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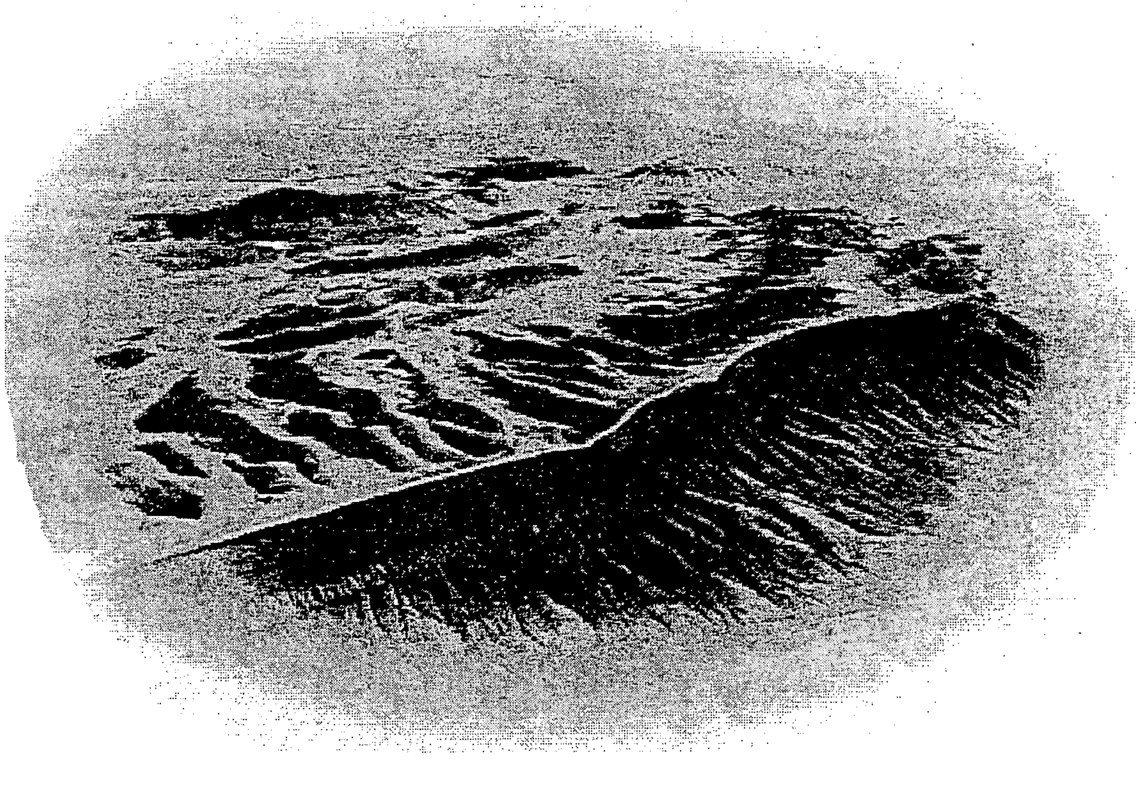
Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program

May 2001



U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, D.C. 20585

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For further information contact:

U.S. Department of Energy
Office of Civilian Radioactive Waste Management.
Systems Engineering and International Division, RW-46
1000 Independence Ave., S.W.
Washington, DC 20585

or call:
Yucca Mountain Information Center
1-800-225-6972

or visit:

the OCRWM Home Page
http://www.rw.doe.gov

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LETTER FROM THE DIRECTOR

The *Analysis of the Total System Life Cycle Cost (TSLCC) of the Civilian Radioactive Waste Management Program* represents the Office of Civilian Radioactive Waste Management's most recent estimate of the costs to dispose of the Nation's spent nuclear fuel (SNF) and high-level radioactive waste (HLW). This TSLCC analysis projects all Program costs through 2119 for a surrogate, single potential repository. The design and emplacement concepts in this TSLCC analysis are the same as those presented in the *Monitored Geologic Repository Project Description Document*.

Since the enactment of the Nuclear Waste Policy Act (NWPA) in 1983 through fiscal year 2000, the Program has expended $6.7 Billion in year-of-expenditure dollars. The total estimated cost to complete the Program, from fiscal year 2001 through permanent closure of a potential repository, is approximately $49.3 Billion in constant 2000 dollars. This TSLCC analysis differs from the previous TSLCC analysis published in 1998, as the design basis has changed. From a cost standpoint, the major changes include waste package fabrication costs, inclusion of the titanium drip shields, increasing the ventilation rate, and changing the underground design. These changes were made to reduce system uncertainties.

The TSLCC analysis provides the basis for assessment of the adequacy of the Nuclear Waste Fund Fee as required by the NWPA. The *Nuclear Waste Fund Fee Adequacy: An Assessment* [DOE/RW-0534] is published as a separate report and is available on the Office of Civilian Radioactive Waste Management's Home Page [http://www.rw.doe.gov]. In addition, this TSLCC is the basis for the calculation of the Government's share of disposal costs for DOE-owned and managed SNF and HLW. The cost estimates in this TSLCC reflect the Department's best estimates – given the scope of the work identified and planned schedule of required activities. Future budget requests for the Program have yet to be established, and in any event, will be determined through the annual Executive and Congressional budget process.

Sincerely,

Lake Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

Dated: May 2001

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ACRONYMS AND ABBREVIATIONS

Acronyms

AP	Absorber Plates
BWR	Boiling-Water Reactor
CALVIN	CRWMS Analysis and Logistics Visually Interactive
CR	Control Rods
CRWMS	Civilian Radioactive Waste Management System
D&E	Development and Evaluation
DOE	U.S. Department of Energy
DPC	Dual-Purpose Canister
FY	Fiscal Year
HH	High-Heat
HLW	High-Level Waste
INEEL	Idaho National Engineering and Environmental Laboratory
IPWF	Immobilized Plutonium Waste Form
LL	Long-Long
LS	Long-Short
LWT	Legal Weight Truck
M&O	Management and Operating (contractor)
MGR	Monitored Geologic Repository
MPC	Multi-Purpose Canister
MOX	Mixed-Oxide
MTHM	Metric Ton(s) of Heavy Metal
MTU	Metric Tons of Uranium
NRC	U.S. Nuclear Regulatory Commission
NWF	Nuclear Waste Fund
NWPA	Nuclear Waste Policy Act of 1982
NWTRB	Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management (DOE)
PETT	Payments-Equal-To-Taxes
PI	Program Integration
PI&I	Program Integration and Institutional
PM&A	Program Management and Administration
PM&I	Program Management and Integration

ACRONYMS AND ABBREVIATIONS (Continued)

PWR	Pressurized-Water Reactor
QA	Quality Assurance
RCA	Radiologically Controlled Area
RSC	Regional Servicing Contractor
RIMS	Regulatory, Infrastructure and Management Support
SDD	System Description Document
SNF	Spent Nuclear Fuel
SP	Single-Purpose
SR	Site Recommendation
SRS	Savannah River Site
SS	Short-short
TSLCC	Total System Life Cycle Cost
UCF	Uncanistered Fuel
VA	Viability Assessment
WAST	Waste Acceptance, Storage and Transportation
WP	Waste Package
YOE	Year of Expenditure

Abbreviations

cm	Centimeter
km	Kilometer
kW	Kilowatt
lg	Large
m	Meter
m^3/s	cubic meters per second

1. INTRODUCTION AND SUMMARY

1.1 EXECUTIVE SUMMARY

This report documents an analysis of the Total System Life Cycle Cost (TSLCC) for the Civilian Radioactive Waste Management System (CRWMS). This analysis is consistent with the design described in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000a), and provides the total system cost. This TSLCC analysis represents the total system cost to emplace all planned waste quantities listed in the *Civilian Radioactive Waste Management System Requirements Document* (DOE 2000). This analysis provides detailed costs for a reference system consistent with the *Monitored Geologic Repository Project Description Document*, and some of the potential costs associated with various lower-temperature operating modes. The reference design will continue to evolve to reflect a more flexible repository design and mode of operation requiring reassessments of projected capital and operating costs. These assessments will be conducted at the appropriate milestones. The total cost estimate includes the costs for the Monitored Geologic Repository, transporting waste to a potential repository at Yucca Mountain, and other associated programmatic costs.

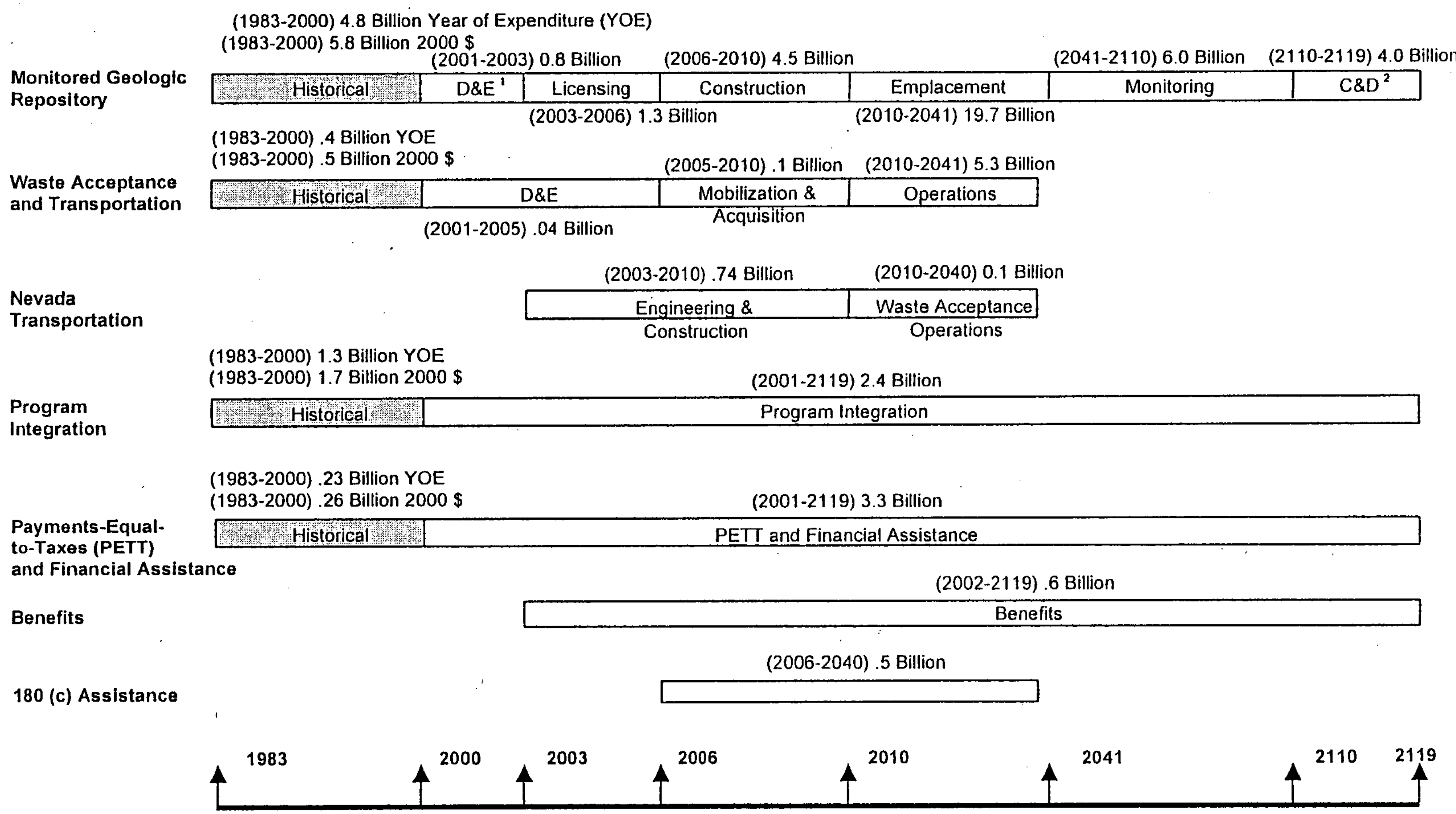
The current repository design as documented in the Project Description Document, Revision 2, ICN 1 (CRWMS M&O 2000a), is optimized to accommodate high temperature operations (i.e., above the boiling temperature of water). The design is evolving to more readily accommodate a potential range of operating modes. This flexibility allows repository operations over various heat loading (i.e., heat inputs) and heat removal (i.e., ventilation rates and duration) schemes. The differences in thermal operating modes relate to the maximum postclosure temperatures of the waste package surfaces, the temperatures of the emplacement drift rock walls, the overall temperature of the repository rock, and the humidity within the emplacement drifts. Repository baseline documents will be revised to reflect a design that is more compatible with the entire range of thermal operating modes and will be described in future revisions to the Project Description Document.

The total estimated future (2001 – 2119) cost to complete the reference system is $49.3 Billion in constant 2000 dollars. A total of $6.7 Billion was spent on the total program through FY 2000 in year-of-expenditure (YOE) dollars. Table 1-1 provides a summary of the major CRWMS cost categories. The program is assumed to continue from its inception in 1983 through closure and decommissioning of the potential repository in 2119. In Figure 1-1, costs are represented in terms of areas of work scope over the life of the program. Figure 1-1 represents historical costs both in year-of-expenditure and constant 2000 dollars, and all future costs in constant 2000 dollars. Appendix B provides a comparison between the 1998 TSLCC (DOE 1998a) estimate and the current estimate. The 26% cost increase from the 1998 TSLCC captures significant scope changes intended to improve modeling of total system performance, reduce uncertainty, enhance the engineered barrier system, and provide additional corrosion resistance performance of waste packages. An annual breakout of costs is provided in Appendix C.

Table 1-1. Summary of Reference System Results (in Millions of 2000$)

Cost Element	Historical Costs (1983-2000)	Future Costs (2001-2119)
Reference System		
Monitored Geologic Repository	5,780	36,290
Waste Acceptance, Storage and Transportation	500	5,460
Nevada Transportation	0	840
Program Integration	1,690	2,380
Institutional	260	4,320
Total	**8,230**	**49,290**

NOTE: Historical costs total $6.7 Billion in YOE dollars.



1983 - President signed NWPA and OCRWM established.
1998 - Viability Assessment sent to Congress.
2000 - End of Historical Period.
2001 - Environmental Impact Statement finalized.
2001 - Site Recommendation decision.
2003 - License Application submitted to the NRC.
2006 - Construction authorization received from the NRC.
2010 - Acceptance and emplacement begins.
2041 - Emplacement completed. Monitoring begins.
2110 - Closure and Decommissioning begins.
2119 - End of Program.

[1] Development and Evaluation
[2] Closure and Decommissioning
Note: All dollars are in Constant 2000$s unless otherwise stated.

Figure 1-1. Time-Phased Cost Summary

The reference system addressed in this TSLCC estimate (Sections 1-7) is for an above-boiling operational repository concept that allows for the free drainage of water and water vapor, mobilized by heat from the waste, between widely spaced drifts. In anticipation of the evolution to a more flexible repository design, Section 8 of this report discusses some of the potential cost impacts from operating the potential repository over a lower thermal mode. The analysis is parametric in nature; i.e., it is based on making changes to the principal operational variables that enable maintaining the potential repository in a lower-temperature operating mode. These variables are waste package spacing, waste package size, duration of ventilation prior to closure, and surface staging of the hottest SNF to allow thermal decay to achieve a reduction of the thermal energy emplaced in the potential repository.

At the current time, a specific thermal operating mode has not been selected for the potential repository. Engineering evaluations are being conducted to evaluate how the potential repository will perform under a variety of operating modes and subsurface temperatures. Once these evaluations are completed, an appropriate range of operating modes will be selected to represent the flexible design. Cost estimates that will be prepared to support the SR will include this range of operating modes.

1.2 PURPOSE AND SCOPE

This report documents a detailed cost analysis for a reference system for the CRWMS that utilizes a high temperature (above-boiling) mode of repository operations that allows for the free drainage of water between widely spaced drifts. This cost analysis is consistent with the design described in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000a), and provides the total system cost. This report also discusses in Section 8 some methods for achieving a lower-temperature operating mode repository and provides some parametric estimates of costs associated with these modes. The TSLCC analyses represent the total system cost to emplace all planned waste quantities listed in the *Civilian Radioactive Waste Management System Requirements Document* (DOE 2000).

The *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000a) describes a design for a 70,000 metric tons of heavy metal (MTHM) repository layout. Existing law prohibits emplacement in the nation's first potential repository of a quantity of spent fuel and high-level waste in excess of 70,000 MTHM, until such time as a second potential repository is in operation. However, current cost information, designs, or authorization for a second potential repository do not exist. Therefore, consistent with the 1998 TSLCC (DOE 1998a), a one-repository system, containing all waste and without interim storage, has been assumed and costed. Yucca Mountain is assumed for this report to be the location for the potential repository since it is the only location that the DOE is authorized to characterize. This, however, does not constitute a decision on the determination of Yucca Mountain as an acceptable site for the potential repository.

The TSLCC estimate is based on acceptance and disposal of approximately 83,800 MTHM of commercial spent nuclear fuel (SNF), including mixed-oxide (MOX) fuel; this assumption is detailed in the *Operational Waste Stream Assumption for TSLCC Estimates* (CRWMS M&O 2000c). The estimate is also based on acceptance and disposal of approximately 2,500 MTHM of government-managed SNF, including naval SNF, and approximately 22,000 canisters of vitrified high-level waste (HLW), including some canisters containing immobilized plutonium waste form (IPWF) contained in HLW glass (CRWMS M&O 2000c). The estimate of commercial SNF assumes existing nuclear power reactors operate for their planned service life, under current U.S. Nuclear Regulatory Commission (NRC) licenses. Subsequent to the formulation of the input data to the *Operational Waste Stream Assumption for TSLCC Estimates* (CRWMS M&O 2000c), five reactors were granted 20-year life extensions. The impact of reactor life extensions is addressed in Section 4.2. While little additional generation of HLW is expected at U.S. Department of Energy (DOE) sites in the future, quantities of HLW canisters may vary due to uncertainties in the planned processing and vitrification of the wastes.

This TSLCC updates the previous *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program* (DOE 1998a). The 1998 TSLCC was based on the design presented in the *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998b). Between the 1998 TSLCC and this TSLCC estimate, the repository design underwent changes to reflect a different thermal management strategy. These changes will be described throughout the remainder of the document.

This reference TSLCC estimate aids in financial planning, provides policy makers information for determining the course of the program, and is an input to a companion report (DOE 2001) on the adequacy of the one mill ($0.001) per kilowatt-hour fee charged to generators of commercial SNF. Since this estimate is for a system that spans over 100 years into the future, the concept upon which the estimate is based should be viewed only as representative of the system that may ultimately be developed.

The TSLCC estimates should not be interpreted as final estimates. Numerous assumptions were required with respect to waste management system design and operations where final decisions have not yet been made. Since these assumptions are critical to the resulting cost estimates, any changes in assumptions could influence the resulting estimate. Assumptions used in these analyses are for cost purposes, and should not be interpreted as final Office of the Civilian Radioactive Waste Management (OCRWM) or DOE policy.

Alternative designs and approaches for implementing the repository system have been and will continue to be analyzed. These analyses have shown that there are various ways for the program to proceed on schedule with various cash flow profiles, including lower annual funding requirements for the near-term years. Alternative implementation options include modular construction of the surface and underground repository facilities, varying the amount of spent fuel in surface staging, varying receipt rates, and using an approach to transportation with a lower initial capital investment; i.e., deferring the rail branch line to the Yucca Mountain site. Although these options can lower near-term repository cost profiles, they generally increase the TSLCC and may impact costs to utilities for storage at their sites.

This TSLCC analysis is organized as follows:

Section 1. Introduction and Summary: This section introduces the reader to the overall purpose and scope of this analysis, and summarizes the results and conclusions.

Section 2. System Design: This section provides a description of the design concept, including an explanation of design differences between design concepts used for this analysis and the Viability Assessment design.

Section 3. Monitored Geologic Repository: This section discusses the Monitored Geologic Repository (MGR) scope, assumptions, and costs included for each of six phases of the system life cycle.

Section 4. Waste Acceptance, Storage and Transportation: This section discusses the Waste Acceptance, Storage and Transportation (WAST) scope, assumptions, and costs included for each of three phases, and for the construction of the Nevada rail.

Section 5. Program Integration: This section discusses Program Integration (PI) scope, assumptions, and costs. These activities include Quality Assurance (QA); Program Management and Integration (PM&I); and non-OCRWM costs associated with the NRC, Nuclear Waste Technical Review Board (NWTRB), and the Nuclear Waste Negotiator.

Section 6. Institutional: This section discusses Institutional scope, assumptions, and costs. It provides a description of payments-equal-to-taxes (PETT), benefits, 180(c) grants, and financial assistance.

Section 7. Cost Share Allocation: This section presents the cost share allocations for civilian and government-managed nuclear materials.

Section 8. Lower-Temperature Operating Mode Scenario: This section presents rough order of magnitude costs for a lower-temperature repository mode within the flexible operating mode.

Section 9. References: This section contains a list of references used throughout this document.

Appendix A. 2000 Total System Life Cycle Cost Estimate Summary: This section provides a summary of the 2000 TSLCC estimate by major cost categories, with breakouts of historical and future costs.

Appendix B. Comparison With 1998 Total System Life Cycle Cost: This section contains tables and text comparing the 1998 TSLCC (DOE 1998a) and the results of the analysis of the reference system.

Appendix C. Annual Cost Profile: This section contains the annual cost profile for each component of the reference 2000 TSLCC estimate.

1.3 PROGRAM ASSUMPTIONS

The program-level assumptions have not changed significantly since the 1998 TSLCC. The key differences in program-level assumptions between the 1998 TSLCC Report (DOE 1998a) and this report are as follows:

1. Costs are in constant FY 2000 dollars. New escalation rates based on a year 2000 cost escalation report (CRWMS M&O 2000d) are used.

2. The assumed quantity of waste packages (WPs) decreased from 15,706 to 14,768 due to the change in the assumed quantity of commercial SNF requiring disposal (CRWMS M&O 2000c), and the blending of hotter fuel with colder fuel. It is assumed that blending will reduce the quantity of small pressurized-water reactor (PWR) waste packages used in the 1998 TSLCC.

1.4 COSTING APPROACH

The cost estimates use assumptions regarding technical and policy decisions, some of which will not be made until after the Secretary of Energy issues a Site Recommendation report to the President in 2001. The schedule assumes a License Application to the NRC in 2003, NRC authorization for construction approval in 2006, followed by NRC approval to receive and possess waste prior to the start of emplacement in 2010.

All future cost estimates are presented in constant 2000 dollars for ease of comparison and to eliminate the effects of inflation for a program spanning at least 119 years. Historical costs are noted in year-of-expenditure dollars, and are escalated to 2000 dollars, using economic escalation for purposes of comparison (CRWMS M&O 2000d). This cost estimate does not include settlement costs with utilities, which are addressed in the companion report, *Nuclear Waste Fund Fee Adequacy: An Assessment* (DOE 2001). Future cost estimates are rounded to the nearest $10 Million for costs greater than $100 Million.

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2. SYSTEM DESIGN

In December 1998, DOE published the *Viability Assessment of a Repository at Yucca Mountain* (Viability Assessment) (DOE 1998b), as required by Congress in the 1997 Energy and Water Development Appropriations Act (Public Law 104-206). The Viability Assessment provided information on the design of the proposed repository, and stated that "DOE will continue to improve the repository design to provide an extra margin of safety and will conduct additional research and testing to reduce remaining uncertainty" (DOE 1998b, Volume 1, p.1-1). The DOE began the evaluation of design options and alternatives during the preparation of the Viability Assessment as documented in the *License Application Design Selection Report* (CRWMS M&O 1999), which presented five design alternatives. DOE completed this report in August 1999.

The *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000a) reflects the performance criteria and the design elements from the selected design alternative. Figure 2-1 demonstrates the concept for the CRWMS. The *Monitored Geologic Repository Project Description Document* describes the design for the three fundamental parts of a potential repository: a surface facility, subsurface repository, and waste packaging. It also presents the current conceptual design of the key engineering systems for the emplacement operations, monitoring, closure and decommissioning, and postclosure phases of the potential repository.

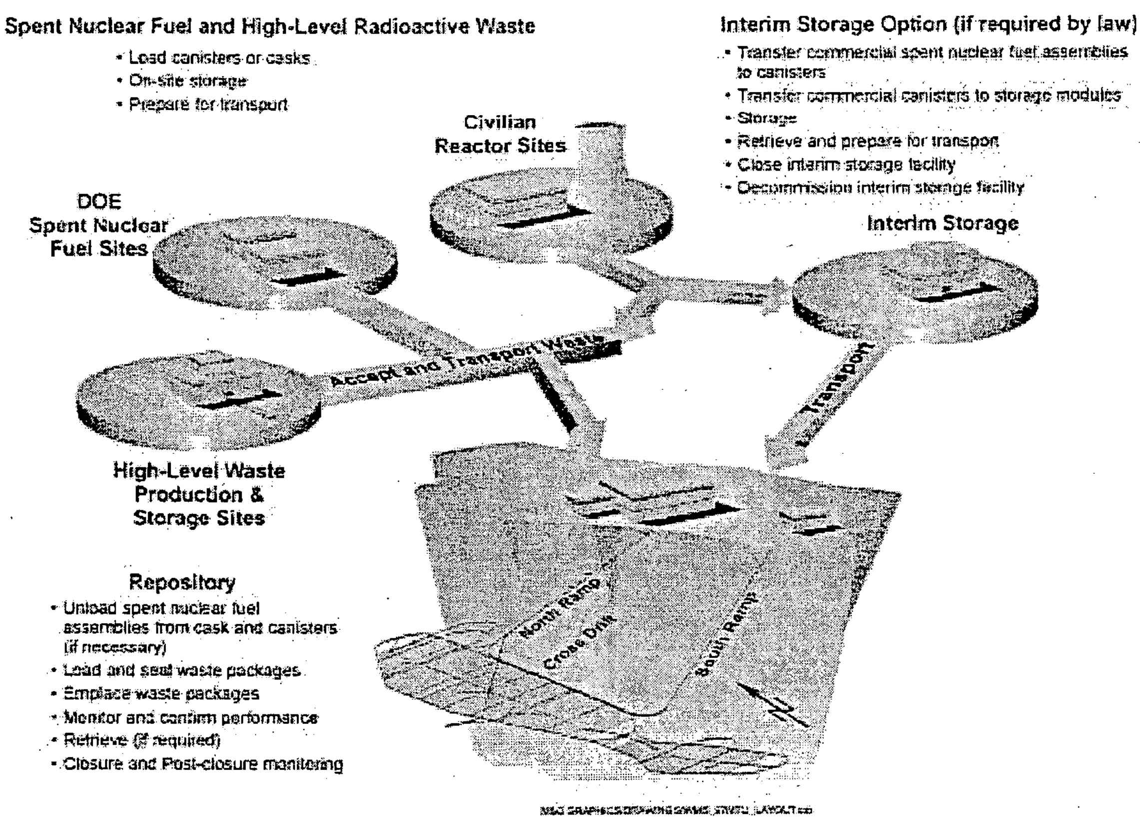

Figure 2-1. Concept for the Civilian Radioactive Waste Management System

2.1 SCOPE

The MGR consists of surface and subsurface facilities with the nuclear waste being permanently emplaced in the waste emplacement block of the subsurface facility. The selected repository concept can be characterized as a low thermal effects design. This design uses more extensive thermal management techniques than the Viability Assessment design to limit the impacts of the heat released by the waste. These thermal management techniques include thermal blending of SNF assemblies, closer spacing of the waste packages, wider spacing of the waste emplacement tunnels (drifts), and increased preclosure ventilation. Thermal blending of SNF assemblies reduces the peak heat output of the waste packages, making it easier to limit temperatures in the rock around the waste packages. Closer spacing of the waste packages in the emplacement drifts reduces temperature variations in the drifts, simplifies the analysis of the effects of heat, and reduces the total length of the drifts excavated. Spacing the drifts further apart reduces the effects of the heat from each drift on neighboring drifts, leaving a wide region of rock between drifts that stays below the boiling point of water so that water can move around the hot drifts and flow down through the cooler areas. This limits the long-term alterations to the repository rock caused by the heat from the waste. Preclosure ventilation makes it possible to stay within temperature limits in the rock and around the waste package during operation despite the closer waste package spacing. It also reduces maximum temperatures after closure by removing thermal energy before closure that would otherwise have heated the repository rock.

The waste will be placed in underground drifts (horizontal excavations) located in the emplacement block area. HLW packages will be placed in the drifts between the commercial SNF waste packages. The distance between the drifts and the spacing of the waste packages within the drifts have been established to meet thermal objectives. These objectives include keeping commercial nuclear fuel cladding below 350°C (662°F), providing flexibility to operate the potential repository at a temperature above or below the boiling point of water, and allowing drainage of any potential water between the emplacement drifts.

After emplacement of the nuclear waste inventory has been completed and the monitoring and performance confirmation program has shown that the potential repository will perform as expected, it will be closed. Closure activities include installation of drip shields, sealing and backfilling all openings to the surface, dismantling the surface facilities, restoring the surface area as closely as possible to original conditions, preparation of a postclosure monitoring plan, and protecting the potential repository from unauthorized intrusion.

2.2 DESIGN DIFFERENCES BETWEEN THE VIABILITY ASSESSMENT AND THE PRESENT REFERENCE SYSTEM DESIGN

The design basis used in this report is compared with the Viability Assessment design in Table 2-1. The sources of the data are noted in Table 2-1. For the purposes of this report, all the commercial waste OCRWM is contractually obligated to accept is assumed to be emplaced in the first potential repository. The present reference system design uses more area in the upper block than the Viability Assessment design and is capable of emplacing more than 97,000 MTHM, which includes 83,800 MTHM of commercial SNF, 2,500 MTHM of DOE SNF, and 22,000 canisters of HLW, in the characterized area. The subsurface layout depicted in Figure 2-2 overlays the two designs to show the variations in design.

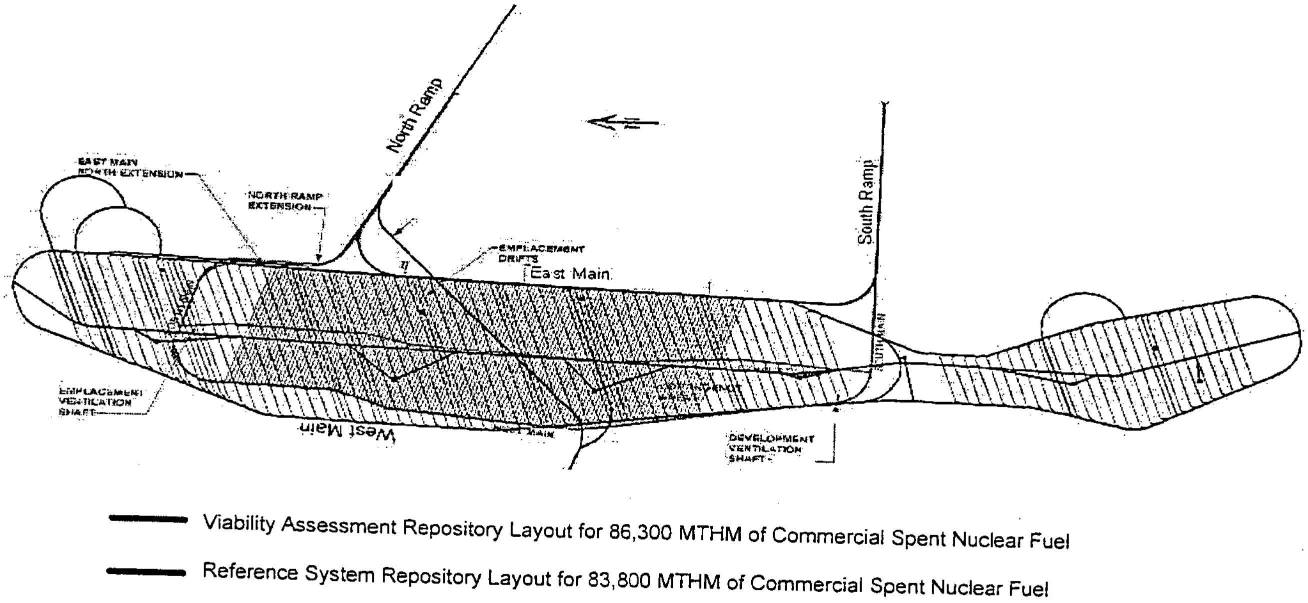

Figure 2-2. Subsurface Layout

Table 2-1. Comparison of Reference System Design and Viability Assessment Design

Design Characteristics	Reference System Design	Viability Assessment Design[a]
Drift Spacing	81 m[b]	28 m
Drift Diameter	5.5 m[b]	5.5 m
Waste Package Spacing	Line loading: 10 cm[b]	Point loading: Spacing varies (several meters)
Total Length of Emplacement Drifts	Function of the WP inventory and WP spacing[b]	107 km
Ground Support	Carbon Steel[b]	Concrete lining
Invert	Carbon Steel with granular ballast[b]	Concrete
Number of Waste Packages	14,768 [c]	15,706
Waste Package Materials	2-2.5cm Alloy-22 over 5-cm stainless steel 316NG[b]	10-cm carbon steel over 2-cm Alloy-22
Maximum PWR Waste Package Capacity	21 PWR assemblies[b]	21 PWR assemblies
Drip Shield	15 mm Titanium [b]	None
Preclosure ventilation rate	15 m^3/s[d]	0.1 m^3/s

NOTES: [a]CRWMS M&O 1999, Table 6-3

[b]CRWMS M&O 2000a

[c]The Waste Package count for the SR design represents 83,800 MTHM of commercial SNF (CRWMS M&O 2000c). The Waste Package count for the VA represents the scope of 86,300 MTHM of commercial SNF.

[d]CRWMS M&O 2000h, Section 4.2.3

The wider drift spacing utilized in the reference system design improves drainage and thermal independence of the drifts. Its steel ground support, invert, and Alloy-22 waste package pallet reduce performance uncertainties attributable to the effects of concrete on radionuclide mobilization and transport. In the reference system design, the waste package corrosion-resistant material, Alloy-22, protects the underlying structural material, stainless steel 316NG, from corrosion. In contrast, the Viability Assessment design had its structural material, carbon steel, covering the corrosion-resistant material, Alloy-22. One reason for the change was the possibility that the failure mode of the Viability Assessment structural material may accelerate the failure of the corrosion-resistant material. The waste packages will be positioned in the emplacement drifts with a nominal 10-cm spacing between adjacent waste packages. This is referred to as "line loading" and results in less drift excavation than the "point loading" used in the Viability Assessment design. Titanium drip shields that cover the waste packages form an additional engineered barrier from the Viability Assessment design (see Figure 2-3). The installation of titanium drip shields at closure will require reliable operation of remotely controlled equipment in a high-temperature, radioactive environment.

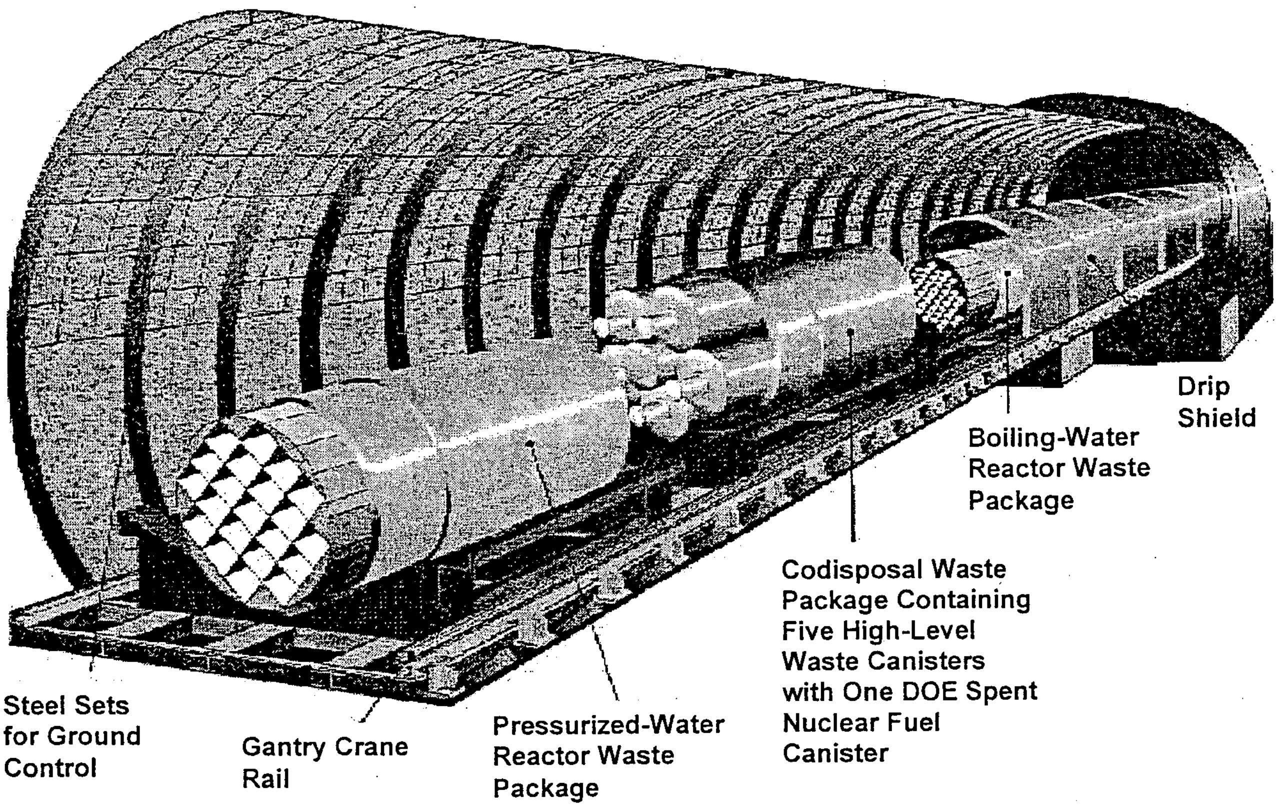

Figure 2-3. Engineered Barrier System

3. MONITORED GEOLOGIC REPOSITORY

3.1 SCOPE

The MGR detailed in this section reflects the reference system design. The MGR is assumed to be located at Yucca Mountain about 160 km (100 miles) northwest of Las Vegas, Nevada. The nearest populated area is Amargosa Valley, approximately 30 km (19 miles) to the south. Yucca Mountain itself is a ridge composed of a sequence of tilted layers of variably welded and fractured tuffs. The host rock proposed for the potential repository is a welded tuff unit of the Topopah Spring Member (CRWMS M&O 2000, Section 2.3). Figure 3-1 depicts the layout of the potential repository site.

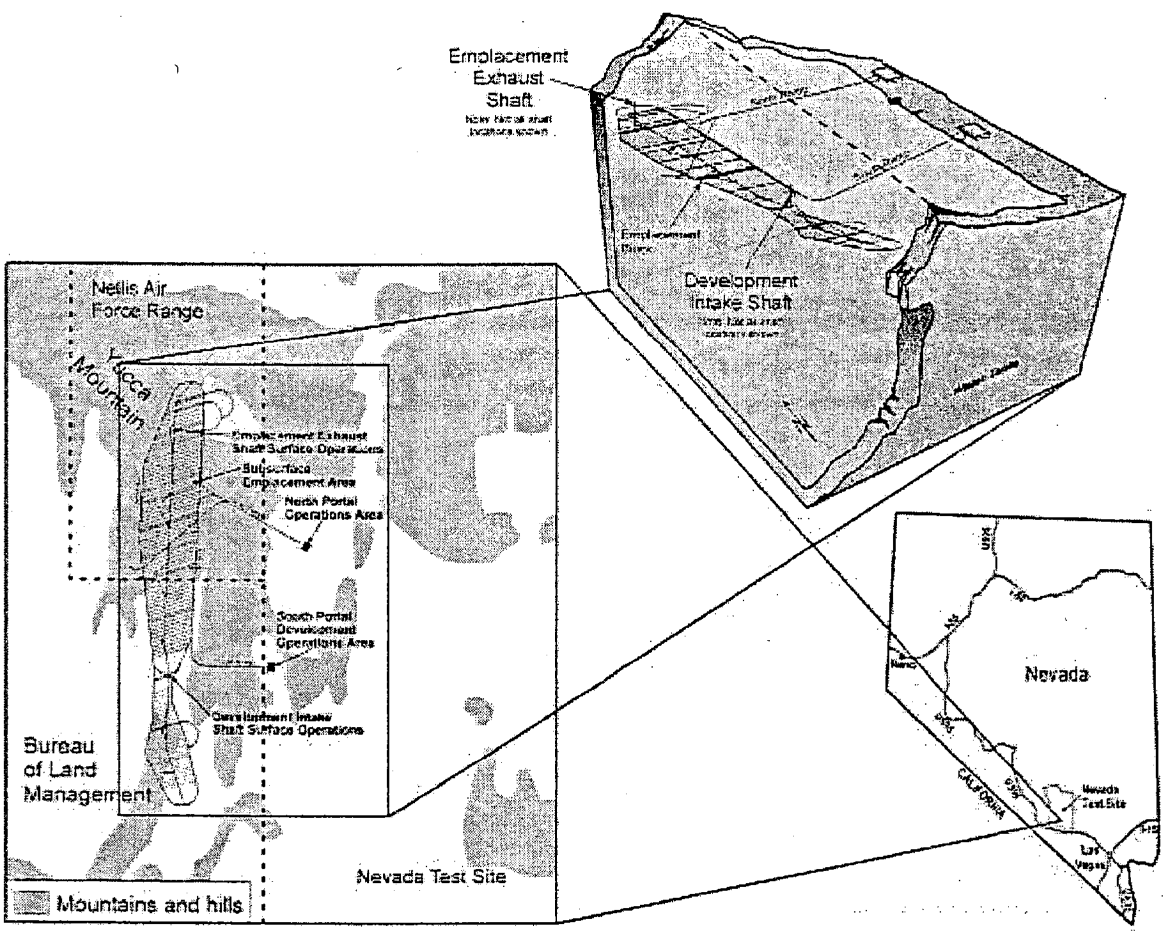

Figure 3-1. Layout of Potential Repository Site

The waste packages provide containment of the nuclear wastes for tens of thousands of years. The natural barriers and the waste packages retard the release of radionuclides to the accessible environment. The disposal system will operate under a license issued by the NRC, pursuant to 10 CFR 63, *Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada* (64 FR 8640), when finalized.

Receipt of waste at the potential repository is planned to begin in 2010. 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. Surface staging may be provided at the potential repository to compensate for any differences between receipt and emplacement rates, and to provide for blending of fuel assemblies to thermal limits.

The conceptual repository design consists of surface and subsurface facilities, which constitute the geologic repository operations area, as defined in the proposed 10 CFR 63 (64 FR 8640). Existing law prohibits emplacement in the nation's first potential repository of a quantity of spent fuel and high-level waste in excess of 70,000 MTHM, until such time as a second potential repository is in operation. The need for a second potential repository will be determined between January 1, 2007 and January 1, 2010, in accordance with the Nuclear Waste Policy Act of 1982 (NWPA). Current cost information, designs, or authorization for a second potential repository do not exist. Therefore, consistent with the 1998 TSLCC, a one-repository system, without interim storage, has been assumed for cost estimating purposes.

3.1.1 Surface Facilities

The nuclear wastes that are destined for disposal in the potential repository will be received and packaged for emplacement in a 60-hectare (150 acre) area located at the northern entrance to the potential repository (the North Portal Operations Area) (CRWMS M&O 2000a, Section 2.3, Section 4.2.1). The surface facilities at the North Portal consist of those systems and components used to receive, prepare, and package the waste for underground emplacement, and are situated as shown in Figure 3-2. The operations at the North Portal are divided into two work areas: a protected area (radiologically controlled area) and the Balance of Plant area. The operations involving radioactive materials would be conducted in the protected area, which contains, among other structures, the Waste Handling Building. Support operations will be accomplished in the Balance of Plant area.

Within the Waste Handling Building, there are three processing lines: two wet lines and one dry. The wet processing lines are used to extract SNF assemblies from transportation casks or non-disposable canisters and place them in disposal containers. The dry processing line only handles HLW or SNF 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 waste packages awaiting transfer to the subsurface emplacement areas. The protected area also includes a Waste Treatment Building for the treatment of low-level waste for off-site disposal, a Transporter Maintenance Building for servicing and repairing vehicles that are used for transporting and emplacing waste packages in the potential repository, and a Carrier Preparation Building.

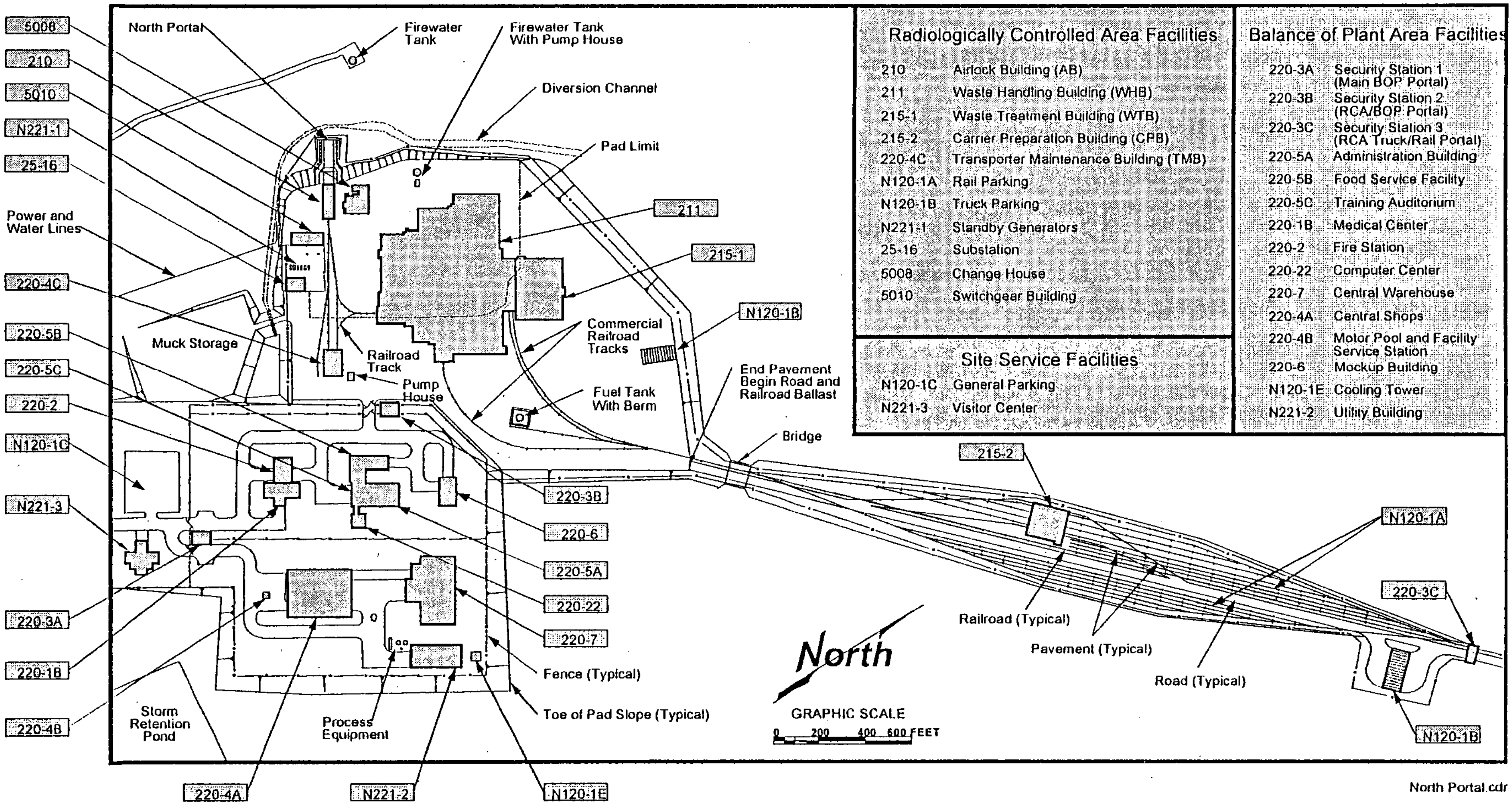

Figure 3-2. North Portal Repository Area Site Plan Above Ground

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.

Other operations areas are included in the surface facilities. The South Portal Operations Area, covering about 15 hectares (37 acres) adjacent to the southern entrance to the potential repository, provides systems and equipment to support the excavation of the underground area. The South Portal surface facility includes basic structures for personnel support, maintenance, warehousing, material staging, security, and transportation. The remaining areas, each of minimal acreage, are the Emplacement Exhaust Shaft and Air Intake Areas. The exhaust shaft areas contain the ventilation exhaust fans for waste emplacement operations and support fan maintenance and the intake shaft areas house the development intake fans and auxiliary hoisting system for excavation operations.

The MGR design concept also includes a solar power component that will generate power used to offset part of the power requirements of the ventilation system for the MGR. The solar component will be of a modular design that permits future expansion.

3.1.2 Subsurface Facilities

The waste emplacement horizon in the potential repository will be located in the Topopah Spring Member, a welded tuff unit of the Paintbrush Tuff. The potential site for the emplacement area location is bounded by geologic faults, but the emplacement area itself is free of significant faults. These potentially usable areas include a primary area and an expansion area.

The primary area consists of an area bounded on the east by the Ghost Dance Fault, and on the west by the Solitario Canyon Fault. Expansion areas are potentially available; however, additional characterization activities would be required. These areas lie west of the Solitario Canyon fault.

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 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 (CRWMS M&O 2000a, Section 2.5, Section 4.2.2).

Emplacement drifts are 5.5 meters (18.2 feet) in diameter, and are spaced at 81 meters (266 feet) between the centers of each drift. Each emplacement drift has two sets of doors to control access. Each door has ventilation regulators (louvers) to control the flow of air through the emplacement drift. These doors are remotely controlled from the surface control room. Approximately 10 percent of the total number of emplacement drifts will be developed prior to the start of emplacement operations. Development of the remaining emplacement drifts will be performed concurrently with waste emplacement during the repository operations phase, using two separate and independent ventilation subsystems. One system will provide ventilation for the excavation operations required for drift development, while the other will provide 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 (CRWMS M&O 2000a, Section 2.5).

The ventilation system that supports drift development operations will force air into the drifts using fans at the intake shafts, expel air through the South Ramp and exhaust shafts, and maintain air pressure in the development area above that in the emplacement area to prevent the potential migration of contaminants from the latter to the former in the possible event of a system failure in either area. The ventilation system that supports waste emplacement operations will draw air into the emplacement area through the North Portal and intake shafts using fans at the exhaust shafts, and maintain air pressure in the emplacement area lower than that in the development area. The ventilation system maintains a temperature suitable for human occupancy in areas where personnel are working. Personnel will not be allowed in the emplacement drifts during normal emplacement operations. The ventilation flow rate may vary with time to meet thermal performance requirements (CRWMS M&O 2000a, p. 2-23).

3.1.3 Waste Packages and Drip Shields

The waste package would include two concentric, cylindrical metal barriers with three accompanying lids (a closed cylinder within a closed cylinder). The outer barrier of the waste package and its outer and middle lids would be made of highly corrosion-resistant nickel Alloy-22. The inner barrier and lid would provide structural support and be made of a different material, 316NG stainless steel. The representative waste package designs illustrated in Figure 3-3 will contain commercial SNF assemblies, a single large canister containing a number of naval spent nuclear fuel assemblies, or five canisters of HLW plus one canister of DOE SNF (CRWMS M&O 2000a, pp. 2-14, 2-19, 2-39 to 2-41).

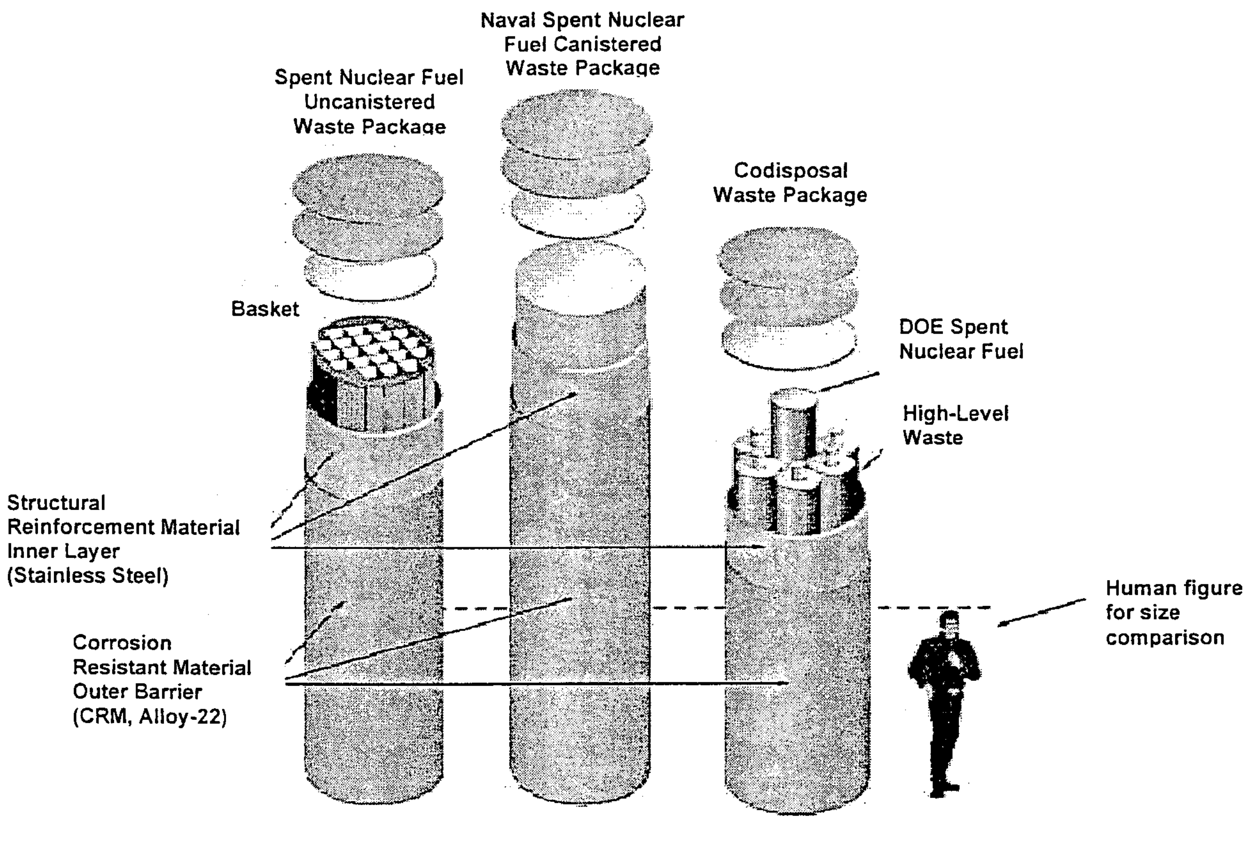

Figure 3-3. Representative Waste Package Design

In conjunction with the waste packages, the repository design includes a titanium drip shield installed over the waste packages at the time of repository closure to provide defense-in-depth for postclosure performance. The drip shields and the heat from the waste package will keep the waste packages dry for thousands of years, which reduces the corrosion rate of the waste packages. The titanium drip shield also protects the waste package from rock falls that could compromise the corrosion barrier of the waste package.

3.1.4 Confirmation and Retrieval

Activities to confirm that a potential repository is working as expected would begin long before the first waste is emplaced. In the current site characterization phase, information concerning Yucca Mountain and the surrounding environment is being collected and compiled to provide a baseline against which to compare what occurs after the potential repository is built and waste is emplaced. The *Performance Confirmation Plan* (CRWMS M&O 2000e) specifies monitoring, testing, and analyses to evaluate the accuracy and adequacy of the information used to determine that the defined repository postclosure performance objective is met. When repository operations begin, remote sensors will monitor the waste packages, emplacement drifts, and surrounding rock. The observed effects will be compared with the pre-emplacement repository characteristics and to the model predictions. These confirmation activities will continue until the potential repository is closed and sealed.

If a problem is detected prior to closing the potential repository, remedial action or retrieval of the waste will be possible using remotely operated equipment. The NRC currently requires that the potential repository be designed to allow the retrieval of waste at any time, up to 50 years after waste emplacement operations begin. Any retrieval of waste will follow, in reverse order, the same steps taken in emplacing the waste and, for the most part, will use the same systems and equipment. This cost estimate does not include costs for retrieval, since this option will be exercised only if the potential repository is not performing satisfactorily, or if future decision makers decide the disposed material is valuable.

After the last package is placed underground, the potential repository can be monitored for many decades, perhaps even centuries. Permanently installed sensors will monitor waste packages, emplacement drifts, and the surrounding rock, providing the data required to confirm performance. A remotely operated inspection gantry will track conditions in the waste emplacement drifts.

3.2 ASSUMPTIONS

This analysis assumes, for cost estimating purposes, a single potential repository at Yucca Mountain capable of handling all projected waste streams of SNF and HLW currently forecasted. The NWPA specifies that the need for a second potential repository will be assessed between 2007 and 2010.

NRC proposed regulation 10 CFR 63 for licensing the potential repository (64 FR 8640) requires a geologic repository to be designed with a waste retrieval capability for up to 50 years after initiation of waste emplacement operations. Compliance with these requirements means that the potential repository must be designed to be kept open for a number of years after the last waste package has been emplaced. Future generations will decide how long to maintain the potential repository in an open, monitored condition, whether to retrieve the waste, and when to permanently close the potential repository. To ensure future decision-makers have flexibility regarding these decisions, the potential repository is being designed with the capability to be closed promptly, or to remain open for up to 300 years with appropriate monitoring and maintenance. For the purposes of this estimate, it is assumed that closure and decommissioning activities begin 100 years after the beginning of waste emplacement and are completed by 2119.

The MGR assumptions for the 2000 TSLCC were extracted from the *Monitored Geologic Repository Life Cycle Cost Estimate Assumptions Document* (CRWMS M&O 2000h). There are key differences between the 2000 TSLCC assumptions and the MGR assumptions used in the 1998 TSLCC (DOE 1998a). One difference is the extension in the closure and decommissioning period from 7 years to 10 years. In the 1998 TSLCC, the closure and decommissioning phase ended in FY 2116; however, for this estimate, this phase will be completed in FY 2119. Other significant changes are in the surface facility, subsurface facility, and waste package assumptions that added drip shields. Changes in assumptions have resulted in adjustments to the estimate.

3.2.1 Surface Facility

Key surface facility assumptions that differ from the Viability Assessment design (DOE 1998b) are as follows:

1. A fuel pool, with a capacity for 5,000 MTHM, was added for fuel blending (CRWMS M&O 2000h, Section 4.1).

2. A solar power facility will be constructed as part of the potential repository. The energy generated by the solar facility will be supplied to the power grid that supplies power to the subsurface emplacement ventilation system (DOE 2000, Section 3.4).

3.2.2 Subsurface Facility

Key subsurface facility assumptions that differ from the Viability Assessment design are as follows:

1. The change to positioning the waste packages using line loading, instead of point loading, will result in less emplacement drift excavation. An increase in access drift excavation occurs, however, due to the increase in spacing between emplacement drifts.

2. Drip shields of titanium will be installed over all waste packages (CRWMS M&O 2000a, Section 2.10).

3. The cost for ventilation will be based on the flow rate of 15 cubic meters per second for 100 years to allow for cooling. There will be 10 ventilation shafts to handle the volume of ventilation air required (CRWMS M&O 2000h, Section 4.2.3).

3.2.3 Waste Package

The waste package assumptions that differ from the 1998 TSLCC are as follows:

1. The quantity of waste packages decreased from 15,706 to 14,768 due to the change in assumption of the quantity of commercial SNF to be disposed (CRWMS M&O 2000c), and the blending of hotter fuel with colder fuel. Blending reduced the quantity of small PWR waste packages assumed in the 1998 TSLCC.

2. The waste package design has changed to corrosion resistant, 2-2.5 cm Alloy-22 over 5-cm stainless steel. This, combined with the addition of a titanium drip shield, will achieve a much longer life for the waste package.

3.3 COST

The MGR cost estimate is comprised of integrated costs from six time phases:

- Development and Evaluation (D&E) (1983 – 2003)
- Licensing (2003 – 2006)
- Pre-Emplacement Construction (2006 – 2010)
- Emplacement Operations (2010 – 2041)
- Monitoring (2041 – 2110)
- Closure and Decommissioning (2110 – 2119).

The MGR cost estimate for the phases after Development and Evaluation are comprised of integrated costs from five scope elements:

- Surface
- Subsurface
- Waste Package and Drip Shield Fabrication
- Performance Confirmation
- Regulatory, Infrastructure, and Management Support (RIMS).

Table 3-1 provides, by phase, historical and future costs. Detailed costs for each of the phases in Table 3-1 are presented in the remainder of Section 3.

Table 3-1. Monitored Geologic Repository Costs by Phase (in Millions of 2000$)

Phase	Historical (1983-2000)	Future Costs (2001-2119)
Development and Evaluation (1983-2003)	5,780	800
Licensing (2003-2006)	0	1,290
Pre-Emplacement Construction (2006-2010)	0	4,450
Emplacement Operations (2010 – 2041)	0	19,710
Monitoring (2041 – 2110)	0	6,000
Closure and Decommissioning (2110 – 2119)	0	4,040
Total	**5,780**	**36,290**

NOTE: Historical costs total $4.8 Billion in YOE dollars.

3.3.1 Repository Development and Evaluation

The repository D&E phase began with program inception and will continue until submittal of a License Application in 2003. Repository D&E activities include site characterization and preliminary design development activities associated with the potential repository.

Repository D&E costs are summarized in Table 3-2. Historical costs are divided into two categories: the costs associated with the potential repository at Yucca Mountain, and all other costs for site characterization activities. The other repository historical costs include technical support, the repository technology program, and the salt and basalt sites formerly considered for the first potential repository program. Future costs are projected for a potential repository based upon the Yucca Mountain site. All site characterization activities at other sites were terminated in accordance with the Nuclear Waste Policy Amendments Act of 1987, Section 160.

Table 3-2. Repository Development and Evaluation Costs (in Millions of 2000$)

Phase	Historical (1983-2000)	Future Costs (2001-2003)
Repository Development and Evaluation at Yucca Mountain	4,000	800
Other Repository Development and Evaluation	1,780	0
Total	**5,780**	**800**

NOTE: Historical costs total $4.8 Billion in YOE dollars.

3.3.2 Licensing

The repository licensing phase begins with the submittal of the License Application in 2003 and continues until construction authorization in 2006. This phase includes limited procurement activities, such as the acquisition of long-lead construction materials and equipment for surface and subsurface facilities. Table 3-3 details the costs for the licensing phase.

Table 3-3. Repository Licensing Costs (in Millions of 2000$)

Cost Element	Future Costs (2003-2006)
Surface	310
Subsurface	190
Waste Package and Drip Shield Fabrication	54
Performance Confirmation	210
Regulatory, Infrastructure and Management Support	530
Total	**1,290**

3.3.3 Pre-Emplacement Construction

The pre-emplacement construction phase covers the period from construction authorization in 2006 through early 2010. This phase includes costs for MGR procurement, design, and construction. Construction includes costs for site preparation, and construction of surface and subsurface facilities. Additionally, costs are included for startup and training. Table 3-4 details the costs for the pre-emplacement phase.

Table 3-4. Repository Pre-Emplacement Construction Costs (in Millions of 2000$)

Cost Element	Future Costs (2006-2010)
Surface	1,780
Subsurface	1,200
Waste Package and Drip Shield Fabrication	200
Performance Confirmation	330
Regulatory, Infrastructure and Management Support	940
Total	**4,450**

3.3.4 Emplacement Operations

The emplacement operations phase covers the period from 2010-2041. This is different than the emplacement period described in Section 4 for the Waste Acceptance, Storage and Transportation estimate. The Waste Acceptance, Storage and Transportation estimate calculates that all waste is transported to the MGR by 2040. However, some commercial SNF is stored for blending purposes until 2041 and then disposed. The operations phase consists of three activities: waste receiving, waste handling, and emplacement of waste. It includes all costs for staffing, maintenance, supplies and utilities during waste emplacement; completing the underground facilities; and procurement of waste packages. Table 3-5 details the costs for the emplacement phase.

Table 3-5. Repository Emplacement Operations Costs (in Millions of 2000$)

Cost Element	Future Costs (2010-2041)
Surface	4,690
Subsurface	4,940
Waste Package and Drip Shield Fabrication	8,270
Performance Confirmation	870
Regulatory, Infrastructure and Management Support	940
Total	**19,710**

3.3.5 Monitoring Operations

The monitoring operations phase covers the period from 2041 through 2110. This includes collecting and analyzing data to confirm predicted repository performance, as well as maintenance of the subsurface facility. It includes all costs for staffing, maintenance, supplies, ventilation of the emplacement drifts, and utilities. It also includes the recovery costs for separately emplaced samples of waste package material that will be used for performance confirmation testing, and an initial purchase of drip shields as they are long lead items. Table 3-6 details the costs for the monitoring phase.

Table 3-6. Repository Monitoring Costs (in Millions of 2000$)

Cost Element	Future Costs (2041-2110)
Surface	710
Subsurface	2,180
Waste Package and Drip Shield Fabrication	1,550
Performance Confirmation	860
Regulatory, Infrastructure and Management Support	700
Total	**6,000**

3.3.6 Closure and Decommissioning

The closure and decommissioning phase covers the period from 2110 through 2119. It includes costs to fabricate and install drip shields; backfill shafts, ramps, mains, and extension drifts; permanently seal the underground repository; dismantle surface facilities; and construct monuments. The surface area will be restored to its original condition and the repository protected from future unauthorized intrusion. Table 3-7 details the costs for the closure and decommissioning phase.

Table 3-7. Repository Closure and Decommissioning Costs (in Millions of 2000$)

Cost Element	Future Costs (2110-2119)
Surface	210
Subsurface	470
Waste Package and Drip Shield Fabrication	3,220
Performance Confirmation	0
Regulatory, Infrastructure and Management Support	140
Total	**4,040**

The NRC requires that the potential repository be designed to allow the retrieval of waste at any time, up to 50 years after waste emplacement operations begin. However, the cost for the possibility of retrieving waste packages is not included in this analysis.

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4. WASTE ACCEPTANCE, STORAGE AND TRANSPORTATION

4.1 SCOPE

DOE will rely on the private sector to provide the necessary services and equipment required to accept and transport commercial SNF to the potential 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 SNF who have entered into contracts with DOE for disposal of their SNF. Each CRWMS regional servicing contractor (RSC) will be responsible for all activities and services in its region, including the provision of transportation cask/canister systems and ancillary equipment to accept commercial SNF and transport it to the potential repository for disposal. Specific performance requirements for each RSC will be set forth in detail in the procurement documents.

Transportation will be carried out using commercially available equipment and approved routes in compliance with NRC and U.S. Department of Transportation regulations. To the extent practicable, DOE will rely on the private sector to provide the necessary services to accept and transport HLW and DOE SNF (except naval SNF) to the potential repository. The Naval Nuclear Propulsion Program will provide for transportation of its SNF to the potential repository.

The waste acceptance and transportation elements of the CRWMS will accept commercial SNF, including MOX fuel, from commercial reactors; DOE SNF and HLW from DOE sites; and HLW and SNF from West Valley; and will transport these materials to the potential repository. The operational waste acceptance element provides the interface between the CRWMS, the utilities and DOE sites; maintains contracts and agreements; verifies records; verifies loading; accepts the waste; and maintains material control and accounting. The operational transportation element is responsible for the shipment of commercial SNF, HLW, and DOE SNF to the potential repository. Costs for decommissioning the commercial transportation casks at the end of operations are included. Commercial reactors are assumed to store commercial SNF on-site until accepted and transported to the potential repository.

4.2 ASSUMPTIONS

As a basis for planning, OCRWM uses the "no-new-orders, end of reactor life" case, as referenced in the *2000 Waste Acceptance, Storage, and Transportation Life Cycle Cost Report* (CRWMS M&O 2000g). After this analysis began, the NRC granted 20-year life extensions for five commercial reactors. This analysis does not assume any service life extensions that would increase projected quantities of SNF. The net increase due to granted life extensions would be approximately 1,460 MTHM (or a 1.7 percent increase). Disposal of this small amount of additional fuel would not have a significant affect on the estimate, nor change any conclusions.

Commercial SNF, DOE SNF, and HLW pickup is assumed to begin in 2010. Initial acceptance rates for DOE SNF and HLW are assumed to ramp up until 2015. Commercial fuel pickup assumes that the youngest fuel, greater than or equal to 10-years old, is picked up from the sites first. Allocation rights for commercial SNF will be assigned to Purchasers using the oldest fuel first, in accordance with the *Acceptance Priority Ranking and Annual Capacity Report* (DOE 1995b) and agreements with the utilities. Table 4-1 shows the acceptance rates for commercial

SNF in MTHM per calendar year (CRWMS M&O 2000c, Section 3.3, Table 10). Decommissioning activities of transportation casks are assumed to begin at the conclusion of shipping activities and continue for a year. The WAST operations period ends in 2040 with the final shipment of waste to the MGR. All of the waste will be transported by 2040; however, some is stored at the potential repository until 2041 and then disposed.

Table 4-1. Acceptance Rates for Commercial Spent Nuclear Fuel

Year	Acceptance (MTHM/calendar year)
2010	400
2011	600
2012	1,200
2013	2,000
2014	3,000
2015 – 2039	3,000
2040	1,600
Total	**83,800**

Note: The acceptance rates in Table 4-1 are targets only, and do not create any binding legal obligation upon DOE.

All commercial SNF is stored at utility sites prior to being transported to the MGR. Neither storage nor "take title" costs at utility sites are included in this TSLCC analysis. The cost of MOX SNF transportation casks and transportation from utility sites to the MGR is included in this TSLCC analysis as part of the commercial allocation. MOX SNF is assumed to be transported in a commercial 21 or 24-PWR uncanistered fuel cask.

It is assumed that DOE SNF will arrive in disposable canisters. The canisters will contain various quantities of fuel assemblies depending on fuel types and characteristics. Transportation casks for DOE SNF are assumed to contain from one to nine disposable canisters per cask, depending on fuel type.

The acceptance rate for DOE SNF, shown in Table 4-2, is based on the *Operational Waste Stream Assumption for TSLCC Estimates* (CRWMS M&O 2000c, Section 3.3, Table 12), and was used in the development of transportation-related costs. Transportation costs of DOE materials are included in the TSLCC analysis, with the assumption that transportation is to be via round trip one-car rail general freight. Development and procurement of transportation casks for DOE SNF are not part of the CRWMS. These casks will be designed and purchased by the DOE without funds from OCRWM. Prior to acceptance into the transportation system, DOE SNF is placed in canisters at the DOE facilities managing the nuclear material. Transportation costs do not include any costs for shipping naval SNF to the potential repository.

The acceptance rate for HLW, shown in Table 4-3, is based on the *Operational Waste Stream Assumption for TSLCC Estimates* (CRWMS M&O 2000c, Section 3.3, Table 11). All HLW is transported to the potential repository in rail transportation casks, which will be certified by the NRC. HLW rail transportation costs are based on round-trip general freight shipping charges. Costs for vitrification of HLW, by West Valley and DOE, are not included in this estimate. The costs for transportation cask design, acquisition, and transport of HLW from the DOE producer sites to the MGR are included in this estimate. Defense HLW includes approximately 18 metric tons of immobilized plutonium waste form, which equals approximately 635 HLW canisters, containing plutonium and vitrified HLW.

Table 4-2. Acceptance Rates of DOE Spent Nuclear Fuel

Year	Acceptance (Canisters)
2010	10
2011	28
2012	57
2013	78
2014	98
2015	138
2016	140
2017	150
2018	150
2019 - 2031	159
2032	161
2033	163
2034	148
2035	139
2036	121
2037	134
2038	132
2039	123
2040	104
Total[a]	**4,141**

[a]The total canister quantity is equivalent to approximately 2,500 MTHM of spent nuclear fuel.

Note: The acceptance rates in Table 4-2 are targets only, and do not create any binding legal obligation upon DOE.

Table 4-3. High-Level Waste Annual Acceptance Rates

Year	Acceptance Rate (Canisters)
2010	105
2011	295
2012	430
2013	520
2014	610
2015	790
2016	790
2017	835
2018	835
2019	880
2020	855
2021-2028	820
2029	810
2030	770
2031	770
2032	650
2033	580
2034	582
2035	825
2036	745
2037	825
2038	750
2039	705
2040	630
Total	**22,147**

Note: The acceptance rates in Table 4-3 are targets only, and do not create any binding legal obligation upon DOE.

Cask design assumptions are based on the type, size, and thermal properties of all fuel assemblies expected to be transported to the potential repository for disposal. Costs for acquisition, maintenance, refurbishment, and decommissioning of transportation casks are included, with the exception of DOE SNF casks. The costs for DOE SNF transportation cask acquisition and maintenance are not part of the CRWMS. Contingencies on cask cost estimates are assumed to be sufficient to procure any specialty casks required to accommodate unique assemblies.

Table 4-4 provides an estimate of the size of the required transportation cask fleet (CRWMS M&O 2000c, Section 4, Table 14). This cost estimate assumes a competitive private sector approach for the transportation of waste to the potential repository. This approach assumes DOE contracts for commercial SNF transportation with four separate regional servicing contractors, who acquire a cask fleet and provide shipping for their region. This estimate does not assume any sharing of transportation assets between regions. The cost estimate assumes all rail shipments to the potential repository are via one-car general freight.

Table 4-4. Transportation Cask Fleet

Cask Type	Quantity
Commercial Legal Weight Truck (LWT)	
BWR	5
PWR	7
Commercial Rail	
Large	35
Medium	22
Small	16
High-Heat (HH)	19
South Texas	3
Yankee Rowe	1
Big Rock Point	1
West Valley – PWR	1
West Valley – BWR	1
Government-Managed Rail	
HLW	17

4.3 COST

The CALVIN model (CRWMS M&O 2000f) was used to calculate transportation costs (CRWMS M&O 2000g). Commercial reactors are assumed to store commercial SNF on site, until acceptance and transport to the potential repository. Table 4-5 summarizes all waste acceptance and transportation costs, including Nevada rail construction and operations costs.

Table 4-5. Summary of Waste Acceptance, Storage and Transportation Costs by Phase (in Millions of 2000$)

Phase	Historical (1983-2000)	Future Costs (2001-2041)
Development and Evaluation (1983-2005)	500	42
Mobilization, Acquisition, and Construction (2005-2010)	0	860
Waste Acceptance and Transportation Mobilization and Acquisition	0	120
Nevada Transportation Engineering and Construction (2003-2010)	0	740
Operations and Cask Acquisition (2010-2041)	0	5,400
Waste Acceptance and Transportation Operations and Cask Acquisition	0	5,300
Nevada Transportation Operations	0	98
Total	**500**	**6,300**

NOTE: Historical costs total $0.4 Billion in YOE dollars.

4.3.1 Waste Acceptance, Storage and Transportation Development and Evaluation

The D&E phase for the waste acceptance and transportation elements began with program inception and will continue until the acquisition of transportation equipment begins in 2005. D&E activities include planning technical assistance for training pursuant to NWPA, Section 180(c), establishing contracts with regional servicing contractors, establishing waste form criteria for DOE wastes, systems engineering, technology demonstrations, quality assurance, and environmental safety and health activities. The storage and multi-purpose canister (MPC) cost elements are for activities that have been canceled. Table 4-6 provides costs for D&E activities.

Table 4-6. Waste Acceptance, Storage and Transportation Development and Evaluation Costs (in Millions of 2000$)

Cost Element	Historical (1983-2000)	Future Costs (2001-2005)
Storage	210	0
National Transportation	220	26
Waste Acceptance	24	9
Multi-Purpose Canister Project	39	0
Project Management and Integration	9	7
Total	**500**	**42**

NOTE: Historical costs total $0.4 Billion in YOE dollars, and column totals may not add due to rounding.

4.3.2 Waste Acceptance and Transportation Mobilization and Acquisition

The Waste Acceptance, Storage and Transportation Project mobilization and acquisition phase begins in 2005, and continues until acceptance operations begin in 2010. After contracts are awarded for mobilization and acquisition, the regional servicing contractors will perform waste acceptance and transportation activities. The activities include establishing agreements with each site regarding schedule, procuring and licensing of transportation hardware, and contracting for rail and truck shipments of SNF to the potential repository. Table 4-7 shows the costs for the mobilization and acquisition phase.

Table 4-7. Waste Acceptance and Transportation Mobilization and Acquisition Costs (in Millions of 2000$)

Cost Element	Future Costs (2005 - 2010)
National Transportation	95
Waste Acceptance	10
Project Management and Integration	11
Total	**120**

NOTE: Column total does not add due to rounding.

4.3.3 Waste Acceptance and National Transportation Operations

The operations phase begins in 2010, when acceptance and transportation of SNF and HLW from sites to the potential repository starts. The operations phase concludes in 2041 when all

SNF and HLW have been transported to the potential repository, and the transportation casks have been decommissioned. During this phase, acquisition of transportation hardware occurs to handle increases in throughput and transportation equipment replacement. Table 4-8 shows the costs for waste acceptance and national transportation during the operations phase.

Table 4-8. Waste Acceptance and Transportation Operations Costs (in Millions of 2000$)

Cost Element	Future Costs (2010 - 2041)
National Transportation	5,240
Waste Acceptance	57
Total	**5,300**

NOTE: Column total does not add due to rounding.

The cost basis for railroad shipping rates for nuclear waste is unchanged from the 1998 TSLCC estimate (DOE 1998a).

4.3.4 Nevada Transportation

The Nevada transportation engineering and construction phase begins in 2003 and concludes in 2010 with the start of emplacement operations. Activities include the design and construction of a branch rail line in Nevada to the potential repository site. Since no specific rail routing has been selected, the estimated cost is based upon an average of the five studied route options. An engineering and construction contingency of 60 percent was included to allow for cost estimating uncertainty (15 to 25 percent) and route uncertainty. Nevada rail transportation operations begin in 2010, and continue until the end of emplacement in 2041. Table 4-9 shows the Nevada transportation costs.

Table 4-9. Nevada Transportation Costs (in Millions of 2000$)

Cost Element	Future Costs (2003-2041)
Engineering and Construction (2003-2010)	740
Emplacement Operations (2010-2041)	98
Total	**840**

NOTE: Column total does not add due to rounding.

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5. PROGRAM INTEGRATION

5.1 SCOPE

Program Integration activities include Quality Assurance and Program Management and Integration. Program Integration costs outside of the OCRWM budget funded from the Nuclear Waste Fund include NRC costs, the NWTRB costs, and costs for the defunct office of the Nuclear Waste Negotiator.

5.1.1 Quality Assurance

The OCRWM program maintains a mandatory QA program to identify and ensure implementation of requirements that protect the health and safety of the public, workers, and the environment. The QA program must meet NRC requirements. Extensive development and review of technical and implementation documentation, as well as effective implementation of the requirements, will be necessary to ensure sound data and engineering, and to support eventual licensing of the potential repository by the NRC. Through QA audits, the QA program independently verifies that the various design and scientific activities incorporate the necessary regulatory requirements. The QA program includes work scope related to providing QA program management advice and planning, establishing and maintaining the OCRWM QA program and implementing procedures, and conducting QA verification activities. QA activities are assumed to continue through closure and decommissioning of the potential repository in 2119.

5.1.2 Program Management and Integration

Program Management and Integration activities support the Program Director in communicating program policy to key internal and external audiences, and in articulating the rationale for strategy and plan changes to program stakeholders. Support is provided for the Program Director's interactions with Congress and the Office of Management and Budget during the appropriations process. Program Management and Integration staff also support interactions with the NRC and the NWTRB in its independent evaluation of the program's technical and scientific activities.

Program Management and Integration has two areas of work: Systems Integration, and Program Management and Administration (PM&A). Systems Integration is comprised of Systems Engineering, Systems Analysis, TSLCC Analysis, Baseline Management, and International Information and Technical Exchange. Program Management and Administration is comprised of Regulatory Coordination, Program Management, Human Resources, Reports and Audits, Information and Education, OCRWM Headquarters Information Management, M&O Information Management, and Front Office Support. The costs for the salaries, travel expenditures, and overhead charges of all Federal employees assigned to the OCRWM program are also included in the Program Management and Integration cost estimate.

5.1.3 Nuclear Regulatory Commission Costs

NRC costs cover that agency's operating costs for participating in the CRWMS program. Funds for NRC activities that support the program are appropriated separately by Congress as part of the NRC budget rather than the DOE budget. The CRWMS portion of the NRC budget is paid from the Nuclear Waste Fund. Consequently, NRC costs are included in the TSLCC analysis.

5.1.4 Nuclear Waste Technical Review Board

The costs for the NWTRB cover the formation and operation of an independent establishment in the Executive branch of government. The Board, consisting of 11 members appointed by the President, evaluates the technical and scientific validity of the activities undertaken by OCRWM. Funds for the Board's activities are appropriated from the Nuclear Waste Fund. The Board's activities began in 1990 and are assumed to cease one year after receipt of the first waste in 2010.

5.1.5 Nuclear Waste Negotiator

The costs for the Office of the Nuclear Waste Negotiator covered the formation and operation of an independent establishment within the Executive branch of government. The Negotiator, appointed by the President, attempted to find a state or Indian tribe willing to host a Monitored Retrievable Storage facility at a technically qualified site. The funds for these activities were appropriated from the Nuclear Waste Fund. The Negotiator's activities began in 1990 and were terminated in 1995.

5.2 ASSUMPTIONS

QA activities are expected to decrease once routine emplacement operations begin. During the monitoring phase, most QA activities are transitioned to DOE Federal staff. Prior to beginning the closure and decommissioning phase, additional QA staff is required.

Program Integration costs are expected to decrease as the program proceeds with implementation, and will be significantly reduced during the monitoring phase.

NRC costs began in 1989 and are assumed to continue through closure and decommissioning of the potential repository in 2119.

The costs for the NWTRB are assumed to end in FY 2011.

5.3 COST

Table 5-1 summarizes Program Integration costs. The Program Integration costs have not changed significantly from the 1998 TSLCC estimate.

Table 5-1. Program Integration Costs (in Millions of 2000$)[a]

Cost Element	Historical (1983-2000)	Future Costs (2001-2119)
Program Management and Administration	1,360	2,050
Quality Assurance	120	560
Program Management and Integration	1,240	1,490
Non-OCRWM Nuclear Waste Fund Costs	330	330
Nuclear Regulatory Commission	290	300
Nuclear Waste Technical Review Board[b]	28	29
Nuclear Waste Negotiator	10	0
Total	**1,690**	**2,380**

NOTES: [a]Historical costs total $1.3 Billion in YOE dollars, and column totals may not add due to rounding.
[b]Nuclear Waste Technical Review Board costs occur over the following time periods : Historical : 1989-2000; Future Costs : 2001-2011

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6. INSTITUTIONAL

6.1 SCOPE

Institutional cost elements cover scope that is prescribed by the NWPA. These cost elements are PETT, Benefits, 180(c) Assistance, and Financial and Technical Assistance.

6.1.1 Payments-Equal-To-Taxes

The NWPA authorized the Secretary of Energy to grant, to affected states and units of local government, an amount each fiscal year equal to the amount a state or affected unit of local government, respectively, would receive if authorized to tax DOE activities at the same rate as commercial activities. States and units of local government are entitled to PETT for real property and industrial activities, including site characterization activities and development and operation of a potential repository. PETT costs reflect neither a tax nor a payment of tax, but rather a payment under the NWPA.

The commencement date for repository-related PETT eligibility was May 28, 1986, the date the President approved sites in Nevada, Texas, and Washington as candidates for site characterization. The termination date for PETT eligibility for repository-related site characterization activities at the Texas and Washington sites was December 22, 1987, the date the Nuclear Waste Policy Amendments Act of 1987 suspended site characterization at the two sites. The State of Nevada and local jurisdictions in Nevada and California remain eligible for PETT through decommissioning of facilities at the potential repository site at Yucca Mountain, assumed to be 2119.

6.1.2 Benefits

The Nuclear Waste Policy Amendments Act of 1987 allows the Secretary of Energy to enter into benefits agreements with the State of Nevada or affected Indian tribes pertaining to a potential repository for the acceptance of HLW or SNF. The Act states that the state or Indian tribe in which the potential repository is located is eligible to receive annual payments commencing on the date a repository site agreement is signed, and ending with the decommissioning of the potential repository. In return for these benefits, the state or Indian tribe waives its rights to disapprove the recommendation of a specific site. The Nuclear Waste Policy Amendments Act of 1987, Section 172(a), requires that a six-member Review Panel and a Chairperson be established to advise the Secretary on matters relating to benefits from the proposed potential repository, including issues relating to design, construction, operation, and decommissioning of the facilities.

6.1.3 180(c) Assistance

Section 180(c) of the NWPA directs the Secretary of Energy to provide technical assistance and funds to States for training public safety officials through whose jurisdiction SNF or HLW will be transported. This training will cover the procedures required to safely transport SNF or HLW, as well as procedures for dealing with emergency response situations.

6.1.4 Financial and Technical Assistance

The program has been providing the State of Nevada, local counties, and educational institutions with Financial and Technical Assistance from 1983 through the present. Financial and Technical Assistance provides eligible units of government (i.e., Churchill, Clark, Esmerelda, Eureka, Lander, Lincoln, Mineral, Nye, and White Pine Counties in Nevada and Inyo County in California) funds for conducting oversight and monitoring activities as required under the Nuclear Waste Policy Amendments Act of 1987. The program also provides funding for universities and colleges for cooperative agreements applicable to the OCRWM program.

6.2 ASSUMPTIONS

On July 27, 1994, the Director of OCRWM signed a negotiated PETT settlement agreement with Nye County, Nevada, for the tax period from May 28, 1986, through tax year 1998-1999. The Director of OCRWM signed a second agreement on July 26, 1999, for the tax period from July 1999 through tax year 2002-2003. PETT costs to the State of Nevada and other local jurisdictions in Nevada and California for 2004 through 2119 are based on estimates provided by the Yucca Mountain Site Characterization Project Office. Assumed PETT costs average $10 million per year, plus an 34 percent contingency. Annual PETT costs will depend on future negotiations with local jurisdictions based on activities at the site.

Annual Benefit amounts are established in the NWPA. Payments made prior to the acceptance of SNF will be at the rate of $10 million per year; payments made after the receipt of SNF will be at the rate of $20 million per year. These payments are not indexed for inflation; therefore, annual payments are adjusted to constant 2000 dollars for purposes of this estimate. It is assumed, for the purposes of this estimate, that the Secretary of Energy enters into a benefits agreement with the State of Nevada in 2002. Annual payments will then be made to the state at the rate of $10 million per year from 2002 through 2009. From the first spent fuel receipt at the potential repository in 2010, until closure of the potential repository in 2119, annual payments to the state will be $20 million per year. The Review Panel and associated costs are assumed to begin with panel selection in 2001.

Financial and Technical Assistance experienced a significant increase in scope from the 1998 TSLCC. The 1998 TSLCC assumption was that Financial and Technical Assistance activities were terminated after FY 2002; however, for this estimate it has been assumed that Financial and Technical Assistance activities continue through closure and decommissioning.

6.3 COST

Costs are presented in Table 6-1 for the elements that comprise Institutional: PETT, Benefits, 180(c) Assistance, and Financial and Technical Assistance.

Table 6-1. Institutional Costs (in Millions of 2000$)

Cost Element	Historical (1983-2000)	Future Costs (2001-2119)
PETT	55	2,870
Benefits	0	580
180(c) Assistance	1	460
Financial and Technical Assistance	200	410
Total	**260**	**4,320**

NOTE: Historical costs total $0.2 Billion in YOE dollars, and column totals may not add due to rounding.

The PETT, Benefits, and Financial and Technical Assistance costs have changed scope from the 1998 TSLCC. PETT costs have increased primarily due to the sales tax and use tax applied to the fabrication of drip shields. Benefits costs have increased slightly due to the change in escalation rates used for discounting, and inclusion of an additional Review Panel member. Estimated Financial and Technical Assistance costs increased significantly due to an assumption that Financial and Technical Assistance activities continue through closure and decommissioning, an additional 117 years of scope.

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7. COST SHARE ALLOCATION

The CRWMS is funded on a full-cost recovery basis, with generators of waste funding their respective disposal costs. The allocation is based on the methodology published in the August 20, 1987 *Federal Register Notice* (52 FR 31508). In accordance with the *Federal Register Notice* methodology, the costs of activities performed solely for the disposal of a specific type of waste, whether civilian or government-managed, are directly assignable to the waste generators. The remainder of the program costs is appropriately shared preventing cross-subsidization between waste generators, ensuring that each bears the full cost of disposal of its wastes.

The cost allocation decomposes system components to a meaningful level permitting an assignment of a share methodology. The percentage used to calculate the shared cost account is called a cost-sharing factor. Cost accounts are grouped into one of the following categories:

1. **Assignable direct costs** are solely for the disposal of DOE SNF and HLW, or commercial SNF and HLW, and are allocated in total to their respective cost share account.

2. **Assignable common variable costs** are allocated among the civilian and government purchasers by applying cost-sharing factors, piece count, and areal dispersion to the specific waste generator cost accounts. Sharing costs by a piece-count factor is based on the number of waste packages emplaced. Sharing costs by areal dispersion is based on the potential repository disposal area required for government-managed nuclear material and commercial SNF divided by the total disposal area.

3. **Common unassigned costs** are the remaining costs that cannot be either directly allocated or allocated on cost-sharing factors. These unassigned costs are allocated by deriving cost-sharing factors based on the ratio of assignable government-managed nuclear material cost or commercial costs to the total assignable costs for repository costs, transportation costs, or Development and Evaluation costs.

The allocation of estimated CRWMS costs between civilian and HLW and government purchasers are shown in Table 7-1. In this table, PETT, Benefits, and Nevada transportation costs are included with the repository costs. Historical second repository costs are included with the **Program - Unassigned** costs.

Table 7-1. Summary of Civilian Radioactive Waste Management System Cost Share Allocations (in Millions of 2000$)

Category	Cost Share Allocation		
	Government-Managed Nuclear Material	Civilian	Total
Monitored Geologic Repository	**13,390**	**34,320**	**47,710**
Assigned	7,630	19,560	27,190
Unassigned	5,760	14,760	20,520
Allocation Percent	28.1%	71.9%	100%
Waste Acceptance, Storage and Transportation	**1,360**	**5,050**	**6,410**
Assigned	1,190	4,410	5,600
Unassigned	170	640	810
Allocation Percent	21.2%	78.8%	100%
Program – Unassigned	**910**	**2,470**	**3,380**
Allocation Percent	26.9%	73.1%	100%
Total	**15,660**	**41,840**	**57,500**
Aggregate Allocation Percent	27.2%	72.8%	100%

NOTE: Totals may not add or compare with other totals due to independent rounding.

8. FLEXIBLE DESIGN AND OPERATING MODES

This section addresses the potential cost changes for a flexible potential repository that could be operated over a range of thermal modes. The TSLCC estimate (Sections 1-7) utilizes a high temperature (above-boiling) mode of operations that allows for the free drainage of water between widely spaced drifts. This design and operational concept was described in Section 2. The Viability Assessment design was a hotter repository mode of operations than the reference case.

With the flexible design, the temperatures at the drift wall and waste package surfaces, along with the relative humidity in the drifts, can be varied by using one or more of the methods discussed below. For each of these methods, a general discussion of the potential cost impacts is provided.

Ventilation - During active repository operations, an appreciable fraction of the heat generated by waste packages is removed from the repository system by forced ventilation of the loaded emplacement drifts. The amount of energy the waste transfers to the host rock and the maximum temperatures of the rock at closure can be reduced by extending the time during which the emplacement drifts are ventilated. Extending the forced ventilation period increases the repository operations cost by adding more years of operation and maintenance. It is estimated that each additional year of forced ventilation (assuming no increase in total drift length) would increase subsurface operations costs relative to the reference case by approximately $22 million (CRWMS M&O 2000j, Section 4.1.2).

Waste Package Spacing - Spacing waste packages further apart in the emplacement area effectively decreases the linear thermal density in the drift (measured in kilowatts of heat output per meter of drift length). Increasing waste package spacing has the effect of requiring more drift length to emplace the same number of waste packages. This in turn increases subsurface construction costs. Increasing waste package spacing will also increase drip shield costs, particularly if a continuous drip shield is used. As waste package spacing increases, the costs associated with segmenting the drip shield are likely to become less than the additional cost for the drip shields covering the space between waste packages. Increasing the total drift length also increases operations costs, principally due to the costs of operating and maintaining ventilation fans for the additional drift volume. It is estimated that each additional kilometer of drift length (assuming no increase in operation time) would increase subsurface construction costs relative to the reference case by approximately $30 million, drip shield costs (if continuous) by approximately $60 million, and subsurface ventilation costs by approximately $12 million (CRWMS M&O 2000j, Sections 4.1 and 4.2).

Staging - Staging involves the temporary storage of hot fuel after receipt until it has cooled sufficiently to meet waste package emplacement limits. This reduces waste package heat generation at emplacement and, therefore, the maximum subsurface temperature. This option results in increased capital costs, since a surface storage facility and storage casks are needed. Current commercial nuclear utility surface storage systems (consisting of a canister and storage overpack) cost up to approximately $100,000/MTHM (a unit cost of about $1.1 million per system, assuming 11 MTHM per canister). If a large amount of CSNF requires staging, this could significantly increase repository capital costs. If these canisters are not disposable, repository operations costs would also be increased due to the unloading and emplacing of staged fuel. For example, if staged fuel in non-disposable storage canisters was unloaded and emplaced at a rate of 2000 MTHM per year it is estimated that operations costs could increase by approximately $120 million per year during the emplacement period (CRWMS M&O 2000j, Section 4.4).

One factor that could reduce the staging cost per MTHM is the relatively large number of staging casks that may be required by the potential repository. Current utility storage system costs are based on small orders of newly-developed systems. The potential repository would likely procure many times the number of casks required by a single utility, and it is reasonable to assume the economies of scale would reduce individual unit costs. Another option for reducing staging costs would be to utilize "stage and dispose" canisters. Upon receipt, the fuel would be placed in a disposable canister for staging, and staged using a shielded overpack. When cooled sufficiently, the canister would then be removed from the storage overpack and placed inside a disposal overpack for emplacement. Since the staging canister is also part of the waste package, staging capital costs would be reduced to the cost of the storage overpacks (approximately $210,000 to $310,000 per overpack [CRWMS M&O 2000j, Section 4.4]). Waste package costs would increase slightly, due to the addition of the "stage and dispose" canister to the current waste package design. In addition, if utility storage canister designs could be qualified for disposal, these canisters could either be staged or disposed of directly upon receipt.

Waste Package Size - Using smaller waste packages reduces the heat generation from each waste package. Emplacing these smaller packages at the same spacing as large waste packages effectively lowers the linear heat generation rate in the drifts. However, the number of waste packages increases, which increases the total drift length and drip shield length needed. For this reason this option is similar in subsurface effect to increasing waste package spacing. Reducing waste package size increases total waste package costs, since a waste package's capacity is not proportional to its cost (e.g., a 12 assembly waste package costs more than half as much as a 24 assembly waste package). Increasing the number of waste packages also increases subsurface operating costs, and would likely increase surface facility operating costs since more waste packages are being created.

Other Impacts - For operating modes that extend the repository preclosure period (e.g., ventilation and staging), other miscellaneous operations cost impacts must also be considered, e.g., performance confirmation, surface facilities, RIMS, PI&I, PETT and benefits, and non-OCRWM costs. These other costs are estimated to be approximately $35 million for each year of extended preclosure operations (CRWMS M&O 2000j, Section 4.3). Operating modes that extend the waste receipt period (e.g., extending receipt of government-managed wastes to allow for concurrent disposal with staged CSNF) will also increase waste acceptance and transportation costs.

It must be noted that the above methods of reducing waste package temperatures are not mutually exclusive. In fact, it is likely that a combination of the methods would prove to be the most cost effective, and would be selected if a lower temperature operating mode were chosen. Furthermore, the total cost impacts of choosing a combination of methods are not additive; that is, synergies between the methods (e.g., ventilation time and total drift length) produce cost impacts that cannot be determined by simply adding the cost impacts of the individual methods.

At the current time, a specific thermal operating mode has not been selected for the potential repository. Engineering evaluations are being conducted to evaluate how the potential repository will perform under a variety of operating modes and subsurface temperatures. Once these evaluations are completed, an appropriate range of operating modes will be selected to represent the flexible design. As more engineering detail is provided, it is expected that additional cost impacts, both positive and negative will emerge. The rough order of magnitude estimates provided in this section will then be refined. It is OCRWM's intent to include a range of costs for the various options to accomplish a lower temperature operating mode when the TSLCC is updated for the Site Recommendation.

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9.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

10 CFR 961. Energy: Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste. Readily available.

52 FR (Federal Register) 31508. Energy: Civilian Radioactive Waste Management; Calculating Nuclear Waste Fund Disposal Fees for Department of Energy Defense Program Waste. Readily available.

64 FR 8640. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada. Readily available.

Nuclear Waste Policy Act of 1982 (NWPA). 42 U.S.C. 10101 et seq. Readily available

Nuclear Waste Policy Amendments Act of 1987. Public Law No. 100-203. 101 Stat. 1330. Readily available.

APPENDIX A

2000 TOTAL SYSTEM LIFE CYCLE COST ESTIMATE SUMMARY

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APPENDIX A

2000 TOTAL SYSTEM LIFE CYCLE COST ESTIMATE SUMMARY

Table A-1 provides the 2000 TSLCC estimate in constant 2000 dollars. The total estimated future (2001 – 2119) cost to complete the program is $49.3 Billion. A total of $6.7 Billion was spent on the total program through FY 2000 in year-of-expenditure dollars. Escalating historical expenditures to 2000 constant year dollars ($8.2 Billion), plus the cost to complete of $49.3 Billion, results in an estimate for the CRWMS of $57.6 Billion.

Table A-1. 2000 TSLCC Estimate Summary (in Millions of 2000$)

Cost Element	Historical (1983-2000)	Future Cost w/o Contingency	Contingency Cost	Total Costs	Contingency Percentages
Monitored Geologic Repository	**5,780**	**30,570**	**5,720**	**42,070**	**0 - 43%**
Development and Evaluation (1983-2003)	**5,780**	**800**	**0**	**6,580**	**0%**
Single Repository (MGR) (Yucca Mt. Site)	4,000	800	0	4,800	0%
Other First Repository Characterization	1,660	0	0	1,660	0%
Second Repository	120	0	0	120	0%
Surface Facilities	**0**	**6,510**	**1,190**	**7,700**	**16 - 23%**
Licensing	0	260	50	310	19%
Pre-Emplacement Construction	0	1,450	330	1,780	23%
Emplacement Operations	0	4,010	680	4,690	17%
Monitoring Operations	0	610	100	710	16%
Closure & Decommissioning	0	180	30	210	17%
Subsurface Facilities	**0**	**7,620**	**1,360**	**8,980**	**15 - 19%**
Licensing	0	160	30	190	19%
Pre-Emplacement Construction	0	1,000	200	1,200	20%
Emplacement Operations	0	4,160	780	4,940	19%
Monitoring Operations	0	1,890	290	2,180	15%
Closure & Decommissioning	0	410	60	470	15%
Waste Package & Drip Shield Fabrication	**0**	**11,020**	**2,270**	**13,290**	**15 - 26%**
Licensing	0	43	11	54	26%
Pre-Emplacement Construction	0	160	40	200	25%
Emplacement Operations	0	6,670	1,600	8,270	24%
Monitoring Operations	0	1,350	200	1,550	15%
Closure & Decommissioning	0	2,800	420	3,220	15%
Performance Confirmation	**0**	**1,820**	**450**	**2,270**	**0 - 43%**
Licensing	0	150	60	210	40%
Pre-Emplacement Construction	0	230	100	330	43%
Emplacement Operations	0	690	180	870	26%
Monitoring Operations	0	750	110	860	15%
Closure & Decommissioning	0	0	0	0	0%
Regulatory, Infrastructure, and Mgmt. Support	**0**	**2,800**	**450**	**3,250**	**15 - 18%**
Licensing	0	450	80	530	18%
Pre-Emplacement Construction	0	800	140	940	18%
Emplacement Operations	0	820	120	940	15%
Monitoring Operations	0	610	90	700	15%
Closure & Decommissioning	0	120	20	140	17%
Waste Acceptance, Storage and Transportation	**500**	**4,710**	**750**	**5,960**	**0 - 23%**
Development and Evaluation (1983-2005)	**500**	**42**	**0**	**550**	**0%**
Storage (no ISF)	210	0	0	210	0%
National Transportation	220	26	0	250	0%
Waste Acceptance	24	9	0	33	0%
MPC Project	39	0	0	39	0%
Project Management and Integration	9	7	0	16	0%
Mobilization and Acquisition (2005-2010)	**0**	**96**	**20**	**120**	**10 - 23%**
National Transportation	0	77	18	95	23%
Waste Acceptance	0	9	1	10	11%
Project Management and Integration	0	10	1	11	10%
Operations (2010-2041)	**0**	**4,570**	**730**	**5,300**	**10 - 16%**
National Transportation	0	4,520	720	5,240	16%
Waste Acceptance	0	52	5	57	10%
Nevada Transportation	**0**	**540**	**300**	**840**	**25 - 60%**
Engineering and Construction	0	460	280	740	60%
Operations	0	78	20	98	25%
Program Integration	**1,690**	**2,230**	**150**	**4,070**	**0 - 11%**
Quality Assurance	120	560	0	680	0%
Program Management and Integration	1,240	1,340	150	2,730	11%
Non-OCRWM NWF Costs	**330**	**330**	**0**	**660**	**0%**
Nuclear Regulatory Commission	290	300	0	590	0%
Nuclear Waste Technical Review Board	28	29	0	57	0%
Nuclear Waste Negotiator	10	0	0	10	0%
Institutional Costs	**260**	**3,530**	**790**	**4,580**	**0 - 34%**
Payments-Equal-To-Taxes	55	2,140	730	2,930	34%
Benefits	0	580	0	580	0%
180(c) Assistance	1	400	60	460	15%
Financial and Technical Assistance	200	410	0	610	0%
TOTAL CRWMS COST	**8,230**	**41,580**	**7,710**	**57,520**	**19%**

NOTE: Values greater than $100M have been rounded to the nearest $10M.

APPENDIX B

COMPARISON WITH 1998 TOTAL SYSTEM LIFE CYCLE COST

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APPENDIX B
COMPARISON WITH 1998 TOTAL SYSTEM LIFE CYCLE COST

This appendix provides a comparison of the results of the current TSLCC estimate with the 1998 TSLCC estimate (DOE 1998a). The current estimate of $57.5 Billion, in constant 2000 dollars, compares with the 1998 TSLCC estimate of $45.8 Billion in 2000 dollars. The 1998 and 2000 TSLCC estimates assumed repository closure after 100 years from the start of emplacement. Section B.1 and Table B-1 provide a comparison of the 1998 TSLCC with the 2000 TSLCC. Table B-2 provides a summary comparison of the assumptions between the 1998 and 2000 TSLCC estimates.

B.1 SUMMARY COST COMPARISON WITH 1998 TSLCC

This section presents a comparison of the 1998 TSLCC (DOE 1998a) based on the Viability Assessment design to a TSLCC estimate that includes the adoption of the reference system design. The cost increase from the 1998 TSLCC captures significant scope changes intended to improve modeling of total system performance, reduce uncertainty, enhance the engineered barrier system, and provide additional corrosion resistance performance. The fundamental change in the design concept is to operate in a cooler temperature regime, thereby reducing performance modeling uncertainties. These thermal management changes included lowering areal mass loading of the potential repository, increasing ventilation of the emplacement drifts, and significantly increasing pool capacity of the surface facility for blending of fuel assemblies. The lower mass loading requires excavation into the characterized area south of the main repository block to accommodate emplacing the full inventory (83,800 MTHM) of commercial SNF. A significant cost increase to the current estimate resulted from adding titanium drip shields as an additional engineered barrier. Waste package unit costs increased substantially as the design was modified to increase performance. The changes that caused costs to decrease for this analysis are the re-evaluation of the transportation cask fleet types and cost basis, and reducing staffing requirements for Program Management and Institutional.

B.1.1 Monitored Geologic Repository

The cost of the potential repository increased by $11.6 Billion from the 1998 TSLCC (DOE 1998a) estimate. This estimate includes increases of $7.1 Billion in waste package and drip shield fabrication costs, $2.7 Billion in subsurface facility costs, $0.8 Billion in surface facility costs, $0.8 Billion in Regulatory, Infrastructure, and Management Support costs, and $0.4 Billion in development and evaluation costs. Costs for performance confirmation decreased by $0.2 Billion.

The Waste Package and Drip Shield category increase of $7.1 Billion was primarily due to the inclusion of titanium drip shields and a waste package design change that added a third lid. Drip shield fabrication costs added $4.8 Billion. Of the $4.8 Billion, $1.6 Billion was added at the end of the monitoring phase as drip shields are long-lead items that need to be procured before closure of the subsurface can begin. Waste package fabrication costs increased by $2.6 Billion due to an increase in the unit costs for material and the inclusion of a third lid. The waste package fabrication costs decreased by $0.3 Billion due to a decrease of 930 in the quantity of waste packages fabricated. This resulted from blending and a forecast decrease in the quantity of commercial SNF.

Table B-1. Comparison of 1998 and 2000 TSLCC (in Millions of 2000$)

Cost Element	TSLCC 1998		TSLCC 2000	Delta	
	1998 $	2000 $	2000 $	2000 $	
Monitored Geologic Repository Costs	29,120	30,480	42,070	11,590	
Development and Evaluation (1983-2003) Costs	5,900	6,190	6,580	390	
Single Repository (MGR) (Yucca Mountain Site)	4,200	4,400	4,800	400	
Other First Repository Characterization	1,590	1,670	1,660	-10	
Second Repository	110	120	120	0	
Surface Facilities	6,580	6,870	7,700	830	
Licensing	150	150	310	160	
Pre-Emplacement Construction	1,180	1,240	1,780	540	a
Emplacement Operations	4,320	4,510	4,690	180	a
Monitoring Operations	800	840	710	-130	a
Closure & Decommissioning	130	130	210	80	
Subsurface Facilities	6,020	6,310	8,980	2,670	
Licensing	90	100	190	90	
Pre-Emplacement Construction	980	1,030	1,200	170	a
Emplacement Operations	3,660	3,830	4,940	1,110	a
Monitoring Operations	1,080	1,130	2,180	1,050	a
Closure & Decommissioning	210	220	470	250	a
Waste Package & Drip Shield Fabrication	5,950	6,220	13,290	7,070	
Licensing	40	40	54	14	
Pre-Emplacement Construction	50	50	200	150	a
Emplacement Operations	5,840	6,110	8,270	2,160	a
Monitoring Operations	20	20	1,550	1,530	a
Closure & Decommissioning	0	0	3,220	3,220	a
Performance Confirmation	2,320	2,430	2,270	-160	
Licensing	130	140	210	70	
Pre-Emplacement Construction	240	250	330	80	a
Emplacement Operations	1,080	1,130	870	-260	a
Monitoring Operations	870	910	860	-50	a
Closure & Decommissioning	0	0	0	0	
Regulatory, Infrastructure & Management Support	2,350	2,460	3,250	790	
Licensing	350	370	530	160	
Pre-Emplacement Construction	500	520	940	420	
Emplacement Operations	990	1,040	940	-100	
Monitoring Operations	450	470	700	230	
Closure & Decommissioning	60	60	140	80	
Waste Acceptance, Storage and Transportation	6,390	6,680	5,960	-720	
Development and Evaluation (1983-2005) Costs	530	550	550	0	
Storage (no ISF Facility)	200	210	210	0	
National Transportation	240	250	250	0	
Waste Acceptance	30	30	33	3	
MPC Project	40	40	39	-1	
Project Management and Integration	20	20	16	-4	
Mobilization and Acquisition (2005-2010)	140	140	120	-20	
National Transportation	120	120	95	-25	
Waste Acceptance	10	10	10	0	
Project Management and Integration	10	10	11	1	
Operations (2010-2041)	5,720	5,990	5,300	-690	
National Transportation	5,660	5,930	5,240	-690	
Waste Acceptance	60	60	57	-3	
Nevada Transportation	790	830	840	10	
Engineering and Construction	700	740	740	0	
Operations	90	90	98	8	
Program Integration	3,990	4,190	4,070	-120	
Quality Assurance	670	710	680	-30	
Program Management and Integration	2,660	2,790	2,730	-60	
Non-OCRWM NWF Costs	660	690	660	-30	
Nuclear Regulatory Commission	600	630	590	-40	
Nuclear Waste Technical Review Board	50	50	57	7	
Nuclear Waste Negotiator	10	10	10	0	
Institutional Costs	3,400	3,570	4,580	1,010	
Payments-Equal-To-Taxes (PETT)	2,280	2,390	2,930	540	a
Benefits	470	500	580	80	
180(c) Assistance	450	470	460	-10	
Financial and Technical Assistance	200	210	610	400	a
TOTAL CRWMS COST	43,690	45,750	57,520	11,770	

[a] Signifies a scope change to the category. Other deltas are due to rounding and changes in forecasted costs.

Note: Columns may not add due to rounding.

Subsurface costs increased by $2.7 Billion due to additional access drift excavation and ventilation, offset in part by reductions in costs for lower emplacement drift excavation. Ventilation of the emplacement drifts at 15 cubic meters per second during the 100 years of repository operations increased costs. The cost increase for ventilation is due to an increase in the number of ventilation shafts, support facilities and management, and subsurface operations. The additional subsurface operations costs include ventilation fan purchase, replacement, maintenance, and operations. The change of the emplacement drift loading from point-loaded to line-loaded, and the drift lining change from concrete to steel reduced drift excavation costs.

The repository surface facility costs increased $0.8 Billion due to additional pool storage, construction of a solar power facility, and increased operational costs. The surface facility reflects the addition of 5,000 MTHM of lag storage for fuel blending; additional heating, ventilation, and air-conditioning capacity, and improved site access roads. The surface facility construction costs does not reflect costs for additional welding stations to accommodate the third waste package lid. A management decision excluded the rough order of magnitude cost estimate for the additional welding stations since it was believed that further engineering enhancements to the waste package design would eliminate the need for the third lid, and surface contingency costs cover additional welding stations, if required. Surface facility operations cost increases reflect additional activities such as fuel blending and maintenance of the solar power system. Closure and decommissioning costs increased in proportion to the increase in the surface facility construction costs.

Regulatory, Infrastructure, and Management Support costs increased by $0.8 Billion from the 1998 TSLCC. The increase in all phases of the Regulatory, Infrastructure, and Management Support estimate, except the emplacement phase, was $0.9 Billion. This increase was offset by a decrease of $0.1 Billion during the emplacement phase, reflecting a shift of some RIMS costs to the surface facility estimate. The cost increases were due to increased staffing estimates, and an upward revision in the fee calculation reflecting the Request for Proposal for a new Management and Operating contract.

Net costs for development and evaluation increased by $0.4 Billion from the 1998 TSLCC (DOE 1998a). Fiscal year 2001 and fiscal year 2002 costs are projected to be higher than in the 1998 TSLCC, and the License Application date was extended, adding additional time to the development and evaluation phase.

The estimate for Performance Confirmation decreased $0.2 Billion. Performance Confirmation costs decreased and shifted from the emplacement and monitoring phases to the licensing, construction, and monitoring phases, reflecting the revision to the *Performance Confirmation Plan* (CRWMS M&O 2000e).

B.1.2 Waste Acceptance, Storage and Transportation

The Waste Acceptance, Storage and Transportation cost estimate decreased by $0.7 Billion in 2000 dollars. The principal differences between the 2001 and 1998 Waste Acceptance, Storage and Transportation costs resulted from an update to cask fleet assumptions, changes to the waste site modal assumption, and changes in the assumed quantities and characteristics of waste being shipped. Details of these cost and assumptions changes are included in the Waste Acceptance, Storage and Transportation cost report (CRWMS M&O 2000g) and Table B-2.

B.1.3 Nevada Transportation

The estimate for engineering and construction of a branch rail line in Nevada changed slightly in constant 2000 dollars from the 1998 TSLCC (DOE 1998a) estimate. The operations cost estimate increased slightly after re-evaluating the cost basis.

B.1.4 Program Integration

Program Integration costs decreased by $0.1 Billion. The estimate was decreased after re-evaluating the cost basis in both Quality Assurance and Program Management and Integration.

B.1.5 Institutional Costs

Institutional costs increased by $1.0 Billion. PETT costs increased by $0.5 Billion in constant 2000 dollars. The PETT cost increase is due to an increase in sales and use tax payment for increased capital expenditures. Capital expenditures primarily increased from the inclusion of titanium drip shields and increased waste package costs.

Benefit costs increased by $0.08 Billion due to the change in the estimation of the size of the Review Panel, and a change in the assumed escalation rates.

The estimated cost for 180(c) Assistance decreased by $0.01 Billion in constant 2000 dollars from the previous TSLCC estimate due to one less year of acceptance activities. The $0.4 Billion increase in the life cycle cost for Financial and Technical Assistance is attributable to a change in assumptions regarding the duration of Financial and Technical Assistance. This estimate assumes Financial and Technical Assistance activities continue through closure and decommissioning.

B.1.6 Change in Cost Share Allocation

Changes in program scope and in the TSLCC estimate resulted in changes to the civilian and DOE cost shares. The civilian share allocation decreased from 74.9 percent to 72.8 percent, and the DOE share allocation increased from 24.7 percent to 27.2 percent of total costs. The changes in cost shares result primarily from the decrease, due to blending of commercial SNF, in the total quantity of commercial waste packages to be emplaced, and the change from point-loading the emplacement drifts to line-loading. These changes lead to a modification of the piece-count and areal dispersion factors used for calculating the assignable common variable costs. West Valley disposal costs are combined with the civilian cost.

B.2 ASSUMPTION DIFFERENCES

The 2000 TSLCC estimate is based on assumptions that differ from those utilized in the 1998 TSLCC (DOE 1998a). Table B-2 provides a summary of differences in assumptions between the 1998 TSLCC estimate and the 2000 TSLCC estimate. Unless otherwise noted, the 2000 TSLCC assumptions are from the *Operational Waste Stream Assumption for TSLCC Estimates* (CRWMS M&O 2000c, Appendix B, Table B-1).

Table B-2. Differences Between the 1998 and 2000 TSLCC Assumptions

TOPIC	1998 TSLCC	2000 TSLCC
SNF Waste Stream		
SNF Discharge Projection	1995 RW-859 Data	1995 RW-859 Data with extended burnups
MGR Receipt Rate	See Table 3, Table 4, Table 5 in 1998 TSLCC Document	See Tables 10,11, 12 (CRWMS M&O 2000c, Section 3.3)
Waste Acceptance		
Total Amount Accepted	86,300 MTHM Commercial SNF 19,657 defense HLW canisters (5,390 SRS; 1,190 INEEL; 12,442 Hanford; 635 Pu HLW SRS) 276 canisters West Valley HLW 71 canisters Argonne National Laboratory HLW 2570 MTHM DOE SNF (3,857 canisters, including 300 naval canisters)	83,800 MTHM commercial SNF 21,847 defense HLW canisters (5,420 SRS; 1,292 INEEL; 14,500 Hanford; 635 Pu HLW SRS) Note: the Argonne National Laboratory canisters are included in the INEEL count. 300 canisters West Valley HLW 2,500 MTHM DOE SNF (4,141 canisters, including 300 naval canisters)
Start Fuel Pickup	4/2010	6/2010
Last Fuel Pickup	2041	2040
Transportation		
Cask Capacities	Commercial Rail UCF: 26 PWR/61 BWR 12 PWR/24 BWR DPCs: 24/61, 21/44, 12/24 PWR/BWR HH: 7/17 PWR/BWR MOX: 9 PWR LWT: 1-4 PWR/2-9 BWR, various specialty casks HLW: 5 canisters – short (SRS, INEEL, West Valley) 5 canisters – long (Hanford) DOE SNF: 1-6 canisters	Commercial Rail UCF: 26 PWR/68 BWR 12 PWR/32 BWR DPCs: 24/68, 26/56, 21/44 PWR/BWR HH: 12/32, 7/17, PWR/BWR LWT: 1-4 PWR/2-9 BWR, various specialty casks HLW: 5 canisters (small and large) DOE SNF: 9 canisters, 4 MCOs, 1 naval canister
Transportation Modal Split	11 Reactor Pool Facilities and 2 DOE Storage Sites Ship by Commercial LWT 46 Pool Facilities Ship by SM Rail 43 Pool Facilities Ship by LG Rail	8 Reactor Pool Facilities and 2 DOE Storage Sites Ship by Commercial LWT 46 Pool Facilities Ship by SM Rail 46 Pool Facilities Ship by LG Rail
Cask Life (year) / Annual Utilization (days)	Rail 25 / 270 LWT 25 / 300 HLW 40 / 255 DOE SNF 25 / 270	Rail 25 / 270 LWT 25 / 300 HLW 40 / 255 DOE SNF 25 / 270
Rail Shipping	General freight for all rail shipments	General freight for all rail shipments
Travel Speed	Truck 960 miles/day Rail General Freight – ~10 miles/hour	Truck 960 miles/day Rail General Freight – ~10 miles/hour

Table B-2. Differences Between the 1998 and 2000 TSLCC Assumptions (Continued)

Monitored Geologic Repository		
Monitoring Phase	From end of emplacement to 100 years after the beginning of emplacement.	From end of emplacement to 100 years after the beginning of emplacement.
Closure & Decommissioning Phase	7 years	10 years (CRWMS M&O 2000h)
Waste Package Capacity	12 PWR/24 BWR 21 PWR/44 BWR 5 HLW including IPWF 5 HLW co-disposed with 1 DOE SNF DOE SNF various	12 PWR S. Texas only 24 BWR – AP 21 PWR/44 BWR-AP 21 PWR – CR 21 PWR – Big Rock Pt. 5 HLW including IPWF 5 HLW co-disposed with 1 DOE SNF (SS, LL, LS) 2 HLW co-disposed with 2 MCOs 1 naval – Short 1 naval – Long
Emplacement Method	Large in-drift WPs – Point Loaded	Large in-drift WPs – Line Loaded (CRWMS M&O 2000a, Section 2.5)
Cask Maintenance Facility	Limited maintenance Integrated with Repository Facilities; Responsibility of RSCs	Limited maintenance Integrated with Repository Facilities; Responsibility of RSCs
Number of Cask Shipments	Rail UCF 5,616 Rail DPC 5,425 Truck 3,037 HLW 4,003 DOE SNF 1,252 Total 19,333	Rail UCF 5,645 Rail DPC 3,583 Truck 1,039 HLW 4,430 DOE SNF 784 Total 15,481
Number of Waste Packages	Large - 5,723 PWR/3,734 BWR Small - 854 PWR/144 BWR 2,652 HLW including IPWF 1,349 HLW codisposed with DOE SNF 1,250 DOE SNF 15,706 Total	Large – 5,800 PWR/3,732 BWR Small - 293 PWR / 94 BWR 906 HLW including IPWF 3,643 HLW codisposed with DOE SNF 300 naval SNF 14,768 Total

Notes:

AP – Absorber Plates
CR – Control Rods
SS – Short-Short
LL – Long-long
LS – Long- Short
SRS – Savannah River Site
UCF – Uncanistered Fuel
DPCs – Dual-Purpose Canisters
HH – High-Heat
INEEL – Idaho National Engineering and Environmental Laboratory
SM –Small
LG – Large
MCO – Multi-Canister Overpack

APPENDIX C

ANNUAL COST PROFILE

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APPENDIX C

ANNUAL COST PROFILE

Figure C-1 shows the annual life cycle cost profile[1] that has been decomposed into four categories. The first category shows the annual historical expenditures in year-of-expenditure dollars from program inception through 2000. The second through fourth categories shows the Program Integration and Institutional (PI&I), WAST and Nevada Transportation, and MGR future cost estimates for 2001 through 2119.

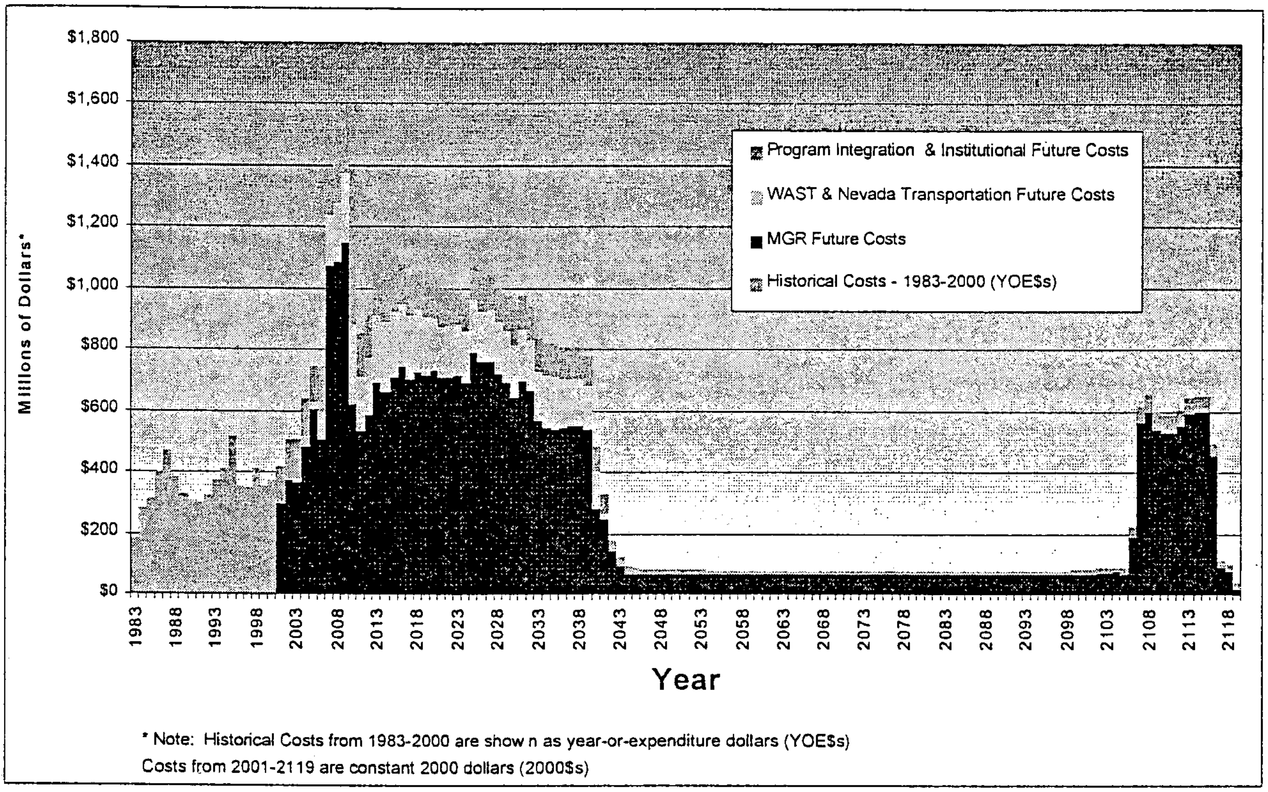

Figure C-1. Annual Total System Life Cycle Cost Profile

[1] These cost estimates reflect DOE's best projections, given the scope of work identified and the planned schedule of required activities. Future events and information could result in changes to both costs and schedules. Future budget requests for the program have yet to be established and will be determined through the annual Executive and Congressional budget process.

Table C-1. Annual Cost Profile (in Millions of 2000$)

Year	MGR	WAST[a]	PI & I[b]	Total
1983	$255	$6	$14	$274
1984	$339	$18	$58	$415
1985	$357	$26	$83	$465
1986	$460	$21	$98	$579
1987	$547	$32	$89	$669
1988	$402	$34	$115	$551
1989	$296	$43	$120	$460
1990	$250	$44	$137	$431
1991	$220	$43	$137	$400
1992	$217	$54	$155	$426
1993	$253	$49	$166	$468
1994	$301	$40	$159	$500
1995	$401	$39	$162	$602
1996	$261	$34	$102	$396
1997	$293	$10	$86	$389
1998	$352	$7	$88	$446
1999	$298	$2	$81	$380
2000	$283	$2	$87	$373
2001	$308	$3	$95	$406
2002	$340	$6	$102	$448
2003	$366	$18	$126	$510
2004	$483	$42	$124	$649
2005	$601	$33	$120	$753
2006	$500	$100	$140	$740
2007	$1,070	$170	$160	$1,400
2008	$1,090	$190	$170	$1,450
2009	$1,150	$230	$180	$1,560
2010	$620	$260	$190	$1,070
2011	$530	$170	$150	$850
2012	$580	$190	$140	$910
2013	$690	$220	$140	$1,050
2014	$660	$220	$140	$1,020
2015	$710	$220	$140	$1,070
2016	$740	$200	$130	$1,070
2017	$700	$210	$130	$1,040
2018	$730	$200	$130	$1,060
2019	$710	$190	$130	$1,030
2020	$730	$170	$130	$1,030
2021	$710	$170	$120	$1,000
2022	$710	$170	$120	$1,000
2023	$710	$170	$120	$1,000
2024	$690	$170	$120	$980
2025	$790	$170	$120	$1,080
2026	$760	$160	$120	$1,040
2027	$760	$170	$120	$1,050
2028	$720	$170	$110	$1,000
2029	$690	$170	$110	$970
2030	$650	$170	$110	$930
2031	$700	$170	$110	$980
2032	$670	$160	$110	$940
2033	$570	$160	$110	$840
2034	$550	$170	$110	$830
2035	$540	$170	$110	$820
2036	$550	$160	$100	$810
2037	$550	$150	$100	$800
2038	$550	$150	$100	$800
2039	$540	$140	$100	$780
2040	$280	$120	$90	$490
2041	$250	$20	$70	$340
2042	$140	$0	$30	$170
2043	$90	$0	$30	$120
2044	$60	$0	$30	$90
2045	$60	$0	$20	$80
2046	$60	$0	$20	$80
2047	$60	$0	$20	$80
2048	$60	$0	$20	$80
2049	$60	$0	$20	$80
2050	$60	$0	$20	$80
2051	$60	$0	$20	$80
2052	$60	$0	$20	$80
2053	$60	$0	$20	$80
2054	$60	$0	$20	$80
2055	$60	$0	$20	$80
2056	$60	$0	$20	$80
2057	$60	$0	$20	$80
2058	$60	$0	$20	$80
2059	$60	$0	$20	$80
2060	$60	$0	$20	$80
2061	$60	$0	$20	$80
2062	$60	$0	$20	$80
2063	$60	$0	$10	$70
2064	$60	$0	$10	$70
2065	$60	$0	$10	$70
2066	$60	$0	$10	$70

Table C-1. Annual Cost Profile (in Millions of 2000$) (Continued)

Year	MGR	WAST[a]	PI & I[b]	Total	Year	MGR	WAST	PI & I	Total
2067	$60	$0	$10	$70	2094	$60	$0	$10	$70
2068	$60	$0	$10	$70	2095	$60	$0	$10	$70
2069	$60	$0	$10	$70	2096	$60	$0	$10	$70
2070	$60	$0	$10	$70	2097	$60	$0	$10	$70
2071	$60	$0	$10	$70	2098	$60	$0	$10	$70
2072	$60	$0	$10	$70	2099	$60	$0	$20	$80
2073	$60	$0	$10	$70	2100	$60	$0	$20	$80
2074	$60	$0	$10	$70	2101	$60	$0	$20	$80
2075	$60	$0	$10	$70	2102	$70	$0	$20	$90
2076	$60	$0	$10	$70	2103	$70	$0	$20	$90
2077	$60	$0	$10	$70	2104	$70	$0	$20	$90
2078	$60	$0	$10	$70	2105	$70	$0	$20	$90
2079	$60	$0	$10	$70	2106	$180	$0	$30	$210
2080	$60	$0	$10	$70	2107	$560	$0	$50	$610
2081	$60	$0	$10	$70	2108	$600	$0	$60	$660
2082	$60	$0	$10	$70	2109	$540	$0	$60	$600
2083	$60	$0	$10	$70	2110	$530	$0	$60	$590
2084	$60	$0	$10	$70	2111	$530	$0	$60	$590
2085	$60	$0	$10	$70	2112	$550	$0	$50	$600
2086	$60	$0	$10	$70	2113	$590	$0	$50	$640
2087	$60	$0	$10	$70	2114	$600	$0	$50	$650
2088	$60	$0	$10	$70	2115	$600	$0	$50	$650
2089	$60	$0	$10	$70	2116	$450	$0	$40	$490
2090	$60	$0	$10	$70	2117	$90	$0	$20	$110
2091	$60	$0	$10	$70	2118	$80	$0	$20	$100
2092	$60	$0	$10	$70	2119	$10	$0	$20	$30
2093	$60	$0	$10	$70	Total[c]	$42,070	$6,800	$8,650	$57,520

[a] The WAST total includes the Nevada Transportation costs.

[b] The PI&I column combines the Program Integration and Institutional costs.

[c] Column totals do not add exactly due to rounding.

NOTE 1: For TSLCC purposes, costs have been rounded to $10M dollars for the 2006 through 2119 time period. PI&I costs includes non-OCRWM costs that are not part of OCRWM budget requests.

NOTE 2: These cost estimates reflect DOE's best projections, given the scope of work identified and the planned schedule of required activities. Future events and information could result in changes to both costs and schedules. Future budget requests for the program have yet to be established and will be determined through the annual Executive and Congressional budget process.

NOTE 3: Historical Costs are shaded.

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