios typically are used (Bandimere 1993). When the cement hardens, the soil mass is bonded together into a monolith with improved bearing capacity. This technique is envisioned to be advantageous for limited situations such as improving bearing capacity of backfill soil around HICs.
- **Void-Fill Grouting:** For certain types of waste containers (such as large heavy-gauge steel boxes) that may retain structural integrity in trench fills for many years, and may be difficult to compact effectively by dynamic methods, a useful alternative is to drill into the container and displace the air volume with a flowable, self-leveling grout formulation. This technique already is used, to a limited extent, in LLBG operations.

3.2.3 Supporting Geophysical Monitoring/Investigation Methods

It is envisioned that sub-grade modification operations will be monitored and evaluated principally by geophysical survey methods. The primary objectives of geophysical surveys over solid waste landfill trenches will be to:

1. Accurately delineate the lateral boundaries of individual trenches, the locations of various disposed materials and void spaces within the trenches, and the thickness of overburden (i.e., operational soil cover),
2. Evaluate the density of trench fill materials.

Geophysical surveys will be used to plan and administer trench fill densification work and to provide confirmation of the effectiveness of densification efforts. Electromagnetic induction, ground-penetrating radar, and micro-gravity surveys are proposed investigative methods for making these assessments. Shallow reflection seismic surveys could also be performed as an alternative to micro-gravity surveys or as a supplemental method for obtaining in-place density data. These methods are all noninvasive techniques.

3.2.4 Implementation of Sub-Grade Modification Methods to LLBG Trench Fills

The goal of sub-grade modification is to densify and/or stabilize trench fill materials so that adequate bearing capacity can be developed to support the weight of an engineered surface barrier over the site. The actual bearing capacity requirement is traceable to specific attributes of the surface barrier design. The key determinants from the design are: (1) the combined weight per unit area of materials in the various barrier layers and (2) the amount of differential settlement that can be tolerated by the barrier without compromising any essential performance functions or design attributes.

For each burial ground undergoing closure, trench-specific remedial designs will be developed that take into consideration the original waste inventory information, the results from geophysical investigations,

1 and the final cover design. Remedial designs will provide specifications for the types of sub-grade
2 modification methods to be implemented for trench fills and remedial action goals (corresponding to
3 acceptable bearing capacity and settlement values).

4
5 Among currently available methods, deep dynamic compaction is envisioned to be the method of choice
6 for densifying trench fills containing bulk waste, drummed waste, and small boxes. Deep dynamic
7 compaction probably will not be suitable for trenches or portions of trenches containing HICs. However,
8 since the number of trenches in LLBGs containing HICs is relatively small, this limitation is not viewed
9 as severe. Deep dynamic compaction may also be unsuitable for compacting boxes with large air voids or
10 large boxes with reinforced concrete or heavy steel construction. Alternative methods (e.g.,
11 vibroflotation, permeation grouting, or compaction grouting) can be used to densify soil in the vicinity of
12 HICs. Large boxes could be filled with grout.

13
14 Trench fills will be periodically resurveyed by geophysical methods during and after sub-grade
15 modification to assess progress toward site improvement goals and to identify areas that require additional
16 remedial attention. The geophysical survey reports generated during the work will provide an effective
17 means of documenting the extent of remedial activities at the conclusion of the work.

18
19 An implementation-testing program will be required to develop and evaluate performance attributes of
20 various candidate sub-grade modification methods. This testing is needed to:

- 21
- 22 • Evaluate performance attributes (e.g., hole spacings, number of passes, drop weights and heights,
23 grout formulations),
 - 24
 - 25 • Develop correlations between geophysical measurements and target bearing capacity values (e.g.,
26 correlations between seismic velocity data and/or micro-gravity readings and in-place bulk density
27 and bearing capacity),
 - 28
 - 29 • Evaluate the overall suitability and effectiveness of various proposed methods,
 - 30
 - 31 • Acquire cost and schedule data for devising appropriate procurement strategies for contracting of
32 geotechnical services and equipment.
 - 33

34 All of these types of information are needed to prepare effective trench-specific remedial action plans and
35 designs.

36 37 38 **3.2.5 Inspection, Monitoring and Maintenance during Interim Closure**

39 It is anticipated that current inspection, monitoring, and maintenance activities performed in support of
40 facility operations will continue into and through the Interim Closure period. Inspections of burial
41 grounds surfaces for newly-formed subsidence features will continue to be performed on a regular
42 schedule. Leachate collection systems for lined mixed-waste trenches will be inspected, monitored and
43 maintained until leachate generation is eliminated. Site access controls also will be inspected at regular
44 intervals. Maintenance activities will be scheduled as needed to address deficiencies noted on inspection
45 logs.

46
47 The regimen of inspection, monitoring, and maintenance practices carried over from LLBG Operations
48 into the Interim Closure period will be revised (downgraded) as specific inspection and monitoring
49 requirements can be eliminated. As sub-grade modification of individual trench fills is completed, there
50 will be no further need to include these areas in periodic inspections. Groundwater monitoring will
51 continue through the Interim Closure period, consistent with requirements and commitments described in

Environmental Monitoring Plan (DOE 1991), Revised Groundwater Monitoring Plan for the 200 Areas Burial Grounds (WHC 1989) and/or successor documents. Currently, groundwater monitoring of LLBGs involves semiannual sampling and analysis of a total of 57 wells. Groundwater sampling procedures, laboratory analytical procedures, statistical evaluation procedures, data quality objectives and quality assurance requirements for the current near-facility groundwater monitoring program are provided in WHC (1989). Changes to the groundwater monitoring program for LLBGs will be documented as revisions to that document or successor documents.

Monitoring wells are inspected at each scheduled sampling event. An inspection log is prepared to document any maintenance issues (e.g., repairs to casing, screen, pump or locking cap) identified.

3.3 FINAL CLOSURE

3.3.1 Background for Final Cover Design

Performance assessments for LLBGs in the 200 East and West Areas of the Hanford Site provide separate assessments of Category 1 and Category 3 LLW facilities. The PAs included the following assumptions regarding final cover treatments:

- Category 1 LLW facility: The Category 1 facility would be covered by a minimum thickness about 3 m (10 ft) of sand-gravel cover with no vegetation or sparse shallow-rooted vegetation such as cheat grass, permitting a maximum amount of moisture infiltration (assumed to be 5 cm/yr, 2 in/yr) into the buried waste layer. The thickness of cover material would not be sufficient to prevent an inadvertent intruder who digs a basement or drills a well from coming into direct contact with buried waste. Stabilization of buried waste to support a final cover was not assumed. Immobilization of radionuclides in waste disposed in a Category 1 facility is not required.
- Category 3 LLW facility: The Category 3 facility would be covered with suitable soil to support natural vegetation, including a mix of shallow- and deep-rooted plant species. The cover treatment would limit infiltration into the waste layer to 0.5 cm/yr (0.2 in/yr). A minimum of 5 m (16.1 ft) of cover materials would be placed over a Category 3 facility, so that the inadvertent intruder would not expose buried waste in a typical basement excavation, but would penetrate the waste layer in the process of drilling a well. The assumption was made that buried waste in a Category 3 facility would have to be stabilized to achieve acceptable cover performance. Immobilization of radionuclides may be required for some wastes disposed in a Category 3 facility, depending on the concentrations of long-lived radionuclides that are mobile in the soil column.

The PAs do not provide specific recommendations regarding the design of either cover treatment. However, it will be necessary to demonstrate during the design process that the proposed final cover design will meet or exceed the performance allocated to (assumed for) covers in the PAs.

Historically, Category 1 and Category 3 wastes have not been segregated. All active burial grounds have received Category 1 and Category 3 LLW, and the two waste classes are commingled in many individual trenches. In addition, all active burial grounds have received some quantities of waste containing constituents that are currently regulated by the State of Washington as dangerous waste under provisions of WAC 173-303. Several burial grounds also inadvertently received small quantities of waste that, based on the current waste designation method, are classified as TRU and/or Greater Than Class C (GTCC) LLW. Because these wastes were designated Category 3 at the time they were received, they were not disposed in a manner that would facilitate retrieval at a later date. There are no current plans to attempt to remove these wastes prior to final closure.

Consequently, closure requirements pertaining to Category 3 facilities in the PAs likely will apply to all active LLBGs. Closure requirements for State regulated dangerous waste also will apply as "Applicable or Relevant and Appropriate Requirements" (ARARs) during final remedy selection under CERCLA. The current PAs for LLBGs have determined that small quantities of waste in LLBGs currently designated as TRU or GTCC LLW are not significant relative to overall facility performance (i.e., additional closure requirements that pertain specifically to these waste types will not apply).

In 1996, the ER contractor prepared a Focused Feasibility Study (FFS) of engineered surface barrier treatments as a class of remedial action strategies for diverse waste sites in the 200 Areas (DOE 1996). The study included a comprehensive review of federal and state regulations and DOE Directives pertaining to various categories of regulated waste as sources of requirements and criteria for cover designs. It drew upon the collective experience with cover designs for Hanford Site applications, including research and development activities as well as site-specific designs for individual waste sites. A graded approach based on a limited number of conceptual cover designs was proposed for a broad range of waste site applications. These designs provide a range of cover options for minimizing health and environmental risks associated with specific waste categories and performance periods ranging from 30 to 1,000 years.

The cover designs in the FFS are generic conceptual designs rather than definitive designs for specific sites. Each conceptual design provides a description of the layer sequence in section view through the cover. The conceptual designs do not address construction details, such as the method of terminating individual layers at the edge of the covered area or the method for collecting surface runoff and/or lateral drainage at the perimeter. A definitive design must be generated to adapt one of these generic designs to a specific site or group of sites. Considerations to be addressed in definitive design include the contaminant inventory at the site, remedial action objectives, the local geology, topography, and proximity and surface grading of adjoining facilities and/or waste sites. In the FFS, it is envisioned that a site-specific definitive design might result in modifications to a generic design or development of an alternate design that is optimal for unique site conditions.

3.3.2 Description of Final Cover Design

Based on the decision logic and selection rationale elaborated in the FFS, the Modified RCRA Subtitle C Barrier design has been designated as the current planning basis for final closure of active LLBGs. The logic and rationale supporting this design are consistent with the current out-year planning and long-range implementation planning of the Department of Energy. This barrier treatment also is assumed in the SW-EIS (DOE 2000) as an element of the Baseline Alternative and the Regional Alternative for purposes of evaluating closure of LLBGs. The planning basis may change in the future to reflect developments and/or modifications to barrier technology for Hanford Site applications. Any changes to the planning basis will be documented in revisions to this document.

Design descriptions of the individual layers in the Modified RCRA Subtitle C Barrier and their respective functions are provided in the following subsections, which are excerpted from DOE (1996). Figure 3.1 shows a profile view through the barrier.

3.3.2.1 Layer 1 (Topsoil with Pea Gravel Admixture) and Layer 2 (Compacted Topsoil without Pea Gravel)

Layer 1 consists of 50 cm (20 in.) of sandy silt-to-silt loam soil containing 15 percent (by weight) pea gravel. Layer 1 will be placed in a relatively loose condition, with a bulk density value of about 1.46 g/cc

(91 to 92 lb/ft³). Layer 2 consists of 50 cm (20 in.) of the same silt loam soil, without pea gravel, placed in a relatively densified state, approximately 1.76 g/cc (110 lb/ft³).

The topsoil component (i.e., Layers 1 and 2) is designed to perform as a storage medium for soil moisture, and to support cover vegetation. The purpose of the pea gravel in Layer 1 is to improve the soil's resistance to wind erosion (Ligotke and Klopfer 1990). The surface slope will be limited to 2 percent (after allowances for settlement and subsidence). This value is steep enough to provide for coherent drainage of runoff from the covered area, yet shallow enough to limit exposure of the surface to wind erosion.

Compaction of Layer 2 during construction will decrease its saturated hydraulic conductivity by three to four orders of magnitude (i.e., from values in the range of 10⁻³ to 10⁻⁴ cm/s down to values between 10⁻⁶ to 10⁻⁷ cm/s). The indicated reduction in conductivity is readily achievable by compacting the silt loam soil to densities in the range of 1.68 to 1.84 g/cc (105 to 115 lb/ft³). Laboratory testing indicates that these results can be accomplished with moderate compactive effort (Skelly et al. 1994). Compaction will retard moisture migration through Layer 2. A capillary barrier at the base of Layer 2 will enhance moisture retention and evapotranspiration within Layers 1 and 2. Numerical performance simulations using the Hydrologic Evaluation of Landfill Performance (HELP) Model predict that essentially 100 percent of average annual precipitation will be removed from the barrier by evapotranspiration (DOE 1996, Appendix C).

Cover vegetation will consist of a mixture of perennial grass species. Specifications for the seed mix, and the methods of seed application, fertilizing, and mulching will be developed during definitive design. Planting of cover vegetation will meet or exceed recommendations in EPA's technical guidance for final covers (EPA 1989).

3.3.2.2 Layer 3 (Sand Filter) and Layer 4 (Gravel Filter)

These layers are components of a two-layer graded filter designed to prevent topsoil particles from moving downward and accumulating in the lateral drainage layer (Layer 5). Both layers are 15 cm (6 in.) thick. These materials will be clean, screened aggregate materials obtained from a local borrow site. The design of the graded filter conforms to the criteria published in Cedergren (1989) and Ecology (1987).

3.3.2.3 Layer 5 (Lateral Drainage Layer)

This layer will facilitate the removal of any moisture that moves completely through the topsoil component of the barrier (Layers 1 and 2). This layer represents a contingency scheme to remove soil moisture in response to extreme climatic events, such as the design storm. Layer 5 will be sloped at 2 percent to move water to the edge of the cover where it will be collected and/or diverted in an appropriate manner. Layer 5 will be 15 cm (6 in.) thick and will be constructed of clean, screened aggregate material with a hydraulic conductivity of at least 1 cm/s. An effective particle size (D₁₀) of 1 mm or greater is needed for the drainage media to achieve the desired permeability value. Layer 5 will be situated approximately 1.3 m (4.3 ft) below final grade, which satisfies the design criterion for frost protection. Performance simulations with the HELP Model indicate that little (if any) lateral drainage will occur (DOE 1996, Appendix C).

3.3.2.4 Layer 6 (Asphalt Layer)

This layer will function as a low-permeability barrier layer and as a biointrusion barrier. Layer 6 will be constructed of a durable asphaltic concrete mixture consisting of double-tar asphalt (i.e., twice the tar content of normal highway asphalt) with added sand as binder material. Laboratory permeability tests on asphaltic concrete cores from the Hanford Barrier prototype yielded values on the order of 10⁻¹⁰ cm/s.

In-field values, measured by falling-head permeameter testing, ranged between 10^{-7} and 10^{-9} cm/s (DOE-RL 1994). Hydraulic conductivity testing will be performed on the asphalt layer in situ to determine the actual in-field value at the time of construction. The asphalt layer will be constructed with a slope of 2 percent (after allowances for settlement and subsidence).

The low-permeability asphalt layer is expected to be a highly effective deterrent to intrusion by plant roots and burrowing animals. As necessary, it will also function as a human intrusion barrier. The strength of the asphaltic concrete material, the thickness of Layer 6, and its deliberate construction should serve to advise inadvertent intruders that this layer is an intentional barrier. Layer 6 can be breached with mechanical excavation equipment, but intrusion scenarios involving the use of heavy equipment probably would be considered advertent rather than inadvertent.

3.3.2.5 Layer 7 (Asphalt Base Course)

This layer will provide a stable base for placement of the overlying asphalt layer. The base course will consist of screened, crushed-surfacing material, with 100 percent passing the 32 mm (1.25 in.) sieve.

3.3.2.6 Layer 8 (Grading Fill)

Grading fill will be placed, as necessary, to establish a smooth, planar base surface for construction of the overlying layers. The preexisting site surface will be contoured and graded to create uniform surfaces sloped at 2 percent, as needed for internal lateral drainage and surface runoff control. Grading the site before construction will facilitate accurate and controlled placement of soil lifts and layers. Grading fill will consist of a well-graded granular soil mixture, which may include as much as 20 percent by volume of cobbles measuring no more than 75 mm (3 in.) in the greatest dimension.

3.3.3 Sources of Cover Materials

Specifications and performance predictions for topsoil in Layers 1 and 2 of the Modified RCRA Subtitle C design in DOE (1996) are based on field and laboratory characterization tests of soil samples obtained from the McGee Ranch site, located north and west of the Yakima Barricade on the Hanford Site. That site is within the portion of the Hanford Site land area that acquired National Monument status earlier in 2000. The draft SW-EIS proposes to obtain silt loam soil for construction of engineered surface barriers over LLBGs from two areas north of State Route 240 and southwest of the 200 West Area. The EIS indicates that approximately $727,000 \text{ m}^3$ ($950,000 \text{ yd}^3$) of silt loam soil will be required for construction of covers over the eight active burial grounds.

Sand and gravel will be obtained from Pit 30 (an existing borrow pit) on the Hanford Site. This pit is located midway between the 200 East and 200 West Areas. The EIS indicates that approximately 1.5 million m^3 (2.0 million yd^3) of screened and unscreened sand and gravel materials will be required for cover construction.

Additionally, the EIS estimates that cover construction will require $377,000 \text{ m}^3$ ($493,000 \text{ yd}^3$) of asphalt from commercial off-site sources.

3.3.4 Cover Performance

Performance Assessments for active LLBGs indicate that long-term performance goals will be achieved if engineered surface barriers over burial grounds limit deep infiltration into/through the waste layer to 0.5 cm/yr (0.2 in./yr) or less. Hydrologic performance of the Modified RCRA Subtitle C Barrier has been

modeled in numerical simulations using the HELP code. Results of simulations for steady-state ambient climate conditions are included in Appendix C of DOE (1996). The results indicate that the proposed final cover treatment will eliminate more than 99 percent of annual precipitation received at the Hanford Site by evapotranspiration and will limit deep infiltration to 0.1 cm/yr (0.04 in./yr) or less.

Sample calculations of potential wind and water erosion of the topsoil surface of the Modified RCRA Subtitle C Barrier are provided in Appendix D of DOE 1996. The calculations indicate that soil losses should be tolerable (i.e., less than two tons per acre per year). Erosion susceptibility is largely attributable to wind erosion. The Modified RCRA Subtitle C Barrier has a design life of 500 years. Over this period of time, topsoil losses should be limited to 15 cm (6 in.) or less. Losses of this magnitude should not have any appreciable effect on the cover's ability to control infiltration of precipitation.

3.3.5 Inspection, Monitoring and Maintenance during Final Closure

It is envisioned that inspection, monitoring, and maintenance practices in place at the time of transition from Interim Closure to Final Closure will be continued. Regularly scheduled inspections of surfaces over filled trenches for evidence of subsidence will have been phased out as a result of sub-grade modification measures implemented during Interim Closure. As lined mixed-waste trenches are covered and cease to generate leachate, inspection, monitoring and maintenance of leachate collection systems can be eliminated.

Groundwater monitoring is planned to continue through the Final Closure period, consistent with requirements and commitments described in *Environmental Monitoring Plan* (DOE 1991), *Revised Groundwater Monitoring Plan for the 200 Areas Burial Grounds* (WHC 1989) and/or successor documents. Changes to the groundwater monitoring program for active LLBGs will be documented as revisions to WHC (1989) or successor documents.

3.4 INSTITUTIONAL CONTROL

An extended period of active institutional control is envisioned following closure of individual LLBG facilities. Activities to be performed during this period include site access control, inspection, monitoring and maintenance of closed LLBG facilities, and maintenance of facility records. Plans and procedures will be prepared for management and administration of these activities during this period. Contingency plans will be developed for foreseeable types of corrective actions that might be needed during the Institutional Control Period. Additional discussion of these activities is provided in the following subsections.

3.4.1 Inspection Plan

Inspections will be conducted on prescribed schedules to ensure continued integrity of the closed facilities and the cover systems during the Institutional Control Period. Inspections will be conducted in accordance with controlled procedures, and permanent logs of inspection results will be maintained. An Inspection Plan and procedures will be prepared which will address the following issues and concerns.

3.4.1.1 Site Access Control

The LLBGs are located within controlled access areas of the Hanford Site, which cannot be accessed by the general public. Physical access controls will be inspected at regular intervals. Any deficiencies will be noted in inspection logs.

3.4.1.2 Erosion Damage

Damage to closure cover surfaces may occur either from wind or water erosion. Visual inspections will be performed at regular intervals (e.g., quarterly) to identify localized areas where significant soil losses have occurred. Inspectors will check for conditions such as sheet or rill erosion (gully formation), sand deposition, uniformity of vegetative cover, and the integrity of run-off and run-on control measures. Observations will be recorded in an inspection logbook.

If soil losses occur over larger areas of the cover, they will be detected by surveys of monuments laid out on a regular grid spacing. Cover surfaces will be most susceptible to wind erosion during the first year after construction, before a mature vegetative cover has been established, or periods following reduction of vegetation by range fires.

3.4.1.3 Cover Settlement, Subsidence, and Displacement

Localized subsidence features will be identified in periodic visual inspections of cover surfaces. Settlement over larger areas will be detected by surveys of surface monuments (also used to detect soil losses from wind erosion). Covers will be reinspected for settlement/subsidence damage following seismic events producing surface accelerations above a predetermined threshold. Accelerometers in the 200 Areas will record the amplitude and frequency of surface accelerations during seismic events. The threshold for significant acceleration will be determined based on a seismic evaluation of the final cover design. Inspectors will check for ground fractures and surface displacements of cover materials.

3.4.1.4 Vegetative Cover Condition

Frequent (e.g., monthly) visual inspections of cover vegetation will be performed beginning with seeding of the cover surface and continuing until vegetation becomes well established. Inspectors will record quantitative measures of the condition and density of the vegetative cover, and note colonization of covers by deep-rooted plants and/or other invasive species. More frequent inspections would be implemented (as necessary) to monitor recovery of vegetation after range fires.

3.4.1.5 Burrowing Animal Activity

During visual inspections, any evidence of destructive activity by burrowing animals will be noted. Observations will be recorded in an inspection logbook.

3.4.1.6 Cover Drainage System

Accessible drainage components of the cover system will be inspected at regular intervals for evidence of sedimentation or blockage.

3.4.1.7 Leachate Collection/Detection System

If some cover systems over regulated mixed waste trenches will need to include leachate collection/detection and removal systems, then visual inspections of these systems will be performed. The tubing, pumps, and holding tanks will be inspected for leaks, damage, corrosion, or blockage. Observations will be recorded in an inspection logbook.

3.4.1.8 Monitoring Well Condition

Monitoring wells will be examined on each occasion that groundwater samples are withdrawn. Locking caps, vehicle guard posts and pump connectors will be inspected semiannually for damage. Any damage or other problems will be noted in an inspection logbook.

3.4.1.9 Benchmark Integrity

Benchmarks and survey monuments will be inspected as an aspect of erosion and settlement surveys. Any indication that a benchmark has been damaged or misaligned will be noted in an inspection logbook.

3.4.2 Monitoring Plan

Monitoring plan contents are discussed in the following subsections.

3.4.2.1 Groundwater Monitoring

It is anticipated that groundwater monitoring will continue during the Institutional Control Period, consistent with requirements and commitments described in *Environmental Monitoring Plan* (DOE 1991), *Revised Groundwater Monitoring Plan for the 200 Areas Burial Grounds* (WHC 1989) and/or successor documents. Active LLBGs are undergoing detection-level monitoring at the present time. It is also anticipated that detection-level monitoring will continue into the institutional control period unless dangerous waste constituents from a LLBG facility are detected at a designated point of compliance at some time in the future. In that event, more stringent sampling and analysis requirements may be imposed (e.g., assessment- or compliance-level monitoring requirements), or it may be necessary to implement a corrective action program.

Currently, groundwater monitoring of LLBGs involves semiannual sampling and analysis of a total of 57 wells. Several active monitoring wells are situated inside areas that will be covered during Final Closure. Consequently, some wells will have to be modified or capped and abandoned and replaced in order to maintain current monitoring capabilities during the Institutional Control Period.

Groundwater sampling procedures, laboratory analytical procedures, statistical evaluation procedures, data quality objectives and quality assurance requirements for the current near-facility groundwater monitoring program are provided in WHC 1989. Program changes will be documented as revisions to that document or to successor documents.

3.4.2.2 Leachate Collection/Detection and Removal

For facilities with leachate collection systems, operation of the leachate collection/detection and removal system will be continued (if necessary) into the Institutional Control Period to monitor leachate generation after closure. Leachate production should attenuate over time during or after cover construction, enabling monitoring and maintenance requirements for this system to be incrementally reduced and eventually eliminated.

3.4.3 Maintenance Plan

The cover, groundwater monitoring, and leachate collection systems will be regularly maintained to ensure their continued integrity during the Institutional Control Period. Maintenance activities generally will be triggered by inspection reports generated as discussed in Section 3.4.1. Maintenance reports will

be prepared to document all maintenance activities. Maintenance reports will reference the initiating inspection report and the follow-up maintenance record to provide comprehensive documentation of all maintenance activities. Maintenance reports and records will be maintained available for inspection at a designated location.

3.4.3.1 Security Controls

Security controls, consisting of perimeter fences, locked gates, and warning signs, will be inspected at regular intervals and maintained as necessary to prevent unauthorized access to closed facilities.

3.4.3.2 Erosion Damage

Depending on the areal extent of the damage and the specific cause (e.g., wind or water erosion), maintenance may simply take the form of replacing lost topsoil to restore the surface to the original grade, or it might also involve revegetation efforts (e.g., mulching and reseeded). Maintenance might also involve removal of soil (silt loam topsoil or windblown sand) from areas of accumulation. Criteria for initiating maintenance (repair) of the cover surface will be developed during definitive design of the cover system.

3.4.3.3 Cover Settlement and Subsidence

Minor settlement or subsidence may be difficult to distinguish from localized topsoil losses due to wind erosion in visual inspections of cover surfaces. Settlement and subsidence affect all cover layers, whereas wind erosion affects the condition of the topsoil layer only. In cases where settlement and/or subsidence are suspected, more detailed inspections must be performed which would involve probing downward through the upper layers of the cover to determine the elevation of the low-permeability asphalt layer. Criteria for initiating maintenance (repair) of the cover surface will be developed during definitive design of the cover system.

Minor settlement over a broad area may not significantly effect long-term performance of the cover system and may be corrected by adding topsoil to restore the surface to design grade. Localized settlement or subsidence is a relatively more serious problem which could produce closed depressions (i.e., ponding conditions) on top of the asphalt layer. Extreme localized subsidence or differential settlement could lead to rupture of the asphalt layer, depending on the severity of the event. Contingency corrective action plans will be developed to address the range of appropriate remedial responses that can be anticipated.

3.4.3.4 Vegetative Cover Condition

Active maintenance of cover vegetation will be performed in cases where vegetation fails to become sufficiently well established within six months to a year after planting to limit erosion damage. As experience is acquired over time, more suitable mixes of shallow-rooted perennial species may be identified and substituted. Revegetation of entire cover areas may be necessary following range fires.

3.4.3.5 Animal Activity

Large burrows identified within covered areas will be filled in and the animals involved in the activity will be trapped and removed from the site.

3.4.3.6 Cover Drainage Components

Components of the cover design that are provided to control or collect drainage will be maintained so that they remain functional for the duration of active Institutional Control. Blockages will be eliminated using methods that minimize disturbance to the cover system.

3.4.3.7 Leachate Collection/Detection and Removal System

Maintenance activities will be performed (as needed) on tubing, pumps, and holding tanks of any leachate collection/detection and removal systems included in covered areas as long as these systems are required to remain functional.

3.4.3.8 Groundwater Monitoring Wells.

Maintenance will be performed as needed on groundwater monitoring wells, including locking caps, down-hole casing, screens, and pumps. Damaged equipment will be repaired or replaced as necessary.

3.4.3.9 Benchmark Integrity.

A benchmark that is found to be damaged or out of alignment will be replaced as necessary and its location will be resurveyed.

3.4.4 Contingency Corrective Action Plans

Contingency plans and procedures will be developed describing detailed responses for foreseeable types of major problems with the cover system and/or facility monitoring systems during the Institutional Control Period. Corrective action plans will be developed in conjunction with the inspection, monitoring, and maintenance plans described above. Specific threshold values and conditions will be identified to enable inspectors to distinguish situations requiring maintenance from situations requiring corrective action. Any of the following types of problems may require a corrective action response:

- Excessive settlement or subsidence of portions of the cover system
- Excessive infiltration through the cover, resulting in detectable contaminant migration
- Damage to the cover as the result of natural phenomena (e.g., earthquakes or severe storm events)
- Failure of monitoring systems/equipment
- Loss of cover vegetation (e.g., by range fires) or replacement by undesirable plant species
- Excessive erosion (e.g., formation of deep gullies through the topsoil layers of the cover)
- Uncontrolled site access.

3.5 UNRESTRICTED RELEASE OF SITE

Institutional Control will continue until such time as the facility can qualify for unrestricted release consistent with requirements in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* and/or successor directives or documents. Section 4 of DOE Order 5400.5 addresses guidelines and authorized limits for residual radioactive material (e.g., residual radionuclides in soil and surface contamination limits) at sites where radioactive waste management activities have been performed. Site-specific release criteria (dose and residual concentration limits) can be developed by procedures given in DOE/CH-8901, *A Manual for Implementing Residual Radioactive Material Guidelines* (DOE 1989). As a prerequisite for unconditional release, DOE would have to authorize discontinuation of post-closure monitoring activities.

The Hanford Future Site Uses Working Group (HFSUWG) was established by DOE in 1992 and was tasked with developing a consensus vision regarding future uses of various parts of the Hanford Site. The HFSUWG includes local, state and federal officials, representatives of tribal nations in the region, individuals representing agricultural and labor interests, and members of environmental and special interest groups. The following position statement is from the Working Group's 1992 summary report (HFSUWG 1992):

"In general, the Working Group desires that the overall cleanup criteria for the Central Plateau should enable general usage of the land and groundwater for other than waste management activities in the horizon of 100 years from the decommissioning of waste management facilities and closure of disposal areas."

DOE recently issued the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999). This plan proposes that, for the foreseeable future, the 200 Area Plateau will be used exclusively for management of Hanford Site waste.

3.6 COMPLIANCE WITH PERFORMANCE OBJECTIVES AND OTHER REQUIREMENTS

The PAs for 200 East and West Area LLBGs identify performance objectives for LLBGs and provide the current technical basis for demonstrating that there is a reasonable expectation that all objectives will be met. These objectives are summarized in Table 3.1. The purpose of this section is to show that the conceptual design for closure of LLBGs supports and conforms to the models (exposure/release scenarios) forming the basis for the assessments.

Table 3.1. Performance Objectives for 200 East and West Area LLBGs*.

Exposure Pathway	General public protection	
	Time Period (yr)	Performance objective
All Pathways	≤10,000	25 mrem/yr
Air Emissions (excluding Rn)	≤10,000	10 mrem/yr
Air Emissions (Rn)	≤10,000	20 pCi/m ² s
Intruder Protection		
Continuous Exposure	100 to 500	100 mrem/yr
Single Acute Exposure	100 to 500	500 mrem/yr
Groundwater Resource Protection		
Drinking Water	≤10,000	4 mrem/yr

*Limits apply to the maximum exposed individual.

In the PAs, the performance objectives listed in the table were interpreted to distinguish two basic types of release scenarios: (1) exposure mechanism due to inadvertent intrusion by humans at some time after cessation of active institutional control and (2) release of radionuclides from the facility by natural causes, with the primary mechanism being leaching of radionuclides through the soil column to groundwater.

3.6.1 All-Pathways Dose

The all-pathways exposure scenario was evaluated in the PAs as a series of events in which radionuclides are first leached from the disposal facility by infiltration of precipitation into and through the disposed waste. Contaminated water then moves downward through the vadose zone to the unconfined aquifer. Subsequently, man drills a well into the aquifer and draws contaminated water for drinking, crop irrigation, and livestock consumption. Dose is received by direct exposure to gamma-producing radionuclides in the soil, inhalation of contaminated dust, and ingestion of contaminated crops, water, beef, and milk. The performance objective for the all-pathways dose is 25 mrem/yr. All-pathway dose estimates developed in the PAs do not exceed 1.65 mrem/yr (Wood, 1999).

The limiting dose estimate is derived from evaluation of a Category 3 LLBG with a soil cover system supporting natural vegetation, including a mix of shallow- and deep-rooted species. It is assumed that the cover treatment limits infiltration into the waste layer to 0.5 cm/yr (0.2 in/yr). A minimum of 5 m (16.4 ft) of cover materials (including operational soil cover within trenches and engineered cover materials over trenches) is assumed to be placed over the disposed waste, so that an inadvertent intruder would not expose buried waste in a basement excavation, but would penetrate the waste layer in the process of drilling a well.

The Modified RCRA Subtitle C cover (the current planning basis) will meet or exceed all performance criteria assigned to the cover in the PAs. Disposed waste will be covered with a minimum of 5 m (16.4 ft) of operational soil and engineered cover materials as required for inadvertent intruder protection for a Category 3 facility. The design of the cover includes two topsoil layers. Layer 1 consists of 50 cm (20 in.) of silt loam soil with pea gravel admix for enhanced resistance to wind erosion. Layer 2 consists of 50 cm (20 in.) of the same silt loam soil, without pea gravel, which will be placed in a relatively densified state to impede vertical moisture movement. The topsoil system is designed to perform as a storage medium for soil moisture and to support cover vegetation. The combined thickness of Layers 1 and 2 is sufficient to support continued storage and removal of moisture by evapotranspiration even if significant topsoil losses should occur. Cover vegetation will consist of a mixture of perennial grass species. A capillary barrier at the base of Layer 2 will enhance moisture retention and evapotranspiration within Layers 1 and 2. Numerical performance predictions of the Modified RCRA Subtitle C cover design indicate that essentially 100 percent of average annual precipitation will be removed from the barrier by evapotranspiration (refer to Appendix C of DOE 1996). The assumed value of 0.5 cm/yr (0.2 in/yr) for deep infiltration in PAs corresponds to about 3 percent of average annual precipitation at the Hanford Site.

The Modified RCRA Subtitle C design incorporates a contingency strategy for removing any moisture that infiltrates through (below) the topsoil system. The lateral drainage layer (Layer 5) and low-permeability asphalt layer (Layer 6) provide the capability to intercept and divert the excess moisture to the perimeter of the covered area. However, due to the predicted efficiency of the topsoil system, numerical performance predictions indicate that the volume of lateral drainage will be negligibly small (Appendix C, DOE 1996).

3.6.2 Air Pathway Dose

The PAs address vapor release as a potential exposure mechanism. Only three radionuclides, ^{14}C , ^3H , and ^{222}Rn , have the potential to migrate upward from disposed LLW and escape into the atmosphere in gaseous form. Two on-site exposure scenarios were considered for ^{14}C and ^3H . In one case, human intrusion occurs 100 years after closure of the site, waste is exhumed during basement excavation and mixed with uncontaminated soil in a garden plot, and the intruder resides in a home constructed on top of the contaminated soil. In the second case (also assumed to occur 100 years after closure), buried waste is

not disturbed but the intruder builds and resides in a home situated directly above the waste. A steady-state diffusion model was used to calculate release rates and to estimate dose for ^{14}C and ^3H . For the air release assessments, a 3-m (10-ft) thickness of cover soil materials with a diffusion coefficient of $0.01 \text{ cm}^2/\text{s}$ was assumed. The performance objective for the air pathway dose is 10 mrem/yr. A maximum on-site annual exposure of 0.012 mrem/yr was calculated (Wood et al. 1995). This dose is more than an order of magnitude higher than the largest calculated off-site dose. Therefore it has been concluded that the air pathway performance objective will be easily satisfied, and minimal reliance will be imposed on the final cover treatment to limit releases of radionuclides in gaseous form.

Any RCRA-compliant surface barrier treatment (which must include some type of a low-permeability layer) will limit vapor diffusion well below the level of performance assumed in the air pathway dose evaluation. The Modified RCRA Subtitle C barrier includes a 15-cm (6-in.)-thick low-permeability layer (Layer 6) that will be constructed of a durable asphaltic concrete formulation containing twice the tar content of normal highway asphalt. Laboratory permeability tests on cores of this material have produced values on the order of 10^{-10} cm/s . In-field values of between 10^{-7} and 10^{-9} cm/s have been measured (DOE-RL 1994).

3.6.3 Radon Flux

The PAs include evaluations of potential ^{222}Rn flux (emissions) in relation to the performance objective of $20 \text{ pCi/m}^2/\text{s}$. This radon isotope is a decay daughter of ^{234}U , ^{238}U and ^{236}Ra . Radon release rate is dependent on the decay characteristics of the parent and their concentrations. Concentrations of the parents in the LLBG wastes were estimated from waste inventory data. Flux from ^{236}Ra decay decreases over time, while flux from decay of the two uranium isotopes increases over time. Of the two uranium isotopes, the flux contribution from ^{234}U greatly exceeds that from ^{238}U . The maximum anticipated ^{222}Rn flux is $0.033 \text{ pCi/m}^2/\text{s}$ (Wood 1999), which is approximately 0.2 percent of the performance objective. The PAs indicate that radon emissions from LLBGs will remain well within the permissible limit without imposing any specific performance criteria on the design of the final cover. Low-permeability asphalt layers, like the asphaltic concrete layer (Layer 6) in the Modified RCRA Subtitle C Barrier, have been demonstrated to be highly effective in inhibiting the diffusion of radioactive gases with low partial pressures and short half-lives, such as radon. This conclusion is supported by documentation from the *Uranium Mill Tailings Reclamation Act* program (Wing 1994).

3.6.4 Other Requirements

For the design of the Modified RCRA Subtitle C Barrier, a comprehensive review was conducted of state and Federal regulations and other technical guidance sources (DOE 1996). Specific design and/or performance requirements for engineered surface barriers over sites with radiological and/or dangerous waste constituents were applied as design criteria. Applicable requirements and sources (other than DOE Order 435.1) are summarized below, with the design criteria derived from each source.

3.6.4.1 Applicable or Relevant and Appropriate Requirements (ARARs) for Facilities with Low-Level Radioactive Waste Constituents

The intent of the design process summarized in DOE 1996 was to provide a single barrier design that satisfies the requirements for Category 3 LLW facilities as well as sites with hazardous/dangerous waste constituents.

10 CFR 61.41, WAC 173-480-040, WAC 173-480-050, and WAC 246-247-040.

1 These regulations are functionally equivalent. They limit radionuclide releases from radiological waste
2 disposal sites to levels that provide reasonable expectation that the annual equivalent dose to the public
3 will not exceed 25 mrem to the whole body or 75 mrem to any critical organ. To some degree, the natural
4 system contributes to limiting release rates of contaminants to the accessible environment. However, a
5 conservative approach is to require the cover system to satisfy all performance goals for isolating waste
6 from the accessible environment. Therefore, the cover is designed to prevent plants and animals from
7 intruding into the waste zone and redistributing contaminants into the accessible environment. These
8 criteria will generally pertain to the definitive design stage, when the significance of specific release
9 limits can be evaluated in the context of individual waste-site conditions. Criteria applied to the
10 conceptual design are as follows:

- 11 1. Minimize moisture infiltration through the cover.
- 12 2. Prevent plants from accessing and mobilizing contamination.
- 13 3. Prevent burrowing animals from accessing and mobilizing contamination.

14 **10 CFR 61.42.**

15 This ARAR pertains to conceptual and definitive designs of surface barriers for radioactive waste sites.
16 The cover must be designed to protect humans from inadvertent contact with waste above acceptable
17 levels at any time after the loss of active institutional controls. The criterion applied to the conceptual
18 design was to:

- 19 1. Include appropriate design provisions to limit inadvertent human intrusion.

20 **10 CFR 61.44.**

21 This ARAR requires that the cover be designed to achieve long-term stability and to eliminate (to the
22 degree practicable) the need for ongoing maintenance. This requirement can be met with an engineered
23 cover system and supplemented, as necessary, by stabilizing the site sub-grade to minimize settlement.
24 This requirement pertains to conceptual and definitive designs. The criteria applied to the conceptual
25 design were as follows:

- 26 1. Design a multi-layer cover of materials that are resistant to natural degradation processes.
- 27 2. Design a durable cover that needs minimal maintenance during its design life.

28 **10 CFR 61.51.**

29 This ARAR directs that the cover be designed to (1) minimize water infiltration, control runoff and
30 run-on of surface water, and otherwise minimize contact between water and waste after disposal and (2)
31 resist degradation by surface geologic processes (i.e., surface erosion) and biotic activity. These criteria
32 pertain to conceptual and definitive designs.

33 The following criteria were imposed on the design:

- 34 1. Minimize moisture infiltration through the cover.
- 35 2. Design a multi-layer cover of materials that are resistant to natural degradation processes.
- 36 3. Design a durable cover that will require minimal maintenance during its design life.

4. Prevent plants from accessing and mobilizing contamination.
5. Prevent burrowing animals from accessing and mobilizing contamination.
6. Facilitate drainage and minimize surface erosion by wind and water.

10 CFR 61.52(a)(2).

As an ARAR, this regulation requires that Class C LLW (comparable to DOE Category 3 LLW) must be disposed so that either the top of the waste is a minimum of 5 m (16.4 ft) below final grade, or the waste is covered with a surface barrier designed to protect against inadvertent human intrusion for at least 500 years. This requirement pertains to both conceptual and definitive designs.

The criteria applied to the conceptual design are as follows:

Design a cover with a functional life of 500 years.

Ensure that the top of the waste is at least 5 m (16.4 ft) below final grade or include appropriate design provisions to limit inadvertent human intrusion.

3.6.4.2 ARARs for Facilities with Hazardous/Dangerous Waste Constituents

40 CFR 264.111, 40 CFR 265.111, and WAC 173-303-610

These ARARs require a disposal facility for dangerous waste be closed in a manner that (1) minimizes the need for further maintenance; (2) controls, minimizes, or eliminates releases of dangerous constituents to the environment; and (3) returns land to the appearance and use of surrounding land to the degree possible, given the nature of previous waste-handling activities. These requirements can best be met by developing a low-maintenance cover constructed of durable materials that will support perennial vegetative cover similar to vegetation on surrounding land, and be highly effective in limiting moisture infiltration.

Criteria applied to the conceptual design are as follows:

1. Minimize moisture infiltration through the cover.
2. Design a multi-layer cover of materials that are resistant to natural degradation processes.
3. Design a durable cover that will need minimal maintenance during its design life.
4. Prevent plants from accessing and mobilizing contamination.
5. Prevent burrowing animals from accessing and mobilizing contamination.
6. Facilitate drainage and minimize surface erosion by wind and water.

40 CFR 264.228, 40 CFR 265.228, 40 CFR 264.310, and 40 CFR 265.310; and WAC 173-303-650 and WAC 173-303-665.

These six ARARs are functionally identical and require that the cover meet the following requirements: (1) minimize moisture infiltration, (2) function with minimum maintenance, (3) promote drainage and

1 minimize erosion, (4) accommodate settlement, and (5) have a permeability less than or equal to any
2 natural subsoils present. The ARARs pertain to conceptual and definitive design. The ARARs can best
3 be met by designing an engineered cover system supplemented, as necessary, by site sub-grade
4 improvement to minimize settlement. Determination of specific sub-grade improvement methods is an
5 issue to be addressed during definitive design.

6
7 Criteria applied to the conceptual design based on these ARARs are as follows:

- 8
9 1. Facilitate drainage and minimize surface erosion by wind and water.
10
11 2. Design the low-permeability layer of the cover to have a permeability less than or equal to any natural
12 subsoils present.
13

14 **3.6.4.3 Technical Guidance for Facilities with Hazardous/Dangerous Waste Constituents**

15 **EPA Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface**
16 **Impoundments.** This document provides design criteria for specification of granular soil materials used
17 in construction of graded filter media. The intent of the criteria is to prevent failure of the drainage layer
18 by clogging with fines. The criterion imposed on the conceptual design is to:

- 19
20 1. Design the cover to prevent the migration and accumulation of topsoil material within the lateral
21 drainage layer.
22

23 **Hanford Plant Standards.** The standards require the bottom of foundations for permanent buildings at
24 the Hanford Site to be placed at least 0.76 m (2 ft, 6 in.) below final grade for frost protection purposes.
25 This criterion was applied to the lateral drainage layer and the low-permeability component.
26

- 27 1. Ensure that the lateral drainage layer and the low-permeability asphalt component of the barrier are
28 situated at least 0.76 m (2 ft, 6 in.) below final grade for frost protection.
29

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Figure 3.1. Profile View Through Modified RCRA Subtitle C Barrier.

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4.0 CLOSURE SCHEDULE

Closure of each of the burial grounds covered in this plan will require completion of several related activities. First trenches must be filled with waste. All stored TRU waste must be retrieved from the burial ground and replaced with low-level waste where possible. Trench fill must be stabilized by sub-grade modification (Interim Closure). The burial ground will then be turned over to ERC and the final closure cover will be designed and installed. Finally, the final closure cover is designed and installed and the burial ground will be remediated as required.

Estimated fill dates for trenches in each of the burial grounds are calculated based on the waste forecast information, trench geometry, and current fill rates. This information is calculated annually in the "The Low-Level Burial Grounds Disposal Plan" (Pratt 2000). Estimated trench fill sequence and fill dates are shown in Table 4.1. Detailed information about trench size and geometry can be obtained from the Disposal Plan.

TRU waste that is stored for retrieval in each burial ground and an estimated retrieval date is shown in Table 4.2. TRU retrieval activities are described in Johnson (1994). Waste trenches, quantities, and dates for retrieval have been set for the 10,000 drums which will be included in an initial retrieval effort. The remaining TRU waste to be retrieved is outlined in Johnson (1994). A firm schedule for TRU retrieval has not been developed. As a result, dates in Table 4.2 are lacking. For the purpose of developing a closure schedule, it has been assumed that all TRU waste will be retrieved by 2030. Time has not been included in the closure schedule for refilling these trenches with LLW.

Interim Closure includes sub-grade modification to stabilize the disposed waste areas to support the soil cover overburden. Waste density (i.e., the density of waste containers and backfill soil) was not controlled at the time of waste disposal. As a result, when waste containers collapse, a local subsidence event will be created. Sub-grade modification will collapse containers and compact both the waste and the backfill material around the container in a controlled manner to create a stable base on which to build a closure cover. Estimated times required for sub-grade modification and closure cover construction are listed in Table 4.3.

The final closure cover will require the placement of massive amounts of material. Each cover will be constructed in layers. Estimated minimum times to construct each final closure cover are shown in Table 4.3. The closure cover design is described in Section 3.3.2.

A documentation schedule is shown in Table 4.4. Major documents required for LLBGs include safety analysis reports, RCRA permits, environmental impact statement, performance assessment and composite analysis documents.

The final closure schedule is as shown in Table 4.5. The schedule assumes that interim closure will commence directly after TRU retrieval from each burial ground is complete and that final closure covers will be constructed immediately after interim closure activities are complete.

The closure plan is a living document that will be continuously updated throughout the operational life of the facility. Changes in facility design and operations, additional information developed from monitoring data, or improved understanding of LLW disposal facility performance can lead to changes in the analyses and documentation for the facility, which could lead to changes in the closure plan. Updates of the closure plan are necessary to ensure that the radioactive waste management basis is current and protective of workers, the public, and the environment. This closure plan will be reviewed annually and updated as required at least every five years.

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Table 4.1. Current Trench Filling Sequence and Estimated Fill Dates (Pratt, 2000).

Waste Type	Trench I.D.*	Date Filled**
Cat I LLW Drums	218-W-4C(33)	May 2004
	218-W5 (Drums #2)	49 percent filled
Cat I LLW Drums	218-W-5 (33)	Jun 2007
	218-W-5 (Boxes #2)	53 percent filled
Cat I LLW Misc.	218-W-5 (29)	Nov. 2000
	218-E (MISC #2)	53 percent filled
Cat I LLW V Trench	218-E-12B (42)	Feb 2000
	218-E12B (36)	Mar 2002
	218-E-12 B (32)	Feb 2003
	218-W-5 (V-Trench #4)	May 2004
	218-W-5 (V-Trench #5)	Dec 2005
	218-W-4C (V-Trench #6)	Sep 2007
	218-W-5 (V-Trench #7)	Oct 2010
	218-W-4C (V-Trench #80)	Jun 2012
	218-W-3AE (V-Trench #9)	May 2016
	218-W-3AE (V-Trench #10)	Feb 2020
	218-W-5 (V-Trench #11)	Sep 2023
	218-W-4C (V-Trench #12)	Nov 2025
	218-W-4C (V-Trench #13)	Jan 2028
	218-W-4c (V-Trench #14)	80 percent filled
Cat 3 LLW	218-W-4C (14)	July 2000
	218-W-3AE (8)	85 percent filled
Remote handle LLW	218-W-3AE (13)	June 2002
	218-E-10 (9)	May 2003
	W-3AE (16)	77 percent filled
Mixed Waste	218-W-5 (31)	Sep 2005
	218-W-5 (34)	Aug 2009
	218-E-12B (MMLW #3)	23 percent filled

* Trench I.D. values are listed by Burial Ground and (Trench). New trenches are listed by waste type to be disposed (i.e. drums, boxes, misc., v-trench, etc.) and new trench number.

** Trenches that will not be filled with waste in the current forecast are listed as percent filled at the end of FY 2029.

Table 4.2. TRU Retrieval Schedule (Johnson, 1994).

<u>Burial Ground</u>	<u>Trench</u>	<u>Stored for Retrieval</u>
218W-3A 218W-3A	Trench S6	5 EBR II Casks One BATCO Cask
218W-3A	Trench S9	70 Grams
218W-3A	Trench 01	4 Drums
218W-3A	Trench 04	143 Drums
218W-3A	Trench 05	360 Drums
218W-3A	Trench 06	2182 Drums 7 Boxes
218W-3A	Trench 08	460 Drums 53 Boxes (& Other) 22 Concrete Casks
218W-3A	Trench 10	3 Drums
218W-3A	Trench 15	7 Drums
218W-3A	Trench 17	112 Boxes
218W-3A	Trench 23	6 Drums 8 Boxes
218W-3A	Trench 30	29 Drums 5 Boxes (& Other)
218W-3A	Trench 32	2 Boxes
218W-3A	Trench 34	5 Boxes
218W-4B	Trench V7	1320 Drums
218W-4B	Trench 07	8080 Drums 67 Boxes
218W-4B 218W-4B	Trench 11	3140 Drums 106 Boxes
218W-4C	Trench 01	5080 Drums 124 Boxes 46 Casks
218W-4C	Trench 07	67 Drums

<u>Burial Ground</u>	<u>Trench</u>	<u>Stored for Retrieval</u> 73 Boxes 13 Casks (Grouted Drums)
218W-4C	Trench 19	One Drum
218W-4C	Trench 20	613 Drums 29 boxes
218W-4C	Trench 29	2544 Drums 10 Boxes
218E-12B	Trench 17	2660 Drums 60 Boxes
218E-12B	Trench 27	240 Drums

Table 4.3. Closure Schedule Estimates.

LLBG	Area	Length	Interim Cl. @ 50 lf/day + 200 days/12 mos	Final C. @ 2ac/mo
218-W-3A	50 acres	43 trenches @ 1100' = 47,300 lf 14 trenches @ 600' = 8,400 lf	1114 days = 67 mos	25 mos
218-W-3AE	49 acres	8 trenches @ 1500' = 12,000 lf	240 days = 15 mos	25 mos
218-W-4B	9 acres	14 trenches @ 700' = 9,800 lf	192 days = 12 mos	5 mos
218-W-4C	49 acres	20 trenches @ 700' = 14,000 lf	280 days = 17 mos	18 mos*
218-W-5	92 acres	17 trenches @ 900' = 15,300 lf	306 days = 19 mos	46 mos
218-E-10	89.2 acres	13 trenches @ 1200' = 15,600 lf	312 days = 19 mos	32 mos*
218-E-12B	168 acres	41 trenches @ 700' = 28,700 lf + Navy RC Trench	576 days + 1 year for RCT = 47 mos	58 mos*

* Assumes 70 percent of facility area is covered.

Table 4.4. Documentation Schedule.

RCRA Permit Interim Status	1988 (completed)
Interim Safety Basis	1994 (completed)
Initial Performance Assessment for the 200 West Area	1995 (completed)
Initial Performance Assessment for the 200 East Area	1996 (completed)
Initial Composite Analysis	1999 (completed)
Annual PA Review	Annually
Operational Closure Plan	2000
Operational Monitoring Plan	2000
Master Safety Analysis Report	2002
RCRA Permit Final Status	2002
Solid Waste Environmental Impact Statement	2002
Operational Closure Plan Update	2005
Operational Monitoring Plan Update	2005
Final Performance Assessment for the 200 West Area	2030
Final Performance Assessment for the 200 East Area	2030
Final Composite Analysis	2030
Final Closure Plan	2030
Final Monitoring Plan	2030
Final Performance Assessment for the 200 West Area	2030
Final Performance Assessment for the 200 East Area	2030
Final Composite Analysis	2030
Final Closure Plan	2030
Final Monitoring Plan	2030

Table 4.5. Closure Schedule.

Burial Ground	Interim Closure	Final Closure	Institutional Control
218-W-3A	2035-2041	2042-2044	100 yr min
218-W-3AE	2039-2035	2036-2038	100 yr min
218-W-4B	2050-2052	2053-2054	100 yr min
218-W-4C	2053-2055	2056-2057	100 yr min
218-W-5	2042-2044	2045-2048	100 yr min
218-W-6	2033-2035	2036-2038	100 yr min
218-E-10	2033-2035	2036-2038	100 yr min
218-E-12B	2045-2049	2050-2054	100 yr min

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