OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SYSTEM DESCRIPTION DOCUMENT COVER SHEET

1. QA: _QA___

2. SDD Title
Subsurface Facility System Description Document

3. Document Identifier (Including Rev. No. and Change No., if applicable)
SDD-SFS-SE-000001 REV 01

	Printed Name	Signature	Date
4. System Engineer	Norman Bartley	Norman Bartley	6-29-00
5. Checker	S. C. Khamamkar	S C Khamamkar	6-29-00
6. Responsible Manager	R. ~~W~~ M. Dulin RMD 6/30/2000	Robert M Dulin	6/30/2000

7. Remarks:
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 revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

The following TBDs/TBVs are contained in this document:

TBD-189; TBD-4689.

TBV-359; TBV-364;TBV-617; TBV-619; TBV-3298; TBV-4688.

INFORMATION COPY

LAS VEGAS DOCUMENT CONTROL

NMSS07
WM-11

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SYSTEM DESCRIPTION DOCUMENT REVISION HISTORY

1. SDD Title
Subsurface Facility System Description Document

2. Document Identifier (Including Rev. No. and Change No., if applicable)
SDD-SFS-SE-000001 REV 01

3. Revision	4. Description of Revision
00	Initial Issue. This document was previously issued using document identifiers BCA000000-01717-1705-00014. This document supersedes the previous issuances. This document is a complete rewrite of the superseded documents, driven largely by the use of an alternate source of regulatory requirements, the implementation of the License Application Design Selection effort, the use of a new document development procedure, and the combination of the waste emplacement and waste retrieval systems into a single system.
01	This revision adds Section 2 Design Description and incorporate the applicable changes in revision 01 of "Monitored Geologic Repository Project Description Document." Criteria 1.2.1.1 and 1.2.1.2 were revised. Appendix A for 1.2.1.1, 1.2.1.2, 1.2.4.2, 1.2.2.1.4 and 1.2.1.3 were revised. Criterion 1.2.1.9 was added. The table numbers in revision 00 use I-x, the "I-" was deleted from the table numbers. Section 1.4 was revised. The reference section was revised to include the references used in Section 2. The Table of Contents were updated to reflect the changed page number. Changes in DIRS were extensive and cover must input sources. Several input sources were added and deleted in DIRS. Added more acronyms in Appendix C.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

CONTENTS

Page

SUMMARY 6

QUALITY ASSURANCE 8

1. SYSTEM FUNCTIONS AND DESIGN CRITERIA 9
   1.1 SYSTEM FUNCTIONS 9
   1.2 SYSTEM DESIGN CRITERIA 9
   1.3 SUBSYSTEM DESIGN CRITERIA 18
   1.4 CONFORMANCE VERIFICATION 18

2. DESIGN DESCRIPTION 19
   2.1 SYSTEM DESIGN SUMMARY 19
   2.2 DESIGN ASSUMPTIONS 19
   2.3 DETAILED DESIGN DESCRIPTION 27
   2.4 COMPONENTS DESCRIPTION 37
   2.5 CRITERIA COMPLIANCE 42

3. SYSTEM OPERATIONS 45

4. SYSTEM MAINTENANCE 46

APPENDIX A CRITERION BASIS STATEMENTS 47

APPENDIX B ARCHITECTURE AND CLASSIFICATION 72

APPENDIX C ACRONYMS, SYMBOLS, AND UNITS 73

APPENDIX D FUTURE REVISION RECOMMENDATIONS AND ISSUES 75

APPENDIX E REFERENCES 76

TABLES

Page

1. Design Basis Waste Package Inventory 10
2. Waste Package Inventory for Maximum Subsurface Emplacement 11
3. General Performance Characteristics–Test & Evaluation Facilities 12
4. Repository Opening Standoffs 15
5. Air Velocity Constraints 25
6. Invert Areas 26
7. Criteria Summation 42
8. Vertical Rise for Various Grades and Lengths 50
9. System Architecture and QA Classification 72

FIGURES

Page

1. Typical Turnout Configuration 23
2. 70,000 MTU Layout for Site Recommendation 30
3. 97,000 MTU Layout for Site Recommendation 33
4. Lower Block Expansion Layout 35
5. Overall Drainage Pattern 41

SUMMARY

The Subsurface Facility System encompasses the location, arrangement, size, and spacing of the underground openings. This subsurface system includes accesses, alcoves, and drifts. This system provides access to the underground, provides for the emplacement of waste packages, provides openings to allow safe and secure work conditions, and interfaces with the natural barrier. This system includes what is now the Exploratory Studies Facility.

The Subsurface Facility System physical location and general arrangement help support the long-term waste isolation objectives of the repository. The Subsurface Facility System locates the repository openings away from main traces of major faults, away from exposure to erosion, above the probable maximum flood elevation, and above the water table. The general arrangement, size, and spacing of the emplacement drifts support disposal of the entire inventory of waste packages based on the emplacement strategy. The Subsurface Facility System provides access ramps to safely facilitate development and emplacement operations. The Subsurface Facility System supports the development and emplacement operations by providing subsurface space for such systems as ventilation, utilities, safety, monitoring, and transportation.

The repository subsurface facility comprises:

- Portals and access ramps (which connect the surface facilities to the emplacement level)
- Access mains (which delineate the emplacement block and serves as travel-ways and airways for construction)
- Emplacement drifts (which is where the waste will be located)
- Intake/Exhaust air mains
- Emplacement and development ventilation shafts
- Test and Evaluation Facilities
- Miscellaneous support openings such as ventilation connector drifts and operations alcoves

The gradients of access ramps and mains are kept within a practical limit for rail haulage that is needed for both construction and emplacement activities. The emplacement drifts are driven parallel to each other between the east- and west-side mains. Turnouts provide a transition between the access mains and the emplacement drifts for construction equipment and the waste package transport and emplacement equipment. Waste packages are unloaded inside the emplacement drift at their designated position. The extent of the repository subsurface facility precludes its completion in entirety prior to commencement of emplacement operations. The ongoing construction activities during this period will be separated from emplacement operations by isolation barriers. The isolation barriers will be moved periodically as emplacement drift construction is completed and the drifts are handed over to operations.

The high-level scope of the Subsurface Facility System is such that it interfaces with all subsurface systems and waste packages. The Subsurface Facility System's major interfaces are with the:

- Emplacement Drift System for emplacement drift size and spacing
- Natural Barrier for the geologic setting
- Performance Confirmation System for monitoring of the post-emplacement performance
- Subsurface Ventilation System for providing space for equipment and ventilation airways and transportation systems for equipment clearance
- Ground Control System for the required operating envelopes
- Subsurface Excavation System for the required construction opening locations

QUALITY ASSURANCE

The quality assurance (QA) program applies to the development of this document. The "SDD Development/Maintenance (Q SDDs) (WP# 16012126M5)" activity evaluation has determined the development of this document to be subject to "Quality Assurance Requirements and Description" requirements. This document was developed in accordance with AP-3.11Q, "Technical Reports."

1. SYSTEM FUNCTIONS AND DESIGN CRITERIA

The functions and design requirements for the system are identified in the following sections. Throughout this document, the term "system" shall be used to indicate the Subsurface Facility System. The system architecture and classification are provided in Appendix B.

1.1 SYSTEM FUNCTIONS

1.1.1 The system accommodates the safe disposal and potential retrieval of the waste packages (i.e., uncanistered spent nuclear fuel (SNF), canistered SNF, high-level radioactive waste (HLW), and U.S. Department of Energy (DOE) waste forms).

1.1.2 The system provides the location, layout, size, and spacing of the subsurface openings.

1.1.3 The system allows personnel and equipment access to, from, and throughout the repository.

1.1.4 The system provides openings for subsurface ventilation.

1.1.5 The system provides subsurface egress for emergency evacuation.

1.1.6 The system provides refuge areas for subsurface emergency conditions.

1.1.7 The system controls the effects of subsurface flood events and limits subsurface inundation from the surface.

1.1.8 The system provides subsurface radiation protection from emplacement drifts containing waste packages.

1.1.9 The system locates the subsurface repository to limit radioactive release.

1.2 SYSTEM DESIGN CRITERIA

This section presents the design criteria for the system. Each criterion in this section has a corresponding Criterion Basis Statement in Appendix A that describes the need for the criterion as well as a basis for the performance parameters imposed by the criterion. Each criterion in this section also contains bracketed traces indicating traceability, as applicable, to the functions (F) in Section 1.1, the "Monitored Geologic Repository Requirements Document" (MGR RD) and "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." In anticipation of the interim guidance being promulgated as a Code of Federal Regulations, it will be referred to as "10 CFR 63" in this system description document. For the applicable version of the codes, standards, and regulatory documents refer to Appendix E.

1.2.1 System Performance Criteria

1.2.1.1 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 1. The WP lengths are TBV-3298.

Table 1. Design Basis Waste Package Inventory

Type of WP	WP Length (m)	Average Heat Output/Package (kW)	Quantity*
21 PWR AP	5.17	11.330	4500
21 PWR CR	5.17	3.260	100
12 PWR AP Long	5.65	8.970	170
44 BWR AP	5.17	7.000	3000
24 BWR AP	5.11	0.540	90
5 IPWF	3.59	2.450	100
5 DHLW Short/1 DOE SNF Short	3.59	2.575	1100
5 DHLW Long/1 DOE SNF Long	5.22	2.575	1500
2 MCO/2 DHLW	5.22	1.230	160
5 HLW Long/1 DOE SNF Short	5.22	2.575	130
HLW Long Only	5.22	2.450	600
Naval Short	5.43	3.100	200
Naval Long	6.07	3.100	100

- *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). This constraint applies to the capability of the subsurface emplacement, and is not intended to conflict with, or violate, any other design.

- NOTE: See Acronyms and Abbreviations for acronym definitions.

[F 1.1.1, 1.1.2][MGR RD 3.2.A]

1.2.1.2 The MGR shall not preclude the capability of accommodating the emplacement of 97,000 MTHM of the WP inventory with the size and heat output up to that shown in Table 2. The WP lengths are TBV-3298.

Table 2. Waste Package Inventory for Maximum Subsurface Emplacement

Type of WP	WP Length (m)	Average Heat Output/Package (kW)	Quantity*
21 PWR AP	5.17	11.330	5700
21 PWR CR	5.17	3.260	110
12 PWR AP Long	5.65	8.970	300
44 BWR AP	5.17	7.000	3750
24 BWR AP	5.11	0.540	100
5 IPWF	3.59	2.450	130
5 DHLW Short/1 DOE SNF Short	3.59	2.575	1410
5 DHLW Long/1 DOE SNF Long	5.22	2.575	1880
2 MCO/2 DHLW	5.22	1.230	200
5 HLW Long/1 DOE SNF Short	5.22	2.575	170
HLW Long Only	5.22	2.450	800
Naval Short	5.43	3.100	200
Naval Long	6.07	3.100	100

- *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 97,000 MTHM (or equivalent). This constraint applies to the capability of the subsurface emplacement, and is not intended to conflict with, or violate, any other design.

- NOTE: See Appendix C for acronyms and abbreviation definitions.

[F 1.1.1, 1.1.2][MGR RD 3.2.B]

1.2.1.3 The system shall size the emplacement drifts with a nominal diameter of 5.5 m.

[F 1.1.1, 1.1.2]

1.2.1.4 The system shall provide emplacement space to allow for an minimum waste package spacing of 10 centimeters.

[F 1.1.1, 1.1.2]

1.2.1.5 The system shall space the emplacement drifts 81 m center to center.

[F 1.1.1, 1.1.2, 1.1.9][MGR RD 3.1.C][10 CFR 63.113(b)]

1.2.1.6 The system shall provide an upward grade of at least 1 percent for at least the first 10 m of the entrance ramps from the surface.

[F 1.1.7]

1.2.1.7 The system shall orient emplacement drifts at least 30 degrees from dominant rock joint orientations.

[F 1.1.2]

1.2.1.8 The system shall provide drifts and alcoves for implementation of the Test and Evaluation Program. The drifts and alcoves shall have the characteristics (TBV-0364 and TBD-0189) shown in Table 3.

Table 3. General Performance Characteristics–Test & Evaluation Facilities

General Performance Characteristics Test & Evaluation Facilities	
Quantity	Performance Monitoring: Minimum of three (3) (TBV) monitoring areas with one observation drift and a minimum of six (6) (TBV) alcoves for each area. Postclosure Simulation: One (TBV) Engineered Barrier System interaction test area and one (TBV) Near Field Response test area, consisting of two (2) (TBV) simulated emplacement drifts, one (1) (TBV) observation drift and three (3) (TBV) alcoves per area. Test areas may share the same observation drift. Specialized Test Areas: Ten (10) (TBV) seepage alcoves Two (2) (TBV) seismic monitoring niches. One (1) (TBV) ramp-seal test alcove. Two (2) (TBV) shaft-seal test alcoves and one (1) connecting shaft. Other (TBD) test alcoves.
Size	(TBD) Based on equipment / instrument envelope and ventilation duct requirements.
Grade	Performance Monitoring: Observation drifts are to be oriented parallel to emplacement drift horizon within 1% grade (TBV) of target slope and sufficient to provide drainage. Alcoves sloped to provide drainage to observation drifts. Postclosure Simulation: Observation drift(s) are to be oriented parallel to simulated drifts within 1% grade (TBV) of target slope and sufficient to provide drainage. Alcoves sloped to provide drainage to observation drifts. Specialized Test Areas: For seepage alcoves, grade sufficient to provide drainage. For seismic monitoring niches, grade sufficient to provide drainage. For ramp-seal test alcove, slope shall be representative of access mains. For shaft-seal test area, alcove shall slope sufficient to provide drainage, and shaft shall be vertical. Other test alcoves: Sufficient to provide drainage.

Length	Performance Monitoring: Observation drifts for performance monitoring shall, at a minimum, span the width of the emplacement area where they are located. Alcoves shall be of sufficient length to extend from the observation drift and provide coverage of the area between adjacent emplacement drifts, and two (TBV) drift diameters on outer sides of the emplacement drifts. Postclosure Simulation: Simulated Emplacement drifts shall be a minimum of 600 (TBV) m long to provide for 2 (TBV) segment tests and buffer areas. Observation drifts shall provide access for monitoring along the entire length of the associated drift. Specialized Test Areas: For seepage alcoves, alcoves shall be a minimum of 20 (TBV) m in length, and located outside the mechanical-hydrological zone of influence of adjacent excavations. For seismic monitoring niches, niches shall be of sufficient depth to accommodate drilling of monitoring holes within niche without impact to traffic in other tunnels and drifts, and sufficient to house data acquisition system and associated electronics. For ramp-seal test alcove, length shall be sufficient to contain representative seal and sufficient additional length to isolate seal test area from other tunnels and drift, and house related instrumentation and data acquisition systems. Shaft-seal test alcove, test area shall be vertical and access alcoves of sufficient length to isolate seal test area from other tunnels and drifts and house related instrumentation and data acquisition systems. Other test alcoves: (TBD) As required for testing.
Arrangement	Performance Monitoring: Observation drifts are to be located above or below repository horizon so as to not significantly impact the thermal-mechanical-hydrological response of the emplacement drifts. Location above or below the horizon shall be varied to provide both conditions over the range of observation drifts. Postclosure Simulation: Simulated emplacement drifts shall be at grades representative of emplacement drifts. Observation drifts to be located below the simulated drifts so as to not significantly impact the thermal-mechanical-hydrological response of the simulated drifts. Specialized Test Areas: Seepage alcoves shall be located along access mains and performance monitoring observation drifts

	Seismic monitoring alcoves/niches shall be arranged to be located off access mains at opposing ends of the repository configuration. Ramp seal test area shall be arranged to be located off the south access main. Shaft seal test area shall be arranged to be located off the south access main. Other alcoves Alcoves shall be arranged as required (TBD)
Location	Performance Monitoring: One test area and associated observation drift shall be located so to monitor first emplacement drifts containing waste. Remaining observation drifts and test areas shall be located to provide access to varying rock mass conditions, including areas with differing rock stratigraphy, fracture density, and expected percolation rates. Observation drifts shall provide flexibility in locating specific test areas. Postclosure Simulation: Test areas shall be located in rock conditions representative of the repository horizon. Test area may be located in areas outside the siting area designated as suitable for emplacement or as can be accommodated within the siting area. Specialized Test Areas: Seepage alcoves shall be located to provide access to varying rock mass conditions, including areas with differing rock stratigraphy, fracture density, and expected percolation rates. Seismic monitoring alcoves/niches shall be located in areas with different rock mass characteristics at repository depth. Ramp seals test shall be located in similar rock mass conditions as repository ramps. Shaft seal test shall to be located in similar rock mass conditions as repository shafts. Other alcoves (TBD)

[F 1.1.2][MGR RD 3.1.C][10 CFR 63.111(d), 63.131(a)(1), 63.131(a)(2), 63.131(c), 63.132(b), 63.132(e), 63.133(a), 63.133(c), 63.133(d), 63.134(a), 63.134(b)]

1.2.1.9 The system shall not preclude the capability of accommodating up to 115,000 MTHM or equivalent.

1.2.2 Safety Criteria

1.2.2.1 Nuclear Safety Criteria

1.2.2.1.1 The system shall ensure subsurface areas requiring unrestricted access can be maintained at radiation levels less than or equal to 2.5 mrem/hr.

[F 1.1.8][MGR RD 3.1.B]

1.2.2.1.2 The system shall ensure subsurface areas requiring restricted access can be maintained at radiation levels less than or equal to 100 mrem/hr.

[F 1.1.8][MGR RD 3.1.B]

1.2.2.1.3 The system shall locate the entrance of all surface openings to the subsurface facility outside of the probable maximum flood areas as depicted in "Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion," Figure 2.6.2-1 (TBD-4689).

[F 1.1.2, 1.1.3, 1.1.9][MGR RD 3.1.C][10 CFR 63.113(b)]

1.2.2.1.4 The system shall accommodate the minimum standoffs identified in Table 4. Repository openings that are placed within these standoff distances shall be approved per site impact analysis. The standoff distances are TBV-0359.

Table 4. Repository Opening Standoffs

Geologic Areas	Standoff Distance
Top of the present day water table	160 m (TBV) from the closest edge of emplacement drifts
Main Trace of Type I fault zone	60 m (TBV) from the closest edge of repository openings

[F 1.1.2, 1.1.9][MGR RD 3.1.C][10 CFR 63.113(a), 63.113(b)]

1.2.2.1.5 The system shall accommodate a 15-m standoff between waste packages and Type I faults and a 5-m standoff between waste packages and splays associated with Type I faults if repository openings must be placed less than 60-m from a Type I fault as approved per site impact analyses.

Note: Standoff requirements in this document are used to establish usable drift length only. These distances do not specify final waste package standoffs.

[F 1.1.2, 1.1.9][MGR RD 3.1.C, 3.2.B][10 CFR 63.113(b)]

1.2.2.1.6 The system shall allow at least a 5-m standoff from the edge of the waste packages to the perpendicular projection of the centerline of a surface-based borehole if the borehole intercepts the drift or comes within 5 m of the edge of the drift.

[F 1.1.2, 1.1.9][MGR RD 3.1.C][10 CFR 63.113(b)]

1.2.2.1.7 The system shall provide a repository grade (i.e., non-emplacement drift openings) so overall water drainage and accumulation is away from emplacement areas.

[F 1.1.9][MGR RD 3.1.C][10 CFR 63.113(b)]

1.2.2.1.8 The system shall limit the emplacement areas to within the lower part of the lithophysal zone of the TSw1 unit and the entire TSw2 unit (within the characterized area).

[F 1.1.9][MGR RD 3.1.C, 3.2.I][10 CFR 63.113(b)]

1.2.2.1.9 The system shall locate the subsurface emplacement level at least 200 m below the directly overlying ground surface. (TBV-0619)

[F 1.1.2, 1.1.9][MGR RD 3.1.C, 3.3.C][10 CFR 63.113(b)]

1.2.2.2 **Non-nuclear Safety Criteria**

1.2.2.2.1 The system shall have two or more separate, properly maintained escapeways to the surface from the lowest levels, which are so positioned that damage to one shall not lessen the effectiveness of the others. A method of refuge shall be provided while a second opening to the surface is being developed.

[F 1.1.2, 1.1.3, 1.1.5, 1.1.6][MGR RD 3.3.A]

1.2.2.2.2 A method of refuge shall be provided for employees who cannot reach the surface from their work place, through at least two separate escapeways, within a time limit of one hour when using the normal exit method (i.e., walking). These refuges must be positioned so that the employee can reach one of them within 30 minutes from the time the workplace is left.

[F 1.1.2, 1.1.3, 1.1.5, 1.1.6][MGR RD 3.3.A]

1.2.2.2.3 Travel times for exiting or reaching a refuge shall be based on a maximum rate for personnel travel of 2,100 m (TBV-4688) in 30 minutes.

[F 1.1.3, 1.1.5, 1.1.6][MGR RD 3.3.A]

1.2.3 System Environmental Criteria

There are no applicable environmental criteria for this system.

1.2.4 System Interfacing Criteria

1.2.4.1 The system layout shall accommodate the Subsurface Ventilation System design criteria.

[F 1.1.2, 1.1.4][MGR RD 3.3.A]

1.2.4.2 The system shall be designed so the grades of the South Ramp, emplacement drifts, and other openings providing rail transport do not exceed 2.7 percent, 1.0 percent, and 2.5 percent, respectively.

[F 1.1.2, 1.1.7]

1.2.4.3 The system shall size the excavated openings, as a minimum, to accommodate the required operating envelopes while allowing for Ground Control System installation, variations in tunnel dimensions and alignment, and tunnel deformation (based on repository preclosure life).

Note: The diameter of the emplacement drifts is determined to be 5.5 m.

[F 1.1.2, 1.1.3]

1.2.4.4 The system shall accommodate the Emplacement Drift System's temperature constraint for the zeolitized layer within the Calico Hills.

[F 1.1.2]

1.2.4.5 The system shall be designed to accommodate a limit on the temperature change, at 45 cm below the soil surface, to 2 degrees C above the established naturally occurring pre-emplacement average annual ground surface temperature within the footprint of the MGR. The MGR footprint is defined as that area directly above emplaced waste packages and extending 500 m horizontally beyond the edge of emplaced packages. (TBV-0617)

[F 1.1.2][MGR RD 3.2.F]

1.2.4.6 The system shall accommodate the Emplacement Drift System's temperature constraint for the PTn geologic unit.

[F 1.1.2]

1.2.4.7 The system shall orient access drifts, mains, and ramps, etc., as needed to support Waste Emplacement/Retrieval System operations.

[F 1.1.2]

1.2.4.8 The system shall accommodate the Emplacement Drift System's uplift limit in the TSw1 thermomechanical unit.

[F 1.1.2]

1.2.4.9 The system shall interface with the Subsurface Excavation System for the location of construction openings (e.g., Tunnel Boring Machine (TBM) Assembly/Disassembly Chambers, etc.)

[F 1.1.2]

1.2.5 Operational Criteria

There are no applicable operational criteria for system.

1.2.6 Codes and Standards Criteria

1.2.6.1 The system shall comply with the applicable provisions of "Occupational Safety and Health Standards" (29 CFR 1910).

[MGR RD 3.1.E]

1.2.6.2 The system shall comply with the applicable provisions of "Safety and Health Regulations for Construction" (29 CFR 1926).

[MGR RD 3.1.F]

1.2.6.3 The system shall comply with the applicable assumptions contained in the "Monitored Geologic Repository Project Description Document.".

1.3 SUBSYSTEM DESIGN CRITERIA

Not Applicable.

1.4 CONFORMANCE VERIFICATION

This section will be completed in a later revision.

2. DESIGN DESCRIPTION

Section 2 of this SDD summarizes information which is contained in other references. By assembling system specific information contained elsewhere (i.e., analyses, technical reports, etc.), Section 2 provides insight into the current state of the design of this system. However, due to the nature of design development, the information contained in this section will continue to change as the design matures.

2.1 SYSTEM DESIGN SUMMARY

The Subsurface Facility System includes the design of the location, arrangement, size, and spacing of the underground openings, including accesses, alcoves, and drifts. The system provides access to the subsurface, provides for the emplacement of waste packages, and provides openings to allow safe and secure work conditions.

The Subsurface Facility is comprised of:

- Portals and access ramps, which connect the Surface Facility to the emplacement level
- Access mains, which delineate the emplacement block and serve as travel-ways and airways for construction and emplacement
- Emplacement drifts where the waste will be located
- Intake/exhaust air mains, shaft access drifts, and ventilation shafts to support the Subsurface Ventilation System
- Openings to support the Test and Evaluation program

2.2 DESIGN ASSUMPTIONS

An assumption is considered to be a statement or proposition that is taken to be true or representative in the absence of direct confirming data or evidence. The assumptions used in the "Site Recommendation Subsurface Layout," Section 5, are identified and explained in this section.

2.2.1 Controlled Project Assumptions

The following assumptions from the "Monitored Geologic Repository Project Description Document" have been incorporated into this analysis.

2.2.1.1 Waste Package Shielding

The "Monitored Geologic Repository Project Description Document," CPA 019, states that waste package containment barriers will provide sufficient shielding for protection of waste package materials from radiation-enhanced corrosion. Individual waste packages will not provide any additional shielding for personnel protection. The subsurface and surface waste handling structures, systems, and components (SSCs), including the waste package transporter, will provide additional shielding for personnel protection.

Since personnel will be frequently travelling in the mains, potential radiological exposure should be kept as low as reasonably achievable. The individual waste packages will not provide sufficient shielding for personnel protection, the turnouts have been configured to aid in increasing the radiological protection in the mains by eliminating the direct line of radiation from entering the mains. The configuration of the emplacement drift turnouts and the radiological impacts was discussed in the "Site Recommendation Subsurface Layout," Sections 6.2.1.2 and 6.2.7.

2.2.1.2 Emplacement Drift Entrance

The "Monitored Geologic Repository Project Description Document," CPA 021, states that doors are required at entrances to emplacement drifts.

This assumption impacts the configuration of the emplacement drift turnout since an allowance within the turnout has to be made for installation of these doors. The incorporation of the doors in the emplacement drift turnout configuration was discussed in the "Site Recommendation Subsurface Layout," Sections 6.2.1.2 and 6.2.7.

2.2.1.3 Modular Design and Construction Capability

The "Monitored Geologic Repository Project Description Document," CPA 023, states that the Monitored Geologic Repository will be designed in a manner that will permit construction in stages, such that maximum annual funding requirements could be reduced. This will facilitate the start of operations at the repository after the initial construction stage and continuation of operations concurrently with subsequent construction stages. The amount of staging would be selected based on funding and schedule constraints.

The modular design and construction capability of the Subsurface Facility was discussed as part of the construction sequence in the "Site Recommendation Subsurface Layout," Section 6.2.9.1.

2.2.1.4 Subsurface Configuration for Water Drainage

The "Monitored Geologic Repository Project Description Document," CPA 026, states that the repository subsurface layout will be configured for postclosure water drainage such that:

Water entering an emplacement drift can easily drain directly into the surrounding host rock without draining along the drift for collection in a centralized location. (This assumption does not encompass general flooding of the facility.)("Site Recommendation Subsurface Layout," Section 6.2.5.)

- Drifts above the emplacement level will not have direct connection to an emplacement drift such that water entering the over-lying drift could flow by gravity through a man-made opening into the underlying emplacement drifts.
- Drifts above the emplacement level will be configured to slope so that any water entering the drift can flow, by gravity, away from the emplacement area.

2.2.2 Other Assumptions

Other assumptions used in the "Site Recommendation Subsurface Layout" that are not documented in the "Monitored Geologic Repository Project Description Document" are identified in this section.

2.2.2.1 Empty Drifts During Emplacement

A certain number of drifts, excavated within the pillar of two adjacent emplacement drifts, will be left empty during emplacement operations. These drifts are excavated within the pillar of adjacent emplacement drifts so as not to impact the required emplacement area. Some of the empty drifts will be cross-block drifts for ventilation, monitoring, emergency egress, and/or the Test and Evaluation program. These will be located to split the repository block into similarly sized areas. Other empty drifts will be standby emplacement drifts for possible temporary relocation of emplaced waste packages. These drifts will be located within the first half of the emplacement drifts to be available early in the emplacement process.

The incorporation of the standby and cross-block drifts was discussed as part of the emplacement area definition in the "Site Recommendation Subsurface Layout," Section 6.2.1.2.

2.2.2.2 Contingency Area

Two different allowances have been included in the layout. It is assumed that an allowance of 2 percent of the required emplacement drift length will be excavated

in addition to the required length of the emplacement drift. This area will be excavated in the event that additional space is needed during emplacement for variances in the waste package inventory. It is assumed that a 10 percent contingency is included in the conceptual layout to allow for unexpected circumstances such as conditions found during development that prevent the intended emplacement area from being used due to unexpected ground conditions.

The incorporation of the excavation allowance and the contingency area was discussed as part of the emplacement area definitions for both the 70,000 MTU and 97,000 MTU cases in the "Site Recommendation Subsurface Layout" (Sections 6.3, 6.3.1, 6.4, and 6.4.1).

2.2.2.3 Emplacement Drift Turnout Configuration

It is assumed that the start of the turnout is at a 30-degree angle to the perimeter main and that the nose of the pillar between the turnout and the perimeter main will be a minimum thickness of 4 m. This approach angle and pillar thickness for the turnout will provide a stable pillar between the turnout and the perimeter main with a minimal span of the opening at the intersection of the turnout and the main.

It is assumed that two ventilation doors will be accommodated in the turnout. The first door will be located at the entrance to the turnout. This will require a minimum straight portion of 5 m from the nose of the pillar to the curved section to accommodate installation of the door. The second ventilation door will be located at the entrance to the emplacement drift.

It is assumed that the straight portion at the end of the turnout is 24 m. This straight portion of the turnout accommodates the setup and launch of the Tunnel Boring Machine (TBM) as well as provides a docking area for the waste package transporter for unloading of the waste package in line with the emplacement drift.

It is assumed that the end of the waste package will be located at least 1.5 m from the end of the straight portion of the turnout. This standoff distance allows an operational clearance between the waste package transporter docking operation and the final emplacement location of the last waste package.

It is assumed that the direct line of radiation from the last waste package will have a minimum standoff distance of 4.5 m from the nose of the pillar. Preventing the direct line of radiation from entering the perimeter mains, an unrestricted area, will aid in reducing the radiation levels.

It is assumed that the turnout profile is 8-m wide with an arch from spring line to spring line, and 7-m high at the crown. This turnout profile is based on the straight portion of the turnout specified for the Viability Assessment subsurface layout "Repository Subsurface Layout Configuration Analysis," p. 89, and is

assumed to be adequate for the TBM launch and waste package transporter activities in the turnout.

The incorporation of these assumptions in the configuration of the emplacement drift turnouts was discussed in the "Site Recommendation Subsurface Layout," Section 6.2.1.2. A typical turnout configuration is illustrated in Figure 1.

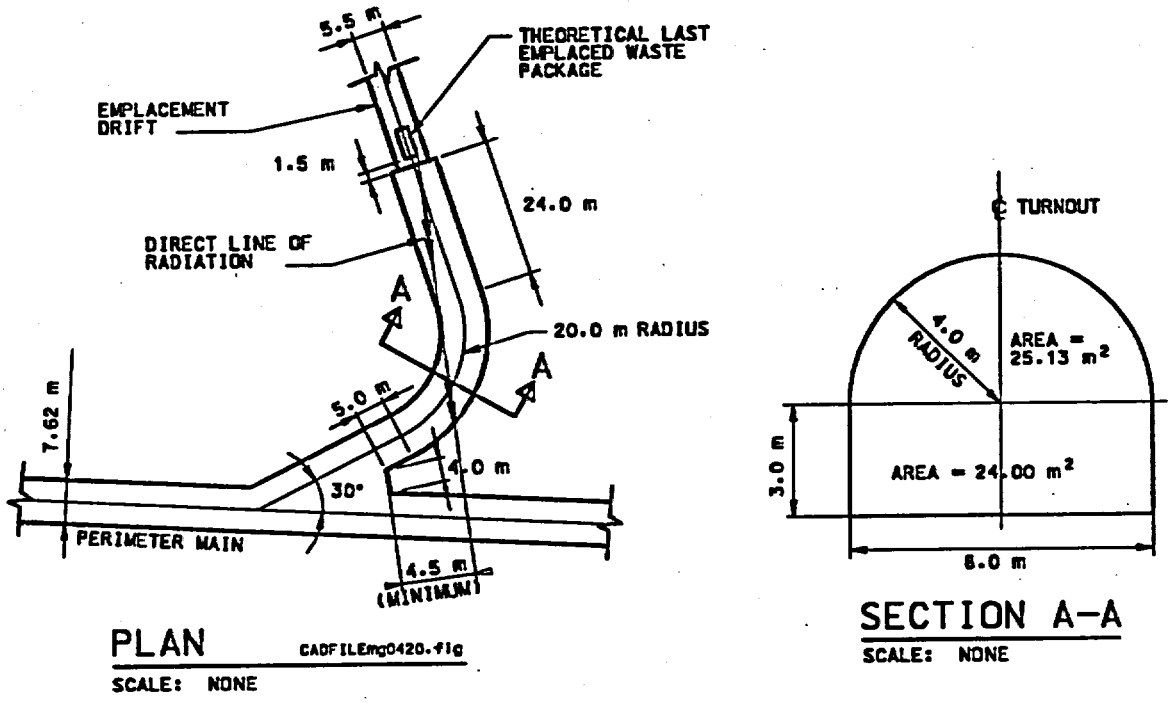


Figure 1. Typical Turnout Configuration

2.2.2.4 Maximum Length of Drift Split

A maximum emplacement drift split length of 600 m is assumed and any emplacement length in excess of 600 m will be considered unusable space. The basis of this restriction is the thermal analysis of the effect of continuous ventilation on the temperature of rock adjacent to the emplacement drifts. The assumed effective length of ventilating airflow in an emplacement drift is 600 m as shown in "ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study," Section 3.6.

The restriction on the useable emplacement drift split length was incorporated into the layout by excluding drift split lengths in excess of 600 m in the "Site Recommendation Subsurface Layout," Attachment I, Table I-1.

2.2.2.5 Pillar Requirements

A pillar between perpendicular crossing drifts is assumed to be a minimum of 10 m from crown to invert. A pillar for drifts running parallel is assumed to be a minimum of three diameters, using the maximum diameter of the largest drifts, from centerline-to-centerline.

The minimum pillar requirement assumes that these minimum allowances will provide stable excavated openings. The incorporation of the minimum pillar requirement as incorporated into the Subsurface Facility was discussed in the "Site Recommendation Subsurface Layout," Section 6.2.1.1.

2.2.2.6 Physical Standoff Distance to the Ventilation Raise

Ventilation raises are located in each emplacement drift to channel exhaust air to the Exhaust Main. A physical standoff distance of 2 m is used, measured from the centerline of the ventilation raise to the end of the nearest emplaced waste package. This standoff distance should minimize interference with the ventilation airflow and/or radiological monitoring around the ventilation raise.

The incorporation of the physical standoff distance to the ventilation raise was discussed in the "Site Recommendation Subsurface Layout," Section 5.2.6.

2.2.2.7 Ventilation Strategy Assumptions

A number of assumptions are required to integrate the subsurface layout with the overall ventilation strategy for the potential repository.

2.2.2.7.1 Minimum Airflow Velocity

The minimum airflow velocity for openings requiring human access during normal operations is assumed be 1 m/s (Subsurface Ventilation and Environmental Engineering, p. 295). This value is based on a typical minimum design airflow velocity requirement from industry, as outlined in "Subsurface Ventilation and Environmental Engineering."

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.1, to establish minimum airflow capacities within ventilation airways.

2.2.2.7.2 Subsurface Openings Supporting Ventilation

It is assumed that the primary subsurface openings supporting ventilation are excavated by a 7.62-m diameter TBM. This sizing of the ventilation openings is consistent with other access openings to minimize the sizes of TBMs required to construct the repository.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Sections IV.1 and IV.3, to provide consistency of opening sizes and configurations within the Subsurface Facility.

2.2.2.7.3 Ventilation Shaft Size

It is assumed that all the ventilation shafts will be excavated the same diameter based on the largest shaft size necessary to support the subsurface ventilation system. This assumption is used to standardize the equipment size required for shaft excavation.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.7, to provide consistency of ventilation shaft sizes and configurations in the Subsurface Facility.

2.2.2.7.4 Air Velocity Constraints

It is assumed that the air velocity constraints for the subsurface ventilation airflows, as listed in Table 5, are sufficient for determining opening sizes. These constraints are based on the typical industry maximum velocities found in "Subsurface Ventilation and Environmental Engineering," p. 295, Table 9.1.

Table 5. Air Velocity Constraints

Repository Openings	Area described in Text	Velocity
Haulage Mains and Ramps	Main Haulage Routes	6 m/s
Intake Shaft Accesses, Exhaust Main, and Exhaust Shaft Accesses	Smooth Lined Main Airways	8 m/s
Intake and Exhaust Shafts	Ventilation Shafts	20 m/s

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, to establish ventilation airflows within openings in the Subsurface Facility.

2.2.2.7.5 Human Access In The Exhaust Main

It is assumed that human access will be required in the Exhaust Main in order to service ventilation controls located at the bottom of the ventilation raises.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.3, to establish the partitioning of the Exhaust Main into an exhaust side and a service side within the Subsurface Facility.

2.2.2.7.6 Ventilation Stopping

It is assumed that a typical mine stopping a physical barrier used for separating ventilation airflow is approximately 0.2-m thick. This mine stopping is typical for

the mining industry (Mine Ventilation and Air Conditioning, p. 463) where permanent or long-term control of airflow is required.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.3, since the partitioning of the Exhaust Main will require a physical containment barrier for separating ventilation airflows.

2.2.2.7.7 Invert Area For Ventilation Openings

It is assumed that the inverts for all 7.62-m diameter excavations will be the same as the invert for the ramps and mains. This invert design has a larger cross-sectional area than the other, as outlined in Table 6, and will bound the maximum airflow volume in the drift.

Table 6. Invert Areas

Invert Type	Cross-Sectional Area (m2)	Reference Source
Exhaust Main	0.603	"Calculation of Effective Areas of Subsurface Openings During Emplacement Mode," pages 31 and 32
Ramps and Mains	1.73	"Calculation of Effective Areas of Subsurface Openings During Emplacement Mode," pages 27 and 28

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.3, to establish consistency between opening configurations in the Subsurface Facility.

2.2.2.7.8 Intake Shaft Accesses

It is assumed that the intake shafts are connected to the East and West Mains by a shaft access to support the overall ventilation system. This allows supply intake air to be distributed to both the East and West Mains and, subsequently, to the emplacement drifts.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.1, for establishing airflow requirements within the Subsurface Facility.

2.2.2.7.9 Exhaust Shaft Accesses

It is assumed that the exhaust shafts that are utilized to their full capacity will be connected to the Exhaust Main with two access drifts. These two exhaust shaft accesses will aid in minimizing the size of the accesses and help maximize the airflow volume supplied to the exhaust shaft.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Sections IV.4.2 and IV.5.2, for establishing airflow requirements in the Subsurface Facility.

2.2.2.7.10 Ventilation Raises

It is assumed that the ventilation raises that support the Subsurface Ventilation System are excavated at 2 m in diameter. This ventilation raise size is based on the "Repository Subsurface Layout Configuration Analysis," p. 78, and is still applicable to the current concept of the subsurface layout.

This assumption was used in the "Site Recommendation Subsurface Layout," Section 6.2.4, to establish the size of the ventilation raise required to direct intake or exhaust air between repository openings.

2.2.2.8 Shaft Sumps

All ventilation shafts will be excavated with a 5-m deep sump at the bottom. The sump provides a place for water entering the Subsurface Facility to collect for subsequent pumping to surface.

This assumption was used in the "Site Recommendation Subsurface Layout," Sections 6.3.2.3, 6.3.2.4, 6.3.2.5, 6.4.2.3, 6.4.2.4, and 6.4.2.5, to establish a sump where any water flow entering the Subsurface Facility will drain to for pumping to surface.

2.3 DETAILED DESIGN DESCRIPTION

The Layouts for Site Recommendation were developed consistent with the usable three-dimensional spatial boundaries within the geology of Yucca Mountain. The identified limits of the repository siting include limiting the emplacement area to within the characterized area, locating the emplacement level at least 200 m directly below the ground surface, and providing minimum standoffs from the top of the groundwater table and the main trace of Type I faults.

The Exploratory Studies Facility is integrated into the MGR. The North Ramp will become the access for the emplacement side of the subsurface repository, and the South Ramp will become the access for the development side. The Exploratory Studies Facility Main Drift will become the East Main. All other subsurface repository openings will be developed from the Exploratory Studies Facility.

The layouts for Site Recommendation were developed using the VULCAN software (Subsurface Facility Planning Layout in Support of ANL-SFS-MG-000001), which is considered unqualified, and, therefore, the results for the layouts for Site Recommendation are considered TBV.

2.3.1 70,000 MTU Layout for Site Recommendation

The 70,000 MTU layout for Site Recommendation (Site Recommendation Subsurface Layout, Figure 11), as shown in Figure 2, will require 58 emplacement drifts ("Site Recommendation Subsurface Layout," Section 6.3) excavated to a 5.5-m diameter at a center-to-center drift spacing of 81 m. Emplacement Drifts 1 through 51 are required for emplacement of the waste package inventory. Emplacement Drift 52 is excavated as an allowance for possible variances in the waste stream. Emplacement Drifts 53 through 58 are contingency drifts that will only be excavated in the event that conditions during development of the repository are found to be such that the intended emplacement area cannot be used due to unexpected ground conditions.

The emplacement drifts will be excavated from the East Main to the West Main. The drifts will be excavated with an azimuth of 252 degrees; the preferred drift orientation to position the emplacement drifts at least 30 degrees from the dominant joint orientations of the repository host horizon ("Site Recommendation Subsurface Layout," Section 6.2.1.2).

The required emplacement length to accommodate the 70,000 MTU Layout for Site Recommendation is 56,222 m, which requires an area approximately 1,125 acres and results in an areal mass loading of approximately 56 MTU/acre ("Site Recommendation Subsurface Layout," Section 6.3.1).

Within the emplacement area, five standby and cross-block drifts will be excavated at a diameter of 5.5-m within the pillars of adjacent emplacement drifts. The two standby drifts will be located within the first half of the emplacement drifts to be available early on for possible relocation of waste packages. The three cross-block drifts will perform possible ventilation, monitoring, emergency egress, and/or Test and Evaluation program functions and are located such that the cross-block drifts equally divide the repository block.

The Test and Evaluation Facility for the 70,000 MTU Layout ("Site Recommendation Subsurface Layout," Section 6.3) will consist of the postclosure test drifts on the north end of the repository with their Observation Drift, and performance monitoring Observation Drifts 2 and 3, along with the Enhanced Characterization of Repository Block. All Test and Evaluation Facility openings will be excavated to a diameter of 5.5 m.

The access mains within the 70,000 MTU Layout for Site Recommendation include the North Main, West Main, North Ramp Extension, East Main North Extension, East Main South Extension, and the South Main ("Site Recommendation Subsurface Layout," Sections 6.2.1.1 and 6.3). The access mains will be excavated to a diameter of 7.62 m. The East and West Mains, including the East Main North and South Extensions, will be used primarily for

waste emplacement operations as access to the emplacement drifts. The North and South Mains have been configured between the East and West Mains to provide access from one side of the repository block to the other. The North Ramp Extension is provided to the north end of the repository block as a bypass from the North Ramp to allow concurrent waste emplacement operations and continued Subsurface Facility development.

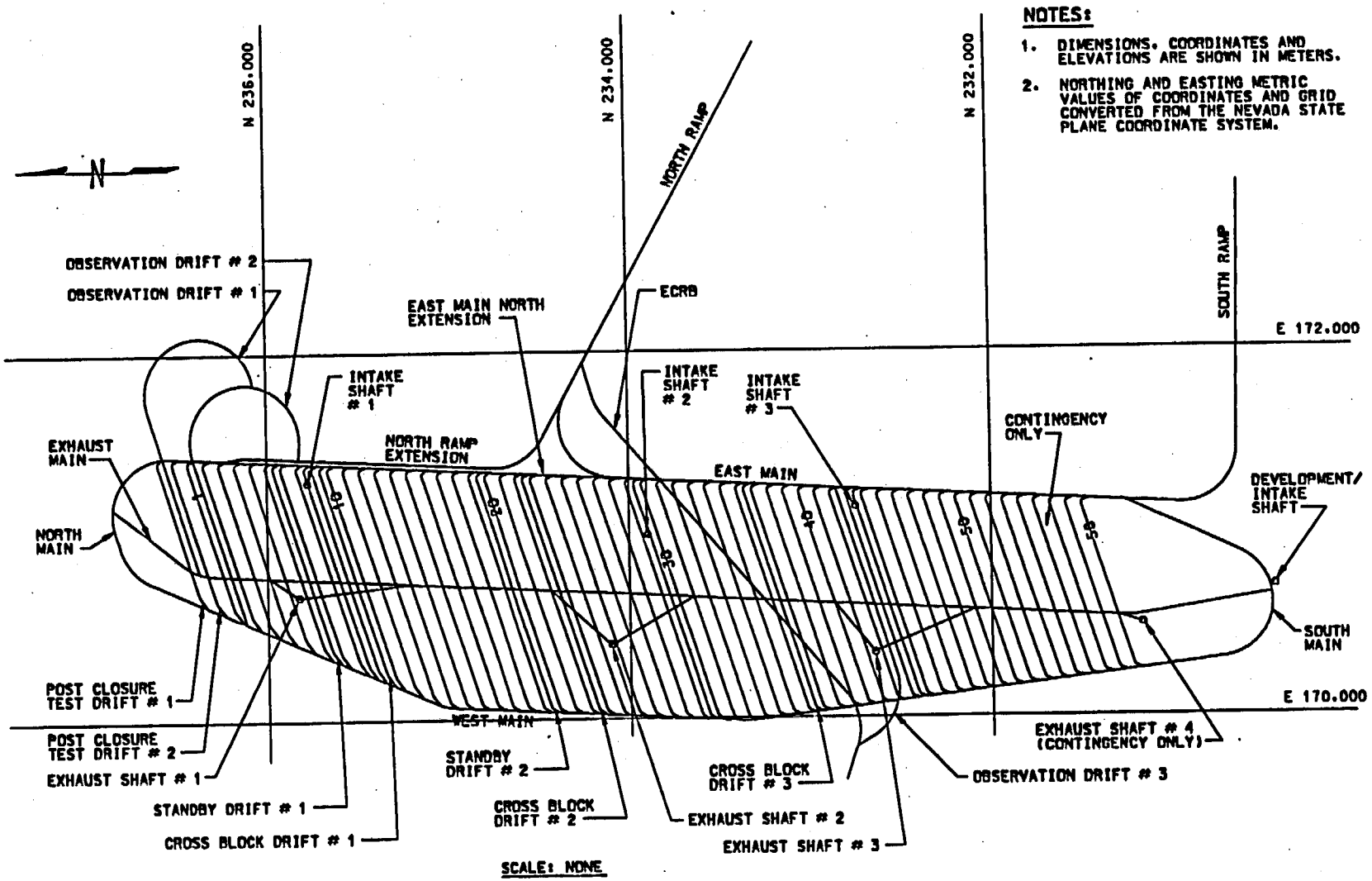


Figure 2. 70,000 MTU Layout for Site Recommendation

The Exhaust Main, excavated to a diameter of 7.62 m, is approximately 6,540 m in length and is situated below the repository elevation extending from the north end of the repository block to the extreme south end ("Site Recommendation Subsurface Layout," Sections 6.3.2.1). The Exhaust Main is graded in the vicinity of the North and South Mains to allow intersection of the two headings and to provide access into the Exhaust Main from either the North Main or the South Main.

Three intake shafts, excavated to a diameter of 8 m, are required to supply the required ventilation flow rates to the Subsurface Facility for the 70,000 MTU case, in addition to the North and South Ramps. The Development Shaft, located in the vicinity of the South Main, also excavated to a diameter of 8 m, provides intake airflows for the construction and development operations in the Subsurface Facility and will not be required after construction and development is complete. Three exhaust shafts, excavated to a diameter of 8 m, are required to exhaust air from the Subsurface Facility for the 70,000 MTU case. Exhaust Shaft 4, considered a contingency shaft, will only be required in the event that excavation within the contingency area deems it necessary to support additional ventilation capacities.

The repository emplacement drift average thermal load, based on line-loading with a 10-cm end-to-end spacing between waste packages ("Site Recommendation Subsurface Layout," Section 6.2.3.2), was 1.42 kW/m for the 70,000 MTU case.

2.3.2 97,000 MTU Layout for Site Recommendation

The 97,000 MTU Layout for Site Recommendation (Site Recommendation Subsurface Layout, Figure 12), as shown in Figure 3, will require 90 emplacement drifts ("Site Recommendation Subsurface Layout," Section 6.4). Emplacement Drifts 1 through 78 are required for emplacement of the waste package inventory. Emplacement Drifts 79 and 80 are excavated as an allowance for possible variances in the waste stream. Emplacement Drifts 81 through 90 are contingency drifts that will only be excavated in the event that conditions during development of the repository are found to be such that the intended emplacement area cannot be used due to unexpected ground conditions.

The emplacement drifts will be excavated from the East Main to the West Main. The drifts will be excavated with an azimuth of 252 degrees; the preferred drift orientation to position the emplacement drifts at least 30 degrees from the dominant joint orientations of the repository host horizon ("Site Recommendation Subsurface Layout," Section 6.2.1.2).

The required emplacement length to accommodate the 97,000 MTU Layout for Site Recommendation is approximately 74,214 m, which requires approximately

1,485 acres and results in an areal mass loading of approximately 57 MTU/acre ("Site Recommendation Subsurface Layout," Section 6.4.1).

Within the emplacement area, six standby and cross-block drifts will be excavated at a diameter of 5.5 m within the pillars of adjacent emplacement drifts. The two standby drifts will be located within the first half of the emplacement drifts to be available early on for possible relocation of waste packages. The four cross-block drifts will perform possible ventilation, monitoring, emergency egress, and/or Test and Evaluation program functions and are located such that the cross-block drifts equally divide the repository block.

The Test and Evaluation Facility for the 97,000 MTU layout ("Site Recommendation Subsurface Layout," Section 6.4) will consist of the postclosure test drifts on the north end of the repository with their Observation Drift, and the performance monitoring Observation Drifts 2, 3, and 4, along with the Enhanced Characterization of Repository Block. All Test and Evaluation Facility openings will be excavated to a diameter of 5.5 m.

The access mains within the 97,000 MTU Layout for Site Recommendation include the North Main, West Main, North Ramp Extension, East Main North Extension, East Main South Extension, South Main, and the South End Main ("Site Recommendation Subsurface Layout," Sections 6.2.1.1. These access mains account for approximately 19,879 m of excavation ("Site Recommendation Subsurface Layout," Section 6.4.2.1). The access mains will be excavated to a diameter of 7.62 m. The East and West Mains, including the East Main North and South Extensions will be used primarily for waste emplacement operations as access to the emplacement drifts.

The North Main, South Main, and South End Main have been configured between the East and West Mains to provide access from one side of the repository block to the other. The North Ramp Extension is provided to the north end of the repository block as a bypass from the North Ramp to allow concurrent waste emplacement operations and continued Subsurface Facility development.

The Exhaust Main, excavated to a diameter of 7.62 m, is approximately 9,480 m in length and is situated below the repository elevation extending from the north end of the repository block to the extreme south end ("Site Recommendation Subsurface Layout," Sections 6.2.4.2, 6.2.1.1, and 6.4.2.1). The Exhaust Main is graded in the vicinity of the North, South, and South End Mains to allow intersection of the headings and to provide access into the Exhaust Main from each the North Main, South Main, and South End Main.

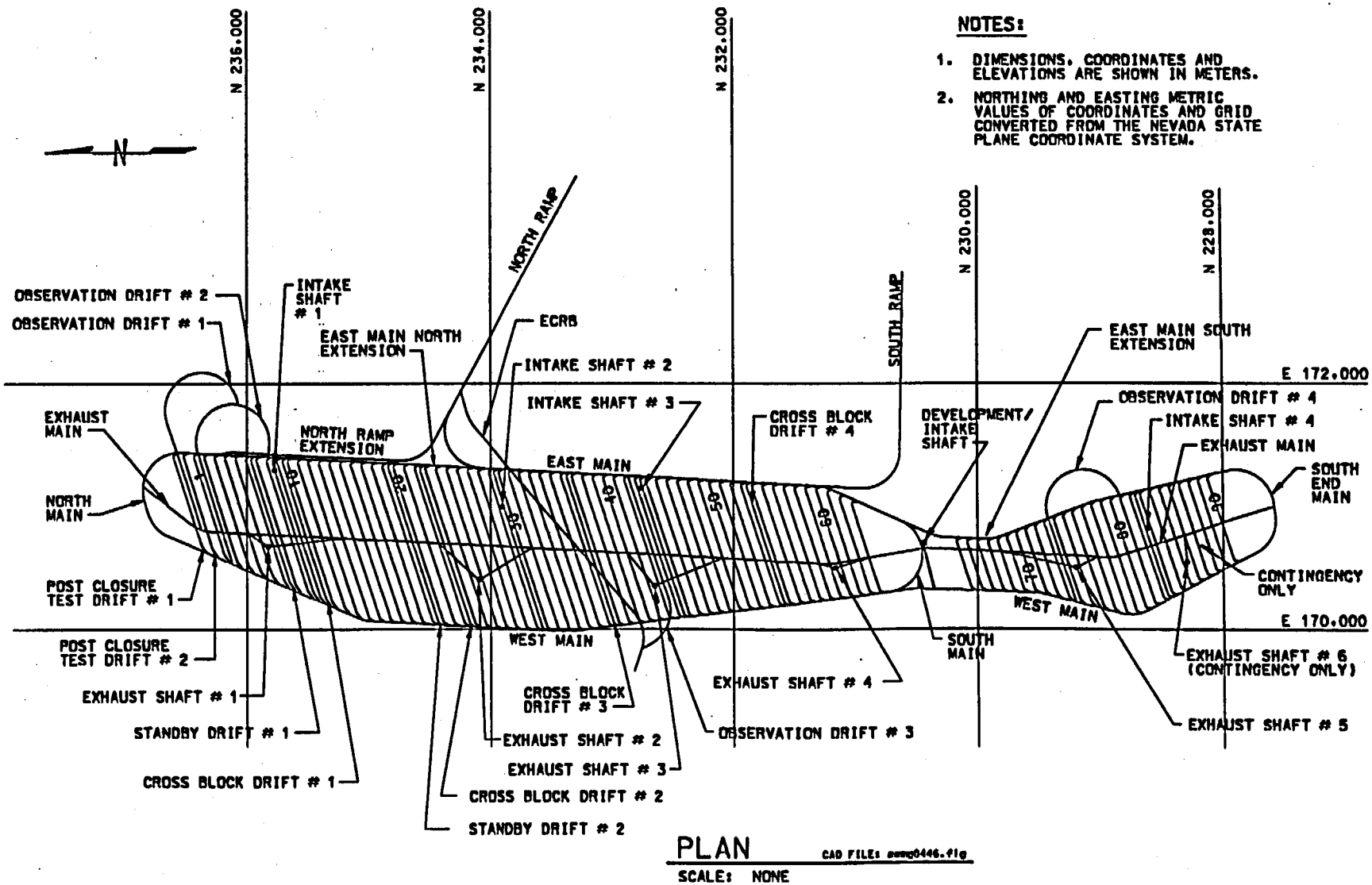


Figure 3. 97,000 MTU Layout for Site Recommendation

Four intake shafts, excavated to a diameter of 8 m are required to supply the required ventilation flow rates to the Subsurface Facility for the 97,000 MTU case, in addition to the North and South Ramps. The Development/Intake Shaft, located in the vicinity of the South Main, also excavated to a diameter of 8 m provides intake airflows for the construction and development operations in the Subsurface Facility and will be required as an intake shaft after construction and development is complete. Five exhaust shafts, excavated to a diameter of 8 m, are required to exhaust air from the Subsurface Facility for the 97,000 MTU case. Exhaust Shaft 6, considered a contingency shaft, will only be required in the event that excavation within the contingency area deems it necessary to support additional ventilation capacities.

The repository emplacement drift average thermal loads, based on a 10-cm spacing between waste packages ("Site Recommendation Subsurface Layout," Section 6.2.3.2), was 1.43 kW/m for the 97,000 MTU case.

2.3.3 Expansion Capabilities

The design of the repository must not preclude the capability of expansion and accommodation of a waste inventory of up to 115,000 MTU or equivalent. An area located to the east of the planning layout, at a lower elevation, is available for this expansion ("Site Recommendation Subsurface Layout," Section 6.5.1). This siting area is referred to as the lower block. The development of this lower block area was approached in a similar manner as the design of the 70,000 MTU and 97,000 MTU layouts. The layout of the lower block only encompassed sufficient area to show the expansion capability of the current Site Recommendation layouts. Consequently, the layout of the lower block was fully integrated with the design of the planning layout. The lower block layout is located approximately 40 m and 130 m below the elevation of the planning layout on the north and south ends of the primary block, respectively. The lower block, as illustrated in Figure 4, can accommodate 52 emplacement drifts with approximately 62,400 m of available emplacement drift.

2.3.4 Safety Considerations

The layout of the Subsurface Facility is required to provide two or more separate, properly maintained escapeways to the surface from the lowest levels that are positioned so that damage to one escapeway will not lessen the effectiveness of the other. The existing North and South Ramps provide the minimum required escape routes from the Primary Area to the surface.

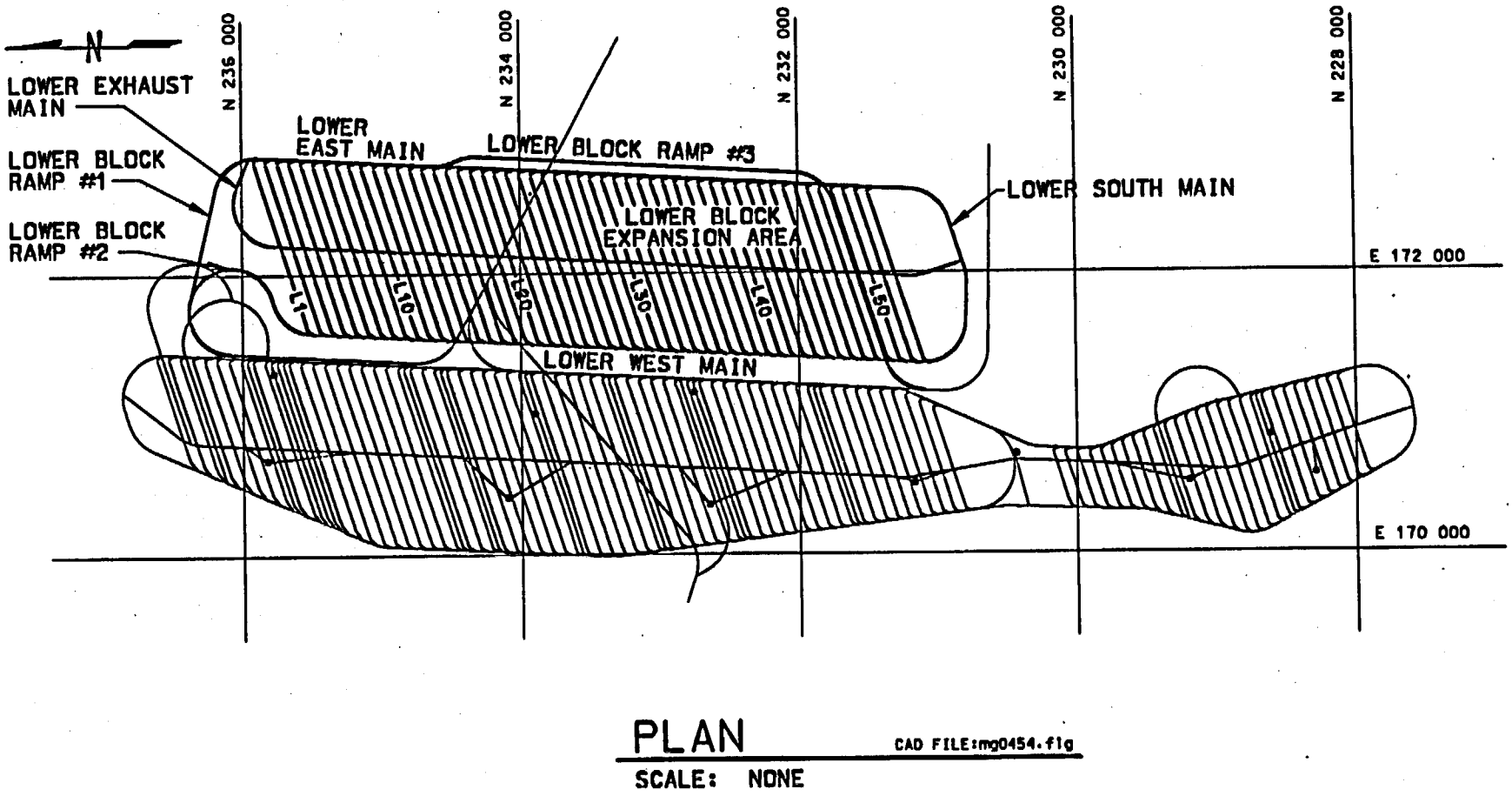


Figure 4. Lower Block Expansion Layout

Within the Subsurface Facility, personnel refuge chambers will also be required. Personnel refuge chambers can serve multiple personnel functions other than emergency refuge, such as first aid stations, temporary offices, and lunchrooms. These personnel refuge chambers will be located at a maximum of 2,100 m from an adjacent personnel refuge chamber or the nearest escapeway such that personnel can reach a refuge chamber within 30 minutes ("Site Recommendation Subsurface Layout," Section 6.2.8).

2.3.5 Construction Methods

The excavation methods include mechanical excavation (using TBMs, roadheaders, raise-borers, and drills), although drilling and blasting methods may be approved for use in special applications ("Site Recommendation Subsurface Layout," Section 6.2.9). A 7.62-m diameter TBM excavated the main Exploratory Studies Facility openings, the North Ramp, Main Drift, and South Ramp. Similar methods will be used for repository construction and development, although drill and blast methods may be used. These methods will be strictly limited to areas where mechanical methods are clearly impractical. The majority of the repository openings will be excavated by TBMs, which require long and relatively straight tunnels for efficient operation. Both the 7.62-m and the 5.5-m TBMs will be designed for transportation through completed tunnels.

Pre-excavated chambers are required to assemble and launch, as well as recover and disassemble, the 7.62-m TBM, which will excavate the ramps and mains, and the 5.5 m TBM which will excavate the emplacement drifts and Test and Evaluation drifts. For the ramps and mains, the assembly and disassembly chambers are located as needed to support the desired construction sequence. The emplacement drift turnouts that are required for the waste emplacement operations would serve as the launch chambers on the east side and recovery chambers on the west side for the 5.5-m TBM. For the Test and Evaluation drifts located above and below the repository block, assembly chambers will be excavated as needed. The 5.5-m TBM will be designed to back out of a completed Test and Evaluation drift so disassembly chambers will not be required. The locations and sizes of the assembly and disassembly chambers will be presented in future analyses. The specifics of these chambers do not affect the layout of the Subsurface Facility.

The TBM assembly and disassembly chambers, the emplacement drift turnouts, and other miscellaneous access drifts will be excavated by either roadheader or drill and blast methods. Roadheader productivity is low compared to that of a TBM and, for that reason, the use of these machines for repository excavation will be limited to short openings. The crawler-mounted roadheaders have the advantage over TBMs of greater mobility and the capability to excavate openings with non-circular cross-sections. They are also better suited to excavating turnouts and similar openings.

Typical drill and blast operations utilize several pieces of equipment, in sequence, to excavate. The operations include drilling holes for explosives, loading the holes with explosives and detonating them, ventilating the blast zone, muck removal, and rock support installation. This operation may disturb the rock surrounding the opening and is not usually used where mechanical excavation methods are applicable.

2.3.6 Construction Sequence

The construction sequence and schedule for the Subsurface Facility indicate completion of the pre-emplacement construction between 2005 and 2009 to ensure that the facility will be ready to begin waste emplacement in 2010 ("Site Recommendation Subsurface Layout," Section 6.2.9.1). The remaining development of the repository will occur concurrently with emplacement, from 2010 to completion of the facility. Construction and development of the repository will be accomplished in two general phases. The first, the construction phase, will occur prior to the beginning of waste emplacement operations; the second, the development phase, will occur concurrently with waste emplacement operations.

The construction phase will include partial excavation of the mains on the north end of the repository block, excavation of the ventilation shafts required to support the first panel of several emplacement drifts, and ventilation raises that will accommodate the initial emplacement requirements and support continued development. Isolation airlocks will be erected after the first panel of emplacement drifts is finished to allow simultaneous emplacement and development operations. Emplacement operations will use the first panel of emplacement drifts on the north side of the isolation airlocks while the next panel of emplacement drifts, ventilation raises, and the supporting main drift excavation is under development on the south side of the airlocks. As a panel of emplacement drifts is completed, a new set of isolation airlocks will be erected, the completed panel turned over to emplacement operations, and the previous set of isolation airlocks dismantled. As each new panel is being developed, only sufficient excavation is completed to support turnover of the next emplacement panel. In this way, the facility will be constructed in a manner that will permit construction in stages such that the maximum annual funding requirements could be reduced. This will also facilitate the start of operations concurrently with subsequent construction stages.

2.4 COMPONENTS DESCRIPTION

2.4.1 Emplacement Drift Turnouts

A transition from the East and West Mains into the emplacement drifts is required to support emplacement operations and accommodate the waste emplacement

equipment. The emplacement drift turnouts will function as this transition from the Mains into the emplacement drifts and support activities, such as TBM launch for emplacement drift excavation and WP transporter unloading and transfer. ("Site Recommendation Subsurface Layout," Section 6.2.1.2).

One of the functions of the turnout is to aid in reducing the radiation levels in the East and West Mains. The direct line of radiation, the line-of-sight from the last emplaced WP in the emplacement drift, could increase the radiation levels in the East and West Mains. To prevent this, the projection of the direct line of radiation from this last WP will have a minimum standoff distance back from the nose of the pillar.

2.4.2 Standby and Cross-block Drifts

A number of drifts excavated in the pillar of adjacent emplacement drifts will be left empty during emplacement operations ("Site Recommendation Subsurface Layout," Section 6.2.1.2). These drifts will serve two purposes. First, the cross-block drifts will be left empty to facilitate ventilation, emergency egress, and possibly to assist in the Test and Evaluation program. The cross-block drifts will also be one of the paths for cool, fresh air to get to the Exhaust Main service side. The Test and Evaluation program may also use the cross-block drifts to monitor the adjacent emplacement drifts.

The standby drifts will be left empty for temporary relocation of waste packages, if necessary ("Site Recommendation Subsurface Layout," Section 6.2.1.2). If, for some reason, the waste packages must be removed from a loaded emplacement drift, the standby drifts will serve as receiving locations instead of removing the waste packages back to the surface. Relocated waste packages can remain in the standby drifts on a temporary basis and must moved to a permanent location, depending on the situation that caused the relocation.

2.4.3 Test and Evaluation Facilities

The Test and Evaluation program will operate during both construction and development to confirm that the design objective, the long-term isolation of waste in the Subsurface Facility, is accomplished. The Test and Evaluation program will require a number of facilities for performance monitoring, postclosure simulations, and specialized test areas ("Site Recommendation Subsurface Layout," Section 6.2.1.3).

The performance monitoring facility will require a minimum of three monitoring areas with one observation drift and a minimum of six alcoves for each area. Performance monitoring observation drifts are located within the Primary Area. These performance monitoring observation drifts are located above the repository horizon to provide access for monitoring of preclosure conditions in the near-field

environment. Along with each of the observation drifts, a number of testing alcoves are required.

A postclosure simulation facility is located within the Primary Area. The first two drifts within the emplacement block are designated as the two simulation drifts. An observation drift to monitor the postclosure simulation drifts is located between the drifts below the repository horizon. Along with the observation drift a number of testing alcoves are required.

Additional specialized test areas are required within the Subsurface Facility. These test areas include seepage measurement alcoves, seismic monitoring alcoves, ramp-seal test alcoves, and shaft-seal test alcoves. These specialized alcoves require specific testing locations that will provide the varying conditions needed for the test. These specialized test areas have not yet been designed.

2.4.4 Ventilation Raises

Ventilation raises located in the emplacement drifts, cross-block drifts, standby drifts, and Test and Evaluation Facility headings, will connect the headings to the Exhaust Main below the repository ("Site Recommendation Subsurface Layout," Section 6.2.4). A raise bore will be used to excavate the raises to a diameter of 2 m from the upper headings to the crown of the Exhaust Main. The raises serve as ventilation airways for emplacement operations and for Test and Evaluation Program activities.

2.4.5 Surface Based Boreholes

There are 15 surface-based boreholes in the vicinity of the planning layout ("Site Recommendation Subsurface Layout," Section 6.2.6). The design of the layout must allow at least a 5-m standoff from the edge of the WPs to the perpendicular projection of the centerline of a surface-based borehole if the borehole intercepts the drift or comes within 5 m of the edge of the drift. To determine the perpendicular projection of the borehole at the repository elevation, the deviation surveys for these boreholes are required. Since these deviation surveys are not available at this time, this requirement cannot be fully addressed in this analysis. The maximum impact this criteria could have on the emplacement area definition as outlined in this analysis is 150 m (15 boreholes with 5 m standoffs to two WPs) of unusable emplacement drift length that is currently included in the design. Future analyses using the actual borehole deviation surveys will determine the actual impact of this criterion on the Subsurface Facility design.

2.4.6 Alcoves

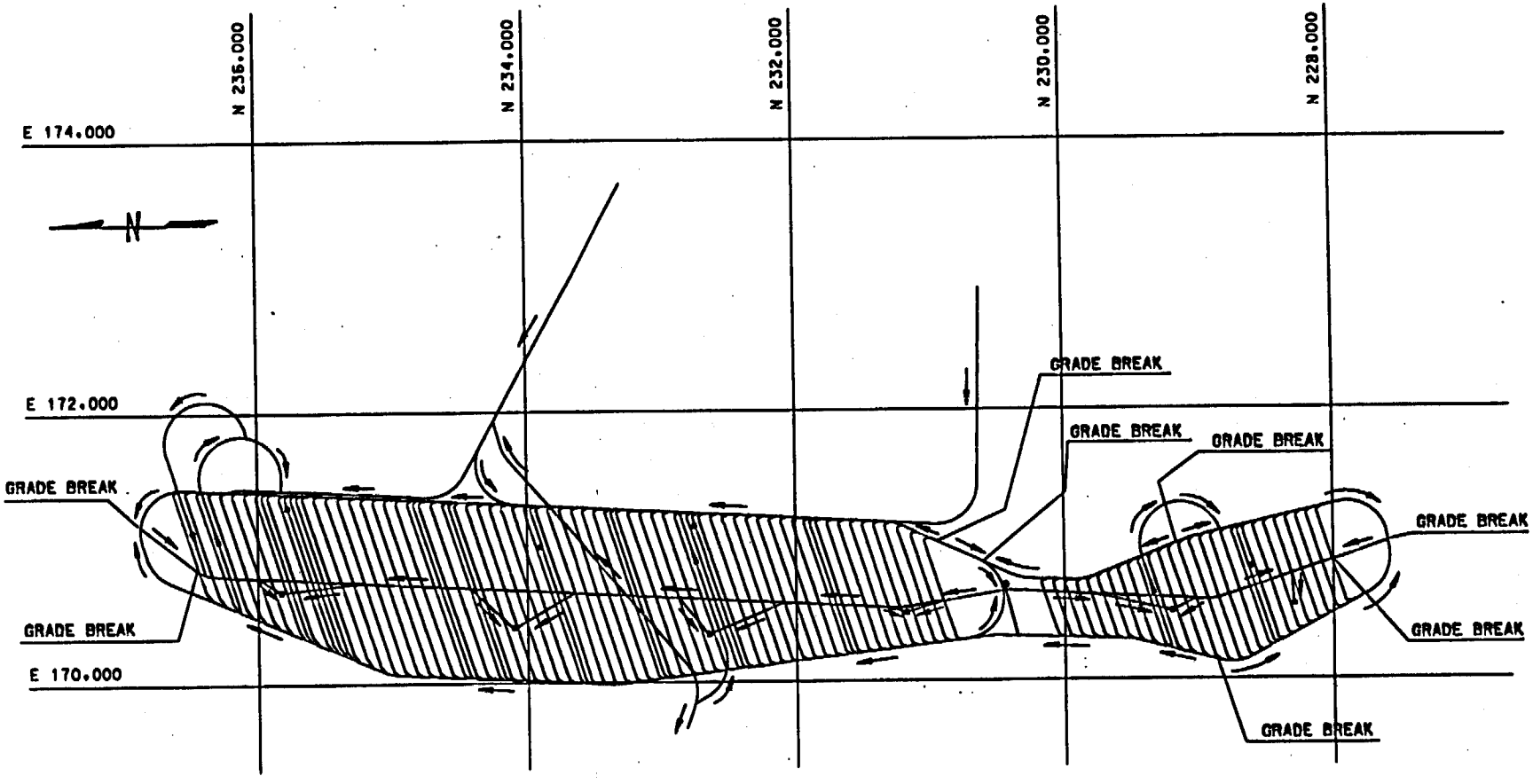
A number of Test and Evaluation Facility alcoves, refuge chambers, and operational alcoves are required throughout the Subsurface Facility. The functions of these alcoves will dictate both their size and locations. These alcoves have not yet been designed.

2.4.7 Assembly and Disassembly Chambers

Pre-excavated chambers are required to assemble and launch, as well as recover and disassemble, the 7.62-m TBM, which will excavate the ramps and mains, and the 5.5 m TBM which will excavate the emplacement drifts and Test and Evaluation drifts ("Site Recommendation Subsurface Layout," Section 6.2.9). For the ramps and mains, the assembly and disassembly chambers will be sized and located as needed to support the desired construction sequence, but have not yet been designed.

2.4.8 Overall Drainage

The Layouts for Site Recommendation facilitates preclosure and postclosure water drainage away from the emplacement drifts, by sloping the subsurface openings away from the emplacement area along the mains to drainage areas at the ventilation shaft sumps as shown in Figure 5 ("Site Recommendation Subsurface Layout," Section 6.2.5). The gradients in all sections of the mains and ramps have also been configured to allow rail transportation within the opening. The emplacement drifts have been designed with a flat gradient. This allows any water entering the emplacement drifts to drain directly into the surrounding rock without draining along the drift for collection into a centralized location.



PLAN CAD FILE: [illegible]0443.fig

SCALE: NONE

Figure 5. Overall Drainage Pattern

2.5 CRITERIA COMPLIANCE

Table 7. Criteria Summation

Criterion	Adherence to Criteria
Section 1.2.1.1	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.3.1.
Section 1.2.1.2	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.4.1). The subsurface layout has been designed to accommodate the waste package inventory.
Section 1.2.1.3	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.1.2). The emplacement drifts have been specified to be excavated with a nominal diameter of 5.5 meters.
Section 1.2.1.4	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Sections 6.2.3.2, 6.3.1, and 6.4.1). The average thermal loading and the emplacement area capacities have been calculated based on 0.1-m average waste package spacing.
Section 1.2.1.5	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Sections 6.2.1.2, 6.2.3.7, 6.3.1, and 6.4.1). The thermal analysis of the subsurface facility and the emplacement area calculations have been based on spacing the emplacement drifts 81 meters center-to-center.
Section 1.2.1.6	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.5). The ramp accesses in the subsurface facility have been shown to be capable of providing the sufficient grading to prevent floodwater from entering the subsurface facility.
Section 1.2.1.7	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Sections 6.2.1.2 and 6.2.2.2). The orientation of the emplacement drifts has been specified at 252°, which orients the emplacement drifts at least 30° from the dominant rock joint orientations.
Section 1.2.1.8	Criterion has been partially met for major facilities in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.1.3). Details of minor facilities have not yet been included in the layout. The Specialized test areas, and lengths of specialized test areas will be addressed in a later revision to this document.
Section 1.2.1.9	Criterion has met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Sections 6.5. Additional repository siting area will be available to expand the capacity of the repository.
Section 1.2.2.1.1	This criterion cannot be evaluated at this time. It is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. A discussion of this criterion with respect to the Subsurface Facility is located in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.7). It will be revisited when full operational aspects of the repository are available.
Section 1.2.2.1.2	This criterion cannot be evaluated at this time. It is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. It will be revisited when full operational aspects of the repository are available.
Section 1.2.2.1.3	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Sections 6.2.4 and 6.2.5). The shafts are located outside the probable maximum flood areas and the existing ramp system of the Exploratory Studies Facility fall outside the probable maximum flood areas.
Section 1.2.2.1.4	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Sections 6.2.2 and 6.2.2.1). The Subsurface Facility has been located such that the closest edge of the emplacement drifts are placed a minimum of 160 meters from the top of the groundwater table and 60 meters from Type I faults, namely the Solitario Canyon Fault.

Table 7. Criteria Summation (Continued)

Criterion	Adherence to Criteria
Section 1.2.2.1.5	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.2.1). The Subsurface Facility does not intersect any Type I faults or splays associated with Type I faults and, therefore, a 15 meter standoff between waste packages and Type I faults and a 5 meter standoff between waste packages and spays associated with Type I faults has not been required.
Section 1.2.2.1.6	This criterion has not been met because it requires knowledge of specific borehole locations. Potential impacts associated with applying this criterion have been discussed in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.6) and contingency emplacement space provided.
Section 1.2.2.1.7	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.5). The overall grading, excluding the emplacement drifts diverts any water entering the Subsurface Facility away from the emplacement drifts and to the shaft sumps for removal to the surface.
Section 1.2.2.1.8	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.2). The emplacement area of the Subsurface Facility has been located entirely within the lower part of the TSw1 and the entire TSw2 unit of the characterized area.
Section 1.2.2.1.9	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.2). The identified limits for repository siting included limiting the emplacement area to within the characterized area and locating the emplacement level at least 200 meters below the directly overlying ground surface.
Section 1.2.2.2.1	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.8). Two separate escapeways, namely the North and South Ramps have been provided and designated the escapeways to the surface from the lowest level of the repository.
Section 1.2.2.2.2	This criterion has not been addressed at this stage as stated in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.8). The details of the locations and specifics of the personnel refuge chambers do not affect the design of the Subsurface Facility and will be addressed in the future.
Section 1.2.2.2.3	This criterion has not been addressed at this stage as stated in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.8). The details of the locations and specifics of the personnel refuge chambers do not affect the design of the Subsurface Facility and will be addressed in the future.
Section 1.2.4.1	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.4). The Subsurface Facility has been designed to accommodate the Subsurface Ventilation Systems design criteria and provide the necessary openings to support preclosure continuous ventilation of the emplacement drifts.
Section 1.2.4.2	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.1.1 & 6.2.5). The Subsurface Facility has been designed such that the openings providing rail transportation do not exceed the gradient criterion.
Section 1.2.4.3	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.1.1). The openings within the Subsurface Facility have been designed to accommodate the required operating envelopes while allowing for ground control installation, variations in tunnel dimensions and alignment and tunnel deformations.

Table 7. Criteria Summation (Continued)

Criterion	Adherence to Criteria
Section 1.2.4.4	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.3.10). The location of the Subsurface Facility has been shown to be such that the Emplacement Drift System's temperature limit constraint for the zeolitized layer will not be violated.
Section 1.2.4.5	This criterion has not been addressed. Analyses to verify that the layouts for Site Recommendation will meet this criterion will be conducted in the future. This criterion is briefly discussed in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.3.11).
Section 1.2.4.6	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.3.10). The location of the Subsurface Facility has been shown to be such that the Emplacement Drift System's temperature constraint for the PTn geologic unit will be met.
Section 1.2.4.7	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.1.1). The openings within the Subsurface Facility have been designed such that in conjunction with each other, they support waste emplacement and potential retrieval operations in the emplacement drifts.
Section 1.2.4.8	This criterion has been met in "Site Recommendation Subsurface Layout," Section 6.2.3.12. It is expected that the ground deflection will not exceed the differential uplift limit in the TSw1 geologic unit.
Section 1.2.4.9	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.9). The construction methods and equipment, construction sequence, and equipment productivity have been considered to ensure overall constructability of the Subsurface Facility.
Section 1.2.6.1	This criterion has not been addressed. Analyses to verify that the layouts for Site Recommendation will meet this criterion will be conducted in the future. This criterion is briefly discussed in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.8).
Section 1.2.6.2	This criterion has not been addressed. Analyses to verify that the layouts for Site Recommendation will meet this criterion will be conducted in the future. This criterion is briefly discussed in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Section 6.2.8).
Section 1.2.6.3	Criterion has been met in the Site Recommendation Subsurface Layout ("Site Recommendation Subsurface Layout," Sections 4.2 and 5.1). The design of the Subsurface Facility complied with applicable assumptions contained in the "Repository Subsurface Layout Configuration Analysis."

3. SYSTEM OPERATIONS

This section will be completed in a later revision.

4. SYSTEM MAINTENANCE

This section will be completed in a later revision.

APPENDIX A CRITERION BASIS STATEMENTS

This section presents the criterion basis statements for criteria in Section 1.2 of Volume I. Descriptions of the traces to "Monitored Geologic Repository Requirements Document" (MGR RD) and "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada" are shown as applicable. In anticipation of the interim guidance being promulgated as a Code of Federal Regulations, it will be referred to as "10 CFR 63" in this system description document.

1.2.1.1 Criterion Basis Statement

I. Criterion Need Basis

The "Monitored Geologic Repository Project Description Document," Section 5.2.3, requires a MGR that accommodates 70,000 MTHM of WP inventory. The criterion is provided to ensure this system is designed to accommodate the amount of waste forms shown in Table 1. The repository layout has to ensure sufficient space for waste disposal.

Table 1 identifies the expected waste package types and the total number of each. The diameter of the waste packages is not provided because the operating envelope bounds the diameters of waste packages. The number of waste package types and their lengths impact the total length and number of emplacement drifts. Input transmittal "Revised Waste Package Lengths" provides waste package lengths that differ from the current version of the "Monitored Geologic Repository Project Description Document." The WP lengths are TBV.

This criterion supports MGR RD 3.2.A.

II. Criterion Performance Parameter Basis

The design basis waste package inventory is provided in "Monitored Geologic Repository Project Description Document," Section 5.2.3. The design basis waste package inventory is provided in the "Monitored Geologic Repository Project Description Document," Section 5.2.3. The quantities of the waste packages for the Naval short canisters and the Naval long canisters come from Section 5.1.4.2 of the "Monitored Geologic Repository Project Description Document." The Navy's position is that the maximum Naval short canisters is 200 and the maximum Naval long canisters is 100. The additional quantities provided in section 5.2.3 is not necessary for the Naval canisters. This Navy position is corroborated in "Information Requested BY Yucca Mountain Site Characterization Office For Use in the Repository Environmental Impact Statement."

1.2.1.2 Criterion Basis Statement

I. Criterion Need Basis

This criterion provides the maximum WP inventory for the 97,000 MTHM. The size and total number of waste packages need to be established. The allocation of waste packages and the sizes of the packages are needed to ensure the design of the repository layout and the repository configuration can support the total emplacement capacity.

Table 2 identifies the expected waste package types and the total number of each. The diameter of the waste packages is not provided because the operating envelope bounds the diameters of waste packages. The number of waste package types and their lengths impact the total length and number of emplacement drifts.

This criterion supports MGR RD 3.2.B.

II. Criterion Performance Parameter Basis

The waste package types and their total number come from the Monitored Geologic Repository Project Description Document," Section 5.2.4. The quantities of the waste packages for the Naval short canisters and the Naval long canisters come from Section 5.1.4.2 of the "Monitored Geologic Repository Project Description Document." The Navy's position is that the maximum Naval short canisters is 200 and the maximum Naval long canisters is 100. The additional quantities provided in section 5.2.3 is not necessary for the Naval canisters. This Navy position is corroborated in "Information Requested BY Yucca Mountain Site Characterization Office For Use in the Repository Environmental Impact Statement." Input transmittal "Revised Waste Package Lengths" provides waste package lengths that differ from the current version of the "Monitored Geologic Repository Project Description Document." The WP lengths are TBV.

1.2.1.3 Criterion Basis Statement

I. Criterion Need Basis

This criterion provides the diameter of the emplacement drifts. This is determined to be sufficient size for safe disposal and retrieval of waste canisters inside the emplacement drifts via the "Monitored Geologic Repository Project Description Document."

II. Criterion Performance Parameter Basis

The emplacement drift diameter size is 5.5 m and is obtained from "Monitored Geologic Repository Project Description Document," Section 5.2.5.

1.2.1.4 Criterion Basis Statement

I. Criterion Need Basis

This criterion is provided to ensure the total length of emplacement drifts is sufficient to accommodate the waste package spacing.

II. Criterion Performance Parameter Basis

The nominal waste package spacing is 10 centimeters from "Monitored Geologic Repository Project Description Document," Section 5.2.10. This distance is expected to be the average spacing for computing the aggregate length of emplacement drifts.

1.2.1.5 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.C. 10 CFR 63.113(b) requires the engineered barrier system be designed to work in combination with the natural barriers to limit radioactive materials released from the geologic repository. This criterion promotes drainage of thermally mobilized water and increases the independence of individual drifts, which contributes to the implementation of 10 CFR 63.113(b).

II. Criterion Performance Parameter Basis

The 81 m is established in "Monitored Geologic Repository Project Description Document," Section 5.2.1.

1.2.1.6 Criterion Basis Statement

I. Criterion Need Basis

Although the repository subsurface entrances are located outside the probable maximum flood areas ("Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion," Section 2.6.2), heavy rains could cause flooding in the repository if surface drainage is toward the repository entrance. Therefore, this criterion is provided to ensure that surface water drainage is away from the repository subsurface entrances. The method of controlling surface water drainage is to provide an upward grade for the first few meters of the tunnels. The following analysis provides bounding grades' values and the minimum distance required.

II. Criterion Performance Parameter Basis

Analysis: Grade at the Entrance to Ramps

Purpose

The ramps descend from the surface to the repository level. To limit the inflow of surface rainwater and runoff, a slight upward grade at the entrance to the ramp should be made. This analysis establishes the slope and length of this section of the ramp.

Assumptions

1. The repository shall be designed so that a combination of characteristics will support the engineered barrier system to prevent seeping water from coming into contact with the waste form.

Rationale: Supports the philosophy of defense-in-depth for exclusion of water from the repository. Water is one of the main factors in corrosion of waste packages.

2. The North and South Portals will maintain a grade that is sloped away from the entrances to the subsurface facility.

Rationale: The Exploratory Studies Facility is required to maintain a grade on the pads away from the tunnel entrances.

Criterion Analysis

Assumption 1 is interpreted to mean that water shall be prevented from entering the repository. A slight upward grade at the entrance to the repository is needed to prevent rainwater from freely flowing down the ramp to the repository level.

The grade outside of the North and South Portals is sloped away from the entrance to the subsurface tunnels. Rainwater will not flow into the ramp unless ponding of the water occurs outside of the portal. To prevent water from flowing down the ramp, a tenth of a meter rise is selected as a minimum vertical rise for the short section of ramp near the portal. A tenth of a meter is approximately the height of a street curb and is considered sufficient considering the grade (Assumption 2) on the pads.

The data shown in Table 8 shows that 10 m will provide at least a vertical rise of 0.10 m for all grades between 1 percent and the maximum grade allowed for rail transport.

Table 8. Vertical Rise for Various Grades and Lengths

	Vertical Rise (m)				
Grade/Length	5m	10m	15m	20m	25m
1%	0.05	0.10	0.15	0.20	0.25
2%	0.10	0.20	0.30	0.40	0.50
3%	0.15	0.30	0.45	0.60	0.75

Conclusion

A slight upward grade of at least 1 percent over a minimum length of 10 m is recommended at the portion of the ramp near the portal.

1.2.1.7 Criterion Basis Statement

I. Criterion Need Basis

The subsurface opening orientations relative to the orientation of the dominant rock joints effect opening stability. The orientation of emplacement drifts relative to the dominant rock joint is a consideration for ground stability and block size failure. This consideration is based on maximizing stability of emplacement drifts which minimizes maintenance in the emplacement drifts. Also, the size of a block failure is affected by drift orientation. Lesser stability is acceptable in the other excavations because of more accessibility.

II. Criterion Performance Parameter Basis

The minimum orientation of emplacement drifts to dominant joints is established in "TBV-361 Resolution Analysis: Emplacement Drift Orientation."

1.2.1.8 Criterion Basis Statement

I. Criterion Need Basis

10 CFR 63.111(d) requires the repository be designed to permit implementation of a performance confirmation program that meets the requirements of Subpart F. This criterion is needed to provide test facilities for implementation of specific elements of the testing program that address the following Subpart F requirements: 10 CFR 63.131(a)(1), 10 CFR 63.131(a)(2), 10 CFR 63.131(c), 10 CFR 63.132(b), 10 CFR 63.132(e), 10 CFR 63.133(a), 10 CFR 63.133(c), 10 CFR 63.133(d), 10 CFR 63.134(a), and 10 CFR 63.134(b). The test facilities provide access to locations where testing and monitoring are needed to support the performance confirmation and test and evaluation program. The facilities provide locations for the installation of monitoring and testing equipment and instrumentation. The facilities also provide for periodic human access to conduct tests, maintain instrumentation, calibrate instrumentation, etc.

II. Criterion Performance Parameter Basis

The basis for test facility characteristics is described in the following paragraphs and provided in Table 3 in criterion statement 1.2.1.8. The specific characteristics are (TBV) and other characteristics are (TBD). Qualified values will be established in later revisions to this system description document via analyses.

Performance Monitoring:

The Performance Monitoring facility characteristics are based on satisfying 10 CFR 63.132(e) and to support 10 CFR 63.131(c). The Performance Monitoring facility areas are to establish continuous records on a more detailed level of the thermal-mechanical and coupled thermal-mechanical-hydrological response of the rock mass in representative areas of the repository. These monitoring areas will be supplemented by other monitoring, such as in-drift inspections and ventilation monitoring, that provide additional coverage in space and time, but with less detail. The combination of detailed monitoring at representative conditions, periodic in-drift inspections, and continuous ventilation monitoring will provide sufficient coverage of the entire repository, thereby enhancing confidence that the performance of the geologic and engineering features is within the design limits.

A minimum of three performance monitoring areas is needed. One shall be located to provide monitoring of the first emplacement drifts to contain waste. Two others shall be located to cover rock mass conditions that are important to the coupled thermal response including rock stratigraphy, fracture density and expected percolation rates. For each monitoring area, one observation drift is needed. The observation drift provides access to the performance monitoring areas of the repository near emplacement drifts. A minimum of six alcoves is needed at each area to provide access to the rock mass at a specific monitoring area location and to provide for a detailed pattern of monitoring instrumentation in the rock mass to confirm performance related to coupled thermal processes.

The size of the facilities will be based on the equipment/instrument envelope and ventilation needs. The grade of observation drifts is to be oriented parallel, within 1 percent of the grade of the emplacement drift horizon. This simplifies the confirmation and analysis considerations including the geometry of and around the monitoring areas. A uniform separation will reduce the amount of variation due to the separation between the emplacement and observation drifts. The observation drifts should also be at a grade sufficient to provide drainage of any liquid water away from the emplacement area. This will limit the affects of any liquid water spills from having an adverse impact on the monitoring area. Similarly, the alcoves for the performance monitoring areas should be at a grade sufficient to provide drainage from monitoring areas.

Postclosure Simulation Testing:

The Postclosure Simulation facility characteristics are to establish a basis for satisfying parts 10 CFR 63.131(a)(1), 10 CFR 63.131(a)(2), 10 CFR 63.132(b), 10 CFR 63.133(a), 10 CFR 63.133(c), 10 CFR 63.134(a), and 10 CFR 63.134(b). In toto, the characteristics are to provide for the testing of thermal interaction effects of waste packages, backfill, drip shield, rock and groundwater and the testing of backfill, as well as provide data on the functioning of geologic and engineered barriers under postclosure conditions. Facility characteristics are also to provide data on coupled processes under simulated postclosure conditions as a basis for the License Application to close the repository.

Two types of test facilities are required to address different scales of performance. One facility, the Engineered Barrier System (EBS) Interaction test area, is focused on the interaction of the engineered components and the immediate rock around the emplacement drift. The second facility, the Near Field Response test area, focuses on the coupled rock mass response of the larger rock mass around the emplacement drifts, especially in the mid-pillar region which is to allow the bypass of percolation around the drifts.

A minimum of one test area for each type of facility is required. For each test area, two simulated emplacement drifts and one observation drift is required, based on engineering judgement. A minimum of three alcoves is needed at each area to provide access to the rock mass at a specific monitoring area location so as to provide for a detailed pattern of monitoring instrumentation in the rock mass to confirm performance related to coupled thermal processes. The length of the facility shall be sufficient to test a range of conditions. At least two test areas, each 150 m in length, are needed. In addition, an associated buffer length between test sections (75 m on each end of the two 150 m test areas) is needed. Observation drifts for this testing shall extend along the entire length of the simulated alcoves. The diameter of the simulated drifts will be equal to (or scaled to be representative of) emplacement drifts. The size of the equipment to be utilized during installation, operation, and maintenance of the performance confirmation monitoring facilities will determine the minimum size (equipment envelope) required for the observation drifts excavation cross-section.

Simulated emplacement drifts shall be at grades representative of emplacement drift design. Associated observation drifts are to be located below the simulated drifts so as to not significantly impact the thermal-mechanical-hydrological response of the simulated drifts. The grade of observation drifts is to be oriented parallel, within 1% of grade (i.e. the slopes shall not differ by a grade of 1 m vertical to 100 m horizontal) of the simulated emplacement drift axis to simplify confirmation and the analysis considerations including the geometry of and around the monitoring areas. A uniform separation will reduce the amount of variation due to the separation between the emplacement and observation drifts. The observation drifts should also be at a grade sufficient to provide drainage of any liquid away from monitoring areas. This will limit the adverse effects of any spills on the monitoring area. Similarly, monitoring alcoves should be at a grade sufficient to allow for drainage into the associated observation drift.

Specialized Test Areas:

Specialized test areas will be required to satisfy parts 10 CFR 63.133(a) and (d) (seal performance), as well as to satisfy 10 CFR 63.131(a)(2) to ensure aspects of the geologic system barriers are performing as intended, specifically seepage.

For monitoring seepage at depth, seepage alcoves are required to provide access to varying rock mass conditions across the repository horizon, including areas with differing rock stratigraphy (rock units of the repository horizon), fracture density, and percolation rates. In considering local rock units, three units (the Middle Nonlithophysal, Lower

Lithophysal and Lower Nonlithophysal Zones of the Topopah Spring Tuff Formation) are identified to occur at the repository horizon. To bound these conditions (i.e., the three rock units, fracturing and percolation), a minimum of two alcoves for each condition are considered necessary for a total of ten alcoves, based on engineering judgement. Alcoves are to be a minimum of 20 m in depth based on prior testing experience, and located outside the hydrological-mechanical influence zone of adjacent excavations. Alcoves will be located along Performance Monitoring observation drifts and access mains as required to bound rock mass conditions and provide areal coverage of the emplacement horizon. Seepage alcoves will also be at a grade sufficient to provide drainage from the monitoring areas.

In addition to seepage, seismic monitoring will record the ground response to earthquake events in the region, to provide additional data on potential seismic hazard. Monitoring shall be conducted at the repository horizon to provide seismic amplitude and acceleration records, which do not include near-surface resonance effects as would occur in surface station data. For seismic monitoring, two seismic monitoring areas are the minimum required to provide measurements at the repository horizon with allowance for redundancy, based on engineering judgement.

The excavations for seismic monitoring will be relatively shallow and can be termed niches. As stated, the seismic niches should be located at repository depth to monitor representative seismic response of the repository. The seismic monitoring niches should be laterally separated on opposing ends of the emplacement area and, if possible, located in different stratigraphic horizons and in areas with different rock mass characteristics, to bound underground seismic conditions.

Still other required testing will require specialized alcoves. Regulatory requirements indicate the provision for test sections for shaft and ramp seals. Due to the expected differences in configurations and placement technologies between the ramps and shaft seals, two separate test areas are required, at a minimum, based on engineering judgement. To provide for a shaft test area, two short horizontal connecting alcoves are required. Therefore, the minimum configuration for seal testing is one alcove for ramp seal testing, and two alcoves and a connecting shaft for shaft seal testing.

Seal tests are to be in similar rock conditions as the respective ramp or shaft seals locations, with a focus on fracturing and effective permeability of the rock mass. The grade of the ramp seal test alcoves shall be representative of access ramps into the repository facility. All seal alcoves are to be long enough to house associated instruments and data acquisition systems, and should be at a grade sufficient to provide drainage of any liquid water away from the test areas. To place these facilities away from active emplacement conditions, the test alcoves are to be located along the south access main.

It is estimated that technology demonstration and constructability testing for both seals and backfill operations can economically be performed at the surface, and no underground facilities are required for such testing.

Additional facilities will be required to provide more widely spaced monitoring of the repository. Alcoves spaced along the observation drifts, exhaust drifts, and access mains outside the monitoring areas will provide additional confirmatory information. The number of these other areal monitoring alcoves is to be determined.

1.2.1.9

I. Criterion Need Basis

This criterion is provided to ensure the subsurface facility will not preclude the expansion of the MGR to accommodate an expanded number of waste packages. This criterion ensures flexibility of the subsurface facility in not precluding the expansion of the facility to accommodate added additional WP inventories (e.g., 115, 000 MTHM).

II. Criterion Performance Parameter Basis

The 115,000 MTHM is provided in "Monitored Geologic Repository Project Description Document," Section 5.1.4.2.

1.2.2.1.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.B requires that the MGR comply with the applicable provisions of "Standards for Protection Against Radiation" (10 CFR 20). To ensure the radiation levels can be maintained in the access mains and other areas requiring human access, a standoff from the waste package must be provided for in the subsurface layout. This criterion implements the guidance provided in "MGR Compliance Program Guidance Package for the Subsurface Facility System," guidance statements 6.5g1 and 6.5g3. The following analysis provides limiting radiation levels for subsurface areas requiring unrestricted access. The design is required to use a repository layout that accommodates limits on radiation levels.

II. Criterion Performance Parameter Basis

Title: Radiation Dose Rate Limits in Turnout Areas and Access Mains

Purpose

The purpose of this criterion analysis is to identify the radiological basis for waste package emplacement and shadow shield design for any emplacement drift to protect occupational personnel in the turnout areas and access mains. This criterion is required to establish the standoff distance from the emplacement drift isolation doors to the nearest emplaced waste package.

Assumptions

1. This criterion applies to normal repository operations only.

Rationale: The waste package standoff is required for radiological protection of personnel in the turnouts and access mains for normal conditions. Abnormal conditions, which may result in a higher radiation level as caused by an exposed or damaged waste package, will not affect the waste package standoff.

2. This criterion is exclusive of the temporary presence of the transporter with a waste package on-board in either the turnout or access main.

Rationale: The presence of the loaded transporter is governed by the radiation dose rate limits on the outside surfaces of the transporter and inside the locomotive operator's cab.

3. This criterion is based on the limiting waste form with design basis fuel source terms, which should be consistent with the waste package thermal design basis ("Preliminary Design Basis for WP Thermal Analysis").

Rationale: The design basis fuel source terms are conservative as compared to average SNF characteristics (see discussion below).

Criterion Analysis

MGR RD 3.1.B requires that the MGR comply with the applicable provisions of 10 CFR 20. For normal conditions that involve no radioactive leakage from emplaced waste packages (i.e., no internal radiation exposures), the controlling occupational radiation exposure limit, as specified in 10 CFR 20.1201, is the total effective dose equivalent of 5 rem/yr for external radiation exposures. To meet the 5-rem/yr limit, the dose rate should be designed not to exceed 2.5 mrem/hr in normally occupied areas (based on 2,000-hr/yr occupational access). Higher dose rate limits may be allowed in intermittently occupied areas (less than 2,000-hr/yr access) depending on occupancy duration and frequency of exposure, provided that annual exposures are less than 5 rem.

The access mains are considered normally occupied areas accessible up to 40 working hours per week or 2,000 working hours per year when the loaded waste package transporter is not present and the emplacement drift isolation doors are closed. Therefore, the dose rate in the access mains at the personnel elevation should not exceed 2.5 mrem/hr under these conditions.

The turnout areas are considered intermittently occupied areas where personnel access is required for inspection and maintenance on the emplacement drift isolation doors. 10 CFR 20.1003 defines the "radiation area" as an area with dose rates between 5 and 100 mrem/hr at 30 cm from the radiation source or any surface that the radiation penetrates. Areas with radiation levels in excess of 100 mrem/hr fall into high radiation areas, per 10 CFR 20.1003. 10 CFR 20.1601 requires control of access to high radiation areas with

alarms and locks. To avoid this control, the turnout area should be designed as a radiation area with the dose rate not to exceed 100 mrem/hr at 30 cm from the drift isolation doors. This limit is applicable whether the drift isolation doors are closed or open.

The dose rate limits of 2.5 mrem/hr in the access mains and 100 mrem/hr in the turnout areas should be based on the conservative design basis fuel specifications as indicated in Assumption 3. The design basis fuel specifications provide a design margin in terms of radiation levels by a factor of about 5 as compared to average commercial SNF characteristics ("MGDS Subsurface Radiation Shielding Analysis"). In other words, use of average SNF would result in the corresponding dose rate limits of 0.5 mrem/hr in the access mains and 20 mrem/hr at 30 cm from the drift isolation doors.

Conclusions

The radiological limits shall be based on limiting the dose rates not to exceed 2.5 mrem/hr in the access mains, and 100 mrem/hr in the turnouts at 30 cm from the drift isolation doors. The conditions and assumptions used in this criterion analysis apply to these dose rate limits.

1.2.2.1.2 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.B. To allow for possible human access in the turnouts, the radiation levels in the turnouts have to be within acceptable levels. Although the thermal effects can be controlled by various heat-stress reducing methods (e.g., local ventilation, cooling vests, exposure limits, etc.), the same is not true for radiation. Therefore, this criterion is provided to ensure sufficient standoff from the closest waste package and the emplacement entrance/door.

II. Criterion Performance Parameter Basis

The radiation level limit of 100 mrem/hr for the turnouts is established in the analysis above.

1.2.2.1.3 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.C and 10 CFR 63.113(b). Floods occur within the probable maximum flood areas. This criterion is provided to ensure the entrances to the subsurface facility are located outside the probable maximum flood areas. This criterion implements the guidance provided in "MGR Compliance Program Guidance Package for the Subsurface Facility System," guidance statements 6.2g1, 6.4g1, 6.8g1, 6.8g2, and 6.9g1. A subsurface flood would have adverse effects on repository operation and could cause unpredictable impacts to the natural barrier due to water infiltration. Therefore,

this criterion is provided to ensure all subsurface entrances are located outside the probable maximum flood areas. The probable maximum flood area is depicted in "Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion," Figure 2.6.2-1 and is TBD.

II. Criterion Performance Parameter Basis

N/A

1.2.2.1.4 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.C. 10 CFR 63.113(a) requires the geologic repository to include a natural barrier.

This criterion is needed to ensure that future climactic changes predicted to occur in the Yucca Mountain area do not cause the water table to rise to the level of the emplacement area of the repository. A standoff distance is established between the emplacement drifts and the present day water table to compensate for water table elevations higher than the present day water table.

Type I faults are defined as those faults whose displacement during a seismic event could impact repository design and performance. Since these faults represent potential preferential pathways, a standoff distance is established between repository openings and Type I faults. This criterion allows repository openings inside this standoff only if justified via a site impact evaluation. This option is provided because of the complexity of Type I faults' impact on repository design and performance and to allow the use of site impact analyses in determining the suitability of openings within the Type I fault standoff.

II. Criterion Performance Parameter Basis

Water Table Standoff

Several lines of evidence point to a past water table elevation at Yucca Mountain of at most 115 m above the present day water table (articles "Strontium Isotopic Evidence for a Higher Water Table at Yucca Mountain," [p. 1951] and "Late Quaternary History and Uranium Isotopic Compositions of Groundwater Discharge Deposits, Crater Flat, Nevada," [p. 1579] from "High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference, Las Vegas, Nevada, April 26-30, 1993;" and "Fossil Spring Deposits in the Southern Great Basin and Their Implications for Changes in Water-Table Levels Near Yucca Mountain, Nevada, During Quaternary Time" [p. 228] from "Geological Society of America Bulletin," Volume 107, Number 2). Additionally, the analysis of total system performance of the MGR for Site Recommendation will be performed based on a 120 m water table rise that is assumed in Section 3.7.5.2 of

"Unsaturated Zone Flow and Transport Model Process Model Report." Further, should the water table rise occur during the time where the rock surrounding the emplacement drifts are at their warmest, the water table should be located outside the boiling isotherm surrounding each drift. Given that the current repository design is to ensure that the majority of the pillar space between emplacement drifts should remain below the boiling point of water ("Monitored Geologic Repository Project Description Document," 5.2.1), and that the emplacement drifts are spaced 81 m apart ("Monitored Geologic Repository Project Description Document," 5.2.1), a standoff of about 20 m between the emplacement drift and any future water table should be established (81 m between drift centers, minus at total of 5.5 m for half of each emplacement drift diameter ["Monitored Geologic Repository Project Description Document," 5.2.5], minus 50 percent of the remaining width [the minimum non-boiling portion], with half of the remainder allocated to each drift, rounded up to 20 m). This standoff may need to be larger, to account for undesirable effects of water located in the saturated zone being heated to near boiling temperatures.

Thus, the standoff will be established in this document based on the potential water table rise plus the distance necessary to keep the boiling isotherm outside of the saturated zone. The 120 m water table rise assumed in "Unsaturated Zone Flow and Transport Model Process Model Report" envelopes the 115 m historical water table rise, and is used here to ensure consistency between the criteria and the analysis of total system performance. The previously mentioned 20 m spacing is added the 120 m, giving a standoff of 140 m. An additional 20 m is added to this standoff to compensate for any undetermined and undesirable effects of near boiling temperatures occurring in the saturate zone, for a total water table standoff of 160 m.

The standoff is established with respect to the emplacement drifts only, since postclosure saturation of the non-emplacement areas of the repository should not be of concern for waste isolation.

Fault Standoff

The "Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository" (p. 5) defines Type I faults as "Faults or fault zones that are subject to displacement and of sufficient length and located such that they may affect repository design and/or performance. As such, they should be investigated in detail. Only faults that are determined to be Type I are of regulatory concern, because it is those faults, both inside and outside the controlled area, that may require consideration in repository design, could have an effect on repository performance, or could provide significant input into models used to assess repository performance." Based on "Seismic Design Basis Inputs for a High-Level Waste Repository at Yucca Mountain, Nevada" (pp. 4-7 to 4-9), the only Type I fault identified in the immediate area of the repository is the Solitario Canyon fault which forms the western edge of the repository. The Bow Ridge fault is not in the immediate area of the repository.

Based on engineering judgement, it is conservatively assumed that a 60-m (197-ft) offset from the main trace of a Type I fault at the repository level is adequate. This value is TBV and needs confirmation. This distance was an engineering judgement and considers potential fractured ground in proximity to a Type I fault and uncertainty as to where the fault is at depth. Using a 60-m (197-ft) standoff for License Application design is conservatively applied. When the initial cross drifts are completed through the Solitario Canyon fault, its location will be better known and the condition of the rock in proximity to the fault can be examined first hand. A construction standoff will then be determined based on actual observations.

1.2.2.1.5 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.C. 10 CFR 63.113(b) requires the engineered barrier system be designed to work in combination with the natural barriers to limit radioactive materials released from the geologic repository. To accommodate the inventory of nuclear materials, in accordance with MGR RD 3.2.B, this system must provide space for waste package standoffs. A standoff distance between waste packages and Type I faults is conservatively allowed for in the layout. The minimum standoff is provided in the following Type I analysis. This standoff is not the final required standoff for waste package emplacement, but is criterion to establish the additional length of emplacement drift required. If the waste package standoffs from Type I faults and splays associated with Type I faults are altered by the Emplacement Drift System design, then this criterion will have to be revised.

II. Criterion Performance Parameter Basis

Title: Minimum Distance from Waste Packages to Type I Faults

Purpose

The purpose of this analysis is to identify the minimum distance allowed between waste packages and Type I faults encountered in the emplacement drifts.

Assumptions

None

Criterion Analysis

Type I faults, by definition ("Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geological Repository," p. 5), are "Faults or fault zones that are subject to displacement and of sufficient length and located such that they may affect repository design and/or performance." Only faults that are determined to be Type I are of regulatory concern and require consideration in repository

design. They could have an affect on repository performance, or could provide significant input into models used to assess repository performance. The first criterion for the identification of Type I faults addresses the seismic hazard component of faults and includes those that are subject to displacement. A fault that has evidence of displacement in the Quaternary Period is considered to be subject to displacement. The second criterion addresses the health and safety component and specifies that they are of sufficient length to potentially affect repository design and performance of SSCs important to safety, containment, or waste isolation. Faults must meet both of these criteria to be considered Type I faults ("Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geological Repository," p. 10).

Fault splays are also considered to be Type I because of their association with a Type I fault. The displacement hazard identified on these faults is through distributed faulting associated with slip on the nearby primary feature ("Seismic Design Basis Inputs for a High-Level Waste Repository at Yucca Mountain, Nevada," p. 4-8). However, it is also stated in this reference that away from primary faults, such as the Solitario Canyon and Bow Ridge, the displacement hazard is low.

Areas that contain Type I faults should be avoided ("Staff Technical Position on Consideration of Fault Displacement Hazards in Geological Repository Design," p. 4), but, if unavoidable, they must be allowed for in engineering design.

If fault splays encroach into the emplacement area and are predicted to have a low displacement hazard, they are not Type I faults. Fault splays may be a preferential pathway for water movement because of association with a Type I fault. The design shall provide for control of water intrusion ("Staff Technical Position on Consideration of Fault Displacement Hazards in Geological Repository Design," p. B-6). An offset of canisters from unavoidable Type I faults is considered prudent as a safeguard against this possible water intrusion.

The waste packages are to be offset from the edge of the fault or fault zone by 15 m (49 ft). Since the splays have a very low displacement hazard potential, the only potential hazard to be avoided is water entering the repository along these faults. If there is a water potential, it would be desirable to offset the waste packages from these areas to avoid water coming into contact with the waste packages, resulting in possible increased corrosion and escape of radionuclides. For engineering design, waste packages should be offset 5 m (16 ft) from the outside edge of any identified fault splay associated with a Type I fault. This offset would prevent water dripping on the waste packages and protect it from any pooling of water.

Conclusions

If a Type I fault is identified in the emplacement area, waste packages will be offset 15 m from the edge of the fault or fault zone.

If known fault splays from Type I faults are identified in the emplacement area, waste packages will be offset 5 m (16 ft) from the edge of the fault or fault zone.

1.2.2.1.6 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.C. 10 CFR 63.113(b) requires the engineered barrier system be designed to work in combination with the natural barriers to limit radioactive materials released from the geologic repository. Surface boreholes represent potential preferential pathways to the emplacement area. Therefore, a minimum standoff between emplacement drift openings and surface drilled boreholes will be maintained as a defense-in-depth measure. Therefore, this criterion is provided to ensure that a minimum standoff is maintained. The following analysis provides the minimum standoff that will be allowed in the design.

II. Criterion Performance Parameter Basis

Title: Minimum Distance from Borehole to Emplaced Waste Package

Purpose

The purpose of this analysis is to identify the minimum distance allowed between surface-based boreholes and waste packages in the emplacement drifts.

Assumptions

1. All boreholes in the vicinity of the repository will be surveyed for deviation to an accuracy of +/-1 m at a borehole depth of 300 m. This corresponds to a 2-m sphere of uncertainty at a depth of 300 m.

Rationale: This is reasonable accuracy that can easily be attained with industry-standard gyro deviation surveys. Past surveys of boreholes drilled on the project have had better accuracy than this assumption. For example, the forensic evaluation of the deviation survey log for borehole USW SD-9, "Forensic Evaluation of Geophysical Log Data for Borehole USW SD-9 in Support of the Yucca Mountain Site Characterization Project" (p. 8), identified a difference of less than 0.1 degree between down log and up log runs. This equates to a 0.5-m sphere of uncertainty at 300 m, or an accuracy of +/-0.25 m at that depth. The +/-1-m assumption is a conservative requirement when compared to actual project cases.

2. All surface-based boreholes that penetrate to within 100 m of the repository horizon (underground repository level), and lie within an area bounded by a distance of 400 m outside the repository emplacement area perimeter, will be sealed to limit vertical flow of water.

Rationale: This area within which boreholes are to be sealed is based on a study of requirements for repository seals ("Repository Seals Requirements Study," p. 6-5). Boreholes are to be sealed to minimize the potential that they become pathways that compromise the ability of the geologic repository to meet the performance objectives.

3. Borehole casing will be removed from all boreholes to be sealed.

Rationale: The removal of casing is based on "Repository Seals Requirements Study," p. 5-27. Casing is to be removed to avoid development of preferential pathways for seepage due to disintegration of the casing in place.

Criterion Analysis

The requirement for a borehole standoff distance from underground repository openings should consider potential effects on tunnel boring machine operation, hydrology, and rock integrity.

Because the casing will be removed from all the boreholes within the repository area prior to construction (Assumption 3), the boreholes will not affect tunnel boring machine operation.

Although boreholes in the vicinity of the repository will be sealed (Assumption 2), they may still provide a pathway for some water to enter the repository. This water could enter the borehole along fractures intersecting the boreholes and capture zone. Water flowing down the sealed borehole may be a result of substandard seal performance, or a result of poor sealing due to collapsing or bridging of the borehole when the casing is pulled.

In the emplacement drifts, the hydrologic effects of a borehole intercepting the opening would be of particular concern. Water entering the drifts could drip or run onto a waste package, promoting corrosion of the package and increasing the chance for the escape of radionuclides. Therefore, based on hydrologic considerations, waste packages should be offset from the boreholes to avoid water intrusions.

In an underground excavation, there is a zone of alteration or weakened rock surrounding the opening, which is a result of the excavation process. This altered zone, expressed as relative rock mass permeability, decreases on a logarithmic curve with increased distance from the excavation wall and is scaled to the diameter of the opening ("Modification of Rock Mass Permeability in the Zone Surrounding a Shaft in Fractured, Welded Tuff," p. 58). Likewise, boreholes have a zone of alteration surrounding them. It is reasonable to deduce that if a drift intersects with a borehole, the effect of the small zone of alteration around the borehole will be negligible compared to the disturbance caused by excavation of the drift. Thus, the minor effect of borehole drilling on local rock integrity need not be considered in determining minimum standoff distance for boreholes.

For long-term postclosure performance, the most important consideration is the potential for water intrusion to the waste packages. To protect the waste packages from the intrusion of water, the requirement should be to offset the waste packages from any boreholes that intercept or come close to the emplacement drift. The design offset is 5 m for any borehole intercepted by the emplacement drift. This standoff is the same as that required for waste package offset from splays associated with Type I faults, which are also potential flow paths for seepage. For boreholes that come close to an emplacement drift (closer than 5 m from the edge of the drift), the 5-m standoff will be applied to the perpendicular projection of the borehole to the drift. The uncertainty in location of the borehole (Assumption 1) must be accounted for in locating waste packages, to ensure meeting the offset criterion.

Conclusions

For the emplacement drifts, if a borehole is intercepted or comes within 5 m of the edge of an emplacement drift, the waste packages must be offset at least 5 m from the perpendicular projection of this borehole into the drift.

1.2.2.1.7 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.C and 10 CFR 63.113(b). Natural water infiltration is expected at the repository horizon. It is an objective of the repository design to minimize the amount of water accumulation in the emplacement area, thereby reducing the chance of contact with the waste packages. This system will be designed to ensure water drainage is not toward the emplacement area. Layout of the drifts cannot preclude water contact with the waste packages, but this criterion will reduce the chance of water flow being focused onto the emplacement area.

II. Criterion Performance Parameter Basis

N/A

1.2.2.1.8 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1.C and 10 CFR 63.113(b). The primary location shall be within the TSw2 geologic unit. The "Determination of Available Repository Siting Volume for the Site Recommendation," Section 5.2.3, concludes that the lower part of the lithophysal zone of the TSw1 unit and the entire TSw2 unit are suitable rock for the repository.

The "Determination of Available Repository Siting Volume for the Site Recommendation"" contains non-qualified inputs, but the stratigraphic constraint

provided in this criterion does not require additional qualification. It is established fact that the Yucca Mountain Site Characterization Project (YMP) will locate the repository primarily within the TSw2 unit. "Determination of Available Repository Siting Volume for the Site Recommendation," Section 5.2.3, indicates that the lithophysal zone within the TSw1 unit is similar to the lower lithophysal zone within the TSw2 unit.

II. Criterion Performance Parameter Basis

N/A

1.2.2.1.9 Criterion Basis Statement

I. Criterion Need Basis

This criterion supports MGR RD 3.1and 10 CFR 63.113(b). MGR RD 3.3.C requires a 200 m overburden for the perimeters of the drifts at the emplacement level. This criterion is provided to comply with this requirement.

II. Criterion Performance Parameter Basis

The 200 m is TBV and is established as a requirement in the MGR RD 3.3.C.

1.2.2.2.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed and fabricated using good engineering principles with particular attention to system safety. "Safety and Health Standards - Underground Metal and Non-metal Mines" (30 CFR 57 Section 11050(a)), requires at least two separate escapeways to the surface, which are so positioned that damage to one shall not lessen the effectiveness of the other(s). This feature is judged to be applicable to the MGR. A method of refuge shall be provided during the development of a heading when only one escapeway is obtainable. The design of this system determines the subsurface openings and layout.

II. Criterion Performance Parameter Basis

The "at least two" separate escapeways to the surface is provided in "Safety and Health Standards - Underground Metal and Non-metal Mines" (30 CFR 57 Section 11050(a)).

1.2.2.2.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed and fabricated using good engineering principles with particular attention to system safety. "Safety and Health

Standards - Underground Metal and Non-metal Mines" (30 CFR 57 Section 11050(b)) requires refuge areas for workers that cannot reach the surface from their work place, though at least two separate escapeways, within a time limit of one hour when using the normal exit method. 30 CFR 57.11050(b) states that refuges must be positioned so that the employee can reach one of them within 30 minutes from the time he leaves his workplace.

II. Criterion Performance Parameter Basis

"Safety and Health Standards - Underground Metal and Non-metal Mines" (30 CFR 57 Section 11050(b)) requires refuge areas for workers that cannot reach the surface from their work place, though at least two separate escapeways, within a time limit of one hour when using the normal exit method. The 30 minutes is provided in 30 CFR 57.11050(b).

1.2.2.2.3 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed and fabricated using good engineering principles with particular attention to system safety. The Mine Safety and Health Administration requires a method of refuge be provided for every employee who cannot reach the surface from his working place, through at least two separate escapeways, within a time limit of one hour when using the normal exit method ["Safety and Health Standards - Underground Metal and Non-metal Mines" (30 CFR 57 Section 11050(b)]. Refuge chambers must be positioned so that the employee can reach one of them within 30 minutes from the time he leaves his workplace if he cannot reach the surface in one hour.

II. Criterion Performance Parameter Basis

The distance an average worker can walk in 30 minutes is 2,100 m and is established in "Layout and Sizing of ESF Alcoves and Refuge Chambers," Section 7.2.4.1(A). The distance is TBV.

1.2.4.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed and fabricated using good engineering principles with particular attention to system safety. The layout of the underground facility has to accommodate the safe repository operations. This criterion implements the guidance provided in "MGR Compliance Program Guidance Package for the Subsurface Facility System," guidance statement 6.4g5. This system provides the subsurface layout which has to accommodate the Subsurface Ventilation System. For example, the layout has to consider the thermal loading strategy so that the temperature limit in the unrestricted access areas in the subsurface can be maintained. This criterion

is provided to ensure the Subsurface Facility System supports the design criteria of the Subsurface Ventilation System.

II. Criterion Performance Parameter Basis

N/A

1.2.4.2 Criterion Basis Statement

I. Criterion Need Basis

The design of this system is responsible for the grade of the excavated openings. The limiting determinant of grade is that which is required to support waste emplacement and retrieval operations. This criterion is provided to ensure the maximum grade of the access mains and emplacement drifts do not exceed the limit for waste emplacement and retrieval operations. The analysis below provides the maximum grades allowed for the South Ramp, emplacement drifts, and other openings providing rail transport.

II. Criterion Performance Parameter Basis

The maximum grade for the Waste Emplacement/Retrieval System is +/-2.7 percent for the portions that use the South Ramp. The "Waste Emplacement/Retrieval System Description Document," Section 1.2.4.4, requires that the Waste Emplacement/Retrieval System be able to negotiate a slope of +/-2.7 percent as it is required to retrieve waste canisters from both the North and South Ramps.

Waste Emplacement/Retrieval System to be able to negotiate a +/-2.5 percent grade for portions that will not use the South Ramp. The Exploratory Studies Facility's South Ramp is steeper than the North Ramp. Therefore, all other openings requiring rail transport must be limited to the maximum grade of +/-2.5 percent and not +/-2.7 percent. The +/-2.5 percent basis is provided in Section 1.2.4.3 of the "Waste Emplacement/Retrieval System Description Document."

The Waste Emplacement/Retrieval System will be designed to operate with a maximum grade of +/-1 percent in the emplacement drifts. The +/-1 percent grade is provided in Section 1.2.4.3 of the "Waste Emplacement/Retrieval System Description Document." Thus, the Subsurface Facility System must limit the grades in the emplacement drifts to +/-1 percent or less.

1.2.4.3 Criterion Basis Statement

I. Criterion Need Basis

The subsurface openings' final sizes are design solution dependent. There is no basis for establishing the opening sizes as design criteria in Section 1.2 of this system description document. However, the subsurface openings have to be designed to accommodate

repository operations. This criterion implements the guidance provided in "MGR Compliance Program Guidance Package for the Subsurface Facility System," guidance statement 6.4g6 by allowing accessibility for maintenance. This criterion is provided to ensure the excavated openings are, as a minimum, sized and shaped to accommodate the operating envelopes for each opening after accounting for ground control installation.

II. Criterion Performance Parameter Basis

N/A

1.2.4.4 Criterion Basis Statement

I. Criterion Need Basis

The "Thermal Loading Study for FY 1996," Section 3.2.4, states that the mineralogic conversion of clinoptilolite to analcime is to be limited. Analcime has poor sorptive properties. The study also states that the conversion may take place above 90 degrees C. Although the Emplacement Drift System is primarily responsible for the temperature in the zeolitized layer, the distance between the emplacement area and the zeolitized layer impacts temperature. This criterion is provided to ensure the emplacement area location does not preclude the Emplacement Drift System from limiting the temperature in this area.

II. Criterion Performance Parameter Basis

N/A

1.2.4.5 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.2.F limits the temperature at 45-cm below the surface to 2 degrees C above the established naturally occurring pre-emplacement average annual ground surface temperature. This criterion is provided to ensure the repository layout accommodates the Emplacement Drift System temperature constraint on surface ground temperature. Although the temperature effects are primarily from the thermal loading of the repository, a portion of the rock temperature is from the location of the waste packages within the drift. Although a temperature analysis has not been performed to evaluate these effects, the MGR RD bounding requirements provide a suitable criterion.

II. Criterion Performance Parameter Basis

The thermal bounds on the soil temperature are provided by the MGR RD 3.2.F.

1.2.4.6 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to ensure the layout does not interfere with the Emplacement Drift System's temperature limits in the PTn geologic unit. The effects of temperature changes in the PTn geologic unit have not been fully studied. This criterion ensures the Emplacement Drift System meets its temperature limit for the PTn geologic unit.

II. Criterion Performance Parameter Basis

N/A

1.2.4.7 Criterion Basis Statement

I. Criterion Need Basis

This criterion is provided to ensure that the orientation of the accesses relative to the emplacement drifts will support waste emplacement and retrieval operations and is considered in the design. Waste emplacement operations could be adversely affected or involve unnecessary difficulties if the access orientation angles are not optimized; that is, minimize the difficulties for waste emplacement and potential retrieval operations in the emplacement drifts. The actual orientations that will be allowed are dependent on final waste emplacement and waste retrieval design solutions.

II. Criterion Performance Parameter Basis

N/A

1.2.4.8 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to preserve the integrity of the natural barrier, as discussed in the Assessment of Goals (p. 10) in the "Site Characterization Plan Thermal Goals Reevaluation." The following discussion is paraphrased from that document. The potential repository will initially be surrounded by relatively undisturbed rock formations. After waste emplacement begins, the repository will locally heat up and expand. If this expansion is sufficient, this can result in large horizontal stresses developing in the far field and an uplift in the repository region. If this uplift is large enough, it could cause the rock above the repository, especially the non-welded PTn units, to extend, resulting in fracturing of the units. This would damage the principal natural barrier above the potential repository, and could result in the opening of preferential pathways for water infiltration, or pathways for gas migration.

II. Criterion Performance Parameter Basis

N/A

1.2.4.9 Criterion Basis Statement

I. Criterion Need Basis

This system interfaces with the Subsurface Excavation System to accommodate repository openings. This criterion ensures the layout design addresses the location needs of miscellaneous construction openings required to support repository construction.

II. Criterion Performance Parameter Basis

N/A

1.2.6.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.E requires compliance with the applicable provisions of "Occupational Safety and Health Standards" (29 CFR 1910). This criterion invokes applicable requirements on this system.

II. Criterion Performance Parameter Basis

N/A

1.2.6.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.F requires compliance with the applicable provisions of "Safety and Health Regulations for Construction" (29 CFR 1926). This criterion invokes the applicable section of 29 CFR 1926 to the design of this system.

II. Criterion Performance Parameter Basis

N/A

1.2.6.3 Criterion Basis Statement

I. Criterion Need Basis

The "Monitored Geologic Repository Project Description Document" allocates controlled project assumptions to systems. This criterion identifies the need to comply with the

applicable assumptions identified in the subject document. The approved assumptions will provide a consistent basis for continuing the system design.

II. Criterion Performance Parameter Basis

N/A

APPENDIX B ARCHITECTURE AND CLASSIFICATION

The system architecture and QA classification are identified in Table 9. The QA classifications are established in "Classification of the MGR Subsurface Facility System."

Table 9. System Architecture and QA Classification

Subsurface Facility System	QL-1	QL-2	QL-3	CQ
Emplacement Drifts	X			
Mains & Raises				X
Miscellaneous Support Openings				X
Performance Confirmation Openings				X
Portals and Access Ramps				X
Ventilation Shafts				X

APPENDIX C ACRONYMS, SYMBOLS, AND UNITS

C.1 ACRONYMS

ALARA	As Low As Reasonably Achievable
AP	Absorber Plates included in waste package
BWR	Boiling Water Reactor
CQ	Conventional Quality
CR	Control Rods included in waste package
CFR	Code of Federal Regulations
CPA	Controlled Project Assumption
DHLW	Defense High-Level Waste
DSNF	Defense Spent Nuclear Fuel
DOE	U. S. Department of Energy
EBS	Engineered Barrier System
EFS	Exploratory Studies Facility
F	Function
HLW	High Level Waste
IP	Immobilized Plutonium
IPWF	Immobilized Plutonium Waste Form
MCO	Multi-Canister Overpak
MGR	Monitored Geologic Repository
MGR RD	Monitored Geologic Repository Requirements Document
MTHM	Metric Tons Heavy Metal
NRC	Nuclear Regulatory Industry
P	page
PWR	Pressurized Water Reactor
PTn	Paintbrush tuff nonwelded
QA	Quality Assurance
QL	Quality Level
SDD	System Description Document
SSCs	Structures, Systems, and Components
SNF	Spent Nuclear Fuel
TBD	To Be Determined
TBM	Tunnel Boring Machine
TBV	To Be Verified
TSw1	Topopah Spring welded, lithophysae-rich thermal mechanical unit 1
TSw2	Topopah Spring welded, lithophysae-poor thermal mechanical unit 2
YMP	Yucca Mountain Site Characterization Project
WP	Waste Package

C.2 SYMBOLS AND UNITS

%	percent
C	Celsius
cm	centimeter

ft	feet
hr	hour
kW	kilowatt
m	meter
mrem	millirem
m/s	meters per second
rem	Roentgen equivalent man
kW/m	kilowatts per meter
yr	year

APPENDIX D FUTURE REVISION RECOMMENDATIONS AND ISSUES

This appendix identifies issues and actions that require further evaluation. The disposition of these issues and actions could alter the functions and design criteria that are allocated to this system in future revisions to this document. However, the issues and actions identified in this appendix do not require TBDs or TBVs beyond those already identified.

Issue 1 – Resolve the outstanding TBDs and TBVs.

Issue 2 - The thickness of the zeolitized layer within the Calico Hills is of variable thickness. It may be appropriate to apply the temperature limit only to fixed lower thickness zone.

Issue 3 – The maximum radiation levels in restricted and unrestricted access areas are based on an analysis, which is provided in this document. The results of the analysis do not require a TBV, but the project ALARA (as low as reasonably achievable) program, once established, could supersede the results of this analysis.

Issue 4 – The Test & Evaluation criterion should be moved to a subsystem section and the requirement revised to address the individual requirements for Test & Evaluation facilities.

Issue 5 – A evaluation is needed to determine if the rate of travel of subsurface personnel for exiting the subsurface repository via shafts is the same as for drifts/ramps.

APPENDIX E REFERENCES

This section provides a listing of references used in this SDD. References list the Accession number or Technical Information Catalog number at the end of the reference, where applicable.

"ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study." CRWMS M&O. CAL-EBS-MG-000001, Rev. 00. December 9, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000119.0134.

"Calculation of Effective Areas of Subsurface Openings During Emplacement Mode." CRWMS M&O. BCAA00000-01717-0210-00002, Rev. 00. 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990302.0101.

"Classification of the MGR Subsurface Facility System." CRWMS M&O. ANL-SFS-SE-000001, Rev. 00. August 31, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0214.

"Determination of Available Repository Siting Volume for the Site Recommendation." CRWMS M&O. TDR-NBS-GS-000003, Rev. 00. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: URN-0395.

"Forensic Evaluation of Geophysical Log Data for Borehole USW SD-9 in Support of the Yucca Mountain Site Characterization Project." CRWMS M&O. BAAA00000-01717-0200-00005, Rev. 00. June 6, 1996. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19970606.0345.

"Geological Society of America Bulletin." Fossil Spring Deposits in the Southern Great Basin and Their Implications for Changes in Water-Table Levels Near Yucca Mountain, Nevada, During Quaternary Time. Quade, Jay; Mifflin, Martin D.; Pratt, William L.; McCoy, William; and Burckle, Lloyd. Volume 107, no. 2. February 1995. Boulder, Colorado: Geological Society of America. TIC: 234256 (pp. 213-230).

"High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference, Las Vegas, Nevada, April 26-30, 1993." Late Quaternary History and Uranium Isotopic Compositions of Ground Water Discharge Deposits, Crater Flat, Nevada. Paces, James B.; Taylor, Emily M.; and Bush, Charles. 1993. La Grange Park, Illinois: American Nuclear Society. TIC: 208542 (Volume 2).

"High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference, Las Vegas, Nevada, April 26-30, 1993." Strontium Isotopic Evidence for a Higher Water Table at Yucca Mountain. Marshall, Brian D.; Peterman, Zell E.; and Stuckless, John S. 1993. La Grange Park, Illinois: American Nuclear Society. TIC: 208542 (Volume 2).

"Information Requested by Yucca Mountain Site Characterization Office for Use in the Repository Environmental Impact Statement (EIS)." Guida, Richard A. July 3, 1997. Washington, D.C.: U.S. Department of Energy, Office of Naval Reactors. ACC: MOL.19981105.0299.

"Layout and Sizing of ESF Alcoves and Refuge Chambers." CRWMS M&O. BABEA0000-01717-0200-00001, Rev. 00. August 25, 1995. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960328.0030.

"MGDS Subsurface Radiation Shielding Analysis." CRWMS M&O. BCAE00000-01717-0200-00001, Rev. 00. June 26, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971204.0497.

"MGR Compliance Program Guidance Package for the Subsurface Facility System." CRWMS M&O. BCA000000-01717-5600-00007, Rev. 00. October 14, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991029.0159.

"Mine Ventilation and Air Conditioning." Hartman, H.L.; Ramani, R.V.; Mutmansky, J.M.; and Wang, Y.J. 3rd Edition. 1997. New York, New York: Johnn Wiley & Sons. TIC: 236391.

"Modification of Rock Mass Permeability in the Zone Surrounding a Shaft in Fractured, Welded Tuff." Case, J.B. and Kelsall, P.C. SAND86-7001. 1987. Albuquerque, New Mexico: IT Corporation, Sandia National Laboratory. ACC: HQS.19980517.2264.

"Monitored Geologic Repository Project Description Document." CRWMS M&O. TDR-MGR-SE-000004, Rev. 01 ICN 01. June 2000. Las Vegas, Nevada: CRWMS M&O. ACC: URN-0377.

"Monitored Geologic Repository Requirements Document." U.S. Department of Energy. YMP/CM-0025, Rev. 3, DCN 02. May 2000. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office. ACC: URN-0376.

"Occupational Safety and Health Standards." Occupational Safety and Health Administration, Department of Labor. 29 CFR 1910. July 1, 1999. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"Preliminary Design Basis for WP Thermal Analysis." CRWMS M&O. BBAA00000-01717-0200-00019, Rev. 00. October 30, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980203.0529.

"Quality Assurance Requirements and Description." U.S. Department of Energy. DOE/RW-0333P, Rev. 10. April 2000. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000427.0422.

"Repository Seals Requirements Study." CRWMS M&O. BC0000000-01717-5705-00018, Rev. 00/DCN 1. November 3, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980224.0346.

"Repository Subsurface Layout Configuration Analysis." CRWMS M&O. BCA000000-01717-0200-00008, Rev. 00. July 17, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971201.0879.

"Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." U.S. Department of Energy. OL&RC:SB-1714. September 3, 1999. North Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office. ACC: MOL.19990910.0079.

"Revised Waste Package Lengths." CRWMS M&O. 00309.T. June 26, 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000626.0298.

"Safety and Health Regulations for Construction." Occupational Safety and Health Administration, Department of Labor. 29 CFR 1926. July 1, 1999. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"Safety and Health Standards. Underground Metal and Non-metal Mines." Mine Safety and Health Administration, Department of Labor. 30 CFR 57. 1997. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"SDD Development/Maintenance (Q SDDs) (WP# 16012126M5)." CRWMS M&O. October 11, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991025.0001.

"Seismic Design Basis Inputs for a High-Level Waste Repository at Yucca Mountain, Nevada." CRWMS M&O. B00000000-01727-5700-00018, Rev. 0. February 23, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980806.0711.

"Site Characterization Plan Thermal Goals Reevaluation." CRWMS M&O. B00000000-01717-5705-00005, Rev. 00. September 8, 1993. Las Vegas, Nevada: CRWMS M&O. ACC: NNA.19931208.0034.

"Site Recommendation Subsurface Layout." CRWMS M&O. ANL-SFS-MG-000001, Rev. 00. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: URN-0220.

"Staff Technical Position on Consideration of Fault Displacement Hazards in Geologic Repository Design." McConnell, K. I. and Lee, M. P. NUREG-1494. 1994. Washington, D.C.: Nuclear Regulatory Commission. TIC: 212360.

"Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geological Repository." McConnell, K. I., Blackford, M. E., et al. NUREG-1451. 1992. Washington, D.C.: Nuclear Regulatory Commission. TIC: 204829.

"Standards for Protection Against Radiation." U.S. Nuclear Regulatory Commission. 10 CFR 20. January 1, 1999. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"Subsurface Facility Planning Layout in Support of ANL-SFS-MG-000001, Rev 00." CRWMS M&O. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0387.

"Subsurface Ventilation and Environmental Engineering." McPherson, M.J.. 1993. New York, New York: Chapman & Hall. TIC: 215345.

"TBV-361 Resolution Analysis: Emplacement Drift Orientation." CRWMS M&O. B00000000-01717-5705-00136, Rev. 00. July 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990802.0316.

"Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion." CRWMS M&O. YMP/TBR-0001, Rev. 0. April 1995. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19951201.0049.

"Technical Reports." U.S. Department of Energy, Office of Civilian Radioactive Waste Management. AP-3.11Q, Rev. 1, ICN 0. May 16, 2000. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000516.0008.

"Thermal Loading Study for FY 1996." CRWMS M&O. B00000000-01717-5705-00044, Rev. 01. November 8, 1996. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19961217.0121.

"Waste Emplacement/Retrieval System Description Document." CRWMS M&O. SDD-WES-SE-000001, Rev. 00. February 11, 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000214.0302.