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Monitored Geologic Repository Project Description Document

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Monitored Geologic Repository Project Description Document

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REVISION RECORD

Revision Number	ICN/DCN No.	Effective Date	Description of Change
00	--	06/09/99	Initial issue. Only Sections 1, 2.5, and 5 and Appendices A, B, C, and D. Supersedes *the Controlled Design Assumptions Document*, B00000000-01717-4600-00032 Rev. 05.
00	DCN 01	11/24/99	Added performance criteria in Section 2.1.1 and design constraints in Section 2.1.1 and design constraints in Section 2.2.1.1 to capture Guidelines for Implementation of Enhanced Design Alternative II. Added one assumption to Section 2.5 to indicate that the design constraints are to provide assumed design solutions for use in Performance Assessment to support Site Recommendation decision. Updated one assumption and withdrew two assumptions based on LADS results. Updated another assumption to eliminate conflict with current design and performance assessment efforts in support of Site Recommendation decision. Modified Section 1.1.2 to define expanded phasing of the development of the document to reflect this change and a planned revision to capture Interim Regulatory Guidance and other requirements imposed by DOE prior to completing the other parts of the document. Included related changes in Preface, Acknowledgements, Section 6, Appendix A, and Appendix D. Affected pages: title page, signature page, v, vi, vii, viii, ix, x, xi, 1, 2, 2a, 6, 7, 9, 9a, 9b, 9c, 20, 34, 35, 41, 42, 44, 54a, 54b, 57, 60, 61, 62, 67, 68, 69, 70, 71, A-1, A-2, C-1, C-2, C-3, C-4, C-5, C-9, C-14, C-15, D-1, D-2, D-3, E-1, and E-2.
01	--	03/30/00	Document identifier changed, supersedes B00000000-01717-1705-00003 REV 00. Reorganized document structure due to expanded scope. Added Section 2 to capture the current SR design and to include a description of repository operations. Added Section 3 to address repository safety. Added Section 4 to address repository architecture, functions, and interfaces. Revised and amended Section 5 (previously Sections 2.1-2.4) to reflect current SR design as per the *Approach to Implementing the Site Recommendation Design Baseline.* Updated Section 6 (previously Section 2.5) to reflect the current design assumptions. Reorganized appendices for clarity and appropriate support for changes described above.
01	01	06/02/00	Added clarification to Section 2 for subsurface facility description. Added explanatory text for Section 5.1.4 for ease of traceability of inventory. Provided miscellaneous editorial changes to improve readability. Withdrew assumptions in Section 6 as appropriate to the SR design. Changes throughout document in

REVISION RECORD

Revision Number	ICN/DCN No.	Effective Date	Description of Change
			response to DOE and Change Control Board comments. This document supersedes "Monitored Geologic Repository Architecture," B00000000-01717-5700-00011 REV 03 ICN 01.
01	02	08/25/00	Added description of natural site characteristics (Section 2.2), a description of the WP sealing (Sections 2.3, 2.4), and Natural Barriers (Section 2.6.2). Added a description of TSPA process (Section 7). Added figures to describe natural site characteristics (Figures 2-1 through 2-6, 2-8, and 2-26). Added figures in support of TSPA process description (Figures 7-1 through 7-15). Provided Table 1-1 in Section 1 that identifies the portion of the information in this document that is under CM baseline control. These changes were made in response to DOE direction. Various editorial changes throughout document to improve clarity. All text changes are identified by the use of change bars in the margin.
02	--	09/30/00	This revision adds the flowdown and traceability of all the MGR requirements from the "Monitored Geologic Repository Requirements Document." Also added were sections describing preclosure safety, system interfaces, and confirmation verification. Several CPAs from Section 6 were withdrawn. Editorial changes were made throughout the document.
02	01	01/30/01	This change incorporates the conditions and comments directed by DOE in response to YDAR 26476. All text changes are identified by the use of change bars in the margin. Environmental specification design constraints were added to Section 5. SR Critical TBXs were resolved in REV 02 for design purposes and incorporated in the following sections: TBD 0234 - 5.2.29, 5.2.24, 5.2.30, 5.2.25, 5.2.26, 5.2.27, 5.2.28 TBD 0389 - 5.2.25 TBD 3882 - 5.2.10 TBV 0358 - 5.2.3, 5.2.4 TBV 0286 - 5.2.29 TBV 0287 - 5.2.24 TBV 0322 - 5.2.30 TBV .3881 - 5.2.29, 5.2.24, 5.2.30, 5.2.25, 5.2.26, 5.2.28 Although the above TBVs are resolved for design purposes, many of them maintain an "open" status as reflected in DIRS, and will not be given "resolved" status in DIRS by any work done in this document.

REVISION RECORD

Revision Number	ICN/DCN No.	Effective Date	Description of Change
02	02	04/01/01	This change incorporates the requirements and description changes in support of the operational flexibility over a range of thermal modes, updates the heat output and inventory for the commercial and DOE waste forms, and updates the document to reflect the revision of the YMP RD.

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ACRONYMS, ABBREVIATIONS, SYMBOLS, AND UNITS

ACRONYMS AND ABBREVIATIONS

A list of the system designator acronyms is located in Appendix A.

ALARA	As Low As Reasonably Achievable
AP	Absorber Plates included in waste package
ATS	Assembly Transfer System
BWR	Boiling Water Reactor
CFu	Crafter Flat Group undifferentiated
CHn	Calico Hills Formation nonwelded
CPA	Controlled Project Assumptions
CQ	Conventional Quality
CRD	Civilian Radioactive Waste Management System Requirements Document
CRWMS	Civilian Radioactive Waste Management System
CR	Control Rods included in waste package
CSNF	Commercial Spent Nuclear Fuel
CTS	Canister Transfer System
CVM	Conformance Verification Matrix
DBE	Design Basis Event
DC	Disposal Container
DCN	Document Change Notice
DHLW	Defense High-Level Waste
DOE	U. S. Department of Energy
DPC	Dual-Purpose Canister
EBDRD	Engineered Barrier Design Requirements Document
EBS	Engineered Barrier System
EDA	Enhanced Design Alternative
EIS	Environmental Impact Statement
ESF	Exploratory Studies Facility
ES&H	Environmental Safety and Health
HEPA	High-Efficiency Particulate Air
HHV	Heavy-Haul Vehicle
HLW	High-Level Waste
IPWF	Immobilized Plutonium Waste Form
LA	License Application
LADS	License Application Design Selection
LLW	Low-Level Waste
LWT	Legal-Weight Truck

ACRONYMS AND ABBREVIATIONS (Continued)

M&O	Management and Operating Contractor
MCO	Multi-Canister Overpak
MGR	Monitored Geologic Repository
N/A	Not Applicable
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
NUREG	NRC Regulation
PAD	Performance Assessment Department
PDD	Monitored Geologic Repository Project Description Document
PSS	Preclosure Safety Strategy
PTn	Paintbrush Tuff nonwelded
PWR	Pressurized Water Reactor
QA	Quality Assurance
QL	Quality Level
R&RSD	Radiological and Regional Studies Department
RT	Regional Transportation
SFD	Surface Facilities Department
S&HD	Safety and Health Department
SDD	System Description Document
SED	Systems Engineering Department
SNF	Spent Nuclear Fuel
SPC	Single-Purpose Canister
SR	Site Recommendation
SSFD	Subsurface Facilities Department
SSCs	Structures, Systems, and Components
TBV	To Be Verified
TCw	Tiva Canyon welded
TSPA	Total System Performance Assessment
TSw	Topopah Spring welded
TSw1	Topopah Spring welded unit 1
TSw2	Topopah Spring welded unit 2
WP	Waste Package
WPD	Waste Package Department
YMP RD	Yucca Mountain Site Characterization Project Requirements Document
YMSCO	Yucca Mountain Site Characterization Office

SYMBOLS AND UNITS

%	percent
°C	degrees Celsius
cm	centimeters
ft	feet
Hz	Hertz
kW	kilowatt
mm	millimeters
mrem	milli-Roentgen equivalent man
mR	milli-Roentgen
MT	metric ton
MTHM	metric tons heavy metal
pH	potential of Hydrogen

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1. INTRODUCTION

1.1 OBJECTIVES

The primary objective of the Monitored Geologic Repository Project Description Document (PDD) is to allocate the functions, requirements, and assumptions to the systems at Level 5 of the Civilian Radioactive Waste Management System (CRWMS) architecture identified in Section 4. It provides traceability of the requirements to those contained in Section 3 of the *Yucca Mountain Site Characterization Project Requirements Document* (YMP RD) (YMP 2001a) and other higher-level requirements documents. In addition, the PDD allocates design related assumptions to work products of non-design organizations. The document provides Monitored Geologic Repository (MGR) technical requirements in support of design and performance assessment in preparing for the Site Recommendation (SR) and License Application (LA) milestones. The technical requirements documented in the PDD are to be captured in the System Description Documents (SDDs) which address each of the systems at Level 5 of the CRWMS architecture. The design engineers obtain the technical requirements from the SDDs and by reference from the SDDs to the PDD. The design organizations and other organizations will obtain design related assumptions directly from the PDD. These organizations may establish additional assumptions for their individual activities, but such assumptions are not to conflict with the assumptions in the PDD. The PDD will serve as the primary link between the technical requirements captured in the SDDs and the design requirements captured in U.S. Department of Energy (DOE) documents. The approved PDD is placed under Level 3 baseline control by the CRWMS Management and Operating Contractor (M&O) and the following portions of the PDD constitute the Technical Design Baseline for the MGR: the design characteristics listed in Table 1-1, the MGR Architecture (Section 4.1), the Technical Requirements (Section 5), and the Controlled Project Assumptions (Section 6).

1.2 SCOPE

The PDD addresses the technical requirements and design related assumptions associated with the engineered components of the MGR. Where appropriate, it provides the background and rationale for the technical requirements and design-related assumptions. The PDD includes a summary of the elements and structure of the MGR architecture; summarizes the performance functions, interfaces, requirements, design criteria, design constraints, and assumptions that apply to the MGR engineered components; and allocates the technical requirements to the appropriate MGR systems and/or work products. The PDD also addresses the concepts for verifying that the designs are compliant with the technical requirements.

1.3 BACKGROUND

The PDD is being developed in phases. The first phase, which resulted in REV 00, consisted of Controlled Project Assumptions (CPAs). The second phase, which resulted in REV 00 DCN (Document Change Notice) 01, provided performance criteria and design constraints to capture the "Guidelines for Implementation of EDA II" (Enclosure 2 to Wilkins and Heath 1999). The third phase, which resulted in REV 01, ensures that all DOE design requirements are captured and allocated to the appropriate Level 5 system (SDD level). The fourth phase (REV 02 and REV 02 ICN 01) provided full flow-down and traceability from the YMP RD (YMP 2001a) to the PDD. This version (REV 02 ICN 02) addresses the Flexible Operation Design Concept and updates the document to reflect the YMP RD (YMP 2001a). The interfaces and confirmation verification sections were also added. Because this is a living document that must remain viable in a dynamic design environment, other additions and changes are expected on a regular basis leading up to and beyond the LA milestone.

1.3.1 PDD REV 00–Controlled Project Assumptions

The purpose of the CPAs is to provide a consistent program-wide framework for planning and conducting both design and non-design activities. The initial focus of the CPAs contained in PDD REV 00 was on consistent assumptions for design; however, design related assumptions also are included to support non-design activities, such as performance assessment or environmental impact analysis. These assumptions are applicable to the SR and LA design, and replace the *Controlled Design Assumptions Document* (CRWMS M&O 1998a) which was applicable to Viability Assessment design. The CPA documentation lists each assumption, provides its rationale, allocates it to MGR systems and/or work products/activities, allocates its applicability to M&O user organizations, and assigns responsibility for establishing and maintaining the assumption to one or more M&O organizations.

1.3.2 PDD REV 00 DCN 01–Design Constraints and Criteria for Implementing Enhanced Design Alternative (EDA) II

Guidelines for implementing the EDA II that had been selected as a result of the License Application Design Selection effort were issued in Enclosure 2 to the Wilkins and Heath letter providing *Direction to Transition to Enhanced Design Alternative II* (Wilkins and Heath 1999). This revision captures these "Guidelines for Implementation of EDA II" (Enclosure 2 to Wilkins and Heath 1999) in the form of performance criteria and design constraints. It also updates the CPAs by adding assumptions to reflect the EDA II characteristics and support its implementation.

1.3.3 PDD REV 01

This revision added descriptions of the MGR physical features and operational concepts. Also included were the CRWMS architecture and the results of updated functional and requirements development. The technical requirements expanded to include appropriate requirements from the YMP RD (YMP 2001a; formerly the *Monitored Geologic Repository Requirements Document*, YMP/CM-0025, Rev 03, DCN 02), any new or modified design criteria or constraints (Stroupe 2000), and the allocation of technical requirements to Level 4 of the MGR architecture.

1.3.4 PDD REV 01 ICN 01

This change added clarification to the subsurface facility description and waste inventory traceability. DOE and Change Control Board comments were incorporated throughout the document. Upon issuance of this document, the *Monitored Geologic Repository Architecture* was superseded.

1.3.5 PDD REV 01 ICN 02

This change adds descriptions of the natural site characteristics and the Total System Performance Assessment (TSPA) process. Additional graphics are added to enhance these descriptions. A summary table (Table 1-1) of the configuration management baseline-controlled elements of the repository design is added.

1.3.6 PDD REV 02

This revision adds the flowdown and traceability of all the MGR requirements from the YMP RD (YMP 2001a; formerly the *Monitored Geologic Repository Requirements Document*, YMP/CM-0025, Rev 03, DCN 02). Also added were sections describing preclosure safety, system interfaces, and confirmation verification. Environmental specification design constraints were added to Section 5. Several CPAs from Section 6 were incorporated into Section 2 or Section 5, or withdrawn.

The following SR-critical TBXs were resolved for design purposes: TBD-0234, TBD-0389, TBD-3882, TBV-0358, TBV-0286, TBV-0287, TBV-0322, and TBV-3881. While some of these TBXs have been completely resolved (by analysis, calculation, or mandate, etc.), some maintain an "open" TBX status due to the lack of any qualified analysis of calculation, and are so indicated in the Document Input Reference System. The latter of these are considered resolved only for design purposes, and technical requirements have been provided in this revision for that purpose.

1.3.7 PDD REV 02 ICN 01

This change addresses the conditions and comments directed by DOE in response to REV 02.

1.3.8 PDD REV 02 ICN 02

This change addresses the operational flexibility to achieve a range of thermal goals, the YMP RD (YMP 2001a), the direction to add the legal obligation caveat to the receipt rate schedules, and editorial and technical updates to reflect any updated references that are cited.

1.4 HIERARCHY

The ultimate role of the PDD is to pass along technical requirements from higher level requirements documents by allocating functions, interfaces, requirements, criteria, constraints, and assumptions to the systems reflected in SDDs as depicted in Figure 1-1. Figure 1-1 represents the ultimate objective of the hierarchy of requirements documents. As indicated in Figure 1-1, the documents are shown in order of their precedence (level of authority with respect to other requirements documents); i.e., the order of precedence from top to bottom is *Civilian Radioactive Waste Management System Requirements Document* (CRD, DOE 2000b), YMP RD (YMP 2001a), PDD, and SDDs.

As indicated in Section 1.1, design engineers will obtain the technical requirements from the SDDs and, by reference where appropriate, from the PDD.

1.5 QUALITY ASSURANCE

The QAP-2-0 activity evaluation for the development of the PDD (Rindskopf 1999) indicated that the activity is subject to the requirements of the *Quality Assurance Requirements and Description* (DOE 2000a). Consequently, this document is being updated and maintained in accordance with AP-3.11Q, *Technical Reports.*

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent versions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

No method of controlling electronic management of data was specified in the development plan of this document. Electronic management of data has not been used in the preparation of this document. No computer software or models were used in the generation of this report.

1.6 DOCUMENT ORGANIZATION

This document is organized to give the reader an overall description of the repository and how it is expected to operate.

Section 2 provides the design and operational descriptions necessary to create the context of a total, operational repository.

Section 3 provides a summary of the safety arguments important in the development and operation of the repository.

Section 4 provides the architectural structure of the facilities, structures, systems, subsystems, and major components that make up the repository. It also provides the start of a functional description of the repository. The important functions of the repository are identified and discussed, and related to the architectural items. In addition, system interfaces are identified.

Section 5 provides the technical requirements for those already familiar with the description and architecture of the MGR, and should be the most useful section in the document for those with this knowledge. This section also provides a table that allocates the technical requirements components to the appropriate items of the architectural structure.

Section 6 provides the assumptions that are intended to provide consistent guidance to all organizations working on the program. It is anticipated that, with time, these assumptions will either work their way into the technical requirements, the design solution, or will be eliminated.

Section 7 provides the description of how to verify that the design solution is in compliance with the appropriate technical requirements. The TSPA process is described as one way of accomplishing this verification.

Section 8 provides a list of the documents, regulations, standards, etc., that are cited throughout this document.

1.7 SALIENT MGR FEATURES/ATTRIBUTES CONTROLLED BY THE TECHNICAL BASELINE PROCESS

The features and attributes listed in Table 1-1 summarize those salient portions from this document that are controlled by the Technical Baseline process. For each baselined item, the highest Configuration Management level controlling that item is listed. Each item is designated as a requirement or a solution, as appropriate. This document is not the source document for any level 1 or level 2 requirements identified in Table 1-1. A complete set of the level 1 and level 2 requirements can be found in the CRD (DOE 2000b) and the YMP RD (YMP 2001a). Solutions identified in Table 1-1 are described in greater detail in other sections of this document, and their sources are cited as appropriate.

The baselined items are presented in categories that include those Configuration Items that have baselined features or attributes associated with them. Configuration Items are the systems of the Level 5 Architecture of the MGR. For a complete list of these systems (Configuration Items), see Appendix A.

Table 1-1. Salient MGR Features/Attributes

Category	Feature/Attribute	Value	Control Level[1]	Requirement (R) or Solution (S)	Location in PDD
MGR Site Layout	North Portal Area (excluding Surface Facility For Aging)	Nominal 150 acres	3	S	2.3
	South Portal Area (excluding Muck Storage)	Nominal 37 acres	3	S	2.3
MGR – Waste Receipt	Receipt Mode Capability	Rail, LWT and HHV	1	R	2.4
	Transportation Cask Storage	15 LWT 5 HHV 140 Rail Cars	3	R	5.2.22
	CSNF Steady-State Receipt Rate	Nominal 3,000 MTHM/yr	1	R	5.1.4.3
	HLW Steady-State Receipt Rate	Nominal 840 Canisters/yr	3	R	5.1.4.4
	DOE SNF Steady-State Receipt Rate	Nominal 150 Canisters/yr	3	R	5.1.4.4
	Naval SNF Steady-State Receipt Rate	Peak: 15 Canisters/yr	3	R	5.1.4.4
	IPWF Receipt Rate	Nominal 60 Canisters/yr	1	R	5.1.4.4
	Peak WP Throughput	572 WP/yr	3	S	2.4
Emplacement Drift Environmental Specifications	Emplacement Drift Wall Temperature	Normal Preclosure Operations: ≤96°C Postclosure Maximum: 200°C	3	R	5.2.24
	WP surface temperature (for low end of range of thermal modes)	<85°C	3	R	5.1.1.3
	Long Term Accumulation of Water in Rock Above Emplacement Dirfts (for high end of range of thermal modes)	Free Drainage in Pillars	1	R	5.1.1.3
	Emplacement Drift Humidity	EBS SSCs Designed to Accommodate 95%	3	R	5.2.25
	Emplacement Drift Seepage Rate	EBS SSCs Designed to Accommodate Seepage per 5.2.26	3	R	5.2.26
	Emplacement Drift Drainage	Based on Seepage per 5.2.27	3	R	5.2.27

Table 1-1. Salient MGR Features/Attributes (Continued)

Category	Feature/Attribute	Value	Control Level[1]	Requirement (R) or Solution (S)	Location in PDD
Emplacement Drift Environmental Specifications (cont'd)	Emplacement Drift Seepage pH	EBS SSCs Designed to Accommodate pH Range of 7-11	3	R	5.2.28
	Maximum Zeolite Temperature	90°C	3	R	5.2.29
	Maximum PTn Geologic Unit Temperature	70°C	3	R	5.2.30
MGR Inventory	MGR WP Inventory, Size, and Heat Output	See below	3	R	5.2.3, 5.2.4

Category	WP Loading Configuration	Approximate Length (m)	Base Case/Full Inventory Nominal Heat Output/WP (kW)	Base Case/Full Inventory Nominal[2] Quantities	Base Case/Full Inventory Quantities (NTE)[2]
MGR Inventory	21 PWR AP	5.17	11.53/11.33	4299/5690	4,500/5,700
	21 PWR CR	5.17	3.11/3.26	95/106	100/110
	12 PWR AP Long	5.65	9.55/8.97	163/293	170/300
	44 BWR AP	5.17	7.38/7.00	2831/3732	3,000/3,750
	24 BWR AP	5.11	0.52/0.54	84/96	90/100
	5 IPWF	3.59	3.53/3.53	95/127	100/130
	5 DHLW/1 DOE SNF Short	3.59	2.98/2.98	1052/1403	1,100/1,410
	5 DHLW/1 DOE SNF Long	5.22	0.407/0.407	1406/1874	1,500/1,880
	2 MCO/2 DHLW	5.22	1.67/1.67	149/199	160/200
	5 HLW Long/1 DOE SNF Short	5.22	0.407/0.407	126/167	130/170
	HLW Long only	5.22	0.282/0.282	584/780	600/800
	Naval Short	5.43	3.07/3.07	200/200	200/200
	Naval Long	6.07	3.07/3.07	100/100	100/100

Table 1-1. Salient MGR Features/Attributes (Continued)

Category	Feature/Attribute	Value	Control Level[1]	Requirement (R) or Solution (S)	Location in PDD
MGR Inventory (cont'd)	CSNF (MTHM)	Base Case: 63,000, Full Inventory: 83,800, Maximum EIS: 105,000	1	R	5.1.4.1, 5.1.4.2, 2.3
	DOE SNF (MTHM)	Base case: 2,333, Full Inventory: 2,500, Maximum EIS: 2,500	1	R	5.1.4.1, 5.1.4.2, 2.3
	DHLW (MTHM)	Base Case: 4,027, Full Inventory: 10,923, Maximum EIS: 11,140	1	R	5.1.4.1, 5.1.4.2, 2.3
	Commercial HLW (MTHM)	All Cases: 640	1	R	5.1.4.1, 5.1.4.2, 2.3
	DHLW Canister Equivalence	1/2 MTHM	3	S	2.3
MGR – TSPA	TSPA Implementation Methodology	Stochastic Assessment of Integrated Abstractions of System Components	3	S	7.1
	Disruptive Events Analyzed in TSPA	Earthquake, Human Intrusion, Volcanic Eruption/Dike Intrusion	3	S	7.2
	System Components Analyzed in TSPA	Natural System, Engineered System, Biosphere	3	S	7.1
	Natural System Components Analyzed in TSPA	Climate and Infiltration, UZ Flow and Transport, SZ Flow and Transport, Near-Field Environment	3	S	7.1
	Engineered System Components for TSPA	In-Drift Geochemical Environment, EBS Flow, WP, Waste Form, EBS Transport	3	S	7.1
MGR – Natural System	Fault Displacements in Yucca Mountain Area	See below	3	S	2.2.2

Table 1-1. Salient MGR Features/Attributes (Continued)

Category	Feature/Attribute	Value	Control Level[1]	Requirement (R) or Solution (S)	Location in PDD
MGR – Natural System (cont'd)	**Faults**	**Tertiary Age**		**Quaternary Age**	
	Windy Wash Fault	< 500 m		0.08 – 1.0m	
	Fatigue Wash Fault	≈ 75 m		< 2.2 m	
	Solitario Canyon Fault	61 m – 500 m		≤ 2.1 m	
	Sundance Fault	≤ 11 m		0	
	Ghost Dance Fault	≈ 30 m		0	
	Dune Wash Fault	50 m – 100 m		0	
	Bow Ridge Fault	≥ 125 m		20 cm – 165 cm	
	Midway Valley Fault	≤ 60 m		0	
	Paintbrush Canyon Fault	250 m – 500 m		1 m – 8 m	
Category	**Feature/Attribute**	**Value**	**Control Level[1]**	**Requirement (R) or Solution (S)**	**Location in PDD**
MGR – Natural System (cont'd)	Seismic Event Categories	Frequency Category 1 and 2	3	R	5.1.3.2
	Surface Design Nominal Seismic Acceleration	0.8 g Horizontal, 0.9 g Vertical	3	S	2.2.2
	Repository Stratigraphic Location	Topopah Spring Welded Tuff unit	3	S	2.3
	Upper Bound of Precipitation	277.5 mm/yr	3	S	2.2.3
	Upper Bound of Infiltration	11.6 mm/yr	3	S	2.2.3
	Erosion Rate for Unconsolidated Material on Hillslopes	<0.5 cm/ky	3	S	2.2.3
	Erosion Rate for Bedrock on Ridge Crests	0.1 – 0.3 cm/ky	3	S	2.2.3
MGR – Architecture	MGR Architecture	Per figures 4-2, 4-3, and 4-4 (this document)	3	S	4.1 and figures 4-2, 4-3, 4-4
MGR - Operation	Operator Qualification	Trained and NRC Certified	3	R	5.3.1
	Emplacement Drift Personnel Access	Limited-Time Personnel Access for Operational Upset Conditions	3	R	5.3.2
	Operational Flexibility to Achieve a Range of Thermal Goals	Variation of Duration of Repository Operation and Ventilation, WP Spacing, and Heat Output, and Surface Facility Aging	3	R	5.3.6

Table 1-1. Salient MGR Features/Attributes (Continued)

Category	Feature/Attribute	Value	Control Level[1]	Requirement (R) or Solution (S)	Location in PDD
Site Electrical Power	Alternative Energy Source	Solar Power	1	R	2.3
Waste Handling Building System	Processing Lines	1 Dry CTS, 2 Wet ATS	3	S	2.4
	Liquid Waste Handling	Off-site Disposal	3	R	5.2.21
Assembly Transfer System	Blending Inventory Capacity	5,000 MTHM	3	R	5.2.14
Aging Facilities-Surface	Quantity and Duration of Aging	40,000 MTHM for up to 30 years	3	R	5.2.14
Disposal Container Handling System	Weld Stations	1 Cell, 15 Stations	3	S	2.4
Subsurface Facility	Emplacement Drift Spacing	81 m	3	R	5.2.1
	Emplacement Drift Diameter	Nominal 5.5 m	3	R	5.2.5
	Access Main Drift Diameter	Nominal 7.62 m	3	S	2.5
	Exhaust Main Drift Diameter	Nominal 7.62 m	3	S	2.5
	Repository Footprint Area	1,100 acres to 3,000 acres	3	S	2.3
	Emplacement Drift Orientation	North 72° East (Nominal)	3	S	2.5
	Operational Period[3]	Maximum: 300 years after final Emplacement Minimum: 30 years after final emplacement	1	R	5.1.1.1
	Non-emplacement Drifts, Shafts, Boreholes, and Ramps	Backfilled and Sealed during Closure Phase	3	S	2.10
Ground Control System	Emplacement Drift Ground Support	Steel Sets and/or Rock Bolts and Mesh	3	R	5.2.6
	Emplacement Drift Integrity	Open and Stable During Entire Preclosure Period	3	R	5.2.7
	Design Basis Rockfall for Preclosure and Postclosure	6 MT	3	S	2.5
Subsurface Ventilation System	Emplacement Drift Ventilation Rate	15 m^3/s	3	S	2.7
Uncanistered SNF Disposal Container	Maximum Capacity	21 PWR or 44 BWR	3	S	2.6.1
	WP Materials (Nominal)	50 mm 316 SS, 20 mm alloy 22	3	R	5.2.12

Table 1-1. Salient MGR Features/Attributes (Continued)

Category	Feature/Attribute	Value	Control Level[1]	Requirement (R) or Solution (S)	Location in PDD
Uncanistered SNF Disposal Container (cont'd)	Closure (top) Lids	1 316 SS lid and 2 alloy 22 lids	3	S	2.4
	Stress Relief for Closure Welds	Laser Peening and Induction Annealing	3	S	2.4
DHLW Disposal Container	Maximum Capacity	[5 DHLW and 1 DOE SNF] or [2 MCO and 2 DHLW]	3	S	2.6.1
	WP Materials (Nominal)	50 mm 316 SS, 25 mm alloy 22	3	S	2.6.1
	Closure (top) Lids	1 316 SS lid and 2 alloy 22 lids	3	S	2.4
	Stress Relief for Closure Welds	Laser Peening and Induction Annealing	3	S	2.4
Naval SNF Disposal Container	Maximum Capacity	1 Naval SNF Canister	3	S	Figure 2-14
	WP Materials (Nominal)	50 mm 316 SS, 25 mm alloy 22	3	S	2.6.1
	Closure (top) Lids	1 316 SS lid and 2 alloy 22 lids	3	S	2.4
	Stress Relief for Closure Welds	Laser Peening and Induction Annealing	3	S	2.4
All Disposal Container Systems	Zirconium Alloy Cladding (where applicable)	Preserve and not accelerate degradation	1	R	5.1.1.2
	Shielding	Sufficient to Protect WP from Radiation Enhanced Corrosion	3	R	5.2.23
	Max WP Heat Output	11.8 kW	3	R	5.2.13
Emplacement Drift System	Drip Shield/Structural Members	Titanium Grade 7, minimum 15 mm thickness/Titanium Grade 24	3	R	5.2.11
	WP Pallets	Alloy 22 Ends, SS Cross Members	3	S	2.4
	WP Spacing	Minimum: 10 cm	3	R	5.2.10
	Emplacement Drift Linear Heat Load	Maximum: 1.5 kW/m	3	R	5.2.10
	Emplacement Drift Invert	Carbon Steel Frame with Granular Ballast	3	R	5.2.8

Table 1-1. Salient MGR Features/Attributes (Continued)

Category	Feature/Attribute	Value	Control Level[1]	Requirement (R) or Solution (S)	Location in PDD
Assumptions	CPA 002	LLW Disposal at NTS	3	S	6
	CPA 014	Source of Water	3	S	6
	CPA 015	Telephone Communications	3	S	6
	CPA 027	Applicability of Mine Safety and Health Administration Regulations	3	S	6
	CPA 037	Credit for SNF Cladding	3	S	6
	CPA 038	Transportation Mode/Route within Nevada	3	S	6

[1]Refers to Level 1, 2, or 3 of the Change Control Board/Configuration Management process.

[2]NTE quantities are rounded values and represent "not to exceed" (NTE) values for each WP category. The nominal values are those used to specify the quantities described in 5.1.4.1 and 5.1.4.2.

[3]These operational periods do not include the duration of closure activities.

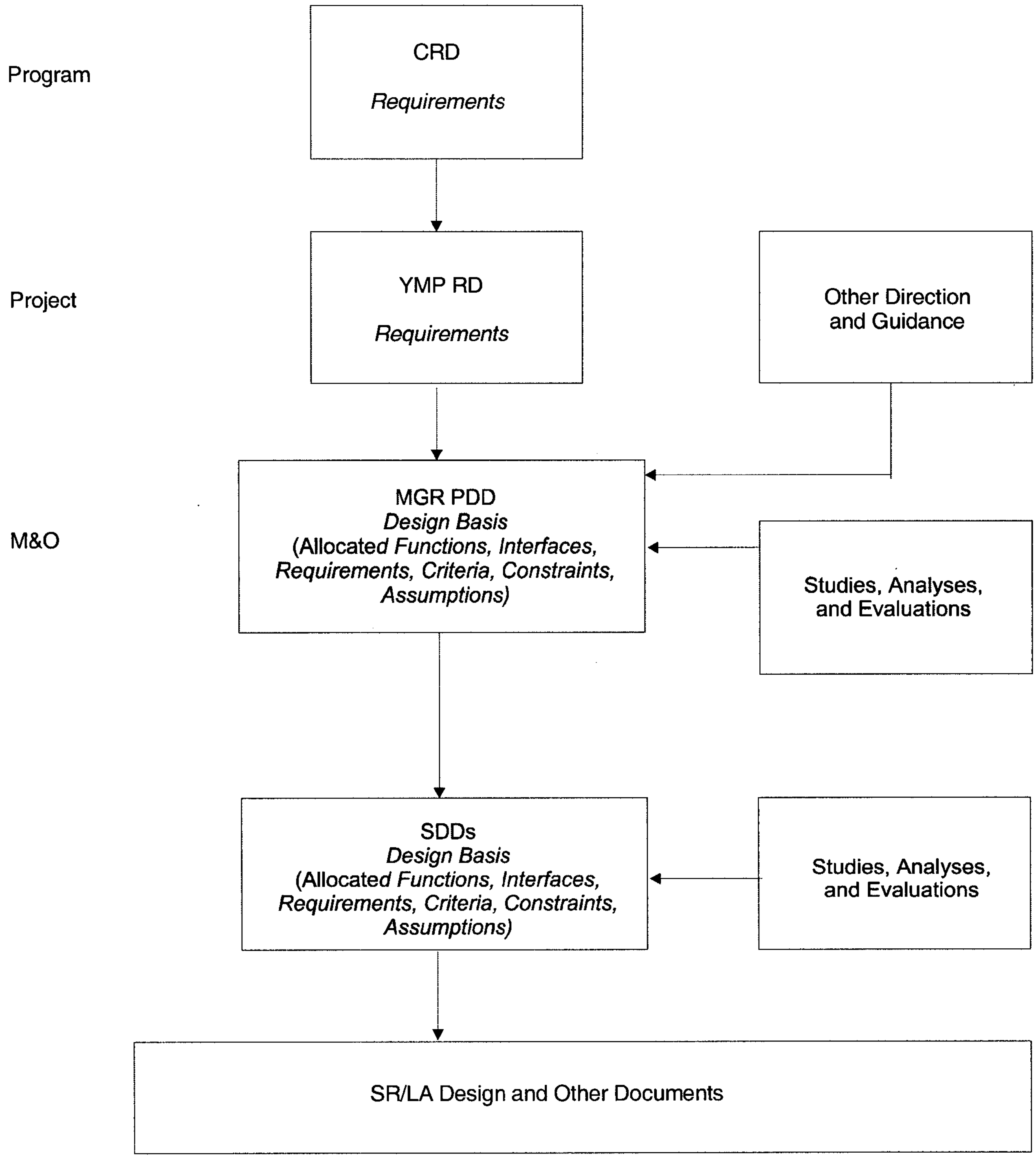

Figure 1-1. Document Hierarchy for SR/LA Technical Requirements

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2. REPOSITORY DESCRIPTION

The proposed MGR at Yucca Mountain is designed to safely receive, handle, emplace, and monitor radioactive waste and to provide a combination of natural and engineered features to contain and isolate waste for 10,000 years (Dyer 1999, Section 113(b)), and is expected to continue to contain and isolate waste for hundreds of thousands of years. This combination of natural and engineered features serves to provide an environment that is safe for workers and the public during the period that the repository is open. Additionally, after closure of the repository, the features limit the water contacting the waste packages (WPs), provide a long WP lifetime, ensure a low rate of release from breached WPs, and reduce the radionuclide concentration during transport from the WPs (CRWMS M&O 2001b, Executive Summary).

The MGR consists of surface facilities and subsurface facilities with the nuclear waste being permanently stored in the waste emplacement block of the subsurface facility. The surface facilities at the North Portal to the underground area provide waste handling capability, Balance of Plant facilities, and engineering and operations support. The surface facilities at the South Portal to the underground area support the subsurface development activities conducted through the period that the repository is open.

Highly radioactive material (spent nuclear fuel (SNF) and high-level waste (HLW)) from commercial and government nuclear reactors and processing plants will be sent to the MGR for underground disposal. Disposal of this waste will be handled in compliance with applicable regulations governing SNF and HLW to protect the public and environment. The repository design will maintain nuclear criticality control, preventing critical conditions during the 10,000 year regulatory period.

The proposed MGR incorporates a design that is compatible with modular construction approaches, variations in operational parameters that accommodate a range of thermal modes, and continual optimization in design. This operational flexibility allows for variation in:

- Ventilation flow rate, method, and duration
- WP spacing and heat load
- Repository closure timing
- Surface aging and blending of SNF.

This allows the MGR design to evolve while the selection of the thermal performance strategy is made.

Those items shown in Table 1-1 that are described in this section are included in the Technical Baseline in support of the SR. All other information in this section is provided for information only and is not considered part of the technical baseline.

2.1 MGR PHASES

There are six phases in the evolution of this repository:

- Site Characterization
- Construction
- Operations
- Monitoring
- Closure
- Postclosure.

The Site Characterization Phase includes those activities associated with:

- Gathering and evaluating data to determine the suitability of the site
- Predicting the performance of the repository
- Preparing conceptual, preliminary, and final repository designs
- Assessing the system performance
- Preparing the application for construction authorization and supporting its review
- Preparing the environmental impact statement and supporting its review
- Planning for the remainder of the phases.

The Construction Phase includes:

- Constructing surface and subsurface facilities
- Initial excavating of subsurface facilities
- Gathering data to support predictions of the repository performance
- Fabricating disposal containers
- Developing operational procedures
- Recruiting and training operational personnel
- Installing and testing operational equipment
- Demonstrating some repository operations
- Preparing an application for a license to receive and possess waste.

The Operations Phase includes:

- Receiving the waste
- Preparing WPs (disposal containers loaded with waste and sealed)
- Emplacing WPs in the repository
- Packaging and disposing of site generated waste
- Continued excavation of the subsurface facilities.

The Monitoring Phase includes:

- Safeguarding the waste
- Maintaining surface and subsurface facilities as required
- Maintaining the ventilation equipment and pathways, as required

- Protecting the retrieval option
- Gathering data to support predictions of the repository performance
- Completing designs of closure systems
- Preparing an application to amend the repository license for permanent closure.

The Closure Phase includes:

- Placing drip shields over the WPs (drip shield emplacement could occur prior to closure activities)

- Closing and sealing the subsurface facilities

- Decontaminating and removing the surface facilities and selected subsurface components

- Placing fences, warning signs and monuments to secure the site

- Creating institutional barriers

- Returning the site to as natural a condition as required by the U.S. Nuclear Regulatory Commission (NRC).

Following repository closure, the WPs will contain the radioactive waste for tens of thousands of years. Even after the WPs have degraded, the surrounding geologic environment is expected to prevent nearly all of the released radioactive materials from leaving the repository region, thereby complying with the requirements during the regulatory time frame.

2.2 SITE DESCRIPTION

Sections 2.2.1, 2.2.2, and 2.2.3, unless otherwise noted, are taken from Volume I of *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a, Section 2.2).

2.2.1 Regional Setting

Yucca Mountain is in the Basin and Range province of the western United States within the region known as the Great Basin (Figure 2-1). The Great Basin encompasses nearly all of Nevada and parts of Utah, Idaho, Oregon, and California. The mountain ranges of the Great Basin, such as Yucca Mountain, are mostly north-south aligned, tilted, fault-bounded blocks that may extend more than 80 km (50 miles) in length and are generally 8 to 24 km (5 to 15 miles) wide. Relief between valley floors and mountain ridges is typically 300 to 1,500 m (984 to 4,921 ft), and valleys occupy approximately 50 to 60 percent of the total land area. The valleys between ranges are filled with thick deposits of alluvium derived from erosion of the adjacent ranges. This pattern is the result of generally east-west directed crustal extension that began in the Tertiary period and continues at present. The extension has caused complex faulting, resulting in ranges composed of tilted fault blocks bounded by major range-front faults.

Yucca Mountain is also influenced by a structural domain known as the Walker Lane (Figure 2-2), which extends northwest from Las Vegas, subparallel to the Nevada-California border, into California. The Walker Lane is a structural belt characterized by northwest-trending right-lateral faults and northeast-trending left-lateral faults. Walker Lane tectonic activity probably originated in the late Oligocene period (approximately 25 to 30 million years ago) as a result of northwest-directed extension.

In addition to faulting, crustal extension resulted in volcanic activity. The rocks composing Yucca Mountain are part of the southwestern Nevada volcanic field. This field was formed by the eruption of large volumes of volcanic rocks from multiple sources to the north, as evidenced by several calderas (extinct volcanic centers) and the widespread extent of volcanic deposits.

The lithology (rock type) and stratigraphy (the sequence in which rocks were deposited) of the regional geologic setting provide the basis for understanding the geologic history and evolution of the area, which is fundamental to analyzing geologic hazards such as those associated with earthquakes and volcanoes. Also, by controlling the regional flow of groundwater, the various rock types would directly control the migration of any potential releases from the repository. Finally, the stratigraphy and lithology provide the framework for understanding more local aspects of the Yucca Mountain site. The following summary briefly describes rock groups important to the regional geologic setting of Yucca Mountain:

Precambrian Era–Precambrian rocks (greater than approximately 570 million years in age) include two major rock types: an older, metamorphosed basement assemblage and a younger, metasedimentary assemblage. Both groups tend to retard the flow of groundwater except where extensive faulting or fracturing is present.

- **Paleozoic Era**–Paleozoic rocks (rocks ranging from approximately 570 million to 240 million years in age) in the Yucca Mountain region include lower (older) carbonate strata (limestone and dolomite); a middle, fine-grained shale, siltstone and sandstone unit; and an upper (younger) carbonate unit (limestone). The carbonate units form important aquifers throughout southern Nevada.

- **Mesozoic Era**–Strata from this era (rocks ranging from approximately 240 million to 66 million years in age) are generally absent near Yucca Mountain. Regionally, these strata are dominantly continental and shallow marine sediments (sandstones and siltstones) with minor Cretaceous granitic plutonic rocks. Structurally, the Mesozoic was a period of active tectonic activity characterized by regional compression.

- **Cenozoic Era**–Cenozoic rocks (66 million years in age to the present) near Yucca Mountain fall into three groups. The last two are of major importance to the Yucca Mountain site:

  - Pre-middle Miocene (greater than about 16 million years old) sedimentary rocks

  - Mid-to-late Miocene (15 million to 7.5 million years old) volcanic rocks that constitute the southwestern Nevada volcanic field, including Yucca Mountain

  - Plio-Pleistocene (3.7 million years old to modern) basalts and basin sediments.

The explosive volcanism that culminated in the formation of the southwestern Nevada volcanic field is the most significant depositional event of the Cenozoic era near Yucca Mountain. This event formed six major calderas (volcanic centers) between 15 million and 7.5 million years ago. This event also created the rocks of Yucca Mountain, and brought to a close the major regional tectonic activity that created the present Yucca Mountain geologic setting.

In evaluating the potential future hazards of volcanic events in the Yucca Mountain area, a probabilistic volcanic hazard analysis (PVHA) was conducted employing a 10-member expert panel. Each of the 10 experts independently arrived at a probability distribution for the intersection of the repository footprint by an intrusive basaltic dike that typically spanned about two orders of magnitude for the annual probability of intersection. From these individual probability distributions, an aggregate probability distribution was computed that reflects the uncertainty across the entire expert panel (CRWMS M&O 2000g). The distributions were combined using equal weights to obtain a composite distribution. The mean value of the aggregate probability distribution is 1.5×10^{-8} intersections per year, with a 90 percent confidence interval of 5.4×10^{-10} to 4.9×10^{-8} (CRWMS M&O 2000g, Section 12.2.6.1).

Results of the PVHA (CRWMS M&O 2000g) have been recalculated to account for the current footprint of the potential repository and extended to include the probability of an eruption within the repository footprint, conditional on a dike intersection (CRWMS M&O 2000g). The resulting values for the recalculated annual frequency of intersection of the repository footprint dike associated with a volcanic event, and the annual frequency of a volcanic event producing one or more eruptive centers within the repository are present in Table 2-1. The values listed in Table 2-1 are the weighted combination of the alternative models that were used for eruptive centers.

Table 2-1. Summary of Frequencies of Disruptive Volcanic Events

Potential Repository Footprint	Hazard Level	Annual Frequency of Intersection of Potential Repository by a dike	Weighted Conditional Probability of No Eruptive Centers	Annual Frequency of Occurrence of One or More Eruptive Centers within Potential Repository
Primary Block	5th percentile	6.6×10^{-10}	0.58	2.8×10^{-10}
	Mean	1.4×10^{-8}	0.53	6.7×10^{-9}
	95th percentile	4.7×10^{-8}	0.53	$2.2\ \ 10^{-8}$
Primary + Contingency Blocks	5th percentile	7.6×10^{-10}	0.56	3.3×10^{-10}
	Mean	1.6×10^{-8}	0.50	7.7×10^{-9}
	95th percentile	5.0×10^{-8}	0.51	2.5×10^{-8}

Source: CRWMS M&O 2000g.

The most recent deposits in the region consist of alluvial sediments formed during highland erosion.

2.2.2 Site Bedrock Geology

The characteristics of the rocks that would host the potential repository are important to virtually all aspects of repository design and performance assessment. The repository safety strategy (CRWMS M&O 2001b) is dependent on thoroughly understanding not only ambient site conditions, but also how the natural system would respond to conditions induced by facility construction and operation. System performance modeling requires knowledge of the hydrologic and transport properties of the rocks above, below, and in the repository horizon. Modeling also requires understanding how properties may be modified by the coupled thermal, hydrologic, mechanical, and geochemical processes that could occur following waste emplacement.

Stratigraphy–The bedrock at Yucca Mountain is composed of Mid-Tertiary volcanic rocks formed by eruptions of ash or magma from volcanic vents to the north (Figure 2-3, shown with one potential main drift layout). All of the individual units, therefore, get progressively thinner from north to south. Most of the rocks are ash flow tuffs, which are formed when a hot mixture of volcanic gas and ash violently erupts and flows at high velocity over the landscape. As the ash settles, it is subjected to various degrees of compaction and fusion depending on temperature and pressure. If the temperature is high enough, glass shards are compressed and fused to produce a welded tuff (a hard, brick-like rock with very little open pore space in the rock matrix). Nonwelded tuffs, which are compacted and consolidated at lower temperatures, are less dense and brittle, and they have higher porosity. Airfall tuffs are formed from ash cooled in the air before reaching the ground, and bedded tuffs are composed of ash that has been reworked by stream action. The major units within the Yucca Mountain section include (from the top down) the Paintbrush Group, composed of the Tiva Canyon tuff and the Topopah Spring tuff, the Calico Hills Formation, and the Crater Flat Group (Figure 2-4). At even greater depth, pre-Tertiary rocks, including the Paleozoic carbonate aquifer, are also present.

Paintbrush Group–The Tiva Canyon tuff is a large-volume, regionally extensive ash flow tuff that comprises most of the rocks exposed at the surface of Yucca Mountain. The unit is divided into two members: a lower crystal-poor member and an upper crystal-rich member. Each member has a characteristic geochemical composition: the lower member is a rhyolite, and the upper member is a quartz-latite.

The pre-Tiva Canyon tuff below the Tiva Canyon varies from nonwelded to partially or densely welded where it is thickest in the northern and western parts.

The lowermost unit in the Paintbrush Group is the Topopah Spring tuff, which is the strongly welded host rock for the potential repository. Like the Tiva Canyon tuff, the Topopah Spring tuff is compositionally zoned from a lower crystal-poor, high-silica rhyolite, to an upper crystal-rich quartz latite. Each member is divided into numerous zones and subzones based on feature variations such as crystal content and assemblage, size and abundance of pumice and rock fragments, distribution of welding and crystallization zones, fracture characteristics, and abundance of lithophysae (voids caused by volume gas bubbles).

The zones of the Topopah Spring tuff that will constitute the host rock for the repository, in descending order, are the lower part of the upper lithophysal zone, the middle nonlithophysal zone, the lower lithophysal zone, and the lower nonlithophysal zone. In turn, these four zones constitute the lower portion of the TSw1 thermal/mechanical unit and the underlying TSw2 thermal/mechanical unit of the repository host horizon. These two thermal/mechanical units are variable in their physical properties, which determine their waste isolation capabilities and their ability to conduct heat away from waste containers. Variations in their dry bulk and saturated bulk densities, average grain density, and calculated porosities from boreholes are summarized in Table 2-2 (CRWMS M&O 2000g, Tables 4.7-5 through 4.7-8). In addition, rock thermal conductivities, of the two thermal/mechanical units for temperatures both below and above 100°C are summarized in Table 2-3 (CRWMS M&O 2000g, Table 4.7-13).

Table 2-2. Summary of Bulk Densities, Average Grain Densities, and Porosities of Repository Thermal/Mechanical Units TSw1 and TSw2

Property		TSw1	TSw2
Dry Bulk Density (g/cc)			
	Range	1.94 - 2.40	1.84 - 2.42
	Mean	2.16	2.27
	Std. Dev.	0.08	0.08
Standard Bulk Density (g/cc)			
	Range	2.12 - 2.46	2.26 - 2.45
	Mean	2.30	2.37
	Std. Dev.	0.05	0.03
Average Grain Density			
	Range	2.50 - 2.60	2.42 - 2.61
	Mean	2.55	2.55
	Std. Dev.	0.02	0.03
Porosity (%)			
	Range	6.80 - 32.10	3.80 - 27.70
	Mean	15.90	11.30
	Std. Dev.	4.03	3.01

Table 2-3. Summary of the Rock Thermal Conductivities of Repository Thermal/Mechanical Units TSw1 and TSw2 Above and Below 100°C

Property		TSw1	TSw2
Thermal Conductivity (W/mk) (Below 100°C)			
	Saturated		
	Mean	1.70	2.29
	Std. Dev.	0.19	0.42
	Partially Saturated		
	Mean	1.23	ND*
	Std. Dev.	0.46	ND
	Air Dry		
	Mean	1.21	1.66
	Std. Dev.	0.12	0.10
	Dry		
	Mean	0.98	1.49
	Std. Dev.	0.26	0.44
Thermal Conductivity (W/mk) (Above 100°C)			
	Mean	1.15	1.59
	Std. Dev.	0.15	0.10

*ND = No data

Calico Hills Formation–The Calico Hills Formation is a series of rhyolite tuffs and lavas. Five separate ash flow units, overlying a bedded tuff unit and a locally occurring basal sandstone unit, have been distinguished.

Several characteristics of the Calico Hills Formation are particularly significant to repository performance models. None of the Calico Hills ash flows are strongly welded; therefore, the rocks have much lower strength than the Topopah Spring tuff (they are less brittle and hard), and they generally have higher porosities. Because of their lower strength, the fractures that are ubiquitous in welded tuffs are much less common in the Calico Hills.

Another important attribute of the Calico Hills is an abundance of zeolite minerals. Zeolites are silicate minerals that have the ability to sorb (attach or bind) radionuclides and other ions. These radionuclides and ions may be soluble in water. The Calico Hills Formation possesses a highly variable mixture of vitric and zeolite materials, resulting in variable sorptive characteristics. The process of sorption in the zeolite material may significantly slow the movement of many radionuclides away from a repository.

Crater Flat Group–The Crater Flat Group consists of three sequences of rhyolitic, moderate to large volume ash flow deposits, and interlayered bedded tuffs. In descending order, these formations are the Prow Pass, Bullfrog, and Tram tuffs.

Faulting and Structural Geology–The spatial and temporal distribution and properties of faults and fractures in the volcanic bedrock of Yucca Mountain are fundamental elements of the structural geology of the potential underground repository at Yucca Mountain. They control the hydrologic and rock mechanical properties of the system and, therefore, they may strongly affect both performance and design of the repository. Documentation and discussion of fault and fracture patterns are based on detailed surface and underground geologic mapping conducted at detailed scales from 1:2,400 to 1:24,000.

The structural geology of Yucca Mountain is controlled by block-bounding faults spaced 1 to 4 km (0.6 to 2.5 miles) apart. These faults include (from west to east) the Windy Wash, Fatigue Wash, Solitario Canyon, Bow Ridge, and Paintbrush Canyon faults (Figure 2-5). Dune Wash and Midway Valley faults are also block-bounding faults, but they differ from the other block-bounding faults in that they have no evidence of Quaternary movement (within the past 1.6 million years). The block-bounding faults commonly dip 45° to 85° to the west. Some of these fault dips are shown in Figure 2-4. Some left-lateral displacement is commonly associated with these faults (Day et al. 1997). The displacements of major faults in the immediate vicinity of Yucca Mountain are summarized in Table 2-4 (CRWMS M&O 2000g and DOE 1998a, p. 2-22).

Table 2-4. Fault Displacements in the Yucca Mountain Area

Fault	Tertiary Age	Quaternary Age
Windy Wash Fault	< 500 m	.08 - 1.0 m
Fatigue Wash Fault	≈ 75 m	< 2.2 m
Solitario Canyon Fault	61 m – 500 m	≤ 2.1 m
Sundance Fault	≤ 11 m	0
Ghost Dance Fault	≈ 30 m	0
Dune Wash Fault	50 m – 100 m	0
Bow Ridge Fault	≥ 125 m	20 cm – 165 cm
Midway Valley Fault	≤ 60 m	0
Paintbrush Canyon Fault	250 m – 500 m	1 m – 8 m

Displacement between the major block-bounding faults occurs along multiple smaller faults that intersect block-bounding faults at oblique angles. These "relay" faults are significant components of the block-bounding fault systems particularly in the southern half of Yucca Mountain. Most of the smaller faults occur in complex zones of faulting. Through most of the site area, block-bounding faults strike to the north and relay faults strike to the northwest; whereas, south of the site area, block-bounding faults strike to the northeast and relay faults strike to the north. Within structural blocks, small amounts of strain are accommodated along intrablock faults that may represent local structural adjustments in response to displacements on the block-bounding faults.

Ten structural domains within the site area have been defined, each characterized by a distinctive structural style. The patterns that characterize individual domains may include the nature and intensity of faulting, as well as magnitude and direction of bedrock dips. Most of the potential repository is within an area known as the Central Yucca Mountain domain. Structurally, this is the simplest and largest domain, comprising three east-tilted blocks, each 1 to 4 km (0.6 to 1.8 miles) wide, bounded by west-dipping block-bounding faults. Intrablock faults are locally present (such as the north-striking Ghost Dance and Abandoned Wash faults). These intrablock faults have a maximum of tens of meters of west-side-down displacement and tend to be associated with a simple, narrow zone of deformation in contrast to the hundreds of meters of displacement and complex deformation zones commonly associated with block-bounding faults.

The Ghost Dance fault, shown in Figure 2-5, is the main intrablock structure within the central part of the Central Yucca Mountain domain with a trace length of 3.7 km (2.3 miles) (Day et al. 1997). In general, the Ghost Dance fault is a north-striking normal fault zone, steeply west-dipping (75° to 85°). The fault zone has a maximum width of approximately 150 m (492 ft) and a maximum displacement of approximately 30 m (98 ft) down-to-the-west offset. There is no evidence of displacement during the past 2 million years. Mapping in the Exploratory Studies Facility (ESF) has shown that the Ghost Dance fault has a consistent dip from the surface to the depth of the potential repository, but that the zone of brecciation is much narrower at depth than at the surface.

The northwest-striking Sundance fault can be traced for approximately 750 m (2,460 ft). The maximum width of the Sundance fault zone is approximately 75 m (246 ft), and the cumulative northeast-side-down vertical displacement across the fault zone does not exceed 11 m (36 ft).

To accommodate the seismic acceleration associated with the potential for earthquakes caused by these faults, the surface facilities of the MGR will be designed to a nominal 0.8g horizontal and 0.9g vertical acceleration (CRWMS M&O 2000m, Attachment I).

Fracture Characteristics in the Yucca Mountain–Rock mass has been studied in natural exposures, cleared pavements, and underground excavations. The largest volume of fractured rock-mass data comes from the detailed mapping of the ESF. Fractures are generally of three types: early cooling joints, later tectonic joints, and joints due to erosional unloading. Cooling and tectonic joints have similar orientations, but cooling joints are smoother. Cooling joints form two orthogonal sets of steeply dipping fractures and, locally, a set of subhorizontal fractures. For tectonic joints, four steeply dipping sets and one subhorizontal set have been identified.

Fracture density, connectivity, and hydraulic conductivity may all strongly influence groundwater flow within the volcanic rocks. Because of their greater brittle strength, values for all of these fracture parameters are greatest in the densely welded tuffs and least in the nonwelded units. The Tiva Canyon welded and Topopah Spring welded units are characterized by well-connected fracture networks, whereas the Paintbrush nonwelded units and the Calico Hills tuffs generally do not exhibit connected fractures. Values are intermediate in the lithophysal zones of welded tuffs, because fracture propagation may be attenuated in the voids. In the Crater Flat tuffs, fracture density is variable, both vertically and laterally, due to the variations in tuff properties.

2.2.3 Hydrogeology

The Yucca Mountain site occupies an intermediate position between areas of recharge and discharge of the regional groundwater flow system. Present-day values of precipitation and infiltration at Yucca Mountain, as well as long-term erosion rates, are summarized in Table 2-5 and Table 2-6 (CRWMS M&O 2000g). The aridity and small average rate of recharge produce a correspondingly small groundwater flux, which is vertically transmitted through extensively fractured rocks of the unsaturated zone. As a result of these conditions, the water table (top of the saturated zone in which all pore spaces and open fractures are filled with water), commonly, is deep beneath the land surface, particularly beneath prominent ridges such as Yucca Mountain. The combination of aridity, large topographic relief, and transmissive rocks results in a thick unsaturated zone, which is a principal hydrologic attribute of the site that enhances waste isolation. The groundwater basins and sections are shown in Figure 2-6. At the crest of Yucca Mountain, the water table is about 750 m below land surface and more than 160 m below the potential repository emplacement drifts. The rock units that comprise the unsaturated zone include Quaternary surface deposits (alluvium and colluvium, soil) and the Tertiary volcanic tuffs.

Table 2-5. Modern Climate Precipitation and Infiltration within the 4.7 km^2 Repository Area

	Precipitation	Infiltration
Lower Bound	191.6 mm/yr	0.4 mm/yr
Mean	196.9 mm/yr	4.7 mm/yr
Upper Bound	277.5 mm/yr	11.6 mm/yr

Table 2-6. Long-Term Erosion Rates at Yucca Mountain (per thousand years)

Unconsolidated material on hillslopes	< 0.5 cm
Bedrock on ridge crests	0.1 cm – 0.3 cm

The saturated zone underlying Yucca Mountain lies within the Alkali Flat-Furnace Creek groundwater sub-basin, one of several that comprise the Death Valley regional flow system. Groundwater in the Alkali Flat-Furnace Creek sub-basin, together with that flowing in the Ash Meadows sub-basin to the east and the Oasis Valley sub-basin to the west, discharges to the surface primarily in the Amargosa Desert south of Yucca Mountain. Part of the flow may continue to Death Valley either by deep westward underflow in a regional carbonate aquifer or by seepage from the basin-fill sediments through the bordering mountain ranges to Death Valley. Recharge (rainfall that enters the flow system) to the northeastern quadrant of the Death Valley system occurs principally at higher elevations such as the Spring Mountains, the Sheep Range, Rainier Mesa, Pahute Mesa, and Timber Mountain. The area north of Yucca Mountain (including Central Pahute Mesa, Timber Mountain, and Shoshone Mountain) provides most of the recharge to the Alkali Flat-Furnace Creek sub-basin. Most discharge occurs by evaporation and plant transpiration in the Amargosa Desert. The hydrogeologic features of the region suggest that water movement to the southeast (toward the Las Vegas Valley area) is precluded.

Near Yucca Mountain, volcanic rocks up to several thousand meters (more than 6,000 ft) thick cover the Paleozoic and older rocks in the region. The volcanic rocks have hydrologic properties that change dramatically over short distances, both laterally and vertically, producing a complex hydrogeology. The volcanic rock section becomes thinner to the south and is not an important component of the saturated zone flow system in southern Amargosa Valley. The dominant regional aquifer, the carbonate aquifer, consists of Paleozoic marine limestones, dolomites, and minor clastic (made up of fragments) sediments that attain a thickness of thousands of meters. Fractures enlarged by dissolution provide the large permeability associated with this aquifer, which underlies most of the Ash Meadows sub-basin and the southern part of the Alkali Flat-Furnace Creek sub-basin. Although the Paleozoic stratigraphic section is segmented and disrupted by complex faulting and volcanic activity in the region, the carbonate aquifer connects and hydrologically integrates the many valleys and intervening ranges. Beneath the carbonate aquifer are relatively impermeable, metamorphosed older rocks. These rocks form the effective hydraulic basement for groundwater flow, but they are locally permeable where they contain unhealed fractures. In the vicinity of Yucca Mountain, the carbonate aquifer is not currently tapped as a source of groundwater because of its great depth below the surface.

In addition to these rocks, structural basins (valleys) formed during Mid-Tertiary crustal extension near Yucca Mountain, are filled with unconsolidated gravel, sand, silt, and clay eroded from the adjacent uplands. These Quaternary-Tertiary Valley fill deposits constitute a major aquifer hundreds of meters thick, though of widely variable properties, in the Amargosa Desert and other deep basins of the region.

2.3 DESCRIPTION OF FACILITIES

Sections 2.3, 2.4, and 2.5 of this PDD summarize information that is contained in other references. By assembling system specific information contained elsewhere (e.g., analyses, technical reports, SDDs), these sections provide insight into the current state of the design of these systems. However, due to the nature of design development, the information contained in this section will continue to change as the design matures.

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 arranged as shown conceptually in Figure 2-7 (DOE 1998b, Volume 2, Figure 4-1).

The majority of the repository horizon footprint for the MGR is located more than 200 m below the surface of Yucca Mountain, wholly contained within the Topopah Spring Welded Tuff stratigraphic unit (CRWMS M&O 2000c, Section 5.2) shown in Figure 2-4. Additional repository siting area may be available at the elevation of the repository layout with less than the 200 m overburden if the restriction that the emplacement area be located in the lower part of the lithophysal zone of TSw1 unit and the entire TSw2 unit is relaxed. This repository horizon is also located more than 100 m above the current groundwater table with the emplacement drifts located more than 160 m above the current groundwater table (CRWMS M&O 2000k, Section 6.2.2). The waste emplacement areal footprint for emplacement drifts occupies a range of approximately 1,100 to 1,650 acres for 63,000 MTHM of commercial SNF (CSNF) and approximately 7,000 MTHM of DOE SNF and HLW depending on the thermal mode. However, full inventory design for approximately 97,000 MTHM of waste (Wilkins and Heath 1999, Enclosure 2, A 1.0; and CRWMS M&O 2000k), including 83,800 MTHM of CSNF plus DOE SNF and HLW, will occupy a range of 1,500 to 2,150 acres of emplacement drifts (Wilkins and Heath 1999, Enclosure 2, A 1.0 and 3.0; and CRWMS M&O 2000k) depending the thermal mode. An expanded inventory case, the maximum analyzed in the Draft Environmental Impact Statement, could include as much as 105,000 MTHM of CSNF, 2,500 MTHM of DOE SNF, and 11,140 MTHM of defense HLW (DHLW), and occupy nearly 3,000 acres, depending on thermal mode used. The areas occupied by each inventory described could change as a result of flexibility in operation of the repository. For example, the flexibility in WP spacing could change the total emplacement drift length. The conversion factor of 1/2 MTHM per DHLW canister is used to determine the equivalent inventory of DHLW (DOE 1999a, Section 1.3.2.2). A potential layout of the emplacement and access drifts and shafts is shown in Figure 2-8 (DOE 2001a, Figure 2-10).

At the North Portal to the repository, there will be an approximately 150-acre disturbed area where nuclear waste is handled (DOE 1999a, Section 2.1.2.1.1). For worker safety, operations at the North Portal are divided into two work areas: a protected area and a Balance of Plant area. All radioactive materials will be handled in the protected area. The Balance of Plant area will perform the administrative and support functions that do not involve handling radioactive materials. The North Portal entrance to the Subsurface Facility will be used for waste transport to the subsurface. These areas are shown conceptually in Figures 2-9 and 2-10, with some structures moved or eliminated for simplicity.

The protected area includes the following facilities:

Waste Handling Building–Prepares incoming waste for transfer to the underground emplacement area. This building contains bays, nuclear waste assembly and canister transfer systems, radiation confinement rooms, welding systems, and other operational support systems.

Waste Treatment Building–Collects and packages site-generated, low-level radioactive and mixed (hazardous and radioactive) wastes for off-site disposal.

Carrier Preparation Building–Prepares incoming casks for transfer to the Waste Handling Building. All shipping hardware and personnel barriers are removed from the casks at this point.

Transporter Maintenance Building–Services and maintains the locomotives, transporters, and emplacement drift gantry cranes used to place WPs underground.

Security Station–Controls entry into the protected area.

Surface Facility for SNF Aging–Suitable facilities for surface aging of SNF will be provided. As much as 40,000 MTHM of SNF could be stored for up to 30 years in this facility. The facility will include adequate shielding for the dry storage of SNF. The duration and method of surface aging is a flexible operational parameter.

The protected area can accommodate several days' worth of transportation casks between the transporter parking area, the Carrier Preparation Building, and the Waste Handling Building.

The Balance of Plant area has a general administration building, medical center, training center, electrical switchyard, shops, motor pool, central warehouse, and other support facilities.

Construction and development of the surface facilities may be accomplished using a modular design or phased-construction technique.

Surface facilities are also provided at other operational areas:

- The Emplacement Exhaust Shaft Areas include fans, power supplies, headframes, and hoist systems. Accommodations are provided to house the emplacement ventilation exhaust fans and to support the maintenance of these fans.

- Air Intake Areas are located at the North and South Portals and at intake-shaft areas above the eastern portion of the repository, within the repository footprint. The North and South Portals and east and west main drifts are shown in Figure 2-8.

- The South Portal Development Operations Area is the second largest surface facility area (approximately 37 acres of disturbed area), and includes multiple structures (DOE 1999a, Section 2.1.2.1.2). This area is located adjacent to the South Portal to support the excavation of the underground and operation of the development ventilation intake fans.

This area functions independently of the emplacement area and includes the basic facilities needed for personnel support, maintenance, warehousing, material staging, security, and transportation (CRWMS M&O 1998b, paragraph 7.6.2). Temporary surface facilities to support construction will be located at the South Portal after emplacement begins.

- The muck storage areas located near the South Portal will provide adequate surface area for muck removal during excavation.

- The solar power electrical generation facility will be located on the east side of Yucca Mountain across (on the opposite side of) the Fortymile Wash.

2.4 CONCEPT OF REPOSITORY OPERATIONS

Repository operations will begin when sufficient repository construction is completed to ensure safe operations, and when the repository has been licensed to receive waste. This phase will overlap part of the construction and monitoring phases, and elements of these phases will occur during repository operations.

The following major activities will occur during the Operations Phase (includes activities from Construction and Monitoring phases which will occur concurrently, as the phases overlap):

Receiving Waste at the Repository–Transportation casks will be loaded with waste at various sites throughout the country and transported to the repository by rail and truck (legal weight and heavy haul). The casks will be moved to the Waste Handling Building carrier bay and removed from their carriers. They will then be opened and the waste removed.

There are several types of waste currently being considered in the design of the repository: two different types of CSNF assemblies (one from boiling-water reactor (BWR) power plants and the other from pressurized-water reactor (PWR) power plants); DOE SNF canisters, which include SNF from weapons production, experimental, and production nuclear reactors; Naval SNF; and canisters filled with vitrified glass for commercial and defense HLW. HLW generated by commercial facilities is managed by the DOE at the West Valley facility, and for purposes of this document is generally referred to as DHLW

Transportation cask carriers will be delivered by diesel locomotives or truck tractors to the protected area of the repository. The carriers will pass through the security station on their way to the Carrier Preparation Building. Impact limiters and weather, radiation, and intrusion barriers will then be removed and transportation casks inspected for external radiological contamination. When inspection is complete, the transportation cask carriers will be moved into the Waste Handling Building carrier bay to await unloading of the casks (Figure 2-11).

The repository must safely accommodate a broad range of canisters and casks that may be used to deliver nuclear waste for disposal.

Preparing Waste Packages–There are two steps in the loading process. The first is to load the waste into a disposal container and seal the container, thus creating a WP. The second step is to load the WP into a transporter to be taken to the emplacement location.

In the Waste Handling Building, waste will be transferred from casks or canisters to disposal containers (Figure 2-12). (There are two Assembly Transfer System lines for handling uncanistered SNF under water, or "wet," and one Canister Transfer System line for handling canistered waste "dry.") They will then be moved to the welding station for sealing.

All movement of fuel assemblies and SNF/HLW canisters will be performed by qualified, certified operators. The NRC will certify each individual fuel-handling operator after extensive training and testing of their skills and knowledge. All fuel movement and handling will be performed in accordance with explicit operating procedures.

There will be several types of disposal containers:

- An uncanistered disposal container designed to hold intact commercial fuel assemblies and/or individually canistered SNF assemblies. Fuel assemblies for this container could be taken from casks or from canisters that are not compatible with canistered disposal containers (see Figure 2-13).
- A Naval spent fuel disposal container designed to hold a canister containing Naval SNF (see Figure 2-14).
- A DHLW/DOE SNF disposal container designed to hold canisters containing DHLW (vitrified glass) and DOE SNF (see Figure 2-15).

Uncanistered Fuel-Handling–In the uncanistered waste cask room, the lids of loaded casks will be removed.

The casks to be unloaded will vary in the number of commercial fuel assemblies they contain, and the fuel assemblies will vary in their characteristics. Several casks or canisters may have to be unloaded before the fuel pool contains enough fuel assemblies with compatible characteristics to fill a single disposal container. When the right set of fuel assemblies has been collected, a disposal container will be moved into position and loaded with dried fuel assemblies from the fuel pool. The disposal container will be inspected, decontaminated as required, and moved into another room for final welding of the disposal container lids.

The loading of individual disposal containers will be performed in accordance with explicit operating procedures, by qualified and licensed operators. The blending of individual assemblies from the fuel pools into a disposal container will be predetermined by engineering calculations taking into account thermal output, criticality, and compatibility of waste forms. Operators will perform only that blending that is specified by those calculations. Precise fuel assembly identification will ensure that the blending is performed in accordance with the planned blending calculations. Independent verification of the assemblies placed into the disposal container will be performed prior to closing and welding the disposal containers.

SNF may be loaded into WPs or canisters for aging in suitable surface facilities. This may be done to satisfy thermal goals.

Disposable Canister Handling–The processes for canistered fuel assemblies and canistered DHLW will be similar but less complex. In the Waste Handling Building, the cask lids will be removed and the loaded canisters of fuel assemblies or DHLW withdrawn and some will be immediately placed into disposal containers or placed in a staging area for later disposal container filling. Each filled disposal container will be moved to an area for welding of three top closure lids.

All of these activities will be remotely controlled and will take place in sealed and shielded rooms that protect the workers and the environment. Precise canister identification will ensure that the loading is performed in accordance with the planned disposal container (DC) and repository loading activities. Independent verification of the canisters placed into the DC will be performed prior to closing and welding the DCs.

Final Sealing of Disposal Containers–Sealing the inner, middle, and outer closure (top) lids on the loaded disposal container will be accomplished in the disposal container handling system in the Waste Handling Building. Disposal containers that have been loaded in either the assembly or canister transfer systems will be transferred to the disposal container handling cell for sealing. The disposal containers will have three closure lids and three closure processes. The inner lid (made of 316 Stainless Steel) is not credited as a waste isolation barrier. The middle lid (made of nickel alloy 22) is welded, laser-peened (a process of heating with laser energy) for stress relief, and inspected. The outer lid (also made of nickel alloy 22) is welded, induction annealed (a process of heating with an induced electrical current) for stress relief, and inspected. The uncanistered SNF disposal container will have had its inner lid installed and temporarily sealed in the assembly transfer system before transfer to the disposal container handling system to minimize the risk of spreading contamination. This temporary seal is removed prior to the final sealing described above. Following the acceptance of all closure lid seals, the container is referred to as a WP (CRWMS M&O 2000f, CRWMS M&O 2000i, CRWMS M&O 2000j).

All of the above sealing, stress relieving, and inspecting operations will be performed remotely in the shielded cells of the disposal container handling system. Fifteen or more welding and sealing stations will be needed to maintain a desired rate of emplacement (maximum of 572 WP/year). The current Waste Handling Building design has not been analyzed in detail to determine precisely how many welding stations are required to maintain the desired emplacement rate; nor has a detailed sequence of equipment and handling operations been defined for the closure weld, stress relief operations, and weld inspections and examinations. This will be resolved in a future revision to this document.

The final Waste Handling Building operations will involve decontaminating a WP and placing it in a WP staging area for future emplacement, or inside the WP transporter for delivery to the emplacement area. The WP will be lifted and rotated to a horizontal position and moved by crane to a separate cell for decontamination. Following decontamination, the WP will be moved to the WP staging area or placed on a pallet constructed of alloy 22 ends and stainless steel cross members. This will be placed on a rolling bedplate near the transporter. A remote-controlled transfer mechanism will reach out from the transporter, connect to the rolling bedplate, and pull it onto the transporter. The transporter will close its doors and the WP will be ready to be moved underground for emplacement (Figure 2-16).

Precise WP identification will ensure that the loading is performed in accordance with the planned repository loading activities. Independent verification of the WP placed into the transporter will be performed prior to loading the transporter.

A summary of the various handling operations is graphically presented in Figures 2-17 through 2-22.

Emplacing Waste Packages in the Repository–The WP transporter on which the WP will be transported will utilize a rolling bedplate under the WP pallet.

Each WP will be transported from the surface Waste Handling Building via the North Ramp into and through the subsurface drifts using a WP transporter to reduce external radiation to safe levels for workers.

There will be a WP loading mechanism within the transporter, which will move the WP and bedplate unit into and out of the transporter. At the emplacement drift, the loading mechanism will push the WP and bedplate unit out of the transporter. If necessary for retrieval, the loading mechanism could be used to pull the WP and bedplate unit back into the transporter at the emplacement drift entrance.

The doors of the transporter will be remotely controlled. If necessary, they can be opened or closed manually from a shielded position behind the transporter.

Transferring Waste Packages to Emplacement Drifts–The WP and bedplate unit will be carried within the WP transporter from the surface facility to the entrance of an emplacement drift. Travel speed underground will be limited in the main drifts and in the emplacement drifts.

The transporter will be moved by electrically powered transport locomotives, one on each end. Braking systems will be incorporated on both the transport locomotives and transporter. The systems will normally work together, but each will be capable of independently stopping the loaded unit on the steepest grade (2.6 percent).

The transport locomotives that move the transporter through the underground ramps and drifts will have both manual and remote operations capabilities (Figure 2-23).

Excavating the Emplacement Drifts–Approximately 10 percent of the emplacement drifts will be completed prior to the start of waste emplacement operations. The remaining 90 percent will be completed while waste is being emplaced in the repository.

These concurrent operations will allow the repository to begin waste emplacement operations within six years from the start of the construction phase.

To ensure worker safety, the excavation and emplacement operations will be physically separated from each other, and each will have its own ventilation system and its own ramp access.

2.5 SUBSURFACE LAYOUT

The majority of the subsurface portion of the repository will be more than 200 m underground. The subsurface layout will be composed of two inclined access ramps, vertical ventilation shafts, and relatively horizontal main drifts and waste emplacement drifts.

The repository subsurface layout consists of main drifts and emplacement drifts with a potential layout of the emplacement area within the characterized area shown in Figure 2-8. The emplacement drifts are shown with a bearing of north 72° east. The repository host horizon is located above the water table in the dry unsaturated zone, consisting of volcanic tuff, to take advantage of the features of the natural barrier (Figure 2-4). Main drifts provide travelways for equipment, personnel, ventilating air, and the WP transporters. Emplacement drifts are the tunnels in which the WPs will be placed. Subsurface access is provided by two inclined access ramps. WP transport into the subsurface facility is via the North Ramp. No waste is moved into the subsurface facility via the vertical shafts. Vertical shafts are used for ventilation intake and exhaust.

Rail vehicles will be used for transporting WPs, equipment, supplies, and personnel during emplacement and construction. Conveyor belts will be used for rock removal.

A remotely controlled emplacement gantry is used to emplace the WPs in the emplacement drifts. This gantry is powered electrically by a third rail energized with a direct-current power supply (Figure 2-24).

The emplacement drift spacing for the MGR has been defined as approximately 80 m from the center of one emplacement drift to the center of the adjacent emplacement drift by the Project Operations Review Board and specified as 81 m (see Section 5.2.1) (Wilkins and Heath 1999, Enclosure 2, A 2.0). A WP spacing of 10 cm results in an areal mass loading of approximately 56 MTHM/acre (CRWMS M&O 2000k). Increasing and varying this spacing results in lower areal mass loadings and increased repository area. For the first repository, a portion of the repository layout shown in Figure 8 will accommodate 70,000 MTHM or equivalent (63,000 MTHM CSNF + 640 MTHM or equivalent commercial HLW + 4,027 MTHM or equivalent DHLW + 2,333 MTHM or equivalent DOE SNF) (YMP 2001a, 1.3.2.A). Larger inventory scenarios discussed in Section 2.3 are not precluded by the design of the subsurface layout.

The repository layout could include additional emplacement drifts to accommodate additional SNF and HLW if authorized (YMP 2001a, 1.3.2.B.1 and 1.3.2.B.2). The total emplacement drift length will be a function of the WP inventory and WP spacing (Wilkins and Heath 1999, Enclosure 2, B 16.0).

The repository is capable of accommodating additional inventory, including 105,000 MTHM of CSNF and additional DHLW and DOE SNF at a nominal WP spacing of 10 cm. This would involve an additional 42,000 MTHM of CSNF and 11,250 additional canisters of HLW/DOE SNF as described in Section 2.3. As the inventory for the potential repository increases, some options for the flexibility in operation could be used to maintain thermal goals.

Main Drifts–There will be two different types of main drifts: service main, and exhaust main.

The service main drifts, including the North Ramp, will be used to transport waste to the emplacement drifts and to support service operations. These will be 7.62 m (25 ft) in diameter and provide the inlet ventilation air for the emplacement drifts. The drift size will be large enough to allow waste transport, ventilation, service utilities, and personnel access. The maximum grade in the ramps will be approximately 2.6 percent.

The exhaust main is located in an approximately north-south orientation. This drift accommodates the flow of exhaust ventilation after it has passed through the emplacement drifts and through the ventilation raise. It is connected in several locations to the vertical exhaust shafts. The exhaust main will be sized to accommodate adequate ventilation flow rates, for both forced and natural ventilation, and is 7.62 m in diameter (CRWMS M&O 2000k, Section 6.3.2.1).

Emplacement Drifts–WPs will only be placed in the emplacement drifts, not in any of the main drifts.

The WPs are emplaced into parallel emplacement drifts having a nominal diameter of 5.5 m (Wilkins and Heath 1999, Enclosure 2, A 4.0). This accommodates large WPs, drip shields, and ground support, while allowing space for handling equipment and adequate clearances and the potential use of backfill if that option is selected in the future.

The WPs are on an alloy 22 pallet, supported by stainless steel structural members. These pallets are laid on top of the steel invert during emplacement. This invert is filled with granular material as ballast (Wilkins and Heath 1999, Enclosure 2, A 6.0).

The WPs will be positioned in the emplacement drifts with a minimum 10 cm spacing between adjacent WPs (Wilkins and Heath 1999, Enclosure 2, A 8.0). WP heat load and WP spacing are flexible operational parameters. The WP spacing could be varied from 10 cm to several meters, as needed, to achieve the desired thermal mode. This is a flexible operational parameter. The maximum linear heat load will be 1.5 kW/m. WPs of varying types can be placed adjacent to one another to affect temperature distribution (Figure 2-25).

Each emplacement drift entrance will have one set of double doors (forming an airlock) at each entrance. The double doors will control access and will have ventilation regulators (or louvers) to control the flow of ventilation air through the emplacement drift. The opening and closing of the doors will be remotely controlled. Additional air flow regulators may be located in the exhaust main at each ventilation raise.

The ground support in the repository drifts will be carbon steel (steel sets and/or rock bolts and mesh). Cementitious grout will be used as necessary to help anchor the rock bolts (Wilkins and Heath 1999, Enclosure 2, A 5.0). This system, installed during the excavation of the facility, provides the means to ensure stability of the subsurface openings and mitigation of rockfall events during the preclosure period. In the absence of ground support, the largest design basis rock expected to fall in the emplacement drift is 6 MT. The ground support is not intended to mitigate rockfall events during the postclosure period. The steel invert frame and ballast are independent of the ground control system.

Once WPs are placed in an emplacement drift, no human entry into that emplacement drift will be allowed under normal conditions.

2.6 BARRIERS

The features of the repository that contain and isolate the waste are divided into two categories: engineered barriers and natural barriers. The engineered barriers will provide the first means of containment for the waste. The drip shields and the heat from the WPs will keep the WPs dry for thousands of years, which reduces the corrosion rate of the WPs. The components of the WP in the dry environment are intended to confine the waste for tens to hundreds of thousands of years. The drip shield protects the WP from rock falls that could compromise the corrosion barrier of the WP. After the WPs eventually corrode and deteriorate and the engineered barrier function is degraded, the natural barriers will provide another means of isolation. The various rock layers in the potential repository at Yucca Mountain, due to low water content and water movement, will retard the movement of released radioactive material to the accessible environment. The roles of both the engineered and natural barriers are graphically summarized in Figure 2-26 and explained in more detail in Section 7.

2.6.1 Engineered Barrier System

Waste Packages–The MGR is designed to receive, package, emplace, and isolate CSNF, DOE SNF (which includes SNF from weapons production, experimental and production reactors, and Naval SNF), vitrified HLW, and immobilized plutonium waste form (IPWF), in accordance with the Nuclear Waste Policy Amendments Act of 1987 and implementing regulations, at the annual rates specified in the YMP RD (YMP 2001a, 1.3.2.C).

The MGR uses a single WP design concept that will be available in sizes to accommodate different waste forms.

The disposal container is a two layer, right-circular cylinder consisting of an inner shell of stainless steel and an outer barrier of nickel-based alloy ASTM B 575 N06022, hereafter referred to as alloy 22 (Wilkins and Heath 1999, Enclosure 2, A 10.0). The stainless steel layer is nominally 50 mm-thick, and the alloy 22 barrier is nominally 20 mm-thick, for corrosion resistance. The Naval SNF and HLW/co-disposal containers have an additional 5-mm thickness of alloy 22 (for a total thickness of 25 mm) for structural strength enhancement. There are outer and inner lids on each end of the DC. The outer lids are Alloy 22, with a thickness of 25 mm. The inner lids are 316 NG stainless steel, with a thickness that varies from 65 mm to 130 mm depending on the specific design. In addition to the inner and outer lids, a 10 mm Alloy 22 lid between the outer and the inner lids on the top end of the DC provides additional protection against stress corrosion cracking in the closure weld area. The two bottom lids are welded on during DC fabrication and the three top lids are welded on during DC closure. Following acceptance of the welds, the filled DC is referred to as a WP. The most common size WP will hold 21 PWR or 44 BWR fuel assemblies (Figure 2-13).

The proposed WP for co-disposal of DHLW and DOE SNF is shown in Figure 2-15. The co-disposal WP holds five DHLW canisters arranged around a center position for co-disposal of a canister of DOE SNF. The amount of highly enriched DOE SNF that can be safely disposed of in a single disposal container is limited to reduce the potential for nuclear criticality. Co-disposal of the DOE SNF with the DHLW makes use of additional space in the WP and eliminates the need for very small WPs for highly enriched DOE SNF. The heat outputs for the co-disposal WPs are shown in *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1999a, Appendix A). Additionally, two DHLW canisters and two DOE multi-canister overpacks will be co-disposed of in a similar WP.

All WPs for uncanistered SNF are designed with internal baskets to provide a framework for holding the fuel assemblies. These baskets ensure a stable, predictable internal geometry for the period of time that the baskets remain intact. In addition to providing secure stability of the assemblies in the WP during handling and emplacement, the baskets serve to assist in criticality control by absorbing neutrons, preventing movement, and maintaining local fuel geometry for a sufficiently long time (CRWMS M&O 1996b, pp. 34-36). There are two design options that may be implemented for criticality control. The first is to introduce a parasitic neutron absorber into the basket structure. The second is to fabricate control fingers to insert into the thimbles of PWR fuel assemblies.

Along with the WP, the repository design includes a drip shield installed over the WP at the time of repository closure to provide defense-in-depth for postclosure performance (Stroupe 2000).

The drip shield (shown conceptually in Figure 2-25) has shield plates made of Titanium Grade 7, with a minimum thickness of 15 mm (Stroupe 2000) and support members made of Titanium Grade 24. The drip shield provides long-term drip and rock-fall protection with its highly corrosion resistant, structurally reinforced design.

2.6.2 Natural Barriers

The Natural Barrier System consists of interdependent geological, climatological, hydrological, and geochemical attributes, which provide various containment barriers that contribute to isolating radioactive waste and achieving the objective of the repository. The geology provides the fundamental framework for waste isolation within the repository. Yucca Mountain is part of the Basin and Range Geologic Province of the western United States, and it consists of a north-south aligned, tilted, fault- bounded mountain block. The waste emplacement area of the repository is bounded on the west by the Solitario Canyon fault and bounded on the east by the Ghost Dance fault, but has no significant faulting within the emplacement area itself (Figure 2-3). The rocks composing the mountain are of Mid-Tertiary age (15 million to 7.5 million years old), and consist mainly of volcanic rocks formed from hot ash ejected from extinct volcanic vents that were located north of Yucca Mountain. Depending upon the temperature, these ash deposits formed either high-temperature fused units (welded tuffs) that are relatively dense, or lower temperature unfused units (nonwelded tuffs) that are less dense and more porous. The stratigraphic groups are shown in Figure 2-4. The sequence of major rock units composing the mountain (from the surface downward) are the TCw; PTn; TSw, which is the repository host rock; CHn; and CFu. At greater depths, pre-Tertiary rocks that include a Paleozoic carbonate aquifer are present. The rock sequence composing Yucca Mountain is itself a barrier that isolates waste materials. The repository horizon within the Topopah Spring tuff is located at a depth of 300m, with a minimum rock overburden thickness of 200m to ensure adequate protection from surface events. The horizon is also located such that the emplacement drifts are at least 160 m above the current water table, a substantial distance that minimizes the possibility of exposing waste to groundwater (DOE 1998b, Figure 4-21).

The climate at Yucca Mountain determines the amount and timing of precipitation, runoff, evaporation, and plant transpiration. In turn, these factors control the amount of surface water and the amount of water infiltration into the mountain. The present-day climate in the area is semi-arid, with hot summers and mild winters. Therefore, infiltration into the mountain bedrock is modest and commonly associated with wet years that are linked with El Nino cycles. Studies of the past climatic history of the Yucca Mountain region over the last 500,000 years provide a basis for predicting future climatic changes in the region over the next 10,000-100,000 years, which is an issue that is addressed in evaluating future repository performance. This provides bounds on the amounts of possible future water infiltration into the mountain and future effects on the hydrologic subsystem.

The hydrology consists of the Unsaturated Zone (UZ) from the ground surface to the water table and the Saturated Zone (SZ) below the water table. Both zones provide barriers that contribute to isolating waste materials. In the UZ, there are presently no permanent surface water bodies to provide infiltration water into the mountain; therefore, infiltration results directly from precipitation and is relatively low at present. Consequently, the amount of deeper water percolation through the mountain is also relatively low under present climatic conditions. Water percolation in the UZ occurs by flowing through both rock fractures and through pores within the rock matrix. Water flow through the porous rock matrix is substantially slower than through rock fractures, and some of the fracture water is attenuated by matrix imbibition (suction into the rock), thus slowing down the overall flow process. The relatively great thickness of the UZ results in a very long groundwater travel time downward through the zone, probably requiring thousands of years for matrix flow and hundreds of years for fracture flow to reach the repository horizon and subsequently the water table. This greatly enhances waste isolation. Below the water table, water in the SZ then flows laterally through both rock fractures and matrix to the unrestricted environment, also with a very long travel time that enhances waste isolation.

The geochemistry of Yucca Mountain controls the mineralogy of the volcanic rock sequence, which provides additional barriers to radionuclide migration in groundwater. Some of the rock units, such as the Calico Hills Formation below the repository, contain abundant zeolite minerals that have sorption properties which bind to some released radionuclides that occur along the transport path. This creates another barrier to radionuclide migration. In addition, abundant clay minerals and some manganese oxides in the rock sequence also react with radionuclides and retard their migration, thus contributing to the overall effectiveness of the Natural Barrier System in isolating radioactive waste materials.

2.6.3 Barriers Potentially Important to Waste Isolation

The summary of key waste isolation attributes leads to a natural identification of the barriers potentially important to waste isolation.

Natural barriers include the following:

- Surficial soils and topography, which limit water infiltration
- Unsaturated rock layers above the repository horizon, which limit water flux in the repository emplacement drifts
- Unsaturated rock layers below the repository horizon, which limit radionuclide transport
- Tuff and alluvial aquifers, which limit radionuclide transport in the saturated zone
- Engineered barriers include the following:
- A drip shield, which limits the water contacting the WP and the water available for advective transport through the WP and drift invert
- CSNF cladding, which limits the water contacting the waste matrix
- A waste form that limits rate of release of radionuclides to the water that contacts the waste
- A drift invert, which limits the rate of release of radionuclides to the natural barriers.

As discussed in Section 2.2.3, near-surface hydrologic processes limit the flux of water at repository depth to a small fraction of the precipitation flux incident on Yucca Mountain. Capillary forces in the rock limit seepage into underground openings because the flux at depth is low.

While the drip shield remains intact, it will divert water from the waste. Further, the drip shield plays a role in limiting transport of radionuclides that might be released from the WPs. Radionuclides could be released by advection (i.e., transport by flowing water) or by diffusion. The drip shield will prevent flow and, therefore, preclude advective transport. In addition, because the diffusion coefficient of the drift invert under the WPs depends on the moisture conditions, diversion of water by the drip shields will also affect diffusive transport.

The WP also prevents exposure of the waste within it to water as long as it remains intact. The WP is corrosion resistant and designed specifically to protect the waste. Further, as long as this barrier remains intact, radionuclides cannot be transported away from the repository. Even after the WPs are breached, the WP could affect transport of radionuclides; that is, if the breach is small, the amount of radionuclides that can be released will be small. If the breach is very small (e.g., a hairline fracture), transport of radionuclides through the breach could be negligible.

The invert forming the emplacement drift floor provides a barrier to movement of radionuclides from the WP to the host rock. The transport properties of the drift invert directly affect advective transport of radionuclides through this barrier. In addition, the diffusion coefficient of the drift invert will affect diffusive transport through it.

Radionuclides released from the engineered barriers would reach the rock units of the unsaturated zone. These rock units, including the Topopah Spring welded, the Calico Hills nonwelded, and the Crater Flat undifferentiated unit, provide barriers to migration of radionuclides. Migration of radionuclides through the solid rock matrix would be relatively slow; however, these units are fractured and more rapid migration could occur through the fractures. The net effectiveness of this barrier therefore depends on the relative distribution of the radionuclides between matrix and fracture migration.

Radionuclides that eventually reach the water table could enter the saturated zone flow system. The saturated zone provides another barrier to radionuclide migration. Directly under the repository, the effectiveness of this barrier depends on the transport characteristics of the volcanic aquifers that dominate the flow system. Further away, near Amargosa Valley, the effectiveness of the barrier is enhanced by the potential for retardation in the valley fill alluvium.

2.7 VENTILATION CONCEPT

Each drift segment in the repository will be ventilated during preclosure. The ventilation concept supports both forced and natural ventilation. The ventilation flowrate may vary with time to meet thermal performance requirements in the emplacement drift. The flexible operational parameters of the ventilation system include the ventilation duration, flow rate, and method.

The subsurface forced ventilation system consists of two separate and independent fan systems and flow networks separated by moveable air locks. One system provides air to the development operations area while another system ventilates the waste emplacement operations area. The emplacement drifts, once loaded with waste packages, will be ventilated at a nominal flowrate of 15 m^3/s (CRWMS M&O 2000k, Section 6.2.3.4). Development of new emplacement areas and emplacement of waste in previously prepared areas, take place simultaneously over a period of approximately 20 years. Air pressure in the development side is always higher than the pressure in the emplacement side. In the unlikely event that radioactive particulates are released into the subsurface airstream on the emplacement side, the pressure differential will prevent the spread of these particles to the development operations area. The intake shafts and exhaust shafts will be 8.0 m in diameter. The ventilation raises will be 2.0 m in diameter. The cross-sectional sizes, lengths, slopes, and profiles of the ventilation shafts are designed to provide the nominal flow rates described in *Site Recommendation Subsurface Layout* (CRWMS M&O 2000k, Section 6.3.2).

The ventilation system and other repository elements are designed such that temperature and radiation values can allow limited-time personnel access for evaluating and remediation planning to deal with operational upset situations (Wilkins and Heath 1999, Enclosure 2, C 20.0).

In the event that subsurface contamination is detected, automated devices will sound alarms and emplacement operations will be shut down until the source of contamination is found and fixed. The combination of the pressure arrangement and the procedural controls will ensure worker safety and protect the environment. Such a contamination event is extremely unlikely, but has been accounted for in the design.

The emplacement drift ventilation system will be provided electrical power from the site electrical distribution facilities, which will be supplemented by a solar power generation system (YMP 2001a, Sections 1.3.3.O, 1.3.3.P, 1.3.3.Q).

After the excavation activities have been completed, only the emplacement ventilation system will be operated.

2.8 PERFORMANCE CONFIRMATION

By NRC regulation (Dyer 1999, Subpart F), a performance confirmation program must be established during the site characterization phase and continue through all subsequent phases until the repository is closed. The performance confirmation activities must provide data that show subsurface conditions during construction and waste emplacement operations are within limits derived in support of the application for a license to receive and possess waste. It must also show that natural and engineered systems and components are functioning as intended. The performance confirmation approach is divided into a baseline period and a confirmation period.

Activities during the baseline period will develop information on subsurface conditions and natural systems important to postclosure performance. These activities will also monitor and analyze changes in this baseline information as a result of site characterization activities. This information will be used to predict changes resulting from construction and operation. These baseline period activities were begun during the site characterization phase.

Activities during the confirmation period will verify that actual subsurface conditions and changes resulting from construction and operation are within predicted limits. These activities will also verify that the natural and engineered systems and components are functioning as intended and anticipated. This information will be used to support the application sent to the NRC requesting a repository license amendment to permanently close the repository.

2.9 REPOSITORY MONITORING

The repository will be monitored and maintained between the time the first WP is emplaced and the time the repository is permanently closed. Permanently installed and/or temporary sensors will be used to monitor WPs, drifts, and the surrounding rock, and to provide the data required by the performance confirmation activity. Robots will be used as required to investigate conditions in the emplacement drifts. This will eliminate risk to workers from heat and radiation coming from the WPs.

Specific facilities and equipment will continue to be maintained after waste package emplacement to support the performance confirmation activities. Facilities and equipment needed to respond to emergencies and treat low-level waste will also be maintained. Some activities can also be performed to protect a cost effective retrieval option. Planning and preparation will be conducted in anticipation of closing the repository.

Information from this performance confirmation monitoring may be used to optimize the repository thermal performance, support a closure decision, or to assist in a decision regarding the potential retrieval of waste.

When emplacement of the waste inventory has been completed, and when it has been determined that the repository will perform as expected, an amendment to the repository license may be sought to close the facility.

2.10 REPOSITORY CLOSURE

Closure is a process intended to place the repository in a configuration that will require little or no human support to continue to isolate the waste for hundreds of thousands of years. The process includes sealing all openings to the subsurface repository, dismantling the surface facilities, restoring the surface area, and protecting the repository from unauthorized intrusion.

The drip shields will be placed over the WPs prior to final repository closure. Determination of the timing of drip shield emplacement will depend on future studies and design analyses. Drip shield emplacement timing should include consideration of:

- Availability of emplacement equipment and support systems
- Availability of forced ventilation
- Impact on emplaced waste
- Impact on retrieval capability
- Impact on ventilation.

This drip shield has shield plates made of Titanium Grade 7 (Wilkins and Heath 1999, Enclosure 2, A 9.0), and structural members made of Titanium Grade 24. The drip shield location is shown in Figure 2-25.

Seals–The repository subsurface is designed such that all ramps and shafts can be backfilled and sealed at the time of repository closure. Plugs and seals will be installed at the surface entrance to the ramps and shafts. The plugs and seals are designed to enhance the prevention of future human intrusion into the repository, but are not relied upon for repository performance (CRWMS M&O 2000b, Section 6.2).

Decontamination and Decommissioning Of Facilities–During closure operations (following the monitoring phase, or retrieval activities if required), the surface facilities, including contaminated components, will be dismantled and decontaminated, as necessary, to restore the site to near its pre-repository condition. Selected subsurface components will be removed, decontaminated, and decommissioned, as appropriate.

The facilities will be designed to include features that will facilitate final decontamination and dismantling operations. The Waste Treatment Building will serve to support the decontamination and decommissioning activities by providing solid and liquid low-level radioactive waste treatment and packaging for transport to a low-level waste disposal site. Mixed wastes, if generated, will be collected and packaged for transport to off-site licensed facilities for treatment and disposal.

2.11 POSTCLOSURE

Institutional Barriers and Warning Signs–As part of the closure activities, detailed records and information on the repository will be distributed to government offices at the local, state, and national level. These government offices will use this information and legal means (such as laws, permits, and zoning) to control access to the site, thus creating institutional barriers. Fences and warning signs will be maintained and modified as required. Permanent monuments will also be put in place.

There are two arguments regarding permanent monuments. The first argument is that, after the institutional barriers have stopped functioning, a monument will serve to identify the location where something of value is buried, thus inviting excavation and the release of radioactive material. The other argument is that a properly designed monument will warn future generations away from the site long after the institutional barriers have disappeared. The current plan for postclosure utilizes a monument to mark the location of the repository.

The materials used for marker construction must be durable but not be attractive for souvenir hunters or recyclers. Good candidates are:

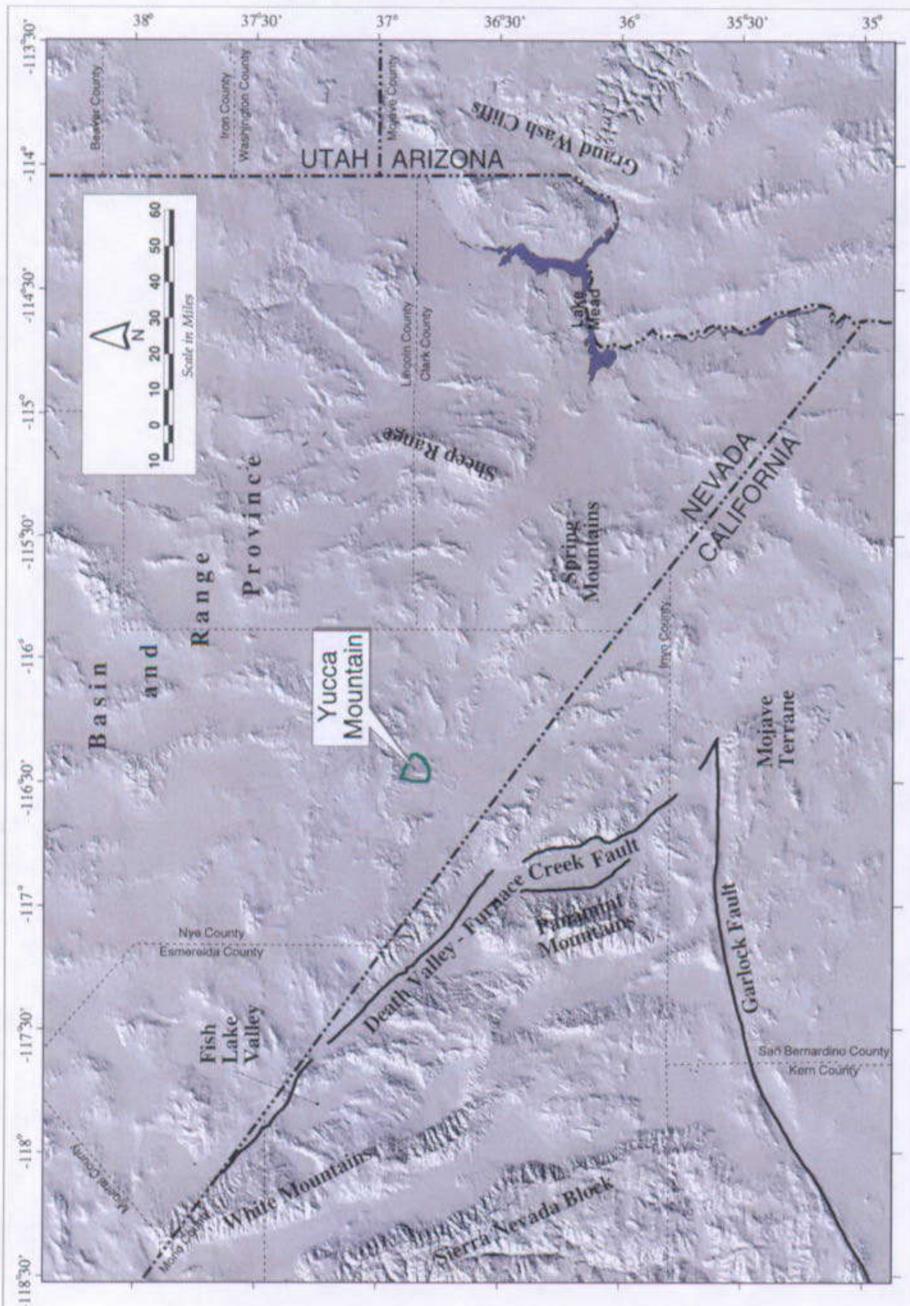
- Synthetic rock (SYNROC-B) with glass-like properties
- Mortar patterned after an ancient lime
- Mortar similar to that found in the great pyramids
- Natural rock such as granite.

A vault could be constructed within a central marker to contain more details about the location and characteristics of the repository. This information would be supplementary to the institutional barriers.

Postclosure Performance–During the first few thousand years after closure the protection of the drip shield and the heat released from the emplaced waste, together with naturally low water movement within the rock, will limit the moisture near the WPs so that they are protected from corrosion. During this time, some of the hazardous radioactive material will decay to very low levels. After most of the heat has dissipated, liquid water could return and contact the WPs. When corrosion of the WP finally allows water to contact the enclosed waste material, the water is expected to be in very small quantities, which will limit how much radioactive material could be picked up and removed from the WP. Human intrusion into the repository and disruptive events, such as volcanism, could also affect the mobility of radioactive material in the future.

More than 100 m of unsaturated rock separate the repository host horizon and the present water table (DOE 1998b, Figure 4-21), and over 160 m of unsaturated rock separate the emplacement drifts from the present day groundwater table (CRWMS M&O 2000k, Section 6.2.2). Given the small quantities of water expected to contact the waste and the long distances that must be traveled, only a small amount of the very long-lived radioactive material could be present at any given time in the future in quantities that could be of concern. If these small quantities of radioactive material were to enter the saturated zone, where volumes of water are moving to the southeast from Yucca Mountain, the likelihood of an excessive environmental hazard is currently expected to be very low within the expected regulatory time period. The amount of radiation that could eventually occur at an inhabited location is predicted to be comparable to or less than the naturally occurring background radiation at that location.

Postclosure monitoring activities, in accordance with federal regulations (Dyer 1999), will be performed for the required periods.



Note: Only faults with the highest rates of activity are shown

Figure 2-1. Great Basin Region

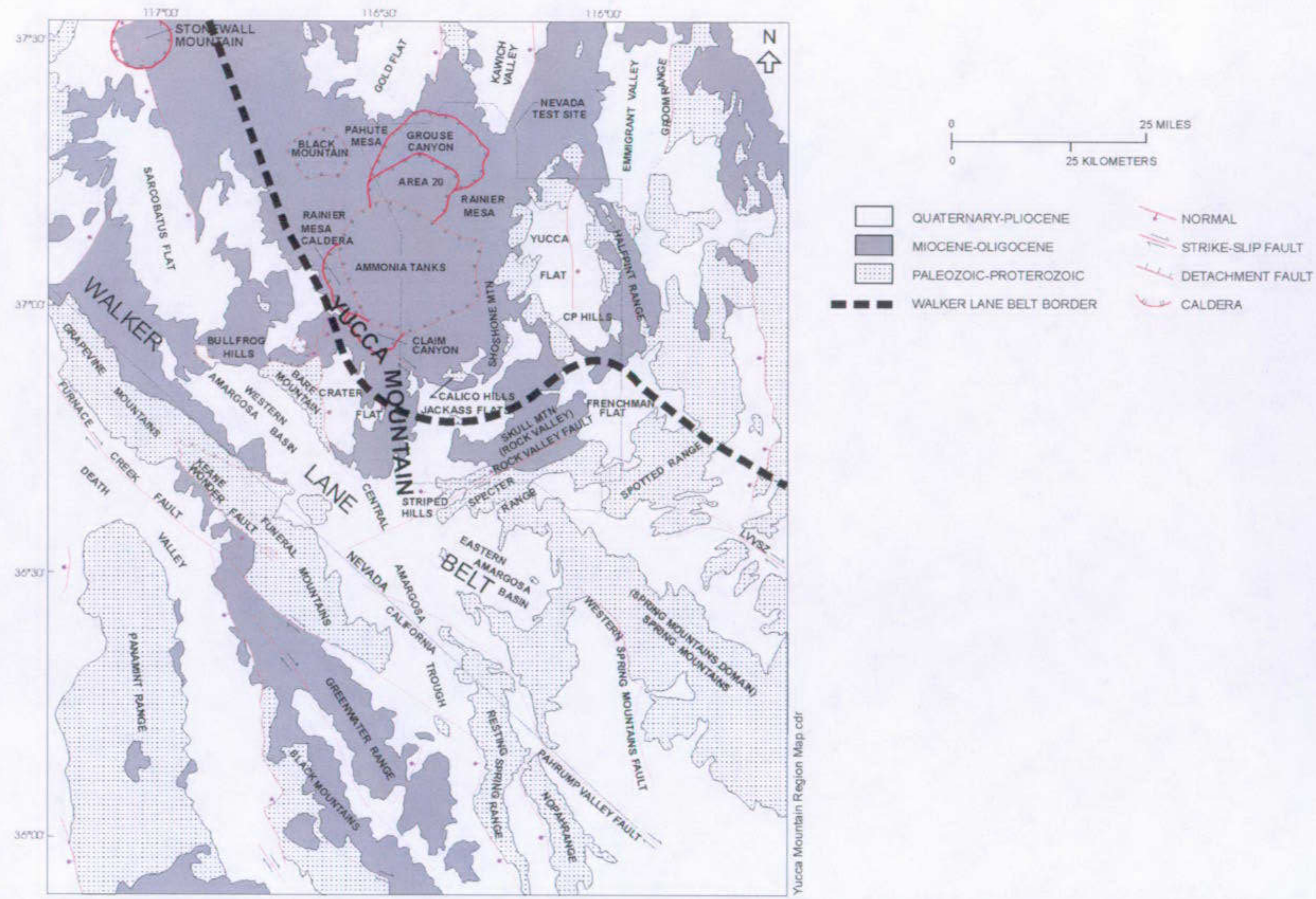


Figure 2-2. Generalized Geologic Map of the Yucca Mountain Region

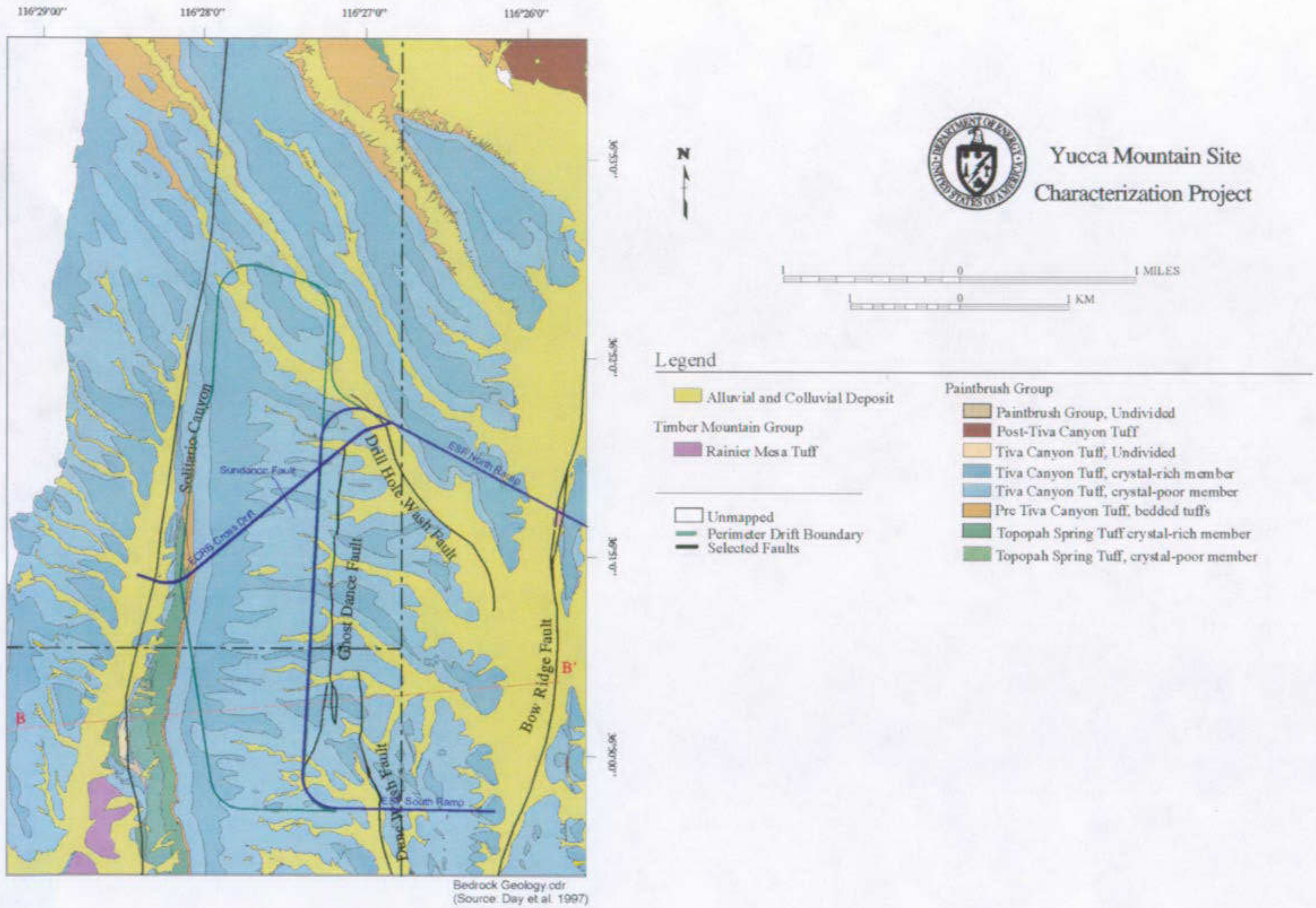


Figure 2-3. General Bedrock Geology Map of Yucca Mountain

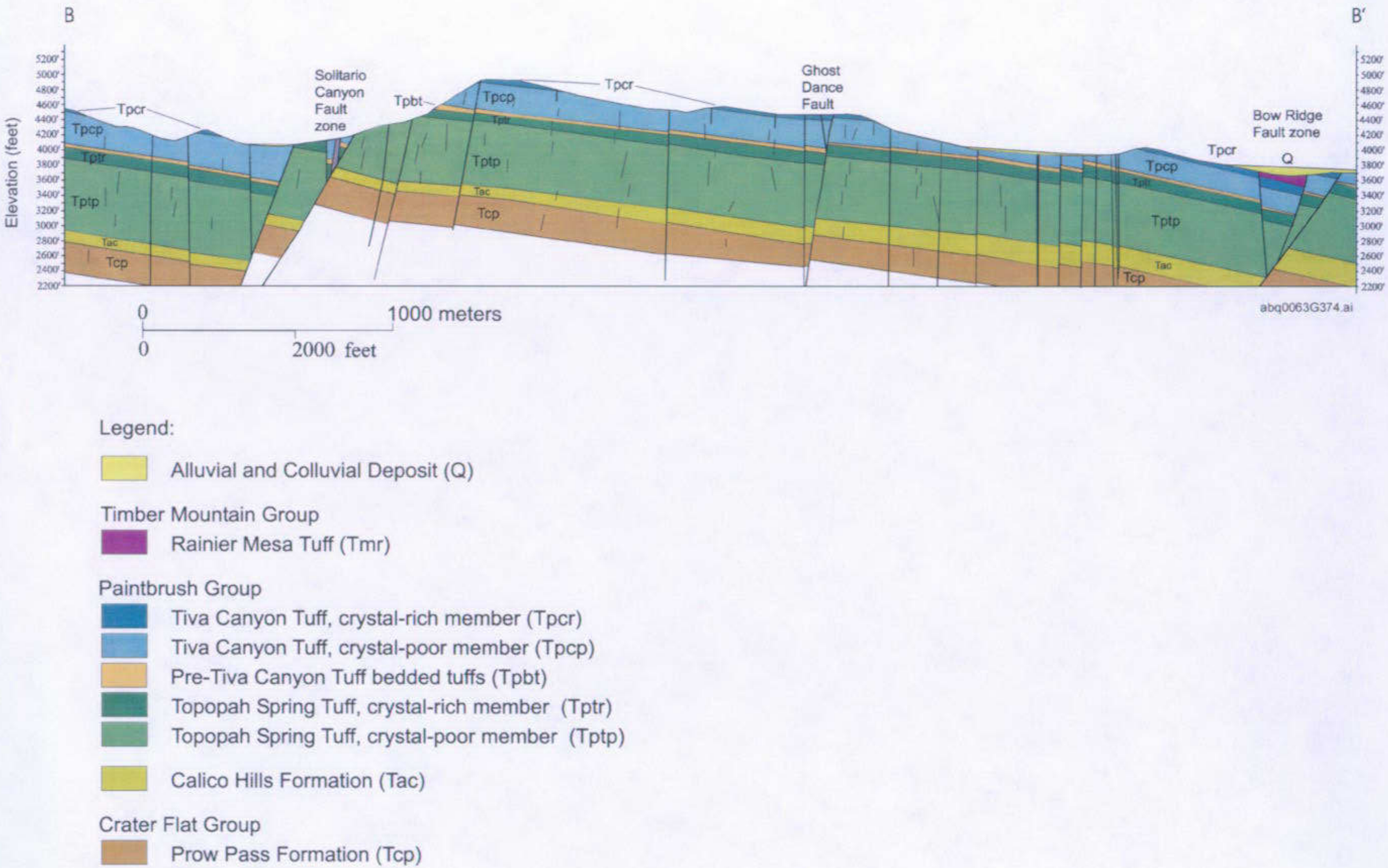


Figure 2-4. Yucca Mountain Stratigraphy (DOE 1998a, Figure 2-9)

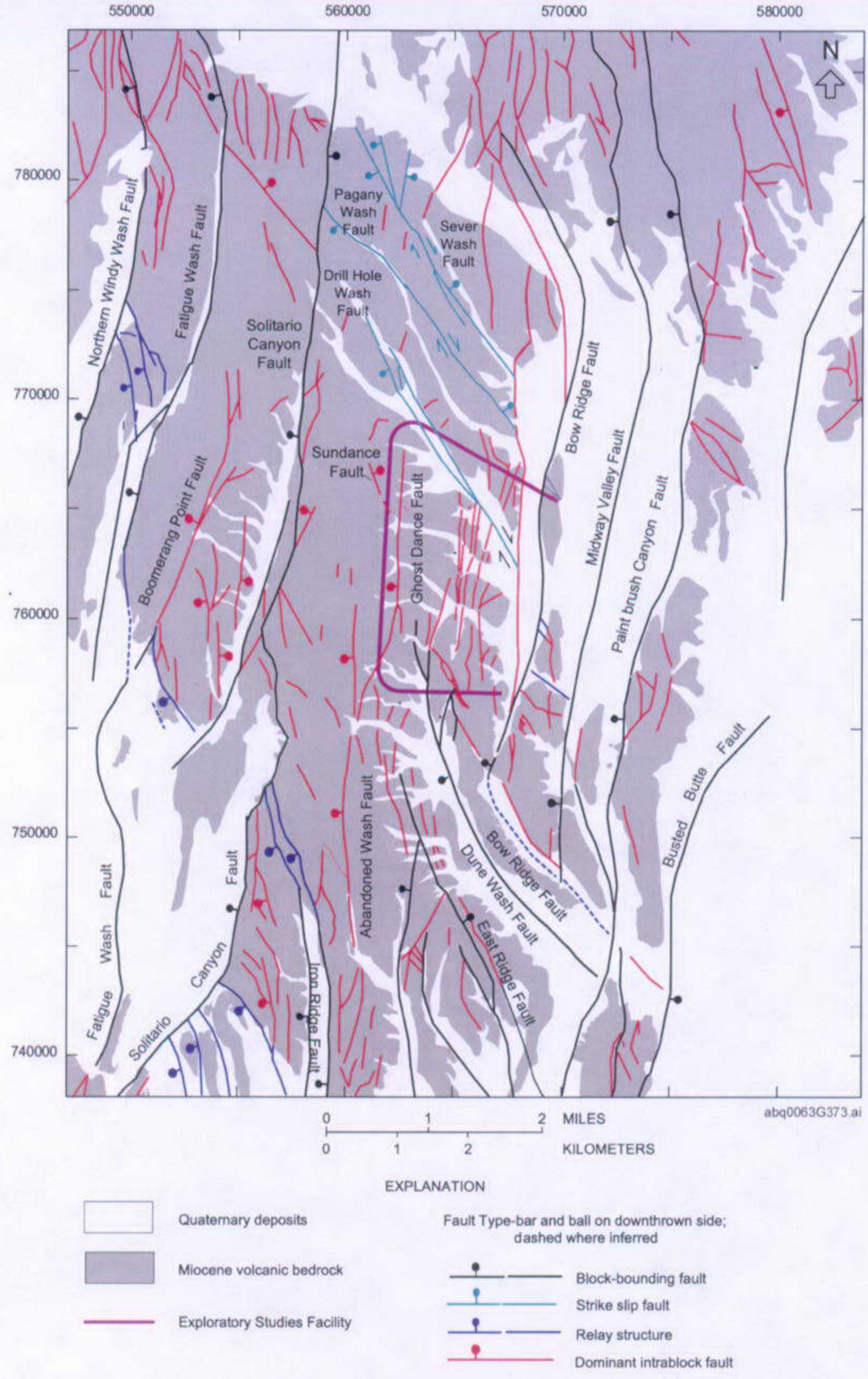
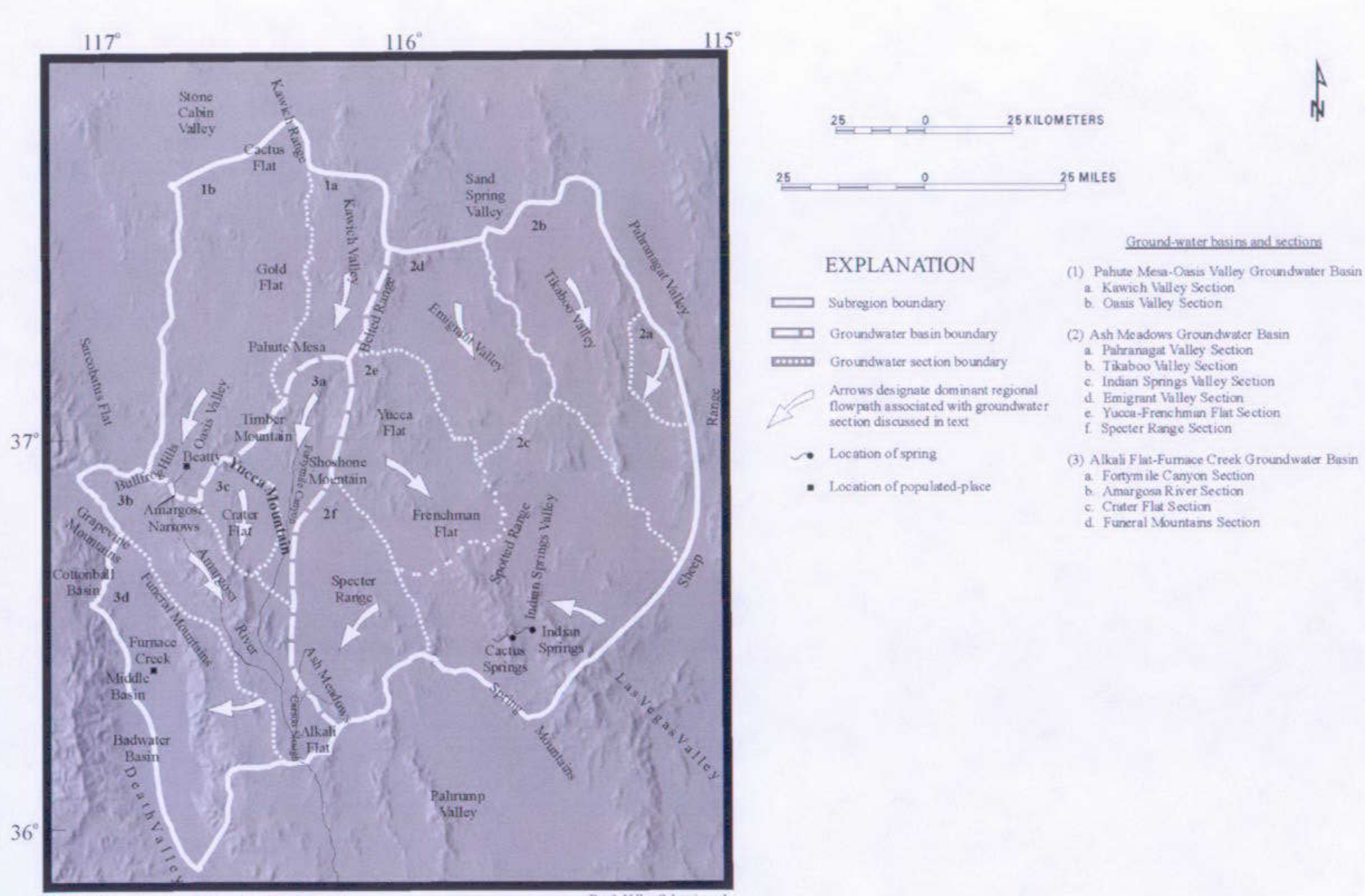


Figure 2-5. Major Faults in the Yucca Mountain Region



Universal Transverse Mercator projection, Zone 11.
Shaded-relief base from 1:250,000-scale Digital Elevation Model;
sun illumination from northeast at 30 degrees above horizon

Figure 2-6. Yucca Mountain Hydrologic Features

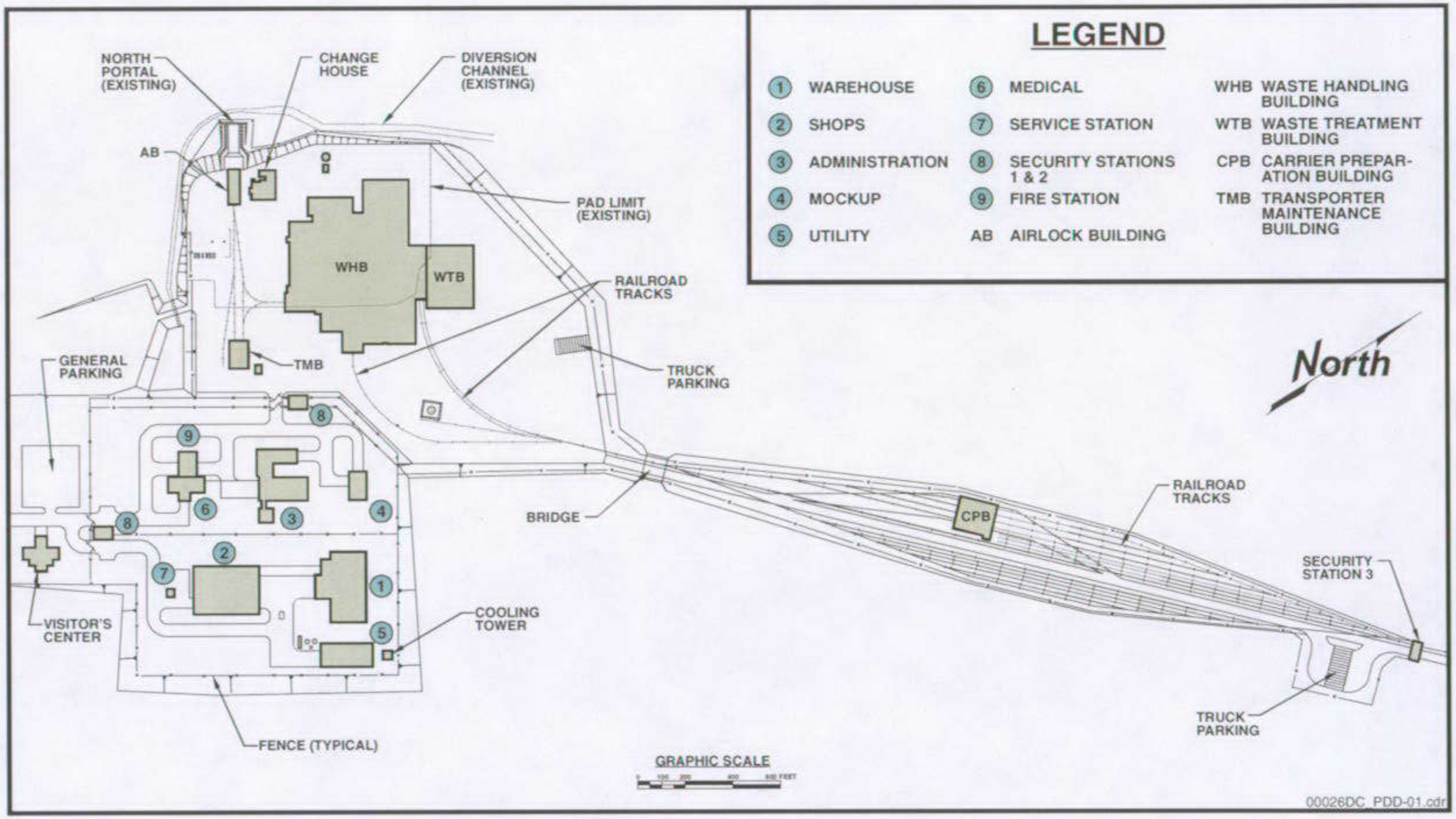
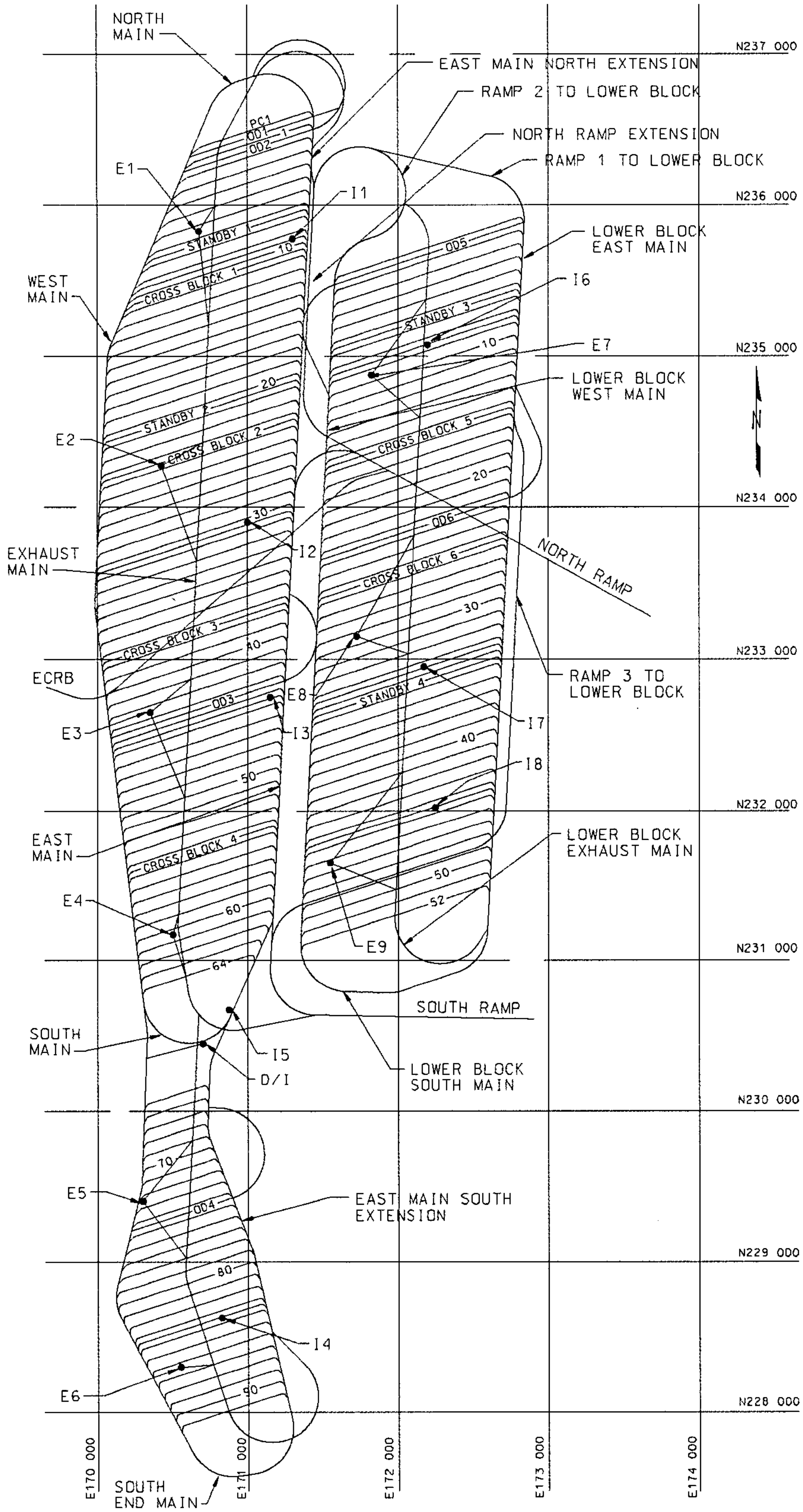


Figure 2-7. North Portal Surface Facilities
(conceptual only, not for design)



ATP_0001.ai

Figure 2-8. Expanded Subsurface Layout - Upper and Lower Block

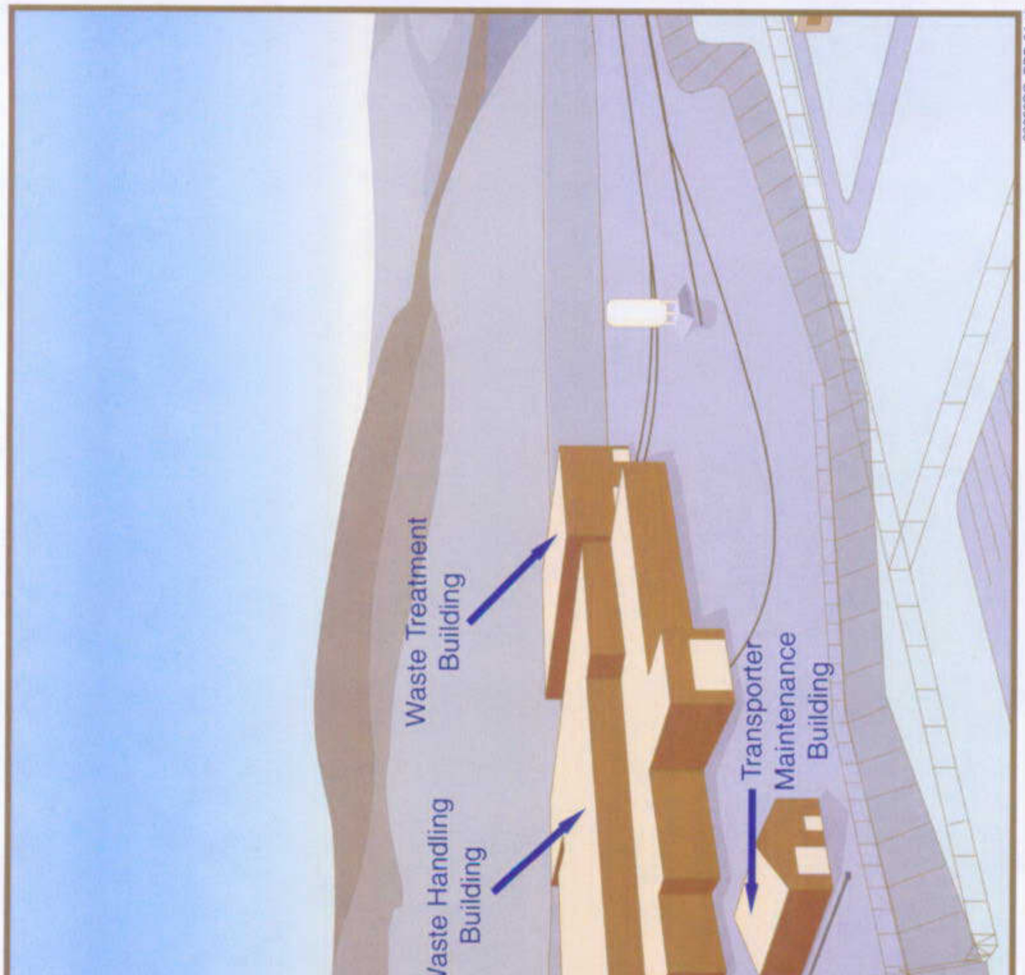


Figure 2-9. Surface Facility: Protected Area
(conceptual only, not for design)

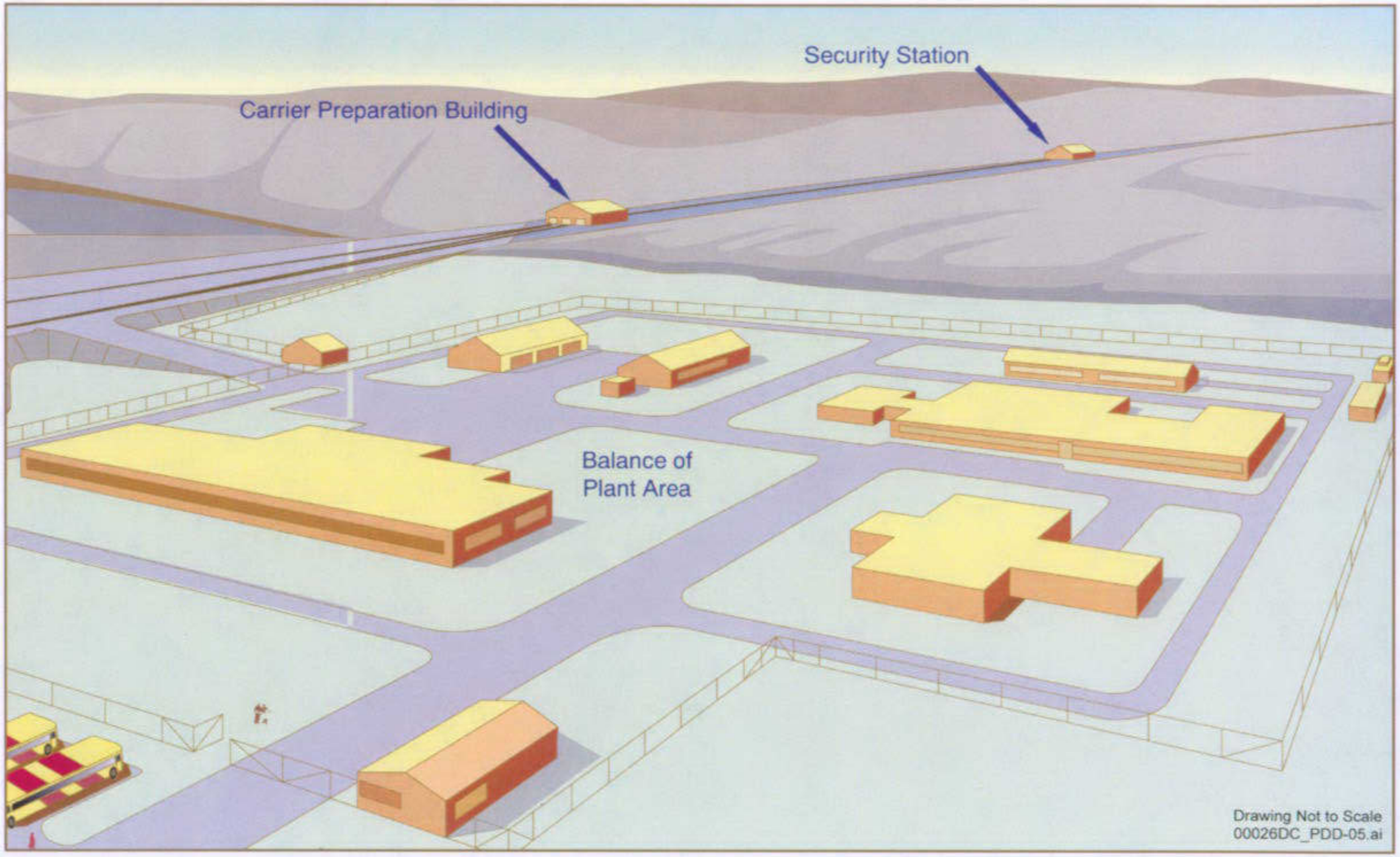


Figure 2-10. Surface Facility: Balance of Plant

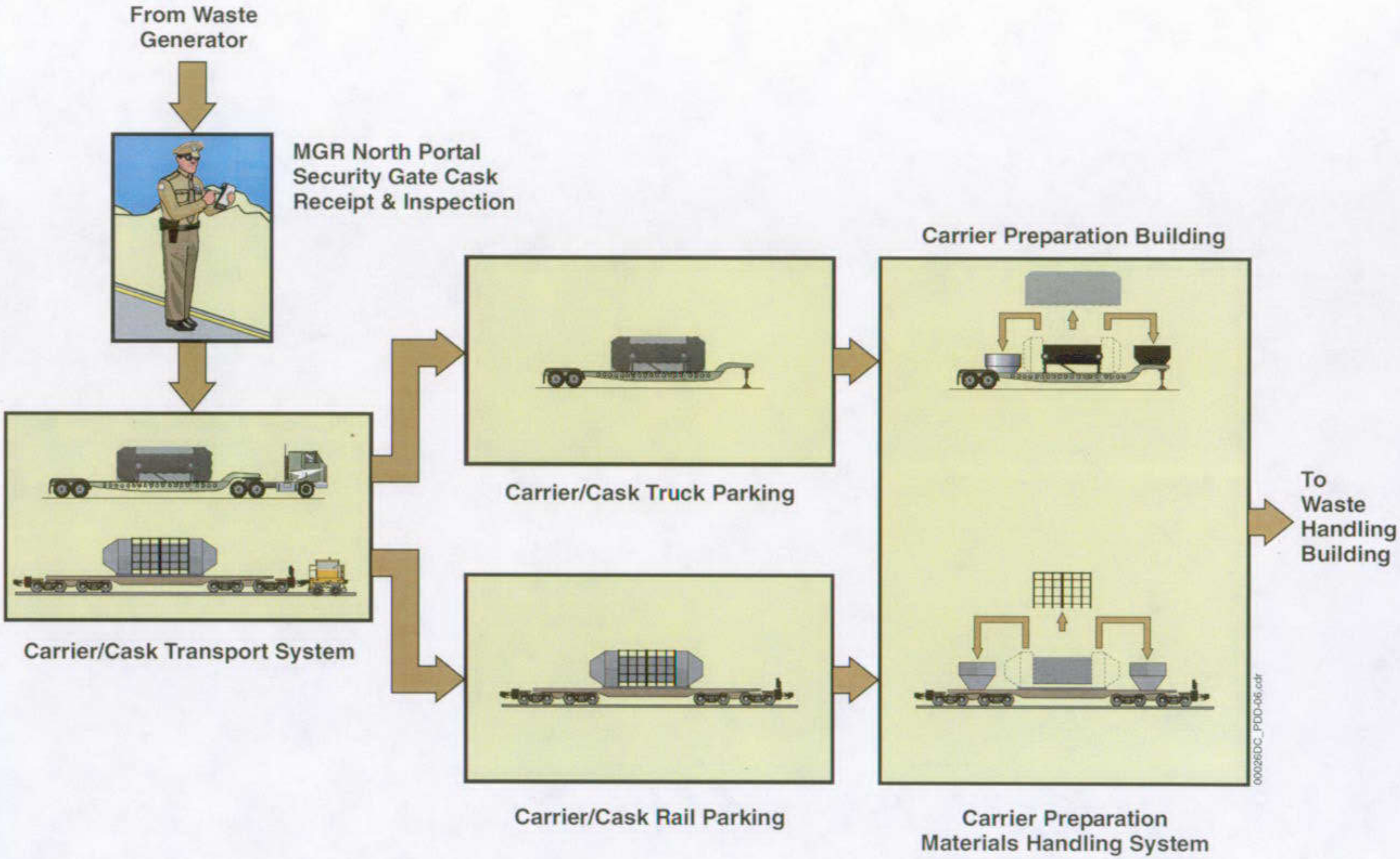


Figure 2-11. Carrier/Cask Transport System to Waste Handling Building

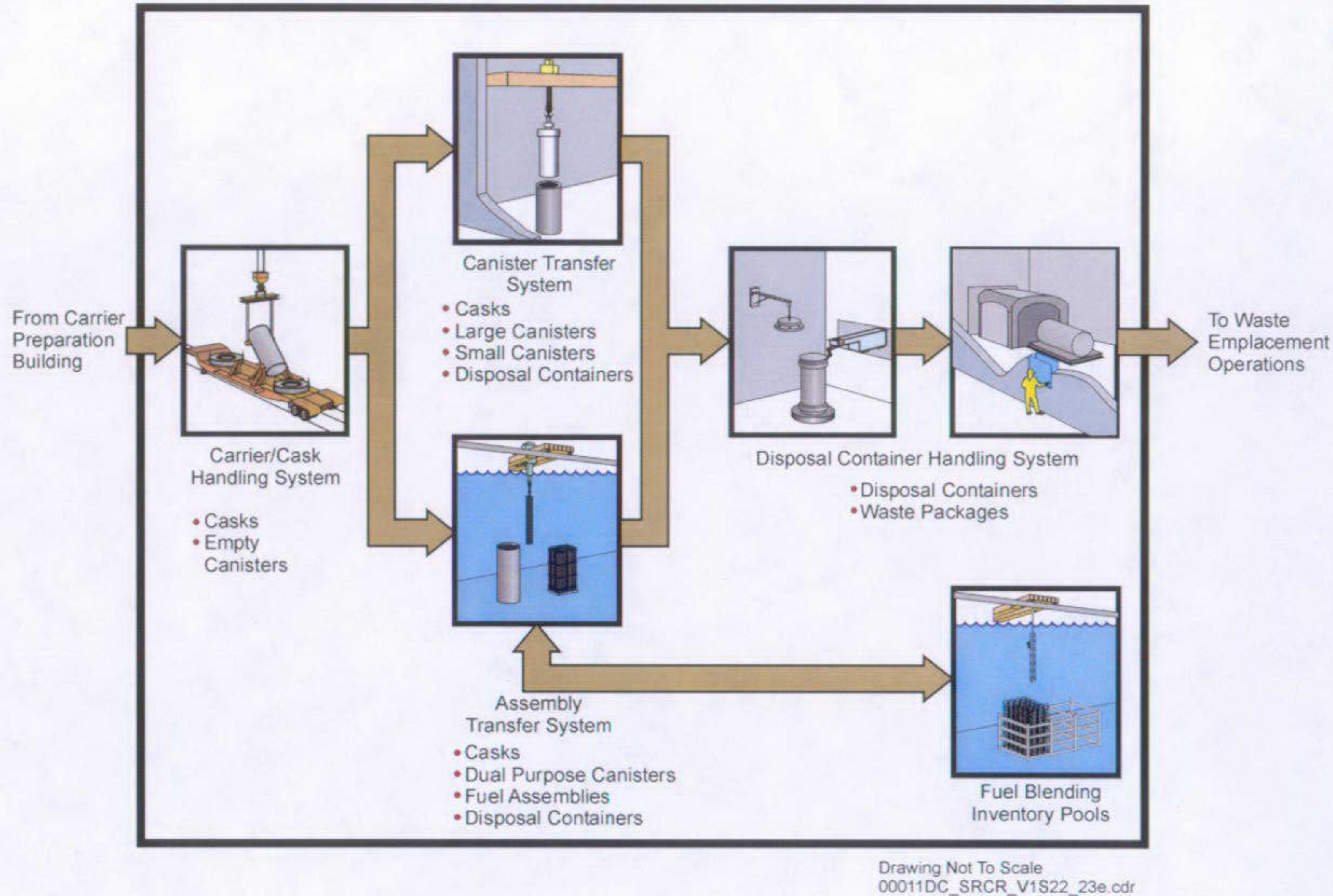


Figure 2-12. Carrier Preparation Building to Waste Emplacement Operations

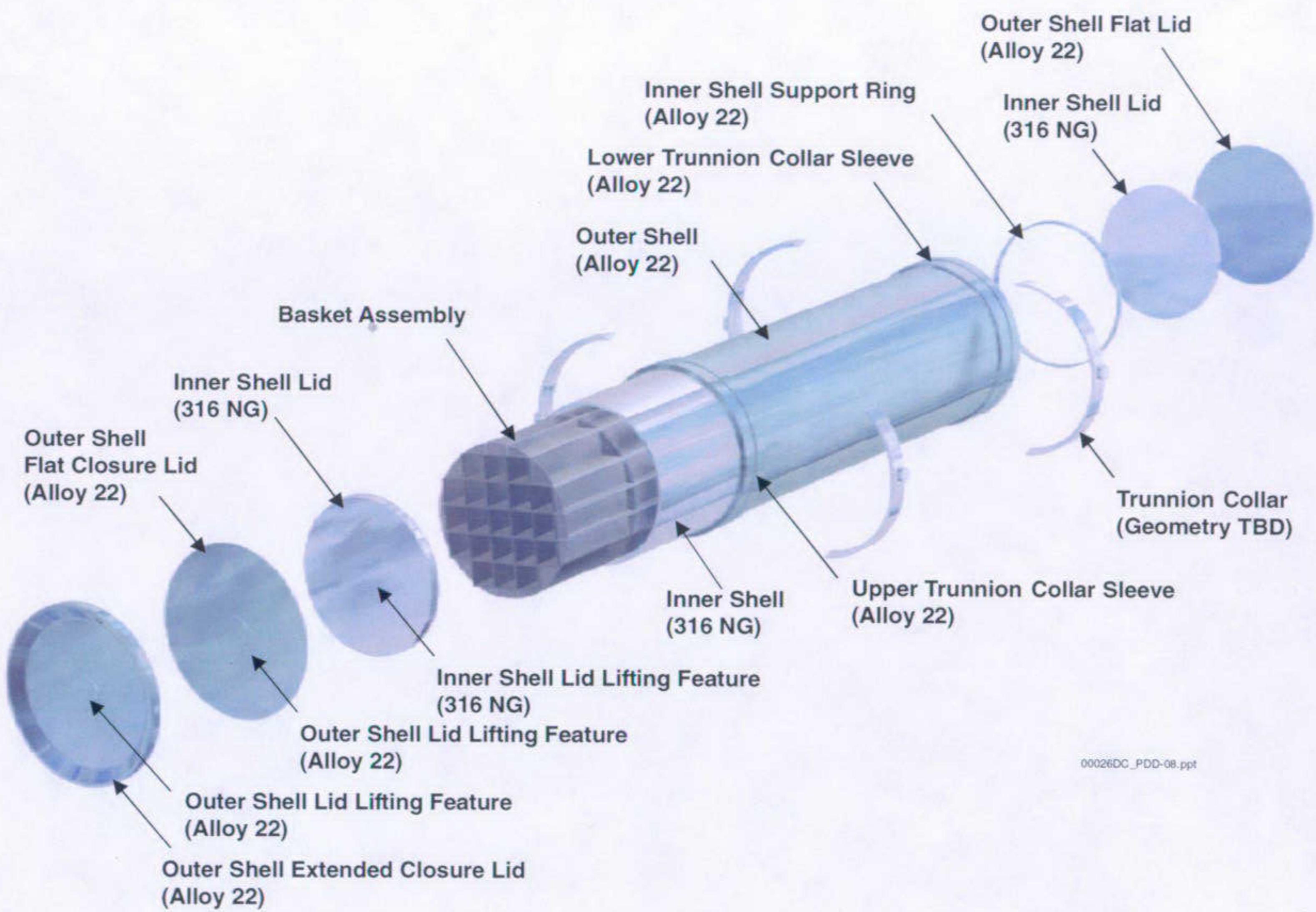


Figure 2-13. Uncanistered CSNF Waste Package

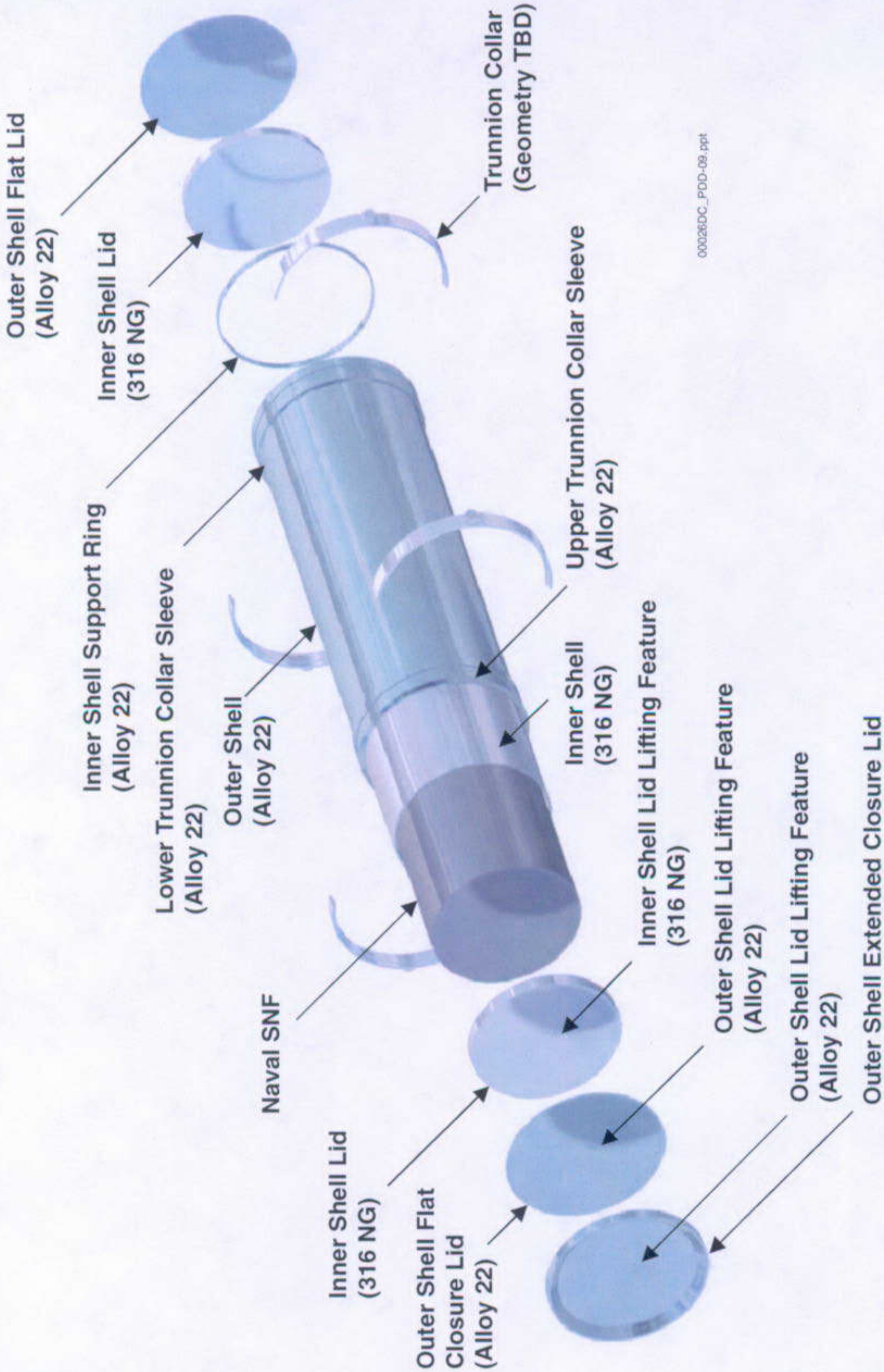


Figure 2-14. Naval SNF Waste Package

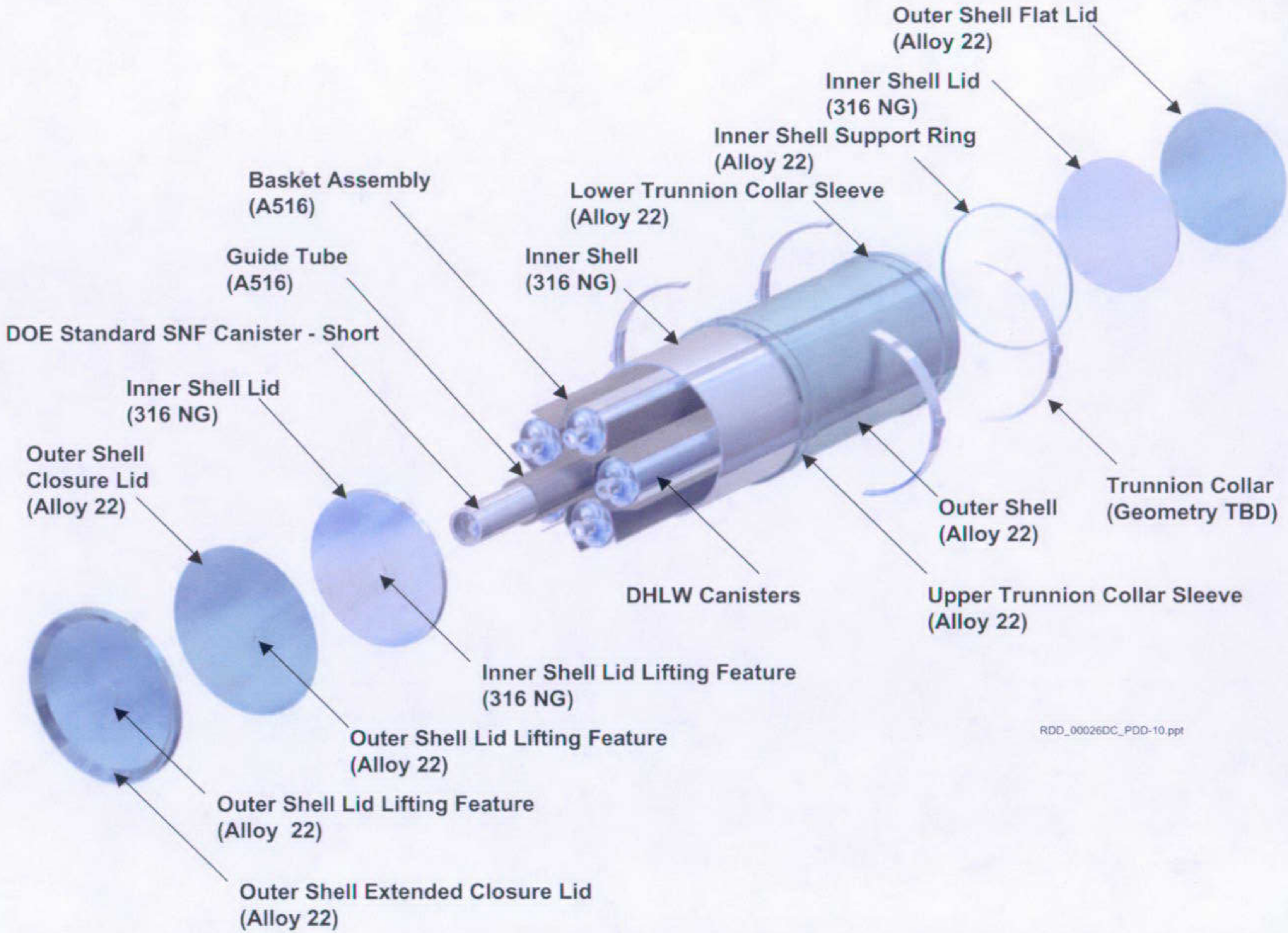


Figure 2-15. DHLW and DOE SNF Waste Package

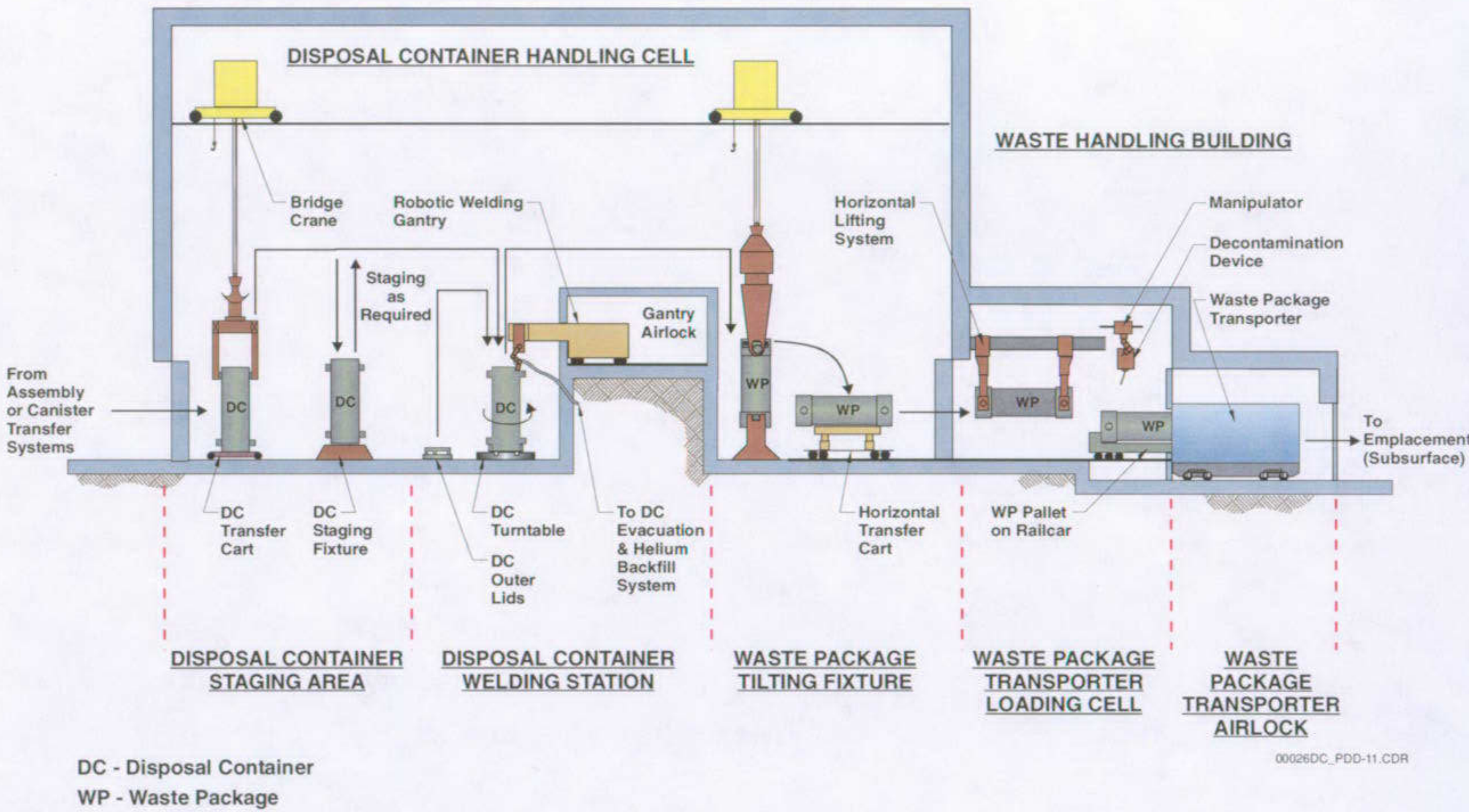


Figure 2-16. Disposal Container Handling System

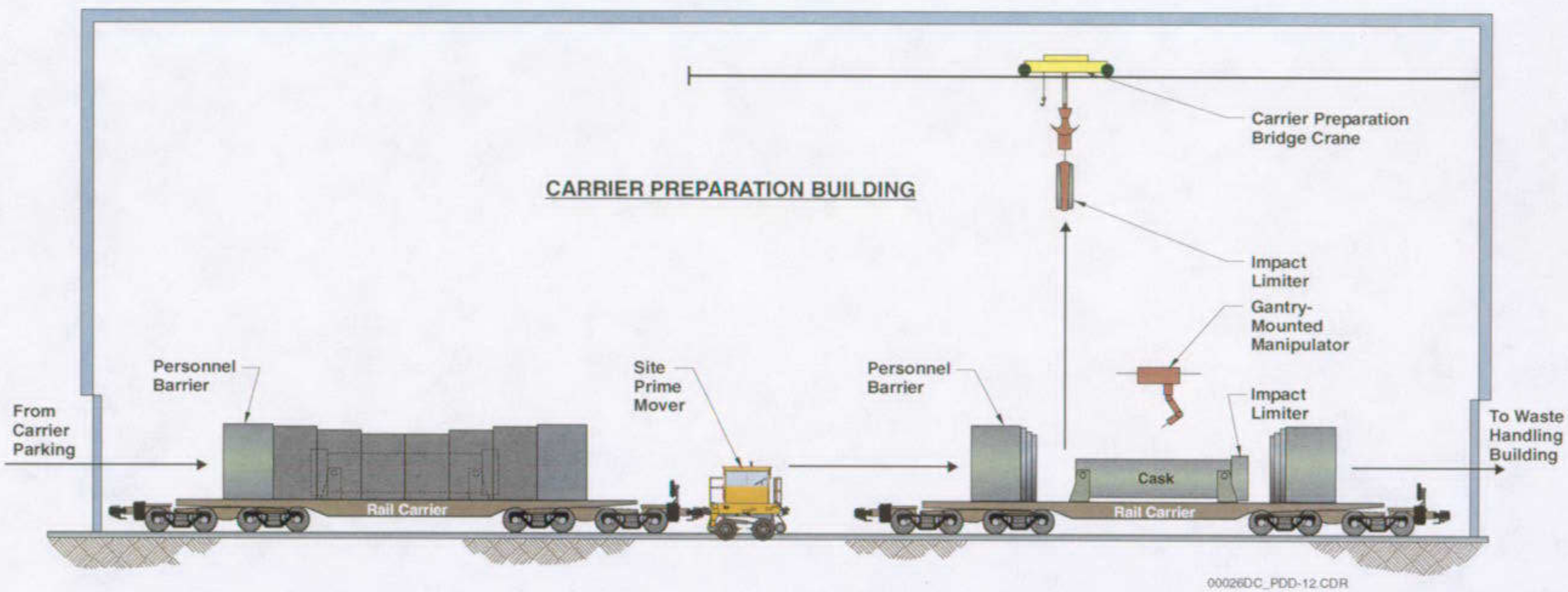


Figure 2-17. Carrier Preparation Building Materials Handling System

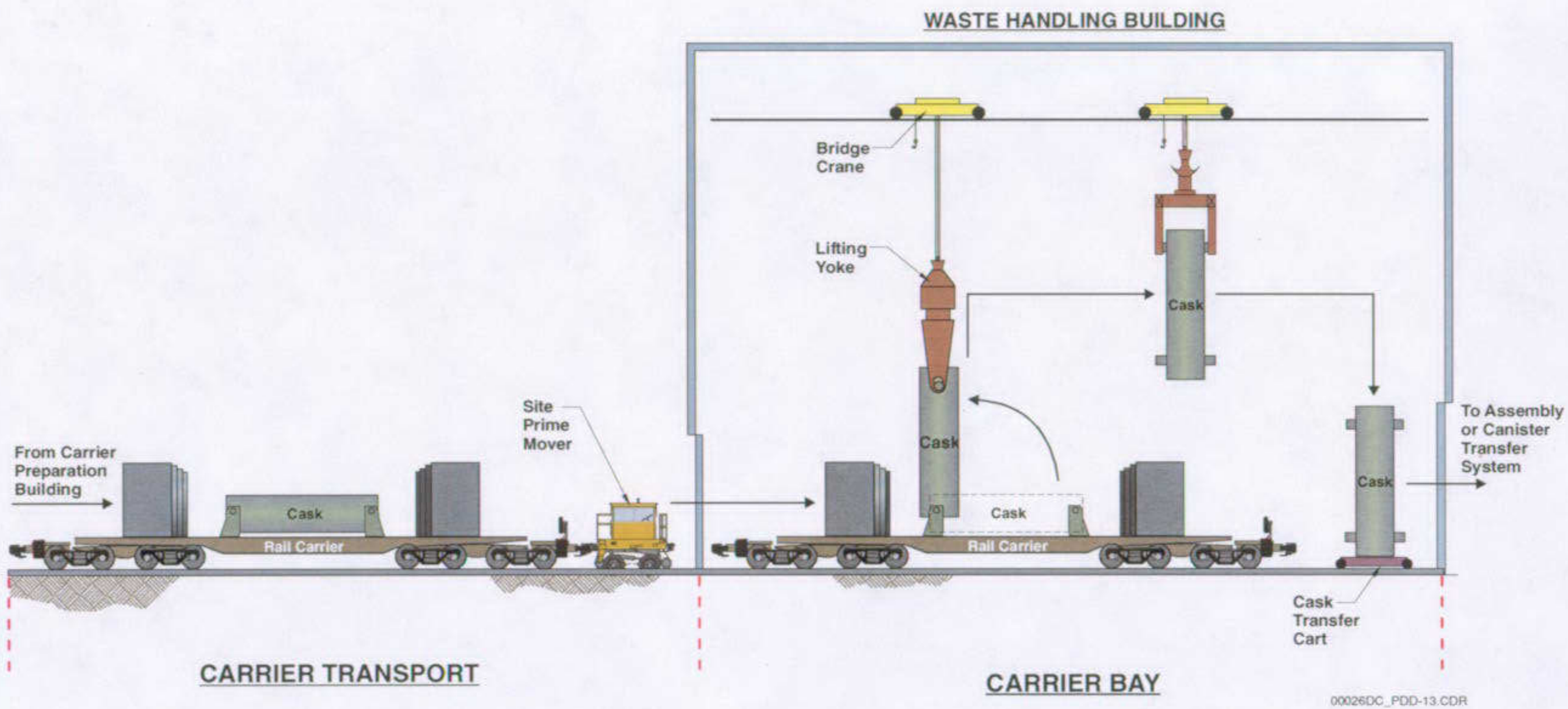


Figure 2-18. Carrier/Cask Handling System

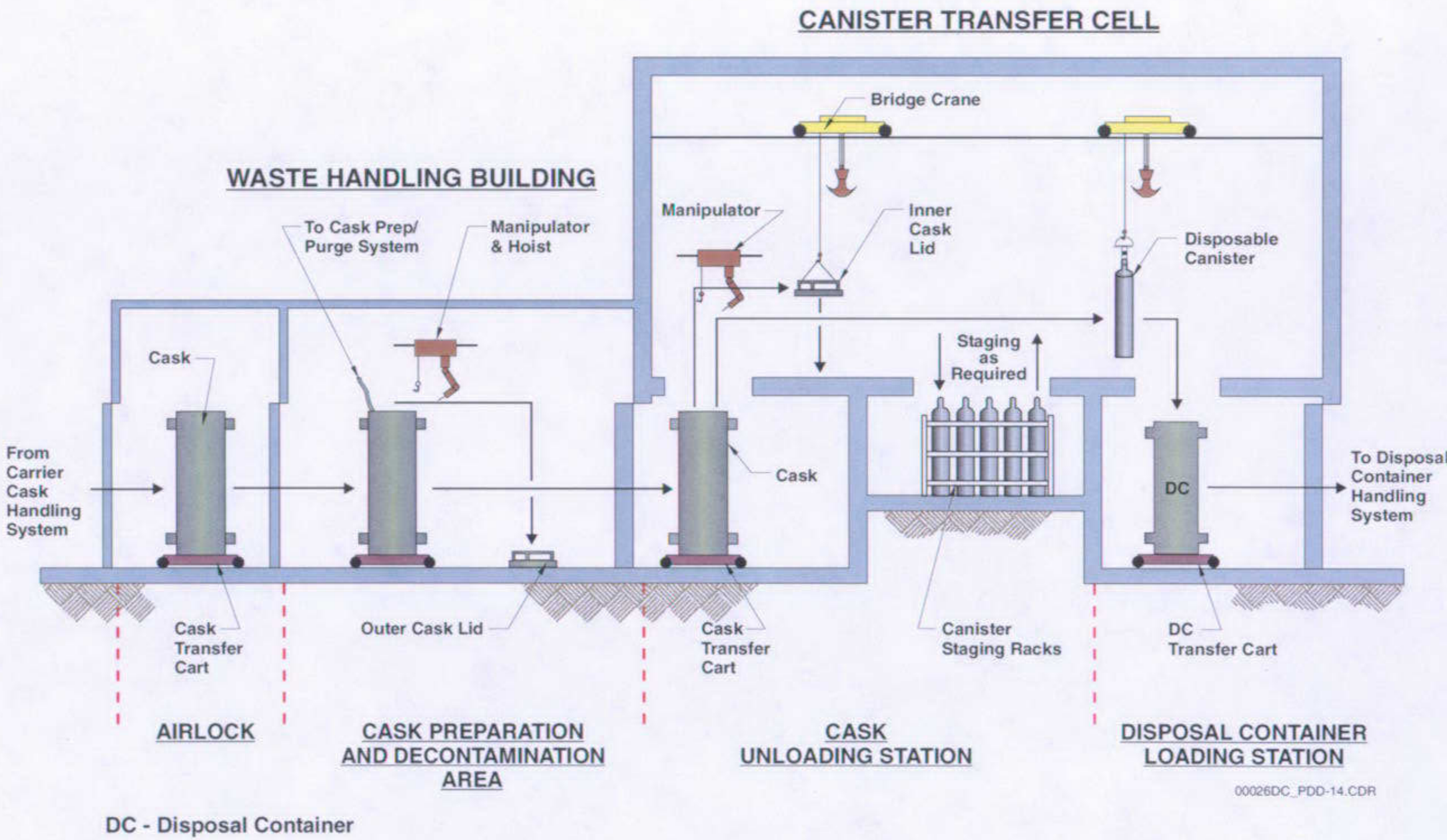


Figure 2-19. Canister Transfer System

NOTE: Canister Staging Racks are not directly under the path of the bridge crane.

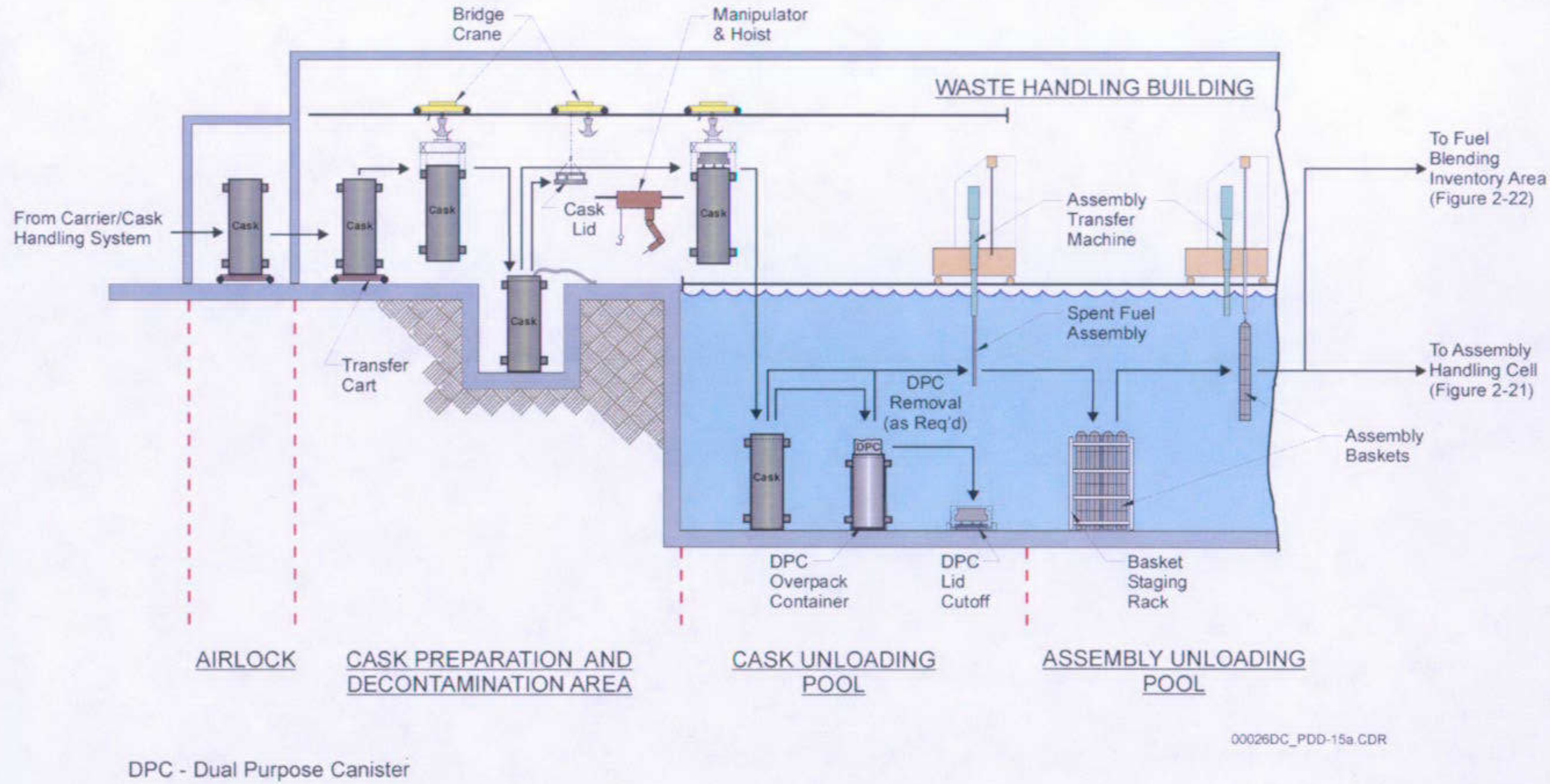


Figure 2-20. Assembly Transfer System-1

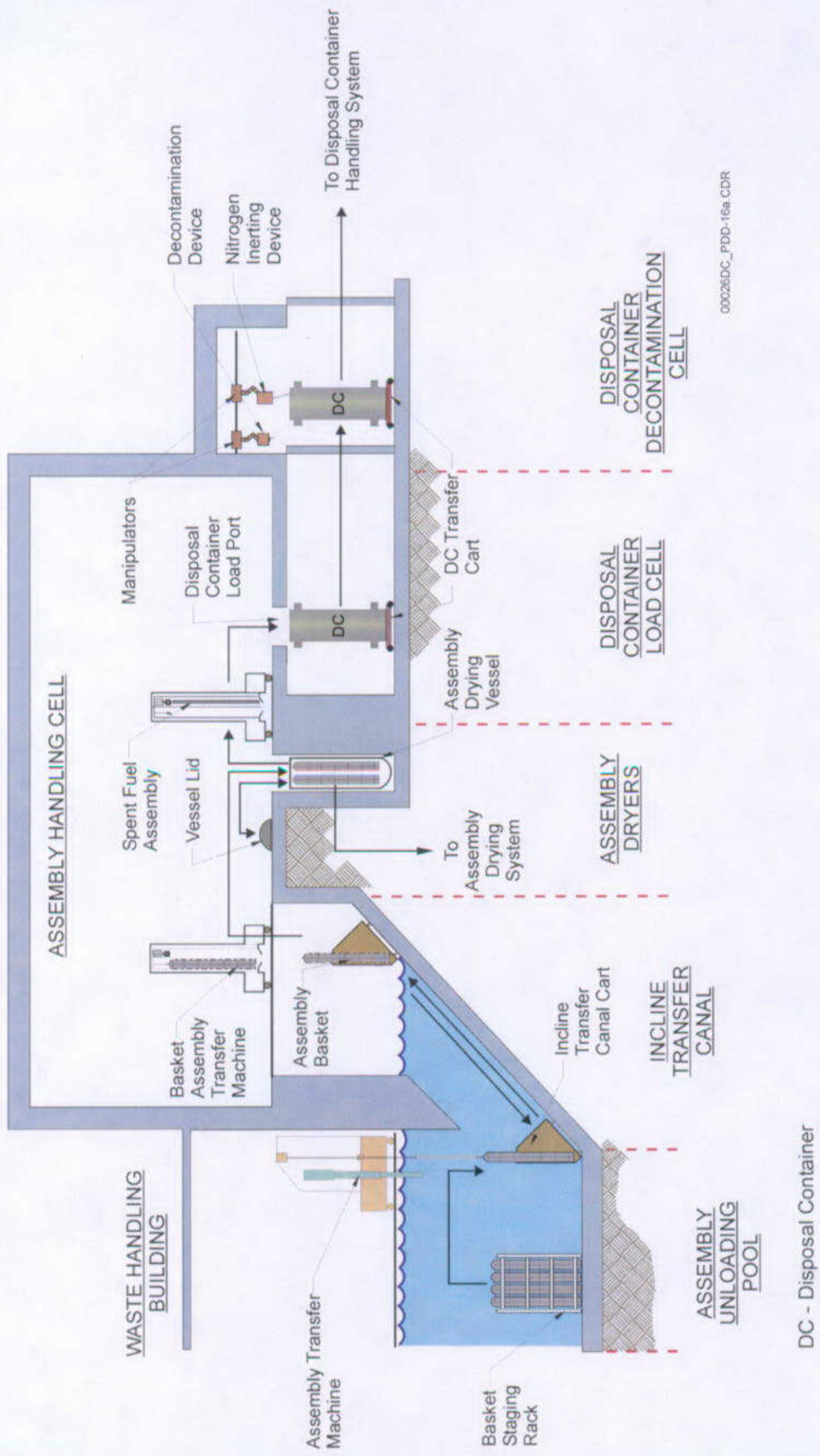


Figure 2-21. Assembly Transfer System-2

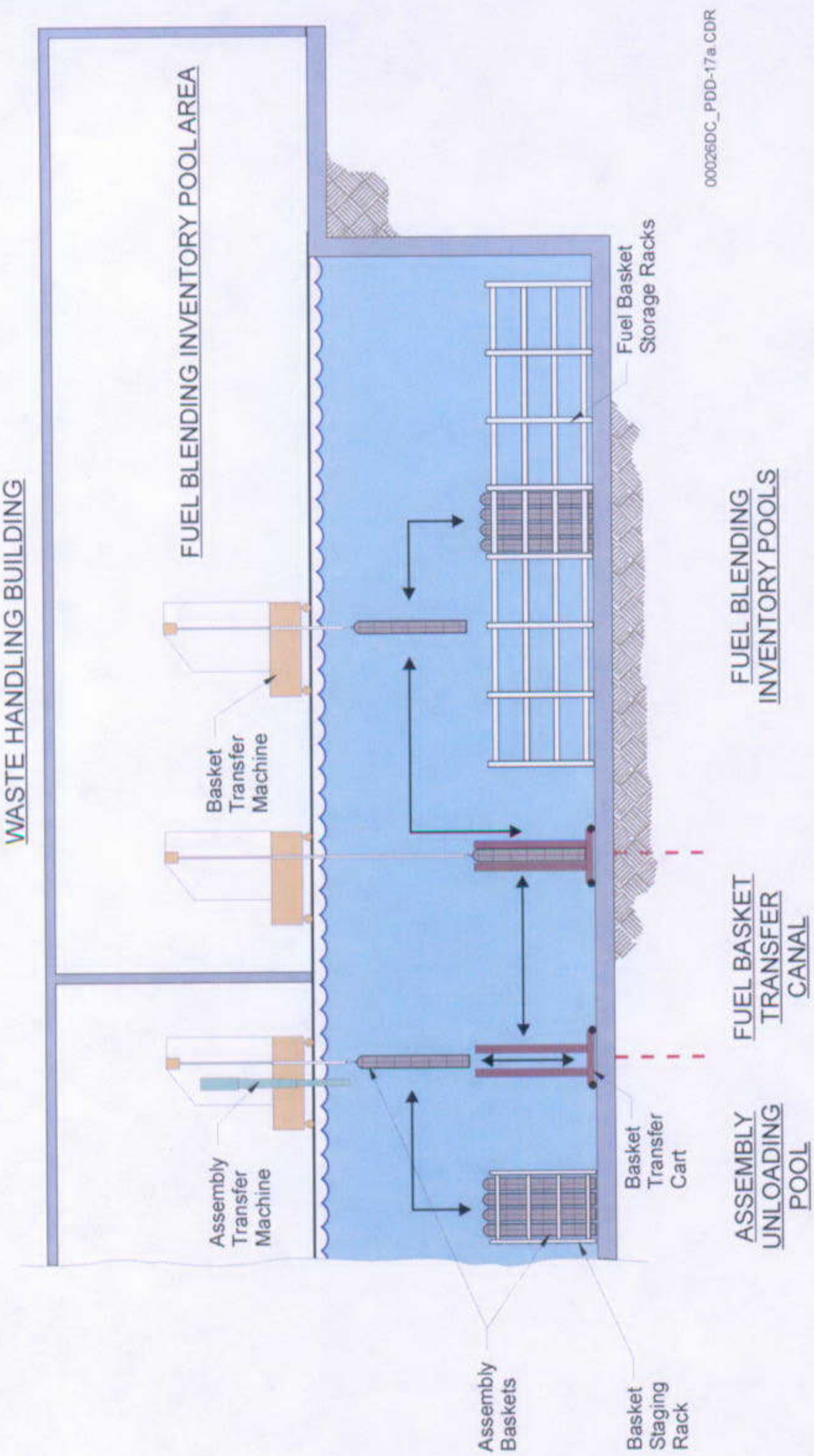


Figure 2-22. Assembly Transfer System-3

Figure 2-23. Transporter

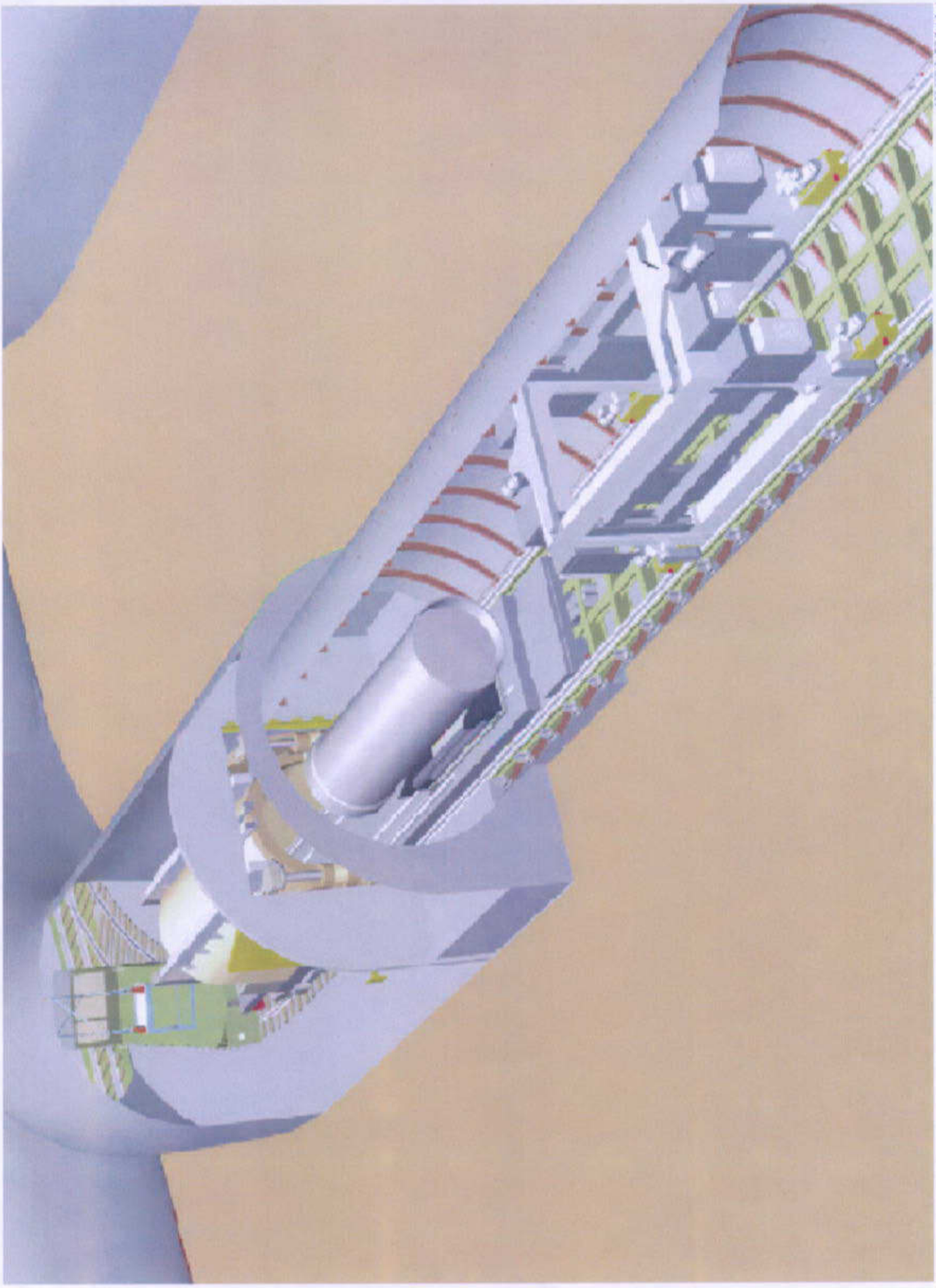


Figure 2-24. Emplacement Drift Gantry

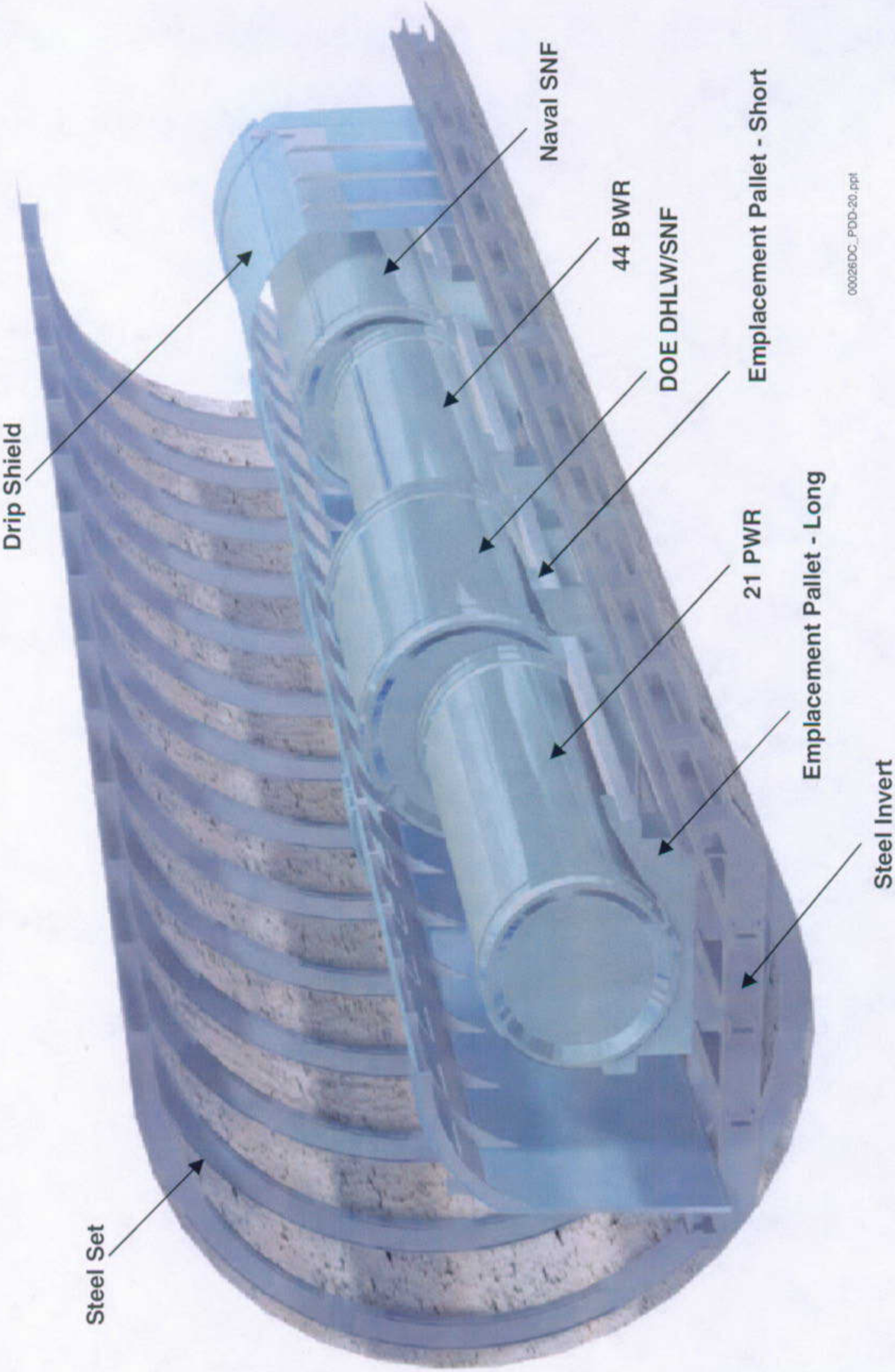


Figure 2-25. Typical Emplacement Drift Arrangement

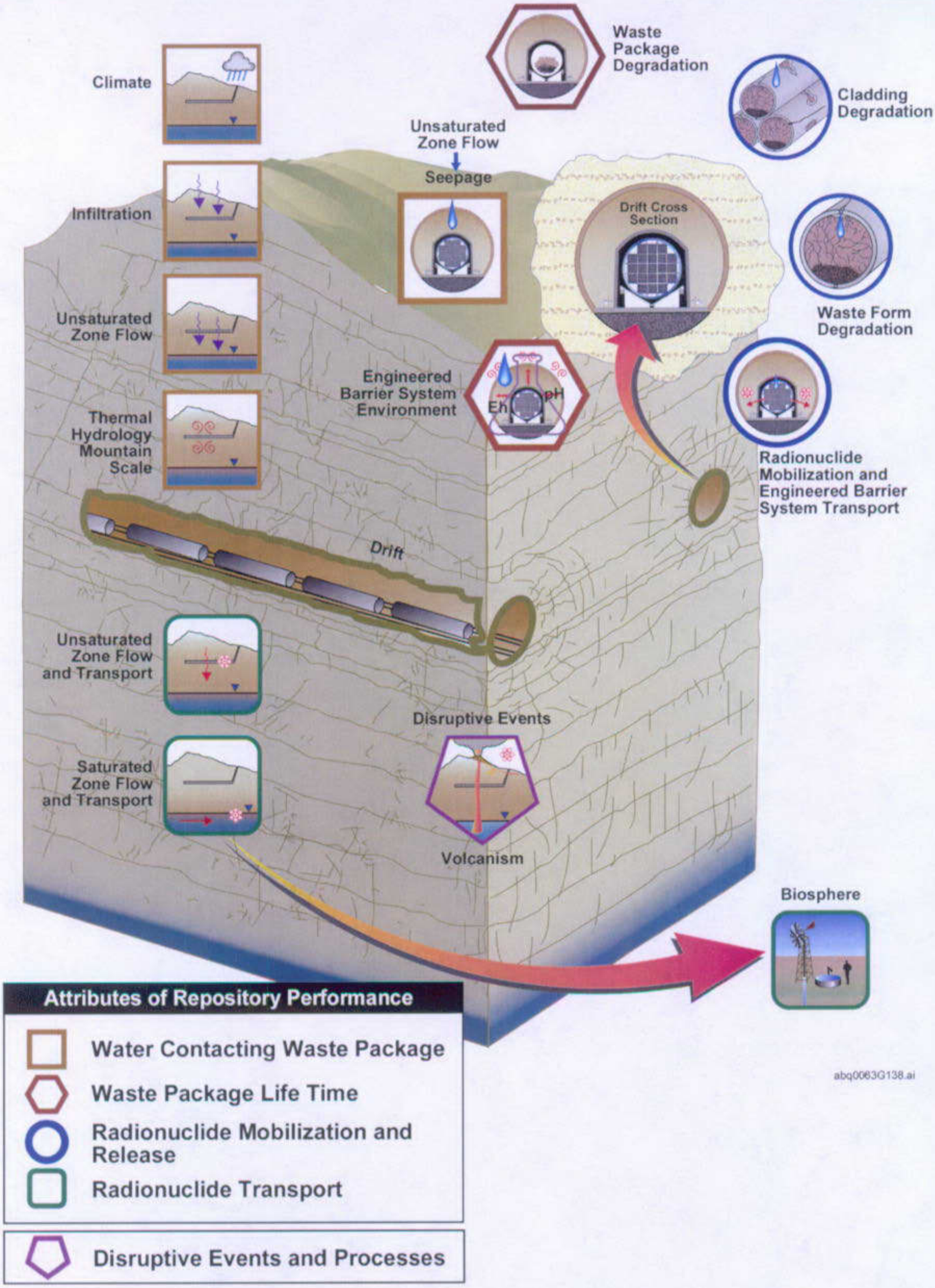


Figure 2-26. Attributes of Repository Performance

3. MGR SAFETY

3.1 PRECLOSURE SAFETY

All of the information in this section, unless otherwise noted, is taken from the *Repository Safety Strategy: Plan to Prepare the Postclosure Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations* (CRWMS M&O 2001b) and is provided in support of the technical requirements in Section 5.

3.1.1 Purpose

The purpose of the Preclosure Safety Strategy (PSS) is to prevent, minimize, or mitigate the preclosure exposure to radiation. The PSS will be used to guide the design of the MGR. It allows the engineering functions to focus on features that are important to preclosure radiological safety. It focuses on the off-site exposure constraints and includes activities leading up to closure of the MGR.

3.1.2 Strategy Development

The PSS will be revised as the MGR design matures with the expectation that the PSS will be expressed in greater detail. The development process of the PSS considered safety standards and constraints needed for the operational functions associated with receiving, handling, emplacing, and isolating waste. A primary goal of the PSS is to minimize the complexity of the design while ensuring safety design features are in place to provide public and worker safety.

The PSS provides an allocation of event and consequence mitigation to structures, systems, and components (SSCs) to address concurrent construction and waste handling operations and equipment based on the operational functions performed.

Importance to radiological safety is defined in terms of SSCs that are needed to show dose compliance to regulatory limits for potential design basis events (DBEs). Consideration of this definition is important to developing an acceptable PSS. Two DBE categories are defined as follows:

> DBE Category 1 describes the natural and human-induced events that are expected to occur one or more times before the MGR is closed.
>
> DBE Category 2 describes other natural or human-induced events that have at least one chance in 10,000 of occurring before closure of the MGR.

Because different dose limits apply to each category, it is necessary to assess the quantitative frequencies of the DBEs and then group the events into the appropriate category. The threshold frequency for identification of credible DBEs is interpreted to be greater than 10^{-6} per year. The DBE categories are currently defined as:

Category 1:	$\lambda \geq 10^{-2}$ per year
Category 2:	$10^{-6} \leq \lambda < 10^{-2}$ per year
Beyond DBE:	$\lambda < 10^{-6}$ per year

Where: λ is defined as event frequency

These frequency limits are interpreted to apply to the DBE scenario that includes the initiating event and any subsequent failures that result in a radionuclide release.

Additional safety assessments are required for criticality control. Appropriate systems within the MGR must be designed for the prevention of criticality, assuming occurrence of DBEs.

Hazard assessment methods are being used to identify events with potential radiological consequences that are applicable to the MGR during the preclosure (i.e., operational) period. The methodology used provides a systematic method to identify and group DBEs. The process of DBE identification is an iterative design process, coupled with requirements development. The iterative process continues until all the design phases are completed.

3.1.3 Mitigating Preclosure Off-site Exposure

The PSS is based on the following MGR functional operations:

- Receipt of waste
- Transfer of waste to the blending storage
- Transfer of waste to the disposal container
- Surface handling of the disposal containers
- Transfer of the WPs to the emplacement drifts
- WPs in the emplacement drifts.

The strategy for each of these functions is either containment augmented by prevention or prevention augmented by containment. Containment is the utilization of features to ensure that off-site exposure is less than 25 mrem/year for Category 1 DBEs, and 5 rem/year for Category 2 DBEs. Prevention is the utilization of features that ensure the frequency of occurrence is either less than 10^{-2}/year to prevent accidents from occurring during the MGR preclosure lifetime, or less than 10^{-6}/year to eliminate the event from the design basis.

As the design matures PSS concepts chosen for each of the operational functions will be expressed in terms of MGR location, the specific SCCs relied upon for safety at this location, the MGR facility functional safety requirements, MGR facility defense-in-depth SCCs, and defense-in-depth functional description. The defense-in-depth features will be determined, as required, when showing compliance with risk-informed guidance.

3.1.3.1 Receipt of Waste

This function covers the period of time from the arrival of the waste on-site until the transportation cask is opened. The safety strategy is to handle transportation casks when in the Cask Preparation Building and the Carrier Bay area of the Waste Handling Building within the cask design basis, such that events that result in a breach of a cask are prevented. Containment is provided by the transportation cask. Prevention of DBE exposures is provided by the surface facility SSCs that will be designed to prevent events that could exceed the cask design basis during preclosure. For canistered DOE fuels the canister also provides containment within the cask.

The MGR design is required to ensure that releases following a credible design basis drop event do not result in doses at the site boundary in excess of regulatory limits. The MGR safety strategy requires that this be done without taking credit for the high efficiency particulate air (HEPA) filtration system (CRWMS M&O 2001b, Table 4-4, Note 2). For some DOE SNF to be delivered in canisters, the canister design requires that it be capable of surviving a credible design basis drop without breach of the containment boundary to meet the MGR requirement.

For other DOE SNF (e.g., Naval SNF) to be delivered in canisters, repository facilities will be designed to ensure that releases from a dropped and breached canister do not result in a dose at the site boundary that exceeds regulatory limits without taking credit for HEPA filtration systems.

3.1.3.2 Transfer of Waste to Blending Storage

This function covers the period of time from waste removal from the transportation cask to storage (if required). After the transportation cask lid bolts are removed within the Waste Handling Building, prevention is provided by the surface facility SSCs that will be designed to prevent events that:

- Results in an unsealed transportation cask drop within the preclosure operations time period
- Reliably maintain pool water levels.

Containment is provided by the pool water and the filtering action of the Waste Handling Building HEPA filters for commercial SNF.

3.1.3.3 Transfer of Waste to the Disposal Container

This function covers the period of time from the waste removal from the transportation cask to loading the DC. After the transportation cask lid bolts are removed within the Waste Handling Building, prevention of DBE exposure is provided by the surface facility SSCs that will be designed to prevent events that result in an unsealed transportation cask drop within the preclosure operations time period. This exposure prevention is also provided by SSCs that reliably handle transfers of SNF when not in pools. Containment is provided by the Waste Handling Building HEPA filters for commercial SNF.

For canistered DOE fuel, the canister within the unsealed transportation cask will provide containment. Containment within the Waste Handling Building is also provided by the Waste Handling Building HEPA filters. Prevention of DBE exposures is provided by the surface facility SSCs that will be designated to prevent events that result in unsealed transportation cask drops that are beyond the canister design basis during preclosure.

3.1.3.4 Surface Handling of DCs

This function covers the handling of the waste from the initial receipt in the DC sealing area to loading onto the transporter.

For commercial SNF, prevention is provided by the surface facility SSCs that will be designed to reliably handle DCs to prevent events that are beyond their design bases. Containment is provided by the Waste Handling Building HEPA filters.

For canistered DOE fuels and canistered HLW, containment is provided by the canister and the Waste Handling Building HEPA filters. Prevention of DBE exposures is provided by the surface facility SSCs that will be designed to prevent DC events that are beyond the canister design basis during preclosure.

3.1.3.5 Transfer of WP to Emplacement Drift

This function covers the handling of waste from the time the WP is transported from the Waste Handling Building through the parking of the transporter at the entrance to the emplacement drift. Three locations are considered:

- Before the decent on the ramp, containment is provided by the WP. For the WPs containing canistered DOE fuel, the canister also provides containment. Prevention of DBE exposures is provided by the transporter and rail system to ensure that no credible event can occur that is beyond the WP design basis during preclosure.

- During the decent phase of the WP transportation, containment is provided by the WP. For WPs containing canistered DOE fuel, the canister also provides containment. Prevention of DBE exposures is provided by the dual locomotives and the transporter and rail system to ensure that no credible event can occur that is beyond the WP design basis during preclosure.

- During the parking of the transporter at the emplacement drift phase, containment is provided by the WP. For WPs containing canistered DOE fuel, the canister also provides containment. Prevention of DBE exposures is provided by the transporter and rail to ensure that no credible event can occur that is beyond the WP design basis during preclosure.

3.1.3.6 WP Emplacement in the Drift

This function covers handling the WP from the entrance to the emplacement drift through emplacement of the WP within the drift.

Containment is provided by the WP. For WPs containing canistered DOE fuel, the canister also provides containment. Prevention of DBE exposures is provided by the emplacement handling system, and the pallet and ground support system to ensure that no credible event can occur that is beyond the WP design basis during preclosure.

3.1.4 DBE Analysis

A preliminary analysis of MGR DBEs has been performed (CRWMS M&O 1998d) to determine the effects of internal and external events on facility radiological safety and in the classification of MGR SSCs. The DBE analysis addresses both the DBE frequencies and dose consequences at the site boundary. The classification analyses utilize the results of the DBE analysis to evaluate MGR SSCs against the classification criteria of procedure QAP-2-3.

3.1.4.1 Important to Safety Structures Systems and Components

MGR SSCs were evaluated against the preclosure criteria of QAP-2-3 to determine the item quality assurance (QA) classification level.

Quality Level (QL)-1 SSCs–QL-1 SSCs include those permanent items required to:

- Maintain WP containment or criticality control for SNF and HLW
- Prevent or mitigate a Category 1 or a Category 2 DBE that could result in exceeding specified off-site dose limits.

Examples of QL-1 SSCs include the WPs, the Waste Handling Building structure, and fissile material storage systems.

QL-2 SSCs–QL-2 SSCs include those permanent items required to:

- Provide control and management of site-generated radioactive waste
- Provide fire protection/suppression to protect the important to safety function of a QL-1 SSC
- Maintain SSC integrity so as not to prevent a QL-1 SSC from performing its intended important to safety function in the event of a DBE
- Prevent or mitigate a Category 1 DBE that could result in exceeding specified off-site dose limits
- In conjunction with an additional item or administrative control, prevent or mitigate a Category 2 DBE that could result in exceeding specified off-site dose limits.

Examples of QL-2 SSCs include system bridge cranes, radioactive low-level waste (LLW) collection and treatment systems, fuel assembly transfer machine, and Waste Handling Building fire detection/suppression systems.

QL-3 SSCs–QL-3 SSCs include those permanent items required to:

- Provide warning of significant increases in radiation levels or concentrations of radioactive materials to maintain doses ALARA
- Monitor variables to verify operating conditions are within technical specification limits

- Support MGR emergency response actions
- Assess radionuclide release or dispersion following a DBE
- Maintain levels of radioactive material in facility effluents ALARA
- Limit worker doses due to normal operations and Category 1 DBEs.

Examples of QL-3 SSCs include manipulators, radiological emergency response, emplacement drift monitoring, WP monitoring, pool water leak detection and level controls, and surface environmental monitoring.

CQ SSCs–CQ SSCs are the remaining permanent items required to support MGR operations and include inspection and sampling equipment, welding and staging fixtures, lifting and transfer mechanisms, portals and access ramps, ventilation systems, power distribution, safeguards and security, solid waste collection, and facilities arrangements. The classifications of important to safety SSCs is found in the *Q-List* (YMP 2001b).

3.2 POSTCLOSURE SAFETY

The issue of postclosure safety is based on protecting the public from any unreasonable long-term risk after permanent closure of the repository. This long-term risk is identified as potential exposure to radioactive material (contained within the initially emplaced waste or decay products of those radionuclides) that could eventually mobilize and migrate to the accessible environment.

3.2.1 Categories of Radionuclides

There are two categories of radionuclides within the radioactive waste material that would dominate long-term performance (CRWMS M&O 2001b, p. v). The first category includes those radionuclides sufficiently insoluble that only trace amounts can dissolve into the water that might seep into the repository. This comprises the vast majority of the radionuclides that would be in the repository's radioactive waste material. In addition to these radionuclides' limited solubility, sorption and other natural processes retard their movement in the rock and dilute their concentration at the site (CRWMS M&O 2001b, p. v).

The second category includes the small fraction (less than 0.004 percent of the total inventory of radionuclides in the radioactive waste material) of radionuclides that are relatively soluble and those that might attach to colloids. There is potential that these might become mobilized and migrate through the rock if exposed to liquid water. Risk from these radionuclides is eliminated if the waste is not exposed to water (CRWMS M&O 2001b, p. v).

3.2.2 Postclosure Principal Factors

The postclosure safety issue will focus on the following key attributes (DOE 2001a, Executive Summary):

- Limited water entering the emplacement drifts
- Long-lived waste package and drip shield
- Limited release of radionuclides from the engineered barriers
- Delayed dilution of radionuclide concentrations by the natural barriers
- Low mean annual dose considering potentially disruptive events.

Additional features, processes, and events that have potential to disrupt the repository system will also be addressed, but are not considered principal factors (CRWMS M&O 2001b, p. vi).

The current understanding of the postclosure safety case strongly suggests that an adequate basis for judging the postclosure safety of the repository exists. This safety case will continue to evolve and mature as future work is accomplished. A completed safety case will be available in time to support the site suitability and licensing decisions (CRWMS M&O 2001b, p. vii).

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4. ARCHITECTURE, FUNCTIONS, AND INTERFACES

4.1 MGR ARCHITECTURE

The identification, structure, and relationships of the items in the MGR Architecture are considered to be part of the technical baseline. The MGR Architecture captures, by logical groupings, the hierarchical arrangement of the MGR project design and represents the physical system that will meet MGR requirements. The SSCs included in the architecture are controlled by the Preclosure Safety and Systems Engineering Section.

SDDs are key system documents for defining and describing the MGR. Because of the importance of SDDs to the development of the MGR design, any system requiring an SDD is shown within the MGR Architecture. Further architecture decomposition of those systems into their subsystems, components, etc., is captured in the SDDs as part of the design process. A list of system designators is given in Appendix A and designators are shown on Figures 4-1, 4-2, 4-3, 4-4, 4-5, 4-6, and 4-7.

In general, repository operational activities are not controlled through the Configuration Management Program and do not lend themselves to a physical architecture. Many activities do identify requirements that must be met by the MGR design. These requirements typically become part of the design input for an SDD and are traceable through design output products that can be directly related to the physical architecture.

Although the Natural Barrier System is included in the top-level architecture, no further decomposition of its characteristics is provided at this time. Descriptions of the Natural Barrier System are captured in the scientific database and provided as design input as discussed above. Most construction and development activities do not lend themselves to the architecture because of the temporary nature of those activities.

If Yucca Mountain is found suitable as a repository site, some parts of the Exploratory Studies Facility will likely become permanent parts of the MGR. Those permanent SSCs will be integrated into the MGR Architecture. The architectural element called Exploratory Studies Facility is not currently a part of the MGR architecture.

The MGR Architecture is depicted in Figures 4-1 through 4-4. Figure 4-1 shows the architecture breakdown to Level 4. Figures 4-2, 4-3, and 4-4 show the architecture breakdown to Level 5. An SDD will be written for each architecture Level 5 system.

All systems in the MGR Architecture have a unique three-letter system designator that is shown in each block. This designator will be included in document identifiers to enable traceability of information and activities to the affected systems.

4.2 PERFORMANCE FUNCTIONS

4.2.1 Introduction

An effective method of identifying requirements associated with the operation of a system is the development of flow charts with Performance Functions that define the operational flow of the products. These flow charts show dependencies between the elements of the system architecture when the elements are performing in accordance with the operations concept depicted for the system. From these interfaces, as well as from the actual flow chart functions, requirements are defined that are then allocated to the appropriate system architecture elements and that ultimately impact the system design.

4.2.2 MGR Functional Flow

The MGR functional flow is shown in Figure 4-5. The transportation casks arrive at the gate to the MGR via the Waste Acceptance and Transportation element.

The Waste Handling System processes the transportation casks, the carriers, and the SNF and HLW for emplacement, then emplaces the SNF and HLW in the Emplacement Drifts.

The disposal container fabricator delivers disposal containers to the Waste Handling System for loading with SNF and HLW. The disposal containers are manufactured and delivered to the Waste Isolation System via the Waste Acceptance and Transportation element.

Once the SNF and HLW are loaded into disposal containers and the resulting WPs are emplaced in the Emplacement Drifts, the Waste Isolation System function monitors and analyzes the condition of the WPs and the response of the natural environment resulting from the emplacement operation.

4.2.3 Waste Handling System Process Functional Flow

The Waste Handling System process functional flow is shown in Figure 4-6.

The second level flow chart (Figure 4-6) begins with a reference function, as shown by block reference Ref 1.0, TCs Arrive at MGR. The Carrier/Cask Shipping & Receiving Systems process the transportation casks and carriers to the Waste Preparation Systems. Here the SNF and HLW are processed for emplacement. Waste Emplacement and Retrieval Systems provide the actual emplacement. Block reference Ref 4.0 indicates the disposal container fabricator delivers disposal containers to the Waste Processing System for loading and disposal.

During the processing of the transportation casks, carriers, SNF and HLW, Site Generated Radiological Waste is processed by the Waste Treatment System. Because this is a lower level flow chart, the flow ends with a reference function as shown by block reference Ref 3.0, PC Monitors and Evaluates MGR.

4.2.4 Carrier/Cask Shipping and Receiving Systems Process Functional Flow

Carrier/Cask Shipping and Receiving Systems process functional flow is shown in Figure 4-7. As with the second level flow chart, this (third level) flow begins with a reference function, block reference Ref 2.1, CSR Processes TC & Carriers. From there the flow indicates the transportation casks and carriers are received at the MGR interface with the Waste Acceptance and Transportation element by the Carrier/Cask Transport System and moved to the Carrier Preparation Building System.

The Carrier Preparation Building Materials Handling System prepares the transportation casks and carriers for movement to the Waste Handling Building. Here the transportation casks are separated from the carriers, which are returned to the Carrier Preparation Building for final processing and inserted into the Waste Acceptance and Transportation element.

The transportation casks are moved to the appropriate processing line (i.e., the Assembly Transfer System or the Canister Transfer System) in preparation for removal of the SNF or HLW. The transportation casks are returned to the Carrier Preparation Building for final processing and insertion into the Waste Acceptance and Transportation element.

The flow ends with block reference Ref 2.2, WPS Unloads TCs.

The performance functions will be further developed and incorporated into a subsequent revision of this document.

4.3 INTERFACE MATRIX

Interfaces within the approved and/or planned SDDs were initially conceptualized. These conceptualized interfaces were then confirmed, where applicable, with SDD authors and with approved SDDs. Once confirmed, the interface was placed into the interface matrix and its supporting documents. Additional interfaces, not originally conceptualized but found in the written SDD, were also added to the matrix. Conceptualized interfaces that were determined to be invalid were not added. The interface matrix and supporting documentation (Appendix C) have been truncated to show only interfaces between SDDs that have been written.

Each identified interface is 3rd, 4th, or 5th Level. The highest level of the system architecture through which one must proceed to trace a path between the two SDDs determines the level of the interface.

4.3.1 Interface Matrix

Table 4-1 is an interface matrix that summarizes the result of the currently identified interfaces. Both axes of the interface matrix contain the same list of currently written SDDs and their respective 3rd and 4th Level architecture. The cells along the diagonal are shaded black where the SDDs along the horizontal and vertical axes are the same. The black shaded cells form a diagonal, which splits the matrix into two identical halves. A unique number is placed in each cell when one or more interfaces exist between the intersecting SDDs. This numbering system was used during development of the interface documentation, and is explained (with examples) in Section 4.3.3. There are three levels of shading in each of the cells: none, light gray, and dark gray. Cells with no shading indicate Level 5 interfaces. Cells with light gray shading indicate Level 4 interfaces. Cells with dark gray shading indicate Level 3 interfaces.

4.3.2 Interface Documentation

Each currently identified interface found in the interface matrix can also be found in the supporting Appendix C, Interface Documentation, with the number from the matrix cell corresponding to the number found in the appendix. The interfaces are listed in numerical order.

An interface begins with a P, F, or P/F. A "P" denotes that the interface is physical, an "F" denotes that the interface is functional, and a "P/F" denotes that the two systems share physical and functional interfaces. If multiple interfaces exist between two SDDs, each interface is identified with a bullet.

4.3.3 MGR Interfaces

All potential MGR interfaces are identified with a unique numbering system in this section. Those currently identified interfaces are shown in the Interface Matrix (Table 4-1) and further described in Appendix C.

LEVEL 3 INTERFACES

When two elements in the architecture interface with each other and the elements are not in the same hierarchical chain, the interface occurs at Level 3 in the System Architecture.

Example:

The Maintenance & Supply System (MSS) is a Level 5 element in the hierarchical chain of the Management & Administrative Systems (MAS). The Management & Administrative Systems (MAS) is a Level 4 element in the architecture and part of the Operational Support System (OSS), which is a Level 3 element.

This is a Level 3 interface because of the traceability from one element of the interface to the other element of the interface. This traceability is defined to go to the highest element in the architecture that is common to the elements of the interface. In this case that commonality occurs at the MGR element at Level 2. Because the MGR would not provide enough definition for defining the interface, the elements common to it, at Level 3, are identified and the interface becomes a Level 3 interface.

The Level 3 interfaces are shown in Table 4-1 as cells with dark gray shading. A detailed description of the currently identified interfaces is located in Appendix C.

LEVEL 4 INTERFACES

The Level 4 interfaces occur between level 4 elements of the same system.

Example:

An interface exists between the Disposal Container Handling System (DCH) and the Waste Emplacement/Retrieval Transportation System (WES). Both of these elements are part of the Waste Handling System (WHS).

The Disposal Container Handling System (DCH) is a Level 5 element in the hierarchical chain of the Waste Preparation Systems (WPS), which is a Level 4 element of the architecture.

The Waste Emplacement/Retrieval Transportation System (WES) is a Level 5 element in the hierarchical chain of the Waste Emplacement & Retrieval Systems (WER), which is a Level 4 element of the architecture.

The Level 4 elements are common under the Waste Handling System (WHS), therefore this becomes the level of the interface.

The Level 4 interfaces are shown on Table 4-1 as cells with light gray shading. A detailed description of the currently identified interfaces is located in Appendix C.

LEVEL 5 INTERFACES

The Level 5 interfaces occur between Level 5 elements of the same hierarchical chain.

Example:

An interface exists between the Assembly Transfer System (ATS) and the Waste Handling Building Electrical System (HBE). Both of these elements are at Level 5 in the hierarchical chain of the Waste Preparation Systems (WPS), which is at Level 4. Since the common element in the interface is at Level 4 the interface has been identified as a Level 5 Interface.

The Level 5 interfaces are shown on Table 4-1 as cells with no shading. A detailed description of the currently identified interfaces is located in Appendix C.

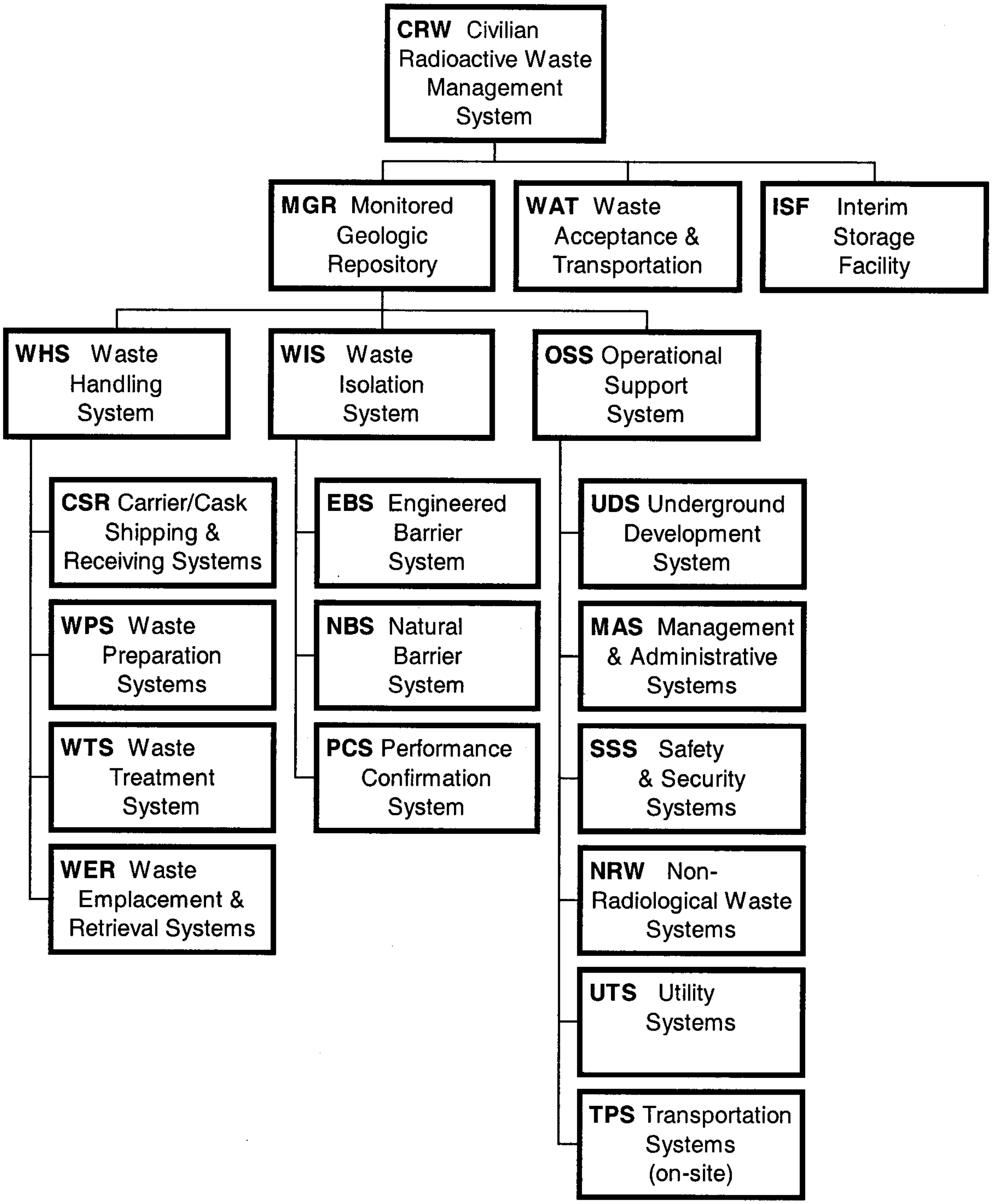


Figure 4-1. CRWMS Architecture

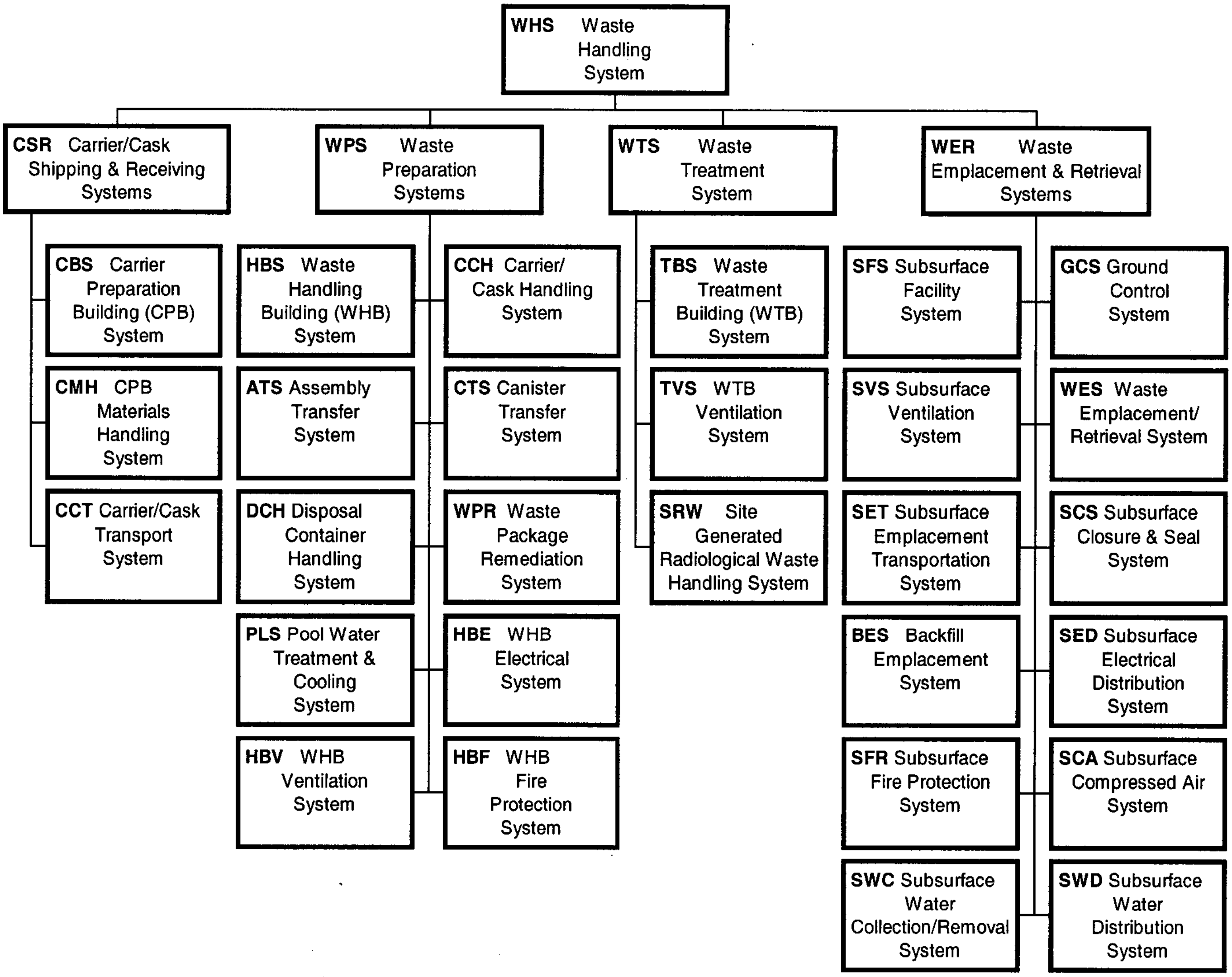


Figure 4-2. Waste Handling System

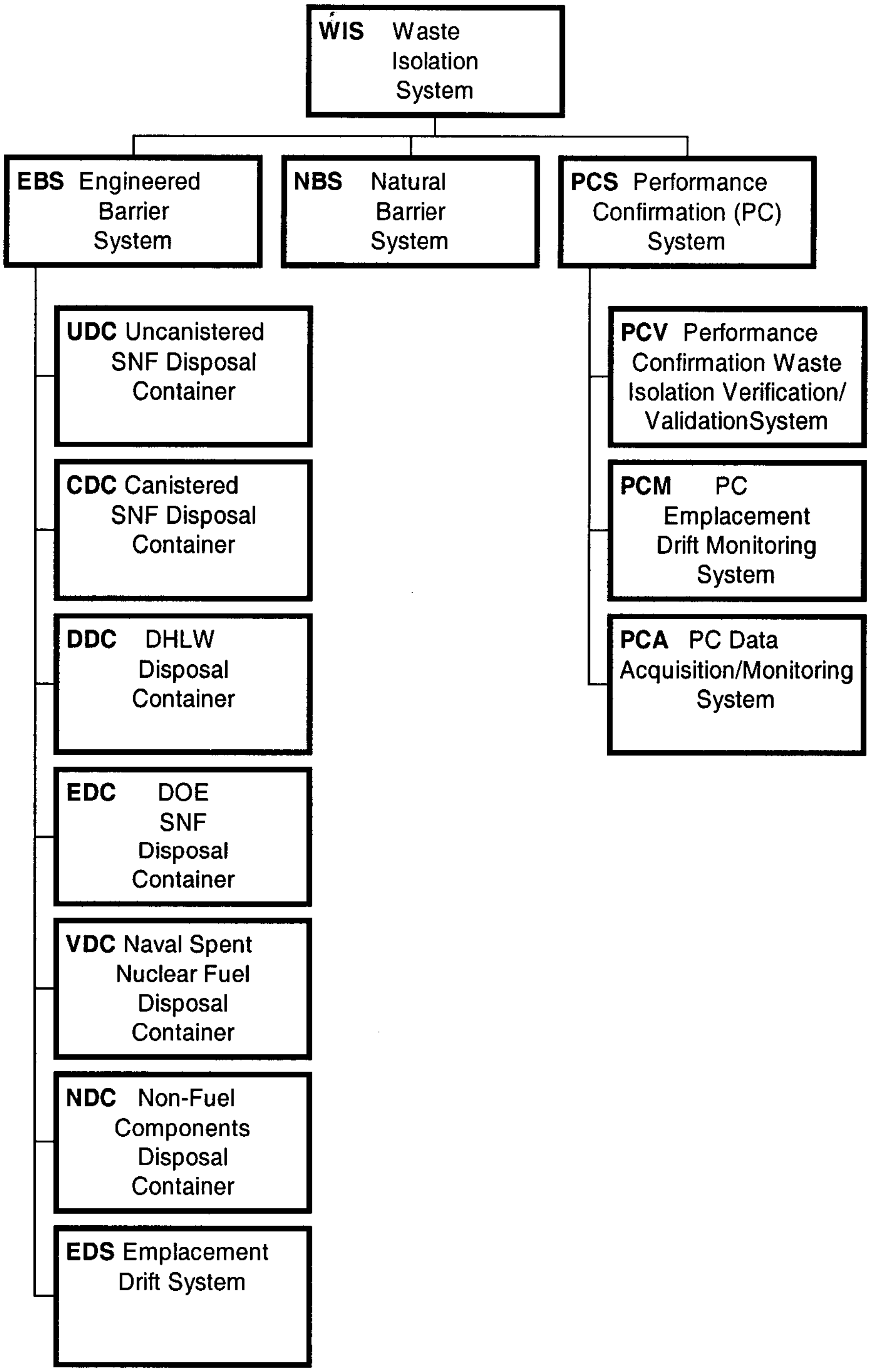


Figure 4-3. Waste Isolation System

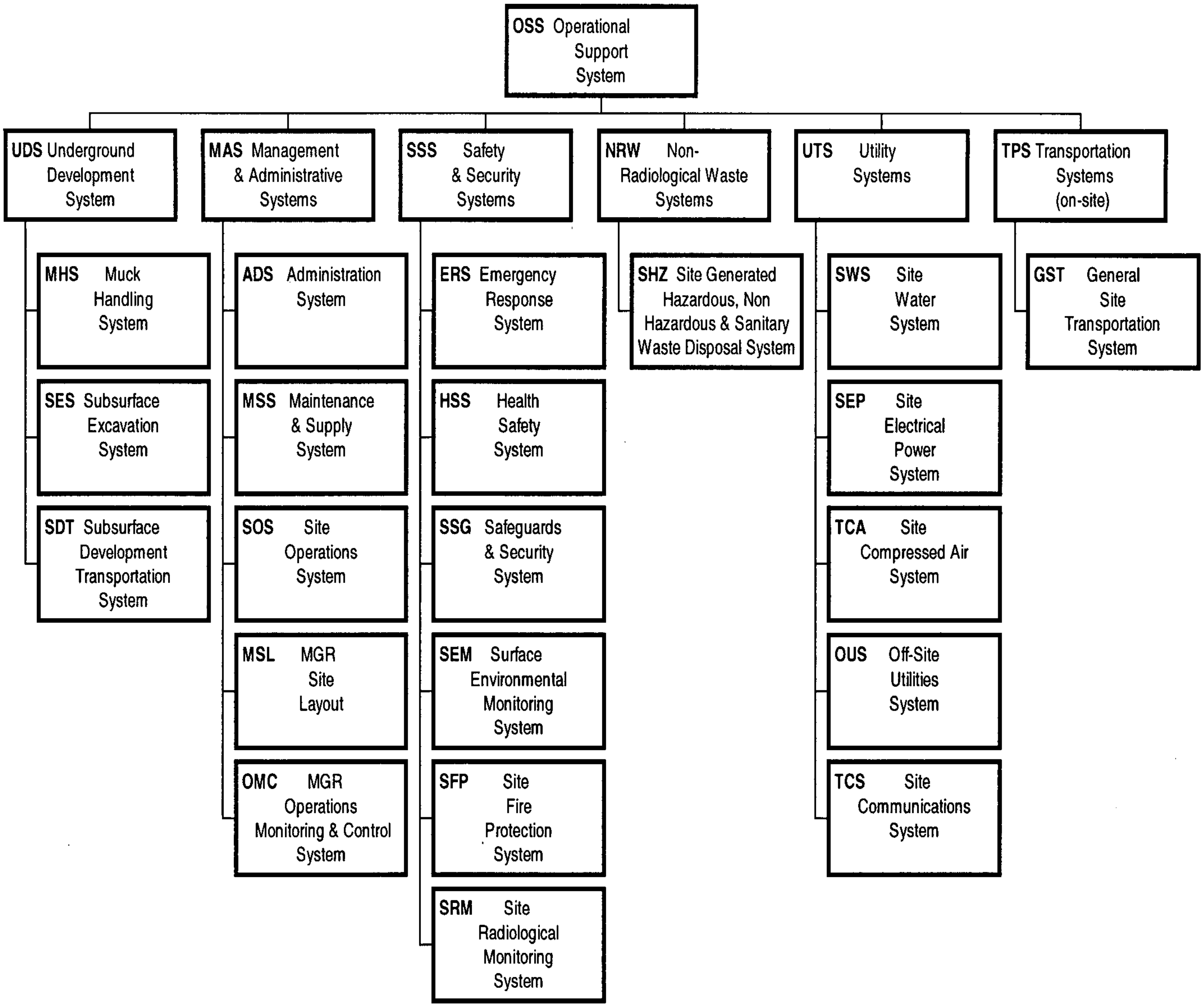


Figure 4-4. Operational Support System

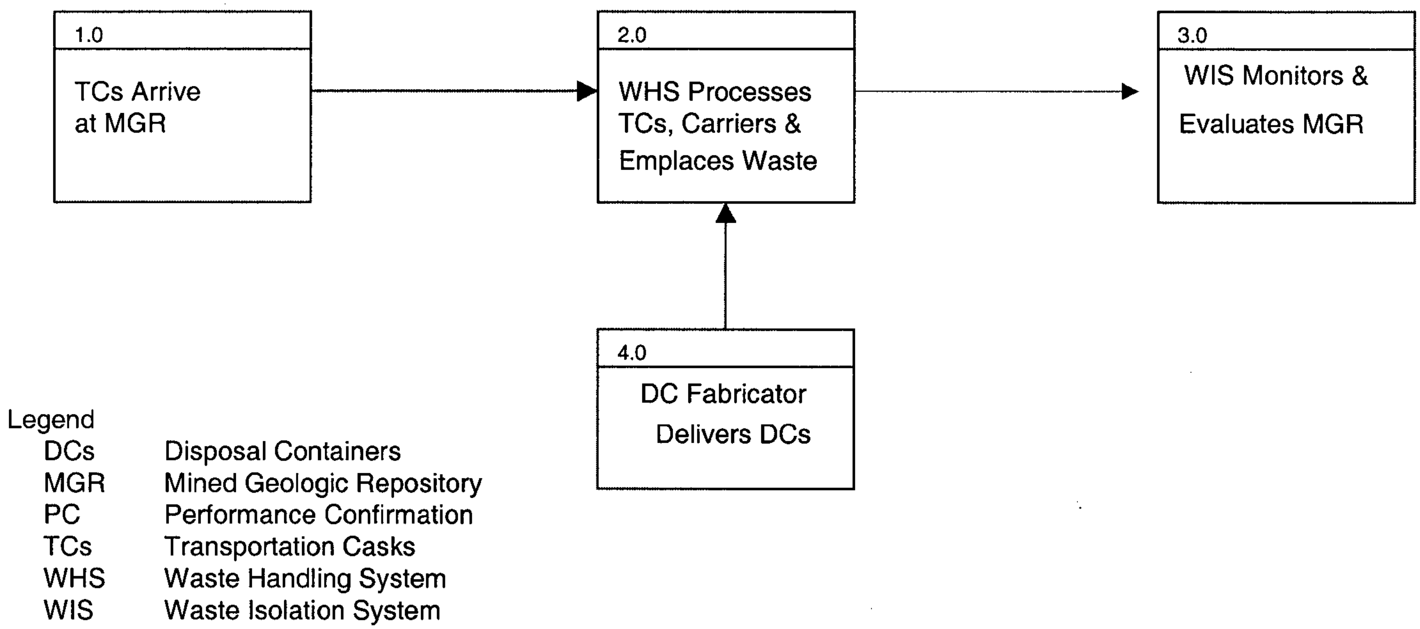


Figure 4-5. MGR Functional Flow

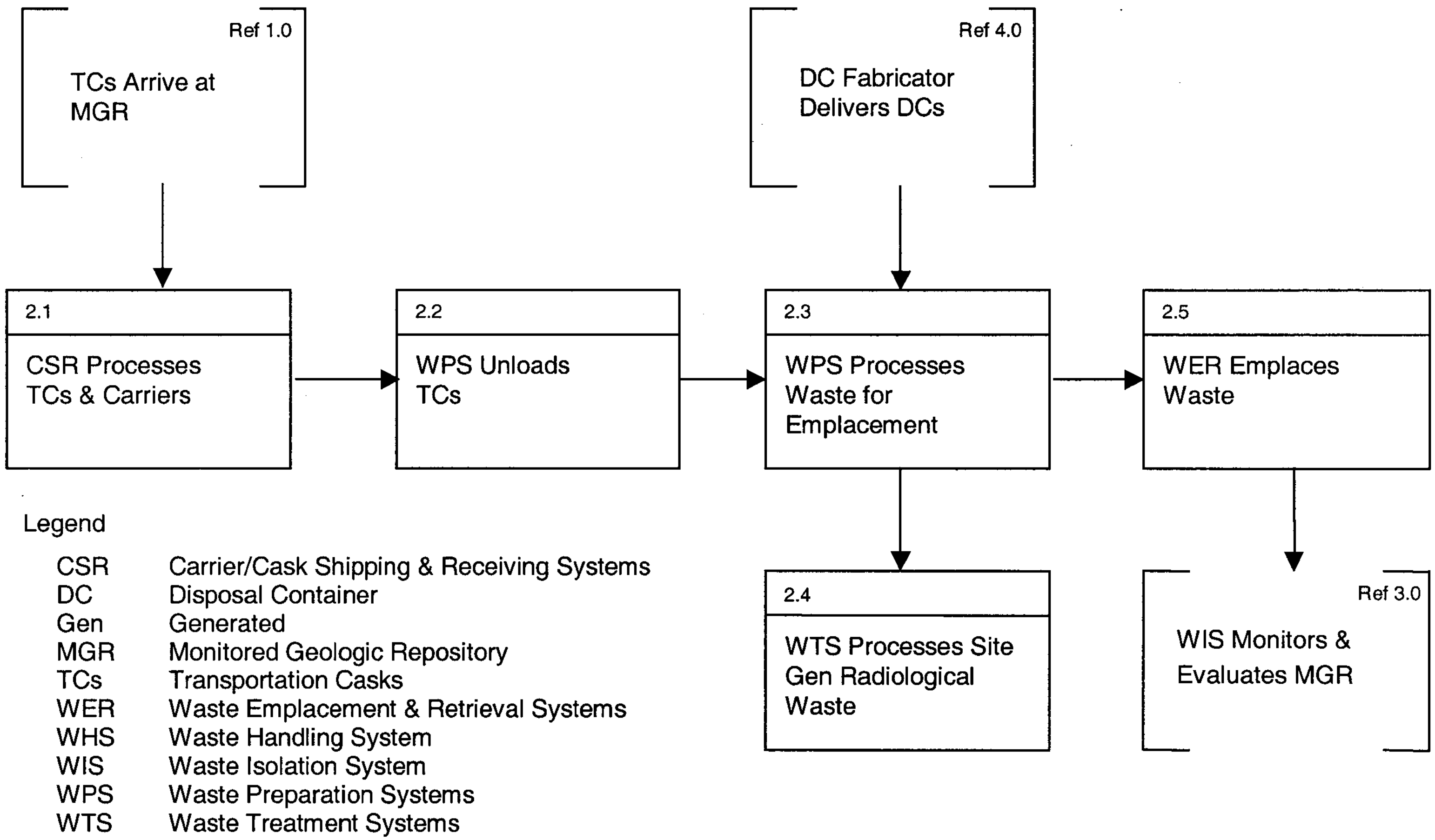
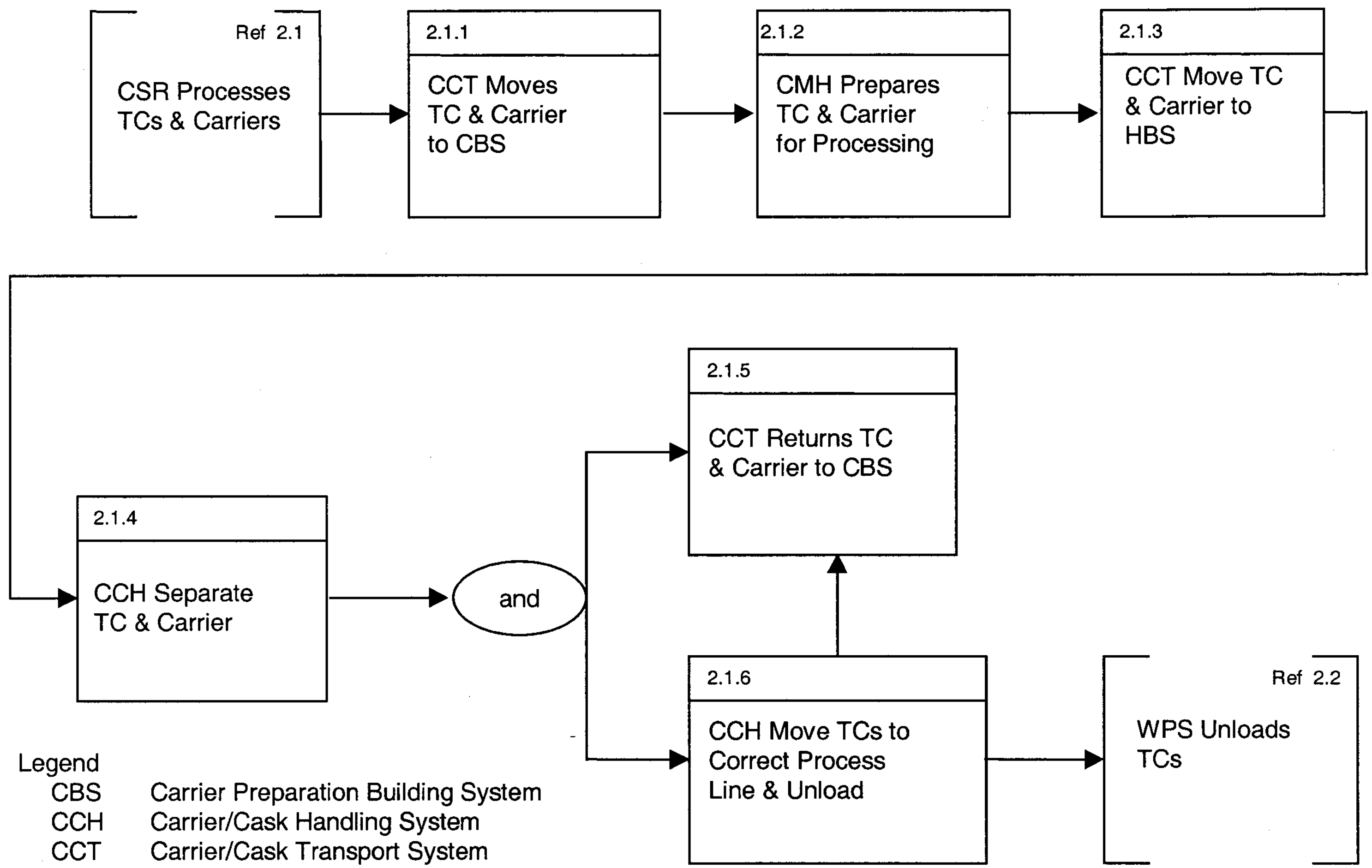


Figure 4-6. Waste Handling System Process Functional Flow



Legend

CBS	Carrier Preparation Building System
CCH	Carrier/Cask Handling System
CCT	Carrier/Cask Transport System
CMH	CPB Materials Handling System
CSR	Carrier/Cask Shipping & Receiving Systems
HBS	Waste Handling Building System
TCs	Transportation Casks
WPS	Waste Preparation Systems

Figure 4-7. Carrier/Cask Shipping and Receiving Systems Process Functional Flow

Table 4-1. MGR Interface Matrix

	Waste Handling System (WHS)	Carrier/Cask Shipping & Receiving Systems (CSR)	CPB Materials Handling System (CMH)	Waste Preparation System (WPS)	Waste Handling Building (WHB) System (HBS)	Assembly Transfer System (ATS)	Disposal Container Handling System (DCH)	Pool Water Treatment & Cooling System (PLS)	WHB Ventilation System (HBV)	Carrier/Cask Handling System (CCH)	Canister Transfer System (CTS)	Waste Package Remediation System (WPR)	WHB Electrical System (HBE)	WHB Fire Protection System (HBF)	Waste Treatment Systems (WTS)	Waste Treatment Building (WTB) System (TBS)	WTB Ventilation System (TVS)	Site Generated Radiological Waste Handling System (SRW)	Waste Emplacement & Retrieval Systems (WER)	Subsurface Facility System (SFS)	Subsurface Ventilation System (SVS)	Backfill Emplacement System (BES)	Ground Control System (GCS)	Waste Emplacement/Retrieval System (WES)	Waste Isolation System (WIS) Interfaces	Engineered Barrier System (EBS)	Uncanistered SNF Disposal Container (UDC)	DHLW Disposal Container (DDC)	Naval Spent Nuclear Fuel Disposal Container (VDC)	Emplacement Drift System (EDS)	Performance Confirmation (PC) System (PCS)	Operational Support System (OSS) Interfaces	Underground Development System (UDS)	Management & Administrative Systems (MAS)	MGR Operations Monitoring & Control System (OMC)	Safety & Security Systems (SSS)	Site Fire Protection System (SFP)	Non-Radiological Waste Systems (NRW)	Utility Systems (UTS)	Transportation Systems (on-site) (TPS)
Waste Handling System (WHS)																																								
Carrier/Cask Shipping & Receiving Systems (CSR)																																								
CPB Materials Handling System (CMH)																																			11.12.25					
Waste Preparation Systems (WPS)																																								
Waste Handling Building (WHB) System (HBS)						1.2.10	1.2.11	1.2.12	1.2.13	1.2.14	1.2.15	1.2.16	1.2.17	1.2.18				1.20.13						1.21.18			10.21.11	10.21.13	10.21.15						11.22.15		11.23.15			
Assembly Transfer System (ATS)					1.2.10		1.2.20		1.2.22	1.2.23			1.2.26														10.21.21	10.21.23	10.21.25						11.22.25					
Disposal Container Handling System (DCH)					1.2.11	1.2.20			1.2.31		1.2.33	1.2.34	1.2.35					1.20.33						1.21.38			10.21.31	10.21.33	10.21.35						11.22.35					
Pool Water Treatment & Cooling System (PLS)					1.2.12								1.2.44					1.20.43																	11.22.45					
WHB Ventilation System (HBV)					1.2.13	1.2.22	1.2.31				1.2.51		1.2.53	1.2.54				1.20.53																	11.22.55					
Carrier/Cask Handling System (CCH)					1.2.14	1.2.23					1.2.60		1.2.62																						11.22.65					
Canister Transfer System (CTS)					1.2.15		1.2.33		1.2.51	1.2.60			1.2.71														10.21.71	10.21.73	10.21.75						11.22.75					
Waste Package Remediation System (WPR)					1.2.16		1.2.34						1.2.80					1.20.83									10.21.81	10.21.83	10.21.85						11.22.85					
WHB Electrical System (HBE)					1.2.17	1.2.26	1.2.35	1.2.44	1.2.53	1.2.62	1.2.71	1.2.80		1.2.90				1.20.93																	11.22.95		11.23.95			
WHB Fire Protection System (HBF)					1.2.18				1.2.54				1.2.90																						11.22.105		11.23.105			
Waste Treatment System (WTS)																																								
Waste Treatment Building (WTB) System (TBS)																	1.3.10	1.3.11																	11.32.15		11.33.15			
WTB Ventilation System (TVS)																1.3.10		1.3.20																	11.32.25					
Site Generated Radiological Waste Handling System (SRW)					1.20.13		1.20.33	1.20.43	1.20.53			1.20.83	1.20.93			1.3.11	1.3.20																		11.32.35					
Waste Emplacement & Retrieval Systems (WER)																																								
Subsurface Facility System (SFS)																					1.4.10	1.4.12	1.4.15	1.4.16						10.41.17							11.43.15			
Subsurface Ventilation System (SVS)																				1.4.10		1.4.21		1.4.25						10.41.27					11.42.25		11.43.25			
Backfill Emplacement System (BES)																				1.4.12	1.4.21									10.41.47										
Ground Control System (GCS)																				1.4.15				1.4.70						10.41.77										
Waste Emplacement /Retrieval System (WES)					1.21.18		1.21.38													1.4.16	1.4.25		1.4.70				10.41.81	10.41.83	10.41.85	10.41.87					11.42.85					
Waste Isolation System (WIS) Interfaces																																								
Engineered Barrier System (EBS)																																								
Uncanistered SNF Disposal Container (UDC)					10.21.11	10.21.21	10.21.31				10.21.71	10.21.81												10.41.81						2.1.15										
DHLW Disposal Container (DDC)					10.21.13	10.21.23	10.21.33				10.21.73	10.21.83												10.41.83						2.1.33										
Naval Spent Nuclear Fuel Disposal Container (VDC)					10.21.15	10.21.25	10.21.35				10.21.75	10.21.85												10.41.85						2.1.51										
Emplacement Drift System (EDS)																				10.41.17	10.41.27	10.41.47	10.41.77	10.41.87			2.1.15	2.1.33	2.1.51											
Performance Confirmation (PC) System (PCS)																																								
Operational Support System (OSS) Interfaces																																								
Underground Development System (UDS)																																								
Management & Administrative Systems (MAS)																																								
MGR Operations Monitoring & Control System (OMC)			11.12.25		11.22.15	11.22.25	11.22.35	11.22.45	11.22.55	11.22.65	11.22.75	11.22.85	11.22.95	11.22.10		11.32.15	11.32.25	11.32.35			11.42.25			11.42.85													3.20.55			
Safety & Security Systems (SSS)																																								
Site Fire Protection System (SFP)					11.23.15								11.23.95	11.23.10		11.33.15				11.43.15	11.43.25														3.20.55					
Non-Radiological Waste Systems (NRW)																																								
Utility Systems (UTS)																																								
Transportation Systems (on-site) (TPS)																																								

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5. TECHNICAL REQUIREMENTS

The elements of the technical requirements in Sections 5.1, 5.2, 5.3, and 5.4 are established to implement the current repository design concept as described in Section 2. These requirements, criteria, constraints, and goals are considered part of the technical baseline and, in addition to the items shown in Table 1-1, address the technical requirements in the YMP RD (YMP 2001a). In conjunction with those requirements, these things compose the engineering design basis for the detailed design process as captured in the SDDs. All requirements, criteria, and constraints below, that are not referenced to another document, will be treated as management edicts once this document is baselined and, consequently, are not referenced to other management directives. Any technical requirement in this section that cites an unqualified, unconfirmed, or uncontrolled reference is not considered "to be verified" (TBV) for the purposes of the design process. The cited document is TBV with regard to its content; however, the requirements criterion or constraint resolves this TBV status for design purposes. Each technical requirement element is allocated to one or more architectural elements, and an allocation arrangement is shown in Section 5.5.

The requirements, criteria, constraints, and goals in this section are assigned unique paragraph numbers for ease of reference.

5.1 DESIGN PERFORMANCE

The requirements and criteria below reflect the current design strategy. The performance goals in Section 5.1.5 represent those design attributes that the current design effort is not required to achieve. These goals may be achieved through further refinements of the design, if so directed.

5.1.1 Performance Requirements

5.1.1.1 The MGR design shall allow the repository to remain open for up to 300 years following final waste emplacement, with appropriate monitoring and maintenance (YMP 2001a, 1.3.2.H), and could allow closure of the repository 30 years following final waste emplacement, with variations in thermal management via operational flexibility.

5.1.1.2 The MGR design under preclosure and postclosure normal operating conditions shall maintain the zirconium-alloy cladding of the CSNF at temperatures that will preserve and not accelerate the degradation of the performance of the cladding as received at the repository (DOE 2001b, 3.4F).

5.1.1.3 The MGR shall be designed to allow flexibility of operations within a range of thermal modes during preclosure and postclosure. The end points of the thermal range are:

- Maintaining WP surface temperature below 85°C (low end of range)
- Avoiding long-term accumulation of water in the rock above the emplacement drifts by controlling rock temperatures so that there is free drainage between the

emplacement drifts (high end of range) (YMP 2001a, 1.3.2.M, 1.3.2.N; DOE 2001b, 3.4.E).

5.1.1.4 The MGR shall limit the change in temperature of the soil near the surface above the repository in accordance with the YMP RD (YMP 2001a, 1.3.2.F).

5.1.1.5 The MGR shall have the capability to retrieve all emplaced WPs in accordance with the YMP RD (YMP 2001a, 1.3.2.J).

5.1.1.6 The expected annual dose to the average member of the critical group shall be in accordance with the YMP RD (YMP 2001a, 1.3.2.P).

5.1.1.7 The MGR shall only accept for disposal, SNF or HLW that is not subject to regulation as hazardous waste in accordance with the CRD (DOE 2001b, 3.2.1.D).

5.1.2 Regulatory Requirements

The "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada" (Dyer 1999) is the controlling regulatory requirement for the MGR. The MGR shall comply with this guidance in accordance with the YMP RD (YMP 2001a, 1.3.1.C). An allocation of the regulatory requirements contained within this guidance is correlated to the MGR Level 5 systems that support SR as shown in Table 5-8. A comprehensive allocation of this guidance and additional regulatory requirements will be provided in a later revision of this document.

5.1.2.1 The MGR shall comply with the applicable provisions of the Nuclear Waste Policy Act of 1982 in accordance with the CRD (DOE 2001b, 3.1.1.A).

5.1.2.2 The MGR shall comply with the applicable provisions of 10 CFR 20, "Standards for Protection Against Radiation," in accordance with the CRD (DOE 2001b, 3.1.1.B).

5.1.2.3 The MGR shall comply with the applicable provisions of 10 CFR 73, "Physical Protection of Plants and Materials," in accordance with the CRD (DOE 2001b, 3.1.1.G).

5.1.2.4 The MGR shall comply with the applicable provisions of 29 CFR 1910, "Occupational Safety and Health Standards," in accordance with the CRD (DOE 2001b, 3.1.1.I).

5.1.2.5 The MGR shall comply with the applicable provisions of 29 CFR 1926, "Safety and Health Regulations for Construction," in accordance with the YMP RD (YMP 2001a, 1.3.1.F).

5.1.2.6 The MGR shall comply with laws, statutes, U.S. Code, treaties, Codes of Federal Regulations, Executive Orders, NUREGs, state and local codes and regulations, DOE Orders, and other directives identified through analysis, as identified in the YMP RD (YMP 2001a, 1.3.1.G).

5.1.2.7 The MGR shall comply with the applicable provisions of 10 CFR 75, "Safeguards on Nuclear Materials-Implementation of U.S./IAEA Agreement," in accordance with the CRD (DOE 2001b, 3.1.1.J).

5.1.3 Performance Criteria

5.1.3.1 RESERVED

5.1.3.2 Two annual hazard frequencies of exceedance shall be considered for seismic events during the preclosure period: one occurrence per 1,000 years (Frequency Category 1) and one occurrence per 10,000 years (Frequency Category 2) (taken from Dyer 1999, Section 2). There are also two design input earthquakes, one referred to as the 1 to 2 Hz earthquake, and the other referred to as the 5 to 10 Hz earthquake. Vibratory ground motions corresponding to both earthquakes for both categories shall be considered in the design of SSCs. Additional seismic design criteria will be provided in future revisions of this document.

5.1.3.3 RESERVED

5.1.3.4 The MGR surface facilities shall be capable of accommodating a range of storage and transportation technologies in accordance with the CRD (DOE 2001b, 3.2.1.E).

5.1.3.5 The MGR facilities shall be capable of opening sealed storage/transportable commercial canisters, handling SNF, and managing site-generated waste in accordance with the CRD (DOE 2001b, 3.2.1.F).

5.1.3.6 The MGR shall maintain the separation of site-generated wastes in accordance with the CRD (DOE 2001b, 3.2.2.A).

5.1.3.7 Site-generated hazardous, low-level radioactive, and mixed waste shall be transported to government-approved off-site facilities for disposal in accordance with the CRD (DOE 2001b, 3.2.2.B).

5.1.3.8 Physical barriers to human intrusion shall be provided in accordance with the YMP RD (YMP 2001a, 1.3.3.M).

5.1.4 Interface Criteria

5.1.4.1 The MGR shall accommodate up to 70,000 MTHM or equivalent, including 63,000 MTHM of CSNF, 640 MTHM of commercial HLW, 4,027 MTHM of DHLW, and 2,333 MTHM of DOE SNF (which includes 65 MTHM of Naval SNF) in the primary area of the first repository (YMP 2001a, 1.3.2.A).

5.1.4.2 The MGR shall not preclude the capability (by adding additional components and features) of accommodating a full inventory, including 83,800 MTHM of CSNF, 2,500 MTHM of DOE SNF (which includes 65 MTHM of Naval SNF) (YMP 2001a, 1.3.2.B.1, 1.3.2.B.2), 10,923 MTHM of DHLW, and 640 MTHM of commercial HLW (Parker 2000).

The MGR shall also not preclude the capability of accommodating the maximum inventory analyzed in the Environmental Impact Statement (EIS) (as described in Section 2.3).

5.1.4.3 The MGR shall be capable of receiving, packaging, emplacing, and isolating commercial SNF that arrives via rail, heavy-haul vehicle, and legal-weight truck, in accordance with the YMP RD (YMP 2001a, 1.3.3.H), accommodating any of the CSNF annual arrival scenarios depicted in Tables 5-1, 5-2, and 5-3 (YMP 2001a, 1.3.2.C). These values are to be used for the purpose of specifying throughput and are not meant to imply any finite quantity of waste and shall not be used to determine total inventory, total heat load, or total radionuclide inventory of the waste to be emplaced in the repository.

There are three annual arrival scenarios for the CSNF each with a nominal 3,000 MTHM/year maximum receipt rate. These three scenarios span a broad range of potential arrival possibilities with Scenario 1 (see Table 5-1) assuming a maximum number of truck casks arriving, Scenario 2 (see Table 5-2) assuming a maximum number of single-purpose canister (SPC) rail casks arriving, and Scenario 3 (see Table 5-3) assuming a maximum number of dual-purpose canister (DPC) rail casks arriving each year. The rates in these schedules are targets only and do not create any binding legal obligation on the DOE.

Table 5-1. Scenario 1 - Annual CSNF Arrival Assuming Maximum Truck Casks

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
	Truck	4	16	64	12	48	28	112	32
2010	SPC Rail	24	27	648	20	480	47	1,128	324
	DPC Rail	38	3	114	2	76	5	190	53
	Total		46	826	34	604	80	1,430	409
	Truck	4	25	100	18	72	43	172	49
2011	SPC Rail	24	40	960	30	720	70	1,680	483
	DPC Rail	38	4	152	3	114	7	266	77
	Total		69	1,212	51	906	120	2,118	609
	Truck	4	49	196	37	148	86	344	99
2012	SPC Rail	24	79	1,896	60	1,440	139	3,336	963
	DPC Rail	38	9	342	6	228	15	570	160
	Total		137	2,434	103	1,816	240	4,250	1,221
	Truck	4	80	320	60	240	140	560	161
2013	SPC Rail	24	130	3,120	98	2,352	228	5,472	1,576
	DPC Rail	38	14	532	11	418	25	950	276
	Total		224	3,972	169	3,010	393	6,982	2,013
2014	Truck	4	131	524	99	396	230	920	265
To	SPC Rail	24	215	5,160	162	3,888	377	9,048	2,606
2022	DPC Rail	38	23	874	17	646	40	1,520	436
	Total		369	6,558	278	4,930	647	11,488	3,307

Table 5-1. Scenario 1 - Annual CSNF Arrival Assuming Maximum Truck Casks (Continued)

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
2023	Truck	4	51	204	39	156	90	360	104
To	SPC Rail	24	185	4,440	139	3,336	324	7,776	2,238
2033	DPC Rail	38	50	1,900	38	1,444	88	3,344	965
	Total		286	6,544	216	4,936	502	11,480	3,307
2034	Truck	4	23	92	17	68	40	160	46
To	SPC Rail	24	47	1,128	35	840	82	1,968	565
2041	DPC Rail	38	141	5,358	106	4,028	247	9,386	2,702
	Total		211	6,578	158	4,936	369	11,514	3,313

[1] Average values for PWR assemblies were used to facilitate the computer modeling for the throughput studies, and these values do not accurately reflect the BWR values.

Table 5-2. Scenario 2 - Annual CSNF Arrival Assuming Maximum SPC Rail Casks

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
	Truck	4	12	48	9	36	21	84	24
2010	SPC Rail	24	27	648	20	480	47	1,128	324
	DPC Rail	38	3	114	2	76	5	190	53
	Total		42	810	31	592	73	1,402	401
	Truck	4	18	72	14	56	32	128	37
2011	SPC Rail	24	41	984	31	744	72	1,728	498
	DPC Rail	38	5	190	4	152	9	342	100
	Total		64	1,246	49	952	113	2,198	635
	Truck	4	36	144	27	108	63	252	73
2012	SPC Rail	24	80	1,920	60	1,440	140	3,360	967
	DPC Rail	38	9	342	7	266	16	608	176
	Total		125	2,406	94	1,814	219	4,220	1,216
	Truck	4	58	232	44	176	102	408	118
2013	SPC Rail	24	132	3,168	99	2,376	231	5,544	1,595
	DPC Rail	38	16	608	12	456	28	1,064	306
	Total		206	4,008	155	3,008	361	7,016	2,019
2014	Truck	4	96	384	72	288	168	672	193
To	SPC Rail	24	217	5,208	163	3,912	380	9,120	2,625
2022	DPC Rail	38	26	988	19	722	45	1,710	489
	Total		339	6,580	254	4,922	593	11,502	3,308
2023	Truck	4	18	72	14	56	32	128	37
To	SPC Rail	24	205	4,920	155	3,720	360	8,640	2,490
2033	DPC Rail	38	41	1,558	31	1,178	72	2,736	789
	Total		264	6,550	200	4,954	464	11,504	3,316
2034	Truck	4	3	12	2	8	5	20	6
To	SPC Rail	24	80	1,920	60	1,440	140	3,360	967
2041	DPC Rail	38	122	4,636	92	3,496	214	8,132	2,343
	Total		205	6,568	154	4,944	359	11,512	3,315

[1] Average values for PWR assemblies were used to facilitate the computer modeling for the throughput studies, and these values do not accurately reflect the BWR values.

Table 5-3. Scenario 3 - Annual CSNF Arrival Assuming Maximum DPC Rail Casks

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
	Truck	4	3	12	2	8	5	20	6
2010	SPC Rail	24	28	672	21	504	49	1,176	338
	DPC Rail	38	4	152	3	114	7	266	77
	Total		35	836	26	626	61	1,462	421
	Truck	4	5	20	3	12	8	32	9
2011	SPC Rail	24	42	1,008	32	768	74	1,776	513
	DPC Rail	38	5	190	4	152	9	342	100
	Total		52	1,218	39	932	91	2,150	621
	Truck	4	9	36	7	28	16	64	19
2012	SPC Rail	24	83	1,992	63	1,512	146	3,504	1,011
	DPC Rail	38	11	418	8	304	19	722	206
	Total		103	2,446	78	1,844	181	4,290	1,236
	Truck	4	15	60	11	44	26	104	30
2013	SPC Rail	24	136	3,264	103	2,472	239	5,736	1,654
	DPC Rail	38	17	646	13	494	30	1,140	329
	Total		168	3,970	127	3,010	295	6,980	2,013
2014	Truck	4	24	96	18	72	42	168	48
To	SPC Rail	24	224	5,376	169	4,056	393	9,432	2,717
2022	DPC Rail	38	29	1,102	22	836	51	1,938	559
	Total		277	6,574	209	4,964	486	11,538	3,325
2023	Truck	4	45	180	34	136	79	316	91
To	SPC Rail	24	166	3,984	125	3,000	291	6,984	2,011
2033	DPC Rail	38	63	2,394	47	1,786	110	4,180	1,201
	Total		274	6,558	206	4,922	480	11,480	3,304
2034	Truck	4	77	308	58	232	135	540	156
To	SPC Rail	24	26	624	19	456	45	1,080	309
2041	DPC Rail	38	148	5,624	112	4,256	260	9,880	2,848
	Total		251	6,556	189	4,944	440	11,500	3,313

[1] Average values for PWR assemblies were used to facilitate the computer modeling for the throughput studies and these values do not accurately reflect the BWR values.

5.1.4.4 The MGR shall be capable of receiving, packaging, emplacing, and isolating the DOE SNF, Naval SNF, IPWF, and HLW per the annual arrival scenario depicted in Table 5-4, in accordance with the YMP RD (YMP 2001a, 1.3.2.C; and Mowbray 2000). The rates in this schedule are targets only and do not create any binding legal obligation on the DOE.

Table 5-4. Annual Cask Receipt Rate of DOE SNF and HLW

Year	DOE SNF Note 1		Naval SNF		DOE HLW Note 2		Immobilized Plutonium Note 2		Total	
	Casks	Cans.	Casks	Cans.	Casks	Cans.	Casks	Cans	Casks	Cans.
2010	3	15	3	3	33	165	12	60	51	243
2011	6	30	3	3	48	240	12	60	69	333
2012	13	65	6	6	83	415	12	60	114	546
2013	16	80	6	6	98	490	12	60	132	636
2014	19	95	12	12	113	565	12	60	156	732
2015 Until end of receipt	30	150	15 **Note 3**	15 **Note 3**	168	840	12	60	225	1065

Notes: 1. Assumes five canisters are shipped in each cask, which represents a 50 to 60 percent efficiency for the casks that can hold nine canisters.

2. Assumes five canisters are shipped in each cask.

3. Fifteen canisters per year is a peak value derived from the distribution of remaining Naval casks/ canisters over the remaining emplacement period.

5.1.4.5 RESERVED

5.1.4.6 The MGR shall be capable of receiving, handling, and emplacing CSNF and DOE SNF, commercial HLW, or DHLW in accordance with the YMP RD (YMP 2001a, 1.3.2.E).

5.1.4.7 Interfaces shall be documented in accordance with the YMP RD (YMP 2001a, 1.3.4).

5.1.4.8 The MGR shall interface with external agencies in accordance with the CRD (DOE 2001b, 3.6.2).

5.1.4.9 MGR roads, railways, queuing points, and the site layout shall be compatible in accordance with the CRD (DOE 2001b, 3.6.5.1.A).

5.1.4.10 MGR equipment shall be compatible with transportation equipment in accordance with the YMP RD (YMP 2001a, 1.3.4.2.B).

5.1.4.11 The MGR operations and facility design shall be consistent with canister containment and internal structure designs in accordance with the YMP RD (YMP 2001a, 1.3.4.2.C).

5.1.4.12 The MGR shall accommodate waste forms that require remedial processing in accordance with the YMP RD (YMP 2001a, 1.3.4.2.D).

5.1.4.13 The MGR shall accommodate radiological surveys and security inspections in accordance with the YMP RD (YMP 2001a, 1.3.4.2.E).

5.1.4.14 The MGR shall address safeguards in accordance with the YMP RD (YMP 2001a, 1.3.4.2.F).

5.1.4.15 The MGR shall accommodate the visual inspection and testing of transportation casks in accordance with the YMP RD (YMP 2001a, 1.3.4.2.G).

5.1.4.16 The MGR shall accommodate decontamination of transportation casks in accordance with the YMP RD (YMP 2001a, 1.3.4.2.H).

5.1.4.17 The MGR and the Waste Acceptance and Transportation interface shall be in accordance with the CRD (DOE 2001b, 3.6.5.1.E).

5.1.4.18 The MGR and the Waste Acceptance and Transportation communications equipment shall be designed to be compatible in accordance with the CRD (DOE 2001b, 3.6.5.1.F).

5.1.4.19 The MGR and the Waste Acceptance and Transportation and MGR information systems shall be designed in accordance with the CRD (DOE 2001b, 3.6.5.1.G).

5.1.4.20 The MGR shall accommodate incidental transportation cask maintenance in accordance with the CRD (DOE 2001b, 3.6.5.1.H).

5.1.4.21 The Waste Acceptance and Transportation and the MGR technical, planning, and operational information exchange shall be designed in accordance with the CRD (DOE 2001b, 3.6.5.1.I).

5.1.4.22 RESERVED

5.1.4.23 The MGR shall not be required to condition DOE SNF, in accordance with the YMP RD (YMP 2001a, 1.3.4.2.O).

5.1.4.24 Assumptions developed during the design of the MGR shall be in accordance with the CRD (DOE 2001b, 3.6.5).

5.1.5 RESERVED.

5.1.6 Industry Codes and Standards

All MGR SSCs shall be designed and fabricated in accordance with the CRD (DOE 2001b, 3.2.3).

5.2 DESIGN CONSTRAINTS

5.2.1 The nominal emplacement drift spacing shall be 81 m, drift center to drift center.

5.2.2 RESERVED

5.2.3 The MGR shall be capable of accommodating the emplacement of 70,000 MTHM of the WP inventory with the size and heat output up to that shown in Table 5-5 (DOE 1999a, Vol. II, p. A-37; CRWMS M&O 2000e, p. III-1 and Tables 5-7 and 5-11; CRWMS M&O 2000l; CRWMS M&O 2000s; DOE 2000c; Naples 1999).

Table 5-5. Design Basis WP Inventory

WP Configuration	WP Length (m)	Average Heat Output/Package (kW)	Nominal Quantity*	Maximum Quantity**
21 PWR AP	5.17	11.53	4299	4500
21 PWR CR	5.17	3.11	95	100
12 PWR AP Long	5.65	9.55	163	170
44 BWR AP	5.17	7.38	2831	3000
24 BWR AP	5.11	0.52	84	90
5 IPWF	3.59	3.53	95	100
5 DHLW Short/1 DOE SNF Short	3.59	2.98	1052	1100
5 DHLW Long/1 DOE SNF Long	5.22	0.407	1406	1500
2 MCO/2 DHLW	5.22	1.67	149	160
5 HLW Long/1 DOE SNF Short	5.22	0.407	126	130
HLW Long Only***	5.22	0.282	584	600
Naval Short	5.43	3.07	200	200
Naval Long	6.07	3.07	100	100

* Nominal quantities represent the potential number of each WP configuration needed to accommodate the 70,000 MTHM (or equivalent) described in 5.1.4.1. The number of HLW canisters used to fill the nominal quantities of WPs will not exceed 8,315.

** These quantities are rounded up to two significant figures from the values in the cited reference, and represent "not to exceed" values for each WP category. It is recognized that if the total quantity of each type of WP were emplaced, the repository would exceed the 70,000 MTHM (or equivalent) described in 5.1.4.1. This constraint applies to the capability of the subsurface emplacement, and is not intended to conflict with, or violate, any other design requirement, criterion, or constraint. Naval WP categories are excluded from the rounding up.

*** This configuration is included for planning purposes only, and no WP design for HLW Long Only is included in the SR design.

NOTE: See Acronyms and Abbreviations for acronym definitions.

5.2.4 The MGR shall not preclude the capability of accommodating the emplacement of the WP inventory with the size and heat output up to that shown in Table 5-6 (DOE 1999a, Vol. II, p. A-37; CRWMS M&O 2000e, p. III-1 and Tables 5-7 and 5-11; CRWMS M&O 2000l; CRWMS M&O 2000s; DOE 2000c; Naples 1999).

Table 5-6. WP Inventory for Maximum Subsurface Emplacement

WP Configuration	WP Length (m)	Average Heat Output/Package (kW)	Nominal Quantity*	Maximum Quantity**
21 PWR AP	5.17	11.33	5690	5700
21 PWR CR	5.17	3.26	106	110
12 PWR AP Long	5.65	8.97	293	300
44 BWR AP	5.17	7.00	3732	3750
24 BWR AP	5.11	0.54	96	100
5 IPWF	3.59	3.53	127	130
5 DHLW Short/1 DOE SNF Short	3.59	2.98	1403	1410
5 DHLW Long/1 DOE SNF Long	5.22	0.407	1874	1880
2 MCO/2 DHLW	5.22	1.67	199	200
5 HLW Long/1 DOE SNF Short	5.22	0.407	167	170
HLW Long Only***	5.22	0.282	780	800
Naval Short	5.43	3.07	200	200
Naval Long	6.07	3.07	100	100

* Nominal quantities represent those used to specify the inventory described in 5.1.4.2.

** These quantities, which are rounded up to two significant figures from the values in the cited reference, represent "not to exceed" values for each WP category. It is recognized that if the total quantity of each type of WP were emplaced, the repository would exceed the inventory described in 5.1.4.2. This constraint applies to the capability of the subsurface emplacement, and is not intended to conflict with, or violate, any other design requirement, criterion, or constraint. Naval WP categories are excluded from rounding up.

*** This configuration is included for planning purposes only, and no WP design for HLW Long Only is included in the SR design.

NOTE: See Acronyms and Abbreviations for acronym definitions.

5.2.5 The excavated emplacement drift diameter shall be nominally 5.5 m. This diameter provides adequate space to accommodate the largest WP, the associated handling and emplacement equipment, the ground support, and drip shield installation.

5.2.6 The ground support in the repository emplacement drift shall be carbon steel (e.g., steel sets and/or rock bolts and mesh) with cementitious grout allowed, where necessary, to anchor the rock bolts.

5.2.7 With periodic maintenance, if necessary, the emplacement drift ground support shall keep the emplacement drift open and stable for the entire preclosure period. This ensures a pathway for emplacement drift ventilation and allowance of remote controlled equipment and/or human access for off-normal conditions.

5.2.8 The invert along the bottom of drifts shall be constructed of a carbon steel frame with granular natural material used as ballast.

5.2.9 The MGR design shall not preclude the option of physically installing the emplacement drift backfill during the repository closure phase, in accordance with the YMP RD (YMP 2001a, 1.3.3.I).

5.2.10 The emplacement drifts shall be loaded with WPs spaced with a minimum distance of 10 cm between the ends of adjacent WPs. (In this context, the "ends" of the WPs include any skirts or other structures that extend beyond the lid of the WP.) The maximum linear heat load shall not exceed 1.5 kW/m, averaged over a fully loaded emplacement drift at the time of completion of loading an entire emplacement drift.

5.2.11 A free-standing drip shield, fabricated from Titanium Grade 7 with a minimum thickness of 15 mm, and structural members made of Titanium Grade 24, shall be installed above but not in contact with the WP.

5.2.12 Each disposal container shall be a two-layer device consisting of an inner structural barrier of nominally 50-mm thick nuclear grade 316 stainless steel and an outer barrier of nominally 20-mm thick alloy 22 material. This constraint is intended only to address the corrosion environment. The design must also address other functions such as structural (handling) and seismic conditions, and, if needed, consider additional thickness.

5.2.13 Individual WPs shall have a maximum heat output of 11.8 kW at the time of emplacement.

5.2.14 The surface facilities shall accommodate a blending inventory of up to 5,000 MTHM and the aging of up to 40,000 MTHM for as long as 30 years.

5.2.15 Transportation requirements and architecture shall not be maintained for post-retrieval waste transport capability, in accordance with the YMP RD (YMP 2001a, 1.3.2.K).

5.2.16 A preclosure controlled area boundary shall be established in accordance with the YMP RD (YMP 2001a, 1.3.3.J).

5.2.17 The MGR design shall provide communication and control capabilities in accordance with the YMP RD (YMP 2001a, 1.3.3.K).

5.2.18 The MGR surface facilities shall be capable of accommodating WPs that need to be recovered from the emplacement drifts in accordance with the YMP RD (YMP 2001a, 1.3.3.L).

5.2.19 The repository and WP designs shall not preclude the addition of filler material in accordance with the YMP RD (YMP 2001a, 1.3.3.N).

5.2.20 Solar electrical power generation shall supplement the site electrical systems in accordance with the CRD (DOE 2001b, 3.4.D) and the YMP RD (YMP 2001a, 1.3.3.O, 1.3.3.P, 1.3.3.Q, 1.3.3.R).

5.2.21 Liquid waste generated from pool water that contacts SNF or HLW will be processed in the Waste Handling Building for shipment to the off-site waste disposal facility addressed in Section 5.1.3.7.

5.2.22 The MGR shall provide parking facilities for 15 legal-weight trucks, 5 heavy-haul vehicles, and 140 rail cars all loaded with transportation casks containing nuclear materials.

5.2.23 WP design will provide sufficient shielding to protect the WP materials (in the as-emplaced condition) from radiation enhanced corrosion.

5.2.24 The repository design shall ensure that the maximum emplacement drift wall temperature, shall not exceed 96°C during normal preclosure operations. Maximum emplacement drift wall temperatures, during postclosure, shall not exceed 200°C (Frey 2000) if a higher thermal mode is selected.

5.2.25 The Engineered Barrier System within the emplacement drift shall be designed to be compatible with a relative humidity of 95 percent (Frey 2000). Relative humidity shall be maintained at less than 50 percent when WP surface temperature exceeds 85°C.

5.2.26 The Engineered Barrier System within the emplacement drift shall be designed to accommodate seepages into the emplacement drifts as a function of infiltration rates of 4.6 mm/yr during the period from the present to the year 2600; 12.2 mm/yr during the period from the years 2600 to 3000; and 17.8 mm/yr during the period from the years 3000 to 12,000 (CRWMS M&O 2000q, p. ix).

5.2.27 The emplacement drift system shall be designed to accommodate the drainage volume of liquid phase water from the emplacement drifts based on seepages as a function of infiltration rates of 4.6 mm/yr during the period from the present to the year 2600; 12.2 mm/yr during the period from the years 2600 to 3000; and 17.8 mm/yr during the period from the years 3000 to 12,000 (CRWMS M&O 2000q, p. ix).

5.2.28 The Engineered Barrier System within the emplacement drift shall be designed to accommodate seepage water into the emplacement drifts within the pH range of 7-11 (bounded by CRWMS M&O 2000q, p. xi; CRWMS M&O 2000r, Section 7.7).

5.2.29 The design and operation of the MGR shall limit the temperature of the zeolite layers located beneath the emplacement area horizon to less than 90°C (Bish and Aronson 1993).

5.2.30 The design and operation of the MGR shall limit the temperature at the base of the PTn hydrogeologic/thermal/mechanical units to less than 70°C (derived from the midpoint in the range in Levy and O'Neil 1989).

5.3 OPERATING CRITERIA

5.3.1 Operation of systems and components that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct operations that are important to safety shall also be certified in such operations (Dyer 1999, Subpart H, Section 151).

5.3.2 The repository system (in combination with appropriate shielding and ventilation) shall allow limited-time personnel access, in consideration of workers' radiation protection, into the emplacement drifts, only for the purpose of evaluating and remediating operational upset conditions after initiation of waste emplacement.

5.3.3 For all workers entering radiological control areas of the repository, radiological exposures shall be maintained ALARA, in accordance with an approved radiological protection program (10 CFR 20.1101).

5.3.4 Any MGR system or process with an expected dose to an individual exceeding 250 mrem/yr or an expected collective dose exceeding 1 person-rem/yr Total Effective Dose Equivalent, shall receive a formal assessment in accordance with the ALARA program (10 CFR 20.1101(b)).

5.3.5 Any MGR system or process where the dose to an individual member of the public is expected to exceed 10 mrem/yr Total Effective Dose Equivalent from air emissions, shall receive a formal assessment in accordance with the ALARA program (10 CFR 20.1101(b)).

5.3.6 The MGR shall maintain the operational flexibility to achieve a range of thermal performance by varying the duration of repository operation, ventilation duration, flow rate, and method; WP spacing, WP heat output, and the duration of surface aging.

5.4 RELIABILITY, AVAILABILITY, MAINTAINABILITY, AND INSPECTION CRITERIA

5.5 ALLOCATION OF TECHNICAL REQUIREMENTS

Table 5-7 provides the primary allocation of the PDD technical requirements for the MGR design. This allocation is to the fifth level of the MGR Architecture as described in Section 4.1. This allocation identifies the architecture that is assigned the primary responsibility for meeting each PDD technical requirement. Additional applications and/or traces to the PDD technical requirements are also allowed, as necessary, to successfully complete the MGR design.

Table 5-7. Allocation of PDD Technical Requirements for MGR Design

PDD Technical Requirement Number	Fifth Level MGR Architecture*
5.1.1.1	BES, SED, PCA, ERS, SEP, SOS, HBE, WPR, WES, OMC, PCM, VDC, NDC, SFP, UDC, CDC, DDC, EDC, SVS, DCH, EDS, MSL, ADS, GCS, SWS, GST
5.1.1.2	UDC, DCH, WES, ADS, SVS
5.1.1.3	EDS, ADS, SVS
5.1.1.4	EDS, VDC, SFS
5.1.1.5	WES, MSL, DCH
5.1.1.6	EDS, BES
5.1.1.7	No fifth level architecture element allocated to this technical requirement
5.1.2	PCM, DCH, BES, SED, TVS, EDC, MSL, PCA, SSG, TBS, CCT, HBV, PLS, DDC, VDC, NDC, CTS, SFR, HBF, HBS, UDC, CMH, CCH, WPR, CDC, SFS, CBS, SVS, SCS, GCS, ATS, SES, EDS, WES, SRW, HBE, OMC, ERS
5.1.2.1	No fifth level architecture element allocated to this technical requirement
5.1.2.2	OMC, TVS, HBV, TBS, CBS, SFS, BES, DCH, WPR, CMH, PCM, CCH, CCT, ATS, CTS, VDC, DDC, UDC, CDC, EDC, NDC, SFR, WPR, PCA, MSL, SRW, SVS, PLS, HBS, HBF, HBE, WES, ERS
5.1.2.3	SED, SEP, OMC, VDC, CDC, DDC, UDC, EDC, MSL, SSG, CMH, CCH, CCT, ATS, CTS, WPR, WES, TBS, CBS, HBS
5.1.2.4	SEP, SED, SVS, BES, PLS, CTS, SFR, OMC, SFP, SRW, HBF, HBV, HBE, CCT, DCH, WPR, PCA, MSL, SFS, PCM, SES, ATS, CCH, TBS, CBS, CMH, HBS, TVS, WES, SOS, SWS, ERS
5.1.2.5	SVS, SES, SED, SCS, DCH, HBF, SEP, PCA, SFP, CBS, HBV, PLS, SFS, TBS, MSL, GCS, BES, HBS, SFR, TVS, SSG, WES, CTS, ATS, SRW, SWS
5.1.2.6	ERS, SED, SCS, HBS, MSL, EDC, UDC, EDS, SWS, PCA, SSG, CDC, TBS, HBE, VDC, NDC, DDC, ATS, TBS, SOS, CCT, SEP, SVS, HBF, CTS, SES, SRW, PLS, PCM, DCH, WPR, OMC, BES, CMH, WES, SFR, CCH, HBV, SFP, GST, TVS
5.1.2.7	No fifth level architecture element allocated to this technical requirement
5.1.3.2	GCS, CBS, CMH, HBS, ATS, DCH, CCH, CTS, TBS, SFS, SET, SDT, WPR, WES
5.1.3.4	CCH, CMH, CCT, CTS, ATS
5.1.3.5	SRW, TBS, HBS
5.1.3.6	SRW
5.1.3.7	TBS, WPR, PLS, SRW, DCH
5.1.3.8	SSG, MSL
5.1.4.1	CDC, NDC, SFS, DDC, EDS, EDC, ATS, SOS, UDC, VDC
5.1.4.2	EDS, NDC, SFS, DDC
5.1.4.3	SRW, DCH, SEP, MSL, WES, CCH, ATS, HBF, SFP, CTS, WPR, CCT, HBS, CBS, TBS, TVS, HBV, EDS, SED, CMH, OMC, HBE, SOS, SES, PLS
5.1.4.4	MSL, SRW, DCH, SEP, WES, CCH, ATS, HBF, SFP, CTS, WPR, CCT, HBS, CBS, TBS, TVS, HBV, EDS, SED, CMH, OMC, HBE, SOS, SES, PLS
5.1.4.6	MSL, HBS, CCT, CMH, WES, SOS, CTS, ATS, DCH, CCH
5.1.4.7	No fifth level architecture element allocated to this technical requirement
5.1.4.8	ERS, SOS
5.1.4.9	MSL, CTS, CCT
5.1.4.10	CCH, CTS, CCT, MSL, ATS, CMH
5.1.4.11	CDC, DDC, CMH, CCT, WPR, CCH, VDC, UDC, EDC, CBS, NDC, WES
5.1.4.12	CTS, ATS, SRW
5.1.4.13	CCT, CMH

Table 5-7. Allocation of PDD Technical Requirements for MGR Design (Continued)

PDD Technical Requirement Number	Fifth Level MGR Architecture*
5.1.4.14	CCT, CMH, CCH
5.1.4.15	CCT, CMH
5.1.4.16	CMH, CTS, ATS
5.1.4.17	SOS
5.1.4.18	No fifth level architecture element allocated to this technical requirement
5.1.4.19	SOS
5.1.4.20	No fifth level architecture element allocated to this technical requirement
5.1.4.21	SOS
5.1.4.23	No fifth level architecture element allocated to this technical requirement
5.1.4.24	No fifth level architecture element allocated to this technical requirement
5.1.6	PLS, ERS, GCS, PCM, SEP, SWS, ATS, SFS, CMH, DCH, CTS, CCT, HBE, PCA, HBV, TVS, OMC, HBS, BES, EDS, MSL, CCH, SOS, SES, HBF, SFP, WES, SSG, SED, UDC, VDC, DDC, SVS, TBS, WPR, CBS, SRW, GST, CDC, NDC, EDC
5.2.1	SFS, EDS
5.2.3	SFS, EDS, SVS, WES, MSL
5.2.4	SFS, EDS, SVS, WES, MSL
5.2.5	SFS, EDS, SES, GCS
5.2.6	SFS, EDS, GCS, SES
5.2.7	SFS, GCS
5.2.8	SFS, EDS
5.2.9	BES, EDS, GCS
5.2.10	SFS, EDS, SET, WES
5.2.11	SFS, EDS
5.2.12	SFS, EDS, UDC, CDC, VDC, DDC, EDC, NDC, WPR
5.2.13	UDC, DCH, WES, ADS, SVS, EDS, WPR, CDC, DDC, EDC, NDC, VDC
5.2.14	HBS
5.2.15	No fifth level architecture element allocated to this technical requirement
5.2.16	MSL
5.2.17	ERS, SEP, OMC, VDC, UDC, DDC, EDC, CCT, CMH, DCH, WPR, SOS, CTS, ATS, SRW, CCH, SSG, WES, NDC, CDC
5.2.18	WPR, DCH
5.2.19	UDC
5.2.20	SEP
5.2.21	PLS
5.2.22	GST, MSL
5.2.23	UDC, CDC, VDC, EDC, DDC
5.2.24	EDS, SVS, DCH, ADS
5.2.25	EDS, GCS, UDC, CDC, VDC, EDC, DDC, NDC, SFS
5.2.26	EDS, SWC, UDC, CDC, VDC, EDC, DDC, NDC, SFS.
5.2.27	EDS, SWS, SFS
5.2.28	EDS, UDC, CDC, VDC, EDC, DDC, NDC, SFS
5.2.29	EDS, SFS

Table 5-7. Allocation of PDD Technical Requirements for MGR Design (Continued)

PDD Technical Requirement Number	Fifth Level MGR Architecture*
5.2.30	EDS, SFS
5.3.1	ADS, SOS
5.3.2	SFS, SVS, ADS, EDS
5.3.3	CBS, HBS, TBS, ADS, SOS, HSS, SRM
5.3.4	CBS, HBS, TBS, ADS, SOS, HSS, SRM
5.3.5	CBS, HBS, TBS, ADS, SOS, HSS, SRM
5.3.6	No fifth level architectural element allocated to this technical requirement

* These MGR architecture designators are defined in Figures 4-1 through 4-4.

Table 5-8 provides the primary allocation of the regulatory requirements from the "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada" (Dyer 1999) for the SR design. This allocation is to the fifth level of the MGR Architecture as described in Section 4.1. This allocation identifies the architecture that is assigned the primary responsibility for meeting each regulatory requirement.

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design

Regulatory Requirement	Fifth Level MGR Architecture
63.21(c)(17)	Assembly Transfer System
63.78	Assembly Transfer System
63.111(a)(1)	Assembly Transfer System
63.111(a)(2)	Assembly Transfer System
63.111(b)(2)	Assembly Transfer System
63.112(e)(2)	Assembly Transfer System
63.112(e)(6)	Assembly Transfer System
63.112(e)(8)	Assembly Transfer System
63.112(e)(10)	Assembly Transfer System
63.112(e)(13)	Assembly Transfer System
63.113(b)	Assembly Transfer System
63.21(c)(17)	Backfill Emplacement System
63.111(a)(1)	Backfill Emplacement System
63.111(a)(2)	Backfill Emplacement System
63.111(b)(2)	Backfill Emplacement System
63.112(e)(8)	Backfill Emplacement System
63.112(e)(13)	Backfill Emplacement System
63.21(c)(17)	Canister Transfer System
63.78	Canister Transfer System
63.111(a)(1)	Canister Transfer System
63.111(a)(2)	Canister Transfer System
63.111(b)(2)	Canister Transfer System
63.112(e)(2)	Canister Transfer System
63.112(e)(6)	Canister Transfer System
63.112(e)(8)	Canister Transfer System

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

Regulatory Requirement	Fifth Level MGR Architecture
63.112(e)(10)	Canister Transfer System
63.112(e)(13)	Canister Transfer System
63.21(c)(17)	Carrier Preparation Building Materials Handling System
63.78	Carrier Preparation Building Materials Handling System
63.111(a)(1)	Carrier Preparation Building Materials Handling System
63.112(e)(10)	Carrier Preparation Building Materials Handling System
63.112(e)(13)	Carrier Preparation Building Materials Handling System
63.21(c)(17)	Carrier/Cask Handling System
63.78	Carrier/Cask Handling System
63.111(a)(1)	Carrier/Cask Handling System
63.112(e)(8)	Carrier/Cask Handling System
63.112(e)(10)	Carrier/Cask Handling System
63.112(e)(13)	Carrier/Cask Handling System
63.78	DHLW Disposal Container
63.111(a)(2)	DHLW Disposal Container
63.111(b)(2)	DHLW Disposal Container
63.111(e)(1)	DHLW Disposal Container
63.112(e)(2)	DHLW Disposal Container
63.112(e)(6)	DHLW Disposal Container
63.112(e)(8)	DHLW Disposal Container
63.113(a)	DHLW Disposal Container
63.113(b)	DHLW Disposal Container
63.21(c)(17)	Disposal Container Handling System
63.78	Disposal Container Handling System
63.111(a)(1)	Disposal Container Handling System
63.111(a)(2)	Disposal Container Handling System
63.111(b)(1)	Disposal Container Handling System
63.111(b)(2)	Disposal Container Handling System
63.111(d)	Disposal Container Handling System
63.112(e)(6)	Disposal Container Handling System
63.112(e)(8)	Disposal Container Handling System
63.112(e)(13)	Disposal Container Handling System
63.113(b)	Disposal Container Handling System
63.131(b)	Disposal Container Handling System
63.134(d)	Disposal Container Handling System
63.111(e)(1)	Emplacement Drift System
63.113(a)	Emplacement Drift System
63.113(b)	Emplacement Drift System
63.111(a)(2)	Ground Control System
63.111(b)(2)	Ground Control System
63.111(d)	Ground Control System
63.111(e)(1)	Ground Control System
63.112(e)(8)	Ground Control System
63.113(b)	Ground Control System
63.132(a)	Ground Control System
63.132(e)	Ground Control System

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

Regulatory Requirement	Fifth Level MGR Architecture
63.111(a)(1)	Monitored Geologic Repository Operations Monitoring and Control System
63.111(a)(2)	Monitored Geologic Repository Operations Monitoring and Control System
63.111(b)(2)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(7)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(8)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(10)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(13)	Monitored Geologic Repository Operations Monitoring and Control System
63.131(b)	Monitored Geologic Repository Operations Monitoring and Control System
63.132(a)	Monitored Geologic Repository Operations Monitoring and Control System
63.132(e)	Monitored Geologic Repository Operations Monitoring and Control System
63.134(d)	Monitored Geologic Repository Operations Monitoring and Control System
63.78	Naval Spent Nuclear Fuel Disposal Container
63.111(a)(2)	Naval Spent Nuclear Fuel Disposal Container
63.111(b)(2)	Naval Spent Nuclear Fuel Disposal Container
63.111(e)(1)	Naval Spent Nuclear Fuel Disposal Container
63.111(e)(2)	Naval Spent Nuclear Fuel Disposal Container
63.112(e)(2)	Naval Spent Nuclear Fuel Disposal Container
63.112(e)(6)	Naval Spent Nuclear Fuel Disposal Container
63.112(e)(8)	Naval Spent Nuclear Fuel Disposal Container
63.113(a)	Naval Spent Nuclear Fuel Disposal Container
63.113(b)	Naval Spent Nuclear Fuel Disposal Container
63.21(c)(17)	Pool Water Treatment and Cooling System
63.111(a)(1)	Pool Water Treatment and Cooling System
63.112(e)(2)	Pool Water Treatment and Cooling System
63.112(e)(3)	Pool Water Treatment and Cooling System
63.112(e)(8)	Pool Water Treatment and Cooling System
63.112(e)(13)	Pool Water Treatment and Cooling System
63.21(c)(17)	Site-Generated Radiological Waste Handling System
63.111(a)(1)	Site-Generated Radiological Waste Handling System
63.111(b)(1)	Site-Generated Radiological Waste Handling System
63.112(e)(2)	Site-Generated Radiological Waste Handling System
63.112(e)(13)	Site-Generated Radiological Waste Handling System
63.111(d)	Subsurface Facility System
63.113(a)	Subsurface Facility System
63.113(b)	Subsurface Facility System
63.131(a)(1)	Subsurface Facility System
63.131(a)(2)	Subsurface Facility System
63.131(c)	Subsurface Facility System
63.132(b)	Subsurface Facility System
63.132(e)	Subsurface Facility System
63.133(a)	Subsurface Facility System
63.133(c)	Subsurface Facility System
63.133(d)	Subsurface Facility System
63.134(a)	Subsurface Facility System
63.134(b)	Subsurface Facility System
63.111(a)(1)	Subsurface Ventilation System

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

Regulatory Requirement	Fifth Level MGR Architecture
63.111(e)(2)	Subsurface Ventilation System
63.112(e)(3)	Subsurface Ventilation System
63.112(e)(5)	Subsurface Ventilation System
63.78	Uncanistered SNF Disposal Container
63.111(a)(2)	Uncanistered SNF Disposal Container
63.111(b)(2)	Uncanistered SNF Disposal Container
63.111(e)(1)	Uncanistered SNF Disposal Container
63.112(e)(2)	Uncanistered SNF Disposal Container
63.112(e)(6)	Uncanistered SNF Disposal Container
63.112(e)(8)	Uncanistered SNF Disposal Container
63.113(a)	Uncanistered SNF Disposal Container
63.113(b)	Uncanistered SNF Disposal Container
63.78	Waste Emplacement/Retrieval System
63.111(a)(1)	Waste Emplacement/Retrieval System
63.111(a)(2)	Waste Emplacement/Retrieval System
63.111(b)(2)	Waste Emplacement/Retrieval System
63.111(d)	Waste Emplacement/Retrieval System
63.111(e)(1)	Waste Emplacement/Retrieval System
63.111(e)(3)	Waste Emplacement/Retrieval System
63.112(e)(1)	Waste Emplacement/Retrieval System
63.112(e)(8)	Waste Emplacement/Retrieval System
63.112(e)(10)	Waste Emplacement/Retrieval System
63.112(e)(13)	Waste Emplacement/Retrieval System
63.131(b)	Waste Emplacement/Retrieval System
63.131(d)(3)	Waste Emplacement/Retrieval System
63.134(d)	Waste Emplacement/Retrieval System
63.111(a)(1)	Waste Handling Building Electrical System
63.112(e)(2)	Waste Handling Building Electrical System
63.112(e)(3)	Waste Handling Building Electrical System
63.112(e)(8)	Waste Handling Building Electrical System
63.112(e)(11)	Waste Handling Building Electrical System
63.112(e)(12)	Waste Handling Building Electrical System
63.112(e)(13)	Waste Handling Building Electrical System
63.21(c)(17)	Waste Handling Building System
63.111(a)(1)	Waste Handling Building System
63.111(a)(2)	Waste Handling Building System
63.111(b)(2)	Waste Handling Building System
63.112(e)(1)	Waste Handling Building System
63.112(e)(2)	Waste Handling Building System
63.112(e)(3)	Waste Handling Building System
63.112(e)(4)	Waste Handling Building System
63.112(e)(5)	Waste Handling Building System
63.112(e)(8)	Waste Handling Building System
63.112(e)(10)	Waste Handling Building System
63.112(e)(13)	Waste Handling Building System
63.111(a)(1)	Waste Handling Building Ventilation System
63.111(a)(2)	Waste Handling Building Ventilation System

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

Regulatory Requirement	Fifth Level MGR Architecture
63.111(b)(2)	Waste Handling Building Ventilation System
63.112(e)(1)	Waste Handling Building Ventilation System
63.112(e)(2)	Waste Handling Building Ventilation System
63.112(e)(3)	Waste Handling Building Ventilation System
63.112(e)(4)	Waste Handling Building Ventilation System
63.112(e)(8)	Waste Handling Building Ventilation System
63.112(e)(10)	Waste Handling Building Ventilation System
63.112(e)(11)	Waste Handling Building Ventilation System
63.112(e)(13)	Waste Handling Building Ventilation System
63.21(c)(17)	Waste Package Remediation System
63.78	Waste Package Remediation System
63.111(a)(1)	Waste Package Remediation System
63.112(e)(8)	Waste Package Remediation System
63.112(e)(10)	Waste Package Remediation System
63.112(e)(13)	Waste Package Remediation System
63.21(c)(17)	Waste Treatment Building System
63.111(a)(1)	Waste Treatment Building System
63.112(e)(1)	Waste Treatment Building System
63.112(e)(2)	Waste Treatment Building System
63.112(e)(3)	Waste Treatment Building System
63.112(e)(4)	Waste Treatment Building System
63.112(e)(5)	Waste Treatment Building System
63.112(e)(8)	Waste Treatment Building System
63.112(e)(10)	Waste Treatment Building System
63.112(e)(13)	Waste Treatment Building System
63.111(a)(1)	Waste Treatment Building Ventilation System
63.112(e)(1)	Waste Treatment Building Ventilation System
63.112(e)(2)	Waste Treatment Building Ventilation System
63.112(e)(3)	Waste Treatment Building Ventilation System
63.112(e)(4)	Waste Treatment Building Ventilation System
63.112(e)(10)	Waste Treatment Building Ventilation System
63.112(e)(13)	Waste Treatment Building Ventilation System

6. CONTROLLED PROJECT ASSUMPTIONS

The CPAs originated from assumptions carried forward from the *Controlled Design Assumptions Document* (CRWMS M&O 1998a). These assumptions were intended to provide a consistent program-wide basis for planning and conducting design activities, and to support some non-design activities such as performance assessment and environmental impact analysis. The original number of assumptions from the *Controlled Design Assumptions Document* (CRWMS M&O 1998a) has been reduced through several changes and revisions to this document. The list of assumptions that remain in this document represents those assumptions that support the current design. Discussions of each individual CPA are presented in this section and summarized in Table 6-1. Each assumption is documented on an Assumption Rationale Sheet in a format similar to that used in the *Controlled Design Assumptions Document* (CRWMS M&O 1998a). The assumption identifier and subject are given at the top of the sheet and followed by the statement of the assumption and the rationale for the assumption. The final portion of the Assumption Rationale Sheet identifies the:

- M&O organization(s) responsible for establishing and maintaining the assumption
- Applicable M&O organizations that will use or be impacted by the assumption
- Systems to which the assumption is allocated for potential applicability
- Other work products to which the assumption is allocated, if applicable

The allocations to systems are identified by system designators defined in Section 4.1 of this document. A listing of the system designators and their names is also provided in Appendix A of this document. Allocations to systems do not necessarily imply that criteria will be established in the corresponding SDDs. For example, the assumption may be an assumed design concept related to the system addressed in the respective SDD and to be described in Sections 2 through 4 of that document.

References to requirements from the YMP RD (YMP 2001a) are given in the following format: YMP RD 1.3.3.G refers to the requirement established in 1.3.3.G of that requirements document.

Table 6-1 lists the controlled project assumptions documented on the assumption rationale sheets in this section. The listing includes the organizational responsibility and applicability allocations from part III of the assumption rationale sheets. The organizational codes are included in the list of acronyms and abbreviations.

Table 6-1. CPA Allocation

Identifier	Subject	System Designator Note 2	Other Allocation
CPA 002	LLW Disposal at NTS	SRW	EIS
CPA 014	Source of Water	SWS	EIS
CPA 015	Telephone Communications	SSG, TCS	EIS
CPA 027	Applicability of Mine Safety and Health Administration Regulations	BES, GCS, MHS, PCM, MHS, SCA, OMC, SCS, SDT, SED, SES, SET, SFR, SFS, SSM, SVS, SWC, SWD, WES, EDS	EIS
CPA 037	Credit for SNF Cladding	UDC, CDC	PA models, EIS
CPA 038	Transportation Mode/Route within Nevada	N/A	EIS; Cost estimation
CPA 001	Withdrawn in REV 02, incorporated into Sections 5.1.3.6 and 5.1.3.7		
CPA 003	Withdrawn in REV 02, incorporated into Section 5.2.21		
CPA 004	Withdrawn in REV 02, incorporated into Section 2.3		
CPA 005	Withdrawn in REV 02, incorporated into Section 2.4		
CPA 006	Withdrawn in REV 02, incorporated into Section 2.3		
CPA 007	Withdrawn in REV 02, incorporated into Section 5.1.4.12		
CPA 008	Withdrawn in REV 00 DCN 01 (Substantiated by LADS decision for No Rod Consolidation)		
CPA 009	Withdrawn in REV 01 (replaced by blending inventory requirement)		
CPA 010	Withdrawn in REV 01 (replaced by blending inventory requirement)		
CPA 011	Withdrawn in REV 02, incorporated into Section 5.2.22		
CPA 012	Withdrawn in REV 02, incorporated into Section 5.1.4.20		
CPA 013	Withdrawn in REV 02, incorporated into Section 5.1.2.2		
CPA 016	Withdrawn in REV 01 DCN 01, incorporated into Sections 5.3.3 and 5.3.4		
CPA 017	Withdrawn in REV 01 DCN 01, incorporated into Section 5.3.5		
CPA 018	Withdrawn in REV 02, incorporated into Section 5.1.2.2		
CPA 019	Withdrawn in REV 02, incorporated into Section 5.2.23		
CPA 020	Withdrawn in REV 02, incorporated into Section 5.3.2		
CPA 021	Withdrawn in REV 02, incorporated into Section 2.5		
CPA 022	Withdrawn in REV 02 due to its administrative nature and non-bearing on repository design		
CPA 023	Withdrawn in REV 02, incorporated into Section 2.3		
CPA 024	Withdrawn in REV 02, incorporated into Section 2.5		
CPA 025	Withdrawn in REV 02 due to no validated studies showing negative impact on diesel-powered equipment		
CPA 026	Withdrawn in REV 02 due to the approval of the *Site Recommendation Subsurface Layout* (CRWMS M&O 2000k)		
CPA 028	Withdrawn in REV 00 DCN 01 (due to removal of backfill (Stroupe 2000))		

Table 6-1. CPA Allocation (Continued)

Identifier	Subject	System Designator Note 2	Other Allocation
CPA 029	Withdrawn in REV 01 ICN 02 (due to the *Disposability Interface Specification's* (CRWMS M&O 1998f) lack of approval)		
CPA 030	Withdrawn in REV 01 ICN 02 (due to issuance of final safety evaluation report) (*Disposal Criticality Analysis Methodology Topical Report*, YMP 2000b)		
CPA 031	Withdrawn in REV 01 ICN 02 (due to issuance of final safety evaluation report) (due to issuance of final safety evaluation report) (*Disposal Criticality Analysis Methodology Topical Report*, YMP 2000b)		
CPA 032	Withdrawn in REV 01 ICN 02 (due to issuance of final safety evaluation report) (due to issuance of final safety evaluation report) (*Disposal Criticality Analysis Methodology Topical Report*, YMP 2000b)		
CPA 033	Withdrawn in REV 02, incorporated into Section 2.6.1		
CPA 034	Withdrawn in REV 01 (replaced by waste type interface criteria)		
CPA 035	Withdrawn in REV 01 (replaced by a performance requirement)		
CPA 036	Withdrawn in REV 02, incorporated into Section 2		
CPA 039	Withdrawn in REV 02, due to the SR design described in Section 2 superseding the EDA II design		
CPA-040	Withdrawn in REV 02, due to the baselining of *Seepage Model for PA including Drift Collapse* (CRWMS M&O 2000o) and *Abstraction of Drift Seepage* (CRWMS M&O 2001a)		

Notes 1: See Acronyms and Abbreviations for Responsible and User Organization definitions.

2: See Appendix A for System Designator identification.

Controlled Project Assumption
Assumption Rationale Sheet

Assumption Identifier and Subject: CPA 002 – LLW Disposal at NTS

I. STATEMENT OF ASSUMPTION

The DOE Nevada Test Site (NTS) LLW disposal facilities will be made available for MGR generated LLW. This would be an off-site facility compatible with the CRD (DOE 2001b, Section 3.2.2.6). It is assumed that NRC will approve disposal of the LLW from the MGR at the NTS facilities under 10 CFR 20.2002. The volume of LLW to be shipped to the disposal facility will be minimized through appropriate means at the MGR.

II. RATIONALE

Recommendations for site-generated waste disposal were provided in Section 7 of *Site-Generated Waste Disposal Options* (CRWMS M&O 1998c). The report recommended that arrangements be made to use the LLW facility at the NTS for the disposal of LLW from the repository. The NTS LLW site is an existing facility with known acceptance criteria and capacity to accommodate MGR LLW. However, an agreement would have to be reached between the Yucca Mountain Site Characterization Office (YMSCO) and the Nevada Operations Office before this assumption could be implemented, because the MGR is currently not listed among LLW producers eligible for disposing LLW at NTS (see Notes below).

Shipping LLW from MGR to NTS will avoid transportation on public roads.

Notes:

1) The MGR must account for 10 CFR 20.2001 requirements for disposal of LLW at a licensed disposal site or obtain NRC approval per 10 CFR 20.2002 prior to use of any non-licensed facility for disposal of LLW. Because the NTS LLW site is not licensed by NRC, the MGR must obtain NRC approval under 10 CFR 20.2002 to be in compliance with 10 CFR 20.2001.

2) MGR is currently not listed among LLW producers eligible for disposing LLW at NTS. Securing this listing must be accomplished. Ensuring NTS availability is necessary because NTS and state of Nevada are currently in litigation regarding the NTS-wide EIS. Any challenge that repository waste is "DOE-owned" waste should be identified and resolved at this time.

III. RESPONSIBILITY AND APPLICABILITY

Responsible M&O Organization(s): Radiological and Regional Studies Department

User Organization(s): Radiological and Regional Studies Department; Surface Facilities Department; Environmental, Safety, and Health

System allocations: SRW

Other allocations: EIS

Controlled Project Assumption
Assumption Rationale Sheet

Assumption Identifier and Subject: CPA 014 – Source of Water

STATEMENT OF ASSUMPTION

The MGR will connect with the existing NTS water supply system as the source of water for the repository. Treatment will be required to provide the potable water.

II. RATIONALE

Use the existing water supply system rather than drilling for a new ground water source.

III. RESPONSIBILITY AND APPLICABILITY

Responsible M&O Organization(s): Systems Engineering Department; Surface Facilities Department; Environmental, Safety, and Health

User Organization(s): Surface Facilities Department

System allocations: SWS

Other allocations: EIS

Controlled Project Assumption
Assumption Rationale Sheet

Assumption Identifier and Subject: CPA 015 – Telephone Communications

I. STATEMENT OF ASSUMPTION

The MGR shall connect to the existing NTS telephone system.

II. RATIONALE

DOE NTS Standard Operating Procedure, NTS-SOP-5301, defines the responsibilities and interfaces for all aspects of telecommunications at the NTS. The assumption is consistent with current policy.

III. RESPONSIBILITY AND APPLICABILITY

Responsible M&O Organization(s): Systems Engineering Department; Surface Facilities Department

User Organization(s): Surface Facilities Department; Environmental, Safety, and Health

System allocations: SSG, TCS

Other allocations: EIS

Controlled Project Assumption
Assumption Rationale Sheet

Assumption Identifier and Subject: CPA 027 – Applicability of Mine Safety and Health Administration Regulations

I. STATEMENT OF ASSUMPTION

There is no implication that the Mine Safety and Health Administration has any enforcement authority over construction or operations of the MGR. Nevertheless, some regulations that implement the Federal Mine Safety and Health Act of 1977 (30 USC 801 et seq.) may be selectively applied as appropriate design criteria for subsurface facilities and equipment, or for those mining-related surface facilities and equipment specifically addressed therein.

II. RATIONALE

Background: The Occupational Safety and Health Administration standards and regulations contained in 29 CFR 1910 (Occupational Safety and Health Standards) and 29 CFR 1926 (Safety and Health Regulations for Construction), as applicable, apply to all repository facilities and equipment. This is not addressed in the assumption because it is a fact. YMP RD 1.3.1.E and 1.3.1.F impose these standards and regulations in 29 CFR 1910 and 29 CFR 1926.

Regulations that implement the Federal Mine Safety and Health Act of 1977 (30 USC 801 et seq.) do not directly apply to the repository. However, they may be selectively applied by DOE or its contractors as effective safety criteria without implying that the Mine Safety and Health Administration has any enforcement authority over construction or operations of the MGR. The applicability of any such provisions would be limited to subsurface facilities and equipment and to those mining-related surface facilities and equipment specifically addressed therein.

III. RESPONSIBILITY AND APPLICABILITY

Responsible M&O Organization(s): Systems Engineering Department; Safety & Health Department; Environmental, Safety and Health

User Organization(s): Subsurface Facilities Department

System allocations: BES, GCS, MHS, PCM, MHS, SCA, OMC, SCS, SDT, SED, SES, SET, SFR, SFS, SSM, SVS, SWC, SWD, WES, EDS

Other allocations: EIS

Controlled Project Assumption
Assumption Rationale Sheet

Assumption Identifier and Subject: CPA 037 – Credit for SNF Cladding

I. STATEMENT OF ASSUMPTION

Credit will be taken for CSNF and Naval SNF cladding in retarding the release of radionuclides based on analysis of cladding damage occurring in the repository in accordance with the *Repository Safety Strategy: Plan to Prepare the Postclosure Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations* (CRWMS M&O 2001b).

II. RATIONALE

In its June 4, 1998 meeting, the Level 3 Change Control Board directed that the *Controlled Design Assumptions Document* be modified to indicate that credit will be taken for cladding. This was reflected in the modification of assumption EBDRD 3.7.1.2.B in REV 05 of the *Controlled Design Assumptions Document* (CRWMS M&O 1998a). The part of the assumption addressing credit for cladding is being carried forward in the CPA.

The nuclear industry has done research on zirconium since the early 1950s and found it to be highly corrosion resistant. Performance assessment modeling by the M&O has considered credit for cladding in retarding the release of radionuclides. After excluding certain cladding from any credit, Performance Assessment models the exposed surface area of fuel resulting from damages to cladding (including perforation, mechanical failures from rockfalls, and localized corrosion) after the failure of the disposal container. The performance assessment modeling will reflect a range of values for cladding damage, prior to its receipt at the repository, that is sufficiently large to accommodate fuel from early reactor cores (including BWRs from 1973-1975) with higher percentages of failed fuel. This range will also be expanded to include pins that are damaged but have not yet failed. There should be no requirements for fuel inspection on the part of the utilities to satisfy the modeling of cladding in performance assessment.

III. RESPONSIBILITY AND APPLICABILITY

Responsible M&O Organization(s): Waste Package Department; Performance Assessment Department

User Organization(s): Waste Package Department; Performance Assessment Department

System allocations: UDC, CDC

Other allocations: Performance Assessment models, EIS

Controlled Project Assumption
Assumption Rationale Sheet

Assumption Identifier and Subject: CPA 038 – Transportation Mode/Route Within Nevada

I. STATEMENT OF ASSUMPTION

SNF and HLW arriving in Nevada on mainline rail lines will be transported to the repository via rail. These rail lines do not currently exist. The five rail routes being considered are described in *Rail Alignments Analysis* (CRWMS M&O 1997). Although some truck shipping casks could be shipped via main line rail lines, these shipping casks are assumed to be transported by truck in the state of Nevada.

II. RATIONALE

The EIS will continue to evaluate heavy-haul truck transportation within the state of Nevada as an option in comparison to rail, as indicated in the Notice of Intent. The EIS will provide the necessary analysis for decision-makers to use to decide on mode and route. Rail in Nevada is used as the assumption because it provides a reasonable basis for design that could be readily modified to heavy-haul transportation, if necessary. The five routes being considered are: Caliente, Jean, Carlin, Valley Modified, and Caliente/Chalk Mountain. There is no TBV associated with this assumption, the nature of the assumption is such that no confirmation is necessary or appropriate.

III. RESPONSIBILITY AND APPLICABILITY

Responsible M&O Organization(s): Regional Transportation

User Organization(s): Radiological and Regional Studies Department (EIS); Systems Engineering Department; Environmental, Safety, and Health

System allocations: N/A

Other allocations: EIS; Cost estimation

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7. DESIGN BASIS VERIFICATION

One of the primary methods of design basis verification for long-term performance is part of and through a process referred to as TSPA. TSPA analyzes the behavior of the reference design and interaction with the natural system for the engineered repository components within the expected natural conditions at the Yucca Mountain site. It also includes sensitivity and uncertainty analyses to illustrate the relative importance of the various natural and engineered system components. Sections 7.1 through 7.4 are taken from DOE 1998d (Overview), and from *Total System Performance Assessment for Site Recommendation Results* (CRWMS M&O 2000n) unless otherwise stated.

7.1 TOTAL SYSTEM PERFORMANCE ASSESSMENT

The general TSPA process was developed as a cooperative effort involving professionals throughout the international community of radioactive waste management. It was a stochastic assessment of Integrated Abstractions of System Components. This process can be visualized as a series of levels going up a pyramid (Figure 7-1). The base of the pyramid is built using all of the necessary and available data and information collected by scientists and engineers involved in site characterization and engineering design. The base is very large because it represents the composite of all the necessary information gathered by the repository program. All of this information feeds, on a very small scale, the conceptualization of how various processes work. An example of this scale is a description of the movement of water molecules as they pass between rock matrices and fractures.

The specific aspects identified or selected for describing a process on a larger scale are then extracted and incorporated into a computer model. An example is a model for all water flow above the water table, which would incorporate flow interactions between the rock matrix and the rock fractures as well as many other specifics needed to describe how water flows throughout the rock mass. Every piece of information is not generally used, or needed, in the computer model. Only information determined to be the primary driver for the process makes it up the next level of the pyramid. A firm technical basis is ensured by comparing model output to available data collected and used to develop the model.

This abstraction or progressive simplification to a more compact and usable form is depicted by the slightly smaller width of the pyramid. The models that eventually analyze the evolution through time of all the various components of the system are generally the most compact or abstracted models of all. Abstraction is necessary for many reasons. One of these reasons is that many of the models are much too large to be run efficiently even on very large computers.

The TSPA must be probabilistic (as opposed to deterministic) to capture the uncertainty and variability in the behavior of the repository system. The models are run many times using many combinations of parameters (derived from site and engineering studies, and used to develop the models). Each of the combinations of parameters has some definite possibility of representing the repository performance. These probabilistic analyses are intended to reflect the range of behaviors or values for parameters that may be appropriate, knowing that perfect or complete knowledge of the system will never be available and that the total system is inherently variable.

A final reason to use abstraction is that, in some cases, an overly complex model would over-represent the actual state of knowledge about a process, so a simpler model is more appropriate.

The TSPA process considers the biosphere components and the natural and engineered components. The natural system components include climate, water infiltration, unsaturated zone flow and transport, saturated zone flow and transport, and the near-field environment. The engineered system components include the in-drift geochemical environment, the Engineered Barrier System flow, the WP and drip shield, the waste form, and engineered barrier system transport.

The visualization of the TSPA process is shown in Figure 7-2. Here, collection of site data and incorporation of the data (or estimates, where data are not available), first into conceptual models, then into mathematical equations, next into computer (numerical) models, and, finally, into a total system model, is illustrated. The figure is a more graphic representation of the process that is depicted using the TSPA pyramid in Figure 7-1.

7.2 VISUALIZATION OF THE REPOSITORY FOR TSPA

In general, the repository system is visualized as a series of processes linked together sequentially and spatially from top to bottom in the mountain. From a computer modeling point of view, it is important to break the system into "bite-size" portions that relate to the way information is collected, the model is constructed, and results produced. In reality, the operating repository system will be completely interconnected, and no one process will be independent of other processes. The complexity of the system demands some idealization of the system be developed for an analysis to be performed.

An overview of the system, from the waste form telescoping out to the mountain scale, is shown in Figure 7-3. The component models are shown on Figures 7-4 through 7-8 in their relative spatial sequence. Each model in the sequence provides input to the model following it and receives the output of the preceding model or models. The shape of the component model icons (e.g., square, circle, hexagon) shown on these figures is determined by the attributes of repository performance (taken from the Repository Safety Strategy principal factors (CRWMS M&O 2001b) they feed. The four attributes are:

- Limited water entering the emplacement drifts
- Long lived WP and drip shield
- Limited release of radionuclides from the engineered barriers
- Delay and dilution of radionuclide concentrations provided by the natural barriers

An additional set of icons is used to depict the models associated with off-normal or disruptive events like volcanism (Figure 7-9). These events, if and when they occur, would affect the nominal case processes and may be incorporated into or added to the nominal case, as appropriate. The following is an abbreviated description of the expected behavior of the major components.

Limited Water Entering the Emplacement Drift. The changes in climate over time provide a range of conditions that determines how much water falls onto the ground surface and infiltrates (Figure 7-5). Based on current scientific understanding, the assumption in the TSPA is that the current climate is the driest that the Yucca Mountain site will ever encounter. All future climates are assumed to be either similar to current conditions or wetter. The water that is not lost back to the atmosphere by evaporation or transpiration enters the unsaturated zone flow system. Water infiltration is affected by a number of factors related to the climate state, such as increase or decrease in vegetation on the ground surface, total precipitation, composition and proportions of surface material, air temperature, and run-off.

Water generally moves downward in the surface sediments, rock matrix, and fractures. The rock mass at Yucca Mountain is composed of thin surficial alluvial cover, and volcanic rock that is fractured to varying degrees as a result of contraction during cooling of the originally nearly molten rock. Fractures may also form in response to extensional faulting in the area. In general, within the welded volcanic units, water flowing in the fractures moves much more rapidly than the water moving through the matrix. In some locations, some of the water collects into locally saturated zones in the rock and is diverted laterally by differences in the rock properties. The overall unsaturated flow system is very heterogeneous, and the locations of flow paths, velocities, and volumes of groundwater flowing along these paths are expected to change over the life of the repository system.

The thermal heat generated by the SNF in the repository causes the temperature of the surrounding rock to rise from the time of emplacement until about 3,000 to 4,000 years after repository closure. The water and gas in the heated rock are driven away from the repository during this thermal pulse. The thermal output of the waste decreases with time; eventually, the rock mass returns to its original temperature, and the water and gas flow back toward the repository. After the water returns to the repository walls, it begins to drip into the repository, but only in a relatively few places. The drip shield assists in directing water away from the WP during this period, up to as long as 10,000 years. The number of seeps that can occur and the amount of water that is available to drip is restricted by the low velocity of flow and low volume of water flowing through Yucca Mountain, which is located in an arid region. Drips can occur only if the hydrologic properties of the rock mass cause the water to concentrate enough to form a seep. Over time, the number and location of seeps change, generally corresponding to increased or decreased infiltration based on changing climate conditions.

Long Lived WP and Drip Shield. Because the repository is located above the water table within the unsaturated zone, an important process controlling nominal case WP lifetime is moisture on the WP (Figure 7-6), either from seeps or moisture in the air. The location of the seeps providing dripping water depends to some extent on the natural conditions of the rock, but may also be related to rock mass alterations caused by repository construction and operation. Alterations such as increased fracturing may be caused by mechanical processes related to drilling the drifts or by thermal heating and expansion of the drift wall. The alternations in the seepage can also be caused by chemical alterations occurring as rock and engineered materials interact after dissolving in water, and various chemical species may precipitate in the surrounding rock, closing the pores and/or the fractures. The chemistry in the drift is continually changing because of the complex interactions among the incoming water, circulating gas, rock, and materials in the drift. The chemical evolution is strongly influenced by heat during the thermal pulse.

In the reference design, the radioactive waste emplaced in the repository will be enclosed in a two-layer WP, covered by a drip shield. The layers of the WP will be constructed of two different materials. These materials are expected to fail at different rates as well as from different mechanisms as they are exposed to evolving repository conditions. The outer layer is made of high-nickel alloy metal and the inner layer of a stainless steel. The drip shield is made of Titanium Grade 7 (see Section 2.6.1). The drip shield will eventually corrode and allow dripping on the WPs. Where water drips onto the WPs, the packages may corrode and eventually become breached. The breaches are thought to occur as deep, narrow pits or as broader areas called patches. Stress corrosion cracks in the end plate welds may also occur. The changing thermal, hydrologic, and chemical conditions in the repository all influence the corrosion rate of the WPs.

Limited Release of Radionuclides from the Engineered Barriers. If liquid water eventually enters a WP through the patches, pits, or stress corrosion cracks, it can contact the SNF contained within the WP. The majority of radioactive waste material comes from commercial reactors, but there is also some material in the form of HLW and DOE reactor fuels. However, the influence of the commercial SNF dominates long-term performance of the repository system, so waste from other sources is not included further in this discussion.

The liquid water first contacts the very thin layer (about 0.7 mm) of a zirconium alloy that covers the surface of the fuel elements, but generally only after the fuel has cooled to below-boiling conditions. This layer, called cladding, must be breached by mechanical or chemical processes before the radioactive fuel pellets can be exposed. Then the individual fuel elements start to degrade, making the radionuclides available for transport away from the waste form (Figure 7-7). The degradation process may involve several stages because the waste forms are sometimes altered to different chemical phases before they reach a phase that will allow the nuclides to be released from the waste. Also, different radionuclides have different chemical properties themselves, so solubilities of individual nuclides in water are greatly variable. The result is that certain nuclides are released much earlier than others are. The results of the TSPA show this effect, as different nuclides become the key contributors to dose rate over time.

Only a small portion of the waste form will leave the drift environment. During this move out of the WP, the radionuclides are either picked up and carried away from the waste form in flowing water or they move in a thin film of water by diffusion. To escape, the nuclides must exit through a pit, patch, or stress corrosion crack in the WP and move out into the waste emplacement drift. WPs are expected to remain intact for the 10,000 year compliance period permitting little, if any, material to reach the saturated zone.

Delay and Dilution of Radionuclide Concentrations Provided by the Natural Barriers. After escaping from the WP, the radionuclides can then advance through materials on the drift floor, which are mainly tuff gravel and the corrosion products from the WP. At this point, the nuclides may either adhere to some of the materials on the drift floor, continue to move in the water, or become attached to extremely small particles of clay, silica, or iron called "colloids" which are suspended or in solution. Because of their molecular charge and physical size, these colloidal particles move through the rock mass under the repository somewhat differently than noncolloidal articles.

The radionuclides generally move downward beneath the repository at different rates based on the nature of their flowpath (matrix vs. fracture), the chemical characteristics of the nuclides and of the rock they are passing through, and on the velocity of the water in which they are contained (Figure 7-8). The rock underlying the repository is unsaturated, and the water movement behaves as described earlier. Some water moves rapidly in fractures and some much more slowly in the rock matrix. The transport rate also depends on the tendency of the individual nuclide to interact with the rock through which it moves. Some radionuclides adhere to some minerals in a process called sorption and are bound in the rock for long periods. These nuclides may eventually desorb and again move through the system. Other types of nuclides move more quickly through the rock with little or no interaction that delays their transport. These species are considered to be poorly sorbed or non-sorbing species.

When the radionuclides reach the water table, they enter in the saturated zone flow system. Beneath Yucca Mountain, the water in the saturated zone flows in a generally southerly direction toward the Amargosa Valley. Nuclide sorption may occur in the rocks and alluvium along the flow paths in the saturated zone. Because of the differences in chemistry between the unsaturated and saturated zone rock and water, the rates, durations, and nuclides involved in sorption are different for the two zones. As the radionuclides move in the saturated zone along different paths and through different materials, they gradually become more dispersed and diluted, and the concentration of the nuclides in any volume of water decreases with distance from the repository to the south.

If the radionuclides are pumped out of the saturated zone by water wells, the radioactive material can cause doses to humans in several ways, for example:

- The water from the well could be used to irrigate crops that are eaten by individuals or livestock
- Water consumed by stock animals that provide milk or meat food products
- Drinking water directly consumed by individuals

If the water pumped from irrigation wells evaporates on the ground surface, the nuclides may be left as fine particulate matter that could be picked up by the wind and then inhaled by humans.

Disruptive Events. The key attributes of the system, given in the previous sections, describe the continually ongoing processes that are expected to occur in and around the proposed repository system. The term used to denote the sequence of anticipated conditions is "nominal case scenario." In contrast, "disturbed case scenario" refers to discrete, unanticipated events that disrupt the nominal case system (Figure 7-9). The disruptive event included in this analysis is the formation of a volcano through or adjacent to the repository. The following other disruptive events are treated separately in the analysis:

- Earthquake
- Human intrusion into the repository
- Volcanic eruption/dike intrusion

Yucca Mountain is in a terrain that has experienced volcanic activity in the geologic past. The rocks in which the repository will be constructed are volcanic in origin. However, scientific studies of the timing, rock volume, and other geologic aspects have concluded that volcanic activity in this area has been waning in the recent geologic past and that the probability of volcanic activity as a repository-disturbing event is very unlikely. However, part of the TSPA analysis is an assessment of the consequences of an igneous dike intrusion and volcanic formation that intersect the repository drifts. Both direct release to the atmosphere of the WP contents and indirect release to the unsaturated and saturated zone from damaged packages are considered in two separate scenarios.

In contrast, earthquakes happen frequently in and around Yucca Mountain. The effects of an earthquake important to postclosure repository performance primarily result from ground motions rather than from direct offset along a fault. The primary effect of ground shaking is to hasten rockfall into the drift. The effects of rockfall and seismic effects on the waste form are included in the nominal analysis.

Human intrusion is treated in a manner based on the regulatory description of such an event in which the contents of a WP are exposed through the borehole of a well drilled directly through the repository. The impact of such inadvertent human intrusion is treated separately and compared against the TSPA results to determine the potential level of influence. Inadvertent human intrusion is assumed to occur according to proposed federal regulations, so it is simply the possible consequences that are evaluated.

In previous TSPA calculations, the effects of nuclear criticality have been assessed for both in-WP and in-rock events. In these analyses, a series of unlikely events was assumed to occur. These unlikely events (such as filling the WP with water or concentrating specific radionuclides in the rock mass) lead to the concentration of certain nuclides, that, in specific low probability environments, might lead to a nuclear criticality. The result is a change in the nuclear material to more highly radioactive forms. The introduction of these new radionuclides into the source term was then compared against the base case to determine if the relative change in dose rate is significant, and it was determined to be inconsequential. Criticality events are not included in the current TSPA calculations because criticality has been screened out as not being a credible event during the 10,000-year regulatory period.

7.3 RESULTS OF ANALYSES

Although the TSPA is usually discussed in terms of a sequence of processes linked one after the other in time and space (as described in the earlier section), this approach may not readily convey how all of the processes evolve with time. This section describes the results at various time intervals of interest, attempting to show the evolution in both time and space for the natural and engineered systems and for the range of nominal-case conditions (CRWMS M&O 2000n). However, the assumptions underlying the modeling development drive results. Different sets of assumptions can give different results. The intent of the TSPA is not only to show how the system is thought to behave but also to provide information on how much uncertainty is associated with each TSPA component, as discussed later. Many of the results shown include a great deal of conservatism and some variation in (large ranges) parameter and model uncertainty. The results discussed below focus on the forecasted time-averaged behavior of the system. This behavior by itself attempts to represent the ranges of uncertainty and variability in the system and its possible future states.

The sequence of nominal-case results in the Figures 7-10, 7-11, 7-12, and 7-13 show schematically what a WP might look like at certain time periods. However, the schematics are only representative of those packages that experience dripping water. The percentage of all packages that experience significant corrosion of the resistant inner high-nickel alloy outer layer is expected to be small until late times. Even though the location and number of seeps change with time, the majority of packages may never experience any significant seepage at all, even in a million years.

From Waste Emplacement through the 10,000 Year Compliance Period. As the WPs are emplaced in the drifts, their combined heat output causes the drift-wall temperatures to rise and the water and gas in the rock is driven away from the repository. This process progressively dries out the rock mass farther and farther away from the repository. At 100 to 200 years after closure, the surfaces of some of the individual WPs start to cool below boiling, and the humidity in the drift climbs to nearly 100 percent. Depending on the local conditions around each WP, the degradation of the high-nickel alloy outer layer begins somewhere between a hundred years and several thousand years, but proceeds at a very slow pace. The fluids that are driven away by the thermal pulse begin to move back toward the repository. Some of the areas that cool more quickly, particularly those toward the edges of the repository, may start to experience dripping water. The drip shield assists in diverting water away from the WP during this period.

From after the 10,000 Year Compliance Period to 50,000 Years after Closure. By this time, the rock surrounding the drift has returned to its original temperature, and subsurface fluid-flow patterns have been reestablished. Some permanent alterations of the rock may remain (such as microfracturing caused by thermal expansion), but this does not appear to be significant in terms of repository performance. The outer layer of the WP is continuing to corrode, though very slowly. Dripping conditions now occur at discrete locations throughout the repository. Where the outer layer has been perforated, corrosion of the inner-barrier material is initiated (Figure 7-12). Inner barrier corrosion proceeds much more quickly than for the outer layer. In the cases where the inner layer has been perforated, the water can enter the WPs through small openings, alter the fuel, and move out of the engineered barrier system. The repository cutaway in Figure 7-12 shows a few paths along which nuclides are being released into the rock under the repository. At this time, the expected value for the number of breached WPs is less than 1 percent of the total emplaced packages. The current expected value for the peak dose rate from a plume in the saturated zone 20 km (12 miles) south-southeast of the repository is calculated to be 1.0 mrem/year at 50,000 years after closure. This value is 0.3 percent of the average background radiation from nonmedical sources in some areas of the United States, which is about 300 mrem/year. The primary nuclides contributing to the dose rate are technetium-99 and iodine-129, both weakly sorbing or nonsorbing species for the system.

Fifty Thousand to 100,000 Years after Closure. The natural conditions in the rock remain unchanged from the previous period except for the likelihood of a change in climate. The likelihood is that, when the climate changes, a significant increase in infiltration has occurred, causing more water to flow through Yucca Mountain, more seeps into the repository to occur, a larger percentage of packages to fail, and more radionuclides to be transported along the unsaturated and saturated zone pathways. The progression of corrosion of the packages experiencing dripping water is shown in Figure 7-12.

Those nuclides that at earlier times are limited in their release from the SNF elements because of their chemistry become larger contributors to the dose rate. In particular, neptunium-237 becomes the dominant isotope controlling dose rate. The number of packages failing by the end of this time is about 60 percent of the total number. The time-averaged peak dose rate at 20 km (12 miles) is 70 mrem/year, as compared to the average of 360 mrem/year due to background radiation from natural sources in the United States.

One Hundred Thousand to One Million Years after Closure. The individual WPs that are contacted by seeps continue to slowly corrode. All packages are releasing nuclides by one million years after closure (Figure 7-13). Dose rates at the 20 km (12 mile) point continue to climb as more packages release their inventory, until a maximum is reached at approximately 300,000 to 400,000 years. Neptunium-237 remains the main contributor to the dose rate, but plutonium attached to colloids is also a dominant contributor to dose at later times.

7.4 SENSITIVITY ANALYSIS

The sensitivity of repository performance to any specific type of information strongly depends on the way performance is being measured. The question to be answered, in terms of how performance is being measured determines the relative importance of the components. An example of how different performance criteria change the relative importance of the various parts of the system is shown by the variability in the specific TSPA parameters' importance at different times. A different suite or priority of parameters is seen in the uncertainty analyses for 10,000 years versus those for 100,000 or 1 million years.

Mathematical methods of assessing parameter sensitivity, such as regression analyses, are used in the TSPA. In general, the sensitivity analyses do not show in an absolute sense the parameters that are most important to performance. Rather, they show in a relative way the parameters in which uncertainty most affects the results. In some cases, if future studies could reduce the range in uncertainty, the parameter might no longer appear as a parameter to which performance is highly sensitive. Conversely, if a parameter or component is assigned an inappropriately low uncertainty range, it might not show up as a particularly important parameter. These analyses must be performed with care to gain the necessary understanding about the parameters that are most important to actual repository performance. The results of the TSPA uncertainty and sensitivity analyses are provided in the following.

Based on the sensitivity and uncertainty analyses of the TSPA and on the judgment of the TSPA analysts, the following aspects of the TSPA components have been determined to be most significant to the nominal-case dose rates at 20 km (12 miles) from the Yucca Mountain repository. In some cases, the TSPA results point to very specific aspects or parameters used to represent the TSPA components which, in turn, are captured in the principal factors of the repository safety strategy. Many of these aspects or parameters are subsets of a principal factor (listed in Section 3.2). The results are shown for three different time periods because the relative importance of different aspects of the modeled system changes as the system evolves.

Postclosure to 100,000 Years after Closure

- Outer WP lid stress profile
- Alloy-22 outer lid median general corrosion rate
- Alloy-22 inner lid median general corrosion rate
- Diversion of water by the drip shield
- Occurrence of premature package failures (loss of integrity of outer WP barrier or of inner WP barrier due to manufacturing flaws or mechanical effects)
- Saturated zone groundwater flux
- Rates of WP degradation (loss of integrity of outer WP barrier and/or inner WP barrier due to environmental conditions)
- Middle WP lid stress profile

100,000 to 1,000,000 Years after Closure

- Infiltration scenario
- Agricultural water usage uncertainty
- Saturated zone groundwater flux
- Outer WP lid stress profile
- Alloy-22 outer lid median general corrosion rate

7.5 TSPA REFERENCE DESIGN

The base case design for TSPA-SR analyses is summarized as follows. The design has been formulated with the intention of enhancing system performance with respect to the following attributes of repository performance:

- Water contacting WP
- WP lifetime (containment)
- Radionuclide mobilization and release
- Reduction in the concentration of radionuclides during transport

The information in this section is summarized from Section 2 of this document.

A schematic of the reference design components at the time of repository closure is presented in Figure 7-14. In general, the major components of the base case design will include a low areal mass load (approximately 60 MTHM/acre), with "line loading" of the WPs. The engineered barrier system will include:

- Drift liner (steel sets with welded wire and rock bolts)
- Initial air gap in the drift (no backfill)

- Titanium alloy drip shield (15-mm thick)
- Two-layer WP (20 mm corrosion resistant material (nickel-alloy) outer layer and 50 mm corrosion allowance material (stainless steel) inner layer)
- In-drift emplacement of the WPs
- Placement of the WPs on a steel and nickel alloy emplacement pallet
- Invert steel with crushed, welded tuff ballast at the base of the drift

The following discussion provides more detail as to the basis for each of these design components.

Drip Shield (Titanium alloy). The drip shield is continuous in the drift over the WPs. It serves to reduce the effect of rock fall and dripping on the WP.

WP–Corrosion Resistant Material. The outer layer of the WP is a nickel-based alloy that is very resistant to aqueous corrosion and nearly totally resistant to humid air corrosion. The current reference corrosion resistant material is 20 mm of Alloy 22. Both the middle and outer closure lids are made of this material.

WP–Corrosion Allowance Material. Because the WP is the single component that is expected to have absolute containment at the time of emplacement, the design strategy is to make the WP robust. The inner layer of the WP is 50 mm thick and serves three functions. It provides structural strength to resist rock falls, to support the internal components, to be supported by the pedestals, and to be handled. It also provides radiation shielding to reduce the WP exterior surface contact dose rate. Coupled with the MGR transport overpack, the shielding is enough to protect workers. In addition, it acts as a containment barrier for the radioactive waste inside the WP. The inner closure lid is made of this same material. The current material in the design is stainless steel.

Large WPs. A large WP reduces cost, handling, closure operations, non-destructive evaluation operations, and allows efficient use of the drift length. The current large WP reference design is based on a 21 PWR SNF assembly WP. Roughly the same size WP can also accommodate 44 of the smaller BWR SNF assemblies or five DHLW glass "logs" surrounding a central canister of DOE SNF. For high heat producing or high criticality potential assemblies, a smaller WP for 12 PWR SNF assemblies may be used.

In-drift Emplacement of WPs. The design calls for in-drift emplacement. This is a consequence of large WPs being designed for in-drift emplacement; consequently, the amount of excavation is minimized.

Invert. The invert is designed to provide support for the WP emplacement pallets during the preclosure period. It will be composed of a steel frame filled with crushed tuff ballast.

Emplacement Pallet. The stainless steel and nickel-alloy pallets provide support for the WPs during the preclosure period from the time following WP closure and decontamination through emplacement.

Thermal Design–Areal Mass Load (Low). The areal mass load for the base case is approximately 56 MTHM/acre. This was determined by consideration of reduction of uncertainty, and preservation of the zeolites below the repository. Thus, to minimize cost, the goal is to load the repository at as high an areal mass load as feasible for acceptable performance. The current reference design areal mass load is set by the temperature maximum which will not exceed the thermal performance requirements of the repository.

Thermal Design–WP Spacing (Line). The line loading of WPs is specified at a nominal spacing of 10 cm.

Thermal Design–SNF Assembly Blending - To Meet 11.8 kW Limit. Each SNF assembly has a specific set of characteristics: Enrichment, burnup, and age. These determine how much thermal power the assembly produces. A limit of 11.8 kW has been set for the collection of assemblies in a WP to prevent heating the cladding beyond 350°C, which could cause it to perforate. SNF assemblies will be packaged appropriately to meet the 11.8 kW limit.

Thermal Design–SNF Assembly Blending - To Meet Criticality Limit. Each SNF assembly also has a specific potential to contribute to nuclear criticality, again based on enrichment, burnup, and age. Based on the finite number of assemblies in the WP and the overall effective criticality constant constraint, $k_{eff} < 0.95$, limits have been set for assembly values of $K_{eff.}$

Backfill–Rock Fall Protection. The SR base case design does not include backfill in the emplacement drifts. However, one design option that will be analyzed (as a sensitivity analysis) is the case that includes backfill. It provides additional protection of the drip shield from the rock fall.

During the postclosure period, the emplacement drift ground support and parts of the near-field rock may fall into the drift. Covering the drip shield with backfill protects other components from damage from such mechanical loads. A design analysis has shown that the WP can withstand impacts from very large rocks. For the drip shield, much smaller rocks can cause localized damage that can later be exacerbated by water contact, since corrosion of the substrate can cause expansion, peeling the coating.

7.6 CONFIRMATION VERIFICATION

Information included in the Confirmation Verification Matrix (CVM) (Table 7-1) summarizes a collaborative effort between the Systems Engineering Department; Environmental, Safety and Health Department; and various design departments including Waste Package, Surface Facilities, and Subsurface Facilities. Designers and Systems Engineers agreed on the most appropriate manner of verification for each requirement in each phase. Systems Engineering has identified five phases of the project that are pertinent to verification of requirements. Because of the manner in which the MGR will be constructed and operated, many of these phases overlap. These five phases are defined as follows.

7.6.1 Development

Verification efforts during this phase will primarily support the design development and integration processes by confirming design concepts, evaluating alternative design concepts, and investigating the availability of needed technology, and applicable permitting requirements. This phase will also support system verification by demonstrating system requirements that cannot be easily confirmed in a pre-operational site environment. Another objective of development verification is to resolve any outstanding design issues. This may include resolving critical but unverified design parameters, and conducting modeling and analyses to support and substantiate preclosure licensing arguments. This phase will employ proof of concept prototype testing to reduce design and integration risk by investigating new technologies or design solutions that have little or no history of testing or use at existing NRC-licensed storage facilities or nuclear power plants.

7.6.2 Component

Verification efforts during this phase include qualification, acceptance, and installation and checkout. Qualification testing verifies, on a limited sampling basis, the proper component operation with respect to extreme bounds (as defined by specifications). Acceptance verification is performed for key parameters, and establishes confidence that the manufacturing process is producing the correct product. The component vendor, with quality assurance oversight and concurrence, performs qualification and acceptance verification. Installation and checkout testing will verify that SSCs are correctly installed and operational. If required, the managing and operating contractor, with vendor support, will perform these verification efforts during the construction phase. Installation and checkout testing will also ensure that installation of hardware and software is consistent with drawings and specifications of the baseline configuration

7.6.3 Pre-operational

Verification efforts during this phase include system, integration, mockup, and cold startup activities. System and integration testing will verify the operational readiness of SSCs and procedures. It will be performed for all operations and procedures involved in receiving, preparing, emplacing, and moving waste (i.e., for recovery or retrieval). Mockup testing will support system and integration testing by providing a testbed for operational requirements verification, procedure development, permit development, and training. Cold startup testing is the final integration test and precedes waste receipt and hot startup testing. Cold startup employs operational and support personnel working with actual operational and support procedures. Hot startup follows cold testing and is preceded by readiness reviews to ensure that facilities and systems needed for waste receipt are complete and installation and checkout test results are acceptable. Hot startup testing will verify that operation and maintenance systems work properly and confirm that exposure times and radiation levels fall within acceptable limits during actual repository operations.

7.6.4 Periodic Performance and Monitoring

Verification efforts during this phase will ensure continued license operations and safe working conditions. Periodic performance and surveillance testing will verify that system performance continues to comply with preclosure requirements and ensures continued proper functioning of SSCs important to radiological safety, waste isolation, fire protection, and repository operations, as well as conventional quality SSCs. Monitoring of surface and subsurface environments will be performed to ensure safe working conditions and to document continuing compliance with applicable permits and existing regulatory standards for air, water, and radiological considerations. Performance confirmation monitoring will also be performed for disruptive events with significant postclosure implication

7.6.5 Performance Confirmation.

Verification efforts during this phase will monitor repository performance, perform tests, collect data, and analyze and evaluate results to assess whether postclosure conditions with long-term performance sensitivity will behave as expected. Testing will provide information to performance analyses to reduce the uncertainty in the assessment of postclosure performance as well as provide data that will confirm the information used to determine that the postclosure total system performance objective will be met. Evaluations can include the use of process models and TSPA.

7.6.6 Description of CVM

The first column of the CVM (Table 7-1) contains the number corresponding to the requirement found in Section 5. Only requirements originating at the PDD level are addressed in this matrix. The adjacent column includes the SDD to which the requirement is linked. Only requirements requiring verification at the SDD level include these links. Within each phase of the project, requirements levied on the MGR will be verified by analysis, examination, demonstration, test, or a combination of these methods. Verification of a requirement may not be necessary for each phase.

Verification of the requirement in each design phase is marked with an "X" under the appropriate verification method (abbreviated "A" for analysis, "E" for non-destructive examination, "D" for demonstration, "T" for test, and "N/A" for not applicable). Several of the requirements found in the CVM require verification by different methods and by different organizations within the same phase of the project. These requirements are marked SF, SS, or WP within the table, the letters of which represent the organization responsible for the verification ("SF" for Surface Facilities, "SS" for Subsurface Facilities, and "WP" for Waste Package).

Table 7-1. Conformance Verification Matrix

	SDD Links*	DEVELOPMENT					COMPONENT (VENDOR)					PRE-OPERATIONAL & STARTUP					PERIODIC PERFORMANCE & MONITORING					PERFORMANCE CONFIRMATION				
CRITERIA		A	E	D	T	N/A	A	E	D	T	N/A	A	E	D	T	N/A	A	E	D	T	N/A	A	E	D	T	N/A
5.1.1.1		X									X					X					X				X	
5.1.1.2	UDC, CDC, EDC, DDC, VDC, EDS	X								X				X						X					X	
5.1.1.3		X									X					X					X	X				
5.1.3.2	UDC, CDC, DDC, EDC, VDC, NDC, EDS, CMH, CCT, HBS, CCH, ATS, CTS, DCH, WPR, HBE, HBV, HBF, TBS, SFS, GCS, WES, BES, SCS, SFR, SED, (CBS, SET, SDT not yet written)	X								X						X				X						X
5.1.4.1		X									X					X					X					X
5.1.4.2		X									X					X					X					X
5.1.4.3		X									X	SS		SF							X					X
5.1.4.4		X									X	SS		SF							X					X
5.2.1			X								X					X					X					X
5.2.3		X									X					X					X					X
5.2.4		X									X					X					X					X
5.2.5			X								X					X					X					X
5.2.6			X								X					X					X					X
5.2.7		X									X					X		X								X
5.2.8			X								X					X					X					X
5.2.9		X									X					X					X					X
5.2.10		X									X					X	X									X
5.2.11			X								X					X		X								X
5.2.12	UDC, VDC, NDC, EDC, DDC, CDC		X								X					X					X					X
5.2.13		X									X					X	SF			WP						X
5.2.14		X						X								X					X					X
5.2.21		X									X			X							X					X

Table 7-1. Confirmation Verification Matrix (continued)

CRITERIA	SDD Links*	DEVELOPMENT					COMPONENT (VENDOR)					PRE-OPERATIONAL & STARTUP					PERIODIC PERFORMANCE & MONITORING					PERFORMANCE CONFIRMATION				
		A	E	D	T	N/A	A	E	D	T	N/A	A	E	D	T	N/A	A	E	D	T	N/A	A	E	D	T	N/A
5.2.22		X									X					X					X					X
5.2.23	UDC, VDC, NDC, EDC, DDC, CDC	X									X					X					X					X
5.2.24		X									X					X		X								X
5.2.25		X									X					X					X					X
5.2.26		X									X					X					X					X
5.2.27		X									X					X					X					X
5.2.28		X									X					X					X					X
5.2.29		X									X					X					X					X
5.2.30		X									X					X					X					X
5.3.1						X					X		X					X								X
5.3.2		X									X			X							X					X
5.3.3		X																								
5.3.4		X																								
5.3.5		X																								
5.3.6		X									X					X					X					X

* Links shown only where conformance verification is required at SDD level.

Legend
- S Verification method for Surface Facilities for this requirement, in this design phase.
- A Analysis
- SS Verification method for Subsurface Facilities for this requirement, in this design phase.
- E Examination
- WP Verification method for Waste Package for this requirement, in this design phase.
- D Demonstration
- T Test
- N/A Not applicable

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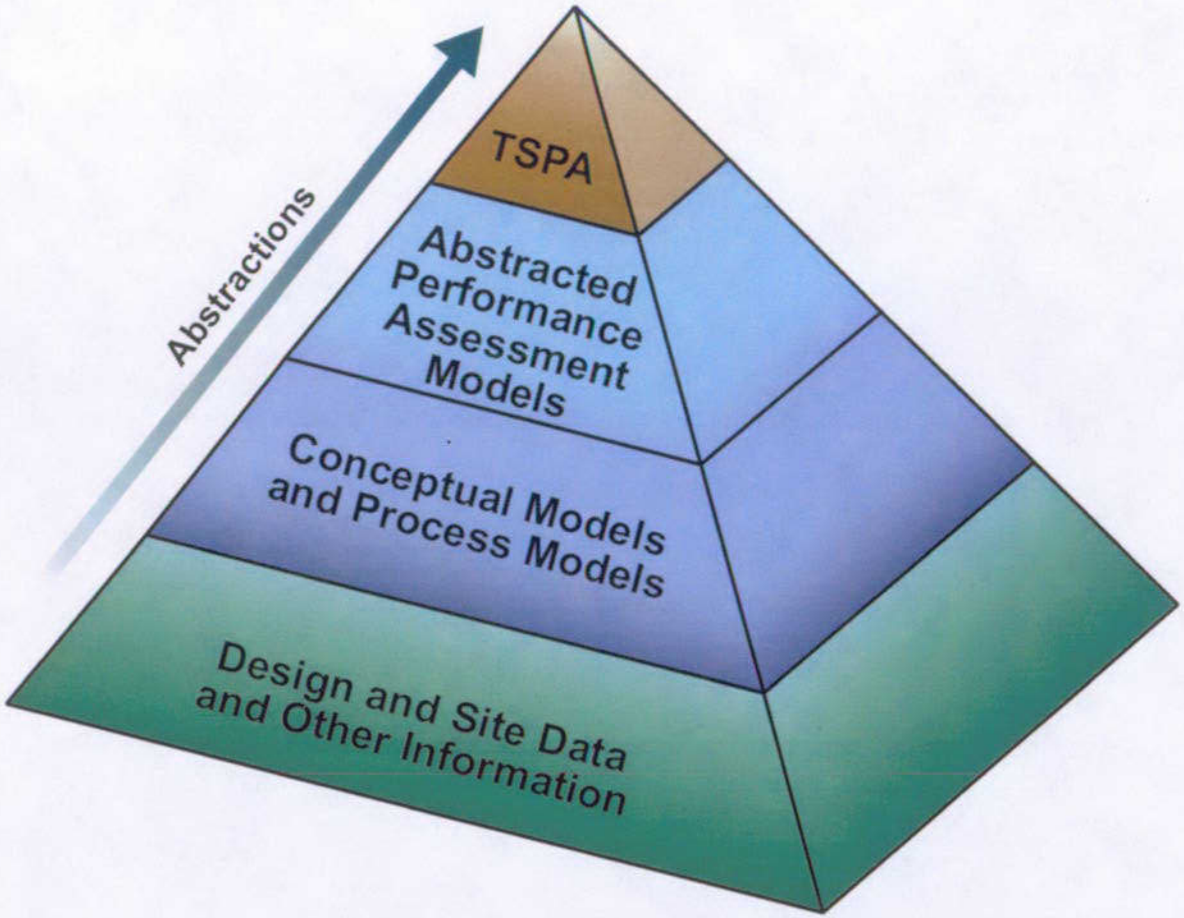

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Figure 7-1. TSPA Process Pyramid

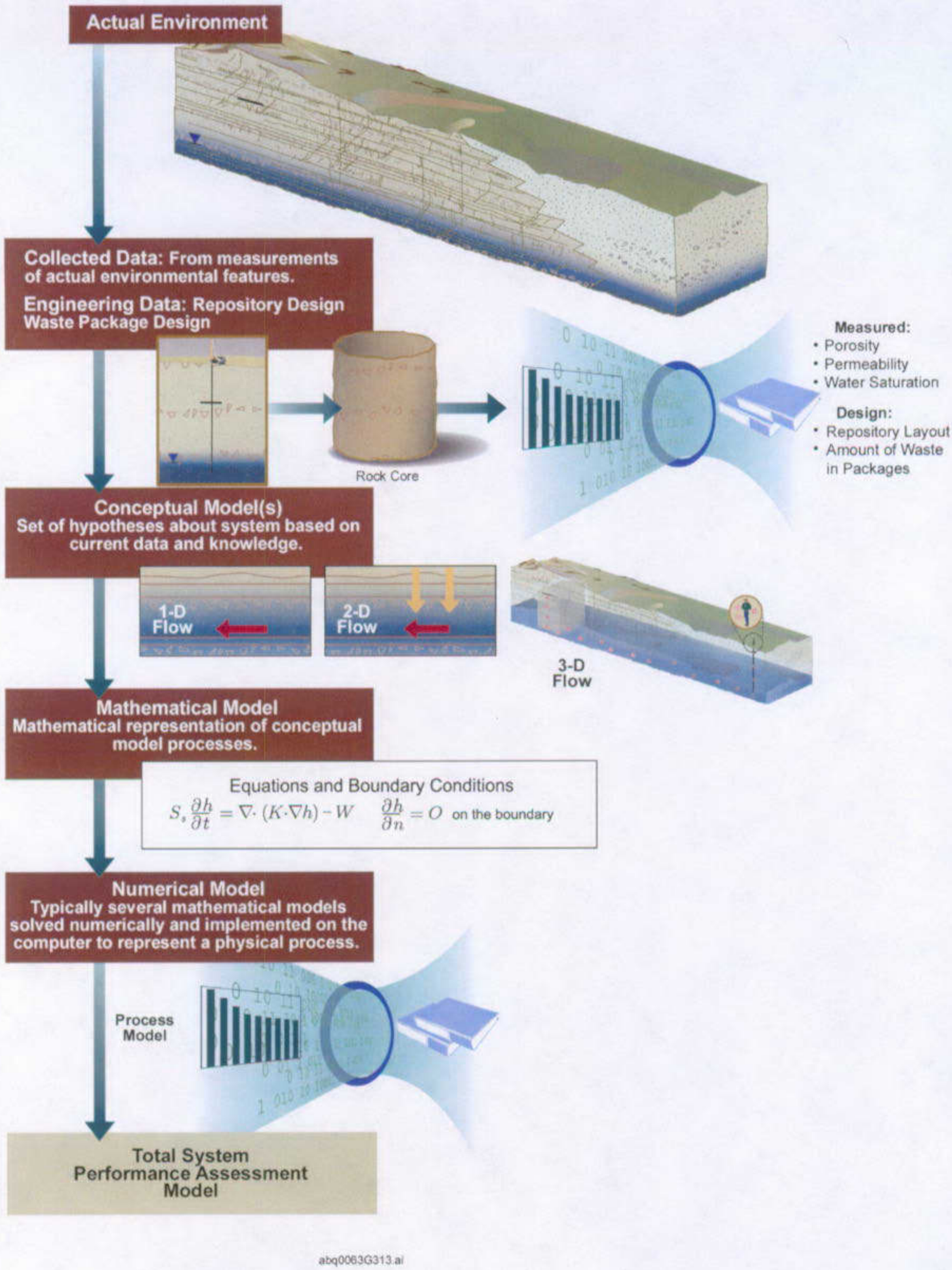

Figure 7-2. TSPA Process Model

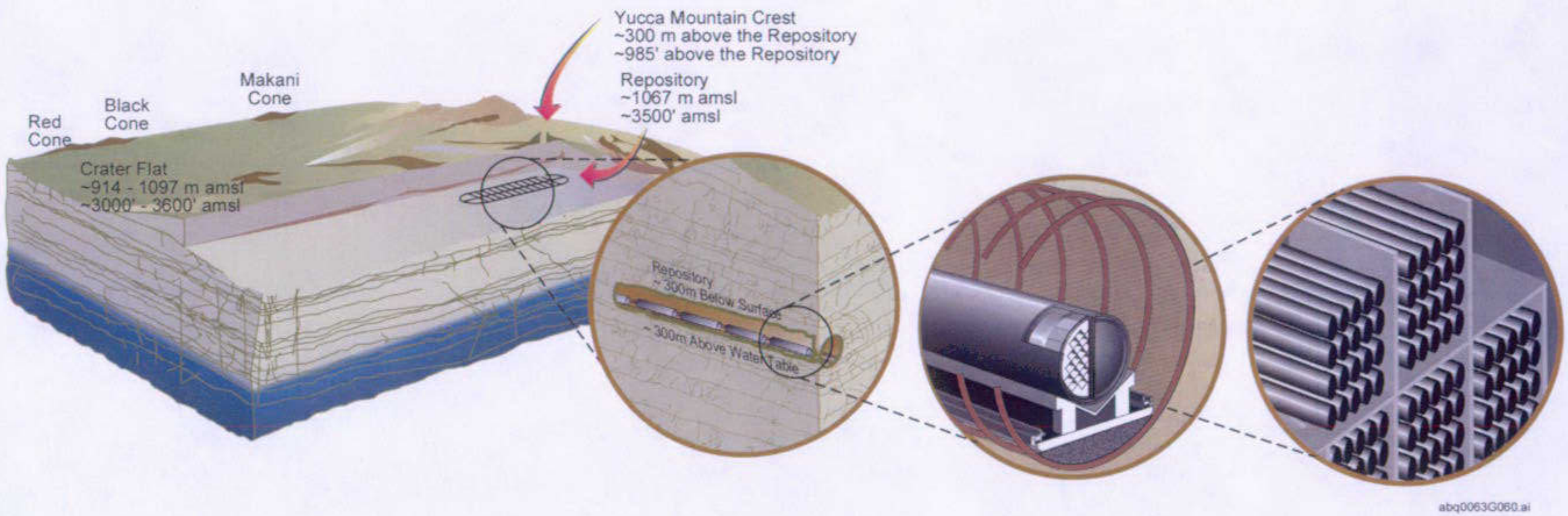

Figure 7-3. Yucca Mountain Overview

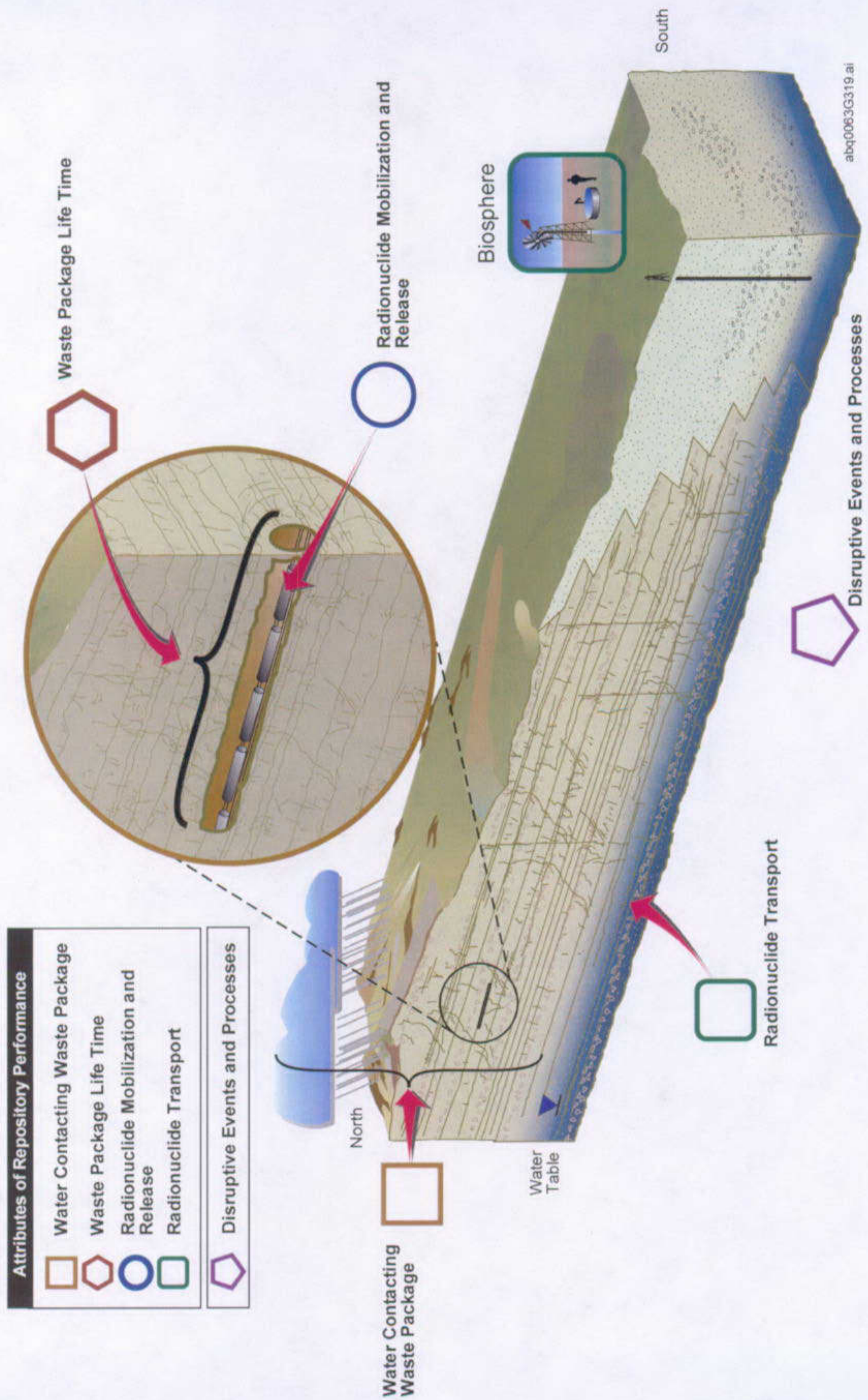

Figure 7-4. TSPA Component Models

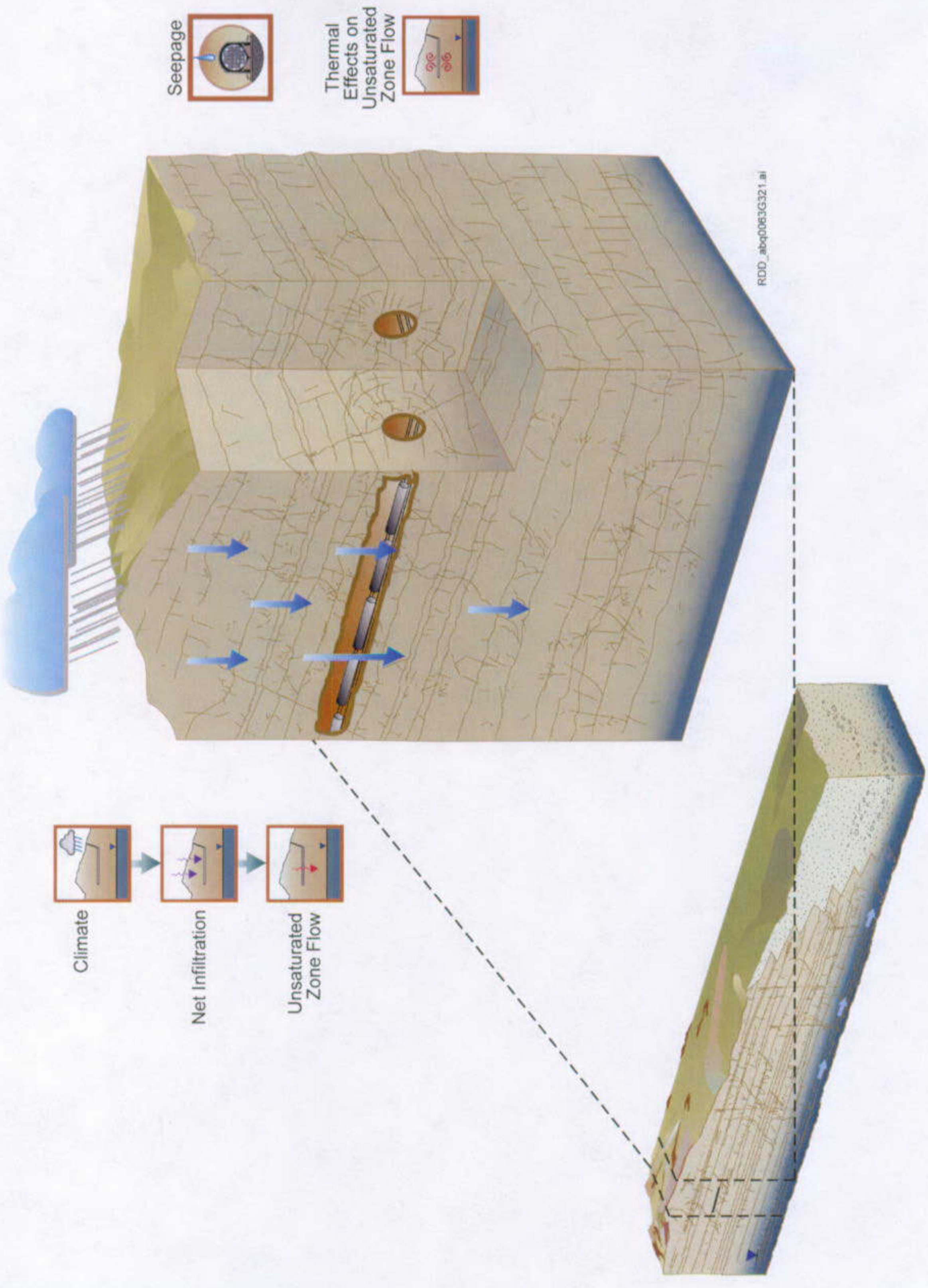

Figure 7-5. TSPA Component Model - Water Contacting the Waste Package

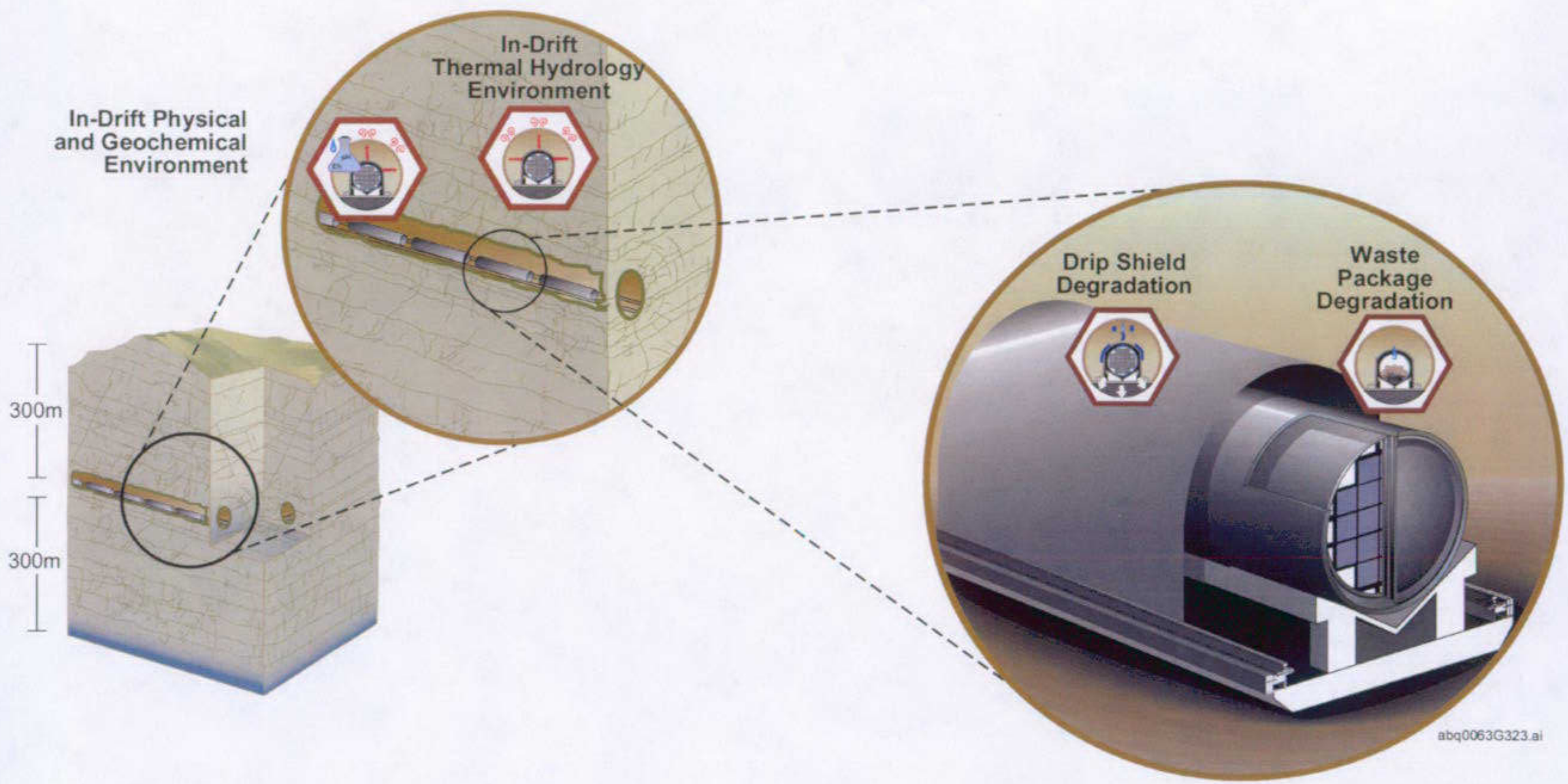

Figure 7-6. TSPA Component Model - Waste Package Lifetime

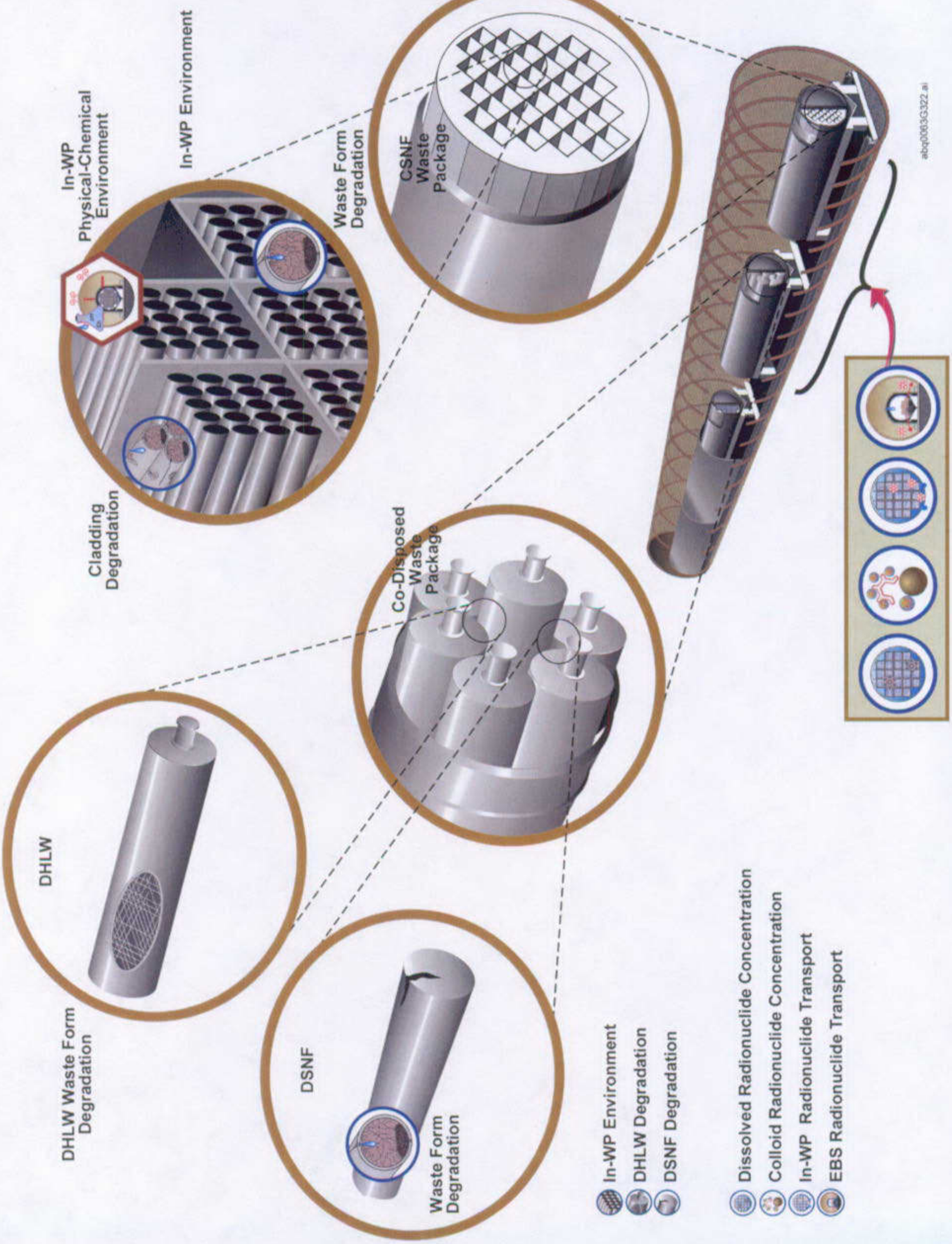

Figure 7-7. TSPA Component Model - Radionuclide Mobilization and Release

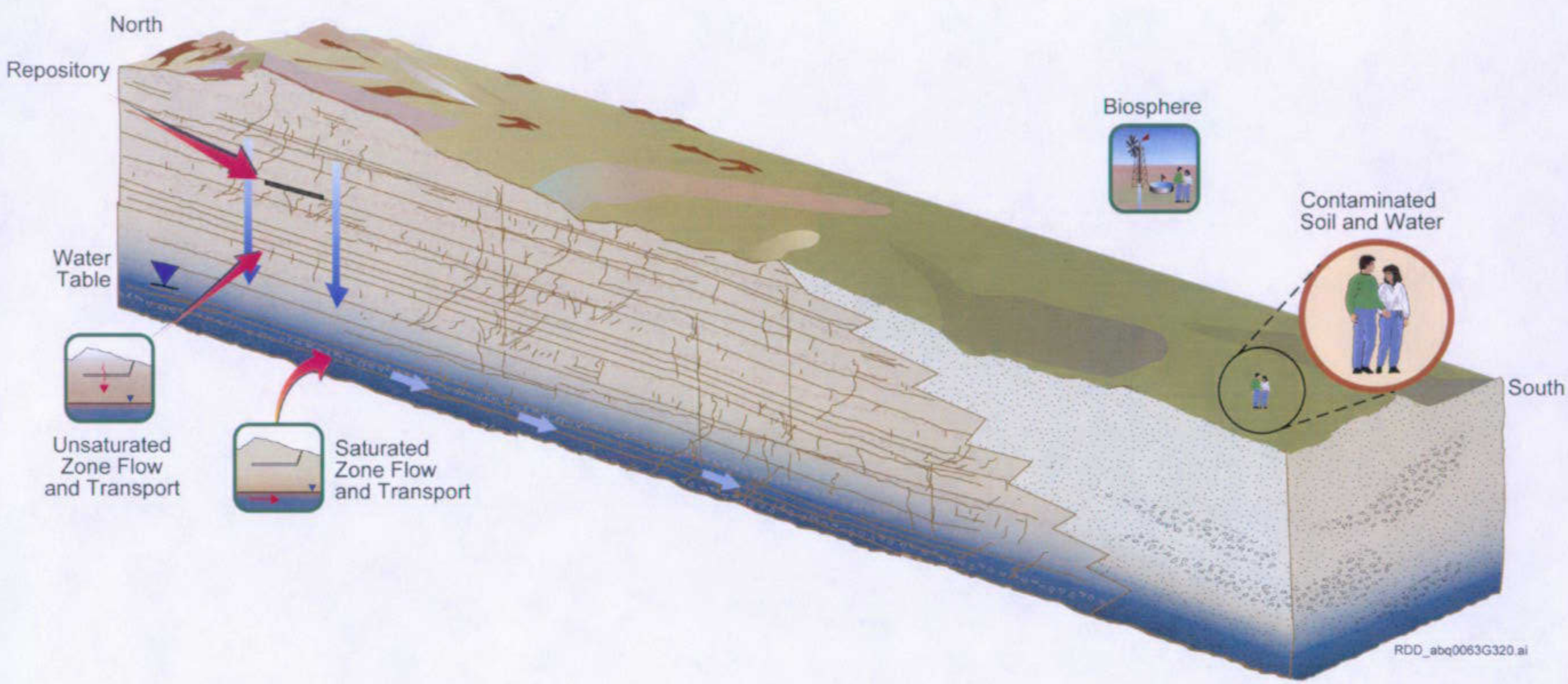

Figure 7-8. TSPA Component Module - Radionuclide Transport

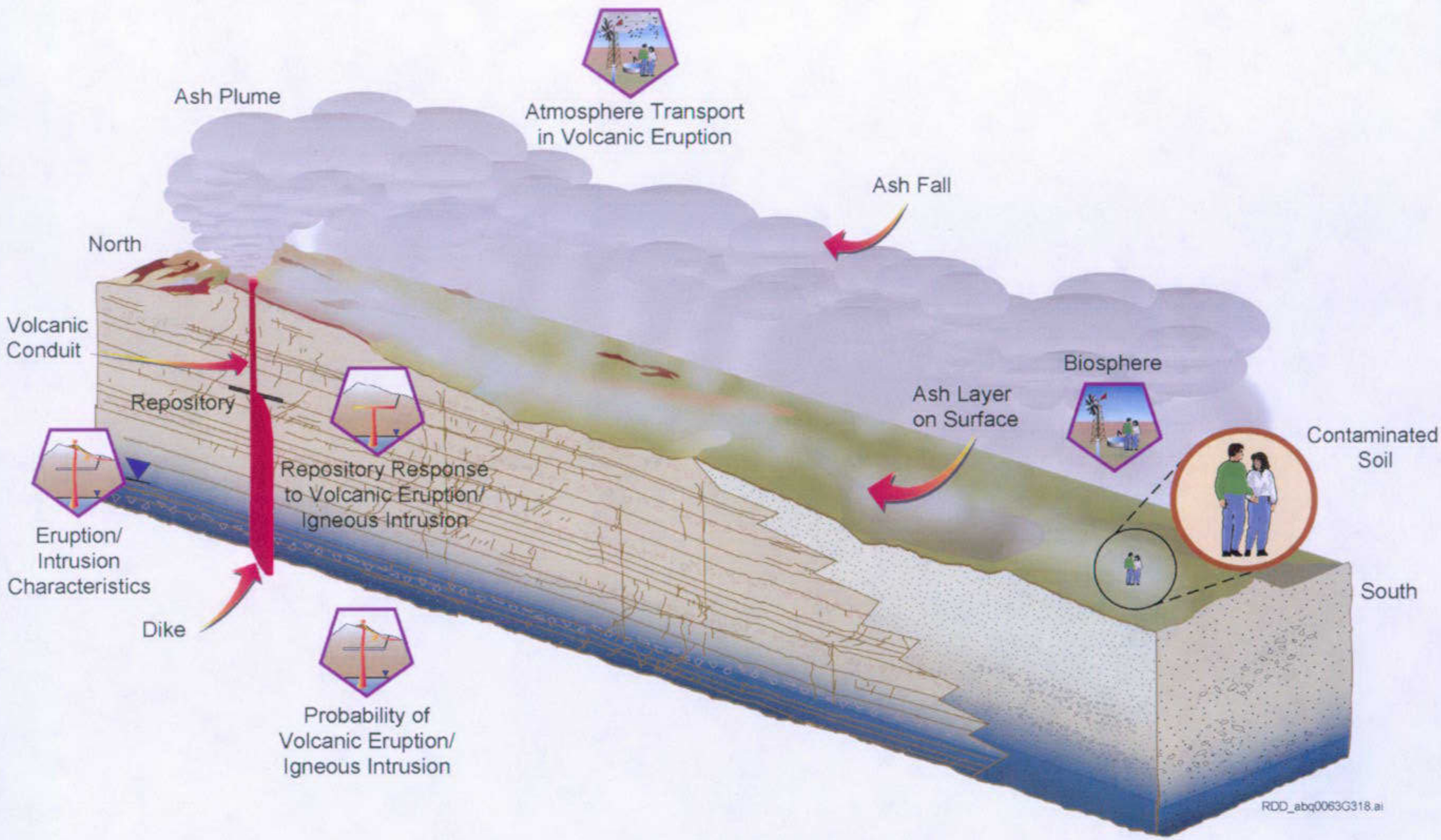

Figure 7-9. TSPA Component Model - Volcanism

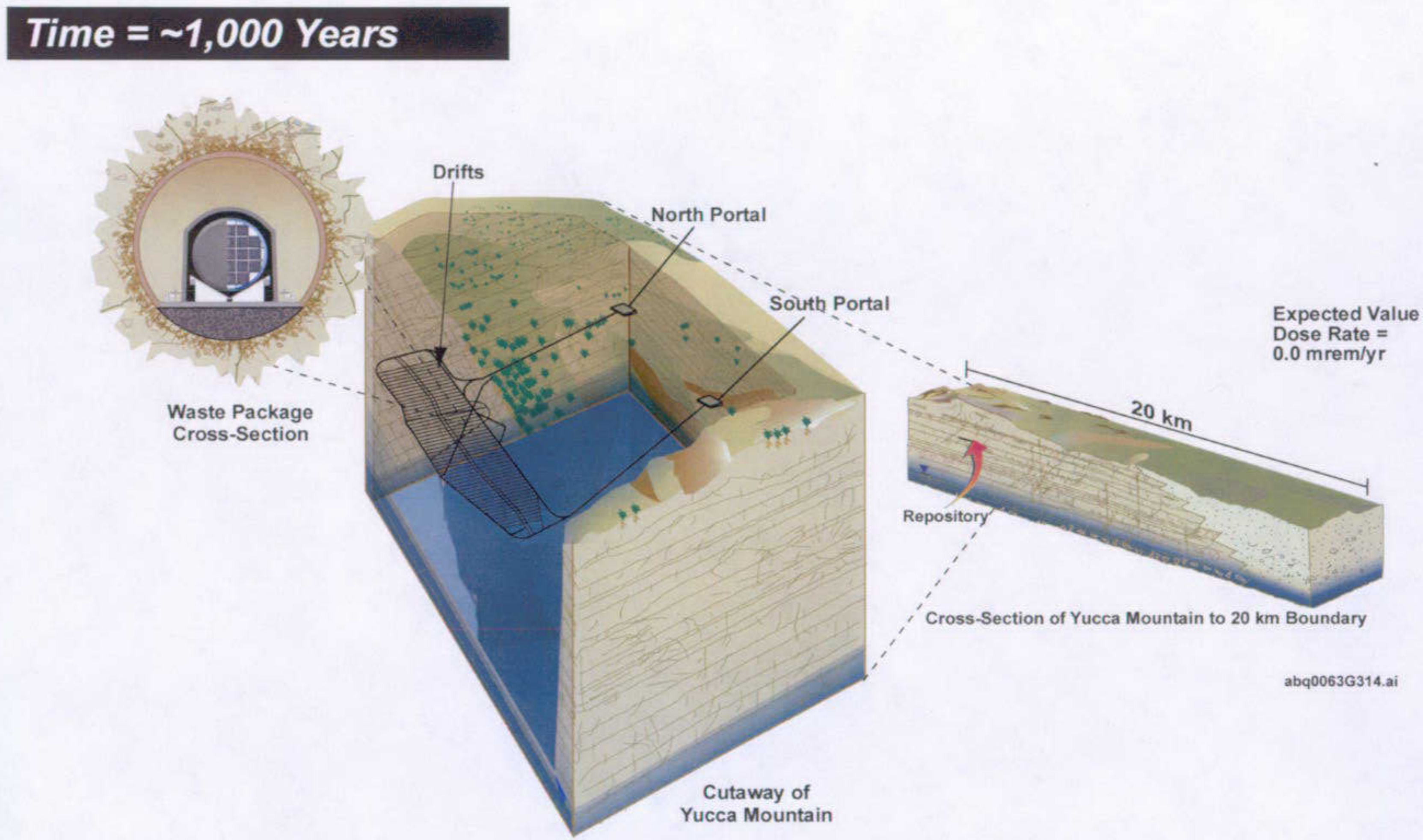

Figure 7-10. TSPA: Repository Conditions at Approximately 1000 Years after Emplacement

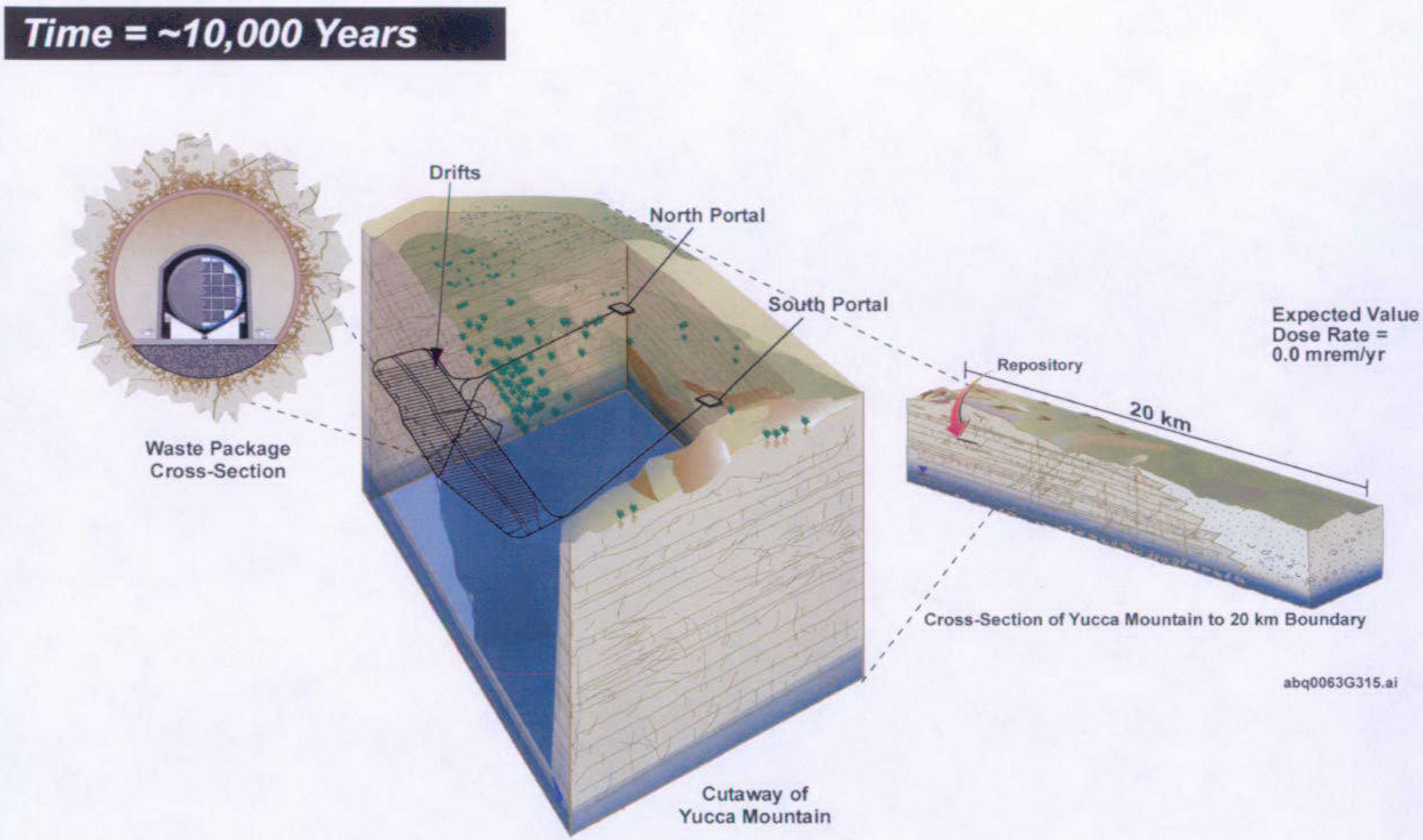

Figure 7-11. Repository Conditions Approximately 10,000 Years after Emplacement

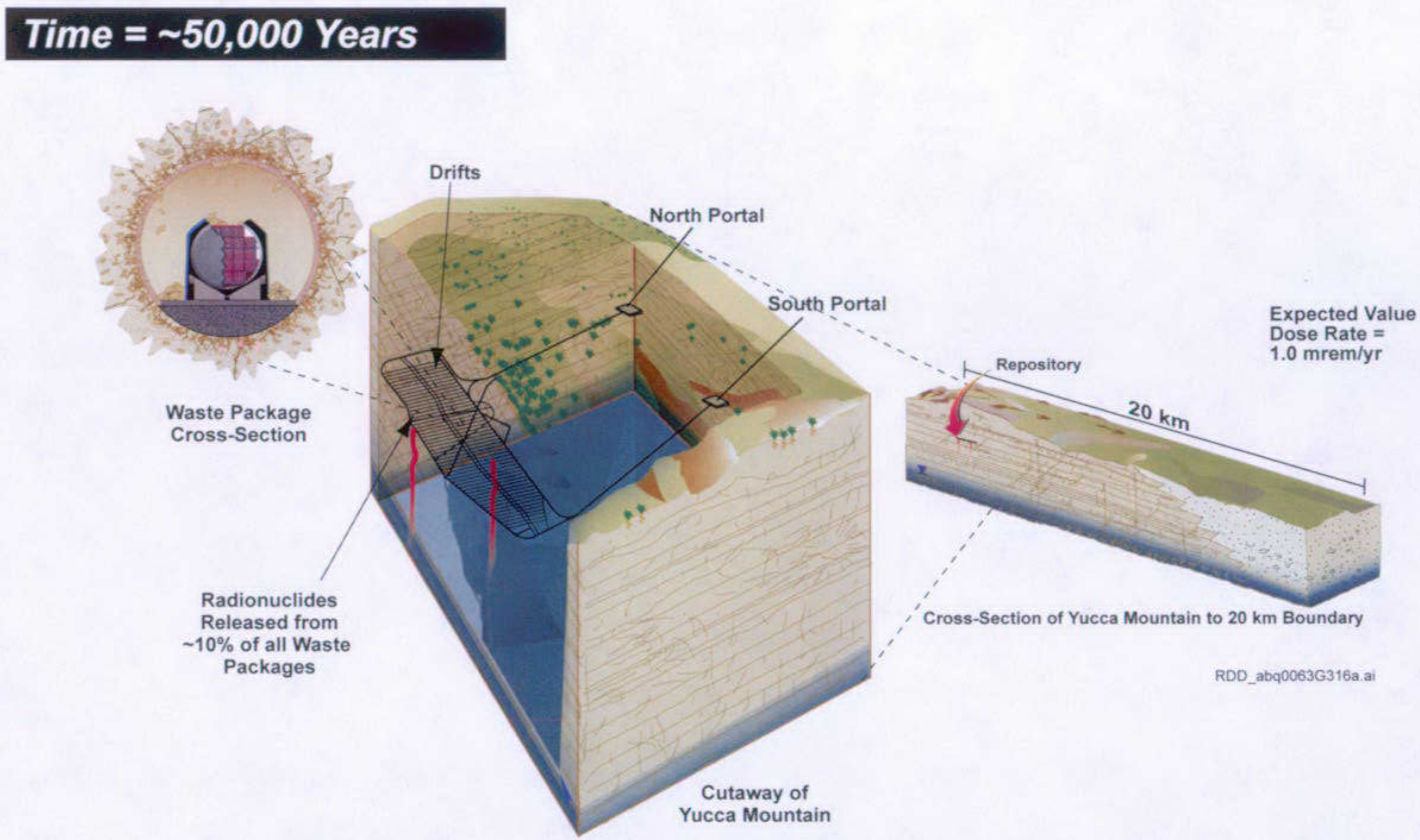

Figure 7-12. TSPA: Repository Conditions Approximately 50,000 Years after Emplacement

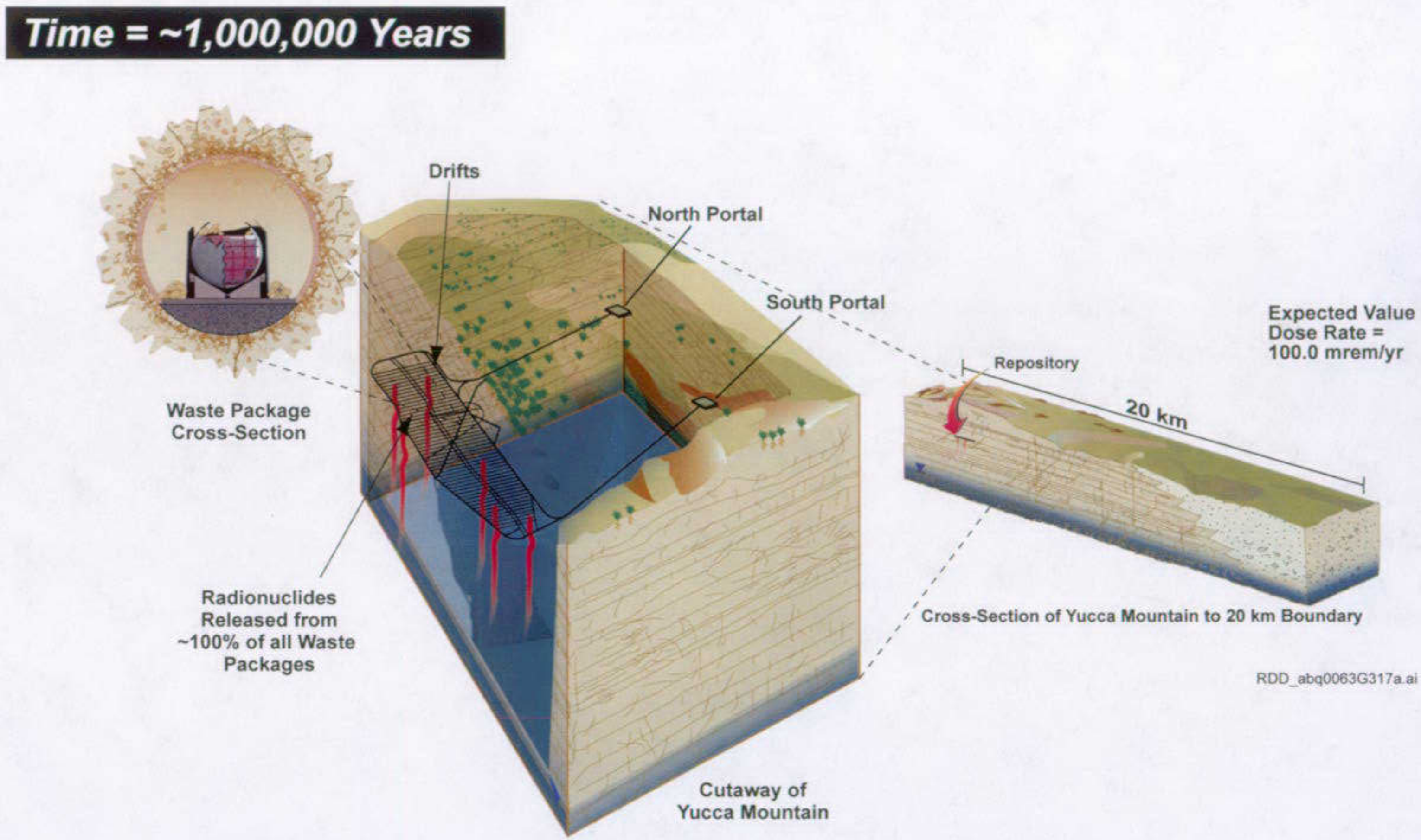

Figure 7-13. TSPA: Repository Conditions Approximately 1,000,000 Years after Emplacement

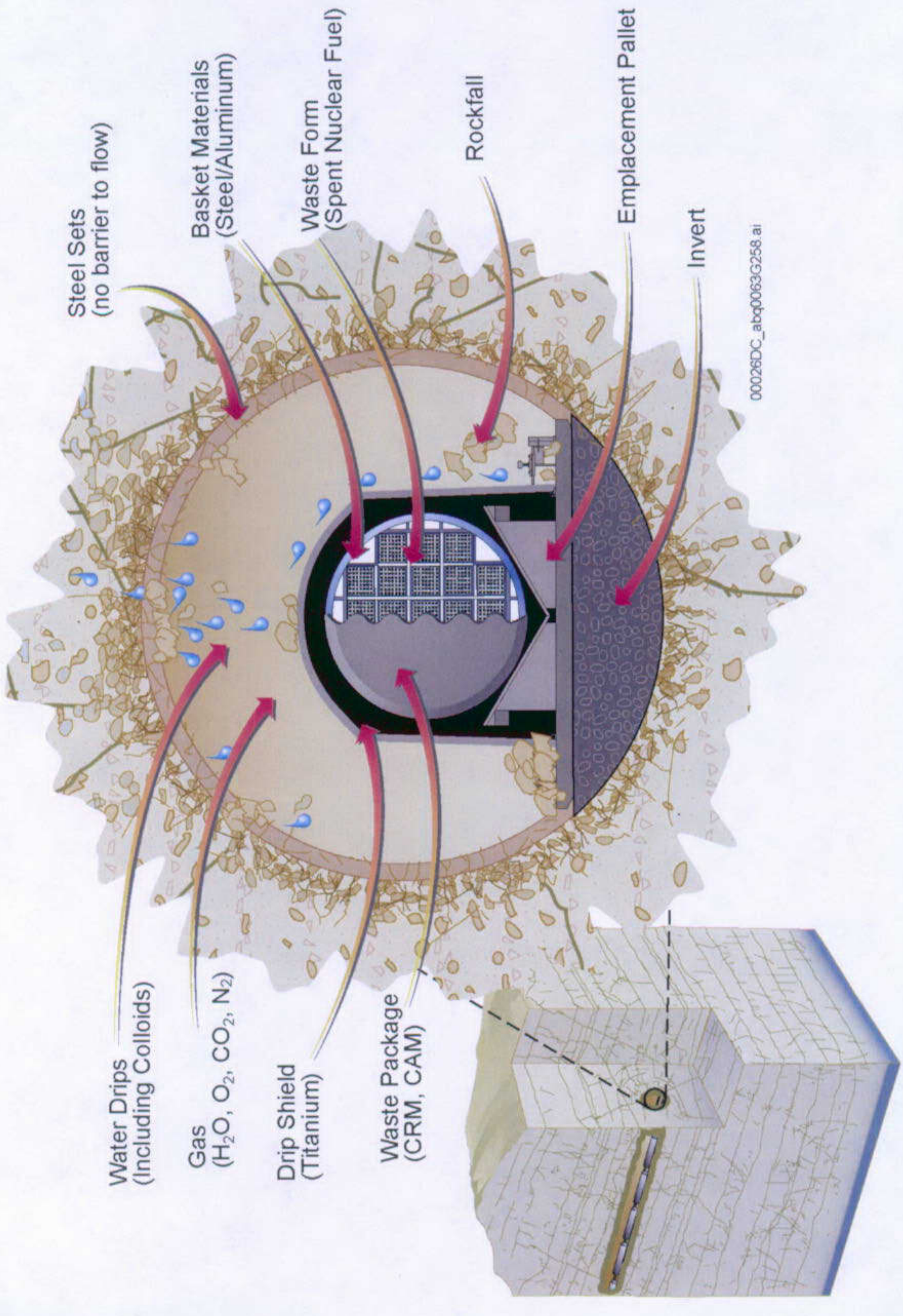

Figure 7-14. TSPA: Reference Design Components

8. REFERENCES

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APPENDIX A

SYSTEM DESIGNATORS

APPENDIX A

SYSTEM DESIGNATORS

The system designators are used to identify the Level-5 systems shown in the body of this document. For configuration management purposes, each system is considered a Configuration Item. Separate SDDs are to be developed for each of these systems

System Designator	System Name
ADS	Administration System
ATS	Assembly Transfer System
BES	Backfill Emplacement System
CBS	Carrier Preparation Building System
CCH	Carrier/Cask Handling System
CCT	Carrier/Cask Transport System
CDC	Canistered SNF Disposal Container
CMH	Carrier Preparation Building Materials Handling System
CTS	Canister Transfer System
DCH	Disposal Container Handling System
DDC	DHLW Disposal Container
EDC	DOE SNF Disposal Container
EDS	Emplacement Drift System
ERS	Emergency Response System
GCS	Ground Control System
GST	General Site Transportation System
HBE	Waste Handling Building Electrical System
HBF	Waste Handling Building Fire Protection System
HBS	Waste Handling Building System
HBV	Waste Handling Building Ventilation System
HSS	Health Safety System
MHS	Muck Handling System
MSL	MGR Site Layout
MSS	Maintenance & Supply System
NDC	Non-Fuel Components Disposal Container
OMC	Monitored Geologic Repository Operations Monitoring and Control System
OUS	Off-Site Utilities System
PCA	Performance Confirmation Data Acquisition/Monitoring System
PCM	Performance Confirmation Emplacement Drift Monitoring System
PCV	Performance Confirmation Waste Isolation Verification/Validation System
PLS	Pool Water Treatment & Cooling System
SCA	Subsurface Compressed Air System

System Designator	System Name
SCS	Subsurface Closure & Seal System
SDT	Subsurface Development Transportation System
SED	Subsurface Electrical Distribution System
SEM	Surface Environmental Monitoring System
SEP	Site Electrical Power System
SES	Subsurface Excavation System
SET	Subsurface Emplacement Transportation System
SFP	Site Fire Protection System
SFR	Subsurface Fire Protection System
SFS	Subsurface Facility System
SHZ	Site-Generated Hazardous, Nonhazardous & Sanitary Waste Disposal System
SOS	Site Operations System
SRM	Site Radiological Monitoring System
SRW	Site Generated Radiological Waste Handling System
SSG	Safeguards and Security System
SSM	Subsurface Safety and Monitoring System
SVS	Subsurface Ventilation System
SWC	Subsurface Water Collection/Removal System
SWD	Subsurface Water Distribution System
SWS	Site Water System
TBS	Waste Treatment Building System
TCA	Site Compressed Air System
TCS	Site Communications System
TVS	Waste Treatment Building Ventilation System
UDC	Uncanistered SNF Disposal Container
VDC	Naval Spent Nuclear Fuel Disposal Container
WES	Waste Emplacement/Retrieval System
WPR	Waste Package Remediation System

APPENDIX B

GLOSSARY

APPENDIX B

GLOSSARY

Colloids–Small particles in the size range of 10^{-9} to 10^{-6} meters that are suspended in a solvent. Naturally occurring colloids in groundwater arise from clay minerals.

Constraint–Subject to the same demand for adherence as a requirement. Constraints are internally imposed by the M&O addressing design solution issues.

Criterion–Subject to the same demand for adherence as a requirement. Criteria are internally imposed by the M&O addressing performance related issues.

Full Inventory Case–The waste inventory listed in YMP RD 1.3.2.B.1 and 1.3.2.B.2 (YMP 2001a) plus additional HLW totaling 97,000 MTHM.

Goal–No demand for adherence to goals is imposed. Goals are created either internally or externally to the M&O and represent design attributes that the current design is aiming towards, which it may achieve through further refinement of the design.

Nominal–(from the Latin *nominalis*, of a name) "having the nature of." When used to establish parametric values, i.e., "a nominal value of 2," it means the designer can work within the range of values that could be considered as having the nature of the specified value, which will generally be determined by the last significant figure. For example, any value between 1.6 and 2.5 would have the nature of a nominal value of 2; any value between 2.46 and 2.55 would have the nature of a nominal value of 2.5; any value between 24.6 and 25.5 would have the nature of a nominal value of 25.

Requirement–A demand imposed on the repository. Requirements are imposed by entities outside the CRWMS M&O, including but not limited to regulatory bodies, federal/state lawmaking bodies, the U.S. Department of Energy, building codes, or government agencies.

Sorption–The binding, on a microscopic scale, of one substance to another, and includes both adsorption and absorption. In this document, the word is especially used for the sorption of dissolved radionuclides onto aquifer solids or waste package materials by means of close-range chemical or physical forces.

Truncated Site Recommendation (SR) Design Case–The waste inventory as calculated by multiplying the Full Inventory Case by the ratio of the CSNF in the 70,000 MTHM (63,000 MTHM) to the CSNF in the 97,000 MTHM (83,800 MTHM). This results in an identical proportion of waste and an identical linear heat rate as the Full Inventory Case.

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APPENDIX C

INTERFACE DOCUMENTATION

CONTENTS

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APPENDIX C

INTERFACE DOCUMENTATION

NOTE: See Section 4.3.2 for directions for use of this appendix.

C.1 WHS TO/FROM WIS (LEVEL 3 INTERFACES)

WPS (in the WHS) Interfaces to/from the WIS

10.21.11 P The Uncanistered SNF Disposal Container (UDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Waste Handling Building (WHB) System (HBS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) by providing Disposal Containers (DCs) to the Waste Handling Building System. The DCs are placed in non-permanent storage, waiting processing by the Assembly Transfer System (ATS) or the Canister Transfer System (CTS).

10.21.13 P The DHLW Disposal Container (DDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Waste Handling Building (WHB) System (HBS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) by providing Disposal Containers (DCs) to the Waste Handling Building System. The DCs are placed in non-permanent storage, waiting processing by the Assembly Transfer System (ATS) or the Canister Transfer System (CTS).

10.21.15 P The Naval Spent Nuclear Fuel Disposal Container (VDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)), interfaces with the Waste Handling Building (WHB) System (HBS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) by providing Disposal Containers (DCs) to the Waste Handling Building System. The DCs are placed in non-permanent storage, waiting processing by the Assembly Transfer System (ATS) or the Canister Transfer System (CTS).

10.21.21 P The Uncanistered SNF Disposal Container (UDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Assembly Transfer System (ATS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- by being designed for identification of the individual disposal container capacities and sealing in a vertical orientation
- for identification of the individual disposal container capacities

10.21.23 P The DHLW Disposal Container (DDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Assembly Transfer System (ATS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- by being designed for identification of the individual disposal container capacities and sealing in a vertical orientation

- for identification of the individual disposal container capacities

10.21.25 P The Naval Spent Nuclear Fuel Disposal Container (VDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Assembly Transfer System (ATS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- by being designed for identification of the individual disposal container capacities and sealing in a vertical orientation

- for identification of the individual disposal container capacities

10.21.31 P The Uncanistered SNF Disposal Container (UDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Disposal Container Handling System (DCH) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- for reducing the dose rate at all external surfaces of a waste package to 1,450 rem/hr or less

- for loading and sealing in a vertical orientation

- for welding and inspection

- for handling vertical, horizontal and transitioning between vertical and horizontal of empty DC, loaded DC, and lid

- for filling of the container with an inert gas

10.21.33 P The DHLW Disposal Container (DDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Disposal Container Handling System (DCH) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- for reducing the dose rate at all external surfaces of a waste package to 1,450 rem/hr or less

- for loading and sealing in a vertical orientation

- for welding and inspection

- for handling vertical, horizontal and transitioning between vertical and horizontal of empty DC, loaded DC, and lid

- for filling of the container with an inert gas

10.21.35 P The Naval Spent Nuclear Fuel Disposal Container (VDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Disposal Container Handling System (DCH) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- for reducing the dose rate at all external surfaces of a waste package to 1,450 rem/hr or less

- for loading and sealing in a vertical orientation

- for welding and inspection

- for handling vertical, horizontal and transitioning between vertical and horizontal of empty DC, loaded DC, and lid

- for filling of the container with an inert gas

10.21.71 P The Uncanistered SNF Disposal Container (UDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Canister Transfer System (CTS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- by being designed for loading and sealing in a vertical orientation
- for loading

10.21.73 P The DHLW Disposal Container (DDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Canister Transfer System (CTS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- by being designed for loading and sealing in a vertical orientation
- for loading

10.21.75 P The Naval Spent Nuclear Fuel Disposal Container (VDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Canister Transfer System (CTS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- by being designed for loading and sealing in a vertical orientation
- for loading

10.21.81 P The Waste Package Remediation System (WPR) (of the Waste Preparation Systems (WPR) in the Waste Handling System (WHS)) interfaces with the Uncanistered SNF Disposal Container (UDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- for the movement of DCs with certain dimensions, size, and weight, etc.
- for remediation of the disposal container/waste package

10.21.83 P The Waste Package Remediation System (WPR) (of the Waste Preparation Systems (WPR) in the Waste Handling System (WHS)) interfaces with the DHLW Disposal Container (DDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- for the movement of DCs with certain dimensions, size, and weight, etc.
- for remediation of the disposal container/waste package

10.21.85 P The Waste Package Remediation System (WPR) (of the Waste Preparation Systems (WPR) in the Waste Handling System (WHS)) interfaces with the Naval Spent Nuclear Fuel Disposal (VDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- for the movement of DCs with certain dimensions, size, and weight, etc.
- for remediation of the disposal container/waste package

WER (in the WHS) Interfaces to/from the WIS

10.41.17 P The Subsurface Facility System (SFS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with The emplacement Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- for the space and location of emplaced WPs
- for the controlled release of radionuclides
- for controlling the heat, chemical, and physical effects that interact between these systems
- for excavated drift diameter that affects the thermal limitations placed on this system
- for drift spacing that affects the thermal limitations placed on this system

10.41.27 P Subsurface Ventilation System (SVS) (of Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with Emplacement Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- to ensure ventilation capacity and availability to support temperature constraints
- for the removal of WP decay heat by the ventilation system that affects the thermal limitations placed on this system

10.41.47 P The Backfill Emplacement System (BES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with Emplacement

Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) for Horizontal in-drift emplacement.

10.41.77 P The Ground Control System (GCS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the Emplacement Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- for spatial distribution of the components of the Emplacement Drift System (EDS)
- by the concrete in the GCS affecting the pH of water entering the drift
- to ensure compatible ground control material

10.41.81 P The Uncanistered SNF Disposal Container (UDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS))

- for reducing the dose rate at all external surfaces of a waste package to 1,450 rem/hr or less
- for handling both vertical and horizontal
- for emplacement and retrieval

10.41.83 P The DHLW Disposal Container (DDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS))

- for reducing the dose rate at all external surfaces of a waste package to 1,450 rem/hr or less
- for handling both vertical and horizontal
- for emplacement and retrieval

10.41.85 P The Naval Spent Nuclear Fuel Disposal Container (VDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS))

- for reducing the dose rate at all external surfaces of a waste package to 1,450 rem/hr or less
- for handling both vertical and horizontal

- for emplacement and retrieval

10.41.87 P The Backfill Emplacement System (WES) (of the Waste Emplacement & Retrieval System (WER) in the Waste Handling System (WHS)) interfaces with The Emplacement Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- for equipment clearance for the emplacement and retrieval
- for a quantification of the criterion to line load the WPs
- for Horizontal in-drift emplacement

C.2 WHS INTERFACES TO/FROM THE OSS (LEVEL 3 INTERFACES)

CSR (in the WHS) Interfaces to/from the OSS

11.12.25 P Carrier Preparation Building (CPB) Materials Handling System (CMH)) (of the Carrier/Cask Shipping & Receiving Systems (CSR) in the Waste Handling System (WHS)) interfaces with MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) for centralized monitoring and control.

WPS (in the WHS) Interfaces to/from the OSS

11.22.15 P/F The MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) interfaces with the Waste Handling Building (WHB) System (HBS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- (P) for the receipt of structural support and space for the OMC equipment

- (F) for the receipt of monitored inputs and sending of control outputs

11.22.25 F The Assembly Transfer System (ATS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) by providing current status of the loading and unloading tasks performed by the ATS.

11.22.35 P The Disposal Container Handling System (DCH) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative System (MAS) in the Operational Support System (OSS)) to provide system and component status and variables input to, and receive control output signals from.

11.22.45 F The Pool Water Treatment & Cooling System (PLS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) by providing current status of water temperature and quality.

11.22.55 P The MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) interfaces with the Waste Handling Building Ventilation System (HBV) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) for receipt of monitored inputs and sending of control outputs.

11.22.65 F The Carrier/Cask Handling System (CCH) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System ((OMC) (of the Management & Administrative Systems (MAS) in the Operational Support system (OSS)) by providing current status of the loading and unloading tasks performed by the CCH.

11.22.75 F The Canister Transfer System (CTS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interface with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) by providing current status of the loading and unloading tasks performed by the CTS.

11.22.85 F The Waste Package Remediation System (WPR) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring and Control System (OMC) (of the Management & Administrative System (MAS) in the Operational Support System (OSS)) to receive and provide the operational information, status, and control data defined in Table 1 below.

Table C-1. System Inputs/Outputs

Inputs	Outputs
Radiation monitoring system data and status	Equipment status and status of operations
WP identification and tracking data	Equipment alarm status
Facility system status	Control equipment status and alarms
Facility, interfacing and support system readiness status	Interlock status
Operational message advisory	Video signals
Activity plans and procedures	Communications equipment status
Emergency response commands	Timeout warnings for handling equipment
Monitored Geologic Repository (MGR) operational alarm status	Control loads left in improper states (suspended loads, unattended controls, etc.)
Supervisory control	

11.22.95 P The MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) for the receipt of modified inputs and sending of control outputs.

11.22.105 F The WHB Fire Protection System (HBF) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) by providing current status of WHB monitored areas.

11.23.15 P Waste Handling Building (WHB) System (HBS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with Site Fire Protection System (SFP) (of the Safety & Security Systems (SSS) in the Operational Support System (OSS)) signals for fire detection, fire alarm, fire suppression components, and loss of system supervision using negotiated signal protocol.

11.23.95 P The Waste Handling Building Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Site Fire Protection System (SFP) (of the Safety & Security System (SSS) in the Operational Support System (OSS)) to supply electrical power to the system.

11.23.105 P/F The Site Fire Protection System (SFP) (of the Safety & Security Systems (SSS) in the Operational Support System (OSS)) interfaces with the WHB Fire Protection System (HBF) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS))

- (P) by providing fire suppression water at the required flow rates, pressures, and duration for the HBF fire suppression components
- (F) by providing signals for fire detection, fire alarm, fire suppression components, and loss of system supervision using a negotiated signal protocol

WTS (in the WHS) Interfaces to/from the OSS

11.32.15 P/F The Waste Treatment Building (WTB) System (TBS) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS))

- (P) by providing structural support and space for the equipment and materials necessary for the monitoring and control of the TBS daily tasks
- (F) by providing voice, data, and video signals for status of current operations

11.32.25 F The Waste Treatment Building Ventilation System (TVS) (of the Waste Treatment Systems (WTS) in the Waste Handling System (WHS)) interfaces with the MGR

Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) for the remote control of the system, and for the monitoring and control of system operations.

11.32.35 F The Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative System (MAS) in the Operational Support System (OSS)) to provide system and component status and variables input to, and receive control output signals.

11.33.15 F/P The Waste Treatment Building (WTB) System (TBS) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the Site Fire Protection System (SFP) (of the Safety & Security Systems (SSS) in the Operational Support System (OSS))

- (F) by providing signals for fire detection, fire alarm, fire suppression components, and loss of system supervision
- (P) by receiving fire suppression water at the required flow rates, pressures, and duration as demanded by the TBS fire suppression components

WER (in the WHS) Interfaces to/from the OSS

11.42.25 F The Subsurface Ventilation System (SVS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS))

- by monitoring airflow direction, as reported, between all emplacement drifts and the related emplacement drift turn-outs and initiate local/remote alarms as required
- by monitoring the subsurface air quality levels, based on input received from the Subsurface Ventilation System (including operational occurrences and accidents), and initiate local/remote alarms as required
- by providing data and video signals reflecting current status of the SVS equipment

11.42.85 F The Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) by providing data and video signals reflecting current status of the WES equipment and receiving control commands.

11.43.15 F Subsurface Facility System (SFS) (of the Waste Emplacement & Retrieval System (WER) in the Waste Handling System (WHS)) interfaces with the Site Fire Protection

System (SFP) (of the Utility Systems (UTS) in the Operational Support System (OSS)) for all fire related status, control signals, and annunciation.

11.43.25 P Subsurface Ventilation System (SVS) (of the Waste Emplacement & Retrieval System (WER) in the Waste Handling System (WHS)) interfaces with the Site Fire Protection System (SFS) (of the Utility Systems (UTS) in the Operational Support System (OSS)) to control the spread of smoke and fire.

C.3 WHS INTERFACES (LEVEL 4 INTERFACES)

WPS Interfaces to/from WTS

1.20.13P The Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the Waste Handling Building System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) to receive shielding, physical support, ventilation boundaries, and environmental boundaries, and to provide the storage and transfer requirements of the radiological waste.

1.20.33 P The Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the Disposal Container Handling System (DCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) to receive used decontamination fluids and solids from the DCH.

1.20.43 P The Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the Pool Water Treatment and Cooling System (PLS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) receive leak-off, filters, and resin from the Pool Water Treatment and Cooling System.

1.20.53 P The Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the Waste Handling Building Ventilation System (HBV) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) for specific areas and selected components to be vented as applicable.

1.20.83 P The Waste Package Remediation System (WPR) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Site Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) for the transfer of collected process fines and wastes.

1.20.93 P The Waste Handling Building Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) to supply electrical power to the system.

WPS Interfaces to/from WER

1.21.18 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS))

- by providing structural support
- by providing space for the installation of the rails
- by providing handling for the loading of the reusable rail car
- for delivery and receipt of WPs

1.21.38 P Disposal Container Handling System (DCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) for the placement of the WPs on and removal from the emplacement pallet and bed plate of the WP transporter.

C.4 WHS INTERFACES (LEVEL 5 INTERFACES)

WPS

1.2.10 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Assembly Transfer System (ATS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing structural support and spatial alignment for the railroad rails and the rubber tired transporters

- by providing structural support and storage and operating space for the handling equipment and materials needed to unload the transportation casks, load the DCs, and prepare the transportation casks for re-shipment

- by providing radiation protection during hazardous materials operations

1.2.11 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Disposal Container Handling System (DCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing storage and operating space for the handling equipment and materials needed to load the DCs

- by providing structural support for the DCs and Waste Packages (WPs), and storage for the empty WPs

- by providing radiation protection during hazardous operations

1.2.12 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Pool Water Treatment and Cooling System (PLS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing equipment space and piping run locations
- by providing structural loading and spatial constraints for the handling equipment and materials needed to load the DCs and Waste Packages (WPs), and storage for the empty WPs
- by providing radiation protection during hazardous operations
- by providing structural load requirements and spatial distribution constraints for the pools located inside the building
- by providing structural support and space for the equipment and materials needed for daily operations, including the piping distribution, heat exchangers, and the chilled water system

1.2.13 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Ventilation System (HBV) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) by providing structural support and spatial distribution of the piping, cabling, and ventilation equipment and duct banks.

1.2.14 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Carrier/Cask Handling System (CCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing structural support and alignment for the rails and roadbeds used by the railcars and trucks carrying the transportation casks
- by providing storage and operating space for the equipment required to transfer the casks from the railcars and trucks to the transfer cart
- by providing storage and operations space for the equipment needed to return the empty casks to the railcars and trucks
- by providing structural loading criteria and spatial distribution constraints on members of the Waste Handling Building (WHB) System (HBS)

1.2.15 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Canister Transfer System (CTS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing structural load requirements and spatial alignment constraints for the railroad rails and rubber tired transporters
- by providing structural load requirements and storage and operating space constraints for the handling equipment and materials needed to unload the transportation casks, load the DCs, and prepare the transportation casks for re-shipment
- by providing radiation protection during hazardous material operations
- by providing structural loading requirements during the unloading of the Transportation Casks (TCs), loading of Disposal Containers (DCs), and the preparation of empty TCs for re-shipment to the Regional Service Contractors

1.2.16 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Waste Package Remediation System (WPR) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing structural support for the DCs and WPs
- by providing structural support and space for the handling equipment and materials needed to perform normal operations and for the welding of the DC and WP lids
- by providing remediation of the DCs and WPs for the re-work of the lid welds (if required)
- by providing radiation protection for the hazardous operations
- by providing structural support and space for the equipment and materials needed to perform operations

1.2.17 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing structural support, environmental control and space for the WHB interior electrical distribution system, including the main distribution panels, conduits, and circuit breaker panels

- by providing the structural support and space for the placement of the emergency power system needed to support those functions important to radiological safety

- by providing structural and electrical loading and spatial distribution constraints for the equipment and cabling required for the building electrical system

1.2.18 P The Waste Handling Building (WHB) System (HBS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Fire Protection System (HBF) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) for the structural support and spatial distribution of the detection, alarm, and suppression elements of this system including all necessary storage space.

1.2.20 P The Assembly Transfer System (ATS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Disposal Container Handling System (DCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) to provide empty Disposal Containers (DCs) for loading. It also receives loaded DCs from the Assembly Transfer System (ATS) for processing.

1.2.22 P The Assembly Transfer System (ATS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Ventilation System (HBV) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) by providing ventilation, heating, and air conditioning load requirements during the operational tasks.

1.2.23 P The Assembly Transfer System (ATS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Carrier/Cask Handling System (CCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing the appropriate, dedicated transfer cart during the TC unloading cycle

- by providing overpacks loaded with empty canisters for loading onto railcars and legal-weight trucks for disposal

- by providing the removal of empty overpacks from the railcars and legal-weight trucks and transfer the overpacks to the dedicated transfer cart

- by providing the delivery of overpacks loaded with canisters that have been cut open and emptied in the Assembly Transfer System (ATS)

- by providing the loading of Transportation Casks (TCs) from the railcars and the legal-weight trucks onto the dedicated transfer cart, as appropriate, based on the TC contents

- by providing the reception of overpacks loaded with canisters that have been emptied in the Assembly Transfer System and loading the overpacks onto railcars and legal-weight trucks for disposal

1.2.26 P The Assembly Transfer System (ATS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing the structural load requirements for the equipment and materials required for the loading of Disposal Containers (DCs), the unloading of Transportation Casks (TCs)

- by providing the layout and operation of a hot cell

- by providing the support for maintaining and operating a pool area

- by providing the power requirements necessary to operate the Assembly Transfer System (ATS) equipment

1.2.31 P The Waste Handling Building Ventilation System (HBV) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the Disposal Container Handling System (DCH) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) for release of gases vented from DCs.

1.2.33 P The Disposal Container Handling System (DCH) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) interfaces with the Canister Transfer System (CTS) (of the Waste Preparation Systems (WPS) in the Waste Handling System (WHS)) to provide empty Disposal Containers (DCs) for loading. It also receives loaded DCs from the CTS for processing.

1.2.34 P The Disposal Container Handling System (DCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Waste Package Remediation System (WPR) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) by transferring Waste Packages (WPs) from the transporter to the Waste Package Remediation System (WPR) for remedial action. It also receives Waste Packages (WPs) that have been remediated for further processing.

1.2.35 P The Disposal Container Handling System (DCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) by providing electrical power for the equipment operation.

1.2.44 P The Pool Water Treatment & Cooling System (PLS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) for equipment power requirements needed to support operations.

1.2.51 F The WHB Ventilation System (HBV) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Canister Transfer System (CTS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) for ventilation, heating, and air conditioning loading required during the operational tasks.

1.2.53 P The WHB Ventilation System (HBV) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) to supply power to the operating equipment.

1.2.54 P The WHB Ventilation System (HBV) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Fire Protection System (HBF) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing space for the WHB Fire Protection System equipment
- by providing the proper signals to the WHB Ventilation System (HBV) during normal and off-normal operations

1.2.60 P The Carrier/Cask Handling System (CCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the Canister Transfer System (CTS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- by providing the loading of Transportation Casks (TCs) from the railcars and the legal-weight trucks onto the dedicated transfer cart, as appropriate, based on the TC contents
- by providing the reception of empty TCs on the dedicated transfer carts and loading the empty TCs onto the railcars or legal weight trucks (or heavy-haul trucks) for re-shipment to the Regional Service Contractors

1.2.62 P The Carrier/Cask Handling System (CCH) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) by supplying the power requirements necessary to the operation of the equipment as to load and unload the railcars and the legal-weight trucks, and all other equipment operations.

1.2.71 P The Canister Transfer System (CTS) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) by providing electrical power for the equipment operation.

1.2.80 P The Waste Package Remediation System (WPR) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) by providing electrical power for the equipment operation.

1.2.90 P The WHB Electrical System (HBE) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS)) interfaces with the WHB Fire Protection System (HBF) (of the Waste Preparation System (WPS) in the Waste Handling System (WHS))

- to supply power to the operating equipment
- by providing electrical load and reliability requirements

WTS

1.3.10 P The Waste Treatment Building (WTB) System (TBS) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the WTB Ventilation System (TVS) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS))

- by providing structural support and space for the equipment and materials necessary for the daily operations of the WTB Ventilation System (TVS)
- by receiving the operational environment inside the building

1.3.11 P The Waste Treatment Building (WTB) System (TBS) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS))

- by providing structural support and space for the equipment and materials necessary to support daily operations of the Site-Generated Radiological Waste Handling System
- by providing structural loads and spatial distribution constraints to be incorporated into the building operations

1.3.20 P The Site-Generated Radiological Waste Handling System (SRW) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS)) interfaces with the WTB Ventilation System (TVS) (of the Waste Treatment System (WTS) in the Waste Handling System (WHS))

- for specific areas and selected components to be vented as applicable
- for the routing of pretreated toxic, corrosive, and radiological contaminated effluent from process equipment to the HEPA filter exhaust duct work and air-cleaning unit

WER

1.4.10 P The Subsurface Facility System (SFS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the Subsurface

Ventilation System (SVS) (of Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) for the location of the ducting, seals, filters, fans, emplacement doors, regulators, and electronic controls are within the envelope created by the Ground Control System

1.4.12 P The Subsurface Facility System (SFS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the Backfill Emplacement System (BES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) by providing the baseline configuration of the emplacement drifts.

1.4.15 P The Subsurface Facility System (SFS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the Ground Control System (GCS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS))

- by providing completed access ramps, access mains, emplacement drifts, exhaust air mains, emplacement and development ventilation shafts, performance confirmation drifts, and miscellaneous drifts and alcoves for the Ground Control System to control the configurations and stability of the openings and prevent rock falls during the development and operational phases of the subsurface facility

- by maintaining the stability of the subsurface openings through the various rock conditions and maintains the size and geometry of the operating envelopes for alcoves, accesses, and emplacement drifts

1.4.16 P The Subsurface Facility System (SFS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) by providing access shafts, access mains, emplacement drifts, miscellaneous shafts and alcoves, and performance confirmation drifts that provide structural support and space for Waste Emplacement/Retrieval System equipment and materials.

1.4.21 P Backfill Emplacement System (BES) (of Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with Subsurface Ventilation System (SVS) (of Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) to accommodate ventilation needs for backfill operations

1.4.25 F The Subsurface Ventilation System (SVS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the Waste Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) for drift operating environment and size of the drift isolation doors.

1.4.70 P The Ground Control System (GCS) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS)) interfaces with the Waste

Emplacement/Retrieval System (WES) (of the Waste Emplacement & Retrieval Systems (WER) in the Waste Handling System (WHS))

- by maintaining the drift openings and preventing rock falls from interfering with the operations of the Waste Emplacement/Retrieval System (WES)
- for clearances in the ramps access mains, turnouts, and emplacement drifts

C.5 WIS INTERFACES (LEVEL 5 INTERFACES)

EBS

2.1.15 P The Uncanistered SNF Disposal Container (UDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Emplacement Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- by transmitting heat into the drifts
- by receiving space and structural support
- by protecting the SNF assemblies and their contents from damage/degradation by the external environment

2.1.33 P The DHLW Disposal Container (DDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Emplacement Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- by transmitting heat into the drifts
- by receiving space and structural support
- by protecting the DHLW from damage/degradation by the external environment

2.1.51 P The Naval Spent Nuclear Fuel Disposal Container (VDC) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS)) interfaces with the Emplacement Drift System (EDS) (of the Engineered Barrier System (EBS) in the Waste Isolation System (WIS))

- by transmitting heat into the drifts
- by receiving space and structural support
- by protecting the SNF assemblies and their contents from damage/degradation by the external environment

C.6 OSS INTERFACES (LEVEL 4 INTERFACES)

MAS Interfaces to/from SSS

3.20.55 F The Site Fire Protection System (SFP) (of the Safety & Security Systems (SSS) in the Operational Support System (OSS)) interfaces with the MGR Operations Monitoring & Control System (OMC) (of the Management & Administrative Systems (MAS) in the Operational Support System (OSS)) by providing signals for fire detection, fire alarm, fire suppression components, and loss of system supervision using negotiated signal protocol.