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Low-Level Radioactive Mixed Waste Land Disposal Facility - Permanent Disposal

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LOW-LEVEL RADIOACTIVE MIXED WASTE DISPOSAL FACILITY - PERMANENT DISPOSAL

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ABSTRACT. Radioactive mixed waste (RMW) disposal at U.S. Department of Energy (DOE) facilities is subject to the *Resource Conservation and Recovery Act of 1976* (RCRA) (1) and the *Hazardous and Solid Waste Amendments of 1984* (HSWA) (2). The U.S. Environmental Protection Agency (EPA) granted waste generators and owners/operators of hazardous waste treatment, storage, and disposal (TSD) facilities a national capacity variance for RMW, as outlined in Appendix VII in the *Code of Federal Regulations* (40 CFR 268) (3), where treatment standards are not well known or defined. Wastes within the national capacity variance were unrestricted from land disposal. The national capacity variance for RMW expired on May 8, 1992. Some case-by-case extensions are pending, but eventually all RMW will be restricted from land disposal.

The RCRA has specific criteria that must be met when designing, constructing, and operating a land disposal facility for hazardous waste (i.e., RMW). The HSWA, under RCRA, identifies minimum technological requirements for the permanent disposal of mixed waste in landfills, as outlined in 40 CFR 268, "Land Disposal Restrictions" (3).

Westinghouse Hanford Company, in Richland, Washington, has completed the design of a radioactive mixed waste land disposal facility, which is based on the best available technology compliant with RCRA (40 CFR 260-265 [4,5,6,7,8,9], WAC 173-303 [10]). When completed, this facility will provide permanent disposal of solid RMW, after treatment, in accordance with the Land Disposal Restrictions. The facility includes a double clay and geosynthetic liner with a leachate collection system to minimize potential leakage of radioactive or hazardous constituents from the landfill. The clay liners will be capable of achieving a permeability of less than 1×10^{-7} cm/s. The two clay liners, along with the two high density polyethylene (HDPE) liners and the leachate collection and removal system, provide a more than conservative, physical containment of any potential radioactive and/or hazardous contamination.

To obtain an operating permit for a facility of this type, as required in 40 CFR 270 (11) and WAC 173-303 (10), is not a simple task. A specific Construction Quality Assurance (CQA) Plan must be developed for the construction of this type of landfill. Guidance for Quality Assurance during construction is outlined in EPA/530-SW-86-031, *Technical Guidance Document, Construction Quality Assurance for Hazardous Waste Land Disposal Facilities* (12). The CQA Plan is analogous to an inspection plan used during construction. The plan identifies appropriate documentation to ensure regulators that the facility is constructed to applicable design criteria, plans, and specifications. The plan requires that deficiencies encountered are corrected before construction is complete.

INTRODUCTION

Various types of waste have been generated during the 50-year history of the Hanford Site. Regulatory changes in the last 20 years have provided the emphasis for better management of these wastes.

Interpretations of the *Atomic Energy Act of 1954* (13), the *Resource Conservation and Recovery Act of 1976* (RCRA) (1), and the Hazardous and Solid Waste Amendments of 1984 (HSWA)(2) have led to the definition for solid radioactive mixed wastes (RMW). The radioactive and hazardous properties of these wastes have resulted in the initiation of special projects for the management of these wastes. Other solid wastes at the Hanford Site include low-level wastes, transuranic, and nonradioactive hazardous wastes.

The U.S. Environmental Protection Agency (EPA) granted waste generators and owners/operators of hazardous waste treatment, storage, and disposal (TSD) facilities a national capacity variance for RMW, where treatment standards were not well known or defined. Wastes within the national capacity variance were unrestricted from land disposal. The national capacity variance for RMW expired on May 8, 1992.

The HSWA of 1984, under RCRA, identifies minimum waste disposal criteria, known as the "Land Disposal Restrictions" (40 CFR 268) (3), that must be met before disposing of solid waste in a landfill. In Washington State, the disposal criteria for RMW are very strict. Currently, few RMWs meet the disposal criteria; therefore, these wastes must be stored until treatment is available to condition the waste for disposal. At the Hanford Site, in south-central Washington State, the Central Waste Complex (CWC) is designed to provide interim and long-term storage of RMW (refer to Figure 1). When completed, the CWC will have the capacity to store more than 75,000 208-L (55-gal) drums of solid waste.

The U.S. Department of Energy (DOE)/Westinghouse Hanford Company (WHC) plans to build a regulatory compliant landfill for the permanent disposal of solid radioactive waste as described within.

THE SOLID WASTE MISSION

The Hanford Site mission is to transform the Site into the nation's model for excellence in environmental management. This mission will include demonstrating and applying advanced technologies for the restoration of land and the creation of facilities for other productive uses. The Hanford Site solid waste mission is to safely construct and operate the solid waste TSD facilities designed to protect human health and the environment. A disposal facility of interest, designed to protect human health and the environment, is a regulatory compliant landfill. This paper concentrates on details about the design, construction, and permitting of such a facility.

WASTE TYPES

DOE Order 5820.2A (14) defines the types of radioactive wastes. Without regard to source or form, waste contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g (3,700 Bq/g), at the time of assay, is considered transuranic. High-level waste is the highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid that contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation. As defined by DOE Order 5820.2A (14), waste that contains radioactivity and is not classified as high-level waste, transuranic waste, spent nuclear fuel, or byproduct material is considered low level. Test specimens of fissionable material irradiated for research and development only, and not for the production of power or plutonium, may be classified as low-level waste, providing the concentration of transuranic isotopes are less than 100 nCi/g(3,700 Bq/g) (15). This paper discusses a method for the permanent disposal of solid low-level mixed waste.

The EPA has delegated its authority under RCRA, thus allowing individual states to manage hazardous waste programs. Washington State hazardous waste regulations are codified in the *Washington*

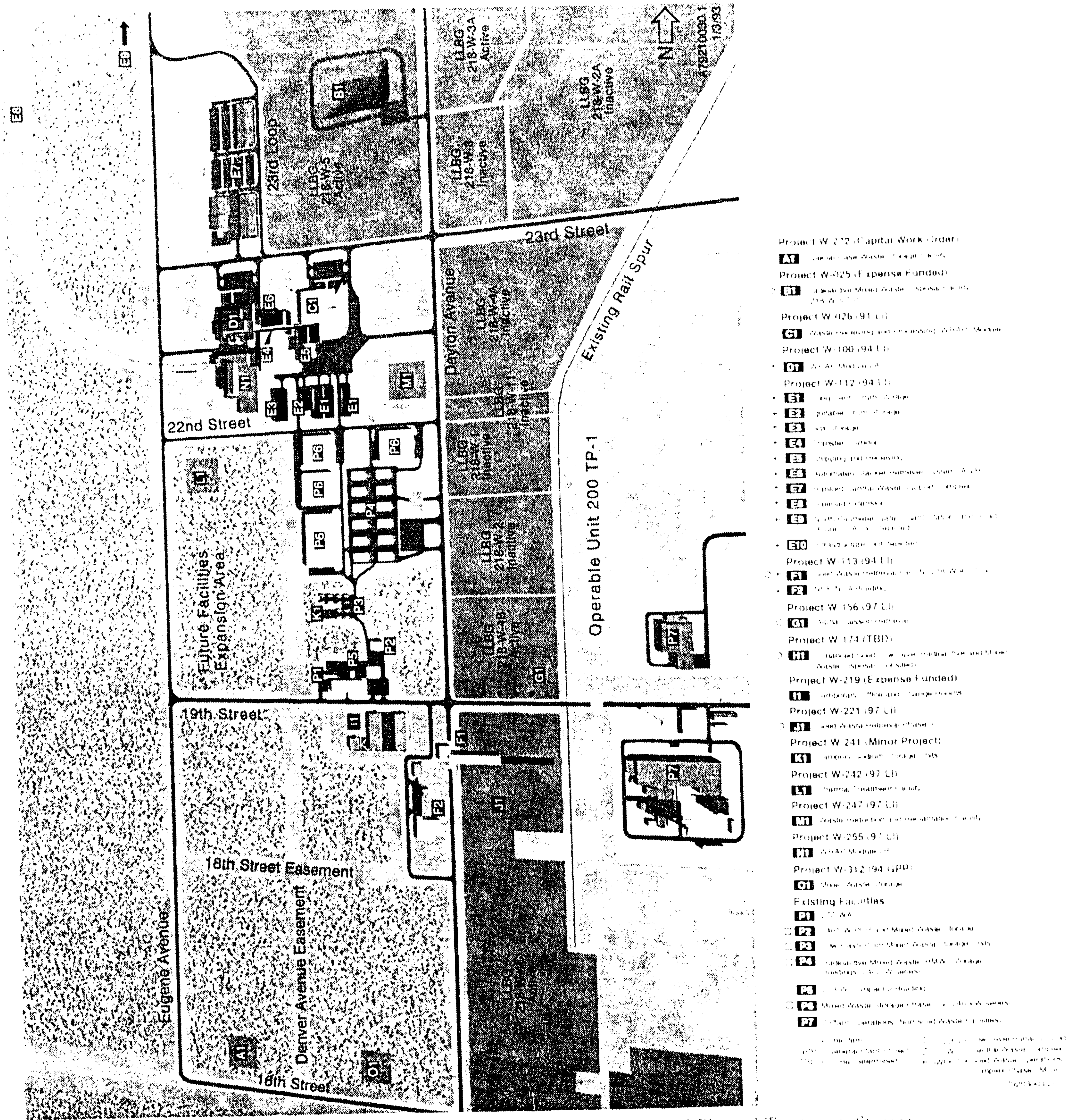

Figure 1. Hanford Central Waste Complex - Existing and Planned Treatment, Storage, and Disposal Facilities.

Administrative Code (WAC), Section 173-303, "Dangerous Waste Regulations" (10). Washington State regulations are more restrictive than the Federal RCRA regulations and cause many additional wastes to be regulated. These wastes are called dangerous wastes in Washington State.

PAST PRACTICES

Hanford Site contractors have buried radioactive solid waste directly into shallow land disposal since 1944. Waste from reactor operations, chemical processing and separations, research and development activities, and other DOE programs has been disposed. Contamination in these wastes consists of fission products, induced activation products, and transuranic isotopes. Solid wastes originate from both onsite and offsite generators. Currently, wastes are segregated by waste type and handled according to the regulatory criteria governing each waste type. Because it is no longer allowable to dispose of RMW in this manner, Subtitle C (RCRA 1976, Section 3004, paragraph o) of RCRA requires minimum standards for disposal facilities and surface impoundments. Disposal facilities, in accordance with Subtitle C, will be built at the Hanford Site for the disposal of solid low-level RMW.

FUTURE APPROACHES

Figure 1 depicts solid waste management in the year 2000 at the Hanford Site. There are numerous planned facilities for the TSD of solid wastes. The goal of these TSD facilities is to provide safe, efficient, and regulatory-compliant management of solid wastes. Based on RCRA regulations, all hazardous waste must either be treated by a specified technology or meet strict concentration limits before being disposed in a RCRA-compliant landfill. Currently, the Hanford Site stores wastes (refer to Figure 1) until treatment and disposal units are available. A Performance Assessment (PA), in accordance with DOE Order 5820.2A (14), is driving the Hanford Site to severely restrict the use of shallow direct burial trenches.

Existing trenches do not meet RCRA leachate collection standards. Once the PA is complete, low-level waste disposal will be restricted further. Barriers similar to RCRA liners may be used in disposal sites for disposal of longer-lived radionuclides.

RADIOACTIVE MIXED WASTE DISPOSAL CAPACITY

Currently, permitted RMW disposal capacity does not exist on the Hanford Site. Because national RMW disposal capacity is also limited, it is appropriate that a RCRA-compliant landfill be constructed at the Hanford Site. Onsite disposal capacity further eliminates the risk and expense of offsite transport of regulated wastes across public access transport corridors.

MIXED WASTE LANDFILL

The purpose of the mixed waste land disposal facility is to provide disposal capacity on the Hanford Site for solid RMW. Figure 2 provides a conceptual picture of the landfill. The landfill is designed to handle both contact-handled (surface dose rate $\leq$ 200 mrem/h) and remote-handled (surface dose rate > 200 mrem/h) waste. The landfill will be limited to constraints developed as part of a PA modeling effort. The PA will determine the upper bound for the allowable concentration (activity-Bq/Volume-m^3 [Ci/Volume-ft^3]) of radionuclides in the waste for shallow landfill disposal. This means that the landfill will have upper limits for a given concentration of a specific radionuclide based on the PA effort.

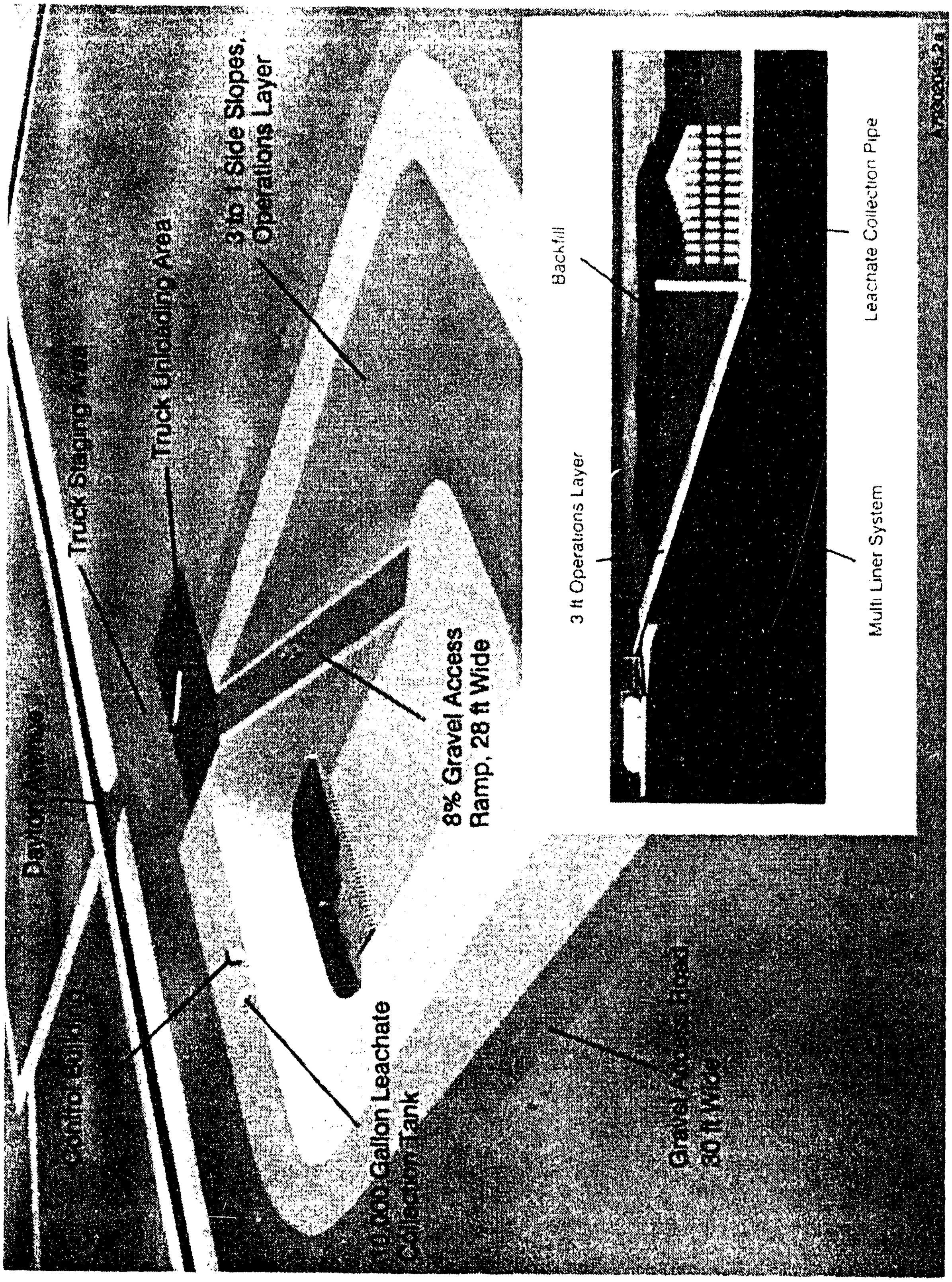

Figure 2. Conceptual Layout of the Radioactive Mixed Waste Land Disposal Facility - Non-Drag-Off.

The RMW landfill is designed to meet all applicable State, Federal, and local regulations (4,5,6,7,8,9,10,16). The landfill is designed to contain the waste as well as prevent leachate from reaching the environment. Excavation of the landfill will be approximately 68,045 m^3 (89,000 yd^3). The footprint at subgrade is approximately 1.32 hectare (3.27 acres), and at the floor it is approximately 0.23 hectare (0.57 acres) or 76 by 30 m (250 by 100 ft). The excavated depth to subgrade will range from approximately 10.4 m (34 ft) at the west end of the floor to about 11.3 m (37 ft) at the east end. The depth varies so that any potential leachate will be collected at one end of the facility known as the sump collection well. Control of leachate infiltration is achieved by a multilayer liner system consisting of a soil-bentonite mixture (admix with 11 to 14% sodium bentonite), geosynthetic liner materials, and a leachate collection and removal system.

The actual waste volume capacity of the landfill is dependent on the design of cover and its slope. Assuming the base case (waste filled to the surface), the estimated waste volume capacity is 7,646 m^3 (270,000 ft^3) or 37,000 208-L (55-gal) drum equivalents.

Multilayer Liner System

The liner system provides a physical containment barrier between the waste packages and the environment. The liner system is designed to protect human health and the environment from potential leachate that may be generated, if any of the drums were to breach. The multilayer liner system from bottom to top is shown in Figure 3 and consists of 0.95 m (3.1 ft) of admix (soil mixed with sodium bentonite, with a permeability of 1×10^{-7} cm/s or less), 60 mil (1.52 mm) flexible membrane liner (HDPE), 198 mil (5.03 mm) geonet, 185 mil(4.7 mm) geotextile, 0.61 m (2 ft) of drainage gravel, 185 mil (4.7 mm) geotextile, 0.46 m (1.5 ft) additional admix (on the floor only), another 60 mil (1.52 mm) flexible membrane liner, 198 mil (5.03 mm) geonet, a 95 mil (2.41 mm) geotextile, 0.31 m (1 ft) of drainage gravel, 95 mil (2.41 mm) geotextile, and 0.91 m (3 ft) of operational backfill soil.

Note that drainage gravel is not used on the side slopes. A geocomposite acts in place of the drainage gravel. Geocomposites consist of a geonet with a layer of geotextile thermally bonded to each side of the geonet. Geotextiles perform the following functions: separation, filtration, and cushioning. Geonets provide a redundant drainage system in combination with the drainage gravel. Transmissivity, for a synthetic drainage layer (EPA requires greater than 5.4×10^{-4} m^2/s or 0.0581 ft^2/s), is the primary selection criteria for geonets. The flexible membrane liners, in conjunction with the admix, provide a physical containment barrier of potential leachate to the environment.

On the side slopes of the landfill, the flexible membrane liner is textured on both sides (Type I HDPE) to mitigate sliding between the liners and the subgrade (slope failure). Generally, a factor of safety of 1.5 for static conditions and 1.1 for dynamic conditions are considered adequate for a facility of this type and were established as the minimum acceptable values for the design analyses. Factors of safety can be calculated using the Infinite Side Slope equation (Stability Analysis of Earth Slopes, (17):

$$FS = \frac{(c/\delta d)\sec\alpha + [(1-r_u)\cos\alpha - c_s\sin\alpha]\tan\phi}{[\sin\alpha + c_s\cos\alpha]} \qquad (1)$$

where:

FS = Factor of Safety
c = Effective Cohesion (kg/m^2 [lb/ft^2]- zero)
δ = Unit Weight of Sliding Mass (kg/m^3 [lb/ft^3])
d = Vertical Thickness of Sliding Mass (m [ft])
α = Slope Angle (degrees, 3 to 1 side-slopes is 18°)

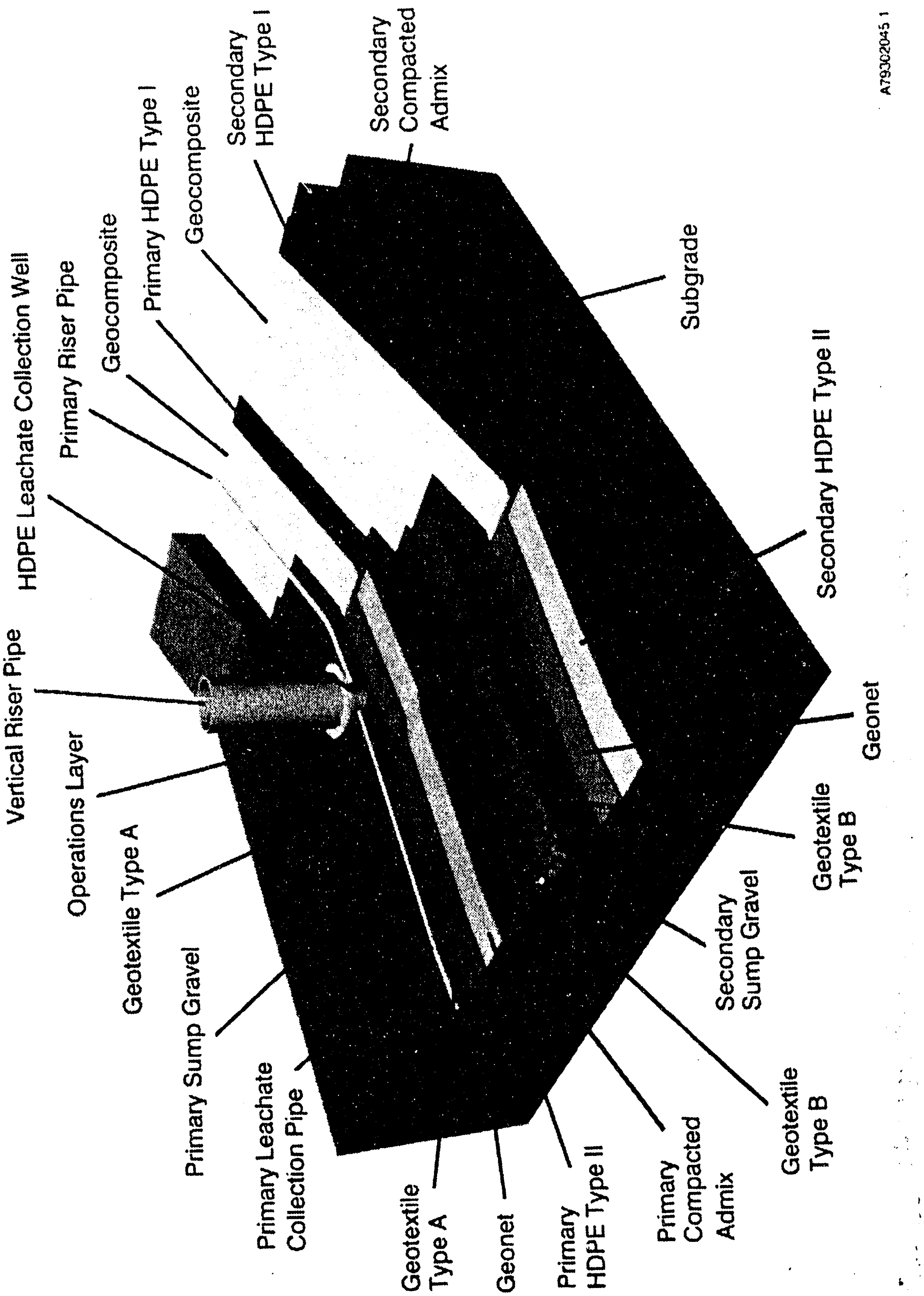

Figure 3. Radioactive Mixed Waste Land Disposal Facility Multiliner Cross Section.

r_u = Pore Pressure Ratio (none)
c_s = Horizontal Acceleration, Seismic Event (0.12 g)
ϕ = Effective Friction Angle of Sliding Mass (36°).

The parameters (c,ϕ,d,δ) are based on laboratory test data of the existing soils at the proposed project site and on the proposed geosynthetics to be used when the facility is built. To be conservative, the effective cohesion is assumed to be zero, and when determining the static factor of safety, the horizontal acceleration is also zero. For the dynamic analysis, a 0.12 g horizontal acceleration is used at the Hanford Site as required by the Hanford Plant Standards (18). The factor of safety for this facility was calculated for the subgrade and the interface between each and every liner to determine the critical interface. The critical interface is the interface that is most likely to fail, or the one with the lowest factor of safety. The critical interface for this specific project proved to be between the operations layer and the uppermost geotextile, with a static and dynamic factor of safety of 1.8 and 1.3, respectively, which is within the minimum acceptance criteria.

Research and experience have shown that desiccation cracks can occur in soil-bentonite liners under geomembranes. Desiccation cracking (of the admix) may occur under the geomembrane liners when either (1) the liner is not in tight contact with the admix and moisture leaves the admix to collect in the adjacent air space or (2) the liner is subjected to wide temperature fluctuations (i.e., freeze-thaw cycles). The operations layer will act as a weight to keep the geomembrane in tight contact with the admix and provides a protective layer for the underlying liners during waste placement. It also minimizes the potential for desiccation cracking of the primary and secondary admix liner by acting as a thermal insulator.

9090 Liner Leachate Compatibility Test

The proposed geosynthetic and admix liners for the RMW landfill were tested for chemical resistance to synthetic leachate in accordance with EPA method 9090 (19). The goal of this testing is to ensure that the proposed liners will not be adversely affected by any potential leachate, if the liners were exposed to a worst case leachate concentration. The synthetic leachate (pH = 9.2) is developed based on the packaging approaches, including stabilization agents of anticipated waste streams emplaced in the landfill. Under this method, samples of geosynthetic materials and laboratory samples of compacted admix were immersed in a synthetic leachate at temperatures of 23 and 50 °C. A portion of the geosynthetic samples is removed at intervals of 30, 60, 90, and 120 days and is tested to determine any changes in physical and mechanical properties. For this specific project, the standard EPA 9090 test procedure was modified; some samples were irradiated while immersed in the leachate to simulate the effects of the radioactive component of RMWs. The irradiated samples were exposed to gamma radiation for about two hours and received a total dose of 50,000 rad, which is considerably higher than the actual expected dose. The important question is, "Does the thermal loading caused by the radioactive constituents of the waste, or the radiation itself, or the combination of the radiation and the hazardous constituents (pH=9.2) cause the liners to deteriorate?" In both the irradiated and nonirradiated cases, the HDPE showed no statistically significant change in the properties of the liner materials. The temperature changes caused by the radioactive component are anticipated to be less than 1 °C. Additionally, laboratory permeability (flexible wall permeameter) testing, using the same synthetic leachate, was conducted on samples of compacted admix, as an added level of assurance (not required). Based on the results of this testing, the admix showed a significantly higher permeability to synthetic leachate than to site water. However, admix containing 12% sodium bentonite clay showed a permeability to leachate that was 3 to 10 times (varied between samples) lower than the regulatory acceptance criteria of 1×10^{-7} cm/s.

Leachate Collection and Handling

The leachate collection and removal system is designed to be capable of collecting and removing leachate to control the hydraulic head on the liner. Leachate is routed to the east end of the trench where the leachate collection well is located. Several pumps are used to remove leachate to a storage tank located abovegrade. The leachate collection and removal system consists of two low-capacity submersible pumps, a high-capacity pump (worst case rain storm), a transfer pump, a 37,850-L (10,000-gal) collection tank, 6.1 m (20 linear ft) of 76.2-cm (30-in.) HDPE (collection well-vertical riser), approximately 67 m (220 linear ft) of 20.3-cm (8-in.) HDPE pipe (removal piping), 378 m (1,240 linear ft) of 10.2-cm (4-in.) perforated (collection piping) HDPE pipe, approximately 488 m (1,600 linear ft) of 10.2-cm (4-in.) HDPE (collection piping) pipe, and 128 m (420 linear ft) of 5.08-cm (2 in.) HDPE pipe. Located inside the 5.08-cm (2-in.) HDPE pipe are level sensors, with a level transducer and a current sensitive relay. The relay is controlled by current from the level transducer and turns the submersible pumps on and off. For a worst case rain scenario, a high-capacity pump will be activated. This self-priming pump has independent high and low on/off levels controlled by mercury float switches in the vertical riser pipe.

WASTE FACILITY FILL PLAN

Engineering studies will be completed to determine the "optimal" waste fill plan. Optimal refers to the largest possible waste volume of the landfill without impacting the performance of the landfill. Waste packages will be placed in the landfill by forklift or crane and across the entire bottom layer of the landfill. Once an entire layer or lift of waste packages has been emplaced, a layer of soil or cement-like backfill will be used between and above the containers to provide an operating surface for the next layer of waste. It is expected that three to four tiers of waste will be accommodated. Each lift is emplaced completely before initiating a subsequent lift so that the driving forces of emplaced waste on the slope do not exceed the resisting forces of the waste on the floor and possibly initiate a slope failure. The void areas between each layer of waste and between waste containers will be filled with soil or cementations backfill. The purpose of the backfill is to provide a stable waste matrix in the trench and to protect the waste packages while providing a working surface for equipment and subsequent lifts. Some commercial names for the cementations backfill are Controlled Density Fill (CDF) or K-Krete. CDF is essentially a low-strength concrete composed of fly ash, portland cement, aggregate, and water. It was developed by engineers at Detroit Edison who sought to find a use for fly ash, a byproduct of their coal burning power plants. K-Krete was developed by Detroit Edison and Kuhlman Ready/Mix. At the Hanford Site, CDF is being evaluated, and fly ash from the two coal-fired steam plants is being considered. Assuming the fly ash can be used as part of the cementations mixture, it would eliminate or reduce the problem of disposing of fly ash at the Hanford Site, and represents a "good" waste minimization program.

DISPOSAL FACILITY SCHEDULE

The RMW disposal trench is scheduled to be constructed during 1994. Trench excavation will occur early in the year. Installation of the geomembranes and liners will occur during the dryer warmer months because of the temperature and moisture sensitive nature of the liner installation process. The operating life of the landfill is 20 years maximum, with a 50-year design life. A 30-year post closure period is planned after the trench is filled. Actual operational trench life will depend on the rate of waste emplacement.

CLOSURE DESIGN AND POST CLOSURE MONITORING

The location of the RMW disposal trench is within the 218-W-5 Burial Ground. This trench is in the vicinity of past waste disposal activities and future or planned waste management activities. Closure of this trench will be accomplished as part of closing a larger area of adjacent contiguous burial grounds.

The cover design will comply with the requirements for dangerous waste disposal as defined in 40 CFR 264 (8) and WAC 173-303 (10). The cover will be designed to control water infiltration. The cover design will include a vegetative surface soil layer, a high permeable gravel layer to remove water, and a flexible membrane infiltration liner with a soil-bentonite liner underneath it. The slope of the cover has not been designed yet. It may be a 33% slope (3H:1V), 25% (4H:1V) or 10% (10H:1V) with rip-rap to minimize erosion. The slope of the cover will affect the volume capacity. Obviously a 33% slope will maximize landfill waste capacity. However, at 2 or 3 percent slopes, wind and water erosion becomes a factor that must be considered, and the uppermost surface must contain coarser material that will still support vegetation. A drainage system around the cover will be used to move any precipitation away from the cover.

At closure, a radiological site survey will be performed to characterize the site grounds. This survey will be part of the permanent decommissioning record. Leachate and groundwater monitoring will give an indication of the integrity of the liners and closure cover. Leachate is not expected to accumulate in the trench other than precipitation during operations. No leachate is anticipated after trench closure. Monitoring of the trench will be performed for 30 years after trench closure.

MIXED WASTE DISPOSAL FACILITY PERMITTING PROCESS

The RCRA requires cradle-to-grave management of wastes; owners and/or operators of TSD facilities are required to obtain permits for continued operation of facilities. The purpose of RCRA is to reduce or eliminate the generation of hazardous waste and to treat, store, and dispose of hazardous waste so as to minimize the present and future threat to human health and the environment (waste minimization is a goal of RCRA).

The Low-Level Burial Grounds Dangerous Waste Permit Application (20) is an example of a RCRA Part A and B permit application, submitted to Washington State for dangerous waste operations at the low-level burial grounds. The Part B permit provides documentation for disposal of RMW at the Hanford Site. Currently, the Hanford Site is covered by RCRA interim status regulations. Construction and operation of the RMW disposal trench will be initiated under interim status and the above permit application. Once the regulators approve the Low-Level Burial Grounds Dangerous Waste Permit Application, the Hanford Site will have final operating status for waste disposal.

An important component of a permit for a disposal facility of this nature is the CQA Plan. A project-specific CQA Plan (21) must be developed for the construction of the facility if an operating permit is to be granted. Guidance for Quality Assurance during construction is outlined in EPA's Technical Guidance Document (12). The CQA Plan is analogous to an inspection plan used during construction and identifies appropriate documentation to ensure regulators that the facility has been constructed in accordance to the applicable design criteria, plan, and specifications. This plan will require the construction contractor to repair any deficiencies encountered before construction completion. In some cases in the United States, failure of a facility of this nature to perform as intended has been linked directly to inadequate construction quality assurance activities. For this reason, an appropriate CQA Plan, similar to reference 21, must be developed for a project of this kind.

The final status permit requires that landfill owners and operators strictly follow the permit. In addition to what is submitted in the permit application and the requirements under interim status, the state may add special conditions to the permit. These conditions can severely limit the operation or add administrative controls.

CONCLUSION

The solid waste program provides a 30-year forecast of solid waste volumes by waste type. Environmental restoration and cleanup of the Hanford Site is expected to take more than 30 years. Environmental restoration and new programs at the Hanford Site will generate solid radioactive waste for disposal during this time frame. The landfill described above and ones similar will be built as appropriate to support these forecasted solid RMW volumes.

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