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The following TBDs/TBVs are contained in this document:

TBD-327; TBD-328; TBD-3552;TBD-3558; TBD-3888

TBV-329; TBV-3756, TBV-5036.

1. SDD Title
Ground Control System Description Document

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3. Revision	4. Description of Revision
00	Initial Issue. This document was previously issued using document identifiers BCA000000-01717-1705-00011. 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 This document is a complete rewrite of the superseded documents, driven largely by the use of an alternate source of regulatory requirements, the implementation of the License Application Design Selection effort,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 incorporates the applicable changes in revision 01 ICN 01 of "Monitored Geologic Repository Project Description Document. The entire reference section was revised to include the references used in Section 2. The entire Document Input Reference Sheet was revised. Editorial changes (such as new table numbering scheme) and non-editorial changes (such as the addition and deletion of TBVs and TBDs) were made throughout the document.
01 ICN 01	The purpose of this ICN is to incorporate changes contained in Revision 02 ICN 02 of the "Monitored Geologic Repository Project Description Document." These changes support the Flexible Operations Concept. All changes in the document that have been made as a result of this ICN are indicated by revision bars.

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SUMMARY

The Ground Control System contributes to the safe construction and operation of the subsurface facility, including accesses and waste emplacement drifts, by maintaining the configuration and stability of the openings during construction, development, emplacement, and caretaker modes for the duration of preclosure repository life. The Ground Control System consists of ground support structures installed within the subsurface excavated openings, any reinforcement made to the rock surrounding the opening, and inverts if designed as an integral part of the system.

The Ground Control System maintains stability for the range of geologic conditions expected at the repository and for all expected loading conditions, including in situ rock, construction, operation, thermal, and seismic loads. The system maintains the size and geometry of operating envelopes for all openings, including alcoves, accesses, and emplacement drifts. The system provides for the installation and operation of sensors and equipment for any required inspection and monitoring. In addition, the Ground Control System provides protection against rockfall for all subsurface personnel, equipment, and the engineered barrier system, including the waste package during the preclosure period.

The Ground Control System uses materials that are sufficiently maintainable and that retain the necessary engineering properties for the anticipated conditions of the preclosure service life. These materials are also compatible with postclosure waste isolation performance requirements of the repository.

The Ground Control System interfaces with the Subsurface Facility System for operating envelopes, drift orientation, and excavated opening dimensions, Emplacement Drift System for material compatibility, Monitored Geologic Repository Operations Monitoring and Control System for ground control instrument readings, Waste Emplacement/Retrieval System to support waste emplacement operations, and the Subsurface Excavation System for ground control installation.

QUALITY ASSURANCE

The quality assurance (QA) program applies to the development of this document. The ”Technical Work Plan For Subsurface Design Section FY 01 Work Activities” (WP#12112124MI) 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 criteria for the Ground Control System are identified in the following sections. Throughout this document the term "system" shall be used to indicate the Ground Control System. The system architecture and classification are presented in Appendix B.

1.1 SYSTEM FUNCTIONS

1.1.1 The system provides structural support for the subsurface repository openings.

1.1.2 The system provides protection against rock falls, loosening of blocks, and fracturing and surface deterioration of the rock mass surrounding each opening.

1.1.3 The system maintains adequate subsurface operating envelopes.

1.1.4 The system provides for monitoring of ground control performance parameters.

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 imposed on the design of this system, refer to Appendix E.

1.2.1 System Performance Criteria

1.2.1.1 The system shall maintain the operating envelopes shown in Tables 1 and 2 while allowing for the expected variations in excavated dimensions, lining thickness, alignment, and deformation. TBV-329 and TBD-327 have been assigned.

NOTE: The operating envelopes provided in Tables 1 and 2 are based on the maximum expected space required for repository subsurface activities in the respective area. The envelopes below are not the actual excavated opening dimensions. The Subsurface Facility System controls the excavated opening dimensions.

Table 1. Operating Envelopes for Non-Alcove Openings

Type of Opening	Dimensions & Shape of Envelope (Above Invert)(1)
Emplacement Drifts	5.1 m diameter circle (TBV)
Access Mains/Portals and Access Ramps	
Ramps & Mains (2)	7.02 m diameter circle (TBV)
Miscellaneous Support Openings	
TBM Assembly & Disassembly Chambers (3) a) Lead-in Section b) Assembly/Disassembly Section c) Launch Section	a) 6.6 m wide x 6.5 m high horseshoe (TBV) b) 10.42 m wide x 10.41 m high horseshoe (TBV) c) 7.6 m wide x 7.5 m high horseshoe (TBV)
Emplacement Drift Turnouts a) Cross Section at Curved Portion b) Cross Section at Straight Portion	a) 7.6 m wide x 5.9 m high rectangle with rounded upper corners (TBV) b) 7.6 m wide x 6.5 m high horseshoe (TBV)
Access Drift	6.6 m wide x 6.5 m high horseshoe (TBV)
Observation Drifts	(TBD) wide x (TBD) high rectangle with rounded roof.
Ventilation Shafts	
Ventilation Shafts(2)	6.1 m diameter circle (TBV)
Exhaust Air Mains & Raises	
Ventilation Raises	1.7 m diameter circle (TBV)
Exhaust Main(s)(2)	7.02 m diameter circle (TBV)

(1) Referenced figures are in "Operating Envelopes for Non-Alcove and Alcove Subsurface Openings "
(2) Development operating envelopes could bound emplacement operating envelopes
(3) TBM chamber dimensions are set by construction needs. These openings will be maintained as travel ways during repository operations.

Table 2. Operating Envelopes for Alcove Openings

Type of Alcove	Dimensions & Shape of Envelope
Miscellaneous Support Openings	
Equipment Decontamination	7.5 m wide x 7.0 m high horseshoe, 21 m long (All TBV)
Personnel Decontamination	3.7 m wide x 3.7 m high horseshoe, 4.0 m long (All TBV)
Electrical Equipment	4.5 m wide x 4.5 m high horseshoe, 8.5 m & 14.0 m long (All TBV)
Borehole	(TBD) Diameter x (TBD) Maximum Length
Personnel Refuge	3.7 m wide x 3.7 m high horseshoe (Both TBV), (TBD) long
Water Collection Sump/Tank a) Sump Part b) Tank Part	a) 1.22 m wide x 1.58 m high rectangle, 10.31 m long (All TBV) b) 3.79 m wide x 3.35 m high rectangle, 9.5 m long (All TBV)
ESF Testing	(All dimensions TBD)

NOTE: See Appendix C for acronym definitions.

[F 1.1.3][MGR RD 3.1.C][10 CFR 63.111(e)(1)]

1.2.1.2 The system shall accommodate geologic mapping of emplacement drifts so the maximum distance between mapped emplacement drifts does not exceed 300 m, geologic mapping of 100 percent of non-emplacement drift openings, and observation/recording of rock mass conditions during construction.

[MGR RD 3.1.C][10 CFR 63.132(a)]

1.2.1.3 The system shall provide for the monitoring of ground control performance parameters including, as a minimum, opening convergence, ground support and rock temperatures, and ground support loads.

[F 1.1.4][MGR RD 3.1.C][10 CFR 63.111(d), 63.132(e)]

1.2.1.4 Emplacement drift ground support shall be carbon steel (steel sets and/or rock bolts and mesh).

NOTE: This criterion does not preclude the use of structural concrete for ground support in other subsurface openings.

[F 1.1.1]

1.2.1.5 The system shall use cementitious grout to anchor the permanent rock bolts.

[F 1.1.1]

1.2.1.6 The system shall be designed for the appropriate worst case combination of the corresponding loads defined in Tables 3 through 6. The TBD and TBV values are assigned tracking number TBD-328 and TBV-5036.

Table 3. In Situ Loads

Type of Load	Load Value or Source of Value
In situ rock stress	Technical Data Base (“In Situ Rock Conditions,” DTN: MO0007RIB00077.000) (TBV-5036)

Table 4. Construction Loads

Type of Opening(s)	Type of Load	Load
Emplacement drift	TBM wheel load*	TBD
TBM Assembly/ Disassembly Chambers	TBM wheel load*	TBD

* Applicable only if the invert is an integral part of the ground support system.
NOTE: See Appendix C for acronym definitions.

Table 5. Operational Loads for Non-Alcove Openings

Type of Opening	Type of Load	Load
Emplacement drifts	Gantry wheel load (loaded)*	TBD
	Gantry wheel tractive load*	TBD
	Gantry rail lateral load*	TBD
	Gantry wheel impact load* a) Due to dead load motion b) Due to live load motion	TBD
	Waste package support load	TBD
	Uniform load on steel invert cover plate	TBD
Turnouts, ramps, & access mains & drifts	Waste package transporter wheel (loaded)* Dead Load Dead load impact Live load impact	TBD
Development & emplacement ventilation shafts	a) Dead load per unit length of shaft b) Live load	TBD
Ventilation raises	Dead load per unit length of raise	TBD
Exhaust main	Maintenance vehicle wheel load*	TBD
Observation drifts**	(TBD)	TBD

* Applicable only if the invert is an integral part of the ground support system.
** Performance Confirmation Drifts

Table 6. Thermal Loads and Loading Considerations

Type of Opening	Temperature Constraints
Emplacement drifts: Heating	TBD
Emplacement Drifts: Cooling & Reheating Cycles	TBD
Non-emplacement openings: Heating & Cooling	TBD

[MGR RD 3.1.C, 3.3.A][10 CFR 63.111(a)(2), 63.111(b)(2)]

1.2.1.7 The system shall limit the maximum emplacement drift wall temperature to 96 degrees Celsius during the preclosure period.

[F 1.1.1]

1.2.1.8 The system shall be designed to allow flexibility of operations within the following range of thermal modes during preclosure and postclosure:

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

[F 1.1.1]

1.2.1.9 The system shall be designed for a maximum emplacement drift wall temperature of 200 degrees Celsius during the postclosure period if a higher thermal mode is selected.

[F 1.1.1]

1.2.2 Safety Criteria

1.2.2.1 Nuclear Safety Criteria

1.2.2.1.1 The system shall be designed to prevent a 6 metric ton rock from falling more than 3.3 meters in the emplacement drifts during the preclosure period.

[F 1.1.2][MGR RD 3.1.C][10 CFR 63.112(e)(8)]

1.2.2.1.2 The system shall use materials having acceptable (i.e., acceptability based on the results of waste isolation site impact evaluations) long-term effects on waste isolation.

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

1.2.2.1.3 The SSCs important to safety shall be designed to withstand a design basis earthquake of Frequency Category 1 or Frequency Category 2, as appropriate to the seismic frequency classification assigned to a specific structure, system, and component.

[MGR RD 3.1.C][10 CFR 63.111(a)(2), 63.111(b)(2), 63.112(e)(8)]

1.2.2.2 Non-Nuclear Safety Criteria

1.2.2.2.1 The system shall be designed to prevent rock falls that could potentially result in personnel injury.

[F 1.1.2][MGR RD 3.3.A]

1.2.2.2.2 The system shall include provisions which allow the repository to remain open for up to 300 years following final waste emplacement, with appropriate monitoring and maintenance.

[MGR RD 3.2.H]

1.2.2.2.2 The system shall use noncombustible and heat resistance material as defined by “Standard Test Method for Behavior of Material in a Vertical Tube Furnace at 750°C.”(ASTM E 136-98)

[MGR RD 3.3.A]

1.2.2.2.4 Reserved

1.2.3 System Environment Criteria

1.2.3.1 The system shall be designed considering the TBD-3552 (pre-emplacement) rock temperature profiles as applicable.

[F 1.1.1]

1.2.3.2 The system shall be designed considering an outside air temperature environment of -15 degrees C to 47 degrees C.

[F 1.1.1]

1.2.3.3 The system shall be designed considering a maximum dominant relative humidity of TBD-3558.

[F 1.1.1]

1.2.3.4 The emplacement drift ground support shall be designed for TBD-3888 radiation.

[F 1.1.1]

1.2.3.5 The system shall be designed for the types of rock properties and temperatures listed below in Tables 7, 9, 10, 11, and 12 (TBV-3756).

Table 7. Rock Parameters for Thermal Analyses

Type of Parameter
Bulk Density
Thermal Conductivity
Specific Heat

Table 8. Rock Units to Be Included in Thermal and Thermomechanical Analyses

TM Unit*	LS Unit**
TCw	Tpcrv
	Tpcrn
	Tpcpul
	Tpcpmn
	Tpcpll
	Tpcpln
	Tpcpv

Table 8. Rock Units to Be Included in Thermal and Thermomechanical Analyses, continued

<table>
<tr><th>TM Unit*</th><th>LS Unit**</th></tr>
<tr><td rowspan="7">PTn</td><td>Tpcpv1</td></tr>
<tr><td>Tpbt4</td></tr>
<tr><td>Tpy</td></tr>
<tr><td>Tpbt3</td></tr>
<tr><td>Tpp</td></tr>
<tr><td>Tpbt2</td></tr>
<tr><td rowspan="2">Tptrv</td></tr>
<tr><td rowspan="4">TSw1</td></tr>
<tr><td>Tptrn</td></tr>
<tr><td>Tptrl</td></tr>
<tr><td>Tptpul</td></tr>
<tr><td rowspan="3">TSw2</td><td>Tptpmn</td></tr>
<tr><td>Tptpll</td></tr>
<tr><td>Tptpln</td></tr>
<tr><td>TSw3</td><td rowspan="2">Tptpv</td></tr>
<tr><td rowspan="4">CHn1</td></tr>
<tr><td>Tpbt1</td></tr>
<tr><td>Tac(v)</td></tr>
<tr><td>Tac(z)</td></tr>
<tr><td>CHn2</td><td>Tacbt</td></tr>
</table>

* TM = Thermomechanical
** LS = Lithostratigraphic

Table 9. Rock Mass Thermomechanical and Mechanical Properties for TCw, PTn, TSw1, TSw2 Units (Continuum Rock Mass Models)

Type of Parameter
Modulus of Elasticity*
Poisson's Ratio*
Cohesion*
Friction Angle*
Tensile Strength*
Dilation Angle*
Coefficient of Thermal Expansion**

* Rock mass quality categories 1 through 5 are needed to model the probable ranges of potential rock mass characteristics.
** Values for each of the temperature ranges listed in Table 12 are needed to model potential variation in this coefficient with temperature.

Table 10. Intact Rock Mechanical Properties for Mainly TSw2 Units (Discontinuum Rock Mass Models)

Type of Parameter
Coefficient of Thermal Expansion
Modulus of Elasticity
Poisson's Ratio
Cohesion
Friction Angle
Tensile Strength
Dilation Angle
Coefficient of Thermal Expansion*

* Values for each of the temperature ranges listed in Table 12 are needed to model potential variation in this coefficient with temperature.

Table 11. Rock Joint Parameters and Properties for TM Units (Discontinuum Rock Mass Models)

Type of Parameter
Cohesion
Friction Angle
Tensile Strength
Normal Stiffness
Shear Stiffness
Orientation
Spacing

Table 12. Temperature Ranges for Values of Coefficient of Thermal Expansion for TM Unit

Temperature Range (degrees C)
25 - 50
50 - 75
75 - 100
100 - 125
125 - 150
150 - 175
175 - 200

1.2.4 System Interfacing Criteria

1.2.4.1 The system shall interface with the Subsurface Facility System to accommodate drift orientation and configuration and excavated opening sizes.

[F 1.1.4][MGR RD 3.3.A]

1.2.4.2 The system shall interface with the Emplacement Drift System to ensure compatible ground control material.

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

1.2.4.3 The system shall interface with the MGR Operations Monitoring and Control System, using appropriate signal protocols, to ensure proper transmission of ground control instrument readings.

[F 1.1.4]

1.2.4.4 The system shall interface with the Waste Emplacement/Retrieval System to support waste emplacement operation.

[MGR RD 3.3.A]

1.2.4.5 The system shall interface with the Subsurface Excavation System to ensure safe ground support installation.

[MGR RD 3.3.A]

1.2.5 Operational Criteria

1.2.5.1 The ground control system for emplacement drifts shall be designed to function without planned maintenance while providing for the ability to perform unplanned maintenance in the emplacement drifts on an as-needed basis.

[F 1.1.1][MGR RD 3.3.A]

1.2.5.2 The system shall accommodate maintenance of non-emplacement openings.

[F 1.1.1]

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 provisions of "Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)."

[MGR RD 3.3.A]

1.2.6.3 The system shall comply with the applicable provisions of "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-97) and Commentary--ACI 349R-97" (ACI 349R-97).

[MGR RD 3.3.A]

1.2.6.4 The system shall comply with the applicable provisions of "Guide to Shotcrete" (ACI 506R-90(95)).

[MGR RD 3.3.A]

1.2.6.5 The system shall comply with the applicable provisions of "Manual of Steel Construction, Allowable Stress Design."

[MGR RD 3.3.A]

1.2.6.6 The system shall comply with the applicable provisions of "American National Standard for Nuclear Facilities - Steel Safety-Related Structures for Design Fabrication and Erection" (ANSI/AISC N690-1984).

[MGR RD 3.3.A]

1.2.6.7 The system shall be designed in accordance with applicable sections of "Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures" (ACI 209R-92).

[MGR RD 3.3.A]

1.2.6.8 The system shall be designed in accordance with applicable sections of "Specification for Shotcrete" (ACI 506.2-95).

[MGR RD 3.3.A]

1.2.6.10 The system shall be designed in accordance with applicable sections of "Standard Specification for Steel Fibers for Fiber-Reinforced Concrete" (ASTM A820-96).

[MGR RD 3.3.A]

1.2.6.11 The system shall be designed in accordance with applicable sections of the "Department of Defense Design Criteria Standard, Human Engineering" (MIL-STD-1472E).

[MGR RD 3.3.A]

1.2.6.12 The system shall be designed in accordance with applicable sections of "Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities" (UCRL-15673).

[MGR RD 3.3.A]

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

1.2.6.14 The system shall be designed in accordance with applicable sections of "Standard Specification for Carbon Structural Steel" (ASTM A 36/A 36M-97a).

[MGR RD 3.3.A]

1.2.6.15 The system shall be designed in accordance with applicable sections of "Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement" (ASTM A185-97).

[MGR RD 3.3.A]

1.2.6.16 The system shall be designed in accordance with applicable sections of "Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel" (ASTM A 572/A 572M-99a).

[MGR RD 3.3.A]

1.2.6.17 The system shall be designed in accordance with applicable sections of "Standard Specification for Portland Cement" (ASTM C 150-99a).

[MGR RD 3.3.A]

1.2.6.18 The system shall be designed in accordance with applicable sections of "Standard Specification for Chemical Admixtures for Concrete" (ASTM C 494-98a).

[MGR RD 3.3.A]

1.2.6.19 The system shall be designed in accordance with applicable sections of "Standard Specification for Expansive Hydraulic Cement" (ASTM C 845-96).

[MGR RD 3.3.A

1.2.6.19 The system shall be designed in accordance with applicable sections of “Standard Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout” (ASTM C 1240-99).

[MGR RD 3.3.A]

1.2.6.20 The system shall be designed in accordance with applicable sections of “Standard Specification for Roof and Rock Bolts and Accessories” (ASTM F 432-95).

[MGR RD 3.3.A]

1.2.6.21 The system shall be designed in accordance with applicable sections of “Guide to Durable Concrete” (ACI 201.2R-92).

[MGR RD 3.3.A]

1.2.6.22 The system shall be designed in accordance with applicable sections of “Standard Practice for the Use of Shrinkage-Compensating Concrete” (ACI 223-98).

[MGR RD 3.3.A]

1.2.6.23 The system shall design non-important to safety ground support using the applicable seismic sections of the “1997 Uniform Building Code." Volume 2, "Structural Engineering Design Provisions.”

[MGR RD 3.3.A]

1.3 SUBSYSTEM DESIGN CRITERIA

There are no subsystem design criteria for this system.

1.4 CONFORMANCE VERIFICATION

This section will be provided in a future 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 Ground Control System consists of ground support structures installed within the subsurface excavated openings, any reinforcement made to the rock surrounding the openings, and non-emplacement inverts designed as an integral part of the system. The system supports the safe construction and operation of the subsurface facility by maintaining the configuration and stability of the openings during construction, development, emplacement, and caretaker modes for the repository preclosure period.

The Ground Control System provides support of the following openings:

- Emplacement drifts, which provide stable storage space for waste packages, including the operating envelope for waste emplacement and retrieval activities during the preclosure period. The emplacement drift ground support consists of steel sets, welded-wire fabric, and (where necessary) fully-grouted rock bolts to maintain the stability of the drifts for the range of anticipated geologic conditions and for all expected loading conditions.

- Non-emplacement drifts, which include access mains, ventilation exhaust main, emplacement drift turnouts, alcoves, and performance confirmation drifts, provide the pathways for access, transportation, ventilation, and monitoring. The non-emplacement drift ground support consists of both the initial and final ground supports to maintain the stability of the openings for the range of anticipated geologic conditions and for all expected loading conditions. The initial ground support uses pattern rock bolts and welded-wire fabric, and, if necessary, shotcrete and/or steel sets. The final ground support uses cast-in-place concrete lining.

- Shafts and related structures, which include development/intake shafts, exhaust shafts, ventilation raises, shaft collars, and station area facilities, including filter drifts. These openings facilitate the construction, ventilation, and other operation activities. The shafts and related structures use ground supports similar to those for the non-emplacement drifts.

2.2 DESIGN ASSUMPTIONS

The assumptions used in the "Ground Control for Emplacement Drifts for SR" and the "Longevity of Emplacement Drift Ground Support Materials" are explained in this section. The longevity of ground support materials is relevant to the ground control system and the assumptions used are, therefore, included in this section.

2.2.1 Assumptions Related to Ground Support Design

2.2.1.1 Initial Ground Relaxation

An initial ground relaxation value of 60 percent is assumed in the ground support analysis of emplacement drifts ("Ground Control for Emplacement Drifts for SR", Section 5.1.1). This results in 40 percent of the pre-excavation in situ stress being imposed on the ground support system, providing a reasonably conservative upper bound to the in situ loading recommended in earlier studies conducted by "Drift Design Methodology and Preliminary Application for the Yucca Mountain Site Characterization Project," Table 8-1.

An initial ground relaxation value of 100 percent is assumed in the ground support analysis for the final cast-in-place concrete lining in non-emplacement drifts ("Ground Control for Emplacement Drifts for SR", Section 5.1.2). This value is considered to be reasonable because the cast-in-place concrete lining will usually be installed months or even years after the drift excavation. Any rock deformation induced by the excavation will most likely be complete before the installation of the concrete lining. This value will also be used for shafts and related structures for the same reason.

2.2.1.2 Drift Wall Temperature in Non-Emplacement Drifts

The maximum temperature on the drift walls of non-emplacement drifts, including the access mains, ventilation exhaust main, and turnout drifts, is assumed to be 50 degrees C during the potential repository preclosure period ("Ground Control for Emplacement Drifts for SR," Section 5.2). The rationale for this assumption is that the non-emplacement drifts should be accessible by personnel during the preclosure period. To achieve this, a sufficient ventilation rate will be used to ensure that the wall temperature will not exceed 50 degrees C as an upper bound. This value will also be used for shafts and related structures for the same reason.

2.2.1.3 Seismic Loads

2.2.1.3.1 Representation of Seismic Waves

Seismic waves are represented as velocity waves that are assumed to be sinusoidal in shape, with the amplitude equal to the peak ground velocity (PGV) value ("Ground Control for Emplacement Drifts for SR," Section 5.3.1). This assumption is based on common practice in lieu of ground motion time histories. This assumption leads to a repetitive peak vibratory ground motion as design input at the potential repository host horizon. Since the peak ground velocity in seismic event actually just occurs once at one location, this assumption is conservative.

2.2.1.3.2 Frequencies and Duration of Seismic Motions

A frequency of vibration is required to generate the sinusoidal velocity waves that are used as the dynamic load input. Since earthquakes generally excite a broad range of frequencies, use of a frequency range of 1 Hz to 10 Hz for the ground support design is appropriate. In the ground control design for SR, a frequency of 10 Hz was used ("Ground Control for Emplacement Drifts for SR," Section 5.3.2). Other frequency values need to be considered in the LA design.

Duration of a seismic event usually last from a few seconds to several minutes. A duration of 3 seconds was assumed in the "Ground Control for Emplacement Drifts for SR" (Section 5.3.3). This assumption is based on the rationale that a 3-second duration at a frequency of 10 Hz will result in 30 major vibration cycles propagating through the rock. This is a reasonable number of cycles, since the peak ground velocity or acceleration, resulting in the maximum rock deformation induced by a seismic event, can be captured with this short duration. A longer duration needs to be considered in the LA design.

2.2.1.3.3 Incidence Angle

Seismic waves are assumed to propagate vertically upwards, i.e., the incidence angle is zero with respect to the vertical direction ("Ground Control for Emplacement Drifts for SR," Section 5.3.4). This is conservative as the vertically-propagating P- and S-waves are the major ones to cause dynamic effects.

2.2.1.4 Rock In Situ Stresses

The upper bound vertical stress value of 10 MPa at the repository drifts is assumed ("Ground Control for Emplacement Drifts for SR," Section 5.4). The range of the ratio (K_o) of horizontal stress to vertical stress is assumed to vary from 0.3 to 1.0. According to the in situ stress measurements by hydraulic fracturing in a test hole located in the TSw2 unit (Data Transmittal Package (DTP) for "Hydraulic Fracturing Stress Measurements in Test Hole: ESF-AOD-HDFR#1, Thermal Test Facility, Exploratory Studies Facility at Yucca Mountain," p.1), the minimum and maximum K_o values are 0.34 and 0.70, respectively. Therefore, the range used (0.3 to 1.0) is bounding.

2.2.1.5 Initial Gap Between Steel Sets and Rock Surface

A minimum "gap" of at least 13 mm, representing an initial mismatch between the steel set ring and the rock surface, is assumed in the ground support design

("Ground Control for Emplacement Drifts for SR," Section 6.5.2.1). According to the "Constructability Considerations for Repository Drifts for Viability Assessment" (Section 4.3.7.5), design of the steel sets will include a tolerance of steel set diameter of about 50 mm to account for the need to provide clearance for maneuvering the steel sets into place. Once a steel set is in place it will be expanded by jacking to reduce the gap between the outer surface of the steel and the excavated surface of the rock. To avoid over stress in the steel and rock due to thermal expansion after waste packages are emplaced a gap of at least 13 mm must be left after jacking. Using standard construction techniques, jacking can be controlled to provide this gap as assumed. Therefore, this assumption is reasonable.

2.2.2 Assumptions Related to Material Longevity

2.2.2.1 Relative Humidity (RH) for Carbon Steel Corrosion

It is assumed that the relative humidity (RH) values for dry oxidation, humid-air corrosion, and aqueous corrosion for carbon steel are less than 60 percent, 60 to 80 percent, and 85 to 100 percent, respectively ("Longevity of Emplacement Drift Ground Support Materials," Section 5.3).

2.2.2.2 Specific Gravity of Silica Fume and Type K Expansive Cement

The specific gravity values of silica fume and Type K expansive cement (are 2.2 and 3.12, respectively ("Longevity of Emplacement Drift Ground Support Materials," Section 5.4). Type K expansive cement is a type of C 845 cement. The specific gravity of silica fume is generally in the range of 2.10 to 2.25 ("Design and Control of Concrete Mixtures," p. 69). Since this reference is commonly used in the concrete and cement industry, it is reasonable to assume the value to be 2.2 (approximate average of the range). The specific gravity value of Type K expansive cement is from the only manufacturer in the U.S. ("The S.G. of Type K Cement as Manufactured by Blue Circle Cement is 3.12"), which is reasonable to be assumed. Results of the radiation analysis, which use input based on these specific gravity values, are not sensitive to possible variations in the specific gravity values.

2.2.2.3 Relative Humidity in Emplacement Drifts

It is assumed that the RH in the emplacement drifts will range from 1 to 40 percent during the preclosure period ("Longevity of Emplacement Drift Ground Support Materials," Section 5.5). The maximum relative humidity expected at the inlet to an emplacement drift is 40 percent ("Overall Development and Emplacement Ventilation Systems," p. 113, Sec. 9.5, Item 1). The relative humidity is expected to decrease to about 1 percent as temperature increases within the drift to 125 degrees C ("Overall Development and Emplacement Ventilation Systems," p. V-8).

2.2.2.4 Material Composition for Fueled Region of Waste Package

The material composition for the fueled region of the waste package is that of fresh fuel (5.0 percent enriched for the maximum fuel assembly) as opposed to spent fuel ("Longevity of Emplacement Drift Ground Support Materials," Section 5.6). This is a commonly used conservative assumption since fresh fuel yields slightly higher neutron fluxes. This effect is from the production of extra fission neutrons due to the higher percentage of fissile ^{235}U still present in the fuel matrix.

2.2.2.5 Neutron Radiation Effects on Structural Steel

Neutron radiation effects on A36 structural steel relative to the change in Reference Temperature, or ΔRT_{NDT}, are assumed to be similar to reactor pressure steel ("Longevity of Emplacement Drift Ground Support Materials," Section 5.8). Reactor pressure vessel material, as represented by grades SA-302, 336, 533, and 508 steel are all low carbon body-centered-cubic (bcc) types of steel similar to grade A36. This is further justified by using recommended conservative values for copper content and nickel content in the calculation of changes in transition temperature ("Radiation Embrittlement of Reactor Vessel Materials," p. 1.99-3).

2.3 DETAILED DESIGN DESCRIPTION

A subsurface layout corresponding to the full waste inventory of approximately 97,000 MTU is illustrated in Figure 1 ("Site Recommendation Subsurface Layout," Section 6.4, Figure 12). This figure shows the types of repository openings and their locations, and is used as general information for design of the ground control system.

2.3.1 Emplacement Drifts

Eighty emplacement drifts will be excavated using a tunnel boring machine (TBM) to a nominal diameter of 5.5 m and a center-to-center drift spacing of 81 m ("Monitored Geologic Repository Project Description Document," Section 5.2) for the subsurface layout supporting the approximately 97,000 MTU waste inventory ("Site Recommendation Subsurface Layout," Section 6.4). In addition, ten contingency drifts are also planned in case the intended emplacement drifts area cannot be used due to unexpected geologic conditions.

According to the "Site Recommendation Subsurface Layout" (Section 6.2.2), 6.5 percent of the emplacement drifts will be excavated in the middle non-lithophysal unit (Tptpmn), 73.3 percent in the lower lithophysal unit (Tptpll), and 20.1 percent in the lower non-lithophysal unit (Tptpln). The drifts will be excavated to an orientation with an average azimuth of 252 degrees to position the emplacement drift at least 30 degrees from the dominant joint orientations of the repository host horizon ("Site Recommendation Subsurface Layout," Section 6.2.1.2).

The ground support systems proposed for the emplacement drifts are steel sets with welded-wire fabric and (where necessary) fully-grouted rock bolts to maintain the stability of the openings for the range of anticipated geologic conditions and for all expected loading conditions. These ground supports will be installed as the final ground supports.

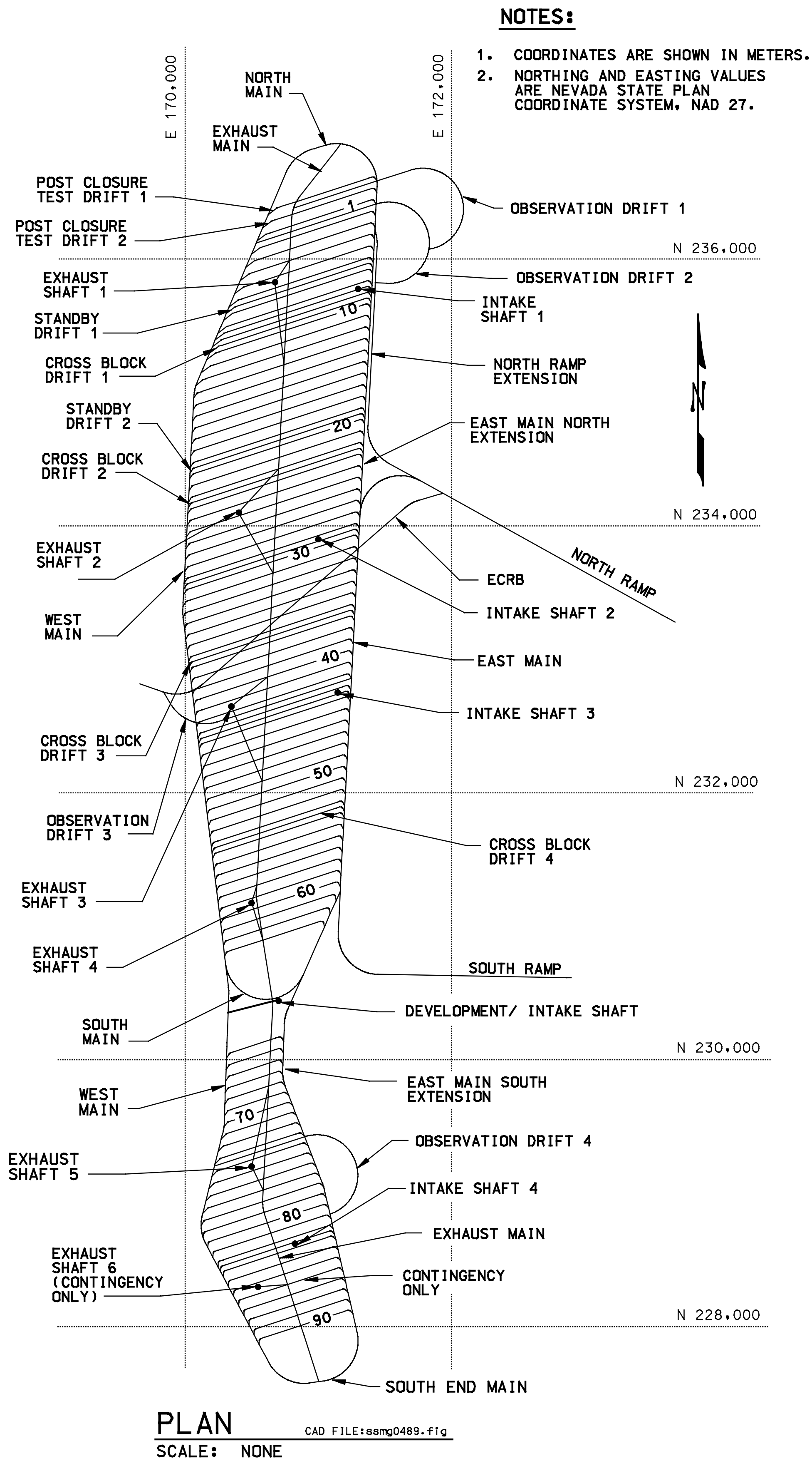

Figure 1. 97,000 MTU Subsurface Layout for Site Recommendation

2.3.2 Non-Emplacement Drifts, Shafts, and Related Structures

The non-emplacement drifts, Section 2.1, will require both initial and final ground supports to maintain the stability of the openings for the range of anticipated geologic conditions and for all expected loading conditions. The initial ground support will use pattern rock bolts and welded-wire fabric, and, if necessary, shotcrete and/or steel sets. The final ground support will use cast-in-place concrete lining.

The shafts and related structures include four intake shafts, one development/intake shaft, six exhaust shafts, ventilation raises, shaft collars, and station area facilities ("Site Recommendation Subsurface Layout," Section 6.4). These openings facilitate the construction, ventilation, and other operation activities.

The shafts and related structures will use ground supports similar to those used for the non-emplacement drifts.

2.4 COMPONENT DESCRIPTION

2.4.1 Steel Sets

Steel sets are proposed as part of the final ground support system for the repository emplacement drifts. The steel sets recommended are W6×20, with a spacing of 1.5 m along the drift ("Ground Control for Emplacement Drifts for SR," Section 4.1.8). Emplacement drift support for lithophysae-rich rock will consist of steel sets and welded-wire fabric. The fabric will be installed between the ribs and the rock, with steel pins holding it against the exposed rock, to prevent movement of the rock blocks into the drift. Figure 2 illustrates the use of steel sets for the lithophysal rock ("Ground Control for Emplacement Drifts for SR," Figure 6-1).

The material for the steel sets will be A36 ("Longevity of Emplacement Drift Ground Support Materials," Section 6.2.3). The steel sets are anticipated to be functional and durable without planned maintenance during a preclosure period of up to 30 years after final emplacement. (as required by the "Monitored Geologic Repository Project Description Document,", Section 5.1.1.1). Appropriate monitoring and maintenance will be needed in terms of the longevity of steel, should a deferral of closure for up to 300 years be required ("Longevity of Emplacement Drift Ground Support Materials," Section 7.2).

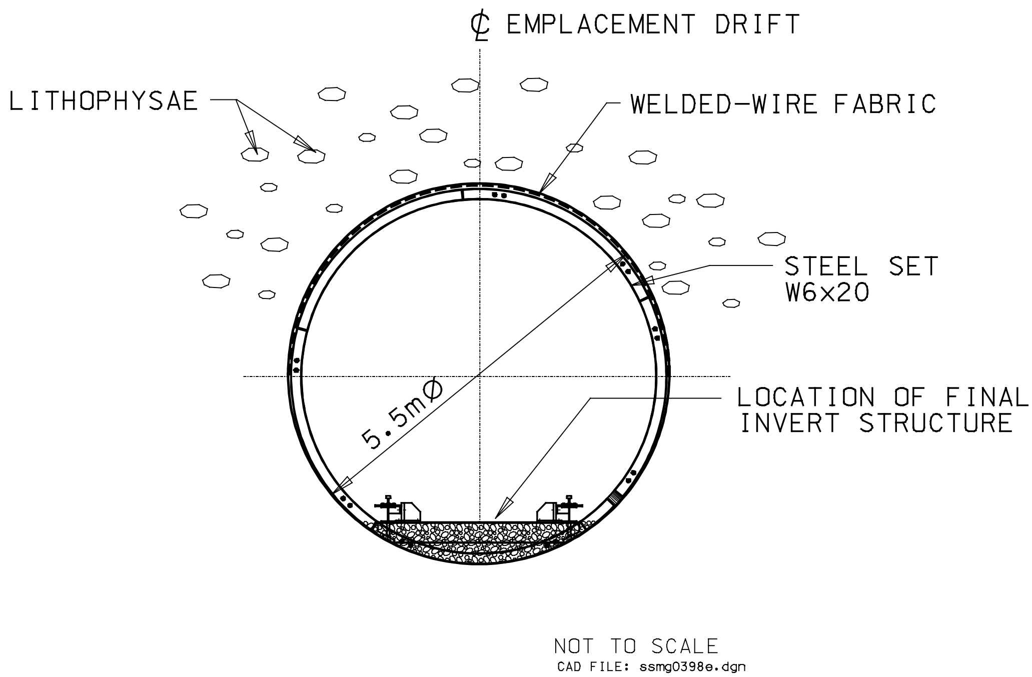

Figure 2. Steel Sets With Welded-Wire Fabric

2.4.2 Fully-Grouted Rock Bolts

Fully-grouted rock bolts are recommended as a supplement to the steel sets, as needed, in the emplacement drifts. It is expected that rock bolts will be needed primarily in the more jointed non-lithophysae-rich rock. A rock bolt system consists of a pattern of steel rock bolts installed through the welded-wire fabric and grouted with cementitious material to hold the rock bolts in place. The welded wire fabric is carbon steel material. The rock bolts proposed for the emplacement drifts are 3-meter long, located as shown in Figure 3, with a spacing of 1.5 m along the drift ("Ground Control for Emplacement Drifts for SR," Section 6.5.2.2). The rock bolts will only be installed, as needed, in areas with massively-jointed rock to prevent any key blocks from loosening or where falling key blocks formed by joints are mobilized by excavation and have the potential of falling. As stated, these conditions are anticipated primarily in non-lithophysal rock areas. Figure 3 illustrates the use of fully-grouted rock bolts with steel sets for the more jointed rock ("Ground Control for Emplacement Drifts for SR," Figure 6-2).

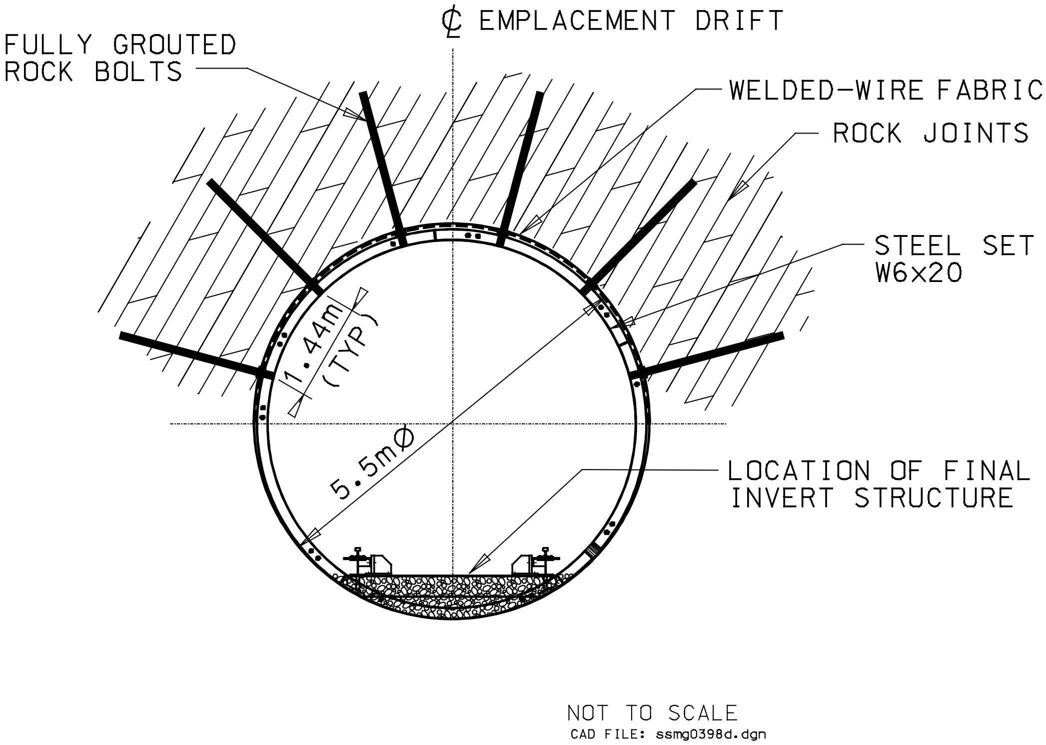

Figure 3. Fully Grouted Rock Bolts With Steel Sets

The materials for fully-grouted rock bolt system will be F432 carbon steel for rock bolts and C845 cement with C1240 silica fume and C494 superplasticizer for grout ("Longevity of Emplacement Drift Ground Support Materials," Section 6.2.3). Under the expected environment and loading conditions in the emplacement drifts, the fully-grouted rock bolts are anticipated to be functional and durable for the repository preclosure period of up to 300 years ("Ground Control for Emplacement Drifts for SR," Sections 4.2.2.6 and 7.4 and "Longevity of Emplacement Drift Ground Support Materials," Section 7.2).

2.4.3 Cast-in-Place Concrete Lining

Separate initial and final ground supports are required for the non-emplacement drifts, shafts, and related structures.

The initial ground support will be needed to allow for safe construction and to accommodate geologic mapping ("Ground Control for Emplacement Drifts for SR," Section 6.2.2). The initial ground support consists of pattern rock bolts and welded-wire fabric, shotcrete, and steel sets. Shotcrete application may be required to address jointed rock conditions, mainly for roadheader excavation.

The use of steel sets may be required in extensively blocky and fractured areas, with TBM excavation.

Cast-in-place concrete lining is recommended as the final ground support for the non-emplacement drifts, shafts, and related structures. ("Ground Control for Emplacement Drifts for SR," Section 6.2.2). The cast-in-place concrete lining will be installed after the completion of the geologic mapping activities and installation of the invert. It can accommodate different sizes and shapes of the non-emplacement drift openings. Figure 4 illustrates the use of a 300-mm-thick cast-in-place concrete lining for the ventilation exhaust main ("Ground Control for Emplacement Drifts for SR," Figure 6-3).

The cast-in-place lining with a design strength limit of 5,000 psi ("Ground Control for Emplacement Drifts for SR," Table 4-11) is expected to be functional, as long as reinforcement is included to counteract the tensile stress anticipated due to elevated temperatures ("Ground Control for Emplacement Drifts for SR," Section 7.3.3).

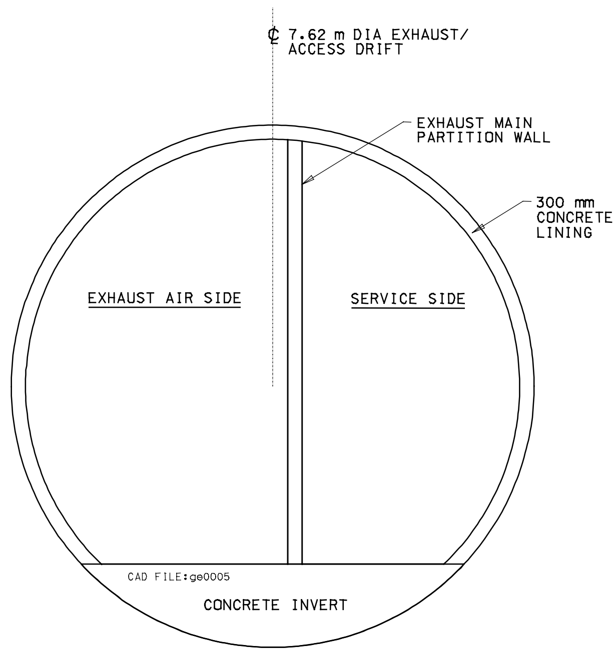

Figure 4. Cast-in-Place Concrete Lining for Exhaust Main

2.5 CRITERIA COMPLIANCE

Table 13 provides explanations of how the design complies with the design criteria for this system.

Table 13. Compliance with Design Criteria

Criterion	Explanations of Compliance
1.2.1.1	Compliance with this criterion for emplacement drifts and exhaust main is addressed in the “Ground Control for Emplacement Drifts for SR” (Sections 4.4.2 and 6.6.1). The nominal diameters of the excavated emplacement drifts and exhaust main are 5.5 m and 7.62 m, respectively. Repository constructability design based on typical industrial practice results in radial overcut of about 1 inch (2.54 cm), leading to a minimum diameter of the drift bore of 5.5508 m (“Constructability Considerations for Repository Drifts for Viability Assessment,” Section 4.3.7.5). The corresponding minimum bore for the exhaust main is 7.6708 m. Considering the dimensions of steel sets (W6×20) and design tolerance of 16 mm for variations in lining thickness and alignment (“Drift Ground Support Design Guide,” Section 2.3.2, Table 2-2), and 10 mm for deformation due to combined in situ and thermal loads (“Ground Control for Emplacement Drifts for SR,” Section 6.5.1.2.1), the diameter of the operating envelope for the emplacement drifts will be about 5.21 m, which is larger than the 5.1 m operating envelope required. Similarly, after installation of a 300-mm-thick cast-in-place concrete lining, and allowing 16 mm for variations in lining thickness and alignment and 16 mm for deformation (“Ground Control for Emplacement Drifts for SR,” Section 6.6.1.2), the diameter of the operating envelope for the exhaust main will be 7.04 m, meeting the requirement of an operating envelope of 7.02 m. Compliance for the other non-emplacement drifts will be addressed in the LA design.
1.2.1.2	Compliance with this criterion is addressed in the “Ground Control for Emplacement Drifts for SR” (Section 6.1). Use of steel sets and/or rock bolts as the ground control components will accommodate the requirement of geologic mapping of emplacement drifts. Geologic mapping of non-emplacement drifts will be accommodated since a two-pass (initial and final) ground support system is recommended (“Ground Control for Emplacement Drifts for SR,” Section 6.1).
1.2.1.3	Compliance with this criterion is addressed in the “Ground Control for Emplacement Drifts for SR” (Section 6.1). Steel sets and/or rock bolts are designed to allow the monitoring of ground control performance parameters.
1.2.1.4	Compliance with this criterion is addressed in the “Ground Control for Emplacement Drifts for SR” (Sections 6.2.1.1 and 6.2.1.2) and the “Longevity of Emplacement Drift Ground Support Materials” (Section 6.2.3). Steel sets and/or steel rock bolts are recommended as the ground supports for the emplacement drifts. The material for the steel sets will be A 36 or A 572 carbon steel, while the material for the rock bolts will be F432 carbon steel.
1.2.1.5	Compliance with this criterion is addressed in the “Ground Control for Emplacement Drifts for SR” (Section 6.2.1.2) and the “Longevity of Emplacement Drift Ground Support Materials” (Section 6.2.1.3). Cementitious grout composed of C845 cement with C1240 silica fume and C494 superplasticizer is recommended to anchor rock bolts for the emplacement drifts.
1.2.1.6	Compliance with this criterion is addressed in the “Ground Control for Emplacement Drifts for SR” (Sections 6.3.1, 6.3.2, 6.3.4). Upper bound in situ, thermal, and seismic loads are considered in the ground control analyses. Other operational and construction loads will be included in the LA design.
1.2.1.7	Compliance with this criterion is addressed in Section 5.2.24 of the “Monitored Geologic Repository Project Description Document.”
1.2.1.8	Compliance with this criterion is addressed in Section 5.1.1.3 of the “Monitored Geologic Repository Project Description Document.”
1.2.1.9	Compliance with this criterion is addressed in Section 5.2.24 of the “Monitored Geologic Repository Project Description Document.”
1.2.2.1.1	Compliance with this criterion is addressed in the “Ground Control for Emplacement Drifts for SR” (Section 7.3). The ground supports are designed to prevent any instability of openings and rock falls in the emplacement drifts during the preclosure period.

Table 13. Compliance with Design Criteria (Continued)

Criterion	Explanations of Compliance
1.2.2.1.2	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Sections 6.2.1.1 and 6.2.1.2) and the "Longevity of Emplacement Drift Ground Support Materials" (Section 6.2). Steel is the main material for the ground support components installed in the emplacement drifts, and is considered acceptable for long-term waste isolation, pending confirmation by studies to be conducted by PA. The small amount of cement grout to be used for anchoring rock bolts is also considered acceptable, pending confirmation by studies to be conducted by PA.
1.2.2.1.3	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Section 6.3.4). A design basis earthquake of Frequency Category 2 is used in the ground control design.
1.2.2.2.1	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Sections 7.1 through 7.4). Stability of the repository drifts will be maintained with the installation of ground supports designed to prevent rock falls.
1.2.2.2.2	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Section 6.3.3) and the "Longevity of Emplacement Drift Ground Support Materials" (Sections 6.3 through 6.5). The ground control system is designed for the preclosure period of up to 300 years, with appropriate monitoring and maintenance as needed. This criterion is also addressed in Section 5.1.1.1 of the "Monitored Geologic Repository Project Description Document."
1.2.2.2.3	A detailed analysis of compliance will be addressed before final design.
1.2.3.1	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Section 4.1.1). The TBD-3552 in situ rock temperature profile is used in the design of the ground support system.
1.2.3.2	An intake air temperature of 25ºC (close to an average of the annual temperature fluctuation at the repository host horizon) is used for ventilation analyses in the "ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study" (Section 3.6), and the results are used as the inputs to the ground control analysis in the "Ground Control for Emplacement Drifts for SR" (Section 4.1.12). The extreme temperatures will only exist at the ground surface, and thus will only affect design of the portions of underground openings that intersect the ground surface (such as ventilation intake shaft collars and tunnel portals. These temperatures will be considered in the LA design.
1.2.3.3	Compliance with this criterion is addressed in the "Longevity of Emplacement Drift Ground Support Materials" (Section 6.1.2). The maximum relative humidity of 40% is considered in the evaluation of ground support performance during the preclosure period of up to 300 years. This may be adjusted in the LA design.
1.2.3.4	Compliance with this criterion is addressed in the "Longevity of Emplacement Drift Ground Support Materials" (Sections 6.1.3, 6.3.5, and 6.4.3.6). The radiation effects are estimated to be insignificant to cause any appreciable damage to steel or cement grout used as the materials for the ground supports of the emplacement drifts.
1.2.3.5	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Section 4.1.3). Applicable data from the required source are used in the ground support design. Supplemental data from other sources as identified in the "Ground Control for Emplacement Drifts for SR" (Sections 4.1.2 through 4.1.7) are also used as necessary.
1.2.4.1	Compliance with this criterion (for opening sizes) is addressed in the "Ground Control for Emplacement Drifts for SR" (Section 4.2.2.1). The

Table 13. Compliance with Design Criteria (Continued)

Criterion	Explanations of Compliance
	drift orientation and opening sizes used in the ground control design are consistent with the Subsurface Facility System ("Site Recommendation Subsurface Layout," Section 6.4). Drift orientation and configuration will be addressed as part of the Subsurface Facility System design.
1.2.4.2	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Sections 6.2.1 and 6.2.2). Carbon steel and limited cement grout are used as the ground control materials, and are compatible with the requirement of waste isolation and thereby the Emplacement Drift System.
1.2.4.3	Compliance with this criterion will be addressed in the LA design.
1.2.4.4	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Sections 4.2.2.1, 6.1 and 6.2). The proposed ground control system is designed to maintain the operating envelope required to accommodate the waste emplacement operation.
1.2.4.5	The proposed ground control system will ensure safe installation as follows: For emplacement drifts, the ground support will be assembled under the protection of the TBM shield and then installed as the shield is advanced. Initial support for non-emplacement openings will be installed during excavation, providing worker protection for installation of permanent support, as identified in the "Ground Control for Emplacement Drifts for SR" (Section 6.1).
1.2.5.1	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Sections 6.1 & 7.4) and the "Longevity of Emplacement Drift Ground Support Materials" (Section 7.2). The ground control system is designed for the preclosure period of 175 years, without planned maintenance, while allowing unplanned maintenance as needed.
1.2.5.2	This criterion will be addressed in the LA design.
1.2.6.1	Compliance with this criterion will be addressed in the LA design.
1.2.6.2	Compliance with this criterion will be addressed in the LA design.
1.2.6.3	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Section 4.3.2). The design of the cast-in-place concrete lining will comply with the "Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)."
1.2.6.4	Compliance with this criterion is not required because concrete lining will not be used for the emplacement drifts, whereas the non-emplacement openings are not safety related.
1.2.6.5	Compliance with this criterion will be addressed in the LA design. Shotcrete will only be used as needed for initial support in non-emplacement drifts.
1.2.6.6	Compliance with this criterion is addressed in the "Ground Control for Emplacement Drifts for SR" (Section 4.3.1). The design of the steel sets and rock bolts complies with the "Manual of Steel Construction, Allowable Stress Design."
1.2.6.7	Compliance with this criterion will be addressed in the LA design.
1.2.6.8	Compliance with this criterion will be addressed by maintaining temperatures in the concrete lining for the non-emplacement drifts to insignificant levels.
1.2.6.9	Compliance with this criterion will be addressed in the LA design. Shotcrete will only be used as needed for initial support in the non-

Table 13. Compliance with Design Criteria (Continued)

Criterion	Explanations of Compliance
	emplacement drifts.
1.2.6.10	Compliance with this criterion will be addressed in the LA design.
1.2.6.11	Compliance with this criterion will be addressed in the LA design.
1.2.6.12	Compliance with this criterion will be addressed in the LA design.
1.2.6.13	Compliance with this criterion is addressed in the “Ground Control for Emplacement Drifts for SR” (Section 4.1.12) and the “Longevity of Emplacement Drift Ground Support Materials” (Section 5.2). The project design requirements and constraints to support the ground support design are obtained from the “Monitored Geologic Repository Project Description Document.”
1.2.6.14	Compliance with this criterion is addressed in the “Longevity of Emplacement Drift Ground Support Materials” (Sections 4.1.11 and 4.3.2). Material properties of carbon structural steel from “Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement” are used in the radiation calculation to determine the radiation effects on steel corrosion.
1.2.6.15	The “Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement” is listed in the “Longevity of Emplacement Drift Ground Support Materials” (Section 4.3.2). Compliance with this criterion will be addressed in the LA design.
1.2.6.16	The “Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel” is listed in the “Longevity of Emplacement Drift Ground Support Materials” (Section 4.3.2). Compliance with this criterion will be addressed in the LA design.
1.2.6.17	Compliance with this criterion is addressed in the “Longevity of Emplacement Drift Ground Support Materials” (Sections 4.3.2 and 6.4.1.1). Cement grout will be used in the fully-grouted rock bolt system, and its desirable characteristics in terms of longevity are addressed based on the “Standard Specification for Portland Cement.”
1.2.6.18	Compliance with this criterion is addressed in the “Longevity of Emplacement Drift Ground Support Materials” (Sections 4.3.2 and 6.4.1.5). Use of high-range water reducer, i.e., superplasticizer will be required to increase the workability of cement grout, and will conform to “Standard Specification for Chemical Admixtures for Concrete.”
1.2.6.19	Compliance with this criterion is addressed in the “Longevity of Emplacement Drift Ground Support Materials” (Sections 4.3.2 and 6.4.1.1). If shrinkage-compensating cement is selected for grouting rock bolts, its use will conform to “Standard Specification for Expansive Hydraulic Cement.”
1.2.6.20	Compliance with this criterion is addressed in the “Longevity of Emplacement Drift Ground Support Materials” (Sections 4.3.2 and 6.4.1.4). Silica fume will be used as an admixture to cement grout, and its use will conform to “Standard Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout.”
1.2.6.21	The “Standard Specification for Roof and Rock Bolts and Accessories” is listed in the “Longevity of Emplacement Drift Ground Support Materials” (Section 4.3.2). Compliance with this criterion will be addressed in the LA design.
1.2.6.22	Compliance with this criterion is addressed in the “Longevity of Emplacement Drift Ground Support Materials” (Sections 4.3.3 and 6.4.3.2). Design of concrete lining subjected to sulfate attack will conform to “Guide to Durable Concrete.”
1.2.6.23	Compliance with this criterion is addressed in the “Longevity of Emplacement Drift Ground Support Materials” (Sections 4.3.3, 6.4.1.1, 6.4.1.3, 6.4.1.5, 6.4.2.1, and 6.4.2.2). Material properties of cement grout for rock bolt system will be based on “Standard Practice for the Use of Shrinkage - Compensating Concrete.”

Table 13. Compliance with Design Criteria (Continued)

Criterion	**Explanations of Compliance**
1.2.6.24	Compliance with this criterion will be addressed in the LA design.

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. 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

MGR RD 3.1.C invokes 10 CFR 63. 10 CFR 63.111(e)(1) requires that the waste retrieval option be maintained. Section 7.13g1 of "Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System" requires safe access to waste packages, transportation vehicles, and installed components for purposes of testing, inspection, and maintenance. The system maintains access to the emplacement drifts and, therefore, supports this requirement. This criterion ensures the subsurface openings will not reduce/change in size over time to a point that would restrict movement of equipment and air flow. This includes waste retrieval and backfill operations.

The dimensions and shapes provided in this criterion do not prescribe the dimensions and shapes of the excavated subsurface openings. The final operating envelopes do depend on repository design features that have not been established for final design. These features include, for example, the size and weight of the waste packages, waste package emplacement and retrieval equipment, backfill equipment, emplacement drift barrier design, etc. An evaluation can be done to establish bounding envelopes when these design features can be established.

II. Criterion Performance Parameter Basis

This criterion defines each operating envelope and corresponding minimum clearance determined to be necessary for subsurface operations and activities. "Operating Envelopes for Non-Alcove and Alcove Subsurface Openings" establishes operating envelopes that require confirmation for the openings shown in Tables 1 and 2. The dimensions and shapes are not specified by this SDD, but are the result of information gathered from the subsurface design disciplines (e.g., ventilation, waste emplacement, personnel access/egress, and performance confirmation). Therefore, they are subject to change based on changes in the subsurface design operating envelopes.

1.2.1.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.C invokes 10 CFR 63. 10 CFR 63.132(a) requires that a continuing program of surveillance, measurement, testing, and geologic mapping be conducted to ensure that geotechnical and design parameters are confirmed, and to ensure that appropriate action is taken to inform the U.S. Nuclear Regulatory Commission of changes needed in design to accommodate actual field conditions encountered. Thus, a criterion to allow for mapping is needed, because ground control design impacts mapping capabilities. The analysis below establishes the basis for the type of mapping capabilities required.

II. Criterion Performance Parameter Basis

Title: SDD Criteria Analysis for Geologic Mapping

Purpose

The purpose of this analysis is to develop a basis for repository subsurface mapping criteria during construction. The scope of this discussion covers the translation of system level and regulatory requirements related to mapping, and of derived requirements from reports or analyses into specific criteria. A qualitative evaluation of the data needs is covered.

Assumption

Rock samples can be obtained regardless of the ground support system installed.

Rationale: The ability to collect core and other rock samples will be needed to enable more complete characterization of the rock. Sampling can provide data needed for repository design confirmation, construction records, performance assessment, and process modeling.

Criteria Analysis

Technical Data Needs:

To establish the technical data needs for performance confirmation, the natural and engineered barrier processes needing analysis on the basis of regulatory and Monitored Geologic Repository (MGR) design requirements were identified in Section 2 of the "Performance Confirmation Plan." Only those postclosure performance parameters or measures that can be observed, monitored, measured, and tested during the preclosure phase of the repository are selected as performance confirmation parameters. The design input information needs from the "Performance Confirmation Plan" provide a reasonably complete selection of the technical data needs that are used to develop the minimum mapping frequency. Additional data needs may be identified as the design progresses.

Performance Confirmation Parameter Data Needs.

Stratigraphy: The additional data needed for performance confirmation related to stratigraphy, such as the location of stratigraphic contact locations, can be acquired by mapping and sampling the non-emplacement drift openings in the reference repository layout. Observations during construction will help to ensure that there are no anomalous conditions related to the stratigraphy, or will indicate when additional information may be necessary. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Location and characteristics of faults and fault zones: Surface and drift wall mapping show that the only significant faults within the repository are North-South trending faults trace lengths of at least 300 meters within the repository ("Bedrock Geologic Map of the Central Block Area, Yucca Mountain, Nye County, Nevada"). Most faults are expected to have an influence on repository performance or are candidates for detailed consideration. These considerations and the current uncertainty in the fault and fault zones' importance to postclosure performance, conservatively lead to a spacing of mapped drifts that would provide a reasonable confidence that these features could be located at the repository horizon and their fault characteristics (width, length, orientation, and displacement) could be established. Mapping non-emplacement drift openings will provide additional information on some faults. In particular, mapping of the perimeter drifts and Exhaust Main provides an approximate 600 m spacing between mapped drifts. These drifts generally run in the north-south direction nearly parallel to the predominant fault orientation. The emplacement drifts run approximately in an east-west direction. To provide a reasonable likelihood that these at least 300 m features are mapped, the frequency of mapped emplacement drifts should be on the order of 300 m. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Location and characteristics of fractures and fracture zones: The mapping of the non-emplacement drift openings provides adequate coverage for confirmation of the fracture statistics. Detailed mapping of an emplacement drift, including fracture parameters, provides the needed rock mass characterization for thermal monitoring and testing of emplacement drifts near performance confirmation observation drifts. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Location of fracture infillings and chemical, mineralogical, and biological characteristics: These data will be collected through the observation of rock mass conditions during construction. If anomalous conditions are observed, the location will be documented, samples will be taken, and investigation will be conducted. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Location and characteristics of seeps: The location and characteristics of seeps will be determined through the observation of rock mass conditions during construction. If anomalous conditions are observed, the location will be documented, samples will be taken, and investigation will be conducted. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Confirm absence of hydrocarbons and mineral resources: Confirmation of the absence of hydrocarbons and mineral resources is needed and will be accommodated through the observation of rock mass conditions during construction. If anomalous conditions are observed, the location will be documented, samples will be taken, and investigation will be conducted. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Repository Design Confirmation Data Needs.

Rock mass quality: Geologic mapping of the non-emplacement drifts provides adequate coverage of the rock mass quality data needs. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Construction Records Data Needs: Description of the materials encountered shall be recorded based on observations during construction. Geologic maps and geologic cross sections shall be developed based on information developed from the mapped drifts. Location and characteristics of seeps will be treated the same as described above under the performance confirmation parameter data needs. Details of equipment, methods, progress, and sequence of work shall be recorded during construction. Construction problems shall be observed and recorded during construction. Anomalous conditions encountered include, but are not limited to, active flow of water, evidence of weathering or oxidation, thick fracture coating/minerals, evidence of hydrothermal alteration, and mineral resources. They will be accommodated through the observation of rock mass conditions during construction. This information is discussed in Appendix G of the "Performance Confirmation Plan."

Conclusion

The three mapping strategies recommended for repository construction are: ensure the maximum distance between mapped emplacement drifts is 300 m (based on the current drift spacing and layout), map non-emplacement drift openings, and observe rock mass conditions during construction.

The rationale for maximum distance between mapped emplacement drifts is that this frequency of mapped drifts will ensure intersection of features anticipated to affect repository performance. Present surface mapping shows several faults with approximately 200 to 300 m fault trace length within the repository block. Most of these faults are expected to penetrate the host repository horizon and extend downward to the water table. The importance of these faults to repository performance is currently uncertain. A maximum distance of 300 meters between mapped emplacement drifts, given the current layout, provides reasonable confidence of intersecting these surface mapped features at depth.

The rationale for mapping the non-emplacement drift openings is to provide adequate coverage for confirmation of fracture statistics. Mapping non-emplacement drifts has the least impact on the ground support design.

Observations during construction will help identify specific locations that should be mapped in yet-to-be constructed emplacement drifts.

1.2.1.3 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.C invokes 10 CFR 63. To comply with 10 CFR 63.111(d) and 10 CFR 63.132(e), in situ monitoring of the thermomechanical response of the underground facility is required. This criterion is provided to ensure monitoring capabilities of ground control performance parameters. The parameters monitored include opening convergence, ground support and rock temperatures, and ground support loads. Opening convergence is monitored to ensure the required clearances are being maintained. Ground control temperature is monitored to confirm thermal stress design limits are not being exceeded. Ground support loads are monitored to confirm actual loads are within design limits. In the future Performance Confirmation could augment the monitoring capabilities of this criterion with additional geologic and engineering features.

II. Criterion Performance Parameter Basis

N/A

1.2.1.4 Criterion Basis Statement

I. Criterion Need Basis

This criterion is provided per management direction as provided in section 5.2.6 of "Monitored Geologic Repository Project Description Document." Postclosure uncertainties associated with the use of steel are considered small. This criterion only applies to the emplacement drifts, even though the general design conditions and constraints provided in "Monitored Geologic Repository Project Description Document" does not clarify this point.

II. Criterion Performance Parameter Basis

The ground support material selection is obtained from section 5.2.6 of "Monitored Geologic Repository Project Description Document."

1.2.1.5 Criterion Basis Statement

I. Criterion Need Basis

This criterion is provided per management direction as provided in section 5.2.6 of "Monitored Geologic Repository Project Description Document." Postclosure uncertainties associated with the use of steel are considered small. This criterion only applies to the emplacement drifts, even though the general design conditions and constraints provided in "Monitored Geologic Repository Project Description Document" does not clarify this point.

II. Criterion Performance Parameter Basis

The grout material constraint for permanent rock bolts is obtained from section 5.2.6 of "Monitored Geologic Repository Project Description Document."

1.2.1.6 Criterion Basis Statement

I. Criterion Need Basis

This system prevents the rock falls in the emplacements drifts that could lead to an annual dose beyond statutory limits. The geologic repository has to be designed for a rock fall in the emplacement drifts in excess of the waste packages design limit. This is considered a design basis event, because a waste package breach is assumed to occur as a result. The system has to consider applicable Category 1 Category 2 design basis events as required in 10 CFR63.111(a)(2) and 10 CFR 63.111(b)(2). MGR RD 3.3.A requires all MGR systems, structures, and components be designed and fabricated in accordance with applicable engineering principles and practices with particular attention to those which incorporate system safety. System safety requires the underground openings be designed to minimize the potential for deleterious rock movement or fracturing, and so that operations can be carried out safely. This criterion is provided to ensure ground control is designed for the worst-case loads and load combinations.

In situ rock load: The load is expressed as in situ stresses; namely, one vertical component and two horizontal components. Consideration shall be given to the maximum value for the vertical stress, and both the minimum and maximum values for the horizontal stresses.

Construction load: The load comes mainly from the combined weight of the tunnel boring machine and transporter during the retrieval of the tunnel boring machine. The weight shall be considered only if the construction invert is an integral part of the final ground support system.

Operation load: For emplacement drifts and access mains, the load mainly occurs during the emplacement and retrieval of waste packages. If the invert is an integral part of the ground support system, consideration shall be given to the weight of the loaded gantry and its motion-associated loadings; namely, gantry wheel tractive load, gantry lateral swing load, and gantry wheel impact load. The weight of the waste package and its associated supports shall also be considered.

Thermal load: The load consists of the heating emitted from the emplaced waste and the cooling caused by ventilation. Heating effects are calculated in terms of heat flux values and are based on the specified thermal loading conditions (e.g., areal mass or line load), initial heat output value, and drift and waste package spacings. Cooling effects are computed by accounting for the cooling rate, intake air temperature, and cooling cycles.

This criterion supports MGR RD 3.1.C.

II. Criterion Performance Parameter Basis

The design loads for the ground control design are TBD and TBV. The in situ loads are TBV and are provided in "In Situ Rock Conditions," DTN: MO0007RIB00077.000. (TBV-5036)

1.2.1.7 Criterion Basis Statement

I. Criterion Need Basis

A functional requirement for this system is to limit the maximum air temperature in the emplacement drift. This criterion is provided based on management's direction to utilize ventilation to limit the maximum temperature in the surrounding rock mass.

II. Criterion Performance Parameter Basis

The maximum air temperature allowed in the emplacement drifts is 96 degrees C s provided in Section 5.2.24 of the "Monitored Geologic Repository Project Description Document."

1.2.1.8 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to allow flexibility of operations within a range of thermal modes during preclosure and postclosure

II. Criterion Performance Parameter Basis

The requirement for the design to provide flexibility of operations is directly in support of Section 5.1.1.3 of the "Monitored Geologic Repository Project Description Document."

1.2.1.9 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to support the requirement that the maximum emplacement drift wall temperature, during post closure shall not exceed 200 degrees C if a higher thermal mode is selected. To allow for flexibility of operations within a range of thermal modes during preclosure and postclosure, a low end of range of maintaining WP surface temperature below 85 degrees C has been selected.

II. Criterion Performance Parameter Basis

The maximum emplacement drift wall temperature of 200 degrees C is provided in Section 5.2.24 of the "Monitored Geologic Repository Project Description Document." Section 5.1.1.3 of the "Monitored Geologic Repository Project Description Document" provides for the low end of the thermal operating range.

1.2.2.1.1 Criterion Basis Statement

I. Criterion Need Basis

The system is relied upon to eliminate the credibility of a design basis event resulting from a large block fall on the waste packages in excess of their design limit. This criterion applies to the preclosure period. This criterion supports 10 CFR 63.112(e)(8) by ensuring the waste packages perform their safety function.

This criterion complies with MGR RD 3.1.C..

II. Criterion Performance Parameter Basis

The 6 metric tons and the 3.3 meters are established in "Preclosure Design Basis Events Related to Waste Packages, " Section 7.2.1.

1.2.2.1.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.C invokes 10 CFR 63. 10 CFR 63.113(b) requires the engineered barrier system to be designed so that, working in combination with natural barriers, it will limit the expected annual dose after permanent closure. Ground control materials remaining after permanent closure may have chemical or other effects on the ability of the engineered and natural barriers to provide this assurance. Thus, this criterion ensures ground control material that does not impede the long-term performance of the engineered and natural barriers.

II. Criterion Performance Parameter Basis

N/A

1.2.2.1.3 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.C requires compliance with 10 CFR 63. This criterion establishes the requirement for the system to withstand a design basis earthquake. This criterion is based on 10 CFR 63.112(e)(8), which requires the performance analysis of SSCs that are important to safety to include consideration of the "Ability of structures, systems, and components to perform their intended safety functions, assuming the occurrence of design basis events."

This requirement is also intended to help meet the overall geologic operations area performance objectives in 10 CFR 63.111(a)(2) and 10 CFR 63.111(b)(2), which state, respectively: "During normal operations, and for Category 1 design basis events, the annual dose to any real member of the public, located beyond the boundary of the preclosure controlled area shall not exceed a total effective dose equivalent (TEDE) of 0.25 mSv (25 mrem)," and, "The geologic repository operations area shall be designed so that taking into consideration Category 2 design basis events and until permanent closure has been completed, no individual located on, or beyond, any point on the boundary of the preclosure controlled area, will receive the more limiting of a TEDE of 0.05 Sv (5 rem), or the sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) of 0.5 Sv (50 rem). The lens dose equivalent shall not exceed 0.15 Sv (15 rem), and the shallow dose equivalent to skin shall not exceed 0.5 Sv (50 rem)."

MGR RD 3.1.C invokes 10 CFR 63. 10 CFR 63.111(a)(2), 10 CFR 63.111(b)(2), and sections 6.1g1, 6.2g1, 6.4g1 of "Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System" require that the geologic repository to be designed for Category I and Category 2 design basis events.

II. Criterion Performance Parameter Basis

N/A

1.2.2.2.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires all MGR systems, structures, and components be designed and fabricated in accordance with applicable engineering principles and practices with particular attention to those which incorporate system safety. System safety requires the underground openings be designed to minimize the potential for deleterious rock movement or fracturing, and so that operations can be carried out safely. To provide for safe operations, this criterion ensures a system design that minimizes the potential of immediate or progressive failure (due to gradual deterioration) of the surrounding rock mass and deleterious rock movement that could result in unsafe subsurface conditions.

II. Criterion Performance Parameter Basis

N/A

1.2.2.2.2 Criterion Basis Statement

I. Criterion Need Basis

This criterion establishes the maximum length of time the system may be asked to operate to allow future generations to continue monitoring the repository. This criterion supports MGR PDD 5.1.1.1.

II. Criterion Performance Parameter Basis

The 300 years is provided in MGR PDD 5.1.1.1

1.2.2.2.3 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that all MGR systems, structures, and components be designed and fabricated in accordance with applicable engineering principles and practices with particular attention to those which incorporate system safety. System safety requires, to the extent practicable, the geologic repository operations area be designed to incorporate the use of noncombustible and heat resistant materials. Ground control material is prevalent underground. It is important to fire safety that the material be noncombustible and heat resistant. Material is considered noncombustible per "Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 [degrees] C" (ASTM E 136-98).

II. Criterion Performance Parameter Basis

N/A

1.2.3.1 Criterion Basis Statement

I. Criterion Need Basis

This criterion provides the natural conditions that are significant for system design. The in situ rock temperature is needed to model the total temperature change which is used to determine the thermal rock stress at the repository horizon.

II. Criterion Performance Parameter Basis

The rock temperature profile that should be used for ground control design is TBD.

1.2.3.2 Criterion Basis Statement

I. Criterion Need Basis

The air temperature conditions are needed in thermal models. The computed thermal induced rock stress is affected by the air temperature conditions assumed in the thermal models.

II. Criterion Performance Parameter Basis

The extreme outside temperature range of -15 degrees C to 47 degrees C is based on the annual extreme minimum and maximum temperatures for the nine meteorological monitoring sites located in the Yucca Mountain area. Locations of the nine sites are shown in Figure 2-1 of the "Engineering Design Climatology and Regional Meteorological Conditions Report." Extreme temperatures (and other data) are in Tables A-1 through A-9 of this report. As used in the criterion, data from this source does not affect the system's critical characteristics and will not be directly relied upon to address safety or waste isolation issues.

The collected temperature data in Tables A-1 through A-9 are based on 11 years of monitoring at Sites 1 to 5 and four years of monitoring at Sites 6 to 9. Site 1 data are typically more representative of the nine sites because it is closest to the repository. However, due to the limited number of years that data were collected, the lowest and highest recorded temperatures for all nine sites are used to bound the extreme temperature range. Site 5 has the lowest recorded temperature of -13.1 degrees C and Site 9 has the highest of 45.1 degrees C. This temperature range was conservatively expanded to -15 degrees C (5 degrees F) to 47 degrees C (117 degrees F).

1.2.3.3 Criterion Basis Statement

I. Criterion Need Basis

The relative humidity levels affects corrosion rates of certain ground control material. The dominant relative humidity is the amount of the maximum dominant level, not the peak level.

II. Criterion Performance Parameter Basis

The maximum dominant relative humidity that should be used for ground control design is TBD.

1.2.3.4 Criterion Basis Statement

I. Criterion Need Basis

The radiation in the emplacement drifts over the preclosure years impacts ground control materials. Depending on the type and the energy levels of the radiation, steel material properties are affected after long periods of exposure. This criterion provides the design radiation levels for ground support design in the emplacement drifts.

II. Criterion Performance Parameter Basis

The radiation conditions that will be used for ground support design in the emplacement drifts are TBD.

1.2.3.5 Criterion Basis Statement

I. Criterion Need Basis

The material property data vary widely. This criterion provides the material properties via "TBV-332/TBD-325 Resolution Analysis: Geotechnical Rock Properties" for system design.

The thermal properties are required for thermomechanical analyses of the repository rock mass. The thermomechanical properties are needed for the lithostratigraphic units because of boundary effects on the calculated temperatures, especially at the near field of the emplacement drifts. Use of the lithostratigraphic units instead of the thermomechanical units in thermal models is consistent with the practice of other groups, such as Waste Package Development and Performance Assessment. This will allow the collaboration and comparison of work done by different groups.

Thermomechanical analyses using a discontinuum model require mechanical properties for rock blocks (e.g., mass density, Young's modulus, Poisson's ratio, cohesion, friction angle, tensile strength, etc.) and rock fractures (e.g., normal stiffness and shear stiffness, fracture friction angle, fracture cohesion, fracture tensile strength, fracture dilation angle). Both include elastic, strength, and post-failure parameters.

Mechanical boundary effects on the thermomechanical model are expected to be negligible. Thus, mechanical properties for the thermomechanical unit are adequate for evaluation of repository ground support needs. Use of mechanical properties as averaged values of three lithostratigraphic units (Tptpmn, Tptpll, and Tptpln), will provide adequate accuracy in results from the thermomechanical model for the mechanical response near the emplacement drifts.

II. Criterion Performance Parameter Basis

The available material properties that are identified in this criterion are provided in "TBV-332/TBD-325 Resolution Analysis: Geotechnical Rock Properties."

1.2.4.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR structures, systems, and components (SSCs) be designed using engineering principles and practices with particular attention to reliability, availability, and maintainability. The subsurface excavated open size, drift configuration, and orientation have a significant impact on ground control design. The criterion ensures this system interfaces with the Subsurface Facility System with respect to these parameters.

II. Criterion Performance Parameter Basis

N/A

1.2.4.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.C invokes 10 CFR 63. To comply with the requirement of 10 CFR 63.113(b), the interface between this system and the Emplacement Drift System has to ensure that ground control materials are compatible with long-term waste isolation objectives. The ground control material used in the emplacement drifts will remain there post-closure. This criterion ensures a system design that does not impede the performance of the Emplacement Drift System.

II. Criterion Performance Parameter Basis

N/A

1.2.4.3 Criterion Basis Statement

I. Criterion Need Basis

The system interfaces with the MGR Operations Monitoring and Control System to ensure transmission of ground control instrument readings.

II. Criterion Performance Parameter Basis

N/A

1.2.4.4 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires all MGR systems, structures, and components be designed and fabricated in accordance with applicable engineering principles and practices with particular attention to those which incorporate system safety. System safety requires the underground openings be designed to minimize the potential for deleterious rock movement or fracturing, and so that operations can be carried out safely. The system interfaces with the Waste Emplacement/Retrieval System to support safe waste emplacement operations. This interface includes consideration for preventing adverse rocking and shifting of the inverts for waste package emplacement operations.

II. Criterion Performance Parameter Basis

N/A

1.2.4.5 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires all MGR systems, structures, and components be designed and fabricated in accordance with applicable engineering principles and practices with particular attention to those which incorporate system safety. System safety requires that the underground openings be designed to minimize the potential for deleterious rock movement or fracturing, and so that ground support installation can be carried out safely. The system interfaces with the Subsurface Excavation System to ensure safe ground support installation.

II. Criterion Performance Parameter Basis

N/A

1.2.5.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires all MGR systems, structures, and components be designed and fabricated in accordance with applicable engineering principles and practices with particular attention to those which incorporate system safety. The conditions in the emplacement drifts are going to be too harsh for human entry. Therefore, planned ground control repairs, which would require retrieving waste packages, should be avoided, or at least minimized. This criterion ensures the system is designed to function during pre-closure without planned maintenance. Due to the length of time of this design and the number of unknown factors that can impact ground control (e.g., amount of convergence, ground relaxation, seismic conditions), system design has to account for the inherent uncertainties. Therefore, ground control design will not prevent the ability to perform unplanned maintenance.

II. Criterion Performance Parameter Basis

N/A

1.2.5.2 Criterion Basis Statement

I. Criterion Need Basis

Due to the unusually long operational life of this system (i.e., 175 years), this criterion is provided to allow or accommodate unplanned maintenance of this system in the non-emplacement openings.

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).

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).

II. Criterion Performance Parameter Basis

N/A

1.2.6.3 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed in accordance with applicable industry codes and standards. Sections 6.3g1 and 7.5g1 of "Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System" invoke "Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)." The applicable provisions of "Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)" provide requirements for design and construction of structural concrete. The minimum standards in "Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)" are conservatively applied because of the unusually long operational life of this system and the high reliability necessary over its operational life.

II. Criterion Performance Parameter Basis

N/A

1.2.6.4 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. Section 7.6g1 of "Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System" invokes "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-97) and Commentary--ACI 349R-97." The applicable provisions in "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-97) and Commentary--ACI 349R-97" provide the minimum requirements for design and construction of nuclear safety-related concrete structures and structural elements for nuclear power generating stations. The minimum standards in "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-97) and Commentary--ACI 349R-97" are applicable to ground support design of safety-related concrete structures. For concrete structures that are not safety-related, "Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)" applies.

II. Criterion Performance Parameter Basis

N/A

1.2.6.5 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. Section 7.8g1 of "Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System" invokes "Guide to Shotcrete." "Guide to Shotcrete" provides guidance for many design aspects of shotcrete design and construction including materials, equipment, crew organization, preliminary preparation, proportioning, shotcrete placement, and quality control. The minimum standards in "Guide to Shotcrete" are conservatively applied because of the unusually long operational life of this system and the high reliability necessary over its operational life.

II. Criterion Performance Parameter Basis

N/A

1.2.6.6 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. Section 7.11g1 of "Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System" invokes "Manual of Steel Construction Allowable Stress Design." The "Manual of Steel Construction Allowable Stress Design" provides recognized engineering principles for designing, fabricating, and constructing efficient and economical steel structures for non-safety related structures.

II. Criterion Performance Parameter Basis

N/A

1.2.6.7 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The American Institute of Steel Construction provides recognized engineering principles for designing, fabricating, and constructing efficient and economical steel structures. The "American National Standard for Nuclear Facilities - Steel Safety-Related Structures for Design Fabrication and Erection" applies to safety-related steel structures. It is undetermined at this point whether this system will contain safety related steel structures.

II. Criterion Performance Parameter Basis

N/A

1.2.6.8 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. Section 7.2g1 of "Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System" invokes "Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures." The American Concrete Institute provides recognized engineering principles for designing, fabricating, and constructing efficient and economical concrete structures. This criterion invokes "Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures" as applicable to the design of this system.

II. Criterion Performance Parameter Basis

N/A

1.2.6.9 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The American Concrete Institute provides recognized engineering principles for designing, fabricating, and constructing efficient and economical concrete structures. "Specification for Shotcrete" describes the requirements for materials, proportioning, and application of shotcrete. This criterion invokes "Specification for Shotcrete" as applicable to the design of this system.

II. Criterion Performance Parameter Basis

N/A

1.2.6.10 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The design for this system may utilize fiber reinforced concrete. The "Standard Specification for Steel Fibers for Fiber Reinforced Concrete" covers minimum requirements for steel fibers intended for use in fiber reinforced concrete. This criterion invokes "Standard Specification for Steel Fibers for Fiber-Reinforced Concrete" as applicable to the design of this system.

II. Criterion Performance Parameter Basis

N/A

1.2.6.11 Criterion Basis Statement

I. Criterion Need Basis

Design, selection, arrangement, configuration, and integration of SSCs involve many elements, including monitoring, operating, maintaining, and observing the facilities and systems. To accomplish an effective and safe work environment, the human-system interface must incorporate human factors engineering (HFE) criteria. Use of the Department of Defense Design Criteria Standard "Human Engineering," in conjunction with the other HFE standards and guidelines cited in this system description document, will provide a human-system interface that maximizes performance and minimizes risk to personnel.

In support of MGR RD 3.3.A, this criterion ensures that the system will be designed to be safely and effectively used by all expected users. The U.S. Department of Energy (DOE) Good Practices Guide "Human Factors

Engineering" (GPG-FM-027, paragraph 2.3.1) endorses the use of MIL-STD-1472E (GPG-FM-027 references an earlier version of MIL-STD-1472).

II. Criterion Performance Parameter Basis

N/A

1.2.6.12 Criterion Basis Statement

I. Criterion Need Basis

Maintainability of system equipment involves many factors, including the human-machine interface. This interface must address the design for maintainability through the incorporation of HFE criteria. In support of MGR RD 3.3.A, this criterion ensures that the system will be designed to be safely and effectively maintained through compliance with applicable industry standards. The DOE Good Practices Guide "Human Factors Engineering" (GPG-FM-027, paragraph 2.3.1) endorses the use of "Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities" for addressing HFE maintainability design criteria.

II. Criterion Performance Parameter Basis

N/A

1.2.6.13 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

1.2.6.14 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for Carbon Structural Steel" covers minimum requirements for ground control carbon steel structures.

II. Criterion Performance Parameter Basis

N/A

1.2.6.15 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement" applies to steel welded wire fabric.

II. Criterion Performance Parameter Basis

N/A

1.2.6.16 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel" applies to the steel set design in the high temperature emplacement drifts.

II. Criterion Performance Parameter Basis

N/A

1.2.6.17 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for Portland Cement" applies to concrete ground support components.

II. Criterion Performance Parameter Basis

N/A

1.2.6.18 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for

Chemical Admixtures for Concrete" applies to admixtures for ground control concrete.

II. Criterion Performance Parameter Basis

N/A

1.2.6.19 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for Expansive Hydraulic Cement" applies to the system concrete design.

II. Criterion Performance Parameter Basis

N/A

1.2.6.20 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout" applies to preparation of grout and concrete.

II. Criterion Performance Parameter Basis

N/A

1.2.6.21 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The "Standard Specification for Roof and Rock Bolts and Accessories" applies to the support of rock bolts.

II. Criterion Performance Parameter Basis

N/A

1.2.6.22 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The “Guide to Durable Concrete” applies to ground control concrete and ensures a durable design.

II. Criterion Performance Parameter Basis

N/A

1.2.6.23 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires that MGR SSCs be designed in accordance with applicable industry codes and standards. The “Standard Practice for the Use of Shrinkage-Compensating Concrete” applies to ground control concrete and ensures a durable design.

II. Criterion Performance Parameter Basis

N/A

1.2.6.24 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A invokes the “1997 Uniform Building Code." Volume 2, "Structural Engineering Design Provisions” for non-safety related seismic design criteria. This criterion applies to ground support that is not subject to the Frequency Category 1 and Frequency Category 2 design basis earthquakes.

II. Criterion Performance Parameter Basis

N/A

APPENDIX B ARCHITECTURE AND CLASSIFICATION

Table 14 provides the Ground Control System architecture and classification. The QA classifications are established in "Classification of the MGR Ground Control System."

Table 14. System Architecture and Classification

Ground Control System Architecture	QL-1	QL-2	QL-3	CQ
Access Mains				X
Emplacement Drifts		X		
Exhaust Air 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

CFR	Code of Federal Regulations
CQ	Conventional Quality
CHn1	Calico Hills and Lower Paintbrush nonwelded thermal mechanical unit
CHn2	Calico Hills and Lower Paintbrush nonwelded thermal mechanical unit
DOE	U. S. Department of Energy
DTN	Data Tracking Number
DTP	Data Transmittal Package
ESF	Exploratory Studies Facility
F	Function
HFE	Human Factors Engineering
LA	License Application
LS	Lithostratigraphic
MGR RD	Monitored Geologic Repository Requirements Document
NRC	Nuclear Regulatory Commission
PA	Performance Assessment
PTn	Paintbrush nonwelded
QA	Quality Assurance
QL	Quality Level
RH	Relative Humidity
RIB	Reference Information Base
SDD	System Description Document
SNF	Spent Nuclear Fuel
SR	Site Recommendation
SSC	Structures, Systems, and Components
Tacbt	Pre-Calico Hills Formation bedded tuff
Tac(v)	Calico Hills Formation vitric zone
Tac(z)	Calico Hills Formation zeolitic zone
TBD	To Be Determined
TBM	Tunnel Boring Machine
TBV	To Be Verified
TCw	Tiva Canyon welded thermal mechanical unit
TEDE	Total Effective Dose Equivalent
TM	Thermomechanical
Tpbt1	Pre-Topopah Spring Tuff bedded tuff
Tpbt2	Pre-Tiva Canyon bedded tuff
Tpbt3	Pre-Tiva Canyon bedded tuff
Tpbt4	Pre-Tiva Canyon bedded tuff
Tpcpll	Tiva Canyon crystal poor lower lithophysal zone
Tpcpln	Tiva Canyon crystal poor lower nonlithophysal zone
Tpcpmn	Tiva Canyon crystal poor middle nonlithophysal zone
Tpcpul	Tiva Canyon crystal poor upper lithophysal zone
Tpcpv	Tiva Canyon crystal poor vitric zone

Tpcpv1	Tiva Canyon crystal poor vitric densely welded subzone
Tpcrn	Tiva Canyon crystal rich nonlithophysal zone
Tpcrv	Tiva Canyon crystal rich vitric zone
Tpp	Pah Canyon Tuff
Tptpll	Topopah Spring Tuff crystal poor lower lithophysal zone
Tptpln	Topopah Spring Tuff crystal poor lower nonlithophysal zone
Tptpmn	Topopah Spring Tuff crystal poor middle nonlithophysal zone
Tptpul	Topopah Spring Tuff crystal poor upper lithophysal zone
Tptpv	Topopah Spring Tuff crystal poor vitric zone
Tptrl	Topopah Spring Tuff crystal rich lithophysal zone
Tptrn	Topopah Spring Tuff crystal rich nonlithophysal zone
Tptrv	Topopah Spring Tuff crystal rich vitric zone
Tpy	Yucca Mountain Tuff
TSw1	Topopah Spring welded, lithophysae-rich thermal mechanical unit
TSw2	Topopah Spring welded, lithophysae-poor thermal mechanical unit
TSw3	Topopah Spring welded, vitrophyre thermal mechanical unit

C.2 SYMBOLS AND UNITS

°C	degrees Celsius
°F	degrees Fahrenheit
cm	centimeter
Hz	Hertz
m	meter
MPa	megapascal
mm	millimeter
mrem	one thousandth of a rem
mSv	one thousandth of a Sievert
rem	Roentgen equivalent man
Sv	Sievert

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 results of this document do not require additional TBDs or TBVs, beyond those already identified, as a result of the issues and actions identified in this appendix.

Issue 1 - Resolve outstanding TBDs and TBVs

Issue 2 - Criterion 1.2.1.2 – Investigate why 100% mapping of non emplacement drifts is required, while only partial mapping (every 300m) is required for emplacement drifts.

APPENDIX E REFERENCES

"1997 Uniform Building Code." Volume 2, "Structural Engineering Design Provisions." International Conference of Building Officials. April 1997. Whittier, California: International Conference of Building Officials. TIC: 233818.

"American National Standard for Nuclear Facilities - Steel Safety-Related Structures for Design Fabrication and Erection." American Institute of Steel Construction. ANSI/AISC N690-1984. 1984. Chicago, Illinois: American Institute of Steel Construction. TIC: 4279.

"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.

"Bedrock Geologic Map of the Central Block Area, Yucca Mountain, Nye County, Nevada." Day, W.C.; Potter, C.J.; Sweetkind, D.S.; Dickerson, R.P.; and San Juan. MAP I - 2601. 1998. Washington, D.C.: U.S. Geological Survey. TIC: 237019. DTN: GS971208314221.003.

"Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)." ACI 318-99. 1999. Farmington Hills, Michigan: American Concrete Institute. TIC: 245142.

"Classification of the MGR Ground Control System." CRWMS M&O. ANL-GCS-SE-000001, Rev. 00. August 31, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0217.

"Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-97) and Commentary-ACI 349R-97." American Concrete Institute. ACI 349-97 and ACI 349R-97. February 1998. Farmington Hills, Michigan: American Concrete Institute. TIC: 237635.

"Constructability Considerations for Repository Drifts for Viability Assessment." CRWMS M&O. BCAA00000-01717-0200-00005, Rev. 00. 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971229.0302.

"Data Transmittal Package (DTP) for "Hydraulic Fracturing Stress Measurements in Test Hole: ESF-AOD-HDFR#1, Thermal Test Facility, Exploratory Studies Facility at Yucca Mountain." CRWMS M&O. TDIF 305878. 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19970717.0005, MOL.19970717.0006, MOL.19970717.0007, MOL.19970717.0008. DTN: SNF37100195002.001.

"Department of Defense Design Criteria Standard, Human Engineering." U.S. Department of Defense. MIL-STD-1472E. October 31, 1996. Washington, D.C.: U.S. Department of Defense. TIC: 235204.

"Design and Control of Concrete Mixtures." Kosmatka, S.H. and Panarese, W.C. 13 Edition. 1994. Skokie, Illinois: Portland Cement Association. TIC: 242269.

"Drift Design Methodology and Preliminary Application for the Yucca Mountain Site Characterization Project." Hardy, M.P. and Bauer, S.J.. SAND89-0837. 1991. Albuquerque, New Mexico: Sandia National Laboratories. ACC: NNA.19910808.0105.

"Drift Ground Support Design Guide." CRWMS M&O. BCAA00000-01717-2500-00001, Rev. 01. 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990326.0104.

"Engineering Design Climatology and Regional Meteorological Conditions Report." CRWMS M&O. B00000000-01717-5707-00066, Rev. 00. October 2, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980304.0028. DTN: MO9811DEDCRMCR.000

"Ground Control for Emplacement Drifts for SR." CRWMS M&O. ANL-EBS-GE-000002, Rev. 00. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000414.0875.

"Guide to Durable Concrete." American Concrete Institute. ACI 201.2R-92. 1992. Detroit, Michigan: American Concrete Institute. TIC: 241421.

"Guide to Shotcrete." American Concrete Institute. ACI 506R-90(95). 1995. Farmington Hills, Michigan: American Concrete Institute. TIC: 238721.

"Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities." Bongarra, Jr., James P.; VanCott, Harold P.; Pain, Richard F.; Peterson, L. Rolf; Wallace, Ronald I. UCRL-15673. June 18, 1985. Livermore, California: Lawrence Livermore National Laboratory. TIC: 206097.

"Human Factors Engineering." Office of Project and Fixed Asset Management. GPG-FM-027. March 1996. Washington, D.C.: U.S. Department of Energy, Office of Project and Fixed Asset Management. TIC: 240421.

"Hydraulic Fracturing Stress Measurements in Test Hole: ESF-AOD-HDFR1, Thermal Test Facility, Exploratory Studies Facility at Yucca Mountain." Submittal date: 12/18/1996. DTN: SNF37100195002.001.

"In Situ Rock Conditions." Submittal Date: July 18, 2000. DTN: MO0007RIB00077.000

"Longevity of Emplacement Drift Ground Support Materials." CRWMS M&O. ANL-EBS-GE-000003, Rev. 01. April 3, 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000414.0874.

"Manual of Steel Construction, Allowable Stress Design." AISC (American Institute of Steel Construction). Ninth Edition. January 1997. Chicago, Illinois: American Institute of Steel Construction, Inc. TIC: 232994.

"Monitored Geologic Repository (MGR) Compliance Program Guidance Package for Ground Control System." CRWMS M&O. TER-GCS-SE-000001, Rev. 00. October 29, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991203.0411.

"Monitored Geologic Repository Project Description Document." Bechtel SAIC Company. TDR-MGR-SE-000004, Rev. 02 ICN 02. June 2001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010628.0224.

"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: MOL.20000720.0540.

"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.

"Operating Envelopes for Non-Alcove and Alcove Subsurface Openings." CRWMS M&O. RSO-EBS-99369.T. December 16, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991216.0043.

"Overall Development and Emplacement Ventilation Systems." CRWMS M&O. BCA000000-01717-0200-00015, Rev. 00. September 19, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980123.0661.

"Performance Confirmation Plan." CRWMS M&O. TDR-PCS-SE-000001, Rev. 01. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000302.0312.

"Preclosure Design Basis Events Related to Waste Packages." CRWMS M&O. ANL-MGR-MD-000012, Rev. 00. May 30, 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000725.0015.

"Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures." American Concrete Institute. ACI 209R-92. 1992. Detroit, Michigan: American Concrete Institute. TIC: 239624.

"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.

"Radiation Embrittlement of Reactor Vessel Materials." Nuclear Regulatory Commission. Regulatory Guide 1.99, Rev. 2. 1988. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 4637.

"Retrievability Strategy Report." CRWMS M&O. B00000000-01717-5705-00061, Rev. 01 DCN 1. August 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990201.0011.

"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.

"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.

"Site Recommendation Subsurface Layout." CRWMS M&O. ANL-SFS-MG-000001, Rev. 00. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000908.0276.

"Specification for Shotcrete." American Concrete Institute. ACI 506.2-95. 1995. Detroit, Michigan: American Concrete Institute. TIC: 226412.

"Standard Practice for the Use of Shrinkage - Compensating Concrete." American Concrete Institute. ACI 223-98. 1998. Farmington Hills, Michigan: American Concrete Institute. TIC: 245440.

"Standard Specification for Carbon Structural Steel." American Society for Testing and Materials. ASTM A 36/A 36M-97a. 1998. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 243523.

"Standard Specification for Chemical Admixtures for Concrete." American Society for Testing and Materials. ASTM C 494-98a. 1999. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246665.

"Standard Specification for Expansive Hydraulic Cement." American Society for Testing and Materials. ASTM C 845-96. 1996. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246401.

"Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel." American Society for Testing and Materials. ASTM A 572/A 572M-99a. 1999. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246273.

"Standard Specification for Portland Cement." American Society for Testing and Materials. ASTM C 150-99a. 1999. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 247046.

"Standard Specification for Roof and Rock Bolts and Accessories." American Society for Testing and Materials. ASTM F 432-95. 1995. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241007.

"Standard Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout." American Society for Testing and Materials. ASTM C 1240-99. 1999. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246205.

"Standard Specification for Steel Fibers for Fiber-Reinforced Concrete." American Society for Testing and Materials. ASTM A820-96. 1996. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 239384.

"Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement." American Society for Testing and Materials. ASTM A 185-97. 1997. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 246271.

"Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 [degrees] C." American Society for Testing and Materials. ASTM E 136-98. July 1998. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246491.

"Standard Test Method for Density of Hydraulic Cement." American Society for Testing and Materials. ASTM C 188-95. 1995. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 249885.

"TBV-332/TBD-325 Resolution Analysis: Geotechnical Rock Properties." CRWMS M&O. Input Transmittal RSO-EBS-99373.T. December 13, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000110.0133.

"Technical Reports." U.S. Department of Energy, Office of Civilian Radioactive Waste Management. AP-3.11Q, Rev. 2. April 3, 2001. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010405.0010.

"Technical Work Plan For Subsurface Design Section FY 01 Work Activities." CRWMS M&O. TWP-MGR-MG-000001. Rev. 01. January 25, 2001. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010405.0014.

"The S.G. of Type K Cement as Manufactured by Blue Circle Cement is 3.12." Russell, E.D.. 2000. Facsimile from E.D. Russell (Blue Circle Cement) to D. Tang, January 24, 2000. ACC: MOL.20000211.0078.