CIVILIAN RADIOACTIVE WASTE MANAGEMENT SYSTEM

TOTAL SYSTEM DESCRIPTION
Revision 1

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Date: 10/30/98

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1. INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide a top-level description of the Civilian Radioactive Waste Management System (CRWMS) and its concept of operations as currently envisioned. The document is consistent with current disposal container and repository conceptual designs as described in the viability assessment of the Yucca Mountain site (DOE 1998a). It can be used as a reference for facilitating communication to program participants, regulatory and oversight entities, and stakeholders.

This document represents a snapshot in time; it is to be revised, as appropriate, to reflect future program redirection or evolving system concepts and designs.

1.2 PROGRAM MISSION

The *Nuclear Waste Policy Act of 1982,* Public Law 97-425 (the Act), established the Department of Energy's (DOE) responsibility to provide for the permanent disposal of the Nation's high-level radioactive waste (HLW) and spent nuclear fuel (SNF), and directed that the owners and generators of these wastes bear the costs of their disposal. The Act also established the Office of Civilian Radioactive Waste Management (OCRWM) to carry out a mission to provide for the disposal of the Nation's nuclear waste in a geologic repository, in a manner that protects the health and safety of the public and workers, and maintains the quality of the environment. The CRWMS is being developed by OCRWM to fulfill that mission.

Since the enactment of the Act, the OCRWM Program has undergone some changes. The *Nuclear Waste Policy Amendments Act of 1987,* Public Law 100-203, designated the Yucca Mountain site in Nevada as the only site to be characterized for a geologic repository. *The Energy Policy Act of 1992*, Public Law 102-486, directed the Environmental Protection Agency (EPA) to promulgate new health and safety standards for the Yucca Mountain site, based on the findings and recommendations of the National Academy of Sciences. Within one year of their promulgation, the Nuclear Regulatory Commission (NRC) is to revise its technical requirements and criteria for licensing the repository, based on those standards.

As directed by Congress in 1997, the Program has completed a viability assessment of the Yucca Mountain site in 1998. The viability assessment describes the preliminary design concepts for the repository and waste packages; a quantitative assessment of the probable long-term behavior of the repository in its geologic setting; a plan and cost estimate for the remaining work required to complete a license application; and an estimate of the costs to construct and operate the repository in accordance with its design concept. The current Program focus is on performing additional activities necessary to support a recommendation to the President in 2001 on the suitability of the site for construction of a repository. If the site is approved, a license application will be submitted to the Nuclear Regulatory Commission in 2002 for repository construction authorization. The current Program schedule projects the start of repository emplacement operations in 2010.

1.3 SYSTEM FUNCTION

The primary function of the CRWMS is to dispose of waste, which includes directing or controlling any physical activity, operation, or process to accept title to and physical possession of spent fuel and high-level waste, and transporting these wastes to the repository for permanent disposal.

1.4 PROGRAMMATIC ASSUMPTIONS

To provide for consistency in program planning, system studies, and total system life cycle cost analyses, the following assumptions are made:

A. Waste Acceptance and Transportation

(1) To the extent practicable, waste acceptance and transportation services for spent fuel and high-level waste will provided by the private sector. The Navy will provide transportation of their spent fuel.

(2) Spent fuel and high-level waste will be delivered in several sizes of truck and rail casks.

B. Monitored Geologic Repository

(1) The repository is presumed to be located at the Yucca Mountain site in Nevada.

(2) The repository will be capable of receiving several sizes of truck and rail casks.

(3) Commercial spent fuel (including mixed oxide spent fuel), DOE spent fuel (including Naval spent fuel), and high-level waste (including immobilized plutonium) will be accommodated in the repository.

(4) Waste emplacement in the first repository is limited by current law to 70,000 Metric Tons of Heavy Metal (MTHM) or equivalent of spent fuel and high-level waste, until a second repository is operational.

(5) The repository will be designed to remain open for a period of 100 years from the start of initial waste emplacement. The design will not preclude the capability for the repository to remain open for up to 300 years, with appropriate maintenance and monitoring, if required.

(6) To the extent practicable, the repository will have the capability to accommodate certain types of DOE spent fuel starting from its first year of operation.

2. WASTE DESCRIPTION

2.1 TYPES OF WASTE

The types of waste that will be delivered to the repository for disposal consist of commercial spent fuel (including mixed oxide spent fuel), high-level waste (including immobilized plutonium), and DOE spent fuel (including Naval spent fuel). Their characteristics vary appreciably in form, radioactive content and condition. Due to age and degradation, some of the DOE spent fuel may require conditioning or stabilization before it can be accepted for disposal in the repository.

Other waste forms that could potentially require disposal are being evaluated as contingencies. These include Greater-Than-Class-C low-level waste, cesium/strontium capsules, and DOE Special Performance Assessment Required Waste.

2.1.1 COMMERCIAL SPENT FUEL

Most of the commercial spent fuel consists of fuel assemblies discharged from 78 pressurized water reactors (PWRs) and 40 boiling water reactors (BWRs). This spent fuel is located at 72 nuclear power plant sites and one independent storage site in 33 states. The total amount of spent fuel in inventory as of 1996 is estimated at 12,100 MTHM in BWR fuel assemblies and 22,150 MTHM in PWR assemblies (DOE 1997). By 2030, the amount of spent fuel in inventory is projected to be 86,700 MTHM in BWR and PWR assemblies. The actual amount of spent fuel to be discharged could exceed the projected amount if reactor life extension programs are authorized by the Nuclear Regulatory Commission and implemented by the utilities. Conversely, the amount of spent fuel could be less than projected if reactors are shut down prematurely. Table 1 shows some typical characteristics of commercial spent fuel.

Table 1. Typical Commercial Spent Fuel Characteristics[a]

Characteristic	BWR	PWR
Overall assembly length, m (ft)	4.47 (14.67)	4.06 (13.32)
Cross section, cm (in)	13.9x13.9 (5.5x5.5)	21.4x21.4 (8.4x8.4)
Fuel rod length, m (ft)	4.06 (13.32)	3.85 (12.63)
Fuel rod array	8x8	17x17
Fuel rods per assembly	63	264
Assembly total weight, kg (lb)	319.9 (705.4)	657.9 (1,450.7)
MTHM per assembly	0.183	0.461
Nominal volume per assembly, m^3 (ft^3)	0.0864 (3.0508)	0.1860 (6.5677)

[a]Reference DOE 1997

The commercial spent fuel to be delivered to the repository includes both fuel assemblies and other waste forms. The other waste forms include canisters containing intact spent fuel assemblies,

consolidated spent fuel assemblies, spent fuel rods or pieces, or other fuel and nonfuel components. These canisters are stored in racks in the reactor spent fuel pools.

2.1.2 HIGH-LEVEL WASTE

The high-level waste to be disposed of is vitrified and encased in metal canisters by both commercial and defense waste generators. The types of canisters to be used for commercial and defense high-level wastes are those shown in Table 2.

Table 2. High-Level Waste Canister Characteristics and Projections

	CHLW	DHLW		
	WVDP[b]	**SRS[c]**	**HANF[d]**	**INEEL[e]**
Number of canisters in 2035[a]	300	5,940	12,200	1,190
Canister Length, cm (in)	300 (118)	300 (118)	450 (177)	300 (118)
Outside Diameter, cm (in)	61 (24)	61 (24)	61 (24)	61 (24)
Loaded Weight, kg (lb)	2,200[f] (4,850)	2,200[f] (4,850)	3,700 (8,160)	2,300[f] (5,070)

[a] Reference DOE 1997
[b] Commercial high-level waste (CHLW) from the West Valley Demonstration Project (WVDP)
[c] Defense high-level waste (DHLW) from the Savannah River Site (SRS)
[d] Defense high-level waste from the Hanford Site
[e] Defense high-level waste from Idaho National Engineering and Environmental Laboratory (INEEL)
[f] Reference ORNL 1992

It is estimated that about 19,630 canisters will be produced through 2035. (This estimate does not include the number of canisters that will contain about 17 metric tons of immobilized plutonium). However, there is currently some uncertainty in the exact number of high-level waste canisters that will ultimately be produced. Production of canisters of commercial and defense high-level waste has already begun at the West Valley Demonstration Project in New York and at the Defense Waste Processing Facility at the Savanah River Site, respectively. Wastes from these two facilities are in the form of borosilicate glass encased in stainless steel canisters. Production of waste canisters is also planned at both the Hanford Site and at the Idaho Chemical Processing Plant of the Idaho National Engineering and Environmental Laboratory. The reference waste form for these two sites is also a glass form, but final decisions on their characteristics and canister sizes have yet to be made.

2.1.3 DOE SPENT FUEL

DOE spent fuel includes fuel from defense production reactors, Navy propulsion reactors, domestic and foreign research reactors, commercial reactors, the Fort St. Vrain High Temperature Gas-Cooled

Reactor, and debris from the Three Mile Island Unit 2 reactor. The DOE spent fuel inventory projected to the year 2035 totals about 2,502 MTHM (DOE 1998b). Table 3 provides a summary of the types and amounts of DOE spent fuel that will be available by 2035.

Table 3. Types and Amounts of DOE Spent Fuel

DOE SNF Category	Representative SNF Type	Mass (MTHM)	Volume m^3 (ft^3)
1. Uranium Metal Matrix, Zirconium or Aluminum Clad	N-Reactor SNF, Single Pass Reactor SNF	2,122	209 (7,380)
2. Uranium Alloy Fuel with Zirconium Clad	Heavy-Water Cooled Test Reactor	<1	1(35)
3. Uranium Molybdenum Matrix, Zirconium Clad	Fermi Core	4	<1(--)
4. Uranium Oxide Matrix, Zirconium or Stainless Steel Clad	Intact Commercial SNF	99	52 (1,836)
5. Uranium Oxide Matrix, Failed Clad or Declad	Three Mile Island Core 2 Debris	87	241 (8,510)
6. Uranium Aluminum or Uranium Oxide Matrix, Aluminum Clad	Advanced Test Reactor SNF	9	150 (5,300)
7. Uranium-silicide, Aluminum Clad	Foreign Research Reactor - Material Test Reactor	12	53 (1,871)
8. Uranium-Carbide/ Thorium-Carbide Matrix, Graphite Clad in Good Condition	Fort St Vrain SNF	25	212 (7,486)
9. Uranium-Carbide/Thorium-Carbide Matrix, Graphite Clad in Unknown Condition	Peachbottom SNF	2	17 (600)
10. Uranium and Uranium-Plotunium Carbide	Fast Flux Test Facility Carbide Fuel Compounds	<1	<1(--)
11. Mixed Oxide Matrix	Fast Flux Test Facility Oxide Fuel Compounds	12	36 (1,271)
12. Uranium-Thorium Oxide Matrix, Zirconium or Stainless Steel Clad	Shippingport Light Water Breeder Reactor SNF, Pathfinder SNF	50	18 (636)
13. Uranium-Zirconium Hydride Matrix	Training Reactor, Isotopics, General Atomics (TRIGA)	2	8 (282)

14. Sodium Bonded[a]	Experimental Breeder Reactor II Driver	--	--
15. Navy Propulsion Reactor SNF	Navy SNF	65	888 (31,356)
16. Miscellaneous SNF	Various one-of-a-kind SNF	11	20 (706)
Total[b]		2,502	1,907 (67,337)

[a]Totals do not include 60 MTHM/27 m^3 (953 ft^3) Metallic Sodium Bonded Experimental Breeder Reactor II SNF and Fermi Blanket, and 151 MTHM/97 m^3 (3,425 ft^3) of Canyon Stabilization with EM Record of Decision (Savannah River Site Driver Fuel & Targets, EBR II Targets), which are candidate fuels for treatment or processing prior to disposal.
[b]Totals may not sum due to rounding

2.2 AMOUNT OF NUCLEAR WASTE DESTINED FOR THE FIRST REPOSITORY

The statutory limit of 70,000 MTHM of nuclear waste to be emplaced in the first repository, until a second repository is in operation, has been allocated as shown in Table 4.

Table 4. Amount and Type of Waste to be Emplaced

Type	**Amount (In MTHM or Equivalent)**
Commercial SNF[a]	63,000
Commercial HLW	640
Defense HLW[b]	4,027
DOE and Naval SNF	2,333
Total	70,000

[a]May include some mixed oxide spent fuel
[b]May include some immobilized plutonium

The allocations are for a repository designed to emplace only a portion of the Nation's projected total nuclear waste inventory. Section 5 will focus on a repository that will emplace all of the projected nuclear waste inventory.

3. WASTE ACCEPTANCE AND TRANSPORTATION

3.1 WASTE ACCEPTANCE AND TRANSPORTATION SERVICES

DOE will rely on the private sector to provide the necessary services and equipment required to accept and transport commercial spent fuel to the repository. These services and equipment will be procured by awarding one or more contracts, with each contract covering Purchasers' sites in certain designated regions in the contiguous United States (Purchasers are those owners of commercial spent fuel who have entered into contracts with DOE for disposal of their spent fuel). Each CRWMS regional servicing contractor (hereafter referred to as RSC) will be responsible for all activities and services in its region, including the provision of transportation cask/canister systems and ancillary equipment, as required, to accept commercial spent fuel and transport it to the repository for disposal. Specific performance requirements for each RSC will be set forth in detail in the procurement documents.

To the extent practicable, DOE will also rely on the private sector to provide the necessary services and equipment to accept and transport high-level waste and DOE spent fuel (except Naval spent fuel) to the repository. The Navy will provide transportation of their spent fuel to the repository.

Transportation will be carried out using commercially available equipment and approved routes in compliance with Nuclear Regulatory Commission and Department of Transportation regulations. RSCs would also be responsible for all required intermodal transport between Purchaser sites and the repository.

3.2 CASK/CANISTER SYSTEMS FOR SPENT NUCLEAR FUEL

Cask/canister systems to be used for transportation and storage will not be specified by DOE. They will be developed by industry, certified by the Nuclear Regulatory Commission, and deployed to meet the waste delivery schedules. Interface requirements have been developed by DOE and reside in requirements documents to ensure that the casks and canisters can be received, handled, and utilized at CRWMS facilities. Interface Control Documents are being developed to document how the interface requirements are being satisfied and will provide for the controlled development of the interfaces.

Cask/canister systems differ in whether they employ casks or canisters; whether their functions include transportation, storage, and/or disposal; and how they are transported. In canister systems, spent fuel is sealed inside a canister and the sealed canister is placed into an overpack for transportation, storage, or disposal. The use of canisters may reduce the number of times individual fuel assemblies have to be handled during transport, storage and disposal. Casks/canisters designed and certified for a single use only, such as for transportation or storage, are known as single purpose systems. Casks/canisters designed and certified for both storage and transportation are referred to as dual purpose canisters or transportable storage casks. Canisters designed and certified for transportation, storage, and disposal are known as multi-purpose canisters (MPCs).

The mix of cask/canisters to be deployed in the CRWMS is unknown at this time. It will depend on the availability of technologies that are certified by the Nuclear Regulatory Commission prior to the start of CRWMS operations, and the needs of the individual Purchasers. Some of the cask/canister systems that have been used in the past or may be available in the future for storage and transportation of spent fuel are shown in Tables 5, and 6. Table 7 shows the types of dry storage systems that are currently available for spent fuel. Additional details may be found in two separate publications (JAI Corporation, 1996; INMM, 1997).

Table 5. Rail Cask and Canister Systems

	NAC STC	**NAC-MPC**	**UNIVERSAL MPC SYSTEM (UMS)[b]**	**Holtec HI-STAR 100**	**Sierra TranStor**
Category	Transportable Storage Cask	Dual Purpose Canister	Dual Purpose Canister	Dual Purpose Canister	Dual Purpose Canister
Status	Certified for storage and transport NRC Docket No. 71-9235 72-1002	Storage and transport designs docketed NRC Docket No. 71-9235 72-1025	Storage and transport designs docketed NRC Docket No. 71-9270 72-1015	Storage and transport designs docketed NRC Docket No. 71-9261 72-1008	Stoage and transport designs docketed NRC Docket No. 71-9268 72-17
PWR Capacity[a] - no burnup credit	26	37	24	24 or 32 (with burnup credit)	24
BWR Capacity - no burnup credit	not applicable	89	56	68	61
Max. Hook Weight, metric tons (tons)	113 (125)	113 (125)	113 (125)	110 (120)	<91 (100)

Table 5. Rail Cask and Canister Canister Systems (Continued)

	Vectra[c] NUHOMS MP-187	**Westinghouse WESFLEX System**	**GE IF-300**
Category	Dual Purpose Canister	Dual Purpose Canister	Metal Transport Cask
Status	Certified for storage and transport NRC Docket No. 71-9255 72-11	Storage design docketed NRC Docket No. 92-1026	Certified for transport but cannot be replicated;2-4 available.
PWR Capacity - no burnup credit	24	21 and 24	7
BWR Capacity - no burnup credit	not applicable	44 and 52	18 without fuel channels; 17 with channels
Max. Hook Weight, metric tons (tons)	110 (122)	113 (125)	64 (70)

[a]PWR and BWR capacities in this table and subsequent tables are in terms of number of fuel assemblies
[b]International consortium effort managed by NAC
[c]Now owned by Transnuclear West

Table 6. Truck Casks

	NAC LWT	**NL Industries NLI ½**	**Trans-nuclear TN-8L**	**Trans-nuclear TN-9**	**GA-4/9 Casks**	
					GA-4	**GA-9**
Category	Uncanistered SNF Legal Weight Cask	Uncanistered SNF Legal Weight Cask	Uncanistered SNF Overweight Casks		Uncanistered SNF Legal Weight Casks	
Status	Certified, can be replicated ; 5 available	Certified, cannot be replicated; 5 available	Certified, cannot be replicated; 2 available	Certified, cannot be replicated; 2 available	Design in NRC review	
PWR Capacity - no burnup credit	1	1	3	not applicable	4	not applicable
BWR Capacity - no burnup credit	2	2	not applicable	7	not applicable	9
Max. Hook Weight, metric tons (tons)	23 (25)	23 (25)	36 (40)	36 (40)	24 (27)	24 (27)

Table 7. Dry Storage Technologies Being Used or Available for Use at Independent Spent Fuel Storage Installations

Technology	Description	Vendor	Capacity
CASTOR V/21	Metal Storage Cask	General Nuclear Systems, Inc	21 PWR
CASTOR X/33	Metal Storage Cask	General Nuclear Systems, Inc	33 PWR
CASTOR X/74	Metal Storage Cask	General Nuclear Systems, Inc	74 BWR
MC-10	Metal Storage Cask	Westinghouse	49 BWR/ 24 PWR
MVDS	Modular Vault Dry Storage	Foster Wheeler Environmental Corporation	Varies
NAC-128 S/T	Metal Storage/ Transport Cask	NAC International	28 PWR
TN-32	Metal Storage Cask	Transnuclear, Inc	32 PWR
TN-40	Metal Storage Cask	Transnuclear, Inc	40 PWR
NUHOMS-7P	Concrete Storage Module	Vectra Technologies, Inc	7 PWR
NUHOMS-24P	Concrete Storage Module	Vectra Technologies, Inc	24 PWR
NUHOMS-52B	Concrete Storage Module	Vectra Technologies, Inc	52 BWR
VSC-24	Concrete Storage Cask	Sierra Nuclear Corporation	61 BWR/ 24 PWR

3.3 WASTE ACCEPTANCE AND TRANSPORTATION CONCEPT OF OPERATIONS

Prior to the start of any shipping campaign DOE is responsible, under Section 180(c) of the Nuclear Waste Policy Amendments Act, for providing technical assistance and funds to States for training public safety officials of appropriate units of local government and Indian tribes through whose jurisdiction the Department plans to transport spent fuel or high-level waste. The training shall cover procedures required for safe routine transportation of the nuclear materials, as well as procedures for dealing with emergency response situations.

The RSC delivers approved transportation cask/canister systems and ancillary equipment, as appropriate, to each Purchaser in accordance with an established schedule and rate. Casks/canisters used for transportation of spent fuel are to be certified by the Nuclear Regulatory Commission under 10 CFR Part 71, *Packaging and Transportation of Radioactive Material*. As necessary, training in the use of the equipment is provided by the RSC to personnel at the Purchaser site and the repository.

The Purchaser site personnel perform loading operations using equipment and procedures approved by the Nuclear Regulatory Commission. During loading, verification activities are conducted by the Purchaser, which include confirming the identity of each fuel assembly placed into a transportation cask or canister. If a canister is used, it is placed into an appropriate transportation cask or overpack. After loading, the transportation casks are prepared for shipment from the site. The loaded casks are placed on transport carriages, secured, surveyed for contamination, and moved to a protected area to await shipment.

No less than 60 days prior to the scheduled delivery date, the Purchaser provides to the RSC and DOE a detailed description of the spent fuel to be delivered. This description specifies the calculated burnup of the fuel assemblies, identifies any non-standard assemblies, and provides other detailed physical characteristics of the assemblies. This information is required pursuant to 10 CFR Part 961, *Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste*.

Prior to beginning waste acceptance and transportation operations at a Purchaser site, the RSC interfaces with repository personnel to ensure that shipments from this site are coordinated with shipments from other sites. Data for each shipment are assembled, including a detailed schedule, a detailed route plan, points of contact, safe parking and routine route stop information, incident response information, and any required permits. During the course of the shipment, additional information is accumulated, including incident reports, driver's log, and any other appropriate information.

The RSC prepares for transportation operations by arranging for all necessary services and equipment required to safely and efficiently ship the spent fuel from the Purchaser site to the repository. This may include appropriate carrier services, on-site/near-site intermodal transfer services, advanced notifications to appropriate jurisdictions, in-transit security and communications, and payment of any State-imposed tolls and fees.

Prior to departure from the site, the cask and its transport carriage undergo final checks and inspections by the RSC. This includes verifying the transportation cask identification number and integrity of tamper-indicating devices. The RSC's carrier and in-transit security personnel are briefed in accordance with established procedures. A final survey is made to ensure that the cask meets contamination and dose rate limits.

After the cask and transport carriage pass their final checks and inspections, Purchaser site personnel turn over to the RSC documented verification that the cask was properly loaded, marked, and labeled. Title transfer and physical possession of the spent fuel from the Purchaser is completed with the RSC accepting the spent fuel on behalf of DOE.

Loaded transportation casks are moved off the Purchaser site by legal weight truck, rail, heavy haul truck, or barge. Rail casks travel as general freight or by dedicated train. Rail casks departing the Purchaser site by heavy haul truck are taken to an intermodal transfer point where they are transferred to a rail car. Rail casks departing the Purchaser site by barge are moved to port or barge

slip where they are transferred to a rail car.

Regardless of the mode of transportation, all shipments are made by the RSC from the Purchaser site via a predetermined route approved by the Nuclear Regulatory Commission. The RSC provides for in-transit tracking and in-transit physical security in accordance with 10 CFR Part 73, *Physical Protection of Plants and Materials.* In the event of an in-transit incident, the RSC notifies the Nuclear Regulatory Commission, Department of Transportation, DOE, and State, Tribal, and/or local officials, and provides technical assistance, if requested, to the officials in charge at the scene.

Loaded transportation casks are delivered by the RSC to the repository. At the repository, the RSC transfers all documentation accompanying each transportation cask to the repository operator. The RSC prepares empty transportation casks for shipment back to Purchaser sites.

Deliveries are continued until the completion of the RSC's service contract. At the completion of the service contract, the RSC retains ownership of equipment and materials that are no longer required, and is responsible for their disposition. Reusable equipment such as casks, rail cars, and ancillary equipment are the property of DOE and will be provided to the next RSC.

While currently not yet formulated, the acceptance and transportation of DOE wastes (except Naval spent fuel) are expected to follow a similar concept of operations.

4. MONITORED GEOLOGIC REPOSITORY DISPOSAL SYSTEM

The two essential components of the waste disposal system consist of the monitored geologic repository and robust disposal containers. The disposal containers provide containment of the nuclear wastes for at least 1,000 years, while the repository host rocks ensure that radionuclides released from the wastes do not constitute an unacceptable risk to public health and safety or to the environment, in accordance with standards that are to be developed by the Environmental Protection Agency. The disposal system is to operate under a license issued by the Nuclear Regulatory Commission pursuant to 10 CFR Part 60, *Disposal of High-Level Radioactive Wastes in Geologic Repositories* (or to new regulations specific toYucca Mountain). A brief description of the disposal container and repository is provided in this section. In addition, a brief description of the repository concept of operations is also provided.

Receipt of waste at the repository is scheduled to begin in 2010 and to continue at the rates shown in Table 8. Although receipt and emplacement rates are assumed to be the same, the actual emplacement rate is a function of the types and sizes of casks and canisters received. Lag storage may be provided at the repository to manage the movement of waste before emplacement and to compensate for any differences between receipt and emplacement rates.

Table 8. Waste Receipt Rates at the First Repository
(In MTHM or Equivalent Per Year)

Year	Commercial Spent Fuel[a]	High-Level Waste[b] and DOE Spent Fuel[c]
2010	400	TBD[d]
2011	600	TBD
2012	1,200	TBD
2013	2,000	TBD
2014	3,000	TBD
2015-2031	3,000	400 TBD
2032	3,000	200 TBD
2033	1,800	0 TBD
Total	63,000	7,000

[a]May include some mixed oxide spent fuel
[b]May include some immobilized plutonium
[c]Including Naval spent fuel
[d]To be determined; (maximum rate of 400 MTHM or equivalent per year expected)

The above receipt rates will allow for emplacement of only a portion of the Nation's projected total

nuclear waste inventory, consistent with a constraint imposed by the Nuclear Waste Policy Act. Section 5 will focus on the receipt rates for a repository designed to emplace all of the Nation's projected nuclear waste inventory.

4.1 CONCEPTUAL DISPOSAL CONTAINER DESIGN

Current efforts are focussed on disposal container designs for canistered spent fuel, uncanistered spent fuel, high-level waste, high level-waste co-disposed with DOE spent fuel, and immobilized plutonium canistered with high-level waste. Once the disposal container is loaded and sealed, it is referred to as a waste package.

Table 9 provides a summary of conceptual design characteristics for disposal containers for uncanistered commercial spent fuel. These disposal containers will be designed to hold as much spent fuel as possible without exceeding the physical and thermal load limits placed on the containers. The disposal container for high-level waste co-disposed with DOE spent fuel will accommodate five waste glass canisters and up to nine assemblies of certain types of DOE spent fuel. To ensure substantially complete containment of the wastes in the repository, the disposal containers will be designed to the regulatory requirement of preventing less than one percent of the containers from breaching for at least 1,000 years.

Table 9. Conceptual Disposal Container Characteristics

Waste Container Type	Outer Diameter m (ft)	Outer Length m (ft)	Outer Barrier Thickness m (ft)	Inner Barrier Thickness m (ft)	Tare Mass kg (lb)	Loaded Mass kg (lb)
21 PWR	1.66 (5.45)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	35,000 (77,200)	52,000 (114,700)
12 PWR	1.32 (4.33)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	25,000 (55,100)	35,000 (77,200)
12 PWR[a]	1.35 (4.43)	5.87 (19.26)	0.10 (0.33)	0.02 (0.07)	29,000 (63,900)	39,000 (86,000)
44 BWR	1.60 (5.25)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	33,000 (72,800)	47,000 (103,600)
24 BWR	1.34 (4.40)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	28,000 (61,700)	36,000 (79,400)

[a] These disposal containers are slightly larger to accommodate the longer South Texas fuel assemblies

Each disposal container, whose design is based on a defense-in-depth philosophy of using multiple barriers, consists of a cylindrical inner barrier made of Alloy C-22 (a nickel-based alloy) and a cylindrical outer barrier made of ASTM A 516 Grade 55 or 70 carbon steel. Two different barrier materials will support the design approach to have different failure mechanisms to protect against

the release of radioactive materials. The outer barrier is a corrosion-allowance material that provides mechanical strength early in the life of the container as well as protects the inner barrier by limiting corrosion to a slow predictable rate. The inner barrier is a corrosion-resistant material that will have a very long life. The functions of the disposal container are to provide a waste containment barrier, act as a structural member to protect the waste from mishandling or falling rock damage, and assist in conducting heat away from the waste. The waste is sealed with an inner barrier lid and an outer barrier lid. The disposal container for uncanistered spent fuel includes a basket for holding the fuel assemblies, which also provides the capability for additional criticality control, if required.

Because of weight and handling limitations, the disposal containers are not designed to provide shielding against radiation from the contained waste; consequently, workers will need to be protected by other aspects of the repository design. These include reinforced concrete walls in the waste handling building, remote handling and robotics, the waste package transporter, and the emplacement drift walls.

4.2 CONCEPTUAL REPOSITORY DESCRIPTION

If approved by the President and Congress, and licensed by the Nuclear Regulatory Commission, the repository will be developed at the Yucca Mountain site, about 160 kilometers (100 miles) northwest of Las Vegas in Nevada. The site is currently undergoing characterization to determine its suitability for hosting the repository. Site characterization activities include surface- and subsurface-based testing at Yucca Mountain. Data collected to date have been used to support the viability assessment of the Yucca Mountain site. Additional data will be collected to support site suitability recommendation to the President and license application to the Nuclear Regulatory Commission.

Although the statutory capacity of the repository is 70,000 MTHM or equivalent of spent fuel and high-level waste, the repository will be physically capable of accommodating a larger capacity. A single repository that is capable of emplacing all of the Nation's projected nuclear waste inventory is a cost-effective alternative to a second repository, the need for which is to be recommended by the Secretary of Energy to the President between January 1, 2007 and January 1, 2010. This alternative will be examined in Section 5.

The conceptual repository design consists of surface and subsurface facilities, which constitute the geologic repository operations area, as defined in 10 CFR Part 60.2.

4.2.1 SURFACE FACILITIES

The nuclear wastes that are destined for disposal in the repository will be received and packaged for emplacement in a 32-hectare (80-acre) area located at the northern entrance to the potential repository (the North Portal Operations Area). The operations involving radioactive materials will be conducted in a Radiologically Controlled Area. Support operations will be accomplished in the Balance of Plant Area.

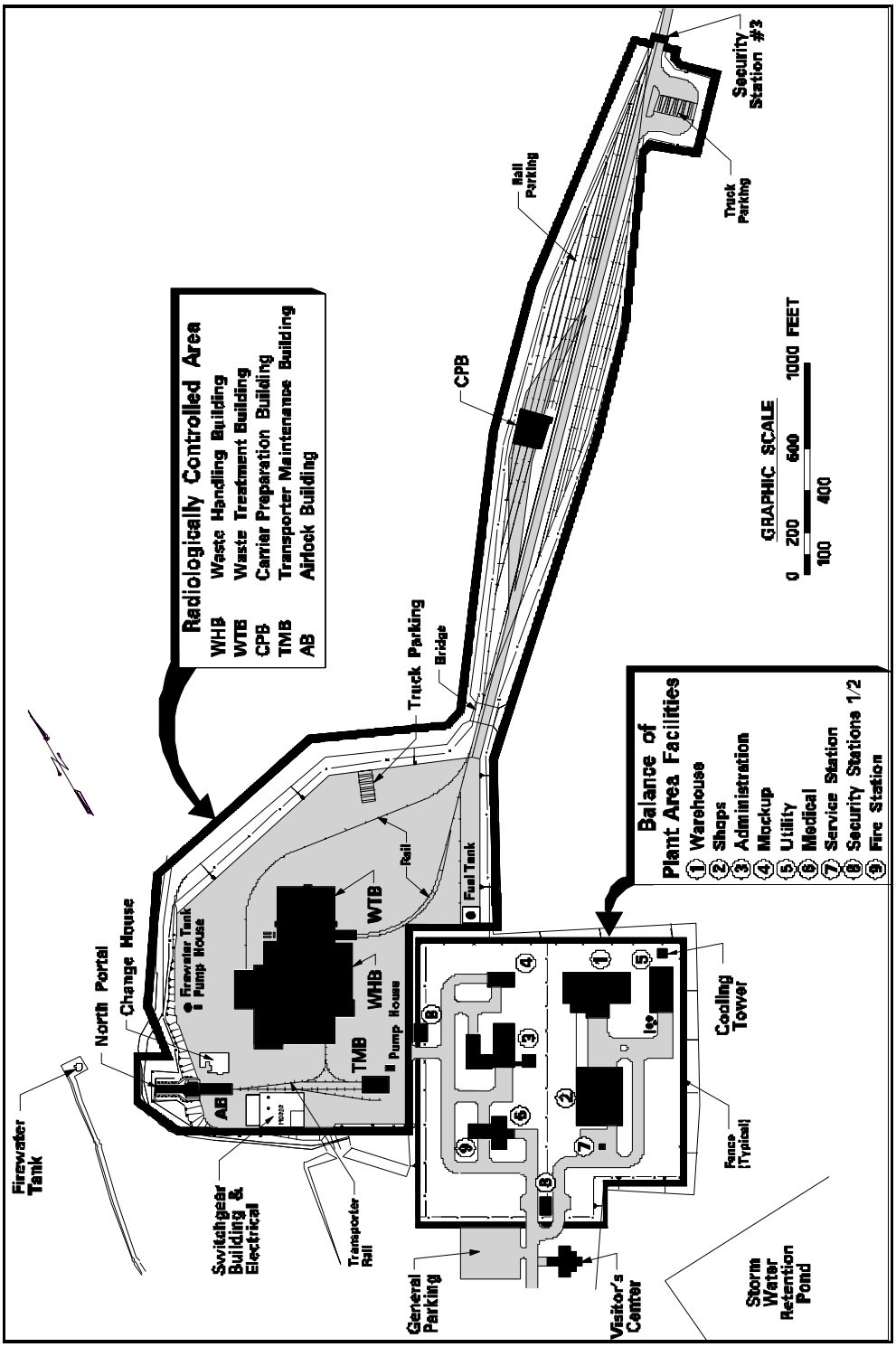

Figure 1. Conceptual Surface Facility Layout of the North Portal Operations Area

The Radiologically Controlled Area includes the Carrier Preparation Building, where shipping casks are prepared for removal from rail or truck carriers. Spent fuel assemblies and disposable waste canisters will be packaged for disposal in the Waste Handling Building Within the Waste Handling Building, there are five processing lines -- three wet lines and two that are dry. The wet processing lines are used to extract spent fuel assemblies from transportation casks or non-disposable canisters and place them in disposal containers. The dry processing lines only handle high-level waste or spent
fuel in disposable canisters. The Waste Handling Building also includes welding stations for sealing the disposal containers, and staging areas for loaded disposal containers waiting to be sealed or for waste packages awaiting transfer to the subsurface emplacement areas. The Radiologically Controlled Area also includes a Waste Treatment Building for the treatment of low-level waste; a Transporter Maintenance Building for servicing and repairing vehicles which are used for transporting and emplacing waste packages in the repository; and an Airlock Building at the entrance to the North Portal.

The Balance of Plant Area includes security stations, an administrative building, a fire/medical center, a warehouse, central maintenance shops, a motor pool and facility service station, a mock-up building for training, a utility building, and a visitors' center. The conceptual surface facility layout for the North Portal Operations Area is shown in Figure 1.

Three other operations areas are included in the surface facilities. The South Portal Operations Area, covering about 12.1 hectares (30 acres) adjacent to the southern entrance to the repository, provides systems and equipment to support the development of subsurface facilities. The surface facility here includes a concrete plant for fabricating and curing precast components and supplying concrete for in-place casting, and basic structures for personnel support, maintenance, warehousing, material staging, security, and transportation. The remaining two areas, each of minimal acreage, are the Emplacement Ventilation Shaft Operations Area, and the Development Ventilation Shaft Operations Area. These two areas have systems and equipment that provide ventilation to support development and emplacement operations underground.

4.2.2 SUBSURFACE FACILITIES

The waste emplacement horizon in the repository will be located in the Topopah Spring Member, a welded tuff unit of the Paintbrush Tuff. At Yucca Mountain the Topopah Spring Member has a maximum thickness of approximately 350 meters (1,150 feet) and dips about 6 degrees to the east. Potentially usable emplacement areas are delineated by major faults. These potentially usable areas, which total about 3,700 hectares (9,150 acres), include a primary area and expansion areas.

The primary area consists of an emplacement block bounded on the east by the Ghost Dance Fault, on the west by the Solitario Canyon Fault, and on the south by the thinning of the Topopah Spring Member in the repository horizon. This block provides about 300 hectares (740 acres) for emplacing 70,000 MTHM or equivalent of waste at a mass loading of 210 MTHM per hectare (85 MTHM per acre). It is located at least 200 meters (660 feet) below the surface and at least 100 meters (330 feet)

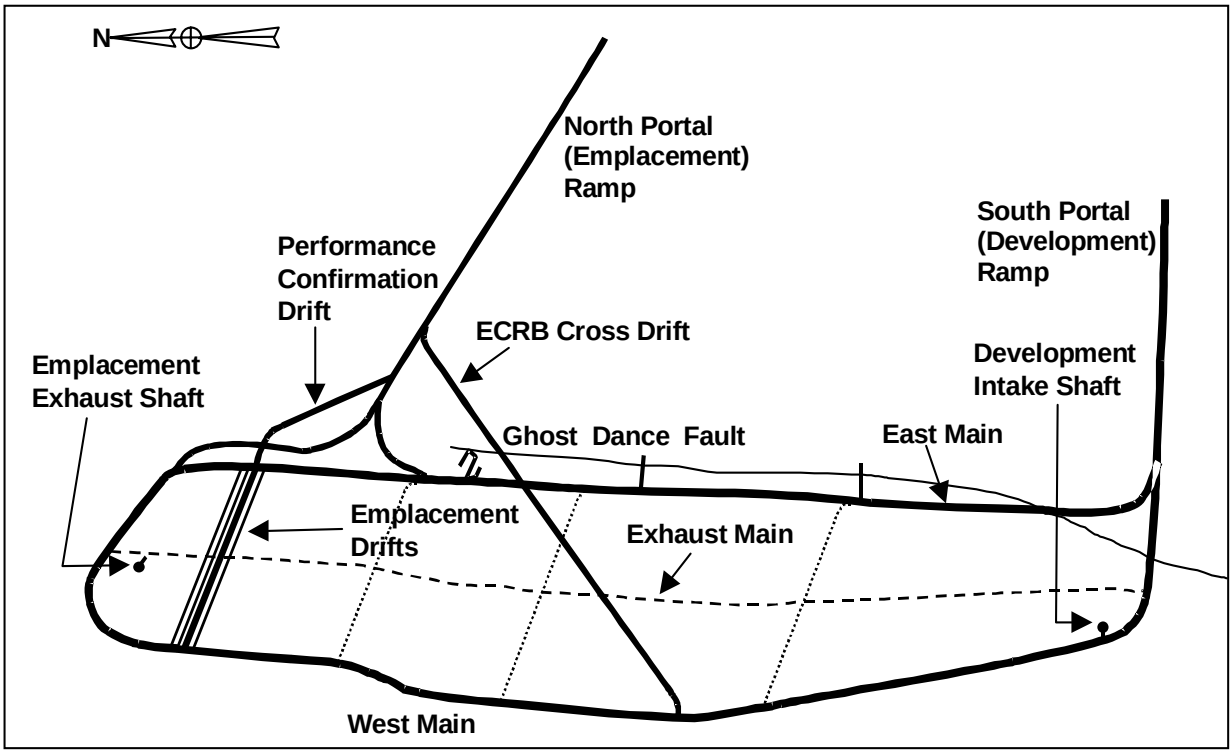

Figure 2. Conceptual Subsurface Facility Layout of the Repository

above the regional water table. Significant expansion areas are potentially available both to the north and south of the planned emplacement area. Up to 470 hectares (1,150 acres) are potentially available but additional characterization activities would be required to validate much of this expansion area.

The conceptual layout of the subsurface facilities, shown in Figure 2, consists of two ventilation shafts, two ramps, two main drifts, about 105 waste emplacement drifts, a central exhaust drift, and five performance confirmation drifts. As a contingency the primary emplacement area contains space for an additional 15 drifts, which will be used if unstable ground conditions are encountered within the intended emplacement areas or if additional space is needed for waste packages with exceptionally high thermal loads. When completed, the layout will contain about 150 kilometers (93 miles) of drifts.

Five of the emplacement drifts will remain empty during emplacement operations. These drifts will be at locations that will divide the emplacement block into areas of similar size. Three of the empty drifts will be designated as cross-block drifts and will be used to facilitate ventilation, emergency egress, and performance confirmation monitoring. The remaining two empty drifts will serve as standby drifts for relocating waste packages, if necessary.

The ramps and main drifts are 7.6 meters (25 feet) in diameter and are used for waste transport,

ventilation, service utilities and personnel access. The North and South Portal Ramps and the main drifts have grades of less than 3 percent to ensure the safe use of heavy rail transport to the emplacement horizon.

The central exhaust drift, located about 10 meters (33 feet) beneath the emplacement block, has a diameter of 7.6 meters (25 feet), and provides exhaust ventilation for the emplacement drifts. It is connected to each of the emplacement drifts by raises (small shafts vertically bored) that are 2.0 meters (6.6 feet) in diameter.

The five performance confirmation drifts, each with a diameter of 5.5 meters (18.2 feet), are located about 15 meters (49 feet) above the emplacement block. Boreholes will be drilled from these drifts to approach the rock mass near the emplacement drifts, and instruments will be installed in the boreholes to monitor conditions in the host rock. Other instruments will be installed in the performance confirmation drifts that will monitor air temperature and humidity in the drifts.

Emplacement drifts are 5.5 meters (18.2 feet) in diameter, and are spaced at 28 meters (92 feet) between the centers of each drift. They may have lengths of approximately 900 meters (2,960 feet) to 1,200 meters (3,950 feet). Each emplacement drift has a set of doors at both ends of the drift to control access. Each set of doors has ventilation regulators (louvers) to control the flow of air through the emplacement drift. These doors are remotely controlled from a safe location within the main drift. Approximately 5 percent of the total number of emplacement drifts will be developed prior to the start of emplacement operations. Development of the remaining 95 percent of the emplacement drifts will be performed concurrently with waste emplacement during the repository operations phase, using two separate, independent ventilation systems. One system will provide ventilation for the excavation operations required for drift development, while the other provides ventilation for the waste emplacement operations. Movable temporary walls (isolation air locks) installed in the main drifts at the points that divide the two operations will keep the two ventilation systems separate. As excavation and emplacement operations progress, these walls will be moved to new positions in the main drifts, thus providing access to the newly excavated drifts for waste emplacement.

The ventilation system that supports drift development operations will force air into the drifts by way of surface-located fans at the intake shaft; exhaust air through the South Portal ramp; and maintain air pressure in the development area above that in the emplacement area. The intake shaft is a concrete-lined vertical shaft 6.1 meters (20 feet) in diameter.

The ventilation system that supports waste emplacement operations will pull air through the North Portal ramp into the emplacement area using surface-located fans at the exhaust shaft; exhaust air through the exhaust shaft; maintain air pressure in the emplacement area below that in the excavation area; and contain high efficiency filters that will activate in the event subsurface radionuclide release is detected. The exhaust shaft is a concrete-lined vertical shaft 6.1 meters (20 feet) in diameter.

The ventilation system maintains the temperature at 27ºC (80ºF) in areas where personnel are working. Personnel are not allowed in the emplacement drifts during emplacement operations. These emplacement drifts are ventilated during waste emplacement to ensure that the drift temperature does not exceed 50ºC (122ºF).

The design of the subsurface facilities accommodates a range of thermal loadings in order not to preclude alternative waste emplacement options that may be shown to be safe by test data obtained after construction is authorized. The conceptual design assumes a thermal loading of between 22.5 watts per square meter (91 kilowatts per acre) and 28.2 watts per square meter (114 kilowatts per acre). This corresponds to a mass loading of between 19.8 kilograms of uranium per square meter (80 MTHM per acre) and 24.7 kilograms of uranium per square meter (100 MTHM per acre). The required thermal loading will be achieved through a combination of strategies (such as drift spacing and waste package spacing within the drifts) that are appropriate for meeting waste package and repository near-field thermal constraints. The wall temperature in each emplacement drift will be less than 200ºC (392ºF).

4.3 REPOSITORY CONCEPT OF OPERATIONS

Each transportation cask arriving at the repository site will pass through a security station and enter the Radiologically Controlled Area near the North Portal where it is inspected by repository personnel for tampering and compared against its documentation. If the cask is off-normal (unacceptable), it is moved to a holding area pending corrective action. If the cask is acceptable, it is moved to a parking area and inspected for radiological contamination. The cask is then disconnected from its off-site transporter and connected to a on-site transporter which moves it to the Carrier Preparation Building. The off-site transporter remains in the Radiologically Controlled Area until an empty cask is ready to be shipped back to a Purchaser site. In the Carrier Preparation Building, personnel barriers and impact limiters are removed from the cask. A radiological survey is performed and the cask is then moved to a wash-down station where road grime is removed from its transport carriage prior to entering the Waste Handling Building.

In the Waste Handling Building, individual fuel assemblies in casks or in non-disposable canisters are unloaded and transferred to appropriate disposal containers, using remote handling equipment. Individual fuel assemblies will be placed into staging racks if there is an insufficient number of assemblies with compatible characteristics to fill a disposal container. Disposable canisters (with spent fuel or high-level waste) are unloaded from their transportation casks and transferred directly into their respective disposal containers or may be staged within a hot cell. A limited amount of lag storage is provided for high-level waste canisters to facilitate co-disposal with DOE spent fuel. During the transfer, the identity of each fuel assembly, canister, and/or cask involved is verified and recorded to provide appropriate material control and accounting, and maintain continuity of knowledge of waste disposition. When loading of each disposal container is completed, it is moved to a welding room where an inner barrier lid is welded by remote control and the integrity of the weld is verified. The outer barrier lid is then welded and the integrity of the weld is verified before the resulting waste package is moved to the staging area to await transport to the subsurface

emplacement area. The unloaded transportation cask is decontaminated, if necessary, and prepared for shipment off the site.

Each waste package is prepared for delivery into the emplacement area by decontaminating it, if necessary, and placing it on a transfer rail car. The identity of the waste package and its contents is verified and recorded. A shielded waste package transporter is brought into the staging area and the transfer rail car is pulled into the transporter by a remotely-controlled mechanism. The transporter doors are closed and the waste package is ready to be moved underground for emplacement.

Two locomotives pull the transporter down the North Portal ramp to the waste handling main drift and then to the entry area for the designated emplacement drift. At the emplacement drift the transporter is positioned by remote control in front of the drift using one of the locomotives. The emplacement drift door and the transporter doors are opened by remote control, and the transporter moves the transfer rail car and waste package into the drift. A mobile gantry is then positioned to lift the waste package off the rail car and move it to its assigned support asembly within the drift. The emplacement location of the waste package is recorded. The rail car is retrieved from the drift, the drift door is closed, and the transporter is returned to the surface.

During the period of waste emplacement and lasting until repository closure, a performance confirmation program, established during site characterization, is continued. The purpose of performance confirmation is to confirm the predicted performance of the engineered and natural barrier systems relative to waste containment and isolation. The performance confirmation activities provide data to show that subsurface conditions and changes resulting from construction and waste emplacement operations are within predicted limits. They also verify that the natural and engineered systems and components are functioning as anticipated and intended. This information is to be used in support of an application to the Nuclear Regulatory Commission for a repository license amendment to permanently close the repository.

The repository will be designed to remain open for a period of 100 years from the start of initial waste emplacement. This design concept is expected to provide the flexibility to extend that period to 300 years, if required. The extended service life of 300 years would allow future generations to decide whether it is appropriate to continue to maintain the repository in an open, monitored condition or to close it based upon development of their own criteria and level of certainty regarding ultimate repository performance. The emplaced waste will be retrieved if performance confirmation activities indicate that the repository is unsuitable for disposal and long term isolation of the waste, or if recovery of the waste as a valuable resource is warranted. Retrieval concepts are currently being evaluated, and they will be incorporated in a future revision of this document once they are developed.

Closure of the repository begins after DOE receives a repository license amendment from the Nuclear Regulatory Commission. The process includes closure of the subsurface facilities; dismantling, decontamination and decommissioning of the surface facilities; site reclamation and restoration; and protecting the repository from unauthorized intrusion.

Closure of the subsurface facilities consists of removing all nonpermanent equipment; filling in the main drifts, ramps and shafts; and installing seals in all openings to the surface, including shafts, ramps, and any boreholes that have been drilled to the repository horizon. Backfilling of the emplacement drifts is not currently required, but flexibility is included in the design so that backfilling is not precluded.

The surface facilities are designed to include features that facilitate dismantling, decontamination and decommissioning operations. The Waste Treatment Building supports decontamination and decommissioning activities by providing solid and liquid low-level radioactive waste treatment and packaging for transport to an off-site low-level waste disposal site. Hazardous and mixed wastes, if generated, are collected and packaged for transport to off-site licensed facilities for treatment and disposal.

At the completion of site reclamation and restoration, institutional and physical barriers are established. Detailed records and information on the repository are distributed to local, state and federal agencies for their use in controlling access to the site, thus creating institutional barriers. Physical barriers include fences, warning signs, markers, and monuments.

5. SINGLE REPOSITORY FOR THE NATION'S NUCLEAR WASTE

As mandated by the Nuclear Waste Policy Act, the first repository will be allowed to dispose of 70,000 MTHM or equivalent of spent fuel and high-level waste. This represents only a portion of the Nation's projected total nuclear waste inventory that will require eventual disposal. Should new legislation be introduced to remove the capacity limitation of 70,000 MTHM, current repository designs can be modified to accommodate all of the Nation's projected nuclear waste inventory.

This section examines the implications of receiving and disposing of all of the Nation's projected nuclear waste inventory in a single repository. The information presented is gleaned from a total system life cycle cost (TSLCC) analysis of the waste management program (DOE 1998c), and its companion assumptions document (M&O 1998). For the purpose of the TSLCC analysis, the Yucca Mountain site serves as a surrogate for a single repository system.

5.1 MAJOR ASSUMPTIONS FOR A SINGLE REPOSITORY

The major assumptions made in the TSLCC analysis include the following:

1) The total amount of commercial spent fuel to be received at the repository is approximately 86,300 MTHM. This includes about 700 MTHM of mixed oxide spent fuel.

2) The total amount of DOE spent fuel to be received is approximately 2,570 MTHM. This includes 63 MTHM of Naval spent fuel. The DOE spent fuel wil be delivered in about 3,857 canisters, including 300 canisters of Naval spent fuel.

3) The number of high-level waste canisters to be received is approximately 20,000. This includes about 635 canisters containing both immobilized plutonium and high-level waste. The waste canisters will be generated at the following sites in the amounts indicated:

   Hanford Site - 12,444 high-level waste canisters
   Idaho National Engineering and Environmental Laboratory - 1,190 high-level waste canisters
   Savannah River Site - 5,385 high-level waste canisters and 635 immobilized plutonium and high-level waste canisters
   West Valley Demonstration Project - 276 high-level waste canisters
   Argonne National Laboratory West - 71 high-level waste canisters

4) Commercial spent fuel pickup is in accordance with the Oldest Fuel First/Annual Priority Ranking (OFF/APR) allocation methdology.

5) Initial receipt rates for DOE spent fuel and high-level waste are low until 2015.

Because the TSLCC analysis uses an independent database which is continually updated, the projected amounts of wastes shown above differ slightly from those indicated in Section 2.

5.2 WASTE RECEIPT RATES AT THE SINGLE REPOSITORY

Tables 10, 11 and 12 show the amount of commercial spent fuel (including mixed oxide spent fuel), DOE spent fuel (including Naval spent fuel), and high-level waste (including immobilized plutonium), respectively, that will be received at the single repository. It is assumed that receipt of spent fuel and high-level waste begins in 2010.

Table 10. Commercial Spent Fuel Receipt Rates at the Single Repository
(In MTHM Per Year)

Year	Receipt Rate
2010 (partial year)	400
2011	600
2012	1,200
2013	2,000
2014	3,000
2015 – 2040	3,000
2041	1,117
Total	86,317

Table 11. DOE Spent Fuel Receipt Rates at the Single Repository
(In Canisters Per Year)

Year	Receipt Rate
2010	1
2011	1
2012	3
2013	6
2014	8
2015	109
2016	150
2017	116
2018	206
2019	172
2020	200
2021	204
2022	144
2023	141
2024	161
2025	232
2026	237
2027	229
2028	236

2029	253
2030	250
2031	253
2032	248
2033	138
2034	100
2035	59
Total	3,857

Table 12. High-Level Waste Receipt Rates at the Single Repository
(In Canisters Per Year)

Year	Receipt Rate
2010 – 2014	150
2015	355
2016	376
2017 – 2018	430
2019	420
2020 – 2025	395
2026 – 2028	375
2029 – 2031	455
2032	450
2033	255
2034 – 2035	1,475
2036	1,471
2037 – 2040	1,450
2041	1,457
Total	20,004

5.3 IMPLICATIONS OF A SINGLE REPOSITORY

All of the Nation's projected nuclear waste inventory can be emplaced in a single repository at the proposed Yucca Mountain site by 2041. Of particular significance is that all of the DOE spent fuel (including Naval spent fuel) would be emplaced by 2035, thereby complying with an existing DOE/Navy/State of Idaho Settlement Agreement that stipulates that all DOE spent fuel at the Idaho National Engineering and Environmental Laboratory must be removed from Idaho by 2035.

Although the repository would have to remain operational for an additional eight years than currently planned, it obviates the need to site, characterize, license, construct, and operate a second repository as required by current law.

6. REFERENCES

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