MOL.19990728.0282

CRWMS/M&O

Determination of Importance Evaluation Interim Change Notice Cover Sheet

QA: L

1. DIE Title
Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility

Document Control Use Only

2. Document Identifier (DI) Number (include revision number)
BAB000000-01717-2200-00005 REV 07/ICN 03

3. Description of Interim Change (include list of pages involved in this ICN)
"No Requirement Changes Were Made". Changes were predominately format changes & enhancements.

* Updated Tracers, Fluids, and Materials (TFM) List to include: Mearlcrete Cellular Concrete, Styrofoam, Wood and FP-1517 Two (2) Part Epoxy.
* Reformatted Attachment II (TFM List) to reflect input from the TFM Database.
* Added applicable reference for Styrofoam to Section 14.
* Added paragraph on "Forms" to Section 13.2.28.

Updated Section 14 references to incorporate new format changes:
Revised incorrect MOL accession number from MOL.19981124.0064. to MOL.19981124.0065.
Removed duplicate reference CRWMS M&O 1997x (Dup of 1997p).
Revised ISBN number on TIC: 217568.
Revised reference CRWMS M&O 1997p to include ICN 03 / MOL.19990330.0531.
Changed Section 14.1 to read 'DOCUMENTION CITED', Section 14.2 to 'CODES & REGULATIONS', Section 14.3 to 'STANDARDS & PROCEDURES'.

Affected Pages:
13, 15, 16,17,20-22,24,26,29,32,34,35,39,40, 45, 48,50-52, 54, 55-57,59-68, 75, 83-85,88,90,92,94,95,97,100-102,105-108,118-130,
and Attachment pages: II-1-~~7~~ 8, ~~III~~-3, V-2, and VIII-9 & 11. ADDED NEW ATTACHMENT PAGE II-8.
WJC 6.21.99

Prepared By

4. Print Name	5. Signature	6. Date
Warren J. Clark	[signature]	06/17/99

Checked By

7. Print Name	8. NC	9. CR	10. Signature	11. Date
Kent M. Fitzgerald		X	[signature]	6/21/99

Reviewed By

12. Organization	13. Print Name	14. NC	15. CR	16. Signature	17. Date
Subsurface ESF Design	Stephen Goodin	✓		[signature]	6/17/99
OQA	Steve Schikemann	✓		[signature]	6/21/99
TCO	BW Pistel	✓		[signature]	6/17/99
Waste Isolation	Patrick D. Mattie	✓		[signature]	6/21/99
N/A					

18. SA Manager's Name	19. Signature	20. Date
Dealis W. Gwyn	[signature]	6/23/99

21. Remarks
This Interim Change Notice (ICN) updates Determination of Importance Evaluation (DIE) BAB000000-01717-2200-00005 REV 07/ICN 02, which addresses activities associated with the subsurface Exploratory Studies Facility (ESF). This ICN and the DIE noted above are required to be used as input in the field work package, design drawing, and design specification documents that implement Subsurface ESF activities. This ICN is distributed as a controlled document in accordance with procedure AP-6.1Q.

CRWMS/M&O

Determination of Importance Evaluation Interim Change Notice Cover Sheet

QA: L

1. DIE Title	Document Control Use Only
Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility	
2. Document Identifier (DI) Number (include revision number) BAB000000-01717-2200-00005 Rev 07/ICN 02	

3. Description of Interim Change (include list of pages involved in this ICN)

1. Updated Tracers, Fluids, and Materials (TFM) list to add newly approved TFMs and incorporate previously approved TFMs listed in the Determination of Importance Evaluation (DIE) for Exploratory Studies Facility (ESF) Subsurface Testing Activities, DI Number BAB000000-01717-2200-00011 Rev 01/ICN 02. Affected pages: Attachment II (All Pages).

Prepared By

4. Print Name	5. Signature	6. Date
Bobby H. Broome Jr.	Bobby H. Broome Jr.	3/10/99

Checked By

7. Print Name	8. NC	9. CR	10. Signature	11. Date
Kent M. Fitzgerald		✓	[signature]	3/11/99

Reviewed By

12. Organization	13. Print Name	14. NC	15. CR	16. Signature	17. Date
Subsurface ESF Design	STEPHEN GOODIN	✓		[signature]	3/11/99
OQA	Steve Schuermann	✓		[signature]	3/11/99
TCO	Alan Mitchell	✓		[signature]	3/10/99
Waste Isolation	Patrick D. Mattie	✓		[signature]	3/11/99
Document Control	Justin Grantham	✓		[signature]	3/11/99

18. SA Manager's Name	19. Signature	20. Date
Dealis W. Gwyn	[signature] for DWG	03/11/99

21. Remarks

This Interim Change Notice (ICN) updates DIE BAB000000-01717-2200-00005 Rev 07/ICN 01, which addresses activities associated with the Subsurface ESF. This ICN and the DIE noted above are required to be used as input in field work package, design drawing, and design specification documents that implement Subsurface ESF activities. This ICN is distributed as a controlled document in accordance with procedure AP-6.1Q.

CRWMS/M&O

Determination of Importance Evaluation Interim Change Notice Cover Sheet

QA: L

1. DIE Title	Document Control Use Only
Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility	
2. Document Identifier (DI) Number (include revision number)	
BAB000000-01717-2200-00005 Rev 07/ICN 01	

3. Description of Interim Change (include list of pages involved in this ICN)

Clarified sections 11.1.8, 13.2.16, and Requirement 7b to note that dust control water applied on the concrete invert portion of the Enhanced Characterization of the Repository Block (ECRB) Starter Tunnel may be treated as if it were applied in the Topopah Spring (TS) Loop. Removed the reference to receipt verification in Requirement 5, since the requirement to perform receipt verification has been eliminated. Added four acronyms to Attachment I (List of Acronyms) and made various editorial changes. Affected pages: 74, 90, 109, 110, 111, 120, I-4, I-5, VIII-2, VIII-11, and VIII-13.

Prepared By

4. Print Name	5. Signature	6. Date
Kent M. Fitzgerald	[signature]	~~1/20/99~~ 1/21/99 KMF 1/21/99

Checked By

7. Print Name	8. NC	9. CR	10. Signature	11. Date
Daniel M. Jenkins		✓	[signature]	01.21.99

Reviewed By

12. Organization	13. Print Name	14. NC	15. CR	16. Signature	17. Date
Subsurface ESF Design	Stephen W. Goodin	✓		[signature]	1/21/99
Natural Barriers	James E. Houseworth	✓		[signature]	1/21/99
~~n/a~~ DJT 1/21/99 OQA	DAN TUNNEY	✓		[signature]	1/21/99
n/a					
n/a					

18. SA Manager's Name	19. Signature	20. Date
Dealis W. Gwyn	[signature] for DWG	01/21/99

21. Remarks

This Interim Change Notice (ICN) updates and clarifies Determination of Importance Evaluation (DIE) BAB000000-01717-2200-00005 Rev 07, which addresses field activities associated with the Subsurface Exploratory Studies Facility (ESF). This ICN and the DIE noted above are required to be used as input in field work package, design drawing, and design specification documents that implement Subsurface ESF activities addressed herein. This ICN is distributed as a controlled document in accordance with procedure AP-6.1Q.

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1. DIE Title
Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility

2. Document Identifier (DI) Number (include revision number)
BAB000000-01717-2200-00005 Rev 07

3. DIE Category (Check one) ☐ I ☐ II ☑ III

Signatures on this document represents signers' acknowledgement that the applicable procedure has been read, understood and complied with.

Prepared By

4. Sections	5. Print Name	6. Signature	7. Date
8.2, 9, 11, & Atts III-VIII	James Houseworth	James Houseworth	1/6/99
8.1, 10	Alan Mitchell	[signature]	1-6-99
Remaining Secs. & Atts.	Kent Fitzgerald	Kent M Fitzgerald	1/6/99
n/a			

Checked By

8. Sections	9. Print Name	10. NC	11. CR	12. Signature	13. Date
8.2,9,11,Atts III-VIII	Darren M. Jolley		✓	[signature]	1/7/99
8.1, 10	Tom Brake	✓		Ron Oliver for	1/6/99
Remaining Secs. & Atts	JAMES A. KAPPES		✓	James A Kappes	1/7/99
n/a					

Reviewed By

14. Organization	15. Print Name	16. NC	17. CR	18. Signature	19. Date
Subsurface ESF Design	STEPHEN GOODIN		✓	Stephen Goodin	1/7/99
Repository Design	D.G. McKENZIE III	✓		[signature]	1/7/99
Site Construction Ops.	Ralph Dresel		✓	[signature]	1.7.99
Document Control	ALICE V. BOYLES		✓	Alice V. Boyles	1/6/99
OQA	STEVE SWENNING	✓		[signature]	1/6/99
n/a					
n/a					

20. SA Manager's Name	21. Signature	22. Date
Dealis W. Gwyn	Robert F Wemheuer for DWG	01/08/99

23. Remarks
This Category III DIE evaluates the Subsurface Exploratory Studies Facility (ESF) and establishes Quality Assurance controls to prevent or minimize the potential impact of such activities on site characterization data, the waste isolation capabilities of a potential geologic repository at the Yucca Mountain site, and/or other Q-List items that have been constructed or installed at the Yucca Mountain site. This DIE also concludes that some activities are sufficiently similar to activities previously evaluated in the DIE for ESF Subsurface Testing Activities (BAB000000-01717-2200-00011 Rev 01) so as to be bounded by the conclusions of that document. This DIE and the DIE for ESF Subsurface Testing Activities, listed above, are required to be used as input in the applicable field work package(s), design drawing(s), and design specification(s) that implement documents for the activities evaluated herein. This DIE is distributed as a controlled document in accordance with AP-6.1.

DIE Title		
Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility		
DI Number (include revision number) BAB000000-01717-2200-00005 Rev 07		
Rev No.	**Date**	**Description of Revision**
00	06/28/94	Original Issue
01	08/25/94	Revised/reissued entire analysis; deleted WIEs and TIEs as attachments (Atts. 11, 111, IV, and VI); changed Atts VII and VIII to 11 and III respectively and added three pages to Att 11 to reflect add'l TFM details; deleted use of two inputs (one TIE and one WIE) whose information has been captured in other revised inputs; responded to minor revisions to WIEs and TIE, as well as clarification of controls and basis information as result of performance-based QA audit findings. The summary of conclusions (previously 11.3, Evaluation of Activities) was deleted, as it was redundant to 10.13.
02	09/07/94	Clarified requirements/bases as a result of ID review of Specification Section 01501. This revision clarifies the water balance accuracy requirements in the bases and the resulting Requirement, diesel requirements to remove low sulfur fuel since it is already mandated by federal law, TBM excavation requirement since the use of qualified operators performing excavation according to specified line and grade tolerances yields the required QA control of excavation methods.
03	12/20/94	Clarified Swellex water removal requirement; evaluated limited pneumatic drill use; clarified transition zone discussion and updated references.
04	02/02/95	Revised based on revised input documents; clarified water tracer concentration, diesel use reporting, and drill-and-blast reporting requirements; added two requirements to minimize future potential test and construction impacts. Updated ESFDR references.
05	07/14/95	Entire document formatted in accordance with NLP-2-0 Rev 01. As such, section numbers changed and test interference and waste isolation evaluations are included in DIE. Revision bus are not used since the entire document has changed. Other changes include: a) Changed tide and added Table of Contents; b) Revised scope of document to include Topopah Spring Loop, including Starter Tunnel; c) Identified documents superseded by this revision of this document; d) Expanded methodology section; e) Revised to include new CI structure; f) Deleted QA classification from DIE (classification analyses are now performed as separate discrete evaluations for each Configuration Item [CI], see references 14.13-14.17); g) Deleted evaluation of surface CIs (Surface Conveyor and Surface Communications) as they are to be covered in applicable surface DIE(s); h) Modified description of CIs; i) Requirements Changes (Requirements renumbered and modified to refer to TS Loop rather than North Ramp, as appropriate, changes listed below by new requirement number); 1) Specific 10CFR60.72 records requirement that was previously implemented through other requirements; 2) Revised list of TBM maintenance requirements based on OPI and A/E review; 3) Included tracer requirements that were previously listed in Starter Tunnel DIE. Also, requirement was modified QA procedure requirements) and clarified (surv frequency); 4) Change to require A/E approval of blast plans and blast patterns (terminology change and clarification);

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Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility		
DI Number (include revision number)		
BAB000000-01717-2200-00005 Rev 07		

Rev No.	Date	Description of Revision
05 (Con't)		5) Clarified requirement for blast size and to agree with modified requirement 4; 6) Eliminated 3 meter criterion in tunnel based on A/E and TCO feedback; modified requirement for TCO approval for test support area grouting; 7) Modified requirement (limit expressed as average with surveillance performed once per shift); clarified water limit for alcoves; changed TFM Management Plan to TFM procedure; 8) Changed TFM Management Plan to TFM procedure; 9) Listed specific testing requirements; further clarified diesel emission minimization activities; eliminated redundancy in requirement; required DPM exhaust conditioning beyond Station 28+05m; allowed diesel use for TS Loop; 10) Changed TFM Management Plan to TFM procedure; 11) Editorial change on equipment listing; 12) No additional change (except is noted above for all requirements); 13) Clarified ESF TCO notification; 14) Clarified requirement (combined two subrequirements); 15) Modified requirement (requires maintenance at prescribed frequency for equipment with fluids of concern, eliminated QA alarm procedure as its intent is bounded by other req'ts); 16) Minor editorial change; 17) Minor editorial change; 18) Previously listed requirement in Starter Tunnel DEE; clarified scope of requirement Also, classification related requirements were deleted (they are now found in the applicable CI classification analysis) and deleted pneumatic pathways related requirement since the requirement has been satisfied and is no longer applicable; j) Editorial changes made throughout the document; k) Updated references; l) Updated ESFDR cites; m) Updated Acronyms and TFMs; n) Deleted QAP-2-3 checklists; o) "deleted" requirements document recommendation as they have been previously transmitted to the document authors and there are no new recommended changes.
06	02/07/97	Revision 06 revised the hydrologic evaluations contained in Section 11.1; added six additional attachments to support the revised hydrologic evaluations; updated Main Drift and South Ramp slopes; updated design information, including information related to test alcoves and the subsurface ventilation system, updated test information; generally exempted information pertaining to the use of temporary items/materials (not permanently emplaced/committed to the subsurface ESF environment or otherwise controlled per Section 13.2 of this DIE) from reporting in accordance with procedure YAP-2.8Q; specifically exempted information pertaining to the use of the gaseous tracer sulfur hexafluoride from reporting in accordance with procedure YAP-2.8Q; revised the text to reflect that the TBM is no longer designated as a separate Configuration Item; added descriptions of ventilation system tests using sulfur hexafluoride that have been and are planned to be performed; revised the text to indicate that chlorinated, untraced water may be used for drinking water, ice, and hand wash stations underground; updated the approved TFM listing (Attachment 11); revised the water controls to require strictly location-based (i.e., independent from TBM advance) water reporting after TBM hole-out at the South Portal; changed the required frequency for water reporting, in both the TS

DIE Title

Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility

DI Number (include revision number)

BAB000000-01717-2200-00005 Rev 07

Rev No.	Date	Description of Revision
06 (Con't)		Loop and alcoves, from once-per-shift to once-per-day, for days when water is used; enhanced the requirement to trace construction water used underground to additionally require that all batches of traced water be mixed, sampled, analyzed, and found to be within the prescribed lithium bromide concentration limits prior to release for use; clarified the reporting requirement for water used in alcoves; added a specific discussion concerning why additional controls on peak particle velocity during drill-and-blast excavation are not required based on test interference concerns; acknowledged Field Work Packages, in addition to Job Packages and Test Planning Packages, as approved test implementation documents; reflected the reorganization of the Surface-Based Testing Coordination Office (SBTCO) and the ESF Test Coordination Office (ESF TCO) into one organizational unit, the Test Coordination Office (TCO); reviewed use of the words "surveillance" and "inspection" in view of their precise QA program definitions, and made changes as appropriate; incorporated five existing Category II.
07	01/08/99	Revision 07 eliminated pre-daylighting requirements and 7.62 m specific TBM requirements (discussions remain where applicable); incorporated and superseded ECRB East-West Cross Drift Starter Tunnel Category II DIE; added discussion on construction, operation, and maintenance of niches and slot cuts; updated drill-and-blast controls; added requirement to use automatic cutoffs for water sprayed on the conveyor when the conveyor is not in operations; eliminated discussion on refuge chambers; discussed water meter accuracy and calibration requirements; adjusted reporting requirements for TS Loop alcoves from 5-m segments to 10-m segments; extended dust control water evaporation credit to alcoves with concrete inverts; discussed two-rail operations in TS Loop; updated ventilation/evaporation discussion; incorporated Interim Change Notice (ICN) 01 for liquid-phase water balance clarifications; updated the reference section and Attachment II (TFMs) to be consistent with current revisions/status; and made various editorial changes. Numerous format changes were made to comply with the M&O Document Checklist Process. Change bars were not included in the Reference section due to the quantity of format changes required.

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CONTENTS (Continued)

CONTENTS (Continued)

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CONTENTS (Continued)

FIGURES

TABLES

DETERMINATION OF IMPORTANCE EVALUATION FOR THE SUBSURFACE EXPLORATORY STUDIES FACILITY

1. PURPOSE

This Determination of Importance Evaluation (DIE) applies to the Subsurface Exploratory Studies Facility (ESF), encompassing the Topopah Spring (TS) Loop from Station 0+00 meters (m) at the North Portal to breakthrough at the South Portal (approximately 78+77 m), the Enhanced Characterization of the Repository Block (ECRB) East-West Cross Drift Starter Tunnel (to approximate ECRB Station 0+26 m), and ancillary test and operation support areas in the TS Loop. This evaluation applies to the construction, operation, and maintenance of these excavations. A more detailed description of these items is provided in Section 6.0. Testing activities are not evaluated in this DIE. Certain construction activities with respect to testing activities are evaluated; but the testing activities themselves are not evaluated. The DIE for ESF Subsurface Testing Activities (BAB000000-01717-2200-00011 Rev 01) (CRWMS M&O 1998a) evaluates Subsurface ESF Testing activities. The construction, operation, and maintenance of the TS Loop niches and alcove slot cuts is evaluated herein and is also discussed in CRWMS M&O 1998a. The construction, operation, and maintenance of the Busted Butte subsurface test area in support of the Unsaturated Zone (UZ) Transport Test is evaluated in CRWMS M&O 1998a. Potential test-to-test interference and the waste isolation impacts of testing activities are evaluated in the ESF Subsurface Testing Activities DIE and other applicable evaluation(s) for the Job Package (JP), Test Planning Package (TPP), and/or Field Work Package (FWP).

The objectives of this DIE are to determine whether the Subsurface ESF TS Loop and associated excavations, including activities associated with their construction and operation, potentially impact site characterization testing or the waste isolation capabilities of the site. Controls needed to limit any potential impacts are identified. The validity and veracity of the individual tests, including data collection, are the responsibility of the assigned Principal Investigator(s) (PIs) and are not evaluated in this DIE.

The following statements represent a summary of previous revisions of this DIE:

> Revision 1 of this DIE covered changes made as a result of revisions to input documents and clarification of the requirements and their bases.
>
> Revision 2 of this DIE incorporated changes made as a result of the Interdisciplinary Review of Revision 01 of General Specification Section 01501 (the current revision of Specification Section 01501 is included as CRWMS M&O 1997a). These changes included: clarification of water balance, diesel fuel, and Tunnel Boring Machine (TBM) excavation plan requirements and bases.

Revision 3 of this DIE was a limited scope revision to clarify the water use requirement by eliminating as a QA control the requirement to recover the water from the Swellex rockbolts. Additionally, the revision also addressed the limited use of pneumatic drills, clarified the definition of the transition zone, and updated the references.

Revision 4 of this DIE incorporated changes made as a result of revisions to the input documents (which included a test interference evaluation of the surface conveyor and drill-and-blast activities associated with design package 2C). Changes in the DIE included: clarification of water tracer concentration, diesel use reporting, and drill-and-blast records requirements. Two new requirements were added regarding testing and construction schedules to minimize the potential of impact to site characterization activities. Exploratory Studies Facility Design Requirements (ESFDR) document references were also updated.

Revision 5 highlights: reformatting due to Revision 01 of NLP-2-0; including waste isolation and test interference impact evaluations in the DIE; eliminating QA classification sections from the DIE (classification analyses are now performed as separate discrete evaluations for each Configuration Item [CI], see CRWMS M&O 1996a; 1997b; 1995a; 1995b; 1996b); revising the scope to include the TS Loop (including associated support areas and the ESF Starter Tunnel); deleting evaluation of surface CIs for Surface Conveyor and Communication Systems (as they are now covered by the applicable surface DIE(s)); deleting classification-related requirements (covered in separate evaluations); modifying and clarifying DIE requirements; and updating ESFDR references. (See revision record for additional information on the revision.) With the approval of Revision 5, the following documents were superseded:

Determination of Importance Evaluation for ESF Starter Tunnel Drill-and-Blast Section, BAB000000-01717-2200-00003-07, Revision 07, January 14, 1994.

Determination of Importance Evaluation for Subsurface Power Substation, BABFAA000-01717-2200-00166, Revision 00, June 2, 1995.

Test Interference Evaluation (TIE) for the Construction of the North Ramp of the Exploratory Studies Facility (ESF) CRWMS/M&O Design Package 2C, BABFA0000-01717-2200-00001 Rev 07, January 25, 1995.

Test Interference Evaluation Specific to Consideration of Planned Use of Tracer, Fluids, and Materials and Planned Starter Tunnel Tests in Conjunction with JP 92-20 Construction of the North Ramp Starter Tunnel, LV.SC.BWD.3/93-075, March 24, 1993.

Addendum to the Test Interference Evaluation on the use of Cement Grout in Placing Rockbolts in the Exploratory Studies Facility (ESF) North Ramp Starter Tunnel, LV.SC.STN.4/93-114, April 23, 1993.

Second Addendum to the Test Interference Evaluation on the Use of Cement Grout in Placing Rockbolts in the Exploratory Studies Facility (ESF) North Ramp Starter Tunnel, LV.SC.BWD.6/93-157, June 15, 1993.

The following documents are no longer used as design inputs to the superseded DIEs listed above. They are used as references in this or other DIEs or as input to JPs, TPPs, etc., for activities not covered by this DIE and are not superseded.

Test Interference Evaluation for the North Ramp Alcove #1 Construction and Associated Testing in the Exploratory Studies Facility, BABEAD000-01717-2200-00061 Rev. 02, December 22, 1993.

Waste Isolation Evaluation, Tracers, Fluids and Materials for Exploratory Studies Facility (ESF) Phase 1A Construction, BAB000000-01717-2200-00062 Rev. 03, January 10, 1994.

Waste Isolation Evaluation, Construction Water for Package 2C Excavation of the ESF North Ramp, BABE00000-01717-2200-00008 Rev. 04, January 26, 1995.

Waste Isolation Evaluation, Tracers, Fluids, and Materials and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction, BABE00000-01717-2200-00007 Rev. 04, January 26, 1995.

Waste Isolation Evaluation, Exploratory Studies Facility Surface Systems for Water Conveyance and Disposal, BABBD0000-01717-2200-00001 Rev. 00, December 31, 1993.

Revision 6 highlights: revised the hydrologic evaluations contained in Section 11.1; added six additional attachments to support the revised hydrologic evaluations; updated Main Drift and South Ramp slopes; updated design information, including information related to test alcoves and the subsurface ventilation system; updated test information; generally exempted information pertaining to the use of temporary items/materials (not permanently emplaced/committed to the Subsurface ESF environment or otherwise controlled per Section 13.3 of this DIE) from reporting in accordance with procedure YAP-2.8Q (YMP 1998a); specifically exempted information pertaining to the use of the gaseous tracer sulfur hexafluoride (SF_6) from reporting in accordance with procedure YAP-2.8Q; revised the text to reflect that the TBM is no longer designated as a separate Configuration Item; added descriptions of ventilation system tests using SF_6 that have been and are planned to be performed; revised the text to indicate that chlorinated, untraced water may be used for drinking water, ice, and hand wash stations underground; updated the approved Tracers, Fluids, and Materials (TFM) listing (Attachment II); revised the water controls to require strictly location-based (i.e., independent from TBM advance) water reporting after TBM hole-out at the South Portal; changed the required frequency for water reporting, in both the TS Loop and alcoves, from once-per-shift to once-per-day, for days when water is used; enhanced the requirement to trace construction water used underground to additionally require that all batches of traced water be mixed, sampled, analyzed, and found to be within the prescribed lithium bromide concentration limits before release for use; clarified the reporting requirement for water used in alcoves; added a specific discussion concerning why additional controls on peak particle velocity during drill-and-blast excavation are not required based on test interference concerns; acknowledged Field Work Packages, in addition to Job Packages and Test Planning Packages, as approved test implementation documents; reflected the reorganization of the Surface-Based Testing Coordination Office (SBTCO) and the ESF Test Coordination Office (ESF TCO) into one organizational unit, the Test Coordination Office (TCO); reviewed use of the words "surveillance" and "inspection" in view of their precise QA program definitions, and made changes as appropriate; made editorial, grammatical, and typographical enhancements throughout; and added and updated references as required. The following Category II DIEs were incorporated (without significant changes) into this DIE with Revision 6 and are therefore superseded:

Determination of Importance Evaluation for Contingency Use of Grout, BAB000000-01717-2200-00147 Rev 00, October 5, 1995.

Determination of Importance Evaluation for the Design and Construction of the TS Loop South Ramp and South Portal, BAB000000-01717-2200-00150 Rev 00, March 22, 1996.

Determination of Importance Evaluation for the Design and Construction of the TS Main Drift Thermal Testing Facility, BABEAF000-01717-2200-00002 Rev 02, September 30, 1996.

Determination of Importance Evaluation for the Design and Construction of the Southern Ghost Dance Fault Alcove, BABEAF000-01717-2200-00005 Rev 01, August 28, 1996.

Determination of Importance Evaluation for ESF Ventilation System Testing Using Sulfur Hexafluoride, BABFAD000-01717-2200-00001 Rev 01, September 11, 1996.

Revision 7 highlights: revised DIE to eliminate pre-daylighting requirements and 7.62 m specific TBM requirements (discussions remain where applicable); incorporated ECRB East-West Cross Drift Starter Tunnel Category II DIE; added discussion on construction, operation, and maintenance of niches and slot cuts; updated drill-and-blast controls; added requirement to use automatic cutoffs for water sprayed on the conveyor when the conveyor is not in operations; eliminated discussion on refuge chambers; discussed water meter accuracy and calibration requirements; adjusted reporting requirements for TS Loop alcoves from 5-m segments to 10-m segments; extended dust control water evaporation credit to alcoves with concrete inverts; discussed two-rail operations in TS Loop; updated ventilation/evaporation discussion; incorporated Interim Change Notice (ICN) 01 for liquid-phase water balance clarifications; updated the reference section and Attachment II (TFMs) to be consistent with current revisions/status; and made various editorial changes. The following Category II DIE was incorporated (without significant changes) into this DIE with Revision 7 and is therefore superseded:

Determination of Importance Evaluation for East-West Cross Drift Starter Tunnel, BABEAF000-01717-2200-00010 Rev. 01, October 1, 1997.

2. QUALITY ASSURANCE

This DIE revision is prepared in accordance with Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) implementing line procedure NLP-2-0 Revision 05 (CRWMS M&O 1998b), subject to the requirements of the United States Department of Energy (DOE) Office of Civilian Radioactive Waste Management Quality Assurance Requirements and Description (QARD) for the Civilian Radioactive Waste Management Program. This evaluation herein is quality-affecting because it establishes the applicability of the QA program to site activities associated with the TS Loop with specific to potential impact on site characterization data, the waste isolation capabilities of a potential geologic repository at the Yucca Mountain site, and other permanent Q-List (YMP 1998b) items (which are classified QA-1, QA-2, and QA-5, including natural barriers) that have been constructed or installed at the Yucca Mountain site. This DIE addresses 1) activities associated with permanent items, and 2) temporary items or activities that are subject to QA control (temporary items are not assigned specific classification numbers). Pursuant to the requirements of Title 10, Code of Federal Regulations Part 60 (10CFR60), Section 15(c)(1), QA controls for minimizing, to the extent practical, any potential for impacts (as identified herein) to permanent, classified items, including potential impacts associated with the use of temporary items, are established by this DIE.

3. METHODOLOGY

This evaluation was performed in accordance with Attachment I of procedure NLP-2-0, "Determination of Importance Evaluations" (CRWMS M&O 1998b). This is a Category III DIE since it addresses field activities that are potentially significant with respect to their effects on Q-List items and/or site characterization data and does not have an applicable Category III DIE or analogous precedent. The DIE is prepared by:

1) reviewing the best available design information related to subsurface construction, operation, and maintenance activities associated with the TS Loop, auxiliary excavations (alcoves, niches, etc.), and ECRB Cross Drift Starter Tunnel;

2) evaluating the potential of these items and activities to affect the Q-List items and site characterization testing;

3) establishing controls where necessary to minimize to the extent practical potential impacts on Q-List items (including the natural barriers) and site characterization testing.

The best available information related to Subsurface ESF activities includes, but is not limited to, preliminary/approved M&O design documents, construction drawings and specifications, FWPs, TCO/PI criteria letters, and applicable E-Mail. In cases where inputs from these documents provide critical characteristics that could impact the conclusions and derived requirements of this evaluation, specific reference citations are provided in the text.

After approval of this DIE, implementing documents (e.g., FWPs, design specifications, and design drawings) will be reviewed by the Safety Assurance Department. These reviews are conducted to:

1) ensure that the original basis for the evaluation (i.e., best available design information) adequately bounds the final scope of activities to be conducted in the Subsurface ESF, and

2) verify that any applicable DIE requirements have been properly integrated into the implementing documents.

4. ASSUMPTIONS

4.1 It is assumed in Section 11.1 and 11.3.3.3 that the minimum offset from the TS Loop (including associated excavations) to the closest waste package emplacement area is 37 m to establish bounding conditions for this analysis (CRWMS M&O 1995c).

4.2 In establishing the boundaries for the DIE, it is assumed that construction and other activities associated with TBM operation, utilities installation, and support for TBM operation for construction of the TS Loop will be done in accordance with the ESF Design specifications and drawings, which implement applicable requirements of the ESFDR (YMP 1997a).

4.3 The TFMs to be used in the Subsurface ESF will be those for which data (e.g., Material Safety Data Sheets [MSDSs]) have been provided and reviewed (Attachment II). TFMs that have not yet been reviewed will be evaluated in accordance with the project TFM procedure (YAP-2.8Q, YMP 1998a). It is assumed that the MSDS-recommended procedures will be followed for use, storage, handling, ventilation, spills and leaks, and personnel safety. Temporary items/materials used for the construction, operation, maintenance and reclamation of facilities and equipment in the Subsurface ESF that are not permanently emplaced/committed to the Subsurface ESF environment (based on the detailed as-built Title III drawings) or specifically controlled by requirements contained in Section 13.3 of this DIE are exempted from the installation and removal reporting requirements contained in procedure YAP-2.8Q. This assumption establishes the scope for this DIE with respect to

TFMs and is based on the ESFDR (YMP 1997a) and procedure YAP-2.8Q (YMP 1998a).

4.4 Based on the TFM procedure (YAP-2.8Q, YMP 1998a), it is assumed that water used for fire suppression and control will be treated as a significant spill.

4.5 Testing support elements (i.e., cable runs, standard power, lighting, compressed air, ventilation, communications, Data and Control System [DCS] connection, etc.) critical to the conduct of specific tests will be addressed in TPPs and/or FWPs developed for those tests. The TPPs and/or FWPs will also address access needed to support the testing operations as soon as practical after testing equipment is installed, or testing space is constructed. This assumption further clarifies the scope of the DIE (as stated in Section 1.0 and throughout the evaluation) with respect to testing activities.

5. COMPUTER CALCULATIONS

No analytical computer programs have been used directly in the preparation of this document. However, computer programs have been used in referenced documents, which form the basis for some of the results presented in this document. Detailed discussions of these computer calculations, including their treatment under the Quality Assurance Program, are given in the referenced documents.

6. DESCRIPTION OF ACTIVITIES

The scope of this evaluation includes the Subsurface ESF as defined by the configuration items (CIs) listed in Table 6.1. The evaluation includes activities associated with construction and use of those same CIs. The description of CIs is a summary based on the Subsurface ESF design documents (including preliminary documentation when final versions are not available). The subsurface design documents (drawings, specifications, and analyses) may be: approved or unapproved documents, draft revisions to existing documents, and drafts of new documents. (Note that certain design documents are referenced separately where specific information is used from those documents (e.g., Brocoum 1995, CRWMS M&O 1996c). For the purposes of this evaluation, TBM refers to the 7.62-m TBM used in the construction of the TS Loop unless otherwise indicated.

Table 6-1 ESF Configuration Items Evaluated

Configuration Item	DIE Section	Configuration Item Description	Permanent/ Temporary
BAB000000	6.1-6.19	Exploratory Studies Facility (ESF)	Permanent
BABDCA000	6.7	Mapping Gantry	Temporary
BABE00000	6.1-6.5	Subsurface Excavations	Permanent
BABEA0000	6.1-6.4	Underground Openings	Permanent
BABEAA000	6.1	Portals (including the ESF Starter Tunnel)	Permanent
BABEAD000	6.2	Main Access Openings	Permanent
BABEAE000	6.3	Operations Support Areas (formerly CIs BABEC0000 and BABECA000)	Permanent
BABEAF000	6.4	Test Support Areas (formerly CIs BABED0000 and BABEDA000)	Permanent
BABEE0000	6.5	Ground Support Systems (formerly CI BABEAB000)	Permanent
BABF00000	6.6, 6.8-6.19	Subsurface Support Systems	Temporary
BABFA0000	6.10-6.19	Subsurface Utilities	Temporary
BABFAA000	6.10	Subsurface Power	Temporary
BABFAB000	6.11	Subsurface Communications	Temporary
BABFAC000	6.12	Subsurface Lighting	Temporary
BABFAD000	6.13	Subsurface Ventilation	Temporary
BABFAE000	6.14	Subsurface Water	Temporary
BABFAF000	6.15	Subsurface Waste Water	Temporary
BABFAG000	6.16	Subsurface Compressed Air	Temporary
BABFAH000	6.17	Subsurface Fire Protection	Temporary
BABFAI000	6.18	Subsurface Sanitary Facilities	Temporary
BABFAK000	6.19	Subsurface Furnishings (formerly CI BABEAC000)	Temporary
BABFB0000	6.6	Machinery and Equipment	Temporary
BABFCB000	6.8	Subsurface Conveyor	Temporary
BABFCC000	6.9	Materials and Personnel Handling	Temporary

6.1 PORTALS (INCLUDING THE ESF STARTER TUNNEL) (CI: BABEAA000)

The North Portal, ESF Starter Tunnel, and South Portal are included in configuration item BABEAA000. The excavation of the ESF Starter Tunnel is completed. As such, it is the remaining construction, operation, and maintenance activities that are evaluated in this DIE to support the bored 7.62-m TS Loop.

The drill-and-blast section of the ESF Starter Tunnel provides a path for TBM emplacement and provides a conduit for utilities and services. The drill-and-blast section of the ESF Starter Tunnel proceeds from the headwall, approximately 60 m into the mountain. The first 10 m of this section of tunnel is sloped approximately negative 2 percent away from the tunnel to minimize the potential of flood water entering the Subsurface ESF.

The design for the South Ramp/South Portal (CRWMS M&O 1996d; 1996e; 1996f; 1996g) indicates that the TBM will maintain an approximately positive 2.6 percent grade as it progresses eastward in the South Ramp until approximately Station 78+27 m. There, the design calls for a 30-m vertical curve that will transition the tunnel from the approximately positive 2.6 percent grade to an approximately negative 2.0 percent grade. Per CRWMS M&O 1996g, the maximum tunnel elevation in the South Ramp occurs at approximately Station 78+42 m. The negative 2.0 percent grade is maintained for the final approximately 20 m before holeout at the South Portal. CRWMS M&O 1996c indicates that the negative 2.0 percent slope need only be maintained for the final 10 m of the tunnel to prevent stormwater runoff from overrunning the South Ramp vertical curve (and thus gaining access to the potential repository horizon). (The calculation supporting these 2.0 percent and 10 m values, Attachment I of CRWMS M&O 1996c, assumes that no stormwater diversion channel will be in place over the South Portal as is present at the North Portal.)

Requirement 1 in the DIE for the Surface ESF (CRWMS M&O 1996h) ensures that the approximately negative 2.0 percent slope established outward at both the North and South Portals be continued across the respective North and South Portal Pads.

6.2 MAIN ACCESS OPENINGS (CI: BABEAD000)

TS Loop (which includes the North Ramp, Main Drift, and South Ramp) work involves the bored excavation, a 7.62-m circular tunnel from Station 00+60 m to approximately Station 78+77 m. In addition, the ECRB Cross Drift and associated Starter Tunnel are considered to be a part of the Main Access Openings and will be excavated to a nominal 5-m diameter. The ECRB Cross Drift Starter Tunnel is evaluated in this DIE. CRWMS M&O 1998c is the DIE for the ECRB Cross Drift from the end of the ECRB Cross Drift Starter Tunnel (approximate ECRB Station 0+26 m) to its terminus. Activities evaluated include: construction, operation, and maintenance of the TS Loop and ECRB Cross Drift Starter Tunnel, and operation of equipment (including a TBM) and vehicles in and around them.

For the TS Loop, the TBM launch chamber face, where boring began, is approximately 0.4 m above the excavated floor of the ESF Starter Tunnel. TBM excavation proceeded from Station 00+60 m, at an elevation of approximately 1123 m, to Station 01+62.5 m, at an elevation of approximately 1122 m. From Station 01+62.5 m to approximately Station 28+04 m, TBM excavation transitioned at an approximate 2.15 percent negative slope. From approximately Station 21+87 m, a horizontal curve (ending in a southerly direction) was to be bored until approximately Station 28+04 m, on the TS Main Drift, was reached. A wastewater sump was excavated at approximately Station 28+05 m (at an approximate elevation of 1065 m). A North Ramp Extension stub drift may be bored or constructed using controlled drilling-and-blasting methods (to provide an area to assemble and launch a TBM), the location of which has not yet been determined. The TS Loop proceeds south through the TS Main Drift at an approximate slope of +1.35 percent along the east edge of the primary emplacement areas (elevation of 1065 m). At approximately Station 56+54 m, the South Ramp begins and the slope steepens to approximately +2.6 percent. From approximately Station 59+35 m, a horizontal curve was bored through an arc of approximately 92 degrees to the left (eastward) to approximately Station 64+25 m. The South Ramp then proceeds eastward at approximately +2.6 percent slope where it terminates at the South Portal at approximately Station 78+77 m (elevation of approximately 1160 m) (CRWMS M&O 1996c). The ESF North Ramp, Main Drift, and South Ramp will provide access to the potential repository. Any construction effects will be incorporated into the design of the potential repository.

6.3 OPERATION SUPPORT AREAS (CI: BABEAE000)

Operation support areas are excavated by the drill-and-blast method or by mechanical excavators, with mucking by a diesel-powered front-end loader. Controlled drilling-and-blasting techniques are used to preserve the integrity of rock outside the excavated areas.

Operation Support Areas include equipment alcoves, niches, and other excavations to support construction and ESF operations along the TS Loop.

A Collection Sump and alcove may be excavated at about Station 28+05 m, which if constructed would include a sump, sump storage tank, and wastewater removal pumps. Temporary construction sumps have been installed at approximately Stations 28+05 m and 59+19 m. Level-actuated pumps located in these sumps pump accumulated water into the tunnel wastewater discharge line. A third temporary construction sump was added at approximately Station 71+45 m (at the bottom of a dip in the South Ramp).

6.4 TEST SUPPORT AREAS (CI: BABEAF000)

Test support areas, also referred to as test alcoves (or test niches for small excavations), are excavated by the drill-and-blast method or by mechanical excavators, with mucking by a diesel-powered front-end loader. Controlled drilling-and-blasting techniques are used to preserve the integrity of rock outside the excavated areas. ESF test-related design requirements are contained in Appendix B of YMP 1997a. Actual test alcove locations, layout, and dimensions are field determined after the faults/contacts to be tested have been identified in the ESF excavation, and geologic information is assessed. Compressed air, water, wastewater, electric power, ventilation, DCS, and telephone communications support will be provided as needed to test alcoves.

North Ramp Testing Alcove #1, the Upper Tiva Canyon Alcove, is approximately 42 m into the ESF Starter Tunnel and currently extends to a length of approximately 34.4 m. Three approximately 30 m deep boreholes were drilled at the face of the Test Alcove for radial borehole testing. Radial borehole drilling and subsequent testing are not evaluated in this DIE, but are evaluated in separate documents supporting the associated TPP(s) and/or FWPs.

Four additional test support alcoves have been excavated in the TS North Ramp: the Bow Ridge Fault Alcove (Alcove #2), the Upper Paintbrush Tuff (Non-Welded) Contact Alcove (Alcove #3), the Lower Paintbrush Tuff (Non-Welded) Contact Alcove (Alcove #4), and the ECRB Cross Drift Starter Tunnel. Each of the alcoves was excavated into the right rib of the North Ramp. The ECRB

Cross Drift Starter Tunnel was excavated into the left rib of the North Ramp. Excavation of a fifth test support alcove in the North Ramp, the Drill Hole Wash Fault Alcove, is currently deferred.

The ECRB Cross Drift Starter Tunnel originates at approximately Station 19+92 m of the North Ramp and was excavated into the left rib at approximately a 45 degree angle from the North Ramp and has a length of approximately 26 m (Kimura 1997).

Concrete was poured over the left half of the rail and invert segments in the North Ramp and throughout the first approximately 14 m of the ECRB Cross Drift Starter Tunnel. The concrete pad has a 0 percent slope in the North Ramp and a positive 0.5 percent slope from the departure point in the North Ramp to the end of the excavated ECRB Cross Drift Starter Tunnel. The flat section of concrete in the North Ramp facilitated assembly of the TBM in the subsurface. The positive slope of the concrete invert in the ECRB Cross Drift Starter Tunnel is expected to match the slope of the excavated invert and is intended to allow for the drainage of water (Kimura 1997).

The excavation of the ECRB Cross Drift Starter Tunnel was accomplished by a combination of controlled drill-and-blast and a mechanical excavator. Diesel-fueled equipment was used to remove the muck from the excavated areas. Ground support in the ECRB Cross Drift Starter Tunnel is consistent with that used in the ESF alcoves, or specifically in the ESF Main Drift transition zone (CRWMS M&O 1996i).

Equipment installed/used in the ECRB Cross Drift Starter Tunnel includes the ECRB TBM and trailing gear, locomotives, conveyor belt, conveyor booster drive, takeup units, electrical switchgear, and rail switching equipment.

Seven test support alcoves have been excavated from the TS Main Drift: the Thermal Testing Facility (Alcove #5), the Northern Ghost Dance Fault Alcove (Alcove #6), the Southern Ghost Dance Fault Alcove (Alcove #7) and four niches (Niches #1, #2, #3, and #4).

The Northern Ghost Dance Fault Alcove (NGDFA) was excavated into the left rib of the TS Main Drift at approximately Station 37+37 m. The alcove extends due east at an approximately 5.0 percent downward slope (CRWMS M&O 1997d; 1997e). Excavation ceased when the extent of the alcove was in proximity to the expected location of the Ghost Dance Fault, and a geothermal borehole was dry-drilled axially from the face of the alcove to locate the fault exactly (at approximately Station 1+54 m, as measured from the centerline of the Main Drift). Excavation then recommenced, at the same grade, azimuth and cross-sectional dimensions, and continued until approximately Station 1+35 m (Hollins 1996a). Excavation ceased at that point pending completion of approximately four months of single borehole testing. Subsequently, the alcove was extended through the Ghost Dance Fault, then doglegged perpendicularly (i.e., approximately paralleling the fault) to allow for additional test boreholes to be drilled back through the fault. Small niches and/or slot cuts may be excavated to support testing in the alcove.

The design for the Southern Ghost Dance Fault Alcove (SGDFA) (CRWMS M&O 1996k; 1996l; 1996m) prescribed that the alcove be excavated off the left rib of the TS Main Drift at approximately Station 50+64 m. The design calls for an Access Drift to extend approximately 125 m due east, as measured from the centerline of the Main Drift. The grade for the Access Drift is nominally level for the first approximately 30.5 m, then ascends at approximately 6.7 percent slope for the remainder of the drift. To facilitate muck removal, the design provides for a Turn Around Bay to be excavated perpendicularly into the right rib of the Access Drift. The centerline of the Turn Around Bay is located approximately 25.5 m from the centerline of the Main Drift, and the terminal face of the Turn Around Bay is approximately 7 m from the centerline of the Access Drift. Beyond the location of the Turn Around Bay, the width of the Access Drift narrows from approximately 6 m to approximately 4 m.

Upon completion of the initial excavation (and similar to the approach used in the NGDFA), a geothermal borehole was dry-drilled eastward into the terminal face of the SGDFA Access Drift to establish the location of the Ghost Dance Fault. If the fault is found to be located more than a nominal 15 m from the initial terminal face of the Access Drift, the drift will be excavated to a final distance that is nominally 15 m from the fault. Additional boreholes may be drilled to define the fault zone, and a period of testing will commence. Upon completion of this testing phase, the alcove will be extended through the fault, and, as with the NGDFA, will dogleg perpendicularly (approximately paralleling the fault) to allow for additional test boreholes to be drilled back through the fault. Small niches may be excavated to support testing in the alcove.

The Thermal Testing Facility (TTF) is the most substantial test support area excavation to date in the Subsurface ESF (excluding the ECRB Cross Drift). The design for the TTF (CRWMS M&O 1996n; 1996o; 1996r; Hollins 1996b; 1996c) prescribed that the facility be excavated off the left rib near the north end of the TS Main Drift at approximately Station 28+27 m. The excavation includes a main Access/Observation Drift (AOD) extending downward (at approximately a negative 11.5 percent slope) toward the east-southeast for approximately 131 m, as measured from the centerline of the Main Drift. A smaller Thermomechanical Alcove (TMA) (also known as the Shakedown Test or Single Heater Test) extends perpendicularly into the right rib of the AOD. The design specifies that the centerline of the TMA be located approximately 38.5 m into the AOD, and that this alcove be approximately 23 m deep. The design also includes a TMA Extension, which originates from the left rib of the TMA and parallels the AOD (as viewed from above). The design minimum unexcavated distance (rib to rib) between the AOD and the TMA Extension is 13 m; and the TMA Extension is approximately 9.5 m deep, as measured from the left rib of the TMA. The TMA and the TMA Extension are located on the same approximate elevation.

A smaller Turn Around Bay is included in the design, located in the right rib of the AOD between the TS Main Drift and the TMA (the design specifies approximately 25.5 m between the centerline of the TS Main Drift and the centerline of the Turn Around Bay). The track of the Turn Around Bay approximately parallels the track of the TS Main Drift. The Turn Around Bay is approximately 10 m deep, as measured from the centerline of the AOD, and is excavated at approximately 0 percent slope.

Additional excavations in the TTF are described as follows:

- A Data Acquisition System (DAS) Niche is located at the far end of the AOD. The DAS Niche extends the length of the AOD by approximately 6 m, and is excavated at approximately 0 percent slope.

- A Connecting Drift extends perpendicularly from the left rib of the AOD. The centerline of the Connecting Drift is approximately 128.4 m from the centerline of the TS Main Drift. The Connecting Drift is approximately 45 m long (total, as measured from the centerline of the AOD), but also includes a branch perpendicularly to the left to reach the locale of the Heated Drift after only approximately 32 m (as measured from the centerline of the AOD to the centerline of the Heated Drift branch). The centerlines of the AOD and of the Heated Drift branch are approximately parallel, as viewed from above. The Heated Drift branch extends approximately 13 m back toward the TS Main Drift (as measured from the centerline of the Connecting Drift) before the start of the actual Heated Drift.

  The floor of the Connecting Drift descends at an approximately 11.4 percent slope to reach the elevation of the Heated Drift branch. Subsequent excavation will be at approximately 0 percent slope.

- A Plate Loading Niche was excavated perpendicularly from the right rib of the Heated Drift branch. The centerline of the Plate Loading Niche is approximately parallel to and 9.25 m away from the centerline of the Connecting Drift. The terminal face of the Plate Loading Niche is approximately 8.5 m from the centerline of the Heated Drift branch.

- The Heated Drift is an axial continuation of the Heated Drift branch, extending from approximately 13 m from the centerline of the Connecting Drift to a terminal face that is approximately 61 m from the centerline of the Connecting Drift. The Heated Drift has a circular cross-section with an initial diameter of approximately 5 m. Between approximately 46 m and approximately 48m into the drift (as measured from the centerline of the Connecting Drift), the drift diameter increases from approximately 5 m to approximately 5.6 m.

- A concrete invert floor will be used in large sections of Alcove #5, but this is considered to be a testing arrangement such that it is evaluated in the DIE for ESF Subsurface Testing Activities (CRWMS M&O 1998a).

Niches are evaluated as temporary testing accommodations. The location of these niches is coordinated between the TCO and the M&O's Repository Subsurface Design Organization. If the potential repository layout design is changed (after the excavation of these niches), the location of the niches must be factored into the new design--including potentially evaluating these niches as permanent accommodations.

Hollins 1997a; Mitchell 1997a describe two small testing niches that were excavated during Fiscal Year 1997 in the west (right) rib of the TS Main Drift (which places these niches within the potential repository waste isolation standoff zone). Niche #1 was excavated at approximately Station 35+66 m. Niche #2 was excavated at approximately Station 36+50 m (which is approximately three 28-m intervals away from the first niche). The niches were excavated at a centerline azimuth of approximately 315 degrees at a 0 percent slope (within standard engineering tolerances). Thus, the centerline of the niches intersect the TS Main Drift at approximately Stations 35+69.4 m and 36+53.4 m, respectively. The niches have a minimum width of 4 m and a minimum height of 4 m (at the top of an arched crown). The minimum distance between the terminal face of a niche and the right rib of the TS Main Drift is about 5 m.

Two additional niches were excavated during Fiscal Year 1998. Niche #3 was excavated on the right rib of the TS Main Drift near the location where the ECRB Cross Drift crosses the TS Main Drift (approximately Station 31+03.5 m per Hollins 1997b) (Mitchell 1997b). Niche #4 was excavated on the right rib of the TS Main Drift near Station 47+84.8 m (Hollins 1997b). The final locations of Niches #3 and #4 were coordinated with the M&O's Repository Subsurface Design Department to ensure they would not interfere with the repository emplacement drift layout design (Mitchell 1997b). Niches #3 and #4 were excavated mechanically with only minor differences from Niches #1 and #2 (e.g., minimum height of Niche #3 is approximately 3.3 m and a slight positive slope upward from the TS Main Drift was required). Consistent with previous ESF construction operations, diesel-powered equipment was used to remove the muck from the excavated areas.

As described in CRWMS M&O 1998a, the niches are designed to provide access to a semicircular testing zone with a radius of approximately 15 m. The testing aspects of the niche studies are evaluated in CRWMS M&O 1998a.

Slot cuts are planned in at least two TS Loop alcoves. Mitchell 1998a; 1998b; YMP 1998d provide a description of the alcove slot cut construction activities in ESF Alcoves #4 and #6. Mitchell 1998a provides a generic description of the alcove slot cuts and the boreholes used to inject tracer material above the slot cuts. The two slot cuts are nominally less than 5 m wide by less than 5 m deep with a height of less than 0.5 m. The Alcove #4 slot cut is located at the terminal (north) end of the alcove with a potential expansion of the slot cut into the last approximately 1 m of the left (west) rib of the alcove. The Alcove #6 slot cut is located along the right (south) rib of the alcove beginning at approximately alcove Station 0+55 m.

Per Mitchell 1998a, the alcove slot cuts are excavated using wet or dry-drilling techniques as follows. A line of NQ-3 size pilot holes are drilled at about 1-foot intervals along the planned centerline of the slot cut. A 1-foot diameter tri-cone reaming bit is used to drill overlapping holes using the pilot holes as guides for the reaming bit. This results in a roughly rectangular shaped slot (with small irregularities across the top/bottom of the slot caused by the use of a round reaming bit to create a rectangular cut). Small support jacks are then inserted into the slot cut to provide support to the surrounding rock and keep the slot cut from collapsing. Boreholes are dry-drilled in a pattern determined by the PI(s) above the given slot cut in preparation for tracer testing. The boreholes extend beyond the depth of the slot cuts, but will be packed off such that the releases of tracers only occur above the slot cut. The drilling of the boreholes and the testing aspects of the alcove slot cut studies are evaluated in CRWMS M&O 1998a.

(Note that all of the dimensions and slopes cited in this section are approximate. Small additional equipment niches may also be excavated. Such minor changes will not impact the conclusions of this evaluation.)

Test alcoves are planned for the South Ramp; however, construction of these alcoves has been deferred. Additional test alcoves and niches could also be excavated as directed by the Yucca Mountain Site Characterization Project (YMP) M&O's TCO.

The final configuration of the test alcoves and niches will be dependent on the geologic conditions encountered and the extent that construction effects, such as grout or water usage, have penetrated the TS Loop tunnel walls. Testing in the test alcoves is in general similar to the tests performed and planned in North Ramp Alcove #1, namely: construction monitoring tests, Multi-Point Borehole Extensometer (MPBX) tests, single-point load cells, mapping and sampling, hydrochemistry radial borehole tests, and other scientific tests. Extensive testing at elevated temperatures is planned for the TTF. The evaluation of these testing activities is allocated to the DIE for ESF Subsurface Testing Activities (CRWMS M&O 1998a).

The need for additional alcoves and niches may be identified during construction to examine other major faults encountered, or to support hydrologic testing of faults or fractures (should perched water be encountered).

6.5 GROUND SUPPORT SYSTEMS (CI: BABEE0000)

TS Loop ground support configurations are dependent on the geotechnical properties of ground encountered. Different types of ground support will be used based on the conditions encountered during excavation. Ground support may include mechanical groutable rockbolts, Super Swellex rockbolts, standard split sets, welded wire fabric (mesh), interlocked wire mesh, shotcrete, concrete, steel sets, channel units, steel lagging, etc. At the portal headwalls, optional disposable drill bits may also be used. In accordance with CRWMS M&O 1996s, steel sets used for the main TS Loop excavation will decrease the radius of the excavation (where used) by approximately 0.21 m, for W8 x 31 steel sets, or approximately 0.16 m, for W6 x 20 steel sets.

In the event that ground conditions are encountered during excavation that are determined to be incapable of supporting TBM operation (such as may be the case in the area of faults), the option of chemical grouting to stabilize the ground may be considered as a contingency. This may involve drilling holes from the surface, or from within the tunnel, and injecting grout materials (involving such mixtures as sodium silicate and sodium aluminate, or cement grout with sodium silicate or aluminum silicate as a set control agent) into a zone in front of the TBM. Less extensive grouting procedures include using cementitious grout to fill voids created by raveling ground in the crown and walls of the tunnel and tunnel grouting with packers to stabilize fractured and weak rock and control water inflows if perched water is encountered in sufficient quantities that tunneling and/or safety issues dictate that the volume of inflow must be significantly reduced.

Rockbolt holes in the TS Loop will normally be drilled by electro-hydraulic actuated rock drills. Two such drills were located on the TBM tail shield, two on the Drill/Cleanup Platform (located at the forward end of the TS Loop Mapping Platform), and one will be located on an alcove Drill Jumbo. The flushing system for all the drills is an air/mist type capable of air and/or water operation; no flushing medium passes through the oiling system. The rock drills are capable of drilling boreholes, and will have an integral bolting unit capable of installing Williams, Super Swellex, Standard Swellex, Split Sets, grouted rebar, or Swellex pins. A man basket may be supplied with the alcove Drill Jumbo. Rock drill assembly operating fluids include lubricating oils, hydraulic fluids, grease, and similar products. Note that pneumatic drills may be necessary to install rockbolts to address personnel safety concerns where access with the electro-hydraulic drills is restricted.

6.6 MACHINERY AND EQUIPMENT (CI: BABFB0000)

The TBM is an electric-powered continuous mechanical mining or excavation machine, which consists primarily of a cutting head, shielding, continuous grippers, and trailing gear. A flat cutterhead design with wrap around buckets continuing radially into the face area is used to enhance picking up muck on a decline. All cutters use wedge-type mounting and can be changed from inside the cutterhead structure. The TBM uses two sets of grippers so that gripping is always maintained. The TBM is capable of backward movement by reversing the gripping cycle; this reversal would require removal of steel sets, if installed (Nordin 1994).

The TBM conveyor system consists of a forward conveyor and a trailing conveyor. The forward conveyor protrudes through the cutterhead support and receives muck through a chute as the cutterhead buckets unload. The unloading point for the buckets is at the approximate centerline of the TBM. The high capacity of the TBM conveyor minimizes the chance of muck spillage. Both conveyors are provided with belt speed indicators and are interlocked with the cutterhead so that the belts must be running before the cutterhead can rotate.

A TBM ventilation system is provided. Air is pulled from the TBM cutterhead through a dust scrubber, and from the tail shield area. Air is discharged directly into the main discharge duct.

The control console is completely electric with no fluid connections. A data acquisition and recording system records TBM operating parameters, error messages, volume excavated, etc. (information may be periodically downloaded and removed to ensure that reports are current and operating methods can be modified as needed). Tunnel line, grade, and TBM roll are monitored by the ZED-26 Guidance System. The position of the TBM is calculated by measuring its position relative to a laser beam that is positioned parallel to design alignment and grade.

Emergency systems for the TBM include emergency stop switch stations (located at the operators control console, inside the forward shield at the point of access to the cutterhead, and on the backup at the two conveyor dump points) and a pull cord located along the length of the trailing gantry. A dry chemical fire suppression system is mounted to the TBM at the hydraulic unit and at the lubrication unit. Hand-held A:B:C fire extinguishers are mounted at accessible locations throughout the TBM and backup system. The TBM also includes a battery operated emergency lighting system and a monitoring and shutdown system for tunnel gas.

The cutterhead drive seal system consists of an inner and outer seal assembly. Each assembly consists of three lip-type face seals, a replaceable and reversible sealing surface and a labyrinth opening to the seal cavity. The inner-most seal has the lip facing inward to contain oil. The cavity between the middle and inner seal is connected to a gravity source of oil, but no oil flow is induced. The middle and outer seals have the lips facing outward to inhibit the ingress of fines. Between the outer and middle seal, grease is injected and flows outward through the labyrinth to inhibit the ingress of fines. This arrangement provides lubrication for the middle and outer seal. Flushing of the cavity with water to purge the main seals of grease inhibits any ingress of foreign material that is discharged with the purging water without loss of grease.

Two water systems are mounted on the TBM:

1) a closed loop system for the main drive motor and speed reducer cooling jackets. This system consists of a water pump and forced air cooling radiator mounted in the backup unit. Water is pumped in a continuous loop through the heat exchanger to the main motors and reducers, then to a collection tank. In the event of water loss, a float switch in the tank will shut off the pump and alert the operator of the fault.

2) an open spray system to be selectively used for dust suppression. This system consists of sprayers in the cutterhead muck pickup area, which spray into the chute where the cutterhead muck buckets dump muck onto the TBM conveyor, and at the two conveyor transfer points. Flapper switches above the conveyor belt ensure that the water spray system cannot be turned on unless muck is moving along the belt. The system is operated from the TBM console. The system also includes a manual, lockable valve to be used to replenish water in the closed loop system, if necessary. If water is needed for rockbolts or coring, this can be routed by flexible line from the hard water pipe in the gantry.

The oil lubrication system is a closed loop system designed to provide a constant flow of lubricating oil to the main bearing, bull gear, and drive pinions. The system is contained within the cutterhead support. The distribution block meters oil to the delivery points, which are all contained within the sealed main bearing cavity. Return oil flows to the bottom of the cavity where it is fed into the sump tank for filtering and redistribution. System flow is monitored by a flow meter.

The grease lubrication system is set to begin pumping when cutterhead rotation is initiated, to prevent grease from being purged needlessly. A manual override switch allows for boosting grease supply to the seals during maintenance.

Speed reducers are lubricated by means of a non-recirculating sump, which is self-contained within each individual reducer. The oil is retained by shaft seals at the input and output ends and by O-ring seals at bolted joints.

The TBM friction joints are lubricated by two centralized, automatic greasing systems; each equipped with a pump that draws from a reservoir. The systems distribute grease to the various wear points by means of distribution manifolds.

The hydraulic components for the thrust, steering, gripper, roof support and ring beam erector circuits, as well as the hydraulic oil tank for these circuits are located inside of the TBM shields. The pumps for all circuits are located below the tank to provide a pressurized inlet for the pumps. The TBM has three main hydraulic systems: 1) thrust and gripper system, 2) erector and auxiliary systems, and 3) conveyor drive circuit.

A two-way telephone system includes phone stations at the operators control console, the conveyor dump stations, and inside the forward shield at the access area to the cutterhead.

The trailing decks are supported by nine flatbed cars located between TBM trailing gear cars 3 and 4. A drill/cleaning platform is located on the second flatbed car. A rolling mapping gantry capable of moving along a portion of the trailing deck is also provided. The gantry supports a camera rail to allow unobstructed photography of the tunnel for an arc of 250 degrees. Electric drive is used to move the mapping gantry independent of trailing gear motion. A supplemental ground support platform is located on the ninth flatbed car.

(Note: The 7.62-m TBM used to excavate the TS Loop has been decommissioned and future uses of this TBM have not been identified. ECRB Cross Drift construction used a 5-m TBM that is evaluated in CRWMS M&O 1998c.)

6.7 MAPPING GANTRY (CI: BABDCA000)

The TS Loop Traveling Mapping Gantry is located over the trailing floor conveyor system between trailing gear cars 3 and 4 (between the Drill/Cleaning Platform and the Supplemental Ground Support Platform), has a nominal travel length of approximately 46 m, and moves independently from the TBM for the purpose of unobstructed geologic mapping and photographing of the TS Loop tunnel wall over a minimum 250 degree arc. Rails supporting the mapping gantry run parallel to those supporting the trailing floor within 4 inches. Wheels are equipped with air- or electric-powered brakes and a backup emergency braking system. Gantry direct drive is provided by electric motors. Horizontal jacks are employed, when necessary, to keep the mapping gantry in a fixed position over the moving trailing floor. Jacks are air- or mechanically-operated, will contact the tunnel walls, and will not lift the gantry off its rails. The gantry can move vertically up to three (3) inches. Wheels are equipped with sealed bearings to prevent hydrocarbon spills. Four movable 500-watt quartz lamps and four fluorescent lighting fixtures are mounted on the mapping gantry. A phone communication system links the mapping gantry to the TBM operator (Koss 1994).

(Note: The Mapping Gantry used in the TS Loop has been decommissioned and future uses of this Mapping Gantry have not been identified. ECRB Cross Drift construction used a 5-m Mapping Gantry that is evaluated in CRWMS M&O 1998c).

6.8 SUBSURFACE CONVEYOR (CI: BABFCB000)

During initial TS Loop excavation, mucking was performed using diesel-powered or electric (battery) locomotives and conventional muck cars. After the conveyor system was installed, water spray for dust control was available to be used at transfer points. In addition to sprays used for the TBM conveyor (at the TBM face and at the TBM conveyor transfer), dust control sprays are available at the point where the TBM conveyor transfers muck onto the main conveyor (on the TBM trailing gear), the conveyor booster drive transfers, and at the Transfer Tower. If used, the dust control spray rate at each conveyor transfer point will be approximately two-thirds liters per second. The design criteria for the system (CRWMS M&O 1993a) required that each spray header include an interlocked solenoid shutoff valve to prevent water usage when the conveyor is not running or when the conveyor is running with no muck on the belt. In addition, each spray header was to include a hand control valve for flow regulation, a separate manual shutoff valve, a pressure indicating meter, and local flow meter to show the amount of water being used.

The subsurface conveyor system uses a belt to convey muck from the TBM(s) and other excavation operations to a surface conveyor system. Major conveyor components include: the remote discharge section; the main drive section; booster drives; the belt storage and take-up unit; the advancing tailpiece section (which includes a hopper for transferring muck onto the main conveyor and a manipulator frame that interfaces with the TBM trailing gear); the intermediate loading section (which includes a loading hopper for transferring muck onto the main conveyor from any intermediate location); straight and curved conveyor segments; fire resistant conveyor belting; the belt splice platform; the belt storage unit; the conveyor control system; the dust control and suppression system; conveyor fire protection system; and miscellaneous equipment.

The subsurface conveyor system employs operating fluids such as lubricating oils, hydraulic fluids, grease, and dust suppression water, which can become potential contaminants if released onto the rock mass. Conveyor system components containing fluids of concern are equipped with leak prevention features. The conveyor belt inside the tunnel is supported at a distance of approximately 3 m above the bottom of the excavation. The conveyor control system provides signals for drive fault, high/low belt speed shutdown, belt side travel limit switch indication, emergency stop switch indication, damaged belt switch indication, plugged chute switch indication, belt speed, dust suppression water spray operation, etc.

This evaluation only covers the Subsurface Conveyor system up to the headwall (Station 0+00 m). Refer to CRWMS M&O 1996h for discussions on the surface portions of the subsurface conveyor. The ECRB Cross Drift portion of the conveyor system is evaluated in CRWMS M&O 1998c.

6.9 MATERIALS AND PERSONNEL HANDLING (CI: BABFCC000)

Locomotives are used to haul muck, personnel, supplies, and invert segments, as well as to transport a crane. The locomotives are capable of operating on grades of ± 3 percent. Diesel, electric, or battery electric locomotives will be used.

If electric (i.e., non-battery) trolley locomotives are used, electrical bonding between the rails will be provided. A trolley wire will be located above the center of the two outside tracks, and will be guarded along its full length.

Plans call for the use of a number of different types of diesel-powered equipment in the ESF. These include, but are not limited to, the following:

- locomotives for rail transportation of muck, materials, and personnel;
- front-end loaders or load haul dumps (LHDs), used in testing and support alcove construction;
- jumbo drills used for drilling blast and rockbolt holes.

The amount of diesel fuel that is underground at any one time is limited to the capacity of the fuel tanks on the equipment or small vessels used to transport fuel for filling equipment such as jumbos that are used underground. No underground storage tanks are planned.

Muck haulage in cars were required during TBM operation until the conveyor system was installed in the initial portion of the North Ramp, and may be used in the event that the conveyor system becomes inoperable, or for alcove muck haulage. Muck haulage cars are moved by means of diesel or battery electric locomotives and are dumped on the east and south sides of the North Portal Pad for extension of the North Portal Pad or transported to designated muck storage areas.

Precast, steel-reinforced concrete invert segments are lowered into place between the TBM and the first trailing gear car as the TBM advances. Backer rod seals may be installed between the inverts and along the edges of the inverts to inhibit leakage of fluids to the ground underneath. The invert segments provide a rail bed and roadway for ESF construction. Rails, inserts, California Switches, turnouts for TBM trailing gear and haulage will also be installed. Turnouts will be designed to permit cross over from one trackway to another when four rails are installed. Turnouts will also be provided for passing/parking when only two rails are used. Additional rail components include joint bars, track bolts, rail bonding (grounding), and grout for securing the rails to the inverts. Some tunnel inverts may be made with observation holes. Alternatively, placement of the reinforcing steel within the precast invert segments has been designed so as to provide locations within the precast invert segments where observation (as well as other testing use) holes can be drilled through a particular invert segment as required by the TCO and/or affected PIs. Lifting eyes will be embedded in the inverts to facilitate handling. The invert segments are designed to support steel sets, where needed. The invert segments are designed to be removable.

"Rolling stock" refers to the rail cars needed for the transportation of personnel, materials, and supplies. Transportation in the TS Loop will be accomplished using diesel or battery electric locomotives and rolling stock. A "fail safe" air brake system will be used for the entire rail car system. The rolling stock for supplies, materials, and personnel transportation consists of several types of rail cars (CRWMS M&O 1994b):

- supply/utility cars used for hauling ground support elements, explosives, water tanks, cable reels, etc.;
- invert segment cars designed to carry invert segments;
- a fan line car to haul ventilation ducts;
- a scissor lift ventilation car, a flat car retrofitted with an electric hydraulic scissor lift for removal and installation of ventilation ducts, fans, etc.;
- a scissor lift platform car, a flat car retrofitted with an electric hydraulic scissor lift and working platform to be used by personnel for utility maintenance and crown access;
- personnel cars;
- a maintenance/lube car, a flat car retrofitted to transport a 2200-l waste oil tank with an air vacuum pump, an 800-l lube oil tank with an air vacuum pump, two 133-l grease barrels with an air vacuum pump, a 2200-l hydraulic oil tank with an air vacuum pump, and four hose reels (mounted on the car);
- a vacuum car, a flat car with a dedicated sealed muck car into which most of the vacuumed waste will be collected (the vacuum is intended to be used to clean up around the TBM and conveyor, and possibly to remove fluid spills);
- a rail mounted jumbo, which contains an electric/hydraulic drill and a boom-mounted two-man basket;

- an equipment car used to transport heavy and/or bulky equipment and supplies;
- a crane car utilizing an electric crane with telescoping boom for lifting supplies, etc.

6.10 SUBSURFACE POWER DISTRIBUTION SYSTEM (CI: BABFAA000)

The subsurface power system is to provide power for communications, lighting, underground testing, ventilation, wastewater removal, fire protection, muck handling, sanitation and safety monitoring, compressed air, transportation, tunnel boring systems, and maintenance of equipment. The major loads include the TBM(s), trolley system (if installed), conveyor drive motors, ventilation duct fan motors, conveyor hydraulic pump motors, waste water pump motors, 480-V lighting panels, 208/120-V power panels, 480- and 120-V receptacles, battery chargers, and the TTF Heated Drift Testing. An alternate 12.47-kV feeder for subsurface power centers will have sufficient capacity.

Subsurface main switchgear will be fed from the surface 12.47-kV switchgear. The surface 12.47-kV supply system is supplied by a 69-kV line, connected to the Nevada Test Site Canyon Substation. Surface power and standby generators are evaluated in CRWMS M&O 1996h.

Underground feeders over 1000 volts are to have a ground check circuit to continuously monitor the grounding circuit to ensure continuity. Protective measures will be provided in the electrical system to prevent damage to the equipment or personnel injury in case of failures. Electrical equipment will support the testing program, as required by the ESFDR (YMP 1997a), Section 3.8.2.1.1.A.

The subsurface grounding system (including grid, connections, bonding, etc.) is completely separate from the surface grounding system to ensure that no lightning potential or other voltage surge will travel into the tunnel system. Ground rods are embedded in holes filled with conductivity enhancing "GEM" type hydraulic carbon cement. The grid size will be approximately 10 by 30 m, meshed at approximately 3 m squares, and located 0.5 m below the surface located outside the ESF Starter Tunnel. The subsurface grounding grid, as well as lightning protection, are evaluated in CRWMS M&O 1996h.

6.11 SUBSURFACE COMMUNICATIONS (CI: BABFAB000)

The communication system consists of those systems, subsystems, and components necessary to provide both telephone and radio communication for surface and subsurface areas of the ESF. These systems include telephone and radio communication systems; the public address system, and the communication center.

The telephone and radio communication systems may be integrated into the Nevada Test Site system. In the subsurface area, the communication system will be designed and constructed to permit phased construction and modular replacement of components. Characterization data will not be transmitted over the telephone. All electrical power wiring in the subsurface telephone system will be kept physically separated from data and communication service to prevent induced interference. The telephone and radio communications systems will be designed such that no detectable electromagnetic signals are induced into the DCS and data acquisition system (if installed), any associated sensors, or other sensitive test equipment.

The public address inductive systems in accesses/stations will be restrictive to prevent "stray currents" from initiating premature detonation when blasting.

The communication center and its equipment will be installed in the Switchgear Building at the North Portal Pad.

Refer to CRWMS M&O 1996h for discussions of these CIs outside the portal headwall (Station 0+00 m).

6.12 SUBSURFACE LIGHTING SYSTEM (CI: BABFAC000)

Metal Halide fixtures are to be used for main tunnel lighting, and fluorescent fixtures are to be used in test alcoves, and shop areas. Emergency light fixtures will use sealed, rechargeable lead-acid or nickel-cadmium battery units rated for 90 minutes; areas for emergency lighting include operation areas, test areas, refuge areas, ramp station areas, and the path of egress. General tunnel lighting fixtures are to be mounted at approximate 15 m intervals, and tunnel emergency lighting fixtures are to be mounted at approximate 45 m intervals.

6.13 SUBSURFACE VENTILATION SYSTEM (CI: BABFAD000)

The ventilation distribution system consists of systems, subsystems, and components that allow fresh air to be supplied to, and exhaust air to be removed from, the underground areas to meet the needs of underground construction and site characterization testing. The ventilation distribution system distributes air supplied by the ventilation system from the surface. Movement of the ventilation air may assist in the removal of particulates, diesel exhaust, and moisture.

The general layout of the ventilation system during TBM construction operations in the TS Loop consisted of duct extending from the North Portal entrance to the TBM trailing gear, with vaneaxial fans in series along the tunnel, operating in the exhaust mode (fresh air being induced into the TS Loop through the tunnel and exhausting out through the duct). The main exhaust ventilation duct is 1.7 m (66 inches) in diameter, and suspended from the tunnel crown by hangers. The maximum design air flow of this system is approximately 52,000 liters/second (approximately 110,000 cubic feet of air per minute), which supported construction ventilation for one 7.62-m diameter TBM, construction ventilation for one alcove[1], maintenance of ventilation of completed alcoves behind the TBM, use of diesel equipment up to 800 bhp, and 100 subsurface personnel distributed throughout ESF working areas.

Smaller exhaust ducts are installed to serve alcoves excavated from the TS Loop. Dust scrubbers, which use water as a circulating fluid, may be installed in these ducts to reduce dust entrained in the airflow. The water circulates through these scrubbers in a closed loop; however, makeup water is supplied to these scrubbers to replenish water lost to evaporation in the airflow in the duct.

Periodic ventilation system testing using SF_6 may be required to assess duct leakage and determine approximate ventilation system recirculation ratios. One such test was performed on April 26, 1996 (Dresel 1996a; Kissell 1996a; 1996b). The test involved establishing sampling stations at nominally two locations in the tunnel. Approximately 1.5 cubic feet of pure SF_6 gas contained in a bottle pressurized to approximately 300 psi (pounds force per square inch) was released into the vent duct at the TBM. Samples were taken contemporaneously with and at regular intervals following the release (real-time SF_6 monitoring equipment may also be used). Any SF_6 that leaked through the ventilation duct became entrained in the airflow in the tunnel (heading back toward the TBM) and was, depending on the location of the leak, captured in the samples. The entire quantity of released SF_6 dissipates quickly. Kissell 1996c documents that the highest concentration of SF_6 observed during the test conducted on April 26, 1996, was only approximately 13 parts per billion (ppb).

Dresel 1996b describes a second test that was planned to be performed. Review of Dresel 1996b identified only one potential substantive difference from the test method described above: Dresel 1996b provided an option that a standard gas bottle containing 10 percent SF_6 be discharged rather than a 1.5 cubic foot bottle of pure SF_6 at approximately 300 psi. However, discussions with the YMP M&O Safety and Health Manager on September 9, 1996 (Skov 1996), indicate that this standard gas bottle option was not to be exercised. In addition, the M&O Safety and Health Manager noted that, due to the increase in length of the ventilation duct since the first test, the test method may be changed such that *two* 1.5 cubic foot bottles of SF_6 may be discharged instead of one. (The discharge of two 1.5 cubic foot bottles of SF_6 would not be expected to result in a maximum concentration in the tunnel of significantly more than approximately double that which was observed during the first test, or approximately 26 ppb).

As described in Heinicke 1996, water is routinely sprayed onto the concrete invert segments in the tunnel for dust suppression purposes. The water is sprayed using a metered hose and a fine spray nozzle. The water is applied to the invert surfaces only (not the ribs or crown) in quantities sufficient

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[1]CRWMS M&O 1994c; 1994d indicate that the subsurface ventilation system is *designed* to support the excavation of *one alcove* in addition to the TBM face. Until the completion of construction, however, the constructor may install and use systems as "temporary construction utilities." Such a system as installed may thus be different from the system as designed by the YMP M&O A/E, and may be used in manners different from its design basis. This explains why excavation has in fact proceeded *in more than one alcove*, in addition to excavation at the TBM face. The constructor of course retains responsibility for complying with applicable employee health and safety regulations until the completion of construction, and is required to ensure that the system conforms with the M&O A/E design (or otherwise justifies discrepancies) before turnover for ESF operations.

only to evenly wet the invert surfaces. Typically, this evolution is performed over a period of approximately four hours per day, applying approximately 200 to 250 gallons per day over a 1300-m interval of the tunnel. This equates to an application rate of about 0.15 to 0.20 gallons per m per day.

After hole-out at the South Portal, the subsurface ventilation system was reconfigured. The flow-through ventilation system that was installed for the Subsurface ESF is described in CRWMS M&O 1997j; 1998g. This system uses an exhaust fan installed at the South Portal near a ventilation bulkhead (an additional fan may be added to increase the flow-through rate). A second bulkhead with a mandoor airlock, and a single, large (approximately 12 feet by 12 feet) equipment door is located approximately 65 m downgrade of the ventilation bulkhead so as to create an airlock near the South Portal. The exhaust fan will pull approximately 120,000 to 130,000 (approximately 248,000 with a second fan installed) cubic feet of fresh air per minute from the North Portal through the length of the TS Loop, then exhaust the air at the South Portal. This airflow will be disrupted whenever the equipment door is opened, which is expected to occur very infrequently.

The existing fans and ductwork in the Subsurface ESF will be used to pull air out of the alcoves and ECRB Cross Drift, consistent with the original design. During ECRB Cross Drift operations, approximately 56,000 cubic feet of air per minute will be exhausted from the head of the ECRB Cross Drift (fresh air being induced into the TS Loop through the North Ramp, into the ECRB Cross Drift, and exhausting out through the duct to the North Portal) (CRWMS M&O 1998h). In addition to the ECRB Cross Drift air flow, approximately 59,000 cubic feet of air per minute (as regulated by a damper downgrade of the ECRB Cross Drift Starter Tunnel) is exhausted out the North Portal duct from the vicinity of Alcove 5 (CRWMS M&O 1998h).

Alcove 5 has a specially designed ventilation system as described in CRWMS M&O 1998i. This ventilation system is required to ensure sufficiently cool air exists outside the TTF Heated Drift to allow for personnel access. This ventilation system like most of the other alcoves simply recirculates air from the TS Loop. Approximately 47,500 cubic feet of air per minute is recirculated during normal operations. This Alcove 5 system includes a backup system that exhausts air directly into the duct leading to the North Portal should the flow-through ventilation system fail. Alcoves #1 and #2 have a dedicated exhaust duct, which exhausts directly to the North Portal. Modifications to the other alcove ventilation systems may be implemented that would exhaust each alcove to the main, North Portal exhaust duct (Schulenburg 1998).

6.14 SUBSURFACE WATER DISTRIBUTION SYSTEM (CI: BABFAE000)

The TS Loop water supply line consists of carbon steel pipe, with isolation valves provided at intervals along the tunnel. A booster pump will be installed on the TS Main Drift. A portion of the water supply line may be heat traced and insulated. A flow meter (equipped with a totalizer) will be installed in the line near the portal. All of this water will be traced before entering the tunnel. The interface between the subsurface/surface wastewater systems is at Station 0+00 m. Refer to CRWMS M&O 1996h for an evaluation of the Surface Water System.

be installed in the line near the portal. All of this water will be traced before entering the tunnel. The interface between the subsurface/surface wastewater systems is at Station 0+00 m. Refer to CRWMS M&O 1996h for an evaluation of the Surface Water System.

A water tracer injection system is provided to tag any water used within the underground system.[2] The initial water tracer injection system consists of two tanks of water into which tracer material (lithium bromide) is mixed. The automatic system that may be installed on the pad consists of a skid-mounted tracer tank and pump (injection) system. A non-portable system may eventually be provided as well. The use of the tracer injection system is evaluated in this DIE based on supporting underground construction, operation, and maintenance activities; refer to CRWMS M&O 1996h for the evaluation of potential leakage and spills from the system occurring on the surface.

6.15 SUBSURFACE WASTEWATER SYSTEM (CI: BABFAF000)

This system is used for the control, handling, treatment, and transfer of wastewater and ground water to the Surface Wastewater Handling System. The interface point for purposes of this DIE is at the North Portal headwall (Station 0+00 m); see CRWMS M&O 1996h for the evaluation of this system beyond this point. This system is designed to handle all credible inflows, including inflow from fault penetrations and water line breakage, and is provided with a backup power supply. During the construction phase, water in the tunnel flowed to the excavation face due to the slope of the ramp until the TBM reached the lowest point of the tunnel at approximately Station 28+04 m. During this phase, most of this water was removed along with the muck from the excavation face. In addition, an electric motor driven submersible pump was used to pump water from the face into a portable sump. Two pumps were available for redundancy. A portable sump is located on one of the rolling stock platform cars, with a capacity of approximately 4 m^3.

A temporary wastewater sump was installed (steel liner, shotcreted in place) as a construction utility at approximately Station 28+05 m, after the TBM passed that location. This may be replaced by a more extensive, engineered wastewater sump at this same location. The engineered sump has been designed to have a minimum capacity of approximately 10 m^3, and would be lined with concrete and a water sealant coating to prevent exfiltration. The engineered sump is sized to handle the worst case water inflow that would result from a water supply pipe break, as well as any construction water or groundwater inflow that might be collected during excavation. Pumps would be provided along with a liquid sump storage tank with an approximate capacity of 14 m^3. Level switches provide for automatic control of the pumps.

A temporary, unlined wastewater sump has also been installed as a construction utility at approximately Station 59+19 m. A third temporary construction sump was added at approximately Station 71+45 m (at the bottom of a dip in the South Ramp).

[2]Note: Chlorinated potable water that does not contain lithium bromide tracer is used for drinking and hand wash stations in the Subsurface ESF. Ice made from untraced chlorinated potable water may also be used in drinking water coolers underground.

Fluids recovered during construction operations are to be disposed of in such a way as to avoid the potential for site impacts. The wastewater removal system will provide for measurement as required. Wastewater may comprise drilling water, rock cleaning water for mapping, fire protection water, main supply water, dust control water, and groundwater.

6.16 SUBSURFACE COMPRESSED AIR DISTRIBUTION SYSTEM (CI: BABFAG000)

Subsurface compressed air is required for rock cleaning, shotcreting, core drilling, cleaning out rock cuttings from rockbolt holes, hand tools, site characterization testing in alcoves, and refuge areas. Compressed air is provided to the North Portal entrance from a system of compressors, receivers, and associated piping located on the North Portal Pad. A steel pipe is used to deliver compressed air in the tunnel at 8.6 bar_{ga} (125 psig), and up to a design flow rate of approximately 1133 liters/second (approximately 2400 cubic feet of air per minute). The low point of the Compressed Air System is at approximately Station 28+04 m. (Refer to CRWMS M&O 1996h for an evaluation of the Surface Compressed Air System.)

The compressed air system includes a surface-mounted filtration and condensate collection system. Relatively clean air, with approximately 85 percent of any contained oils removed, would be produced from ordinary compressed air by using coalescing filters to remove oil. This relatively clean air would then be introduced into the underground compressed air distribution system.

If needed, a portable tracer injection system can be added to the tunnel compressed air system for a specific use, such as core drilling or other testing activities. The portable setup consists of a chemical tracer injection system/air treatment system for compressed air usage in test-related drilling and in support of site characterization experiments (inflation of packers, etc.). The compressed air will also be treated to remove almost all remaining oils and to provide a maximum particulate size of no more than approximately 3 microns. It is anticipated that this air treatment will be incorporated with air tracer injection into a portable skid unit, which can be used where needed for testing construction and testing.

For convenience, the above system may be augmented with a compressor, forming a totally stand-alone system that can be used in alcove testing. The skid-mounted air treatment/tracer injection unit will be used to treat compressed air as required for testing construction and testing. Any requirements to use the portable compressed air system will be addressed in the applicable test-related DIE and/or TPP/FWP. The system is evaluated in this DIE based on its general operation underground.

6.17 SUBSURFACE FIRE DETECTION AND PROTECTION SYSTEMS (CI: BABFAH000)

The primary fire protection system to be installed in the TS Loop will consist of a multipurpose dry chemical system, capable of both manual and automatic activation. Fire suppression systems are installed at the head, tail, drive, and take-up pulleys of the conveyor, on the TBM (at the hydraulic storage tank and the lubricating oil tank), on the maintenance rail car, on mobile, diesel driven equipment, on diesel driven locomotives, on the diesel driven crane locomotive, and on electric locomotives. Portable fire extinguishers are to be installed at the head, tail, drive, and take-up pulleys of the conveyor, at locations along the tunnel, on the TBM(s), on the maintenance and explosives rail cars, on diesel and electric locomotives, on diesel driven mobile equipment, at major electrical transformer locations, at water pumping stations, at testing enclosures, and at refuge areas. Heat detectors, some of which initiate alarmed, dry chemical systems, will be installed at the conveyor head, tail, and take-up pulleys as well as on the TBM, diesel and electric locomotives, maintenance car, and diesel-driven mobile equipment.

A redundant fire protection system is not required. However, a supplemental water fire suppression system is to be installed. This system is to be supplied by the water supply line described above, and will consist of hose stations located at intervals along the tunnel.

6.18 SUBSURFACE SANITARY FACILITIES (CI: BABFAI000)

Subsurface sanitary facilities (portable, self-contained chemical toilets) are located at convenient intervals within the TS Loop for use by personnel. One such unit is provided on the TBM trailing gear.

6.19 SUBSURFACE FURNISHINGS (CI: BABFAK000)

Subsurface furnishings include the various ESF enclosures or blockouts required to support instrumentation and cabling, and ESF utility brackets to facilitate the installation of utilities such as electrical power, communications, compressed air, water, wastewater removal, etc.

7. DESIGN EVENTS

The following events and activities were considered for potential evaluations: earthquake, rockfall, use of and inadvertent spills of oil or other fluids from construction equipment, fires, explosions, ground water inflow, TBM operation, conveyor operation, ground support installation, rail haulage (including use of locomotives), invert installation, use of water and compressed air, and drill-and-blast operations. These events and activities, which include the use of the temporary items discussed above, are evaluated in accordance with NLP-2-0 (CRWMS M&O 1998b).

Fire and explosions are evaluated with regard to potential impacts. Disruption of other items as a result of earthquakes, fires, and explosions are not specifically evaluated in this DIE; however, deterministic failure of systems and components is used to assess the potential impacts on site characterization activities and waste isolation.

Quantities of fluids (other than water) that may be released in any credible equipment or vehicle accident or failure (e.g., maintenance/lube car contains 2200 liter waste oil tank and 800 liter oil tank) are included in the evaluation of potential impacts to site characterization testing activities and waste isolation as potential spills of fluids of concern.

8. AFFECTED Q-LIST ITEMS

8.1 REPOSITORY INTERFACES

The TS Loop construction progresses westward from the ESF Starter Tunnel (elevation ≈ 1120 m), south through the Main Drift along one edge of the primary emplacement areas (elevation ≈ 1067 m), and then eastward where it will terminate at the South Portal at approximately Station 78+77 m (elevation ≈ 1160 m). The ESF Ramps (North and South) and Main Drift will provide access to the potential repository. Any construction effects will be incorporated into the design of the potential repository.

CRWMS M&O 1996c lists existing and planned boreholes in the vicinity of the TS Loop. Surface-based site characterization tests range from surface geologic mapping and sampling, to the drilling and instrumentation of boreholes to water table depth and greater. Surface-based tests having potential sensitivity to the underground construction are those measuring a subset of parameters of the rock mass being penetrated by the TBM and those that may be affected by the vibrational and energy fields about the construction equipment. An evaluation of potential impacts on site characterization testing (including surface-based testing) is included in Section 10.

Approximately 40 tests are or have been previously planned underground. Test Planning Package 91-5 (YMP 1992) provides a relatively comprehensive listing of these tests, including tests not defined in the Site Characterization Plan (SCP). Under current Project plans, a number of these tests are no longer planned or have been completed. In general, testing associated with previously constructed alcoves or alcoves under construction is scheduled for completion. However, the possibility exists that deferred tests could be required in the future, perhaps in response to the requirements of regulatory agencies or to other changing programmatic requirements. Thus, a conservative approach, one in which reasonable efforts are taken to minimize changing the general characteristics of the TS Loop and surrounding rock, is advantageous. The TCO has examined the testing requirements and identified potential construction constraints for each test in Test Planning Package 91-5 (YMP 1992); these were later included in the ESFDR (YMP 1997a).

In the development of the construction schedule, the TCO addressed the accessibility to testing opportunities while the TBM is operating. Although the purpose of the tunnel is to provide the opportunity to test in more representative conditions than can be provided by surface outcrops, the opening of the tunnel will introduce surface atmospheric conditions to a volume of rock where *in situ* data are desired. For example, an anticipated temporal lag between the time of tunnel excavation and when the tunnel effect may be transmitted into the rock mass is the window of opportunity in which certain planned ESF tests should be staged. In these cases, the deferral of testing until construction is complete could result in biasing the test results in an undetectable and unpredictable way (Section 10). Access for testing must also be provided to assure the timely collection of data for Viability Assessment, Site Recommendation, and/or License Application (DOE 1996b).

In developing controls specific to the TS Loop, this evaluation incorporates design and/or construction constraints identified in the ESFDR (YMP 1997a) with regard to the interface between testing and TBM operation or alcove construction. Thus, this evaluation does not include test construction that will occur in the test support areas after the area is constructed. Specific construction constraints applicable to the fielding of the tests, such as whether tracer gas is required in the drilling of hydrochemistry boreholes, will be addressed in the individual DIEs and FWPs for those activities. (Note: FWPs have replaced TPPs and JPs as implementing documents since the initial revision of this document. However, until revised, existing TPPs and JPs are being used as implementing documents. Thus, all three document types are referred to in this evaluation.)

8.2 POTENTIALLY AFFECTED Q-LIST ITEMS

The proposed activities will affect the Timber Mountain Tuff, TCw, PTn and TSw hydrogeologic units. Additional underlying hydrogeologic units may also be affected, depending on the quantity and behavior of the applied construction water. The TCw, PTn and TSw hydrogeologic units are on the Q-List (YMP 1998b). In addition, the engineered items on the Q-List (YMP 1998b) that may be affected include the Underground Excavations, the Waste Ramp or the Tuff Ramp, and the Seals. The planned excavation activities may affect permanent items including ground support and underground openings.

9. EXPECTED CONDITIONS

The TS Loop of the ESF excavation is entirely in the unsaturated zone, beginning at an elevation of about 1120 m at the North Portal, minimizing at an elevation of about 1067 m near the transition from the North Ramp to the Main Drift, and emerging at an elevation of about 1160 m at the South Portal (CRWMS M&O 1998j). The water table under the TS Loop is nearly flat and lies at an elevation of approximately 730 m (Robison et al. 1988). Therefore, the water table lies approximately 430 m below the top of the South Portal, approximately 390 m below the top of the North Ramp and approximately 337 m below the minimum in the TS Loop near the North Ramp/Main Drift transition.

9.1 SIGNIFICANT GEOLOGIC FEATURES

The planned ESF TS Loop excavation is discussed in CRWMS M&O 1998j relative to the major geologic strata in terms of both the revised lithostratigraphic nomenclature and the thermal/mechanical nomenclature for the rock units used in the 3-D site model by the United States Geologic Survey (USGS). The lithostratigraphic units along the TS Loop include three groups (in descending order): the Timber Mountain Group; the Paintbrush Group, which includes five ash flow tuffs separated by bedded tuffs; and the Crater Flat Group.

The Timber Mountain Group is comprised of the Rainier Mesa Tuff (**Tmr**) and pre-Rainier Mesa Tuff bedded tuff (**Tmbt1**) within the TS Loop.

In order of descending stratigraphy, the Paintbrush Group includes:

Tuff Unit "X" (**Tpki**)

Pre-Tuff Unit "X" bedded tuff (**Tpbt5**)

Tiva Canyon Tuff (which is broken into three units: crystal-rich--**Tpcrv**; undifferentiated, devitrified--**Tpcun**; and crystal-poor, vitric, nonwelded--**Tpcpv**)

Pre-Tiva Canyon Tuff bedded tuff (**Tpbt4**)

Yucca Mountain Tuff (**Tpy**)

Pre-Yucca Mountain Tuff bedded tuff (**Tpbt3**)

Pah Canyon Tuff (**Tpp**)

Pre-Pah Canyon Tuff bedded tuff (**Tpbt2**)

Topopah Spring Tuff (which is broken into eight units: crystal-rich, vitric, non- to moderately welded--**Tptrv**; crystal-rich, devitrified, nonlithophysal--**Tptrn**; crystal-poor, upper lithophysal--**Tptpul**; crystal-poor, middle nonlithophysal--**Tptpmn**; crystal-poor, lower lithophysal--**Tptpll**; crystal-poor, lower nonlithophysal--**Tptpln**; crystal-poor, densely-welded subzone--**Tptpv3**; and crystal-poor, vitric, non-to moderately welded--**Tptpv1** and **Tptpv2**),

Pre-Topopah Spring Tuff bedded tuff (**Tpbt1**).

In order of descending stratigraphy, the Crater Flat Group consists of the Calico Hills Formation (**Tac**) and the Prow Pass Tuff (**Tcp**), both of which contain basal bedded tuffs.

The lithostratigraphic units outlined above are grouped into thermal/mechanical (TM) units by the USGS, which are summarized in CRWMS M&O 1998j. Because the TM units are based on properties that result from processes in addition to petrogenesis, the boundaries of these units do not correspond directly to formational boundaries but do, in general, correspond to rock unit boundaries. In order of descending stratigraphy the TM units are:

Undifferentiated overburden (**UO**) that includes the Tmr, Tmbt1, Tpki, Tpbt5, and Tpcrv;

Tiva Canyon welded unit (**TCw**) that is equivalent to the Tpcun;

Upper Paintbrush nonwelded unit (**PTn**) comprised of the Tpcpv, Tpbt4, Tpy, Tpbt3, Tpp, Tpbt2, and Tptrv;

Topopah Spring welded, lithophysae-rich unit (**TSw1**) that includes the Tptrn and Tptpul;

Topopah Spring welded, lithophysae-poor unit (**TSw2**) that includes the Tptpmn, Tptpll, and Tptpln;

Topopah Spring welded, vitrophyre (**TSw3**) that is equivalent to the Tptpv3;

Lower Topopah Spring non-welded unit and Calico Hills Tuff (**CHn**) that is comprised of the Tptpv1, Tptpv2, Tpbt1, Tac, and Tcp.

9.2 SIGNIFICANT HYDROLOGIC FEATURES

The thermal/mechanical (T/M) units given above are closely related to the hydrogeologic units and the designators used here to refer to the hydrogeologic units are taken to refer to the corresponding TM units given above: TCw--Tiva Canyon welded, PTn--Paintbrush nonwelded, TSw (1,2,3)--Topopah Spring welded, and CHn--Calico Hills nonwelded. Because information concerning the thickness and extent of the basal Tiva Canyon units (Tpcpv and Tpbt4) and Topopah Spring caprock (Tptrv) zones is not available in all cases, the PTn hydrogeologic unit in this report will be defined to consist of, at a minimum, the Yucca Mountain and Pah Canyon members of the Paintbrush Tuff (Tpy, Tpbt3, Tpp, and Tpbt2).

Distances to geologic and hydrologic features along the TS Loop (as measured along the tunnel excavation) and the minimum distance from each geologic and hydrologic feature to potential waste emplacement areas (i.e., minimum offsets from potential waste emplacement areas) are given in Table 9-1 (CRWMS M&O 1998j - note that the TCw and UO are shown as a single undifferentiated unit in the cross sections of this reference and therefore are not explicitly differentiated in the listing below). The spatial relation between the TS Loop and the current conceptual design of the potential repository is discussed in CRWMS M&O 1995c. The Main Drift is a minimum of 37 m from potential waste emplacement zones within the primary emplacement area. Potential expansion areas (DOE 1986) that may be used as part of the potential repository lie beneath the North Ramp west of the Bow Ridge Fault and beneath the entire South Ramp, however, the current design of the potential repository does not include these expansion areas. The closest potential waste emplacement zone within the expansion areas under the North and South Ramp is assumed to be in the or within middle nonlithophysal zones of the Tptpmn, which constitutes the top of the TSw2 (CRWMS M&O 1995c).

Table 9-1 Geologic and Hydrologic Features along the ESF TS Loop

GEOLOGIC/HYDRO-LOGIC (G/H) FEATURE	DISTANCE FROM HEADWALL OF G/H FEATURE (m)	MINIMUM DISTANCE FROM G/H FEATURE TO POTENTIAL WASTE EMPLACEMENT AREA (m)
North Ramp		
TCw/UO	0 - 865	155
Bow Ridge Fault	200	268
PTn	865 - 1140	127
Imbricate Fault Zone	470 - 1115	132
TSw1	1140 - 2700	37
TSw2	2700 - 2804	37
Drill Hole Wash Fault	2150	37
Main Drift		
TSw2	2804 - 5935	37
Sundance Fault	3635	37
Abandoned Wash Fault	5710	37
South Ramp		
TSw2	5935 - 6320	37
TSw1	6320 - 6650	37
PTn	6650 - 6760	64
Dune Wash Fault	6760	64
TSw1	6760 - 7375	55
PTn	7375 - 7545	82
Imbricate Fault Zone	6980 - 7735	55
TCw/UO	7545 - 7856	109
South Portal	7856	182

9.3 ANTICIPATED/EXPECTED FRACTURE CONDITIONS

During excavation a number of geologic faults and fault systems are expected to be encountered in the TS Loop of the ESF (see above). The discussion below is summarized from CRWMS M&O 1998j and covers both these expected conditions and the features of the Ghost Dance fault that, although not expected to be directly encountered in the TS Loop excavations, will be studied from two planned exploration drifts to be excavated from the Main Drift eastward to the face of the Ghost Dance fault.

9.3.1 Bow Ridge Fault

This north striking fault occurs in a zone about 2 m thick within the North Ramp about 200 m from the North Portal. This fault is a steeply westward dipping normal fault with about 100 m of Tertiary displacement, which brings the TSw1 in the upthrown foot wall into contact with the TCw/UO in the hanging wall.

9.3.2 Imbricate Fault System

This is a system of steeply dipping (generally westward) normal faults that strike north to northwest and, in general, have less than 3 m of offset. In the North Ramp this system is expected to be encountered as a zone about 650 m wide extending from 470 – 1115 m from the North Portal along the TS Loop. In the South Ramp this system is expected to be encountered as a zone about 750 m wide extending from 6980 m – 7735 m from the North Portal along the TS Loop.

9.3.3 Drill Hole Wash Fault

This "fault" appears to be a complex of faults that results in a breccia zone of indeterminate width that is mapped to occur in the North Ramp at 2150 m from the North Portal along the TS Loop. This zone may be about 180 m wide and, because it will be intersected at an angle, it may be encountered from 1700 - 2400 m from the North Portal within the TS Loop. This nearly vertical, westward dipping, N to NW striking fault zone has an apparent vertical offset of at least 3 m, but is predominantly a right lateral fault zone with a complicated history of movement.

9.3.4 Sundance Fault

This is the main structure occurring close to the center of the Sundance fault system that is comprised of an approximately 274 m wide zone of northwest striking, nearly vertical, strike-slip faults. The Sundance fault is expected to be encountered in the Main Drift at 3635 m from the North Portal of the TS Loop excavation, but associated faults may be intersected from 3395 - 3875 m from the North Portal along the TS Loop.

9.3.5 Abandoned Wash Fault

This fault is part of a system of north-northeast to northwest striking, steeply westward dipping fractures and faults that trend to the north to intersect the Ghost Dance fault. The main structure of the Abandoned Wash fault is expected to be intersected in the Main Drift at 5710 m from the North Portal along the TS Loop excavation, but some of the associated features may be encountered before this point. In this zone, local disruption of dips causes values to increase eastward toward the Abandoned Wash fault to 20°- 40° east, in general, and up to 70° east locally.

9.3.6 Dune Wash Fault

This is a steeply westward dipping normal fault with approximately 8 - 27 m of vertical offset that brings the TSw1 in the upthrown foot wall into contact with the TCw/UO in the hanging wall. This fault is expected to be encountered in the South Ramp at about 6760 m from the North Portal along the TS Loop excavation.

9.3.7 Ghost Dance Fault

This is a zone approximately 213 to 366 m wide consisting of steeply westward dipping, north trending faults with the dominant Ghost Dance fault occurring at about the middle of the zone. The tuff units are displaced a maximum of approximately 30 m, lessening to the north near the end of the fault system just to the south of Drill Hole Wash. This fault zone continues to the south toward the Abandoned Wash Fault system. This fault zone is encountered in the test support alcoves excavated on the TS Main Drift.

9.3.8 Fault Fracture Densities

It is expected that fracture densities will be higher in the vicinity of these faults and fault systems. As such, these fault zones have potential to act as faster pathways for fluid flow, perhaps providing direct access to the water table. Fracture densities expected for the hydrogeologic units discussed above are given (Montazer and Wilson 1984) as 10 - 20 fractures/cubic meter (m^3) for the TCw, 1 fractures/m^3 for the PTn, 8 - 40 fractures/m^3 for the TSw, and 2 - 3 fractures/m^3 for the CHn.

9.4 HYDROGEOLOGIC, GEOCHEMICAL, GEOMECHANICAL CHARACTERISTICS

Beneath the TS Loop excavation, the water table is relatively flat, with a slight gradient to the east, and lies primarily in the Calico Hills nonwelded hydrogeologic unit (CHn) (DOE 1998b; Scott and Bonk 1984). The groundwater table lies in the Topopah Spring Formation (TSw3) west of the Bow Ridge Fault and in the Calico Hills nonwelded unit (CHn) east of the Bow Ridge Fault (Scott and Bonk 1984). The saturated groundwater flow in this area is inferred to be in a southeasterly direction, away from the conceptual repository (Ervin et al. 1993).

Water entering the TCw or TSw hydrogeologic units along the TS Loop may result in water movement through fractures, matrix, or some combination of the two paths (Dunn and Sobolik 1993). The degree to which water movement in fractures is attenuated by capillary imbibition into the matrix is poorly understood at present. The PTn and UO (particularly the Timber Mountain Tuff portion) are believed to be relatively unfractured with matrix permeabilities that are high in comparison with the TCw or TSw matrix. Therefore, movement of water in these materials is believed to be dominated by matrix flow.

The Paintbrush nonwelded (PTn) unit, which underlies the first 1140 m of the North Ramp and the South Ramp from 6650 - 6760 m and 7375 - 7545 m (CRWMS M&O 1998j), is believed to be a capillary barrier to fracture flow between the highly fractured TCw Hydrogeologic Unit (Montazer and Wilson 1984) and potential waste package emplacement zones in the Topopah Spring welded (TSw) Hydrogeologic Units (CRWMS M&O 1993b). This is inferred because, relative to the Pah Canyon Member of the Paintbrush Tuff, the Tiva Canyon Member is highly fractured and has lower porosity and matrix permeability, but higher fracture permeability. The PTn capillary barrier is only effective if the capillary pressure in the PTn is greater than the water entry pressure in the TSw1 fractures. Because the water-entry capillary pressure for fractures is believed to be lower than capillary pressures for pores at unsaturated conditions in the PTn, water is not expected to enter fractures in the TSw1 until the PTn is nearly saturated (Montazer and Wilson 1984). The PTn hydrogeologic unit dips to the east, away from the conceptual repository horizon. Flow along the stratigraphic dip in the PTn has been postulated as a result of the dip, capillary barrier and an enhanced along-dip hydraulic conductivity (Montazer and Wilson 1984).

The Bow Ridge Fault zone has a displacement of about 100 m, which results in a discontinuity in the PTn across the fault (CRWMS M&O 1998j). The hydrogeologic properties of the Bow Ridge Fault are not known. However, this discontinuity may provide continuous fracture pathways for water movement across the PTn hydrogeologic unit to potential waste emplacement zones in the TSw2 hydrogeologic unit. Because of the offset on the Dune Wash Fault, a similar case occurs in this region where, although the hydrologic properties of the fault are not known, it may provide continuous fracture pathways for fluid movement across the postulated PTn capillary barrier to potential waste emplacement sites within the TSw2.

Although it is possible to identify *qualitatively* the potential impacts from perturbations to the geochemical characteristics of the Yucca Mountain site (e.g., dissolved organic carbon may be a food source for microbes, which may then cause changes in water chemistry that may enhance corrosion of the waste package or radionuclide solubility/transport), in many cases the data to quantify each causal link along the path to radionuclide release are not available. Because the quantitative data are not available for these relational links, it is not possible currently to evaluate the potential TFM impacts at the level of consequence to radionuclide releases. Therefore, we have adopted surrogate performance measures as the criteria for indicating that an item/activity **may** impact waste isolation.

In general, such surrogate criteria are based on the idea that potential *local* perturbations to ambient site conditions that are below the level of the natural system variability would be indistinguishable from the ambient system. For cases in which site data are not available to quantify the ambient system variations, the variability of aqueous geochemical parameters across the site is assumed to be *at least* 10 percent of ambient conditions. One example of such a surrogate criterion is the 10 percent increase in background aqueous nitrate concentrations used as the limit for local perturbations to the nitrogen system. This type of evaluation produces recommended limitations based on the *local* perturbations to the geochemistry at the *closest* waste package--if changes were expected across the entire conceptual repository, then these types of surrogate criteria would not be appropriate. As such, these evaluations produce recommended limits to keep *local* geochemical perturbations *within* the "noise" of the ambient geochemistry, with any farther-reaching changes kept commensurately smaller (this would not be applicable if the 10 percent change occurred over the entire site).

The average concentrations and standard deviation of measurements (Yang et al. 1988; Yang et al. 1990) for five constituents of unsaturated zone fluids are shown below in Table 9-2.

Table 9-2 Unsaturated zone dissolved ion concentrations: sample average, sample standard deviation, and percent uncertainty

Ion	Average Concentration* (ppm)	Sample Standard Deviation* (ppm)	Standard Deviation Percent of Average
$SO_4^{=}$	92	53	58
Cl^-	70	25	36
Ca^{2+}	60	30	50
Mg^{2+}	11	4.7	43
Na^+	45	15	33

* Values calculated from data given in Yang et al. 1988; Yang et al. 1990).

Although data are limited for dissolved constituent concentrations in unsaturated zone water, the available data indicate that a 10 percent perturbation of the average ambient value is limited to about 1/3 to 1/6 of the actual sample standard deviation for the dissolved constituents shown above in Table 9-2. Therefore, the assumption that using a 10 percent perturbation of the average ambient value is, in general, a *conservative* criterion for being within the noise of the natural system. In addition, as pointed out by Yang et al. 1988; Yang et al. 1990, the analytical uncertainties for values of the concentrations in the unsaturated zone waters are ±5 percent in general and ±10 percent for sulfate. Based on these data, the assumption that local perturbations to the ambient geochemistry of 10 percent or less cannot be differentiated from the natural system variation is very conservative.

10.1 INTRODUCTION

The purpose of the proposed excavation, utilities installation, and operations support for the Subsurface ESF and associated support areas is to provide direct access for underground testing. The Subsurface ESF is an underground facility for conducting tests and collecting scientific and engineering data to be used for (1) assessing the suitability of the Yucca Mountain site for radioactive waste disposal, (2) providing design information for construction of the rest of the ESF and the potential repository, if the site is found to be suitable, and (3) the characterization of the site for Nuclear Regulatory Commission (NRC) repository licensing requirements. Site characterization activities are planned along the TS Loop, where most of the long-term testing activities are confined to test support areas constructed perpendicular to the tunnel at selected geologic features. Some geologic and geochemical sampling and mapping, and geomechanical monitoring activities in the TS Loop will occur directly behind the TBM or at a later date along the tunnel wall. The design specifications and drawings describe the systems, subsystems, and components that are required to meet the needs of the underground site characterization testing program during construction, operation, and maintenance of the Subsurface ESF. Simultaneously, surface-based testing (SBT) activities will be on-going in the vicinity of the TS Loop during and after its excavation.

The dual goals of (1) expedient operation of the TBM to construct the TS Loop and (2) acquisition of scientific data through testing and monitoring activities require extremely close coordination to meet the objectives of both most effectively. The coordination between construction, and ESF and surface-based testing resides with the Construction Management Organization (CMO) and the TCO. Specification 01501 (CRWMS M&O 1997a) recognizes that the ESF is a testing facility, and that the CMO is to respond to the requests of the TCO, representing the testing community. The CMO and the TCO jointly derive a working construction schedule that defines sequencing of test support area construction during the TBM excavation of the TS Loop. SBT activities are coordinated with the CMO if a time window is needed to conduct surface-based tests. More specific ESF access and construction support requests from the TCO are communicated to the CMO through (1) TPPs, JPs, and/or FWPs for each test activity, (2) other written correspondence, and (3) verbal field interactions.

The TCO serves as the field coordinating agency for ESF test implementation, and represents the interests of both the Department of Energy (DOE) and the PIs for the site characterization tests. The TCO plans to be continuously represented underground when ESF construction and/or testing is occurring. If a technically significant geologic condition (defined in YMP 1998c) is observed by a PI or other participant during TBM operation, and that person believes that temporary suspension of TBM operation is warranted for access for additional observation, the request is made to the TCO. The TCO makes a preliminary assessment of the situation with the PI. If it is judged that the condition could affect on-going or planned testing or construction activities, the TCO will confer with the CMO representative about the significance of the feature, how additional data may be gathered, and if construction should be delayed. Appropriate instructions are issued to construction and testing personnel. Through an established chain of command (Elkins 1994a) these actions are reviewed by DOE and appropriate construction and participant representatives. Schedules and instructions are modified as necessary to reflect the consensus of this review.

actions are reviewed by DOE and appropriate construction and participant representatives. Schedules and instructions are modified as necessary to reflect the consensus of this review.

10.2 UNDERGROUND FACILITIES, EXPERIMENTS, etc.

Underground facilities required to support the TBM and testing operations will be installed as the underground construction proceeds, and as underground experiments are planned throughout the TS Loop. The test interference concerns associated with these activities are addressed in various other sections of this evaluation.

The Calico Hills Formation, which occurs stratigraphically underneath the subsurface TS Loop, is considered a primary natural geochemical and hydrological barrier to potential radionuclide migration from the potential repository. Various *in situ* site characterization tests have been proposed to further assess the Calico Hills unit, with access provided via a Calico Hills drift in the ESF. Current Project plans, however, do not include construction of a Calico Hills drift or any attendant testing of that unit. For example, the Revised Program Plan (DOE 1996b) makes no mention of excavation in, or testing of, the Calico Hills Formation. However, there is no guarantee that testing in the Calico Hills Formation below the TS Loop will not be needed in the future. Minimization of water usage in the TS Loop and removal of this water are therefore important to preserving *in situ* conditions in the underlying Calico Hills unit should Project plans and requirements change in the future.

10.3 WATER TABLE

The TS Loop is approximately 430 m to 337 m above the water table (Section 9.0). Negligible interference from construction is expected for the tests planned in the saturated zone because of this distance of separation. In addition, tracer could be detected in saturated zone water if it were contaminated by significant amounts of construction water.

10.4 SURFACE-BASED TESTS

Although construction of the TS Loop and associated support areas, and the accompanying support systems, is primarily a subsurface activity, some surface-based tests have the potential to be impacted. Surface-based tests that may potentially be impacted by TS Loop and associated support area construction are evaluated in this and other sections.

Coordination between construction and testing is required when the TBM operation may interfere with some geophysical testing activities (such as seismic reflection studies) that record energy input into the ground under controlled conditions. The scheduling of geophysical field data gathering activities, which occur at discrete limited time periods, has been coordinated with underground construction to minimize the potential test interference impact of construction on the geophysical data. No new seismic monitoring studies are currently planned, although the seismic monitoring

The use of explosives during underground ESF construction activities can be detected by nearby seismic monitoring stations. The differences of frequency components, lack of shear waves in explosive blasts, and other factors provide for differentiation from natural seismic events. No other interference with surface-based tests in the area, such as trenching activities, has been identified.

10.4.1 Borehole Pneumatic Testing

CRWMS M&O 1996c lists the existing boreholes within the vicinity of the TS Loop. A set of boreholes (NRG-4, NRG-5, NRG-6, NRG-7a, SD-7, SD-12, UZ#4, UZ#5, UZ-6, UZ-6s, UZ-7a, ONC-1) were constructed to collect geologic, hydrologic, mineralogic, rock characteristics, design, and construction information at the North Portal and along the proposed North Ramp and Main Drift. With the exception of ONC-1, these boreholes are located from 0 to 461 m from the springline of the TS Loop and have been used for pneumatic monitoring purposes. The PTH and RF-series boreholes were single-purpose boreholes, intended to collect geotechnical design data for the ESF surface and support facilities. The targeted geologic and geotechnical data have been collected. Since there are no further tests planned in the PTH and RF boreholes, there is no recognized test interference due to the proposed tunnel and alcove construction relative to the geotechnical data gathering activities.

Measurement and observation of air flow into and out of boreholes on Yucca Mountain indicate that there are diurnal, seasonal, frontal, and wind-driven barometric pressure differences between the atmosphere and the interior of the mountain. These pressure differences induce circulation of air in the unsaturated, fractured rock. Site characterization is concerned with understanding the role of the present-day gaseous flow and pneumatic pathways in the unsaturated zone (UZ) of Yucca Mountain to assist in the prediction of how such pathways affect coupled heat, water, and gas flow systems after a potential repository is in operation (Drefus 1994). Evaluation of the thermal loading strategy is sensitive to discrimination between those regions where gas-phase convection might dominate over conduction as a heat transfer mechanism. The construction of the TS Loop tunnel has disrupted the natural gaseous flow in its vicinity by creating a pneumatic pathway across the relatively impermeable non-welded Paintbrush Tuff (PTn) unit, connecting the more permeable welded units of the Tiva Canyon and Topopah Spring members of the Paintbrush-Tuff. Evaluation of these data have been very successful (Ahlers et al. 1996), and it has been determined that adequate ambient data have been obtained, and that the important data to be collected subsequently are those that reveal the effects of the passage of the TS Loop (Statton 1996).

The issue of the connectivity of pneumatic pathways across the PTn is addressed in the UZ testing and monitoring program in surface-based boreholes planned throughout the site. These data feed into a conceptual model of moisture and gas flow in the unsaturated zone. Some of the tests involve monitoring the barometric pressure changes that occur naturally and observing their effects at depth within the mountain. These tests, conducted in existing boreholes, ultimately use the TS Loop itself to provide information on rock volumes of thousands of m^3. Such large-scale observations are important to the extrapolation of other test information to the scale of the mountain.

Selected boreholes (USW NRG-7a and USW NRG-6) in the vicinity of the ESF North Ramp alignment were instrumented to collect baseline UZ pneumatic data before the passage of the TBM. Data are also available from the Nye County instrumentation of UE-25 NRG#4 and ONC-1, although these data will have to be qualified for use as site characterization data. Other boreholes, SD-12, SD-7, and UZ-7a, were subsequently instrumented and monitored along the main drift. The greatest barometric changes generally occur during the winter months. The TBM has progressed well beyond the above listed boreholes, and many of them have provided two or more winters' worth of pneumatic data, including large data sets for some boreholes before TBM passage (Statton 1996). This particular testing program is winding down, and most of the relevant data have been collected, analyzed, and documented as related to the pneumatic influence of the TS Loop to gas circulation (Ahlers et al. 1996). The relevant pre-construction (ambient) data that can be collected have been. To ensure that the ambient information was gathered, even if the rate of tunnel advancement was more rapid than anticipated, a hold was placed on the TBM advance at the PTn contact, which is in the vicinity of Station 09+00 m, until pre-TS Loop data had been collected in the vicinity of the North Ramp. The hold was rescinded when pneumatic data were collected for several barometric pressure changes from isolated intervals in the TCw, PTn, and TSw (Brocoum 1995).

Additional opportunities to use the TBM advance to facilitate calibration of the UZ gas circulation model have been taken in other boreholes along subsequent sections of the TS Loop. In these boreholes, pneumatic data have been used to calibrate calculations of gas flow, which in turn have been used to predict subsequent pneumatic response to iteratively produce refined gas-circulation models (Ahlers et al. 1996). Borehole pneumatic data will supplement smaller-scale measurements from planned cross-hole testing to be conducted in UZ borehole clusters (Brocoum 1995).

Of the other existing boreholes within 914 m of the TS Loop alignment, the only boreholes in which testing is currently on-going are the water table (WT) and the hydrology (H) boreholes. On-going testing in the WT and H boreholes is focused on water level measurements; because TS Loop construction is above the water table, and no direct impact to the water table is anticipated, no test interference due to TS Loop construction is anticipated. If an impact were noted, it would be useful information in constructing the hydrologic model for the site. Infiltration studies in neutron access boreholes (UZN or UZ-N) have been terminated.

The existing boreholes that do extend to the depth of the North Ramp or the potential repository horizon either have been instrumented to monitor the potential pneumatic effect of the TS Loop opening, or currently have no future planned tests that would be impacted by tunnel construction in the unsaturated zone. The "a" and "b" boreholes were constructed between 1978 and 1981 to collect stratigraphic and hydrologic data. Borehole UE-25 a#4 contains UZ instrumentation, and water level measuring equipment is in borehole UE-25 b#1. As such, no test interference from construction activities is expected for these types of boreholes.

10.4.2 ESF Alcove Testing

10.4.2.1 Southern Ghost Dance Fault Alcove (SGDFA)

CRWMS M&O 1995d shows that there are four surface boreholes in the general vicinity of the SGDFA. Three are existing boreholes, USW WT-2, USW UZ-7a, and USW UZ-8; and one is a planned borehole, UZ-8a. Boreholes WT-2 and UZ-7a are the closest and are both depicted on CRWMS M&O 1996k. The siting of the SGDFA is in fact based on the location of UZ-7a. Hollins 1996d prescribes that the SGDFA Access Drift breakout station in the TS Main Drift "will be located so that the geothermal borehole drilled from the Phase I terminal face of the Access Drift will intersect the Ghost Dance Fault a nominal 30 m south of USW UZ-7a." Since consideration of the proximity of the SGDFA to this borehole is inherent in the test configuration, the prescription of any necessary QA controls to assure this aspect of the test configuration is the responsibility of the assigned PI(s). Borehole WT-2 is depicted in a larger scale on CRWMS M&O 1996l. This 2060-feet deep WT ("water table") borehole was drilled in 1983 (Fenix and Scisson, Inc. 1987). There are no active TPPs for this borehole. The only testing likely in WT-2 is the monitoring of water levels. The SGDFA is well above the water table, and no interference with water-level monitoring is expected. No testing is being conducted in UZ-8, and no new boreholes are planned, precluding interference with UZ-8a. CRWMS M&O 1996l indicates that the subsurface excavation of the SGDFA Access Drift will miss the track of the borehole (corrected to the depth of the SGDFA Access Drift based on Mitchell 1994) by greater than approximately 10 m, or more than approximately 2 1/2 drift diameters. Two drift diameters has been accepted as a conservative minimum standoff distance to preclude test interference from the creation of the mechanically disturbed zone surrounding an excavation (Brake 1995a).

10.4.2.2 Alcove #4 Testing

ESF Alcove #4 was excavated in proximity to surface borehole UE-25 NRG-4. Testing in NRG-4 is the responsibility of Nye County, Nevada (Mitchell 1995), and therefore does not constitute site characterization testing. The PIs and TCO are responsible for configuring alcoves and tests therein, and the alcove and radial borehole designs have been approved by the TCO (Brake 1995a, and Mitchell 1995). As radial borehole drilling essentially comprises test configuration, it is the responsibility of the PI to field his/her test in a manner that protects the validity and veracity of the test data.

With respect to tracer use, Brake 1995b indicates that both Nye County and the PI for the radial borehole drilling and testing in Alcove #4 have mutually agreed that the past use of SF_6 tracer in NRG-4 will not adversely impact radial borehole testing, nor will the use of SF_6 in the radial boreholes affect the NRG-4 activities. Knowledge of past use of SF_6 in both NRG-4 and the Alcove #4 radial boreholes will assure that such usage will not create the potential for unknown impact to future tests.

Based on the above, the radial borehole drilling and testing activities planned in Alcove #4 present negligible potential for adverse impact on testing activities being performed in surface borehole UE-25 NRG-4.

10.5 BOREHOLE CONSTRUCTION

With the possible exception of the proposed Yucca Ridge Boreholes (SD-11 and SD-13), all of the previously planned boreholes in the vicinity of the TS Loop are no longer planned to be drilled. Recent borehole drilling activities (e.g., SD-6 and WT-24) have been evaluated in CRWMS M&O 1997p or similar evaluation. Should drilling of the Yucca Ridge Boreholes or other new boreholes be approved, or should any other future drilling be planned, test interference due to the proximity of the TS Loop will be addressed in the evaluation prepared for the FWP (or equivalent documentation) for those boreholes.

10.6 UNDERGROUND CONSTRUCTION

The excavation of the TS Loop by the TBM occurs concurrently with the installation and operation of the required utilities and support for the TBM. The other underground construction activity in the TS Loop area is the drill-and-blast or mechanical excavation of the operation and test support areas. Excavation effects on rock properties is taken into consideration when fielding tests along the TS Loop and in the support areas. In the following paragraphs the possible test interferences caused by the tunnel and support area excavation methods, the construction of TBM support systems, and utilities systems are discussed.

10.6.1 Impact of TBM Excavation on Testing

The underground ESF and its access ramps represent a major data gathering facility for the Yucca Mountain site characterization activities. Operation of the TBM provides the means by which underground testing in the proposed test support areas and in the ramps and main drift of the ESF will be accessed. The test interference concerns with regard to surface-based tests and with regard to potential tests in the Calico Hills drift of the Subsurface ESF are discussed above in Sections 10.4 and 10.2, respectively. The testing concerns with regard to the potential for TBM operational spills and leaks are presented in Section 10.7.1.3.

As discussed above, the planned tests in the TS Loop have been prioritized to develop an integrated construction and testing schedule. The following grouping and sequencing of tests have been identified by the TCO along the TS Loop:

- Tests that occur in the ESF Starter Tunnel
- Tests in Alcove #1

- Test that occur within the TBM envelope
- Tests in Alcove #2 at the Bow Ridge fault
- Tests in Alcove #3 at the Tiva Canyon/PTn contact
- Tests in Alcove #4 at the PTn/Topopah Spring contact
- Tests in Alcove #5, known as the Thermal Testing Facility
- Tests in Alcove #6 at the Ghost Dance fault
- Tests in Alcove #7 at the Ghost Dance fault
- Tests in TS Loop Niches

10.6.1.1 Tests within the TBM envelope

The tests within the TBM envelope are those that occur in the TS Loop, generally as soon as possible after the TBM passes. Most of the activities are not sensitive to continued TBM operation, but do require that adequate access is provided by the construction operations to the extent that safety concerns allow. However, if flowing (perched) water (see below) or another significant geologic condition (Section 9.0) is encountered, and the initial assessment by the TCO is that it may be significant to on-going or planned testing (e.g., the collection of otherwise irretrievable data) or construction, the TCO may request of the CMO that TBM advance be delayed. This request will be reviewed by DOE for concurrence.

The following tests may occur within the TBM envelope in the TS Loop. The TCO will coordinate with the CMO to address access needs.

<u>Perched Water Testing in the TS Loop</u>

Although excavation of the TS Loop has been completed without encountering perched water, any perched water zones encountered need to be sampled and examined as soon as possible. As soon as practical, an assessment will be made by the TCO of appropriate steps to be taken for sampling. When perched water is detected (as indicated by flowing water), the TCO, in conjunction with the PI and the CMO, will decide whether to suspend excavation operations to allow for more complete testing and sampling. Small-flow perched water zones may only require that water samples be collected along with an estimate of the flow rate and total volume of water produced. Access may be needed for long-term sampling and monitoring of perched water zones, which will continue until the nature of a perched water zone is determined and all test-related quality-affecting activities are completed (CRWMS M&O 1997k).

Hydrologic Properties of Major Faults

Large structural features, such as faults or breccia zones, may be important hydrologic conduits or barriers. As such, they may be targets for testing in the TS Loop, alcoves and niches. Testing would include measurements of pneumatic and hydrologic permeability, porosity, and anisotropy. Major structural features in the subsurface have been anticipated from surface mapping, and alcoves/niches have been constructed or are under construction to accommodate their investigation. To date, all such testing has been or will be accommodated by specially constructed test alcoves. The FWP for Hydrologic Properties of Major Faults (YMP 1997l) does not identify any hold points for TBM advance to accommodate such testing.

Consolidated Sampling

Access will be needed to locations identified during geologic mapping or other testing activities for deferred sample collection. Some samples, such as gels, may need to be collected as soon as practical after they are detected in a new exposure before installation of ground support and wall washing. Many other sample types can be collected at any time after construction. No water or tracer, other than the traced construction water and air-misted water used for cleaning the tunnel wall, should be used in the immediate vicinity of a sampling location without the approval of the PI. At the present time, lithium bromide is the only approved tracer to be used in construction and cleaning water in the Subsurface ESF. Use of TFMs, especially in construction, in the proximity of the sampling location should be documented (YMP 1997m).

Construction Monitoring

Access will be needed to allow for the drilling of boreholes and installation of instrumentation to accommodate construction monitoring. The field activities are described in YMP 1993. Requirements for borehole locations, drilling and coring, instrument installation, data collection, and reporting are described in YMP 1997n. Construction monitoring also includes plans for periodic air-quality sampling at selected locations (YMP 1993), however, many of the requirements on this sampling are yet to be developed (YMP 1997n).

Geologic Mapping associated with TBM operations

Geologic mapping is a Subsurface ESF site characterization activity that may at times be in conflict with required rock support. The Subsurface ESF roof and walls require installation of rockbolts for stability. Where necessary, straps, ring beams, steel lagging, steel sets, wire mesh, interlocking wire mesh, shotcrete, or full concrete lining may also be installed. Because geologic mapping is a photographic and observational activity best performed as soon as possible following excavation, immediate installation of supports could obscure geological details and should be performed, to the extent practical, after geologic mapping has been completed. Thus, for normal mapping operations, nothing more than pattern bolting and, if necessary for safety concerns, approximately 15.2 centimeters (cm) or greater wire mesh is expected to be present. If additional ground control (such as steel rings, lagging, mesh less than 15.2 cm, or shotcrete) is necessary due to poor ground conditions, the TCO and the mapping PI will confer with the CMO to identify if the needed ground support can be installed in a manner that allows the collection of geologic data to the extent practicable (Elkins 1994b).

Water used to clean the tunnel and alcove/niche walls for geologic mapping will have lithium bromide tracer added to it. The appropriate amount of water will be used during blowdown cleaning and drilling operations to suppress dust. If compressed air is used in the cleaning operation, it does not need to be traced (YMP 1997o).

Moisture Studies in the ESF

These studies are conducted in any underground drift, alcove, or niche. Instrumentation in support of this activity may be placed outside of or into boreholes drilled for these studies or into boreholes not utilized for other testing activities. When alcoves or niches are constructed for this activity, temporary bulkheads may be constructed to isolate these areas from ventilation effects. These bulkheads may be constructed of steel and shotcrete or nonpermeable plastic cloth (CRWMS M&O 1997d).

10.6.1.2 Tests in Alcoves #2, #3, #4, #6, #7, and Niches

Alcoves #2, #3, #4, #6, #7, and Niches are located at faults or key geologic contacts. Of particular interest is the permeability of these faults and contacts, and the role they play as fluid pathways. Some of the instrumentation planned in these alcoves and niches both (1) collect data that would be irretrievable if alcove/niche construction were deferred until the entire TS Loop was constructed, and (2) require installation as soon as practical to collect information significant to the Viability Assessment, Site Recommendation, and/or License Application (DOE 1996b). Thus, construction of these alcoves commenced as soon as practical after the TBM crossed the fault/contact; alcove specific testing and construction requirements were identified; design analyses, specifications, and/or drawings were modified (or created) as necessary based on testing and construction requirements; and the TBM and trailing gear reached competent ground such that the TBM excavation could continue or be halted, as safety concerns dictated.

The tests planned in these alcoves and niches are similar to those in Alcove #1 and in the TBM envelope, and the test interference and access concerns addressed above (Section 10.6.1.1) are applicable to the test alcoves/niches. Grouted rockbolts should not be used in the ESF test alcoves/niches without TCO or PI approval due to the distances that grout was observed to have traveled away from rockbolts installed in the ESF Starter Tunnel and in the fractured rock into which

Alcove #1 was excavated (see also Section 10.6.2). This is a precaution to avoid altering gas sample and air permeability data by either altering the rock gas chemistry in the vicinity of the alcove, or by filling fractures that were permeable pathways to gas flow (Elkins 1994b; YMP 1996b).

Temporary bulkheads may be constructed at alcove or niche locations within the ESF to isolate testing areas from ventilation effects. These bulkheads may be constructed of steel and shotcrete or nonpermeable plastic cloth, as appropriate. The formal evaluation of these bulkheads has been allocated to the DIE for ESF Subsurface Testing Activities (CRWMS M&O 1998a).

10.6.1.3 Tests in the Thermal Testing Facility

The Thermal Testing Facility (TTF) is located near the far end of the North Ramp curve, in the TSw2 unit. The purpose of the TTF is to start thermal-mechanical-hydrological-chemical *in situ* tests, which require a long lead time to obtain data.

Water usage need not be limited for construction purposes in the vicinity of the heater tests, as described in Datta 1996. The primary consideration for moisture with respect to the heater test is the relative, rather than absolute, changes in saturation of the host rock. Thus, normal construction water usage during development of this facility will not adversely impact site characterization, and no special constraints appear to be warranted.

No other test interference concerns regarding construction have been identified for thermal-mechanical tests to be conducted in this area. Additional test-specific controls may be included in the associated FWPs, TPPs, and/or JPs.

10.6.2 Operation and Test Support Area (Alcove and Niche) Excavation

The test and operation support areas will be constructed using controlled drill-and-blast techniques developed and modified as work progresses, or by mechanical excavation. The effects of the alcove construction using drill-and-blast techniques may extend farther from the excavated alcove opening than the effects due to TBM excavation. These factors will be taken into consideration during fielding of tests planned in the test support areas and the TS Loop. Drill-and-blast excavation of the TS Loop niches was not permitted.

Blast monitoring, blast damage assessment, and blast residue are monitored as part of the hydrochemistry testing and construction monitoring activities (YMP 1996a; 1997n). Accurate records should be maintained of the time, location, type of explosive used, and size of each blast, and the records submitted to the appropriate project records system. These data may be of interest to Principal Investigators who may need to address the blasting in the tunnel during analyses of their own data; e.g., the PI in charge of seismic monitoring, or the PI in charge of hydrochemistry testing (who may need to consider the possible effects of blast gases on ambient rock-gas chemistry).

The planned blasting materials (semi-gelatin dynamite, detonation cord, primers, etc.) are included in Attachment II, and are not expected to chemically affect the construction monitoring, consolidated sampling, or geologic mapping tests performed in the TS Loop or its support areas. Controlled drilling-and-blasting methods will minimize effects on site characterization testing. Alternative blasting material should be evaluated and recorded in accordance with the TFM Procedure (DOE 1998a).

The YMP Study Plan for *In Situ Design Verification* (DOE 1993), Section 4.1.1.1, identifies peak particle velocity (PPV) as a drill-and-blast parameter to be monitored as part of the Evaluation of Mining Methods experiment. The rationale for this experiment (Section 2.1.1 of the Study Plan) acknowledges that mining methods used in the Subsurface ESF will be adjusted to suit changes in ground conditions as techniques are refined through experience. The experiment is intended to document these adjustments, the reasons for making them, and their results. This documentation "will allow repository designers and constructors to make use of experience gained in ESF excavations." The collection of these PPV data, including determination of which drill-and-blast rounds to be monitored, and the validity and veracity of the data, is the responsibility of the responsible PI(s).

Monitoring of PPV is not considered to be required to prevent or minimize the potential for construction-to-test interference. The blast records discussed above, in conjunction with post-blast observations, if necessary, by the responsible PI(s), are sufficient to ensure that controlled drill-and-blast methods do not impact subsequent or in-process testing in an undetected or unpredictable way. The responsible PI(s) may also prescribe specifically, as part of the configuration for the testing, that excavation be performed by mechanical means.

Diesel-fueled equipment is planned to be used to remove broken rock from alcove and niche excavations (see also Section 10.6.12). Use of hydrocarbons, such as lubricants, engine oil, and coolants for this equipment should be controlled to the extent practical to prevent and mitigate releases to the subsurface environment. No test interference potential is expected from the use of operating fluids as long as they are not spilled or spills are cleaned up to the extent practical. Refueling, routine maintenance that involves lubricants, engine oil, or coolants, and repair should be done carefully to minimize the potential for spills. Any spills should be reported in accordance with the TFM Procedure.

In addition to constraints discussed in Section 10.6.1.2, grouted rockbolts and shotcrete should not be used in the test support areas to avoid altering gas sample and air permeability data and obscuring lithology and structures of interest to mapping activities, except as necessary to meet safety standards or as approved by the TCO. Split sets, other mechanical bolts, wire mesh, steel sets, or other materials (if approved in accordance with the TFM Procedure), are acceptable for ground support. Before placing any shotcrete or other cementitious material in the alcoves/niches for personnel safety, rock support, or other purposes, the field operator will coordinate through the TCO to acquire PI concurrence and special instructions (if any) to minimize testing impacts.

Alcoves and niches are designed before the commencement of excavation. Changes to the design may be required as the excavation proceeds and geologic and safety conditions are observed. When the PIs assess that the alcove/niche is of sufficient dimensions (particularly depth) such that construction effects (i.e., rockbolt grout and construction water) from the TS Loop (Section 10.6.10) or adjacent alcoves/niches are minimal and are not expected to interfere with testing planned in the alcove/niche, the TCO will coordinate the completion of alcove/niche construction and start of testing construction with the CMO (YMP 1996b).

Other potential test interference concerns are in regard to access for testing. It is judged that the coordination between the CMO and the TCO will be sufficient to address access needs such as the following:

> Short boreholes for hydrochemistry samples should be drilled within one day after excavation of selected rounds of alcove construction, to the extent that safety concerns allow access (Elkins 1994b).
>
> Clear access needs to be provided to the alcoves, niches, testing boreholes, and testing equipment in the alcoves/niches.

Additional access requirements and alcove and niche testing support will be addressed by the FWPs, TPPs, and/or JPs for the specific tests.

10.6.3 Compressed Air Distribution System

Provision will be made in the applicable FWP, JP and/or TPP to prevent the introduction of liquid water from the compressed air supply into tests that are sensitive to water, such as the radial borehole test. No other test interference concerns are expected since the accumulated oil and water from the air treatment process will not be reused underground without additional processing and are required to be disposed of in accordance with environmental regulations. It is the responsibility of PIs to ascertain whether or not compressed air treatment is adequate. Compressed air used in the collection of core and in the conduct of experiments and testing for site characterization may be tagged with a chemical tracer. Since this is not a construction-to-test interference requirement but a potential prerequisite for specific site characterization testing activities, any tagging requirements will be addressed by the applicable FWP, TPP and/or JP for the specific test.

10.6.4 Fire Protection System

The use of fire suppressing agents (including water) should be treated as a spill and dealt with accordingly. Fire suppressing dry chemicals proposed for the fire extinguishing system have been considered in terms of TFM parameters by this evaluation (Attachment II). Quantities of all materials used should be reported in accordance with the TFM Procedure (YMP 1998a). If additional fire suppression agents are selected for use, their potential impact on site characterization activities should be evaluated in accordance with the TFM Procedure.

10.6.5 Subsurface Conveyor System

The subsurface conveyor system employs operating fluids such as lubricating oils, hydraulic fluids, grease, dust suppression water, and other potential contaminants. The potential for leakage and spillage from causes including failure, damage, wear, repair, servicing, and accidents have been evaluated, and reasonable methods for precluding and mitigating the leakage and spillage of fluids have been incorporated in the system design. Accidental spills should be reported in accordance with the TFM Procedure (YMP 1998a).

The subsurface conveyor system is equipped with a dust control and suppression system to contain the dust generated by the handling and conveying of muck. As part of this system, water spray headers are installed at each loading and transfer point. Lithium bromide is added as a tracer to water to be used for dust control, as for other underground construction, except as exempted (Elkins 1994c). Water volumes used for dust control should be measured (e.g., totalizing flow meters) and records should be maintained and recorded routinely, identifying the quantities.

It is expected that almost all of the water used for conveyor system dust control will be applied directly to the muck and so will also be carried out with the muck. The design is such that the amounts of water applied at each transfer point are expected to be minimized to avoid excessive water application that could result in spillage of water off the conveyor belt onto the tunnel invert. No construction-to-test or operation-to-test interference is anticipated as a result of this activity, given identification, mitigation, and cleanup of spills. In addition, the amount of water applied will also be monitored. Spills of muck should be avoided to the extent practical, and cleaned up as soon as practical when they do occur, to avoid and/or limit introduction of dust control water onto *in situ* rock.

10.6.6 Power Distribution System and Lighting

Conveyor and ventilation system components may be electrically grounded at intervals of approximately 300 m. Potential test interference exists if the ground enhancing material contains chloride. The ground enhancing material to be used should be one that is chloride-free, such as the coal-derivative GEM.

No test interference is expected to occur from installation and operation of the lighting, Uninterruptible Power Supply (UPS), and emergency lighting systems as long as spills (e.g., battery acid) are avoided. If spills occur, they should be cleaned up as soon as practical. The volumes and locations of any spills should be documented and reported in accordance with the TFM Procedure (YMP 1998a).

10.6.7 Subsurface Wastewater Handling System

No test interference due to the subsurface wastewater handling system is anticipated, provided components such as pumps and motors incorporate methods for minimizing potential for leakage to the extent practical; and leaks and spills are identified, mitigated, and reported in accordance with the TFM Procedure (YMP 1998a).

The engineered sump at approximately Station 28+05 m is to be lined with concrete and a waterproof seal applied to pent water from entering the rock mass. The engineered sump is expected to remain dry most of the time. Temporary wastewater sumps have been installed as construction utilities at approximately Stations 28+05 m, and 59+19 m. A third temporary construction sump may be excavated beyond Station 59+19 m higher up in the South Ramp. Water collected in these sumps is/will be pumped out. This provision minimizes potential test interference concerns regarding seepage into the rock mass of water collected in the sump.

10.6.8 Subsurface Ventilation System

TS Loop ventilation fans will be located (subject to ground conditions, and tunnel construction and safety considerations) as required at stations along the TS Loop. Sealed bearings on these fans reduce the potential for interference due to leakage of lubricating fluids. No interference due to the operation of the ventilation system is anticipated as long as leakage and spillage is avoided to the extent practical and leaks and spills are cleaned up as soon as practical in accordance with the TFM Procedure (YMP 1998a). Site characterization tests monitoring the ventilation system require access to the entry and exit point for the exhaust ventilation line for periodic sampling or instrumentation. In addition, sampling ports need to be installed at selected locations along the vent line (Elkins 1994b). Access for these testing needs will be coordinated through the TCO via the applicable FWP, TPP, and/or JP.

The ventilation system will be circulating large volumes of atmospheric air through the ESF tunnel, which will be at a slight negative pressure relative to the atmosphere. Under static barometric conditions, there will be no advective flow of the tunnel air into the wall rock, and the only mixture with *in situ* gases will be due to diffusion. Under these conditions, the likelihood of test interference with hydrochemical tests of the gaseous system in the unsaturated zone is considered to be small and unavoidable due to personnel safety reasons. However, as atmospheric pressure increases following passage of low-pressure fronts, the tunnel air, drawn from the outside atmosphere, may actually be at higher pressures than the gaseous pressures in the wall rock, which has not yet equilibrated to the increasing air pressure in the tunnel. Under these circumstances, there could be advective flow of the tunnel air into the wall rock. The emanation of Radon/Radon daughter products are being monitored to ensure there impacts on testing activities are minimized.

The mixing of atmospheric air (modern apparent ^{14}C age) that contains diesel combustion products (old apparent ^{14}C age) produces a mixed source of CO_2 with an indeterminate apparent ^{14}C age. This may mix with the *in situ* gases to constitute a test interference in regard to radiocarbon age analyses of the UZ gases collected in the vicinity of the TS Loop. Assessing the extent (distance) to which this impact will be detectable from the Subsurface ESF opening is one application of hydrochemistry tests planned in the ESF. These data will be used to resolve questions of geochemical sample representativeness; therefore, no test interference controls have been identified.

10.6.9 Subsurface Water Distribution System

The water distribution system carries traced, nonpotable water underground. Spill and leak control measures (e.g., isolation valves) have been incorporated into the design to minimize or avoid test interference potential due to possible spills and/or leaks, which could impact *in situ* rock moisture conditions and potentially bias any nearby hydrologic tests. No interference due to the operation of the underground water distribution system is anticipated as long as leakage and spillage is avoided to the extent practical and leaks and spills are identified, mitigated, and cleaned up as soon as practical.

The Subsurface Water Distribution System also includes the tracer injection system. Because it would take simultaneous failure of the water delivery system and the tracer injection system, delivery of untraced water is not considered likely and therefore no test interference impact is expected. If failure did occur, it would be treated as a spill and would be reported in accordance with the TFM Procedure (YMP 1998a).

Small quantities of untraced, chlorinated potable water used for drinking water, ice and hand wash purposes in the Subsurface ESF are considered to present negligible potential for test interference.

10.6.10 Lining and Ground Support

Steel sets, lagging, concrete, grout, shotcrete, mesh, steel straps, and ground support bolts will be used for lining and ground support. Boreholes for rockbolts, anchor-bolts, and other ground support bolts will be drilled into the tunnel walls and lining utilizing electrohydraulic or pneumatic drills, either mounted on the TBM trailing gear or mounted on utility support equipment. Compressed air used for general construction drilling and construction will not contain tracer (Elkins 1994c). It is preferred that these boreholes be drilled dry, although it is not required. If water usage is necessary, the amount of water should be kept to a minimum and the water should be traced.

Rockbolts may be cement grouted, however, this has not been a practice throughout most of the Subsurface ESF. Potential test interference exists due to possible alteration of the *in situ* pH of water/moisture in contact with the grout. Additionally, there may be potential for large volumes of grout to migrate significant distances away from the TS Loop alignment if it is emplaced under pressure. Cement grouting pressures and quantities should be limited to the extent practical for that grouting associated with rockbolt installation. The potential distances to which cement grout will penetrate into and through rock fractures and fault systems is directly related to the grouting pressures and grout quantities used. Accordingly, rockbolts should not be grouted in a test alcoves/niches, to the extent that safety concerns allow, without TCO approval. Because testing alcoves can be lengthened, as necessary, to further remove the testing location from grout injected along the main alignment, no additional controls have been identified.

Mixing water for concrete, grout, and pre-mixed (wet) shotcrete does not need to contain tracer (Elkins 1994c). Grout additives should not contain chloride to the extent practical to minimize the potential of affecting chlorine sensitive site characterization testing.

Tunnel lining and ground support should be installed after planned geologic mapping and sampling has been completed, to the extent practical. If the encountered ground conditions require ground support in excess of the existing design (Section 6.5), the impact of suggested remedial activities (i.e., chemical grout injection) should be addressed in a separate evaluation.

ESF testing includes monitoring of ground support systems in both the TS Loop and the test support areas. Access to selected rockbolts will be provided for installation of load cells. This is being coordinated between the TCO and the CMO.

10.6.11 Precast Concrete Invert Segments

Potential interference could occur due to possible accumulation of fluids beneath the precast concrete invert segments. Although backer rod seals may be installed between the inverts and along the edges of the inverts, they would essentially function simply to slow down the movement of large spills or water inflows under the precast invert segments. Perched water or moist zones (near highly fractured zones or faults, or at the contact between units of contrasting hydrologic properties) may be encountered during TS Loop construction that could introduce water into the opening that would accumulate at the tunnel face (where it would be captured by the wastewater removal system of the TBM or mix and be carried out with the cuttings). Flowing water could accumulate under the invert segments, travel along the tunnel bottom and potentially infiltrate other fractures that could alter *in situ* moisture conditions. However, as of this writing, the TBM is at approximately Station 72+00 m, and although moist zones have been observed in the PTn, no flowing water has been produced along the entire length of the TS Loop. Thus, it is considered unlikely that perched water will be encountered. No interference is anticipated due to the presence of the precast invert segments themselves.

10.6.12 Use of Diesel-Powered Equipment

Diesel-powered equipment is currently planned to be used underground for muck haulage, alcove/niche excavation, and material and personnel transportation. The diesel exhaust will mix with outside air circulated through the tunnel by exhaust fans that create a negative pressure at the tunnel face. The gaseous oxides of carbon and diesel particulate matter (DPM) contained in the diesel exhaust could potentially impact site characterization testing that (1) can be affected by microorganisms that feed on carbon compounds, or (2) is based on chemical analyses of carbon compounds if the diesel products penetrate into the wall rock and contaminate the *in situ* gases collected for site characterization. The potential enhancement of microorganism growth due to the introduction of diesel particulate matter will not have a test interference impact on some proposed tests, and will actually enhance the conduct of other planned tests because effects of introduced materials can be measured more quickly. No test interference due to the generation of diesel particulate matter was identified for the planned site characterization tests.

Because the ventilation system will maintain the tunnel atmosphere at slightly less than atmospheric pressure, it is hypothesized that the diesel-contaminated tunnel atmosphere will be exhausted from the tunnel, without advective inflow into the fractures and rock matrix, for much of the time while the ventilation system is operating. However, since expected variability of atmospheric pressure is an order of magnitude greater than the ventilation induced pressure difference, there could be advective air flow from the tunnel into fractures and the rock matrix as barometric pressure rises after an interval of low pressure, e.g., a winter storm.

Presently, there may be enough data on the permeability of the rock mass, fracture flow, the interconnectivity of fractures, and the magnitude of this pneumatic pressure difference to assess this impact, but such an analysis has not been carried out. Diesel usage in the ESF can provide an opportunity to collect test and monitoring data to better define the above parameters. A testing program was implemented by the scientific testing participants to use this opportunity to collect data in parallel with the use of diesel-powered equipment in the excavation of the North Ramp. Monitoring and testing of diesel emissions should consider emissions of carbon gases. The diesel testing (which had to occur before use of diesel in potential waste emplacement areas [as defined in CRWMS M&O 1994i]) provided data that, in conjunction with continued diesel emission monitoring, diesel use records, and other planned site characterization testing data, will allow testers to assess any potential impact on site characterization testing activities. In addition, the diesel use records should record the type of engine or equipment that consumed the diesel fuel, the volume of fuel used, and the number of hours that the equipment was operated.

10.6.13 Muck Haulage Using Cars

Muck haulage using cars was employed during TBM operations until the muck conveyor system was installed and during periods after installation when the conveyor was not operational. The muck haulage cars are moved by use of locomotives, either diesel or electric-powered, on the rail installed in the TS Loop for the TBM trailing support cars and utility support. The test interference concerns of using diesel underground are discussed in Section 10.6.12.

Muck excavated by the TBM will be loaded into the muck haulage cars within the rear trailing support cars off of the TBM internal conveyor. No interference due to muck haulage is anticipated as long as muck spillage is avoided to the extent practical, and muck spills are cleaned up as soon as practical if excessively wet. In addition, observable spills or leaks of fuel, battery acid, coolant, lubricant, etc., from the locomotives are to be avoided to the extent practical, reported if such occurs, and cleaned up as soon as practical in accordance with the TFM Procedure (YMP 1998a).

10.6.14 Materials and Personnel Transportation

Rolling stock is described in Section 6.9. The electric hydraulic scissor lift cars, along with the maintenance/lube car, have the potential for leaks or spills from the car mechanisms. No interference due to rail car use is anticipated as long as leakage and spillage is avoided to the extent practical; and leaks and spills are identified, mitigated, and cleaned up as soon as practical. The volumes and locations of any spills should be documented and reported in accordance with the TFM Procedure (YMP 1998a).

10.6.15 Subsurface Sanitary Facilities

Portable self-contained chemical toilets will be provided at appropriate locations underground. As long as spills are avoided and cleaned up to the extent practical, should they occur, no test interference is anticipated. The volumes and locations of any spills should be documented and reported in accordance with the TFM Procedure (YMP 1998a).

10.6.16 Communications Systems

No test interference concerns have been identified with regard to these systems at the present time. Should the Principal Investigators (PIs) determine that the communications systems may be causing test interference with the DCS or other data acquisition systems after these systems are in place, further electromagnetic shielding may be installed to one or both of these systems. It is the responsibility of the PIs in to identify additional shielding requirements in the preparation of the applicable FWP, JP, and/or TPP. No test controls are recommended at this time.

10.7 EXPERIMENTS AND OPERATIONS

10.7.1 Tracers, Fluids and Materials (TFMs)

A large variety of TFMs are expected to be used for TBM operation, installation and operation of utilities, support for TBM operation, and for construction of the TS Loop and support areas. All construction materials or substances to be used underground should first be reviewed for potential effects on engineered barriers, waste isolation, and on-site characterization or other testing. The TFM procedure (YMP 1998a) adequately provides for this evaluation through DIEs. The presence of combustible materials underground should be controlled and limited such that testing in the Subsurface ESF is not adversely affected. Attachment II lists those TFMs that were reviewed for this evaluation and indicates identified special handling or storage requirements from a test interference perspective. Potential causes of test interference due to TFMs are discussed below.

Use of materials should be documented in detail and reported in accordance with the TFM Procedure (YMP 1998a). Samples of TFMs used in alcove/niche construction and testing construction are available for examination by ESF Principal Investigators upon request.

10.7.1.1 Tracers

The addition of a universal tracer (lithium bromide is currently the selected tracer) is required for water applied underground in dust suppression, wall cleaning before mapping, and other construction applications. It is not required in water used in concrete, grout, or shotcrete mixtures, except when grout is required in the vicinity of any perched water testing identified by the TCO. The concentration of lithium bromide tracer in the construction and mapping water should be within a maximum range of 10 parts per million (ppm) to 30 ppm. The low end of the required concentration range, 10 ppm, is near the limit of detection of bromide; the upper limit of the range, 30 ppm, is based on a state permitting requirement.

Compressed air used in blast hole drilling, short hydrochemistry boreholes, pneumatic tool usage, and in blowdown operation before geologic mapping does not require tagging with a chemical tracer (YMP 1997a). If required for test purposes, compressed air used to drill core holes and for field experiments and testing in the TS Loop and associated alcoves/niches may be tagged with a tracer, such as SF_6. These and any additional tracer needs for ESF testing will be identified in the FWPs, TPPs, and/or JPs for the tests.

10.7.1.2 Water

Water containing chemical tracer is necessary for dust suppression during TBM operation. The cutter and conveyor spray heads are designed to use a maximum of 30 gallons per minute, most of which is expected to be transported out with the muck.

Additional water may be required for rockbolt installation drilling, cleaning of the tunnel walls for geologic mapping, wetting down of muck piles in alcove/niche excavations, and for cutterheads on a roadheader or alpine miner. A chemical tracer should also be added to this water to allow assessment of any effects on subsequent planned testing. The total volume of water used during TBM operations for dust suppression, alcove/niche construction, shotcrete make-up, blasthole and rockbolt drilling, and wall cleaning purposes to facilitate geologic mapping should be minimized, measured, and recorded. The TFM water records should list the types of applications associated with the water use record. The constructor will provide, at the request of a PI, samples for chemical analyses of all traced water used in the ESF.

10.7.1.3 Fluids used in Operation of the TBM

Numerous spill and leak control measures have been incorporated into the design of the TBM. Four types of fluids are required for TBM operation (in addition to water, which is discussed above): hydraulic oil, lubrication oil, seal grease, and lubrication grease, as discussed below. No interference due to TBM operational fluids is anticipated as long as leakage and spillage is avoided to the extent practical, periodic checks are made to detect leaks and spills, and spills are cleaned up as soon as practical. The volumes, locations, and results of mitigation of any spills shall be documented and reported in accordance with the TFM Procedure (YMP 1998a).

- Hydraulic Oil.

The operating parameters of hydraulic fluid for the TBM should have a negligible effect on testing activities. Numerous spill and leakage minimization features have been incorporated into the TBM design. Some minor losses must be assumed, however, and containment of these losses will be by drip pans and other means. Little hydraulic fluid is expected to contact the tunnel walls or to be introduced into the muck as a result of normal operation of the TBM (Nordin 1994). The maximum reasonable spill from hoses, except for the main hose, is estimated to be 50 gallons. Two spill cleanup kits, each designed to clean and contain a potential 50-gallon spill, will be located on the TBM. The hydraulic reservoir on the TBM has a 1200-gallon capacity. A catastrophic rupture of the tank has been assessed to not be significantly credible (Sandifer 1993). During maintenance of hydraulic system components, appropriate precautionary procedures should be followed to contain any oil loss due to removal of hydraulic lines or components.

- Lubrication Oil.

No lubricating oil is expected to contact the tunnel walls or to be introduced into the muck as a result of normal TBM operation. Emergency loss is possible, however, and a collection system similar to that for hydraulic oil has been incorporated into the TBM design (Nordin 1994). Precautions during maintenance operations should be similar to those taken for hydraulic system oil.

- Seal Grease.

Grease must be purged to protect the main bearing seals. This grease is discharged from the main seals by water at a rate of 2.4 to 9.6 cubic inches per minute to purge the bearings when the TBM is running. The design provides for mechanisms to trap the grease from both sides of the front bearing. The water used to purge the main seals is released into the muck and removed on the conveyor system.

- Lubrication Grease.

The TBM system contains approximately 150 cubic inches of lubrication grease at 58 grease points. Given a dry tunnel where grease is not washed away into the environment, a replenishment rate of 10 percent per week is considered a maximum. This grease is purged at discrete points where it is wiped off the equipment during normal maintenance operations. Little grease is expected to contact the tunnel walls or muck, and no test interference is anticipated (Nordin 1994).

10.7.1.4 Chloride-Based Materials

The use of chloride-based materials (e.g., NaCl, KCl, MgCl) should be limited to the extent practical to minimize potential impact on chlorine-sensitive site characterization testing such as ^{36}Cl studies. A non-chloride-based grounding enhancement material should be used, and the use of chloride-based concrete and grout accelerators (or retarders) avoided to the extent practical.

10.7.2 Duration

It is anticipated that TBM operations for excavating the TS Loop will require less than two years, and construction activities requiring TS Loop utilities and support will last about three years. Following this time, utilities and support will continue to be in use for about 25 years during ESF construction and testing (YMP 1997a).

10.7.3 Materials/Objects Permanently Left Behind

Those items not identified in the ESFDR (YMP 1997a) or Q-List (YMP 1998b) as permanent shall be removed. Those items identified as permanent (i.e., ground support) are not anticipated to cause test interference.

11. IMPACT TO WASTE ISOLATION CHARACTERISTICS

In the sections below, the evaluations of potential hydrologic, geochemical, and thermal/mechanical perturbations that could lead to impacts to waste isolation are discussed. A new analysis for the hydrologic perturbations due to water use and their potential impacts to waste isolation is presented. The evaluations of geochemical and thermal/mechanical perturbations and their potential impacts to waste isolation are based on the analyses in previous Waste Isolation Evaluations covering: (1) the ESF Starter Tunnel and Alcove #1 (CRWMS M&O 1994j); and (2) TFM Usage and Excavation Methods (CRWMS M&O 1995h). In addition, the results of those previous analyses are generalized to the greater extent of excavation represented by consideration of the entire ESF TS Loop to derive controls that can be implemented throughout the TS Loop excavation and operation.

In the specific geochemical evaluations discussed in Section 11.3, the conclusions were based on scenarios that should conservatively bound potential perturbations to ambient conditions. If such conservative calculations indicate that the items/activities are **not** likely to impact the ambient conditions above the level of the chosen surrogate criterion (as discussed above in Section 9.4), then it can be concluded reasonably that the items/activities can be used/performed with negligible risk for potential impact to waste isolation from any reasonable scenario (with only those controls that are applied in this evaluation). Because the specific evaluations discussed in Section 11.3 are conservative bounding scenarios based on surrogate criteria, it *cannot* be concluded that impacts to waste isolation are assured for cases where results *exceed* the surrogate criterion for negligible perturbations to ambient conditions. However, it can be reasonably assumed that the potential impacts to the surrogate performance parameters resulting from the geochemical changes in these scenarios represent upper bounds for impact for any plausible scenario.

To provide a consistent approach to evaluating the potential impacts in all cases, an effort is made to choose a *reasonable* bounding scenario. The bounding scenario is not taken from a subjective consideration of the "most probable" case, nor is it assigned from identification of the "worst case." In many cases, the "most probable" scenario cannot be identified quantitatively because lack of appropriate information precludes quantifying such probabilities. In addition, uncertainties in identification of the "worst case," and quantification of resulting effects, preclude using the "worst case" to constrain these evaluations in most cases. The bounding case is chosen, in part, because it can be quantified in a straightforward manner and includes conservative assumptions to ensure that it encompasses the potential impacts from virtually all reasonable scenarios. In all cases, it will be necessary for a future evaluation of the consequences to waste isolation resulting from the committed items and actual configuration of any final constructed facility.

11.1 HYDROLOGIC EVALUATIONS

11.1.1 The Effects of Irretrievably Lost Water in the ESF on the Potential Performance of a High-Level Nuclear Waste Repository at Yucca Mountain

The performance of a conceptual nuclear waste repository at Yucca Mountain is based on the strategy of waste containment, isolation, and attenuated exposure. Containment refers to keeping the waste inside waste packages, for example steel canisters, while isolation refers more generally to keeping the waste from reaching the accessible environment. Attenuation of exposure is a result of delay in the release and transport of radionuclides to the accessible environment and dilution of the radionuclides in the water. The accessible environment is where the public is potentially exposed to the waste. These three elements of the nuclear waste disposal strategy, containment, isolation, and attenuated exposure, are intimately related to the occurrence and behavior of water in the subsurface environment. Containment of waste is affected by water through the role water plays in corrosion and failure of waste packages, dissolution of radionuclides, and migration of dissolved radionuclides from inside waste packages to the surrounding geologic environment. The principle avenue for migration of the radionuclides from the rock at the potential repository to the accessible environment is by advective transport in water. Similarly, the travel times for radionuclides to reach the accessible environment are affected by advective transport in water. Finally, the dilution of released radionuclides that reach the accessible environment depends on the flow and mixing of water.

One of the important characteristics of Yucca Mountain as a potential nuclear waste repository is that it has a relatively large zone of partially saturated rock (about 600 m of vertical thickness in the primary waste emplacement block [CRWMS M&O 1996ac, p. 13]). This zone lies between the surface and the water table, and is found to have a wide variety of water saturations (ranging on average from about 30 percent to 90 percent of the pore space [CRWMS M&O 1996ac, p. 13]). For unsaturated conditions, most of the ambient water is confined to the smaller interstices of the rock matrix, limiting its ability to interact with the waste container and waste forms. Water, being the wetting phase against air, tends to first occupy the smaller interstices of the rock matrix and fill larger ones as the water saturation increases. As a result, lower water saturations may result in lower rates for corrosion, dissolution, and transport processes. Therefore, unsaturated conditions are considered an important attribute for repository performance, and lower water saturations are expected to provide better performance.

Water in the potential repository environment is expected to be redistributed by the effects of heat produced by the radioactive waste. The heat enhances vaporization of water and gas-phase movement, which tend to create either global or local zones of lower water saturation in the potential repository depending on the density and configuration of waste emplacement, background infiltration rate, and other factors. The thermo-hydrologic behavior of the potential repository system is currently the subject of detailed process-level calculations. At present, these calculations do not incorporate the potential effects of water lost in the ESF as part of the ambient conditions. In addition, these calculations have a large degree of uncertainty due to the complex processes involved, such as vaporization/condensation phenomena and transient, unsaturated, nonequilibrium flow in fractured rock, and uncertainties regarding specifics of the potential repository design. Therefore, such detailed calculations are not yet considered appropriate for the present evaluation.

Depending on a variety of factors, the water lost in the ESF may be redistributed within the geologic environment by the effects of repository heating. Under certain conditions, the heating may tend to redistribute and combine the water lost in the ESF with a much larger mass of water in a zone of condensation outside the dry-out region. In this case, the effects of the water lost in the ESF is expected to be negligible in comparison with the much larger volumes of natural ambient water redistributed around the potential repository. However, other conditions may result in less disturbance of the water lost in the ESF by the waste heat. Under these circumstances, one possible scenario is that the saturation around the waste packages returns to near-ambient conditions and that the ESF water remains relatively localized and migrates to the nearest waste packages. This near-ambient condition repository coupled with the flow of lost ESF water directly towards potential waste emplacement locations is used to bound the effects of lost water on the potential near-field repository performance.

Water is used for a variety of purposes to facilitate underground construction. The primary use is for dust control during rock excavation and removal. It is also used to drill holes for emplacement of rockbolts and testing apparatuses. The underground use of water has no affect on the potential performance of a nuclear waste repository unless that water is irretrievably lost to the environment. An evaluation of this lost water on the potential repository performance is given in the following sections. Uncertainty exists in the evaluation below because of the precision and accuracy of measuring natural variability and the application of various modeling techniques. However, uncertainty of no greater than ±10 percent would not substantively affect the conclusions of this evaluation.

11.1.2 Waste Package Corrosion

The waste package, waste form, backfill (or packing), invert, ground support, emplacement drift, drip shield, etc., and other engineered items in the potential repository constitute the Engineered Barrier System (EBS). Corrosion of the waste package is a process that affects waste containment and is currently modeled as a function of relative humidity and temperature (CRWMS M&O 1995i, p. 5-7). The corrosion model is split into 2 regimes: humid air corrosion for relative humidities less than 85 percent, and aqueous corrosion for relative humidities greater than or equal to 85 percent (CRWMS M&O 1995i, p. 5-8).

The relative humidities at ambient conditions are reported in Attachment III, showing that at ambient conditions, the relative humidity is about 99 percent. Additional water in the rock matrix surrounding the emplacement drifts would only cause a variation in the relative humidity between 99 and 100 percent. Because aqueous corrosion is insensitive to the relative humidity, the increase in water saturation due to additional water lost in the ESF would have a negligible affect on corrosion of waste packages.

11.1.3 Spent Fuel Dissolution and EBS Transport

Spent fuel dissolution rates, in some cases, affect the rates of radionuclide release from the engineered barrier system. The spent fuel dissolution rate model used in Total System Performance Assessment (TSPA) 1995 (CRWMS M&O 1995i) is not dependent on water saturation or humidity, although if this rate is high enough, the mobilization rate will be a function of the radionuclide flux through the waste canister. This flux is dependent on diffusive and advective transport processes, which may be sensitive to local hydrologic conditions. Specific information on these transport processes within EBS materials is very limited. Diffusive radionuclide transport in the local rock matrix may be considered an analog for diffusive EBS radionuclide transport processes (Section 11.1.4), and is used to evaluate potential changes in performance due to increased local water saturations. Advective transport processes in the EBS are expected to be driven by advective flux occurring in the local rock fractures and matrix (CRWMS M&O 1995i, p. 6-25). A discussion of this sensitivity is given in Section 11.1.4. Therefore, the sensitivity of EBS radionuclide transport to water saturation is assumed to be captured through analysis of radionuclide transport in the local rock mass surrounding the EBS.

11.1.4 Aqueous Radionuclide Transport in the Near-Field

The definition of "near-field" used here is the transport pathway through rock matrix to fractures. This near-field movement may be critical if the bulk of the radionuclide transport through the unsaturated zone occurs in fractures and is limited by radionuclide access to fracture pathways. If not, then the analysis of far-field transport (Section 11.1.5) becomes critical.

The effects of water on the near-field are conservatively assumed to be restricted to a 7.62 m wide enhanced saturation zone. The use of a 7.62-m wide zone is a nominal, but conservative, width of the enhanced saturation region corresponding to the diameter of the ESF main drift excavation. This is conservative because smaller quantities of water will have a larger effect on saturation if restricted to this zone rather than more widespread dispersal in the geologic environment. Discharged water may propagate from its discharge point in the ESF to the nearest potential waste emplacement zones. The tunnel diameter is used as the length scale appropriate to the introduction of water discharged in the main drift to the geologic environment.

Although both advection and diffusion mechanisms are likely to be involved in radionuclide transport, these mechanisms are not necessarily contributing equally to the overall radionuclide transport rate. A comparison of advective and diffusive transport rates at different levels of water saturation is given in Attachment IV. Transport rates are probably diffusion dominated at lower saturations, but at elevated saturations advection and diffusion transport rates are expected to be similar. Therefore, the effects of added water in the ESF on near-field advection **and** diffusion must be considered.

The general approach is to consider the estimated natural variability in processes related to near-field radionuclide transport and then compare with the change in average behavior due to an increase in water saturation from the average undisturbed ambient water saturation. If the increase in average transport rate lies within the natural variability of the existing condition, then the saturation increase is not expected to noticeably affect near-field radionuclide transport. The analysis of the natural variations in ambient diffusive transport compared with average diffusive transport behavior under elevated water saturations is given in Attachment V. The results of this analysis indicate that diffusive transport is not sensitive, relative to natural variations in diffusive transport at ambient conditions, to increases in water saturation from the average ambient water saturation to saturated conditions. A similar analysis for advective transport is presented in Attachment VI. This analysis finds that advective transport is not sensitive, relative to natural variations in advective transport at ambient conditions, to an increase of water saturation from the average ambient water saturation to an average water saturation of 0.99, but marginally sensitive to saturated conditions. Because the transport process will disperse the saturation levels due to added water, the limiting quantity of added water in the ESF is assumed to be the amount required to saturate the rock lying between the nearest potential waste emplacement location and the ESF main drift and alcoves. This quantity of water lost per unit length of excavation, Q_L, is $(1-S_i)*\phi*W*D_o$, where S_i is the initial (undisturbed) water saturation, ϕ is the porosity, D_o is the minimum offset between the ESF excavations and potential waste emplacement locations, and W is the width of the saturated zone. Given W=7.62 m (Section 6.2), ϕ=0.13, and S_i=0.74 (CRWMS M&O 1996ac, p. 13), and D_o=37 m (Section 9.2), the limiting quantity of water discharged per unit length Q_L=9.5 m^3/m.

11.1.5 Aqueous Radionuclide Transport in the Far-Field

The definition of "far-field" used here is the transport pathway through the unsaturated zone to the water table. Although added ESF water may move through fractures, this water is not expected to remain in fractures for future potential interaction with radionuclides. Either the water entering fractures will (relatively quickly) drain to the saturated zone or be absorbed into the ambient unsaturated rock matrix. Water that drains through fractures to the saturated zone will have a negligible effect on radionuclide transport to the saturated zone. Water that is held in the unsaturated rock matrix may affect far-field transport. A bounding calculation for far-field transport is given in Attachment VII. The bounding calculation considers the effects of an initially saturated zone 37 m thick with a tracer added to the leading edge of the saturated zone. The travel times for the tracer with and without the disturbance to the flow field are calculated, giving a reduction in travel time of about 15 percent for the disturbed flow case. This reduction is negligible in comparison with the travel time variations that are expected. For example, the variation in travel time through matrix in the unsaturated zone may be computed from velocity and distance data given in Tables 7.2-4 and 7.4-1 in TSPA 1995 (CRWMS M&O 1995i, pp. 7-32 and 7-33). The ratio of maximum to minimum travel times of non-retarded species in the 6 stratigraphic columns used for the high-thermal-load case is a *factor* of 13 to 39.

11.1.6 Aqueous Radionuclide Transport in the Saturated Zone

The quantities of water found to potentially affect aqueous radionuclide transport in the unsaturated zone are far smaller than the quantities of water that would be expected to have a non-negligible effect on aqueous radionuclide transport in the saturated zone. An analysis of perched water flowing down a borehole to the saturated zone was evaluated in terms of its effects on the saturated zone hydraulic gradient, which is proportional to the flow velocity and inversely proportional to the aqueous radionuclide travel time (CRWMS M&O 1997p, Attachment III). This analysis found that a ground-water mound resulting from the loss of 36,500 m^3 over 1 year *in a single borehole that penetrated the saturated zone* would dissipate to negligible levels in less than 4 years. This may be compared with the limiting quantity of water spread throughout the entire 8 km TS Loop, based on a limiting rate of 9.5 m^3/m, giving a total of 76,000 m^3. Therefore if the quantity of water lost in the TS Loop is limited to 9.5 m^3/m of tunnel excavation, any effects of this water on potential aqueous radionuclide transport in the saturated zone is expected to be negligible.

11.1.7 Gaseous Radionuclide Transport in the Unsaturated Zone

The addition of water will affect gaseous radionuclide transport in the unsaturated zone. An increase in water saturation will always reduce the diffusive transport rate in the gas phase (Marshall and Holmes 1979, p. 271), or increase the diffusive travel times of gaseous radionuclides. Therefore, the addition of water is not expected to adversely affect potential repository performance.

11.1.8 Fate of Dust Control Water Applied to Concrete Inverts

As part of the ESF construction operations, water may be sprayed onto the concrete inverts to reduce the concentration of dust in the tunnel atmosphere. The proposed use of water is 0.20 gallons/m-day, or 0.76 liters/m-day (Section 6.13). An analysis of water applied to the inverts (Attachment VIII) indicates that the evaporation rate should exceed this rate of water application over a distance of about 1100 m of the TS Loop (or 1440 m when ventilation is increased to 248,000 cubic feet of air per minute). Therefore, dust control water applied in a fine spray on the inverts at a rate of 0.76 liters/m-day over sections no longer than 1100 m is expected to evaporate and would not need to be counted as water lost to the geologic environment. Based on the short section of concrete invert in the ECRB Cross Drift Starter Tunnel, dust control water applied in this region may be counted as if it were applied in the TS Loop. In other words, dust control water sprayed at a rate of up to 0.76 liters/m-day on the ECRB Cross Drift Starter Tunnel concrete invert should be decremented from the 1100 m, provided the length of dust control water application between the air inlet portal and ECRB Cross Drift Starter Tunnel has not exceeded 1100 m on that day.

The analysis in Attachment VIII indicates that, if dust control water applied in a fine spray on the inverts at a rate of 0.76 liters/m-day is to be used in the TTF on a given day, a total of 900 m of invert may be sprayed before the evaporation rate is exceeded. Here, the 900 m consists of up to 170 m of invert in the TTF and the remainder (of the 900 m) of invert in the TS Loop and ECRB Cross Drift Starter Tunnel.

11.2 TRACERS, FLUIDS, AND MATERIALS (TFMs)

The following discussion of potentially retained constituents from various fluids and materials was taken largely from the Package 2C evaluation covering the North Ramp (CRWMS M&O 1995h) and portions of the Package 1A evaluation covering the ESF Starter Tunnel and Alcove #1 (CRWMS M&O 1994j) because of the similarity of substances to be considered for the entire TS Loop. Additional discussion and detailed references can be found in the corresponding sections of those documents. Tracers are viewed entirely as retained substances and so are not discussed further here but are evaluated below in Section 11.3. The specific TFMs listed in Attachment II have been reviewed to ensure that they all fall into the groups defined below and are therefore covered by any applicable controls.

11.2.1 Fluids and Materials

The only ESF items that are planned to be incorporated into the potential repository (i.e., planned *permanent* items) are (YMP 1998b, pp. 1-2): (1) underground openings; (2) ramp and shaft linings; (3) ground support; and (4) operational seals. Items which are left (intentionally or unintentionally) at the site *post-closure* (above and below ground) are defined as *committed* items in an evaluation of surface-based fluids and materials usage (CRWMS M&O 1994k). *Non-committed* substances are only those fluids and materials that are **not** being emplaced into the environment in such a way as to become a committed part of that environment. Such non-committed substances are those that are planned to be removed from the site at or before the time of closure, *and* are not expected to leave behind noticeable, non-removable residues. Because of the condition of removal before closure, some solid materials are excluded from this evaluation designation of non-committed (e.g., salt) because they are soluble to the extent that they have the potential to dissolve into the environment over a relatively short time period (i.e., days to a few months). Based on the reasoning given in the evaluations of the Package 1A TFMs (CRWMS M&O 1994j), the surface-based non-committed fluids and materials (CRWMS M&O 1994k), and the Package 2C TFM (CRWMS M&O 1995h), non-committed items are assumed to have negligible impact on waste isolation and are not further evaluated.

Substances considered committed items and evaluated here for the TS Loop are: steel sets, lagging (wood and steel), wood blocking, lubricating oil retained (from cutting) on steel sets, rockbolts, wire mesh, shotcrete and/or fibercrete, cementitious grout, oil mist from compressed-air system, steel, concrete, concrete admixtures, and galvanized steel. In addition, because diesel equipment will be employed during construction of the North Ramp (and perhaps the entire TS Loop), and some of the exhaust constituents (both inorganic and organic) may become committed to the underground, the potential impacts of these constituents were explicitly analyzed in the Package 2C evaluation (CRWMS M&O 1995h) to develop controls on the quantities of materials committed as discussed below in Section 11.3. Furthermore, in the event of a fire, combustion products and fire-suppression substances may become committed items. Therefore the potential impacts to waste isolation from the proposed fire-suppression substances were also explicitly evaluated using a bounding scenario in the Package 2C evaluation (CRWMS M&O 1995h). In the event of an actual fire, the specific materials that burn should be evaluated for potential impacts to waste isolation. In the Package 2C evaluation (CRWMS M&O 1995h), substances produced from fires were assumed to be close enough to the constituents produced in diesel exhaust that evaluation of exhaust constituents bounds the potential impacts to waste isolation of fire products. Because fire products are not planned to be incorporated into a potential repository, a more general waste isolation evaluation should be performed if there is a need to further evaluate such potential impacts.

As discussed in detail in the Package 2C evaluation (CRWMS M&O 1995h), explosives are not considered committed items because it is assumed that most of their residues will be removed either as volatiles or within the excavated materials.

It was concluded in the Package 2C evaluation (CRWMS M&O 1995h) that fluids that are not *planned* to be dispersed into the environment (e.g., diesel fuel, lubricants, coolants, battery acid, cleaning solvents, etc.) are expected to have negligible impact provided that a plan for spill containment and clean-up exists. In accordance with the YMP quality assurance procedures for recording TFM use at the site, any planned non-committed fluids or materials that become retained intentionally or unintentionally as part of the committed environment require *documentation* of the amounts of substance retained in the environment and *evaluation* of the potential waste isolation impacts of that specific retention. The evaluation of specific materials that become part of the committed environment will be part of future TSPA evaluations.

11.2.1.1 Committed Inorganic Substances

Items such as steel sets, rebar, lagging (steel), rockbolts, wire mesh, shotcrete and/or fibercrete, cementitious grout, and galvanized steel (in general steel, concrete, and shotcrete) are expected to have negligible impact on waste isolation resulting from perturbations to the near-field geochemistry because their use near potential waste emplacement sites (i.e., within potential repository drifts) is expected to overshadow any effects resulting from their use in the TS Loop. These near-field effects include raising the pH to 11-13 and the potential for generation of colloids from the cementitious material. The former may enhance some dissolved radionuclide concentrations whereas the latter may provide an additional mobile component for some radionuclides. In addition, potential effects on far-field geochemistry caused by dissolved Ca^{+2} introduced from cementitious material are expected to be negligible because mineralogic controls exerted through fluid-rock reaction should constrain large deviations in Ca^{+2} concentrations to close proximity to cementitious materials via calcite precipitation. A more detailed analysis of these qualitative issues would be required if there was to be a large increase in the amount of committed cementitious materials in the TS Loop (i.e., more than an order-of-magnitude increase over the current plans for shotcrete and grouting).

11.2.1.2 Committed Organic Substances

Because of the numerous qualitative issues regarding committed organic materials (e.g., dissolved organic enhanced solubility and transport of radionuclides, and microbial effects), use of such materials in potential repository drifts is unknown. Therefore the above reasoning on committed inorganic substances does not apply to any organic materials that might be contained within cementitious materials as a result of the addition of admixtures. In addition, this discussion covers the previous specific evaluations of discrete sources of aqueous NO_3^-, $SO_4^=$, and $H_2PO_4^-$ addressed in the Package 2C evaluation (CRWMS M&O 1995h) of diesel exhaust constituents and fire-suppression materials. These materials are potential sources of nutrients for microbes and $H_2PO_4^-$ has potential for readily complexing radionuclides (specifically actinide elements). If retained in large quantities, these constituents may also be a concern for generating low pH (i.e., acid) conditions. Constraints based upon the other concerns, however, should conservatively bound any potential pH perturbations because of the large pH-buffering capacity of the geologic system.

As pointed out in the Package 2C evaluation, organic compounds may accelerate waste package corrosion through enhanced microbial activity and/or facilitate radionuclide transport in the geosphere via complexing of cations (CRWMS M&O 1995h). This previous evaluation indicated these effects are constrained by the ability of deposited organic materials to migrate to either waste package locations or radionuclide pathways in sufficient concentration to have a significant impact.

A previous bounding calculation (discussed below in Section 11.3) was performed to determine the potential influence of retained organic substances in the ESF Starter Tunnel and Alcove #1 (CRWMS M&O 1994j) and to generate controls that should result in negligible impact to waste isolation from use of committed organic materials in these areas of the TS Loop. In that general analysis, the retained organic materials were assumed to be a point source that completely dissolves as organic carbon and migrates toward potential waste package emplacement sites. All committed organic fluids and materials were considered as indistinguishable.

A second previous bounding calculation (discussed below in Section 11.3) was performed to determine the potential influence of retained organic substances within the North Ramp (CRWMS M&O 1995h) and to generate controls that should result in negligible impact to waste isolation from use of committed organic materials throughout this region of the TS Loop. In that analysis, the retained organic materials were assumed to convert completely to dissolved organic carbon, and to migrate toward potential waste package emplacement sites within the TSw2 horizon. All committed organic fluids and materials were considered as behaving identically.

The *total* organic budget includes all sources of committed organics in the TS Loop. Examples of such sources are wood blocking/lagging for steel sets, oil mist from the compressed air system, lubricating oil (for cutting) retained on steel sets, organic diesel exhaust components, and concrete admixtures used in shotcrete. In addition to these introduced sources of organics, opening the mountain to the external environment allows the introduction of potentially committed organic materials in the form of airborne particles in the ventilation air and in the form of organisms that may inhabit, and deposit organic residue in, portions of the tunnel.

Accidental loss of any organic fluid such as fuels, lubricants, or coolants used in equipment necessitates documentation and evaluation of the specific unintentional releases, and incorporation of the retained amounts of committed organic fluids into the evaluation of the final configuration of the potential repository.

11.3 GEOCHEMICAL EVALUATIONS

11.3.1 Tracers

As discussed in CRWMS M&O 1994j; 1995h, lithium bromide (LiBr), proposed as a tracer for construction water, will be added at a maximum concentration of 30 ppm (minimum 10 ppm), with a target concentration of 20 ppm (±2 ppm). In addition, SF_6 will be added at concentrations not to exceed 20 ppm to air used for drilling test boreholes. It was concluded in both these previous evaluations that because of the low concentrations and limited quantities used, these tracers are expected to have only negligible effects on the geochemistry near potential waste emplacement sites, or along potential gaseous and aqueous radionuclide pathways.

11.3.2 Committed Organics in the ESF Starter Tunnel and Alcove #1

A previous evaluation (CRWMS M&O 1994j) was performed to evaluate a large mass of potentially committed wood blocking for use in ground support in the ESF Starter Tunnel and Alcove #1. That evaluation placed limits for negligible impacts to waste isolation both for potential waste emplacement in the expansion area boundary (top of the TSw2) and for waste emplacement solely in the potential repository footprint. The negligible impact level for dissolved organic carbon (DOC) was defined as local perturbations of 0.1 ppm (CRWMS M&O 1994j). In that evaluation it was assumed that:

1) the retained organic material represents a point source at the end of the ESF Starter Tunnel,

2) the dissolution of the organic points source is complete and instantaneous,

3) dispersion of the organic source occurs via saturated flow toward potential waste emplacement zones, and

4) no reactions to degrade the concentration of total dissolved organic carbon occur.

It was concluded in the previous evaluation (CRWMS M&O 1994j) that: 1) if the total retained organic materials in the ESF Starter Tunnel and Alcove #1 is less than 420 kilograms (kg), it is expected that there should be negligible impact to the geochemistry of ground water within the Potential Expansion Areas Boundary (i.e., perturbations to fluid compositions should be less than 0.1 ppm DOC); and 2) if the total retained organic materials in the ESF Starter Tunnel and Alcove #1 is less than 2500 kg, it is expected that the impact to the geochemistry of ground water within the Conceptual Repository footprint should be negligible, although there is some potential for impact to the ground water geochemistry within the Potential Expansion Areas 2, 3, and 6. Given adherence to the 420 kg limit for total organic retained in the ESF Starter Tunnel and Alcove #1, the organic substances are not expected to have significant effects on the geochemistry near potential waste emplacement sites, and along potential gaseous and aqueous radionuclide pathways. However, for total amounts of organic retained in the ESF Starter Tunnel and Alcove #1 between 420 kg and 2500 kg, the organic substances are not expected to have significant effects on the geochemistry near potential waste emplacement sites within the Conceptual Repository footprint, nor along potential gaseous and aqueous radionuclide pathways directly below the potential repository, but may affect the geochemistry near potential waste emplacement sites within the Potential Expansion Areas 2, 3, and 6, and along potential gaseous and aqueous radionuclide pathways above or below them.

It should be reiterated here that this evaluation *does not indicate* that an impact to waste isolation will occur if these limits are exceeded, but only that the potential for impacts to waste isolation exist. However, controls developed from constraints on potential impacts from this case are expected to minimize impacts from any reasonable flow scenario (this excludes the worst-case of disequilibrium fracture-flow).

Because the result of this previous evaluation is dependent upon the spatial relation of the source term to potential waste emplacement areas, it is not possible to generalize it to other areas of the TS Loop (e.g., the South Ramp is located entirely above potential waste emplacement zones). Therefore, this previous evaluation is *only* applicable to the ESF Starter Tunnel and Alcove #1 portion of the TS Loop. More general constraints on retained organic and inorganic constituents are discussed in the next section as derived from a previous evaluation for committed substances in the North Ramp (CRWMS M&O 1995h).

11.3.3 Committed Organic and Inorganic Substances in the TS Loop

11.3.3.1 Diesel Exhaust

In a previous evaluation of committed components from diesel exhaust (sulfur oxide gases, nitrogen oxide gases, and diesel particulate matter) in the North Ramp (CRWMS M&O 1995h), it was indicated that potential impacts were bounded by an analysis showing that retention of these materials within the North Ramp for the planned usage of diesel equipment will not impact potential radionuclide release and transport over a 10,000 year time period, provided that the local perturbations to the near-field water compositions at the closest waste package were kept at or below a value of 10 percent of ambient concentrations of their corresponding dissolved constituents ($SO_4^{=}$, NO_3^-, and dissolved organic carbon--DOC, respectively). This previous evaluation was based on the estimated distribution of diesel usage throughout the North Ramp and assumed that relatively insoluble constituents that remain in the gas phase would be removed via the planned ventilation system. In this previous evaluation, it was concluded that although carbon monoxide and dioxide may be retained, the natural aqueous and gas phases have concentrations of carbon dioxide that are high enough that these constituents would produce negligible perturbation to the natural system.

In the Package 2C evaluation (CRWMS M&O 1995h), negligible-impact-limit constraints on the exhaust emission rates of the explicitly evaluated components were derived as:

Table 11-1 Diesel Exhaust Emission Rates

Aqueous Constituent	Total Exhaust Constituents As	Limiting emission rates of Exhaust Constituent (g/hr)
DOC	DPM	24
NO_3^-	NO	120
$SO_4^=$	SO_2	590

Because these constraints were derived for a specific distribution of diesel usage throughout the North Ramp, these emission rates for diesel exhaust constituents cannot be applied in a general way to the entire TS Loop. However, general constraints for each of these constituents for the entire TS Loop can be derived from the more general analysis of perturbations to these components from *all* sources that was done in the previous Package 2C evaluation (CRWMS M&O 1995h) and discussed in the next section.

11.3.3.2 Other Source Constraints

The same approach used above for diesel exhaust constituents was applied to evaluate the limits on DOC, NO_3^-, and $SO_4^=$ from all sources in the North Ramp (CRWMS M&O 1995h), where it was indicated that potential impacts were bounded by an analysis showing that retention of these materials within the North Ramp from all sources will not impact potential radionuclide release and transport over a 10,000 year time period, provided that the local perturbations to the near-field water compositions at the closest waste package were kept at or below a value of 10 percent of ambient concentrations of these dissolved constituents. Because other materials may be used in different distributions (i.e., not necessarily in the proportions assumed for diesel emissions in the Package 2C evaluation), along the North Ramp (and throughout the TS Loop), this additional previous analysis assumed that the major impact for peak concentration perturbation at any point is due to the source density associated with the closest portion of the tunnel.

Based on this analysis the previous evaluation provided general constraints for the total source constraints on DOC, NO_3^-, and $SO_4^=$ in each of the four North Ramp segments as:

Table 11-2 North Ramp Recommended limits, (g/m) (CRWMS M&O 1995h)

Segment	Defined as:	DOC	NO_3^-	$SO_4^=$
1	Station 0+00 m to 13+11 m	95.	950.	3500.
2	Station 13+11 m to 18+59 m	28.	280.	1100.
3	Station 18+59 m to 24+08 m	13.	130.	480.
4	Station 24+08 m to 28+05 m	10.	96.	350.

These limits are spatially dependent, however, the limits provided for Segment 4 constrain impacts in a portion of the North Ramp for which potential waste emplacement zones are at the minimum 37 m offset from the tunnel (Assumption 4.1). Therefore these Segment 4 limits are also appropriate and applicable directly to the Main Drift and lower portion of the South Ramp (throughout the bend) in addition to that Segment of the North Ramp. Because they are the bounding values, it is conservatively recommended that these North Ramp Segment 4 limits also be applied throughout the South Ramp, which is expected to have much less input to source terms of these constituents because of much lower integrated planned diesel usage within that portion of the TS Loop. Therefore, the limits for negligible impacts on committed quantities for these constituents in the Main Drift and South Ramp are:

Table 11-3 Main Drift and South Ramp Recommended limits, (g/m)

DOC	NO_3^-	$SO_4^=$
10.	96.	350.

11.3.3.3 Fire-Suppression Materials

The specific material designed for use as the primary fire-suppressant material is the dry chemical trade named *Ansul Foray*, which represents a potential source of aqueous NO_3^-, $SO_4^=$, and $H_2PO_4^-$, was specifically analyzed in the previous Package 2C evaluation (CRWMS M&O 1995h). In this previous evaluation, it was indicated that potential impacts were bounded by an analysis showing that retention of fire-suppression materials within the North Ramp will not impact potential radionuclide release and transport over a 10,000 year time period in any case for $H_2PO_4^-$, and also for NO_3^- and $SO_4^=$ provided that reasonable clean-up of the material can be achieved following a fire that necessitated the simultaneous discharge of the two automated systems protecting the hydraulic oil tank and the lubrication system on the TBM. In the previous analysis (CRWMS M&O 1995h), it was estimated that the 90 percent of the dry chemical can be removed by simple vacuuming and that half of the remainder of the material will be adhered to equipment and could be removed in the cleanup of that equipment. Therefore, it was noted that if water is used in conjunction with the dry-chemical, clean-up may be much reduced as the water could wash the dry chemical into fractures, and most of the material would therefore become potentially committed to the environment. It was recommended, therefore, that water be used in conjunction with this fire-suppression material only if necessary for safety.

Because the previous evaluation of the fire-suppression material analyzed its impacts throughout the North Ramp based on the ***minimum*** 37 m offset to the closest potential waste package (Assumption 4.1) and the bounding fire scenario is a TBM fire, the previous recommendations for negligible impact from this material in the North Ramp can be applied throughout the TS Loop.

If the committed fluids and materials evaluated above are constrained according to the recommendations given in this section, they are expected to have only negligible effects on the geochemistry near potential waste emplacement sites, or along potential gaseous and aqueous radionuclide pathways. Therefore, the use of committed fluids and materials, subject to these constraints, for construction and operations conducted throughout the entire TS Loop, are expected to have negligible impact to waste isolation capabilities of the site due to construction and operations conducted throughout the entire TS Loop.

11.4 THERMAL/MECHANICAL EVALUATIONS

The previous evaluation of potential impacts to waste isolation caused by thermal-mechanical perturbations resulting from retained TFM and from excavation methods in the North Ramp (CRWMS M&O 1995h) indicated that:

1) the potential effects of committed substances on thermal/mechanical characteristics of natural barriers or engineered items in the North Ramp tunnel are expected to be negligible if the substances do not interfere with the emplacement and performance of North Ramp tunnel seals (at the time when sealing plans for the tunnel are prepared, further analysis of potential impacts to waste isolation should be performed);

2) there is a negligible impact on the overall waste isolation capability of the entire potential repository due to the generation of preferential aqueous pathways through the mechanically disturbed zone;

3) movement of underground fluids along the sealed ramp (and its surrounding mechanically disturbed zone) should have a negligible impact on the waste isolation capability of the potential repository;

4) to minimize the potential impact of the mechanically disturbed zone induced by the excavation, the TBM method, which results in a smaller disturbed zone compared to the drill-and-blast method, is recommended for the primary excavation method for ESF construction;

5) regardless of the excavation method used for North Ramp, no potential impacts to waste isolation resulting from the lack of a specified stand-off distance for boreholes were identified, because boreholes will be sealed above and below the potential repository horizon.

Because sealing issues are identical for the North Ramp and the South Ramp and the previous evaluation analyzed the potential impacts from excavation methods in a general and spatially *independent* manner, the recommendations for negligible impact limits from the Package 2C evaluation summarized above can be applied directly to the entire TS Loop. If these recommendations are followed, then it is expected that there will be negligible impact to waste isolation capabilities of the site due to construction and operations conducted throughout the entire TS Loop.

12. IMPACT TO OTHER Q-LIST ITEMS

Any potential impacts to other Q-List items (e.g., ground support, underground openings, etc.) are bounded by controls applied in applicable classification analyses, along with those applied in the interest of limiting potential adverse impacts to site characterization testing (Section 10) and/or limiting potential impact to the waste isolation capabilities to the site (Section 11) such that additional requirements are not necessary.

13. ESTABLISHMENT OF CONTROLS

13.1 SUMMARY OF RESULTS

This evaluation concludes that various activities associated with the Subsurface ESF require QA controls to limit or prevent potential test interference or waste isolation impacts during construction, operations, and maintenance activities. Controls for these activities are presented in Section 13.3. This DIE is predicated on these items being temporary. Any incorporation of these items or their constituents into the pre-closure or permanent repository will require a new evaluation as part of the design of permanent items.

As stated in Section 1.0, this evaluation applies to construction, operations, and maintenance activities ongoing and planned in the Subsurface ESF. Site characterization testing activities ongoing and planned in the Subsurface ESF are evaluated in the DIE for ESF Subsurface Testing Activities (CRWMS M&O 1998a). It should be noted that the ECRB Cross Drift Starter Tunnel is considered to be part of the TS Loop and is evaluated herein. The remainder of the ECRB Cross Drift is evaluated in the DIE for the ECRB Cross Drift (CRWMS M&O 1998c).

Per NLP-2-0 (CRWMS M&O 1998b), this DIE considers the relevance of applicable requirements from the ESFDR (YMP 1997a) pursuant to ensuring that 10CFR60 Section 15(c)1 (10CFR60) mandates are satisfied. The following ESFDR (YMP 1997a) sections, including their lower-tier subsection requirements, were considered in this evaluation:

> ESFDR 3.2.1.1.1, 3.2.1.1.2.4, 3.2.1.1.3.1, 3.2.1.1.3.2, 3.2.1.1.3.4, 3.2.1.1.4, 3.2.1.2.3, 3.4.5.3.1, 3.4.5.6.1, 3.7.1.2, 3.7.2.1.2, 3.7.2.5.1, 3.7.3.1, 3.8.2.6.1, 3.8.2, 3.8.3, and 3.8.4

Based on the following discussions in Section 13.2, DIE-specified QA control requirements are necessary to satisfy every requirement considered by this evaluation. However, each QA control derived in Section 13.3 cites the specific, applicable requirement from YMP 1997a.

Refer to CRWMS M&O 1998a for evaluation and controls associated with Subsurface Testing Activities and CRWMS M&O 1998c for evaluation and controls associated with the ECRB Cross Drift beyond ECRB Station 0+26 m.

13.2 DISCUSSION/BASIS FOR CONTROLS

13.2.1 Records

It is judged that the record keeping provisions of 10CFR60.72 as applied to the ESF through ESFDR Sections 3.2.1.1.1.A, 3.2.1.1.4.C, and 3.7.1.2.B (YMP 1997a) also provide a function of limiting impact in accordance with 10CFR60.15(c)(1) (e.g., information on locations and descriptions of temporary structural support components that may be needed for the final ground support design) and are therefore required as QA records (Requirement 1).

13.2.2 North and South Portal Entrance Slopes

The first 10 m of the finished drainage surfaces entering into both the North Portal (ESF Starter Tunnel) and the South Portal are designed to provide an upward slope of 2.0 percent or greater (i.e., a minimum of 2 percent, on average, within standard engineering tolerances; there is no maximum slope requirement). This feature is provided, along with other surface design features, to prevent surface stormwater runoff from a probable maximum flood (PMF) event from potentially overrunning the portal entrance areas thereby gaining access to the ramps descending to the planned potential repository horizon. Failure through inadequate controls to properly establish the prescribed slope is a credible failure that is conservatively assumed to result in changes to the potential repository's hydrological characteristics. An as-built verification of the slope will be required to provide adequate assurance of this design requirement. In addition, maintenance of this slope (e.g., following reconstruction activities in the ESF Starter Tunnel and South Portal entrance area) will be required to provide ongoing assurance of this design requirement. (Requirement 18.)

13.2.3 Stormwater Intrusion into the Tunnel

At the North Portal, there is the potential for the upward-pointing ventilation system duct terminus to act as a pathway for stormwater intrusion into the tunnel. Since there is little potential of significant introduction of rainfall (total introduction = rainfall total x duct cross- sectional area) or stormwater intrusion, it is judged QA requirements are not necessary and the former control conservatively established for the construction of the ESF Starter Tunnel is lifted.

The duct configuration planned for the South Portal does not include an upward-pointing terminus. If installed, however, the same rationale as above would apply such that additional DIE-generated QA controls are not necessary.

13.2.4 Tracer

Section 10 indicates that release of untagged water into the tunnel represents a potential test interference item. The delivery of properly traced water is the significant consideration to provide assurance of the ability to differentiate such water from naturally occurring sources. The only approved tracer for water is lithium bromide. The concentration of the lithium bromide tracer shall be checked to be 20 ppm ± 10 ppm (Requirement 3). Tracer is not required in water outside the TS Loop used in mixing concrete, grout, and shotcrete (Elkins 1994c). As a measure applied to support appropriate interpretation of potential site characterization results, this requirement is conservatively judged to be a QA requirement.

It is judged that conventional quality equipment is appropriate for use in the tracer injection system, provided that periodic checking (at a frequency accepted by the Architect/Engineer [A/E]) is performed on the system's ability to deliver water traced at the proper tracer concentration. The checking includes routine sampling of the traced water to ensure proper tracer concentration. For the interim system, the tracer concentration in the tank shall be checked before water transport into the tunnel or connection to a water supply system, and periodically thereafter. Alarms on the tracer delivery system and fluid reservoirs will provide additional assurance that any failure of the system to provide appropriately tagged water can be mitigated. Alarm response procedures (for spill mitigation) and routine checking of these alarm systems will also provide reasonable assurance of their appropriate use and operability. In the absence of alarm systems for the automatic system, continuous attention to the system by a qualified operator using approved procedures will provide this additional assurance (Requirement 3).

13.2.5 ESF Starter Tunnel Water

It is conservatively judged that water use in the ESF Starter Tunnel and Test Alcove #1 shall be minimized for excavation after this evaluation. The use of construction water (for blast hole drilling, washing the tunnel walls for mapping, and miscellaneous purposes not including shotcrete mixing, or grouting) shall be limited to the extent practical. For ESF Starter Tunnel excavation and operation (i.e., limit includes water lost to date as well as future construction and operation), construction water used shall be limited to 7.4 m^3 per m of excavation[3], not including water used for mixing shotcrete, grout, or concrete (Requirement 7).

[3]Note: Although the revised hydrologic evaluation contained in Section 11.1 of this DIE (Revision 06) allows a higher quantity of water to be lost per lineal meter of excavation in the TS Loop (including the Starter Tunnel) than was allowed by the evaluation contained in Revision 05 of this DIE -- i.e., 9.5 m^3/m vice 7.4 m^3/m -- the limiting value of 7.4 m^3/m has been retained in this Revision for conservatism, and to limit the impacts from this DIE revision to applicable implementing documents (specifications, drawings, procedures, etc.).

13.2.6 TBM Excavation of Topopah Spring Loop

Conventional commercial TBM excavation techniques in the TS Loop are not expected to compromise the ability to provide either adequate ground support systems or the roadbed for a potential waste transport roadway. The minimum QA-2 criteria established for Main Access Openings (CI: BABEAD000, CRWMS M&O 1997b) sufficiently bound DIE concerns with respect to the TBM excavation of the TS Loop such that additional QA requirements are not necessary.

13.2.7 Excavation of Support Areas

The use of mechanical excavators to construct support areas (alcoves, niches, slot cuts, ECRB Cross Drift Starter Tunnel, sump excavations) is bounded by requirements discussed elsewhere in the DIE on use of equipment containing fluids of concern (Requirement 15). Drill-and-blast excavation techniques are acceptable for excavation of support areas provided they are controlled. Neither excavation technique is expected to compromise the ability to provide adequate ground support systems.

To provide evidence of the appropriate application of controlled drill-and-blast techniques, work must be performed by trained personnel as approved by the A/E with selected witnessing. Constructor blast plans and blast patterns are approved by the A/E. A/E required inspections are also documented. Explosives are procured from a qualified supplier per 27CFR55. Provisions also include training and qualification documentation, receipt verification of materials, and processing of construction records and changes. A/E approval of blasting materials is considered adequate to ensure explosives are procured from a qualified supplier per 27CFR55. Furthermore, receipt inspection and verification of materials are met by the standard material receipt inspection process employed by the constructor and A/E required inspections. These provisions are judged sufficient for these purposes. Training records, procedures, and inspection records associated with drill-and-blast operations must be retained as QA records. As a minimum the time, location, type of explosive, and size (i.e., pounds explosive per delay) of each blast shall be reported. To provide assurance that appropriate practices have been employed and are in conformance with 10CFR60.72, use and retention of blast records and blast plans as quality records is required (Requirements 4, 5).

13.2.8 Excavation Methods and Ground Support

Controlled drill-and-blast, TBM excavation, or other mechanical excavation methods are not expected to significantly impact the integrity of existing ground support in the TS Loop or its associated alcoves and niches. It is recognized that before completion of formal thermal and seismic analyses, and the Performance Assessment evaluation of the hydrologic effects of these analyses, the impact of these excavations cannot be quantified. The TSPA will assess the possible impacts of thermal and seismic effects. As a result of the above pending analyses and the TSPA, it may be necessary to revise the design of a potential repository.

13.2.9 Linings, Roadway, Seals Impact

Neither seal, lining, nor roadway repository design criteria have been established. No evaluation of the likelihood of disturbing a potential seal mount, lining surface, or roadway can be made at this time. It is judged, however, that commercial-grade equipment and standard design and construction practices, including the controlled use of the TBM for excavation (CRWMS M&O 1997b) and QA control requirements on installation of ESF-function linings (CRWMS M&O 1996a), provide sufficient assurance against such an event (i.e., significant disturbance), and that future design criteria will need to consider as-found conditions. The use of commercial grade ground support for stabilization, as controlled by considerations of the ground support system's importance to radiological safety, is judged sufficient to limit impacts to the potential repository to the extent practical.

13.2.10 Rockbolts and Preferential Pathways

The potential creation of preferential pathways by use of rockbolts is not considered significant. The length and diameter of the hole required for bolt placement are insignificant relative to the size of the tunnel excavation itself. The majority of the bolts are placed in such a way that any preferential path would drain into the tunnel (or alcove), and the bolt itself, along with accompanying materials, act to significantly block the hole that is created. It is judged, therefore, that rockbolt placement has no significant impact to waste isolation.

13.2.11 Damage to Rock from Excavation

Damage to the rock from TBM operation or mechanical excavation is not expected to be significant enough to create preferential pathways during TS Loop or alcove/niche construction. Controlled blasting techniques used in standard excavation are unlikely to result in significant geomechanical damage for greater than a few meters, and not far enough to result in significant waste isolation impacts. TBM excavation is expected to result in even less damage (CRWMS M&O 1995h). The comparison of excavation techniques is not intended to bound the hydrologic impact of underground excavation. The comparison of relative impacts of different excavation techniques indicates that TBM excavation is expected to provide relatively low impact to the site and provides confidence that such techniques, as controlled per the discussion above, are consistent with limiting adverse impacts to the extent practical.

13.2.12 Boreholes and Standoff Distances

Sections 10 and 11 indicate that in consideration of existing and planned boreholes, no minimum standoff distance requirement has been identified for the TS Loop. Any standoff for future boreholes or associated excavations will be defined by DIEs prepared for those activities.

13.2.13 Pneumatic Pathways

As a conservative measure to ensure that adequate controls were in place to preclude the loss of the pneumatic pathways data (Section 10.4.1), it was judged that QA control on TBM advance beyond the Tiva Canyon welded/Paintbrush Tuff non-welded geologic contact (at approximately station 09+00 m) was required. Therefore, a QA requirement was necessary to prevent the TBM from excavating beyond the identified geologic contact until after collection of sufficient pneumatic data from monitored boreholes (as approved by the manager of Scientific Investigations), or until an alternate testing program was developed that met site characterization pneumatic test requirements (as approved by the manager of Scientific Investigations). This requirement was subsequently satisfied (Brocoum 1995) and is no longer necessary.

13.2.14 Geologic Mapping

Test interference in the ESF TS Loop and associated alcoves can occur if obscuring ground support is installed before the completion of geologic mapping since the mapping is a photographic and observational activity. As such, the installation of supports that can obscure geologic information should be performed after geologic mapping is complete. In the current design, the immediate installation of ground support that significantly obscured geologic information before the passage of the mapping gantry occurred only when personnel safety was of concern. Since changes to ground support procedures and materials require A/E review and approval (CRWMS M&O 1996a), it is judged that no specific QA controls to minimize test interference impact are required.

13.2.15 Timing of Test Support Area Construction

The timing of the construction of the test alcoves is important to site characterization activities since the test alcoves are located at or near faults or key geologic contacts. The instrumentation planned for the test alcoves collects data that may be irretrievable if alcove construction were delayed until the entire ESF was constructed. Also, the instrumentation is required to collect information significant for Performance Assessment. To assure the test alcoves are excavated in a timely manner after the TBM and trailing gear have safely passed the test alcove location, the field determined location and timing of test alcove construction shall be subject to TCO approval. This requirement is conservatively imposed as a QA control to limit potential impact on site characterization activities (Requirement 17). TBM excavation and alcove construction may occur concurrently if the TCO and the CMO ascertain that continued alcove construction would not endanger the TBM trailing gear and support systems, and that adequate access could be provided to the test alcove to enable test preparations and testing to continue. This requirement continues to apply after TBM hole-out to address potential operations and maintenance conflicts with test location construction.

13.2.16 Water Controls

As discussed in Section 11.1, unsaturated conditions are considered an important attribute for repository performance, and lower water saturations are expected to provide better performance. Accidental spills of water are to be minimized to the extent practical, and any spills that do occur are to be cleaned up as soon as practical to prevent loss to the environment (Requirement 7). Before TBM hole-out at the South Portal, water lost was limited to an average of 7.4 m^3 per linear m of tunnel excavated (see footnote for Section 13.2.5). For constant ground conditions (which is a reasonable basis for a given day), water lost at the front the TBM and water used in the installation of ground support was considered to be relatively uniform over the tunnel excavation for that day, consistent with discussions in Section 11. Based on this mode of operation, coupled with requirements to minimize and cleanup spills, it was judged that checking that the water lost limit was not exceeded could be performed a minimum of once per day[4] prior to TBM hole-out.

After TBM hole-out at the South Portal, the water loss limit of 7.4 m^3 per linear m of tunnel continues to apply. For water uses where a water loss quantity can be applied as an average water loss over a defined section of tunnel (e.g., dust control), water meter reading and subsequent reporting shall be performed on at least a weekly basis. The total quantity of lost water must have been applied evenly throughout the affected 20-m segment(s) of the TS Loop. The water loss TFM report shall specify the particular 20-m segment(s) of the TS Loop where the water was applied; e.g., Station 15+60 to 15+80 m, Station 67+20 to 67+40 m, etc. When water is used for other than dust control purposes or otherwise exempted water uses, water meter readings and water loss reporting shall continue on a once-per-day basis, for each day that such water is used in the TS Loop. The TFM reporting shall specify the particular 20-m segment(s) of the TS Loop where the water was applied. The cumulative total of water lost in each 20-m segment of the tunnel before closure of the potential repository shall not be allowed to exceed the 7.4 m^3 per linear m limit, as applied over the 20-m segment (i.e., 7.4 $m^3/m \times 20\ m = 148\ m^3$ of total water lost, in each 20-m segment of the TS Loop), without additional Safety Assurance Department evaluation.

The portal in and portal out water meters shall be read and reported on a once-per-day basis, for each day that water is used, and checked against expected water usage to ensure unintentional water loss (i.e., leakage) is not occurring. Should the meter readings indicate unintentional water loss, an observation of the subsurface water lines and reading of all water meters shall be performed to ensure leakage is not occurring (Requirement 7).

[4]Note: Previous revisions (before Rev 06) of this DIE required that water accounting be performed on a shift basis; i.e., that water lost to the environment estimated and checked to be less than the prescribed limit for each working shift. Rev 06 of this DIE changed the accounting period to daily. This change may be applied retroactively; e.g., to TFM records that are in process as of the issue date of Rev 06 of this DIE.

The 7.4 m^3/m limit, as applied either before or following TBM hole-out at the South Portal, does not include water used in the TS Loop for cementitious materials, such as concrete, shotcrete or grout[5], above the lower limit of the PTn (Paintbrush Tuff nonwelded) member. The limit only includes water used for such purposes below the lower limit of the PTn member (i.e., below the PTn-TSw1 contact) where the cementitious material is considered to be committed (i.e., to remain post-closure). This accounting for water used in committed cementitious materials below the lower limit of the PTn member is necessary due to the possibility of thermal dryout resulting from repository heating, causing substantial movement of the cementitious water to the surrounding rock.

To ensure that conveyor system water loss is negligible, all water spray nozzles associated with the operational portion of the TS Loop conveyor system shall have an automatic control system, and water spray shall be confined only to the conveyor belt. In the event the unused portion of the conveyor system is reattached to the operational portion, the automatic control system shall be installed. This control system shall activate water spray when the belt is engaged and shall suspend water spray when belt operation is halted (Requirement 7). If the required automatic water control system for the muck conveyor is temporarily out of service (e.g., for system/component failures or component testing), excavation/conveyor operation may continue. However, continuous manual control of all affected spray nozzles is required during conveyor operations until the automatic water control system is operational. Manual operation of the muck conveyor water spray system requires A/E concurrence and shall not exceed 24 hours without Safety Assurance Department concurrence (Requirement 7).

In addition, as discussed in Section 11.1.8, water applied in a fine spray to the concrete invert top surfaces for dust suppression purposes in the TS Loop, ECRB Cross Drift Starter Tunnel, and TTF, at a rate of no more than 0.20 gallons/m per day (0.76 liters/m per day) over a tunnel section up to 900 m in length, is expected to evaporate and need not be counted as water lost to the geologic environment. If none of the dust suppression water applied to the concrete invert top is applied in the TTF, the length over which the water is expected to evaporate may be extended to 1100 m. (Note that Heinicke 1996 indicates that daily application lengths of approximately 1300 m are typical for the TS Loop. Based on the discussion in Section 11.1.8, as supported by Attachment VIII, any daily application in excess of 900 m [1100m if none was applied in the TTF] would have to be reported as water lost to the environment beyond that 900 m [1100 m] nearest the air inlet portal.)

The limit for water used in excavations off the TS Loop (alcoves, niches, ECRB Cross Drift Starter Tunnel etc.) is to be proportional to the projected floor area of the excavation. To derive an appropriate lineal limiting value for alcoves (m^3 of water per linear m of alcove excavation), the lineal limiting value for the TS Loop must be scaled by the *ratio* of the projected floor width of the alcove to that corresponding to the TS Loop excavation (7.62 m) (Requirement 7). For water uses where a water loss quantity can be applied as an average water loss over a defined section of the at excavation (e.g., dust control), water meter reading and subsequent reporting shall be performed on

[5]Note: As used here, grout includes rockbolt grout and grout used for ground consolidation purposes, as well as *non-cementitious* chemical grouts (if used).

at least a weekly basis. The total quantity of lost water must have been applied evenly throughout the affected 10-m segment(s) of the excavation. When water is used for other than dust control purposes or otherwise exempted water uses, water meter readings and water loss reporting shall be on a once-per-day basis, for each day that water is used in the alcove. The TFM reporting shall specify the particular 10-m segment(s) of the excavation where the water was applied. The 10-m averaging segments is necessary because of the reduced width of alcoves compared to the width of the TS Loop. The cumulative total of water lost in each 10-m segment of each alcove before closure of the potential repository shall not, without additional Safety Assurance Department evaluation, be allowed to exceed the width-based loss limit for that particular 10-m segment, as applied over the 10-m segment. For example, for a 10-m segment in a portion of an alcove that is 5.5 m wide, a cumulative total of 10 m x 7.4 m^3/m x (5.5 m/7.6 m) = 53.6 m^3 would apply. This would be the cumulative total amount of water that could be lost in that 10-m segment of alcove before closure of the potential repository. (Note: Since the segment reporting distance for alcoves has been increased from 5 m to 10 m, the revision of past water records is not considered necessary. Simply adding the cumulative water loss results for the appropriate segments together to create the water loss estimate for the particular 10-m alcove segments is considered adequate to meet this requirement.)

Water used to wet-drill test boreholes emanating (laterally or vertically) from alcoves may be accounted for differently, based on the fact that such water is lost in an area larger than the plan-view "footprint" of the alcove. In these cases, the actual area in which the borehole drilling water will be lost may be used to determined a location-specific water loss limit. This location-specific limit may also be conceived such that ease of implementation is improved; e.g., the limit may be based on borehole length (i.e., a limit on the water that can be lost for each meter of borehole drilled), rather than on alcove length (i.e., a limit on the water that can be lost for each segment of alcove). This provision may only be exercised on a case basis, and only after a location-specific DIE is prepared. (Such DIE may be a Category II DIE if the fundamental water loss model used in Section 11 of this DIE is preserved. Otherwise, a Category III DIE would be required.) In the absence of a location-specific DIE, any water lost during the wet-drilling of test boreholes drilled laterally or vertically from alcoves shall conservatively be considered to have been lost within the footprint of the alcove, and shall count against the limit for that particular 10-m segment of the alcove where the borehole was drilled.

Water used in cementitious materials in alcoves located above the PTn-TSw1 contact need not be included in the determination of water considered to be lost in the alcove. With the exception of cementitious materials used in the Thermal Testing Facility Heated Drift, water used in non-committed cementitious materials in alcoves located below the PTn-TSw1 contact need not be included in the determination of water considered to be lost in the alcove.

The A/E has identified the potential capability to remove water from the Swellex type rockbolts with a Swellex water recovery system. The use of the Swellex water recovery system was required in Revision 02 of this DIE. Further evaluation has concluded, however, that the amount of water either remaining in the Swellex bolts or recovered by such a system is not significant compared to the overall water loss limits, such that the specific use of the Swellex water recovery system does not warrant QA control. Because the water used for the Swellex type rockbolts is reported as construction water lost, any water recovered using a water recovery system can be used to meet the water limits in the TS Loop.

13.2.17 Water TFM Report

Most of the water used for dust control during TBM excavation or mechanical excavation, and wetting down alcove muck piles is expected to be removed in the muck, but water used for geologic mapping (as well as that used in mixing committed cementitious materials below the lower limit of the PTn unit) is assumed to be lost to the environment. Any water not removed[6] shall be reported as a consumed quantity per the TFM Procedure (Requirement 7). QA controls applied per the discussion above are judged sufficient to limit impacts to waste isolation to the extent practical.

13.2.18 Compressed Air for Testing

Section 10.6.3 indicates that compressed air used for testing may need to be free of condensate. Section 6.16 discusses the fact that drying, filtering and tracing may be done with portable units local to such tests. Testing activities are not evaluated in this DIE, and no QA controls are required in this regard. Any compressed air testing requirements are evaluated in the applicable JP/TPP/FWP and/or its associated DIE.

13.2.19 Water Balance

The ESFDR (YMP 1997a) requires the maintenance of the capability to keep a water balance (ESFDR 3.4.5.3.1.O, 3.4.5.6.1.D, 3.8.2.6.1.A, and 3.8.2.6.1.E). Although no specific impacts are identified, total water loss is a potentially important TFM input to understanding the site's performance. The requirement to maintain a water balance is therefore conservatively judged to be a QA requirement to provide an accurate estimate in the event of water loss (Requirement 7). A liquid-phase water balance is defined as the volume (m^3 or gallons) of water loss per discrete linear segment of tunnel (i.e., 10 m for alcoves and 20 m for the TS Loop) as derived from water use/recovery data. Water use/recovery data includes input/output water meter readings, discharge/recovery estimates per water use activity, applicable water removal allowances, and spill estimates, at a minimum. The accuracy required to provide an appropriate estimate, however, is sufficiently broad such that tracking water into and out of the tunnel and reporting such quantities in accordance with the TFM Procedure (YMP 1998a) along with a listing of the subsurface water uses is considered adequate to provide data to fulfill this requirement.

[6]Note: As discussed in Section 13.1.16, water sprayed on the invert top surfaces in the TS Loop, subject to certain, stated limitations, evaporates and therefore may be considered to be "removed." In addition, some of the water used in ventilation scrubber units (if installed; see Section 6.13) in the exhaust ducts from alcoves evaporates, and therefore may be considered to be "removed."

Because most or all of water used for conveyor, TBM, mechanical excavators, and wetting of muck piles is assumed to be removed (i.e., not included as part of "lost" water), the water balance must account for these water uses versus water used for other purposes. Water TFM reporting shall exempt the quantities of water associated with dust control activities as follows: (1) 100 percent of water applied directly to subsurface conveyor muck and (2) 75 percent of water applied during mechanical excavation and drill-and-blast excavation (Requirement 7). Controls applied on minimizing and mitigating spills and ponding, including spills of muck and/or water, are judged adequate to limit the potential for leakage from the conveyor and/or excess duct control water to significantly impact the accuracy of the TFM reporting.

Conventional quality instruments (accurate to ±10 percent or better) can be used to obtain the flow values. Flow meters shall be checked to ensure the continued accuracy. Checking of flow meter accuracy shall be performed at least once every year. Only flow meters appropriate for a respective application shall be used—e.g., only a flow meter for a 2-inch water line is to be used on a 2-inch water line (Requirement 7). It should be noted that, at very high or low flow rates, the amount of error in water meter readings may be very significant. As such, engineering judgement (with A/E concurrence) should be used to estimate quantities of water use/removal associated with very low-flow water applications for use in the water balance. If the appropriate meters are used for individual applications, very high or low rates are not generally expected to occur. Should a TS Loop water line experience an unexpected high-flow condition, engineering judgement (with A/E concurrence) should be used to estimate quantities of water use/removal for use in the water balance. However, the appropriateness of the installed water meter for the associated application should also be reevaluated.

Quantities of wastewater discharged from the tunnel may be based on changes in level of wastewater tanks into which the water flows. Reporting the above values (especially total water not removed from the tunnel) in accordance with the TFM Procedure is also sufficient (Requirement 7). Data that are anticipated to be made available as a result of planned *in situ* moisture and ventilation tests are judged to be sufficient for providing any additional data to TSPA for modification of total water use or validation of impact assumptions as necessary. (Note: It is not the intent of the water balance requirement to provide information to determine the extent and amount of drying of the rock surrounding the ramps/drifts.)

In summary, the liquid-phase water balance shall include as a minimum: record of subsurface water uses; record of water going out of the tunnel; record of water used for conveyor, TBM and mechanical excavator dust control, and wetting of muck piles for the report period. Data obtained from the liquid-phase water balance on recovered water should be used to adjust water lost reports (Requirement 7).

13.2.20 Ponding of Water

Significant ponding of water will lead to further limitation of the amount of water available for use, and should therefore be pented. Any ponded water will be removed to the extent practical with standard pumping equipment, and any water not removed will be reported as a consumed quantity per the TFM Procedure (YMP 1998a). Spill control procedures must reflect a requirement to limit unrecovered spills, and any record generated as a result of the use of a spill control procedure, as well as the procedure itself, must be processed as a QA record (Requirement 7). Use of the TFM procedure is adequate for the records requirement. These controls are conservatively imposed as QA controls to limit impacts to waste isolation.

13.2.21 Water Minimization and Heater Tests

As discussed in Section 10.6.1.3, water usage in the vicinity of the Thermal Testing Facility does not present a particular test interference concern. Location-specific water loss limits are evaluated and controlled by the DIE for ESF Subsurface Testing Activities (CRWMS M&O 1998a). The controls on water ponding and spillage, water lost limits, and water TFM reports are judged sufficient to minimize potential impact on the heater testing such that additional QA requirements are not necessary.

13.2.22 Organics

Section 11 indicates that if the total retained organic constituents do not exceed specified limits, it is expected that no more than a 10 percent change in the ambient aqueous organics concentration will occur. Therefore, there should be negligible geochemical impact in the TS Loop to waste isolation. It is recognized that the "negligible-impact" dissolved organic carbon (DOC) limits given in Section 11 would be impractical if applied as construction/operation limits. Further, no specific impact from a change in ambient conditions has been identified, and there is no indication that the potential impact from exceeding these conservative limits through normal, controlled operation is not mitigable. As such, organic use in the TS Loop shall be minimized.

To limit adverse effects on the long-term potential repository to the extent practical, the amount of organic material that is to be permanently retained in these excavations shall be minimized. The following controls are therefore applied to minimize permanently retained organics and thereby limit potential impacts to the extent practical: the use of permanently retained organics during construction, operation, and maintenance of the TS Loop (including the ESF Starter Tunnel) and associated excavations shall be avoided when practical alternative materials and methods exist, leakage of organics from construction/operational equipment shall be mitigated and repaired as soon as practical, spills of organics in excess of drips (e.g., ruptured hoses, spills from reservoirs, etc.) shall be removed to the extent, and as soon as, practical (Requirement 8). Furthermore, periodic maintenance shall be performed on components containing or associated with minimizing the loss of organic materials. The extent (e.g., type of maintenance, which components, etc.) and frequency of maintenance shall be based on manufacturer's recommendations or as approved by the A/E (Requirement 8).

Any organics that are spilled (subject to the discussion below for spills on inverts) or that are permanently retained in TS Loop excavations shall be reported in accordance with the TFM Procedure (Requirement 10). In addition, QA records shall identify the types of hydraulic and lube oils in TBMs, mechanical excavators, and support equipment used in the TS Loop and associated support areas. These records will facilitate better identification of any materials spilled from construction/operational equipment. Any possible effects on waste isolation of the total amount of organics retained in the TS Loop and associated excavations will be evaluated following construction per TSPA. The above controls are determined to be sufficient to limit impacts to waste isolation and minimize potential test interference impacts.

13.2.23 Invert Spills

Following TBM excavation, most spills should be largely mitigated by the concrete inverts and seals. Liquid spills on the invert segments that are absorbed by the invert segment need not be removed. If visual observation indicates that the spilled material is not likely to penetrate to the tunnel floor or past the invert segment seals, further checking is unnecessary. It is judged that since the likely source of spills is from equipment and operations in areas without invert segments or on top of invert segments, visual observation from the top of the invert segment will provide sufficient indication of leakage past the seals such that cleanup/mitigation controls discussed above can be applied. As discussed in Section 10, accumulation of fluids under the invert segment can be adequately controlled to limit test interference impacts by the fact that the invert segments may be removed or observation ports drilled after a spill, if necessary, to facilitate further visual observation and/or cleanup. Note that invert segment seals are a practical mechanism for limiting impacts of large spills. No specific credit is taken for these seals in mitigating a particular event. Therefore, routine checking is not necessary; normal visual indications of failure and subsequent repair are judged sufficient to limit impacts to the extent practical.

13.2.24 Perched Water and Inverts

As discussed above, invert segment removal, or the drilling of observation ports as necessary, are acceptable mechanisms for minimizing potential test interference impacts from accumulation of fluids under the inverts. In accordance with Section 10 and ESFDR (YMP 1997a) requirement B.8.3.A.2, encountering perched water requires TCO notification to give the TCO or PI the opportunity to determine if such measures are necessary (Requirement 13). For purposes of TCO notification, whenever flowing water is detected from excavated surfaces, the perched water notification shall be made. Following tests or collection of water as mandated by the PIs/TCO, remaining perched water is to be removed in accordance with above requirements.

13.2.25 Diesel Usage and Waste Isolation

CRWMS M&O 19941, an analysis of existing (surplus NTS) diesel equipment, indicated that the actual emission rates may exceed the negligible impact limits for dissolved organic, nitrates, and sulfur dioxide. Very conservative assumptions are made on the amount of exhaust material that is retained in the tunnel. Furthermore, the overall organics limits discussed in Section 11.3 are those limits below which negligible impact is expected, not those limits above which an impact is anticipated. Also, the opening to the mountain to the external environment allows the potential introduction of organic materials to the underground (e.g., rodents, insects, airborne particles, organic byproducts) such that as long as diesel emissions are minimized, the diesel emissions actually retained will be bounded by the organic introduction created by the opening itself. Finally, there is no indication that controlled use of diesel would result in unmitigable impact to the site's ability to isolate waste. Therefore, it is judged that, provided diesel emissions are minimized to the extent practical, diesels are acceptable for use in the TS Loop, subject to checking and reporting as discussed below.

13.2.26 Diesel Usage and Test Interference

Section 10 also identifies potential test interference impact on *in situ* gas testing activities due to the carbon content of diesel exhaust in the potential repository emplacement areas. As a result, diesel checking is required to evaluate carbon gaseous discharges before use in the potential repository emplacement areas (Requirement 9).

13.2.27 Diesel Requirement

As a conservative measure to limit the potential for waste isolation and test interference impact, the following requirements are indicated: Diesel equipment shall be subject to periodic testing for diesel particulate matter (DPM), sulfur dioxide, oxides of nitrogen, carbon monoxide, and carbon dioxide. To ensure that sulfur oxide constituents in exhaust emissions are minimized, the above-ground 40CFR80.29 requirement for low sulfur ($\leq$ 0.05 percent) diesel fuel shall be used. In general, detrimental components of diesel exhaust (as identified above) are to be minimized to the extent practical. Controls that ensure that these emissions are minimized include: minimizing diesel idle time while underground, regularly scheduled maintenance periods, ensuring diesel emissions are below prescribed guidelines (based on manufacturer's recommendations or as approved by the A/E) and reporting of diesel exhaust emissions measurements. In addition, any diesel locomotives used beyond Station 28+05 m or in the ECRB Cross Drift shall have exhaust treatment systems installed on them that are designed to reduce the emissions of DPM into the underground. Diesel use records shall include as a minimum the documentation of diesel fuel sulfur content, type of engine or equipment, volume of fuel used, and number of hours the equipment was operated underground (Requirement 9).

These requirements provide for QA control of diesel emission minimization and are judged to be adequate to limit the potential for adverse impact to the extent practical.

13.2.28 TFM Control

As a conservative measure, it has been determined that the recording of consumed quantities of TFMs as QA records shall be implemented, since these reports provide additional bases for TSPA and allow verification of consumed quantities. As a result, and except as specifically exempted below, any TFMs that are permanently emplaced/committed (i.e., to remain after closure of the potential repository) to the TS Loop or associated alcoves and niches, including water, hydraulic fluid, fuel, wood, etc., must be reported in accordance with the TFM Procedure (YMP 1998a). These reports must be controlled as QA records (Requirement 10). This control is conservatively imposed as a QA requirement to limit potential impacts to waste isolation and site characterization activities.

The use of the non-organic tracer gas SF_6 in the Subsurface ESF is exempted from reporting as a TFM, based on the expected (1) negligible impact that this gas presents to the waste isolation capabilities of a potential repository at Yucca Mountain (as discussed in Section 11.3.1 of this DIE), and (2) alternate availability of SF_6 usage records (e.g., as part of test documentation records), should such records be required in the future for TSPA activities, or to help establish initial conditions for site characterization testing.

Incidental losses of chlorinated, potable water/ice used for drinking and hand washing purposes in the Subsurface ESF does not present a significant test interference concern (Mitchell 1996) and therefore need not be reported in accordance with TFM reporting requirements.

The use of "temporary" building materials (e.g., wood, styrofoam) for the construction of forms and intermediate support plates in the Subsurface ESF (Skorseth 1999) is exempted from reporting - contingent upon removal of such materials to the extent practical, following completion of the construction activity.

13.2.29 TBM, Mechanical Excavators, and Support Equipment Maintenance

Review of Nordin 1994 indicates that five fluids are used to operate a TBM: hydraulic oil (in onboard reservoirs), lubrication oil -- also in onboard reservoirs (used to lubricate the main bearing, bull gear and speed reducers), seal grease, lubrication grease (at wear points on the TBM), and water (sufficient for dust control at the conveyor dump points and at the face, a small amount for bearing purge, and recirculated cooling water (also in onboard reservoirs) to cool the main drive motors and hydraulic oil and an onboard reservoir). TBM fluid systems are closed systems, with the exception of the water spray and seal purge discharges, which are expected to be carried out with the excavated muck. Nordin 1994 also indicates that numerous leak mitigation features are incorporated into the TBM design used in the ESF such as: hydraulic manifold blocks, contained hydraulic power unit with a full drip pan, wire braided hoses, single-piece barrels for the gripper cylinders, positioning of the power pack and actuators so as to eliminate the exposure of hose runs to rock fall, provision for isolating shut off valves and secondary drip pans at standard maintenance points, use of an inner seal main bearing labyrinth with water as the outer seal purge fluid, etc. Similar materials and approaches are used for other mechanical excavators and support equipment. Maintenance of these components should be handled in a similar fashion to a TBM.

The types of design features discussed above are conventional quality features that will limit potential impacts associated with spills from TBM, mechanical excavators, and/or support equipment operations. To minimize the potential for underground TBM equipment spills, the following minimum maintenance practices are also imposed as QA requirements (Requirement 2):

1) TBM, mechanical excavators, and support equipment maintenance procedures shall include provisions to contain loss of hydraulic fluid due to the removal of hydraulic lines or components.

2) Periodic maintenance shall be performed on components containing or associated with fluids of concern. The extent (e.g., type of maintenance, which components, etc.) and frequency of maintenance shall be based on manufacturer's recommendations or as approved by the A/E.

These requirements, along with other requirements discussed elsewhere in this DIE on spill mitigation and cleanup, are judged adequate to limit potential impact to site characterization testing and to waste isolation to the extent practical. The TBM excavation data (as discussed in CRWMS M&O 1997b) and any other records generated as a result of the above controls are QA records (Requirement 1). Normal operating practices such as exchange of information on anomalous indications or problems during shift turnover, information on TBM progress, response to alarms, etc., do not require additional QA control, except where this information requires recording as a QA record under 10CFR60.72 (Requirement 1).

The requirement for periodic sampling of hydraulic and lube oils for contaminants as part of preventative maintenance at a frequency based on manufacturer's recommendations or as approved by the A/E has been eliminated. Standard maintenance procedures for subsurface equipment require periodic sampling of these types of fluids. Furthermore, periodic maintenance of components containing or associated with fluids of concern is considered adequate to ensure any potential for spills that may have been detected by periodic sampling is addressed.

13.2.30 Rolling Stock

The areas of concern with rolling stock (exclusive of locomotives) are the potential for incidental spills (both of fluids included in the rolling stock and of fluids being transported to the surface) and accidental explosions (from explosives being transported). The rolling stock constructor and/or supplier is required to incorporate in the design and manufacture of rolling stock cars reasonable methods for preventing and mitigating the leakage and spillage of fluids. In addition, the rolling stock constructor and/or supplier is required to describe a program addressing design features, maintenance, operation and administrative programs for preventing and mitigating leaks and spills. The following features are incorporated into A/E specified rail cars: wheel bearings designed to mitigate hydrocarbon releases, fail safe airbrakes, and tie-downs and/or guards to prevent supplies and equipment from shifting during transit. Rail grippers are provided on both the scissor lift ventilation car and the scissor lift platform car for stability during lifting operations. A spill board encloses the deck of the maintenance/lube car to contain spilled fluids, and drain plugs will be provided at each end for draining spilled fluids. The maintenance/lube car uses rings welded onto the deck for transporting the grease barrels. Tanks on this car (described above) will be fitted with quick disconnect couplers and caps, sight glasses and ball type shutoff valves for connections (to prevent overflow). Included in the rolling stock is a tank containing water to be used for storage for subsurface operations. This tank is secured on a standard flat car. The constructor will ensure the operational readiness (with respect to leak prevention/mitigation) of rolling stock before using it in the ESF tunnel. It is also a requirement that maintenance be performed on equipment containing or associated with fluids of concern. The extent (e.g., type of maintenance, which components, etc.) and frequency of maintenance shall be based on manufacturer's recommendations or as approved by the A/E. These controls, along with spill controls discussed above, are sufficient to limit impacts to test interference and waste isolation (Requirement 15).

13.2.31 Underground Storage Vessels

It is conservatively judged that additional storage vessels (i.e., beyond the size of on-board vehicle tanks) for fluids must be placed outside the underground opening to limit the potential for underground leakage. This does not include the sump storage tanks, approved testing related storage tanks, or on-board tanks, such as those on the rolling stock, TBM, or on the TBM trailing gear (Requirement 11).

13.2.32 Subsurface Conveyor Operation

Conveyor operation introduces a potential for the release of contaminants that may adversely impact site characterization data, or the capability of the site to isolate waste. Operating fluids of concern are lubricating oils, hydraulic fluid, grease, and dust suppression water. The design of the subsurface conveyor incorporates several features that will limit spills to the extent practical: utilization of labyrinth seals on pulley and idler bearings to limit grease from leaking out, emergency stop switches operated by pull cords located along the full length of the conveyor, use of fully enclosed chutes with a dust suppression water spray system available for use at most transfer points, a solenoid shutoff valve interlock to prevent water usage when the conveyor is empty or not running, and a flow meter on each spray header to indicate the amount of water being used. These conventional quality features are adequate when combined with spill containment/mitigation limits described above, to limit test interference and waste isolation impacts. The previous requirement for QA alarm response procedures is adequately covered by requirements to maintain equipment containing fluids of concern and to minimize spills such that no other QA requirements are necessary. Section 10.6.13 discusses the need to clean up muck spills that are excessively wet to the extent practical to limit exposure of *in situ* rock to water or other contaminants. Controls in place to limit/mitigate spills of water, hydrocarbons, and other materials, are adequate to provide this control.

13.2.33 Fires

The primary means of extinguishing fires during construction will be a dry chemical fire protection system. As discussed above, organics retained in the TS Loop and associated alcoves and niches must be limited to prevent effects on a potential repository. It is judged, however, that chemical releases as a result of fires, or the extinguishment of fires, are insignificant relative to this limit (and are therefore not likely to impact waste isolation) since dry chemical residue will be removed following discharge. Section 11 indicates that dry chemical and water should not be combined for fire protection unless required for safety reasons. The design of the system provides for water hose stations that will be installed only as a supplemental system. It is judged that the backup use of water in the amount required to extinguish a fire is not likely to impact waste isolation, and that any impact as a result of this event can be adequately evaluated when specific details of the event are available. Any actuation of dry chemical fire protection systems or the backup use of water will be evaluated following removal of the powder and/or water to the extent practical. The requirements associated with mitigation and reporting of spills are adequate to control this activity (Requirements 7, 8).

13.2.34 Inadvertent Explosions

Inadvertent explosions could occur in the TS Loop, associated alcoves and niches during construction and transport of explosives for excavation in the ESF. The explosives box is an explosives transportation container for subsurface use. It will be grounded and labeled, lined with non-sparking material, and covered. The box has two separated compartments; one for explosives, and one for detonators. The car transporting the explosives is to be posted with warning signs during transportation, and appropriate multipurpose (A:B:C) fire extinguisher(s) will be mounted on the car. The potential for accidental detonation is considered remote enough not to warrant the need for QA controls since the utmost care will be exercised during the course of ensuring personnel safety. In the event that a significant uncontrolled explosion does occur, an evaluation of potential impacts to the surrounding rock mass will have to be made at that time based on as-found conditions.

13.2.35 Underground Storage of TFMs

Section 10.7.1 recommends that the storage underground of TFMs that have decomposition and/or combustion products potentially adverse to site characterization be controlled and limited. As discussed above, conventional practices including compliance with normal industrial hygiene requirements and personnel safety will be used in the construction of the TS Loop. Leak and spill mitigation programs are also required as a result of this DIE, and tracers, fluids and materials are controlled per the TFM procedure (YMP 1998a). Because of these requirements and practices, the intent of minimizing storage underground is met since any use or uncontrolled releases of these fluids would be reported via the TFM procedure and evaluated appropriately. Therefore, no additional QA controls are required.

13.2.36 Traced Water and Perched Water

Section 10.7.1.1 recommends that grout used in the vicinity of perched water testing be required to contain a tracer. Since the only available supply of nonpotable water in the TS Loop is traced water (see discussion above) and grout is mixed at or near the use location, it is judged that no additional QA controls are required.

13.2.37 Rock Drills

Rock drill hydraulic system features include a system design pressure that is two times the maximum hydraulic system operating pressure, hydraulic fittings and hoses with operating pressure of twice the hydraulic system operating pressure, and full-flow filtering of pressure lines between components and in return lines. Filters are located to provide for ease of servicing. Maintenance of this and similar equipment (e.g., mechanical excavators, front-end loaders, etc.) that involve fluids of concern in accordance with manufacturer's recommendations (or as approved by the A/E) will limit potential impacts to waste isolation and site characterization testing (Requirement 15). Pneumatic drills may be necessary, where access with TBM-mounted electro-hydraulic drills or the drill jumbos is restricted, to install ground support for personnel safety or to drill the first few rounds in alcove excavation. The use of pneumatic drills is bounded by the controls discussed above limiting organics and the TFM reporting of fluids lost or consumed such that additional QA controls are not required.

13.2.38 Drinking Water

Drinking water within the tunnel, alcoves, and niches is expected to be provided in small (on the order of a few gallons) temporary coolers or canteens. For health reasons, drinking water (and any associated ice) will not be traced and may be chlorinated. Untraced, chlorinated water may also be provided to hand wash stations. Because of the conservatism associated with hydrological impact evaluations and conclusions, and because of the small quantities involved, incidental spills of drinking water/ice and hand wash station runoff are not considered to require additional QA controls to limit impacts to waste isolation. (See additional discussion in Section 13.2.40 below.)

13.2.39 Compressed Air

ESFDR 3.8.2.8.1.D (YMP 1997a) indicates that compressed air used underground during construction, operation, and maintenance shall be provided with chemical tracer only upon request by the TCO. As discussed in Section 10.7.1.1, the TCO may request that traced compressed air be used; e.g., to drill core holes and for field experiments and testing in the TS Loop and associated alcoves. Since the scope of this DIE does not encompass testing, the request for tracer is expected to be addressed in the preparation of the individual TPPs, JPs, and/or FWPs. Compressed air leakage is subject to minimization and reporting per Requirements 8 and 10.

13.2.40 Chlorides

The use of chloride is to be limited to avoid potential test interference impact (Section 10.7.1.4) as follows: only non-chloride based ground enhancing material (e.g., GEM) is to be used, and use of chloride-based concrete and grout accelerators is to be limited to the extent practical. TCO concurrence before such use is judged sufficient to provide this control. The amount used shall be recorded in accordance with TFM reporting requirements (Requirement 14), if permanently emplaced/committed. This control is conservatively applied as a QA requirement to limit test interference impacts.

The use of chlorinated water/ice for drinking and hand washing purposes in the Subsurface ESF does not present a significant test interference concern (Mitchell 1996) and therefore does not warrant additional QA controls. Incidental losses as a result of such uses need not be reported in accordance with TFM reporting requirements.

13.2.41 Construction Water and Sampling

Section 10.6.1.1 recommends that no water or tracers, except for the traced water used in construction and in the air-mist used to clean the tunnel walls, are to be used in the vicinity of sampling locations. Since all nonpotable water piped or transported underground is required to be traced (Requirement 3) with the only approved tracer (lithium bromide), no additional QA controls are required.

13.2.42 Cement Grouting

Section 10.6.10 indicates that cementitious grouting pressures and quantities are to be limited to the extent practical for rockbolt installation to limit impacts to the ability to properly characterize the site. The grout material to be used in the TS Loop is thixotropic in nature and the design specification associated with this material calls for it to be controlled to provide for viscous flow with minimal potential for migration. Changes to ground support procedures and materials require A/E review and approval (CRWMS M&O 1996a), including consideration of the above criteria. It is therefore judged that no specific QA controls on pressure/quantity is necessary.

Cement grouted rockbolts are not to be used in test support areas, except as approved by the TCO. It is conservatively judged that this requirement shall be implemented as a QA control to avoid altering gas sample and air permeability data (Requirement 6). Previous requirements for cement grouted rockbolts required TCO approval for installation of the grouted rockbolts within 3 m of the test support area. Since the exact location of the test support area is not determined until after the TBM had passed (and ground support installed) and since test alcoves can be lengthened as necessary to minimize the impact on gas samples and air permeability data, it is judged the 3 m criterion is no longer required.

13.2.43 Shotcrete

The constructor must coordinate with the TCO before applying shotcrete in the test alcoves and in the TS Loop, to assure access for testing (Requirement 12). As a conservative measure applied to limit potential unidentified test interference impacts, this requirement is imposed as a QA control.

13.2.44 Alternative Excavation

Alternative excavation/ground support methods - i.e., contingency-based methods outside of specification requirements for stabilizing extremely poor ground - are expected to be invoked occasionally during loop excavation. (Alternate excavation/ground support methods have been employed in a few instances to date, in accordance with Section 3.01X of CRWMS M&O 1997a.) These contingencies are typically expected to consist of the use of lean cement, steel, and/or wood cribbing, etc., to stabilize weak ground immediately where personnel or equipment safety are at risk. These methods are applied only until competent ground is reached, and all actions taken are documented in accordance with CRWMS M&O 1998k, which requires TCO and Safety Assurance Department concurrence as soon as practical after determination of alternate methods to be used (which may, in some cases, follow implementation). Because of the critical nature of these alternate methods (i.e., required to protect personnel and equipment), these provisions are judged adequate to limit potential impacts.

Use of these alternate methods typically does not include significant quantities of organic materials, although use of chemical injection grouting has been considered. Because of the fact that certain injected chemical grouts violate waste isolation "no-impact" organic thresholds, a prohibition is placed on its use unless it is the only practical method for continuing excavation. In recognition of the fact that chemical grouting requires a non-trivial equipment deployment, it is not to be used in any event until an evaluation (including consideration of potential waste isolation/test interference impact) can be performed based on the as-found conditions requiring its use (Requirement 16).

13.2.45 Surface Controls

Refer to the applicable surface DIE regarding controls that are applicable to the construction, operation, and maintenance of surface equipment including the subsurface power/grounding distribution system, communication system, lightning protection system, and surface conveyor system.

13.2.46 Electromagnetic Interference (EMI)

Electrical equipment, transformers, cabling, etc., installed underground have the potential to influence test equipment as a result of EMI. It has been agreed by the TCO that during the development of each test planning package or field work package (as applicable), the organization responsible for the test will coordinate with the A/E to survey the specific site where test equipment will be located as necessary and determine if additional electromagnetic protection is required. The constructor may be required to install EMI shielding or other mitigation as part of the implementation of the TPP/FWP. Therefore, no additional QA controls are required.

13.2.47 Construction Utilities

Before the installation of the A/E designed support systems, temporary construction systems may be installed to support construction and operations activities. These temporary systems may include muck handling, electric power, lighting, compressed air, ventilation, water, wastewater, fire protection, communications, and monitoring systems. For the construction supplied monitoring system, it is evaluated as part of the system it supports. No additional QA controls are required. These constructor supplied systems are subject to the same applicable DIE requirements as the A/E designed systems.

13.2.48 ECRB Cross Drift Starter Tunnel

The ECRB Cross Drift Starter Tunnel was constructed in a fashion similar to other TS Loop alcoves. The ECRB Cross Drift Starter Tunnel functioned as an assembly and launch chamber for the ECRB TBM and currently houses various utility and conveyor equipment used in support of the ECRB Cross Drift. A series of moisture studies boreholes were drilled near the end of the ECRB Cross Drift Starter Tunnel and have been evaluated in CRWMS M&O 1998a. The continuation of the ECRB Cross Drift beyond the end of the ECRB Cross Drift Starter Tunnel is evaluated in CRWMS M&O 1998c. The QA controls applicable to TS Loop alcoves (e.g., water loss limits, organics minimization, etc.) also apply to the ECRB Cross Drift Starter Tunnel.

A temporary, concrete pad was poured in the first approximately 14 m of the ECRB Cross Drift Starter Tunnel. As a result, an unquantifiable amount of water used in the concrete mixture may be volatilized and released. Since the concrete is planned to be temporary, all materials used in the concrete mixture are expected to be removed prior to potential repository operation, and thus should not impact performance. A positive slope on the temporary concrete pad is expected to provide sufficient drainage to satisfy ponding requirements. Other means (e.g., water collection points and/or pumps) may be used, in lieu of or in conjunction with the sloped grade, to satisfy the ponding requirement.

The physical distance between the ECRB Cross Drift Starter Tunnel and nearby Surface Based Testing (SBT) boreholes presents a minimal potential for test interference concerns. The nearest borehole, UE-25 a#4, is approximately 500 feet deep (Esp 1997) and is located approximately 200 m from the estimated path of the ECRB Cross Drift Starter Tunnel (YMP 1997r). Other boreholes within 400 m include UE-25 NRG#5 (approximately 275 m), USW UZ-N37 (approximately 350 m), and USW UZ-N38 (approximately 400 m) (YMP 1997r). UE-25 NRG#5 is the deepest borehole at approximately 1350 feet deep, whereas USW UZ-N37 and USW UZ-N38 are both shallow boreholes of approximately 271 feet and 94 feet deep, respectively (Esp 1997). Testing activities have been completed at all of the above referenced boreholes except for UE-25 NRG#5, which is instrumented with a USGS "Seamist" monitoring system (Esp 1997). Based upon the scope of the activities covered in this analysis and the distance between the ECRB Cross Drift Starter Tunnel and the nearest SBT boreholes, the potential impact on site characterization testing is judged to be negligible.

The distance of the ECRB Cross Drift Starter Tunnel from TS Loop testing alcoves in the subsurface ESF is considered sufficient to conclude that the excavation activities at the ECRB Cross Drift Starter Tunnel will present negligible potential for impacting site characterization testing in those alcoves. Note: It is the responsibility of the TCO to site subsurface test area locations so as to minimize the potential for impacting testing at other locations.

13.2.49 TS Loop Niche Construction

Except for location-specific considerations (as noted in the following paragraphs), the design, construction, and testing methods to be used for these niches are sufficiently similar to those used for other alcoves so as to be bounded by the applicable evaluation for the construction of the niches

Since these niches are located on the right rib of the TS Main, their siting could potentially impact the design of the potential repository. To minimize this potential for impact, the concurrence of the Repository Subsurface Design Department, the TCO, and the CMO was required to approve or change the planned locations, orientation, or grade of the niches (Requirement 19). In addition, the size of the excavated openings for these niches could have a similar impact upon potential repository design. Potential repository design impacts are minimized since the niches are <u>temporary</u> testing accommodations and since each entire niche facility is expected to be "removed" when the potential repository emplacement drift "turnouts" are excavated (with the possible exception of portions of several testing boreholes--approximately 10 or fewer m in length--that will be drilled laterally into the pillars adjacent to the niches). Limiting the excavated opening of each niche to a maximum height of 5 m and a maximum width of 5 m (with these maximum dimensions being approximately centered at the horizontal and vertical midpoints of the planned excavation) was considered to be a reasonable control for minimizing any potential repository design impact. Additional evaluation by the Safety Assurance Department is required to intentionally exceed these limits (Requirement 19). If inadvertent overbreak due to varying geologic conditions caused the excavated dimensions of niche to exceed these maximum limits, additional evaluation was not required. Any remaining portions of testing boreholes that are not completely removed by the excavation of the emplacement drift "turnouts" will require additional evaluation under the planned YMP Borehole Sealing Program prior to closure of the potential repository.

With specific regard to the design and construction of these niches, there are three location-specific DIE requirements for minimization of potential impacts to waste isolation and/or test interference. The niche-related testing activities are designed to measure moisture flux. Therefore, construction water use could potentially impact the results of these testing activities. Based on the criteria cited in Hollins 1997c, location-specific controls on the use of construction water are required to minimize potential test interferences (i.e., interferences with niche testing) due to construction activities. However, except for the location-specific DIE requirements discussed below, TS Loop alcove requirements and conclusions sufficiently bound the potential waste isolation and test interference impacts associated with the planned construction activities for these niches.

Due to the sensitivity of these tests to additional moisture, the excavation of niches was required to be performed using mechanical excavation equipment only, and the use of construction water--including water for geologic mapping, if applicable--associated with these niches requires monitoring by the TCO (Requirement 19). To ensure that the site waste isolation characteristics associated with water use are not compromised, the total amount of water which may be committed in each niche is limited to 19.5 m^3 or 5,150 gallons (Requirement 19), as calculated using Requirement 7e.

Boreholes associated with these niches (for testing, ground support, and utility installation purposes, as applicable) shall be dry-drilled (Requirement 19). Dry-drilling techniques have been previously evaluated in Sections 11.4.2 and 13.2.7 of CRWMS M&O 1998a.

Hollins 1997c also mandated that Swellex rockbolts be prohibited (due to the potential water loss associated with their installation) and that cementitious material (i.e., grout, shotcrete, etc.) used for ground support was prohibited until further evaluations can be conducted. These prohibitions are directly related to the test interference consideration that these types of ground support potentially add significant amounts of "avoidable" water to the testing environment associated with these niches. Therefore, recognizing the potential test interference concerns and also acknowledging that permanent function ground support must eventually be installed in these niches, a location-specific ground support requirement is considered to be warranted. Specifically, the use of Swellex rockbolts for niche-related ground support is prohibited, and the use of cementitious materials for niche-related ground support shall be deferred until the TCO provides written concurrence, or written notification that testing activities within the niches have been completed (Requirement 19).

Hollins 1997d identifies another potential construction-to-test interference impact associated with the proximity of niche testing boreholes to niche-related ground support boreholes. The PI has indicated that this potential test interference impact can be minimized by ensuring a minimum separation distance between testing and ground support boreholes. Therefore, a site-specific requirement is considered to be warranted to establish a minimum separation distance of 300 millimeters (mm) between niche-related ground support boreholes and niche testing boreholes (Requirement 19). The initial niche testing boreholes (i.e., the boreholes emanating from the TS Main Drift) must also be field-located by the TCO prior to drilling niche-related ground support boreholes in the TS Main Drift (Requirement 19), to ensure that these boreholes are located such that optimum testing results may be achieved.

The use of shotcrete for sealing the niche bulkheads, as described in Mitchell 1997c, could also potentially impact waste isolation or cause test interference. Since this application of shotcrete is temporary (i.e., the shotcrete will be removed along with tunnel muck when the associated emplacement drift "turnouts" are excavated), the waste isolation impact of the shotcrete material is minimized. However, any excess water in the shotcrete mixture could potentially impact the testing in the niches. To limit this potential test interference impact, Mitchell 1997c requires that water used to mix this shotcrete is to be minimized. Controlling the amount of water used in shotcrete under Requirement 12 is expected to sufficiently limit potential test interference to the extent practical.

The physical proximity of the niches to other test sites (e.g., alcoves, radial boreholes, and surface boreholes) presents a potential for test interference concerns. The three nearest alcoves are the TTF, NGDFA, and SGDFA. The TTF is located on the left rib of the TS Main Drift at approximately Station 28+27 m. The NGDFA is located on the left rib of the TS Main Drift at approximately Station 37+37 m. The SGDFA is located on the left rib of the TS Main Drift at approximately Station 50+64 m. The distances between each of these alcoves (including the extent of their radial boreholes) and any of the planned niches are considered sufficient to conclude that the excavation activities associated with the niches will present negligible potential for impacting site characterization testing in these other alcoves. (Note additionally that it is the responsibility of the TCO to site subsurface test area locations--including that for these niches--so as to minimize the potential for impacting testing at other locations.) Therefore, no additional DIE-generated QA controls are required to ensure that testing activities in other Subsurface ESF alcoves are not impacted.

YMP 1997r identifies several surface boreholes in the general vicinity (i.e., ranging between approximately 300 and 400 m) of these niches: USW UZ-N24, USW UZ-N31, USW UZ-N32, USW UZ-N35, USW UZ-N42, USW UZ-N48, USW UZ-N49, USW UZ-N98, USW G-4, USW UZ-7a, USW UZ-8, USW SD-9, USW SD-12, and USW WT-2. Per CRWMS M&O 1997p, USW UZ-8, USW UZ-N24, USW UZ-N31, USW UZ-N32, USW UZ-N35, USW UZ-N42, USW UZ-N48, USW UZ-N49, USW UZ-N98 are all less than 100 feet deep, with USW UZ-N35 (approximately 180 feet in depth), USW UZ-N31 (approximately 190 feet in depth), and USW UZ-N32 (approximately 210 feet in depth) being the deeper UZ-N boreholes. These UZ-N boreholes are relatively shallow surface boreholes that are used to characterize water infiltration processes and quantify net infiltration rates in the surficial materials. The TS Main Drift and the niches are located at a depth significantly below the maximum depths of these boreholes. The significant difference in depth (when combined with the lateral surface distance between these boreholes and the ESF niches) is considered sufficient to conclude that the activities associated with the niches will present negligible potential for impacting site characterization testing in these boreholes. USW G-4, USW UZ-7a, USW SD-9, USW SD-12, and USW WT-2 are in the 750 to 4000 foot depth range (CRWMS M&O 1997p). These deeper boreholes are used to study geologic and hydrologic conditions and to monitor water levels at depths significantly below the elevation of the niches. The distance between boreholes UZ-N24, UZ-N31, UZ-N32, UZ-N35, UZ-N42, UZ-N48, UZ-N49, UZ-N98, G-4, UZ-7a, UZ-8, SD-9, SD-12, and WT-2 and the niches is considered sufficient to conclude that the activities associated with the niches will present negligible potential for impacting site characterization testing in these boreholes. Therefore, no additional controls are required to ensure that surface borehole testing is not impacted.

13.2.50 TS Loop Slot Cut Construction

Per Section 6.4, alcove slot cuts are excavated by a combination of drilling and mechanical mining techniques. Per Mitchell 1998a, this method of slot cut excavation has been approved by the PI(s) responsible for the alcove slot cuts, thus limiting the potential for construction-to-test interference. No test interference or waste isolation impacts have been identified for this slot construction technique. The water lost during the construction of the alcove slot cuts shall be counted against the appropriate water reporting section(s) of the alcove in which the slot cut is constructed.

Alcove slot cut standoff distances and potential NRG-4/Alcove #4 interactions are discussed in Section 13.2.6 of CRWMS M&O 1998a. Review of CRWMS M&O 1994i showed that the proposed slot cuts in Alcoves #4 and #6 were not located above potential waste emplacement areas. The Alcove #4 slot cut was displaced horizontally at least 100 meters and vertically at least 75 meters from the potential lower waste emplacement block expansion area. The Alcove #6 slot cut is down grade (at least 5 percent) for the 55 meters of Alcove #6 (resulting in at least 92 meters of horizontal offset from the upper waste emplacement block) with some additional vertical displacement due to the planned positive grade for the primary waste emplacement drifts. The potential lower waste emplacement block expansion area is displaced vertically approximately 65 meters below Alcove #6, and is separated horizontally by at least 100 meters and the Ghost Dance Fault. The TS Loop niches are sized and located such that the majority of the test area is planned to be excavated during the construction of the potential waste emplacement drifts. No such control exists nor is needed for the specific TFMs approved for use in this DIE for the alcove slot cut test areas.

13.2.51 Other ESF Construction, Operations, and Maintenance Activities

Other subsurface construction, operations, and maintenance activities, described in Section 6, for which waste isolation and test interference impacts were generically evaluated in accordance with NLP-2-0 (CRWMS M&O 1998b), but not specifically identified in Sections 10 and 11, are discussed here for completeness. Potential waste isolation impacts, for the activities described in Section 6, have been identified in Section 11 of this DIE. The TCO interface with the PIs and CMO addresses potential test interference impacts for non-intrusive activities such as Consolidated Sampling, Hydrochemistry Tests, Borehole Wireline Measurements, Construction Monitoring, as well as intrusive testing such as Radial Borehole Tests and Hydrologic Properties of Major Faults. Furthermore, the construction-to-test interference concerns associated with the TTF Heated Drift

DST are addressed by the TCO/PI/CMO coordination. As such, no additional QA controls are required. Any changes to the planned tests or new site-disturbing construction, operations, and maintenance activities will require additional evaluation by the Safety Assurance Department.

13.3 QA CONTROLS

The following QA requirements have been identified as a result of this evaluation. These requirements are to be applied in addition to other conventional design practices.

Requirement 1: Records required for 10CFR60.72 shall be maintained as QA records. [ESFDR 3.2.1.1.1.A, 3.2.1.1.4.C, 3.7.1.2.B]

Requirement 2: The following minimum requirements apply to TBM, mechanical excavators, and support equipment maintenance in the TS Loop to minimize the potential for underground spills of fluids of concern:

a. Maintenance procedures shall include provisions to contain loss of hydraulic fluids due to the removal of hydraulic lines or components.

b. Periodic maintenance shall be performed on components containing or associated with fluids of concern. The extent (e.g., type of maintenance, which components, etc.) and frequency of maintenance shall be based on manufacturer's recommendations or as approved by the A/E.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D]

Requirement 3: Nonpotable water transported into the TS Loop shall be traced (except for water used outside the tunnel for mixing concrete, grout, and shotcrete that is then used in the TS Loop).

a. Checking is required to ensure that the lithium bromide in water is delivered at the proper concentration by the tracer injection system, regardless of whether the system is manual or automatic. The frequency of checking shall be accepted by the A/E.

b. The lithium bromide sample concentration shall be 20 ppm ± 10 ppm (i.e., 10 to 30 ppm).

c. Checking of an automatic tracer injection system's alarm capability shall be performed at a frequency accepted by the A/E. The routine checking shall ensure proper operation of the alarms associated with failure of the tracer delivery portion of the tracer injection (e.g., failure of a tracer delivery pump or inadvertent closing of a delivery valve).

d. If the automatic tracer injection system is not operating in automatic mode or is not alarmed, the system will be continuously manned while in operation by an operator qualified to an operating procedure for that system. All batches of traced water shall be mixed and sampled, and the lithium bromide sample concentration shall be determined, before release for use; only traced water within the limits established above shall be released for use.

[ESFDR 3.2.1.2.3.B, 3.4.5.3.1.G, 3.4.5.3.1.P, 3.7.2.5.1, 3.8.2.6.1.E]

Requirement 4: Controlled drilling-and-blasting of the TS Loop operation and test support areas shall be performed in accordance with the following minimum QA requirements:

a. qualification of those performing the operations,

b. performance to required tolerances (post-blast),

c. A/E approval of blasting plans, and

d A/E approval of blasting patterns and materials.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.G, 3.2.1.2.3.H, 3.7.2.1.2.F]

Requirement 5: Work shall be documented in accordance with drill-and-blast specifications in the TS Loop operation and test support areas. These records shall document work processes in conformance with 10CFR60.72. Records associated with documentation of training and qualifications for drill-and-blast operations shall be treated as QA records. Blast records, blast plans, and blast patterns shall also to be treated as QA records. As a minimum, the type of explosive, size (i.e., pounds explosive per delay), time, and location of the blast shall be reported as a QA record. [ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.G, 3.2.1.2.3.H]

Requirement 6: Cement grouting in the test support areas is prohibited without TCO concurrence. [ESFDR 3.2.1.2.3.B, 3.2.1.2.3.D]

Requirement 7: Water use and purposeful or accidental loss of water to the environment in the TS Loop and associated support areas shall be minimized to the extent practical by imposing the following controls:

a. Any spilled or ponded water shall be minimized and removed from the TS Loop and associated support areas to the extent practical with standard pumping equipment.

b. Any water not removed shall be reported as a consumed quantity per the TFM Procedure. (Note: Water applied in a fine spray on concrete invert top surfaces for dust suppression purposes in the TS Loop, ECRB Cross Drift Starter Tunnel, and TTF, at a rate of no more than 0.20 gallons/m per day [0.76 liters/m per day] over a tunnel section up to 900 m in length [1100 m if the water application is not in the TTF], is expected to evaporate -- i.e., is considered to be *removed* -- and need not be counted as water lost to the geologic environment. The above evaporation credit shall be applied to the 900 m [1100 m if the water application is not in the TTF] section that is nearest the air inlet portal of the TS Loop.)

c. A liquid-phase water balance shall be maintained and reported in accordance with the TFM Procedure. The liquid-phase water balance may be used to adjust reports of use against limits. The liquid-phase water balance shall include as a minimum: subsurface water uses, water going out of tunnel, water used for conveyor, TBM and mechanical excavator dust spray, water used for wetting of muck piles for the record period. Note: It is not the intent of this requirement to provide information to determine the extent and amount of drying of the rock surrounding the ramps/drifts.

d. The cumulative total of water lost in each 20-m segment of the tunnel before closure of the potential repository shall not be allowed to exceed an average of 7.4 m^3 per linear m (or approximately 1955 gallons per linear m) as applied over the 20-m segment (i.e., a <u>total</u> of 148 m^3 of water can be lost in each 20-m segment of the TS Loop before closure of the potential repository), without additional Safety Assurance Department evaluation.

   The water loss checking frequency shall be performed on at least a weekly basis for water uses where the water loss quantity can be applied as an average water loss over a defined section of tunnel (e.g., dust control). The total quantity of lost water must have been applied evenly throughout the affected 20-m segment(s) of the TS Loop. When water is used for other than dust control purposes or otherwise exempted water uses, water meter readings and water loss reporting shall continue on a once-per-day basis, for each day that such water is used in the TS Loop.

   The water loss reporting shall also specify the particular 20-m segment(s) of the TS Loop where the water was applied. The water loss limit does not include the water applied directly to subsurface conveyor muck nor 75 percent of water applied during mechanical excavation and drill-and-blast excavation, since that water is assumed to be removed with the muck. Any water recovered that is metered or otherwise measured is also not included in the limit.

The 7.4 m^3/m limit, as applied either before or following TBM hole-out at the South Portal, does not include water used in the TS Loop for cementitious materials, such as concrete, shotcrete or grout, above the lower limit of the PTn (Paintbrush Tuff nonwelded) member. The limit only includes water used for such purposes below the lower limit of the PTn member (i.e., below the PTn-TSw1 contact) where the cementitious material is considered to be committed (i.e., to remain post-closure).

e. For excavations associated with the TS Loop, such as alcoves, the lineal water lost limit is proportional to the projected floor width of the excavation, or

$$\text{Alcove Water Limit } (m^3/m) = \frac{\text{Alcove projected floor width (m)}}{\text{TS Tunnel projected floor width (7.6 m)}} \times 7.4\ m^3/m$$

Water use/recovery checking shall be performed on at least a weekly basis for water uses where the water loss quantity can be applied as an average water loss over a defined section of tunnel (e.g., dust control). The total quantity of lost water must have been applied evenly throughout the affected 10-m segment(s) of the excavation. When water is used for other than dust control purposes or otherwise exempted water uses, water meter readings and water loss reporting shall continue on a once-per-day basis, for each day that such water is used in the excavation.

The water loss reporting shall specify the particular 10-m segment(s) of the alcove where the water was applied. The cumulative total of water lost in each 10-m segment of each alcove before closure of the potential repository shall not, without additional Safety Assurance Department evaluation, be allowed to exceed the width-based loss limit (determined from the equation above) for that particular 10-m segment, as applied over the 10-m segment.

Water used to wet-drill test boreholes emanating (laterally or vertically) from alcoves may be accounted for differently, as discussed in Section 13.2.16 of this DIE, provided that a location-specific DIE (Category II or Category III, as applicable) is prepared. In the absence of a location-specific DIE, any water lost during the wet-drilling of test boreholes drilled laterally or vertically from alcoves shall conservatively be considered to have been lost within the foot print of the alcove and shall count against the limit for that particular 10-m segment of the alcove where the borehole was drilled.

Water used in cementitious materials in alcoves located above the PTn-TSw1 contact need not be included in the determination of water considered to be lost in the alcove. With the exception of cementitious materials used in the Thermal Testing Facility Heated Drift, water used in non-committed cementitious materials in alcoves located below the PTn-TSw1 contact need not be included in the determination of water considered to be lost in the alcove.

f. The portal in and portal out water meters shall be read and reported on a once-per-day basis, for each day that water is used, and checked against expected water usage to minimize unintentional water loss (i.e., leakage). Should the meter readings indicate unintentional water loss, an observation of the subsurface water lines and reading of all water meters shall be performed to ensure leakage is not occurring.

g. Conventional quality instruments may be used to obtain this data and shall be accurate to ±10 percent or better for water meters. Water meters shall be flow checked to ensure continued accuracy. Checking of water meter flow meter accuracy shall be performed once every year. Only water line sizes and flow meters appropriate for a respective application shall be used.

Note: At very high or low flow rates, the amount of error in water meter readings may tend to increase significantly. As such, engineering judgement (with A/E concurrence) should be used to estimate quantities of water use/removal in the water balance that is associated with very low-flow water applications. If water meters are appropriate sized for their respective applications, very high-flow conditions are not generally expected. Should an water line experience an unexpected high-flow condition, engineering judgement (with A/E concurrence) should be applied to estimate quantities of water use/removal in the water balance, but the appropriateness of the meter for its application should be reevaluated.

h. All water spray nozzles associated with the operational portion of the TS Loop muck conveyor system shall have an automatic control system, and water spray shall be confined only to the conveyor belt. In the event the unused portion of the conveyor system is reattached to the operational portion, the automatic control system shall be installed. This control system shall activate water spray when the belt is engaged and shall suspend water spray when belt operation is halted. If the automatic water control system is temporarily out of service (e.g., for system/component failures or component testing), excavation/conveyor operation may continue. However, continuous manual control of all affected spray nozzles is required during conveyor operations until the automatic water control system is operational. Manual operation of the muck conveyor water spray system requires A/E concurrence and shall not exceed 24 hours without Safety Assurance Department concurrence.

[ESFDR 3.2.1.1.2.4.H, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.D, 3.2.1.2.3.E, 3.4.5.3.1.O, 3.4.5.6.1.C, 3.4.5.6.1.D, 3.7.1.2.C, 3.7.2.1.2.E, 3.8.2.6.1.A, 3.8.2.6.1.H, 3.8.2.7.1.E, 3.8.2.7.1.F, 3.8.2.7.1.G]

Requirement 8: The amount of organic material that is to be permanently retained in the TS Loop and associated support areas shall be minimized to the extent practical as follows:

a. The use of permanently retained organics during construction, operation, and maintenance of the TS Loop and associated excavations shall be avoided when practical alternative materials and methods exist.

b. Leakage of organics from construction/operational equipment shall be mitigated and repaired as soon as practical.

c. Spills or releases of organics, powders, solvents, etc., in excess of drips (as in from ruptured hoses, spills from reservoirs, etc.) shall be removed to the extent, and as soon as, practical.

d. Any materials that are spilled (subject to the criteria above) or that are permanently retained in excavations shall be reported in accordance with the TFM Procedure.

e. Periodic maintenance shall be performed on components containing or associated with minimizing the loss of organic materials. The extent (e.g., type of maintenance, which components, etc.) and frequency of maintenance shall be based on manufacturer's recommendations or as approved by the A/E.

Note: Spills that are absorbed by the invert segment need not be removed. If the spilled material is not likely to have penetrated to the tunnel floor or past the invert segment seals, further observations are unnecessary. Invert segments may be removed or observation ports drilled after a spill if necessary to facilitate further visual observation.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.E]

<u>Requirement 9:</u> The following minimum requirements apply to the use of diesel equipment underground:

a. Diesel equipment shall be subject to periodic testing for diesel particulate matter (DPM), sulfur dioxide, oxides of nitrogen, carbon monoxide, and carbon dioxide. Diesel equipment shall be tested before initial use underground, and at a frequency accepted by the A/E thereafter, and checked to be within manufacturer's recommendations for diesel emission constituents of concern (or within standards developed on site in a manner acceptable by the A/E).

b. Diesel exhaust shall be minimized to the extent practical. Controls to minimize diesel emissions shall include minimization of diesel idle time in the tunnel and regularly scheduled maintenance (including maintenance of emissions related systems).

c. Diesel locomotives shall not be used beyond Station 28+05 m or in the ECRB Cross Drift unless exhaust treatment systems have been installed on them that are designed to reduce emissions of DPM.

d. Low sulfur ($\leq$ 0.05 percent) diesel fuel shall be used.

e. Diesel use records shall include as a minimum the documentation of diesel fuel sulfur content, type of engine that consumed the diesel fuel, volume of fuel used, and number of hours of diesel operation underground.

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C]

<u>Requirement 10:</u> QA records shall be made and provided in accordance with the TFM Procedure of all tracers, fluids, and materials that are permanently emplaced/committed (i.e., to remain after closure of the potential repository) to the TS Loop and associated operation and test support areas, including water, wood, hydraulic fluids, fuels, oils, etc., and unrecovered spills, except as specifically exempted in a DIE (e.g., see Section 13.2.28 of this DIE). In addition, QA records shall identify the types of hydraulic and lube oils in TBMs, mechanical excavators, and support equipment used in the TS Loop and associated support areas. [ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.E]

<u>Requirement 11:</u> Large fluid storage systems shall not be placed underground. Large systems are defined as storage tanks or vessels that exceed the volume of normal on-board vehicle fluid reservoirs, not including the sump storage tank, or those volumes within tanks or systems mounted on the TBM, TBM trailing gear, conveyor drives and belt storage units, or rolling stock. [ESFDR 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.E]

Requirement 12: The application of shotcrete in any of the test support areas or TS Loop shall be coordinated with the TCO before its application to assure access for testing. [ESFDR 3.2.1.2.3.B]

Requirement 13: Provisions shall be made for immediate TCO notification if perched water is encountered, as indicated by water flowing from excavated surfaces. [ESFDR 3.2.1.2.3.A, 3.2.1.2.3.D]

Requirement 14: The use of chloride shall be limited as follows:

a. Only non-chloride-based ground enhancing material shall be used.

b. Use of chlorides (including chloride-based concrete and grout accelerators) shall be limited to the extent practical. Their use (other than to chlorinate water/ice used for drinking and hand wash purposes) shall require TCO concurrence, and shall be recorded as a TFM if permanently emplaced/committed.

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B]

Requirement 15: Minimize the potential of leaks from equipment (e.g., rolling stock, mechanical excavators, diesel locomotives, etc.) containing fluids of concern in the tunnel (such as hydraulic fluid, oil, etc.) by the following minimum requirements:

a. Maintenance shall be performed on equipment containing or associated with fluids of concern. The extent (e.g., type of maintenance, which components, etc.) and frequency of maintenance shall be based on manufacturers' recommendations or as approved by the A/E.

b. The constructor shall ensure the operational readiness of equipment containing fluids of concern (with respect to leaks) before using it in the ESF tunnel by checking for leaks.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.E]

Requirement 16: Evaluation of the use of chemical grout injection to stabilize weak ground (including re-evaluation of potential waste isolation and test interference impact) shall be performed before its implementation. [ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.D]

Requirement 17: The field-determined location and timing of construction of test support areas shall be subject to TCO approval. [ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.F]

Requirement 18: Before ESF construction completion (i.e., before turnover for ESF operations), perform an as-built verification of the minimum average slope of the finished drainage surface for at least the first 10 m inside both the North Portal and the South Portal. The average slope shall be greater than or equal to 2 percent, within standard engineering tolerances (there is no maximum slope requirement), for at least the first 10 m upward into both the North Portal and the South Portal. Maintain this length of as-built minimum average 2 percent slope following any maintenance or reconstruction of the finished drainage surface in these sections of the tunnel. [ESFDR 3.2.1.2.3.A, 3.2.1.2.3.D, 3.7.2.2.1.B, 3.7.2.3.1.E]

Requirement 19: The location, construction, and testing associated with testing niches in the TS Loop shall be controlled by imposing the following controls:

a. The final design for location (i.e., centered in a potential repository drift), orientation (at a centerline azimuth of approximately 315 degrees, within standard engineering tolerances), and grade (at approximately 0 percent or slightly positive slope upward from the Main Drift, within standard engineering tolerances) or any changes to the location, orientation, or grade of the niches requires the concurrence of the Repository Subsurface Design Department, the TCO, and CMO prior to the initiation of drilling and/or excavation activities.

b. The planned excavations shall each be limited to a maximum height of five meters and a maximum width of five meters (with these maximum dimensions being approximately centered at the horizontal and vertical midpoints of the planned excavation) to ensure that repository design impacts are minimized. Additional evaluation by the Safety Assurance Department is required to intentionally exceed these limits. However, if inadvertent overbreak due to varying geologic conditions causes the excavated dimensions of the niche to exceed these maximum limits, additional evaluation is not required.

c. The excavation of the niches shall be performed using mechanical excavation equipment only. The TCO shall monitor water use in these niches by ensuring that water committed to the subsurface environment--including construction water used in shotcrete for sealing the niche bulkheads and also water used for geologic mapping, if applicable--does not exceed approximately 19.5 m^3 or about 5150 gallons for each niche. The quantities of dyed testing water to be used for niche testing shall also be counted against the total water limit for these niches.

d. Boreholes associated with niches (for testing, ground support, and utility installation purposes, as applicable) shall be dry-drilled. Furthermore, the use of Swellex rockbolts for ground support associated with niches is prohibited. The use of cementitious material (i.e., grout, shotcrete, etc.) for niche excavation-related ground support shall be deferred until the TCO provides written concurrence, or written notification that testing activities within the niches have been completed.

e. A minimum separation of 300 mm shall be maintained between testing boreholes and niche-related ground support boreholes. Testing boreholes emanating from the TS Main Drift shall be field located by the TCO prior to installation of niche-related ground support in the TS Main Drift.

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C]

The requirements shall be documented, as appropriate, in design analyses, specifications and/or drawings to ensure the requirements are adequately translated to implementing documents. Records generated as a result of QA requirements shall also be maintained as QA records.

13.4 REMOVAL REQUIREMENTS

Non-permanent items shall be removed to the extent practical, before the licensed operation phase of a potential repository. Any incorporation of these items or their constituents into the permanent repository will require a new evaluation as part of the design of permanent items.

13.5 RECOMMENDED CHANGES TO REQUIREMENTS DOCUMENTS

There are no recommended changes to the requirements documents as a result of this revision to the DIE. Recommended changes to the ESFDR based on past revisions of the DIE were previously transmitted to the appropriate requirement document authors and are not repeated in this DIE revision.

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40CFR80.29. *Protection of the Environment.* Controls and Prohibitions on Diesel Fuel Quality. TIC: 241904.

14.3 STANDARDS and PROCEDURES

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15. ATTACHMENTS

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Attachment III	Natural Relative Humidity in the Potential Emplacement Zone
Attachment IV	Comparison of Advective and Diffusive Transport Mechanisms in the Near-Field
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ATTACHMENT I

LIST OF ACRONYMS

(5 PAGES)

ATTACHMENT II

TFMs APPROVED FOR USE IN THE TOPOPAH SPRING LOOP

(8 PAGES)

LIST OF ACRONYMS

A/E	Architect/Engineer
AOD	Access/Observation Drift (part of the Thermal Testing Facility)
CFR	Code of Federal Regulations
CHn	Calico Hills Nonwelded Hydrogeologic Unit
CI	Configuration Item
cm	Centimeter(s)
cm^2	Square Centimeters
CMO	Construction Management Office
CRWMS	Civilian Radioactive Waste Management System
DCS	Data and Control System
DIE	Determination of Importance Evaluation
DOC	Dissolved Organic Carbon
DOE	United States Department of Energy
DOI	United States Department of Interior
DPM	Diesel Particulate Matter
EBS	Engineered Barrier System
ECRB	Enhanced Characterization of the Repository Block
EMI	Electromagnetic Interference
ESF	Exploratory Studies Facility
ESFDR	Exploratory Studies Facility Design Requirements
FWP	Field Work Package

g/m	Grams per Meter
H_2O	Water
$H_2PO_4^-$	Phosphate(s)
IRS	Important to Radiological Safety
ITWI	Important to Waste Isolation
JP	Job Package
kg	Kilogram(s)
LHD	Load Haul Dump
m	Meter(s)
m^2	Square Meters
m^3	Cubic Meters
M&O	Civilian Radioactive Waste Management System Management and Operating Contractor
mm	Millimeters
MPBX	Multi-point Borehole Extensometer
MSDS	Material Safety Data Sheet
NGDFA	Northern Ghost Dance Fault Alcove
NLP	Nevada Line Procedure
NO_3^-	Nitrate(s)
NRC	Nuclear Regulatory Commission
NRG	North Ramp Geologic
NTS	Nevada Test Site
PA	Performance Assessment
PI	Principal Investigator

PMF	Probable Maximum Flood
ppm	Parts per Million
PPV	Peak Particle Velocity
PTn	Paintbrush Nonwelded Hydrogeologic Unit
QA	Quality Assurance
QAP	M&O Quality Assurance Procedure(s)
QARD	Quality Assurance Requirements and Description
RF	Repository Facility
SBT	Surface-Based Testing
SCP	Site Characterization Plan
SD	Systematic Drilling
SF_6	Sulfur Hexafluoride
SGDFA	Southern Ghost Dance Fault Alcove
$SO_4^{=}$	Sulfate(s)
SSC	Structure, System, or Component
Tac	Calico Hills Formation
TBM	Tunnel Boring Machine
TCO	Test Coordination Office
TCw	Tiva Canyon Welded Hydrogeologic Unit
TFM	Tracers, Fluids, and Materials
TIE	Test Interference Evaluation
TM	Thermal/Mechanical
TMA	Thermomechanical Alcove (part of the Thermal Testing Facility)

TPP	Test Planning Package
Tptpln	Topopah Spring Crystal-Poor, Lower Nonlithophysal Lithostratigraphic Unit
Tptpmn	Topopah Spring Crystal-Poor, Middle Lithophysal Lithostratigraphic Unit
Tptpv1	Tertiary, Paintbrush, Topopah Spring, Crystal-poor vitric zone, Nonwelded subzone
Tptpv2	Tertiary, Paintbrush, Topopah Spring, Crystal-poor vitric zone, Moderately welded subzone
Tptpv3	Tertiary, Paintbrush, Topopah Spring, Crystal-poor vitric zone, Densely welded subzone
TS	Topopah Spring
TSPA	Total System Performance Assessment
TSw	Topopah Spring Welded Hydrogeologic Unit
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
TTF	Thermal Testing Facility
TWIEZ	Test and Waste Isolation Evaluation Zone
UE	Underground Exploratory
UO	Undifferentiated Overburden
USGS	United States Geologic Survey
USW	Underground-Southern Nevada-Waste
UZ	Unsaturated Zone
YAP	Yucca Mountain Site Characterization Project Administrative Procedure
YMP	Yucca Mountain Site Characterization Project

ATTACHMENT II

TFMs APPROVED FOR USE IN THE TOPOPAH SPRING LOOP

(7 PAGES)

TFMs APPROVED FOR USE IN THE TOPOPAH SPRING LOOP

General Notes: Any TFMs containing organics that will be permanently retained are subject to DIE Requirement 6. See notes section at the end of this TFM list for other applicable notes, as indicated on individual items in the following lists.

Group 1: Approved for use in accordance with the manufacturer's directions and precautions relative to application, storage, disposal, etc., if applicable.

1 007 - Chemical Sharpener (torch tip cleaner)
2 Aervoe-Pacific Marking Paint
3 American Polywater,SpliceMaster Cable Cleaner Type GX
4 Argon (Noble Gas)
5 Austin Powder Company - Detonating Cord
6 Austin Powder Company - Dynamites Series
7 Austin Powder Company - Emulex 500 and 700 Series
8 Austin Powder Company - Gelatin and Semi-Gelatin Dynamites
9 Austin Powder Company - Shock*Star Tubing
10 Blastoff (for improvement of traction on rails)
11 Brazaloy (welding flux)
12 Burke/EDOCO Acrylic Bondcrete CM-0170
13 Carlon Standard Clear PVC Solvent Cement
14 Citra Scrub Cleaner
15 Clor-D-Tect 1000 (for analysis for chlorinated compounds used in oil)
16 Clor-D-Tect 4000 (for analysis for chlorinated compounds used in oil)
17 Concresive Liquid LPL (Part A and B) (for grouting rails to concrete inverts)
18 Concrete
19 CRC Extreme Duty Silicon
20 Crosslinked Polyethylene Backer Rod
21 Delvo Stabilizer, set retarder admixture for concrete
22 Detacord – 18 grain Detonating Cord
23 Detonation Cord – 200 grain
24 DYNO-Nobel Explosive - K622A
25 DYNO-Nobel IRESPLIT Semi-Gelatin Dynamite
26 DYNO-Nobel UNIGEL Semi-Gelatin Dynamite
27 Ensign-Bickford - K622B

28 Ensign-Bickford PRIMADET Non-Electric Delay Detonator Noiseless Lead-In-Line (NLIL)
29 Ensign-Bickford PRIMADET Non-Electric Delay Detonators (LP) Series
30 Ensign-Bickford PRIMADET Non-Electric Delay Detonators (MS) Series
31 Ensign-Bickford Shock Tube
32 Federal Cartridge Company Small Arms Primers
33 Firedam 150 Caulk
34 FX-250 rapid-setting mortar (powder and liquid)
35 Helium (Noble Gas)
36 ICI Explosives CORDTEX Detonating Cord
37 ICI Explosives EXEL Flexible Plastic Shock Tubes
38 ICI Explosives EXEL Lead-In Line instantaneous detonator
39 ICI Explosives EXEL LP Long Delay Detonator
40 ICI Explosives EXEL MS Short Delay detonator
41 ICI Explosives GELDYNE Semi-Gelatin Dynamite (cartridges)
42 ICI Explosives USA, Inc., "Magnum 65" Detonator Sensitive Emulsion Explosive
43 ICI Explosives USA, Inc., PRIMACORD Detonating Cords
44 ICI Explosives XACTEX Semi-Gelatin Dynamite (cartridges)
45 Iresplit D&D1
46 ITP Standard Backer Rod (including Hot Rod XL)
47 Kit 82-A1 (Scotchcast 4)
48 Kit 82-A2 (Scotchcast 4)
49 Krypton (Noble Gas)
50 LAMTEC Corporation Brand 3035 Facing Material
51 LAMTEC Corporation Brand WMP-30 Facing Material
52 LAMTEC Corporation Brand WMP-F Facing Material
53 Lithium Bromide (LiBr)
54 M28R metal magnetic particle weld-testing powder (iron)
55 MARKAL Paintstik "B" and "B 3/8" markers
56 Masterflow® 928 (for grouting rails to concrete inverts)
57 Midwest Fasteners, Inc., Product Code IHSP spindle fastener
58 Monobath 50-50 (a photographic developer/fixer)
59 Neon (Noble Gas)
60 Nitrogen Gas
61 Nonel Super LP Series Detonator
62 Owens-Corning Fiberglass Duct Wrap
63 Polyheed, cement dispersing agent

64 POWERCORD 60-, 100-, 150-, 200-grain Detonating cords
65 R-12 (Forane), Food Freezant 12
66 Rheobuild 1000, cement dispersing agent
67 Rheobuild 2500, cement dispersing agent
68 Rockbolts
69 Rolled channel arches (steel)
70 Sanford "Mean Streak" Waterproof Marking Sticks
71 Sherwin-Williams Co. KRYLON Interior/Exterior Spray Paint
72 Sikacrete 950, silica-fume admixture for concrete
73 Sikacrete 950DP, densified dry powder microsilica admixture for concrete
74 Sikament 300, water-reducing liquid admixture for concrete
75 SikaTard 902/908/914, set retarder admixture for concrete
76 Silica Flour
77 Stay-Silv 400023 brazing flux
78 Steel
79 Steel lagging
80 Steel sets
81 Sulfur Hexafluoride (SF6)
82 Super Filter Coat No. 412
83 SUVA-COLD MP® (tetra fluoroethane)
84 TD 210 rubber insulating compound
85 Tremproof waterproofing
86 Unigel
87 Weld-Aid Tip Dip - 006 Nozzle Gel
88 White & Wib Hi Performance Acrylic Paint
89 Wil-X Cement
90 Windex glass cleaner - blue
91 Wire mesh
92 Xenon (Noble Gas)

Group 2: **Approved for use subject to special requirements and in accordance with the manufacturer's directions and precautions relative to application, storage, disposal, etc.**

1	1275 Almaplex Industrial Lubricants	1
2	1607 Contact Cleaner	1,2
3	2001 Monolec Wire Rope Lubricant	1
4	3752 Almagard Vari-purpose Lubricant	1
5	3M 1606 Cable Cleaner and Degreaser	1
6	3M FireDam Spray (for sealing the TTF Heated Drift bulkhead	7
7	3M SCOTCH-WELD DP-190 Grey Epoxy Adhesive	7
8	3M Super 77 Spray Adhesive	1
9	605 Almasol Vari-purpose Gear Lubricant	1
10	607 Almasol Vari-purpose Gear Lubricant	1
11	A-55 Clean Fuel	8
12	Air Kontrol Filter Spray	1
13	Ansul "Foray" dry chemical fire suppression agent	4
14	Aqua Resin Clear with and without dye	1
15	AS-43 Anti-slip Non-skid Surface Coating (for use in the TTF)	7
16	ATF Dextron (automatic transmission fluid)	1
17	Bortz Paint Thinner	1
18	Burke Non-Ferrous, Non-Shrink Grout	6
19	Burrell Fibercrete	3
20	Burrell Shotcrete	3
21	Butyl rubber adhesive	7
22	CC-2 Preparation Kit (Cable Cleaner)	1
23	Chevron Soluble Oil HD (Machining Oil)	1
24	Chevron Special LS Diesel Fuel	8
25	Chlorides	5
26	Citgo C-500 Motor Oil, SAE 30	1
27	Citra Spray Paint Numbers 2124, 2125, 2133, 2137, 2143, 2148, 2155, 2156, 2163, 2169, 2171, 2175, 2178, 2182, 2183, 2187, 2190, and 2192	1
28	CITRIKLEEN (parts cleaner/degreaser)	1
29	Copper Sulfate (must be retained within reference electrodes)	
30	Cotronics epoxy resin w/ hardeners	7
31	Cotronics two component ceramic adhesive w/ thinners and hardeners	7
32	CRC Moly Lube	1

33	CRC Quick Clean	1
34	Cresset Crete-Lease 727 release agent	7
35	DB-Series Oil	1
36	Devcon Sure Shot Super Epoxy Resin and Hardener	7
37	Devguard Industrial Gloss Enamel	7
38	Devguard Tank and Structural Primer	7
39	Diesel Fuel	8
40	Dow Corning 4 electrical insulating compound	7
41	Dow Corning plastic adhesive 739	7
42	Drive Train Fluid HD SAE 30	1
43	Drive Train Fluid HD SAE 50	1
44	Dura-Lith Grease EP NLGI 2	1
45	Ensign-Bickford PRIMADET non-electric detonators and lead-in lines	5
46	Epple 28 sealant	1
47	EPY500 Part A and EPY500 Part B - two part epoxy	7
48	EZ Mud Shale Stabilizer and Viscosifier (used inside SEAMIST liner)	7
49	FE-36 fire suppressant agent	4
50	Fiske Brothers Refining Co. Fiske No. 35 Soluble Oil (cutting oil)	1
51	Flowcable, powder admixture for cement grout	6
52	FM-200 (fire suppressant inside building at end of TTF AOD)	4
53	Foster 36-10, Weatherite Mastic (roof sealant)	1
54	FP-1517 Comp. A and B - Two Part Epoxy	7
55	FR-40 Fire Retardant Material (wood treatment)	4,7
56	GE Silocones Silicone Rubber Compounds SILOGLAZE 2800/2900, SILGLAZE-II	7
57	Gear Compound EP ISO 220	1
58	Gear Compound EP ISO 320	1
59	GEM®	4
60	Greenlee-Textron Blue Gel Cable Pulling Compound	1
61	HILTI (CF 128) Filler Foam	7
62	HPS Shotcrete Accelerator	3
63	Hydraulic Oil AW ISO 46	1
64	ICI Explosives POWERsplit Detonator Sensitive Slurry Explosive (cartridges)	5
65	ITW-Philadelphia Resins Corp. Ramset EPCON System Hardener Ceramic 6 formula	1
66	ITW-Philadelphia Resins Corp. Ramset EPCON System Resin Ceramic 6 formula	1
67	John Deere & Company Hy-Gard Transmission and Hydraulic Oil	1
68	Litton/Kester flux-cored solder wire	1
69	Lubrication Engineers 9200 Almasol Dry Film Lubricant	1

70	Lubrication Engineers, Inc., 608 Almagard Vari-Purpose Gear Lubricant	1
71	Macklanburg-Duncan POLYCEL Expanding Foam	7
72	Master Builder MicroAir - air entraining agent	7
73	Matheson Gas Products POLY-ETCH Active Sodium Solution	7
74	MB-QSL 100, liquid shotcrete accelerator	3
75	MB-SF, accelerator, silica-fume mineral admixture for concrete, shotcrete	3
76	Mearlcrete Cellular Concrete	3,4
77	Meyco Rockbolt and Anchor Grout, cement grout	6
78	Mollub-Alloy 777-2 lubrication grease	1
79	Monoammonium phosphate dry chemical fire suppression agent	4
80	National Floor Sweep	7
81	Non-Ferrous Shrink Grout No. CM-0010	6
82	Option 1 (Relton) (water based metal working fluid)	1
83	Para-Chem Southern, Inc. Kraloy PVC Pipe Cement	1
84	Pot-Pouri solution, in portable toilet units	1
85	Potato Starch (Organic Developer)	7
86	Rawlplug Co. Chem-stud Anchor Capsules	1
87	Rectorseal Corp. HURRICANE HOMER PVC Solvent Cement	5,7
88	Resbond 907GF-6 Adhesive	7
89	RPM Heavy Duty Motor Oil SAE 15W-40	1
90	RPM Universal Gear Lube SAE 80W-90	1
91	RPM Universal Gear Lube SAE 85W-140	1
92	Rust-Oleum paint, aerosol	1
93	S5Z Wil-X Cement Grout (B)	6
94	SAE 90, Chevron RPM Gear Oil (transmission oil)	1
95	Safety Kleen Corp. Safety-Kleen #6638 Premium Gold Solvent	1
96	Scotch Brand 1602 Insulating Sealer (red)	1
97	Scotchcast Brand Flame Retardant Compound	1
98	Scotchkote Brand Electrical Coating	1
99	Seymore Marking Paint, 16-657	1
100	Shellzone (R) All Season Antifreeze (ethylene and diethylene glycol)	1
101	Sigunit L20 Liquid, shotcrete set accelerator	3
102	Sigunit NC Liquid, shotcrete set accelerator	3
103	Sigunit Powder, shotcrete set accelerator	3
104	SikaTell 100, liquid shotcrete admixture	3
105	SikaTell 200, liquid shotcrete admixture	3

106	Silli-Soda-Crete Grout (including Type I/II cement, sodium silicate, and Pozzolith 100-XR dispersing agent)	6
107	Sodium Hypochlorite (Organic Developer)	7
108	Stay-Clean 40028 (Lead Free) soldering flux	1,2
109	Styrofoam	4,7
110	SUNISO 3GS, viscosity=150 (specially refined oil for air conditioning compressors)	1
111	Tactoo GPA-72 hi-temp construction adhesive	7
112	Tempil 2500 white paint (for painting the TTF Heated Drift bulkhead)	7
113	Thermo Trap	7
114	Type HP Cleaner/Degreaser	1
115	United Duct Sealer	1
116	Water (Non-potable and Chlorinated)	9
117	WELD-ON P-70 Primer for PVC and CPVC plastic pipe	7
118	Wood	4

NOTES:

1. These materials have decomposition or combustion products that have the potential to interfere with site characterization testing (i.e., chlorine and carbon). Limiting storage underground or storing in fireproof cabinets are conventional practices that can be used to address this concern. Refer to DIE Requirement 8 for QA controls.

2. These materials react with water to form products such as hydrochloric acid and acetic acid. Hydrochloric acid could bias Chlorine-36 measurements. Limiting storage underground or storing in such a way as to limit contact with water are conventional practices that can be used to address this concern. Refer to DIE Requirement 8 for QA controls.

3. Refer to DIE Requirement 12 for limits or constraints.

4. Refer to DIE Requirement 8 for limits or constraints.

5. The use of any materials containing chloride in the TS Loop shall require TCO concurrence, with the exception of chlorinated water/ice used for drinking and hand wash purposes (see DIE Requirement 14).

6. Refer to DIE Requirement 6 for limits or constraints.

7. Remove these materials to the extent practical upon completion of testing/activity.

8. Refer to DIE Requirements 8, 9, 10, and 11 for limits or constraints.

9. Refer to DIE Requirements 2, 7, 10, and 11 for limits or constraints.

ATTACHMENT III

NATURAL RELATIVE HUMIDITY IN THE POTENTIAL EMPLACEMENT ZONE

(3 PAGES)

NATURAL RELATIVE HUMIDITY IN THE POTENTIAL EMPLACEMENT ZONE

The relationship between relative humidity and water pressure is given by (Marshall and Holmes 1979, p. 73),

$$RH = \exp\left\{ -\frac{M_{H2O}\, g\, \psi}{R\, T} \right\} \qquad \text{(III-1)}$$

where

$R \equiv$ universal gas constant
$M_{H2O} \equiv$ molecular weight of H_2O
$T \equiv$ absolute temperature
$p_v \equiv$ water vapor pressure
$p_{vs} \equiv$ saturated water vapor pressure
$p_w \equiv$ water pressure
$\rho_w \equiv$ water density
$g \equiv$ gravitational acceleration

$$\psi \equiv \text{water pressure head} = \frac{-p_w}{\rho_w\, g}$$

$$RH \equiv \text{relative humidity} = \frac{p_v}{p_{vs}}$$

The pressure head for an unsaturated porous system may be modeled using the empirical van Genuchten relationship (van Genuchten 1980, pp. 892-898),

$$\psi(S_n) = \frac{1}{\alpha}\left\{ S_n^{\frac{\beta}{1-\beta}} - 1 \right\}^{\frac{1}{\beta}} \qquad \text{(III-2)}$$

where

$S_n \equiv$ normalized water saturation
$\alpha \equiv$ pressure head scale factor, units of inverse length
$\beta \equiv$ pressure head shape parameter, dimensionless

and

$$S_n = \frac{S_w - S_r}{1 - S_r} \qquad \text{(III-3)}$$

where

$S_W \equiv$ water saturation
$S_r \equiv$ residual water saturation

Equations (III-1), (III-2) and (III-3) may be used to estimate *RH* for the potential emplacement level, which is currently expected in the Tptpln lithologic unit (CRWMS M&O 1996ac). The values of α, β, S_r, and the ambient value of S_W for the Tptpln lithologic unit (CRWMS M&O 1996ac, p. 13) are:

$\alpha = 0.0073\ m^{-1}$
$\beta = 1.748$
$S_r = 0.05$
$S_W = 0.74$

With these values, the ambient pressure head, ψ, of water may be calculated for the potential waste emplacement zone using equation (III-2),

$$\psi = 145.5\ \text{m}$$

The following values may be used to evaluate equation (III-1) (Houghton 1977, p. 164):

$R = 8.3143\ J\ K^{-1}\ mol^{-1}$
$g = 9.81\ m\ sec^{-2}$
$M_{H2O} = 0.018\ kg\ mol^{-1}$

and the underground temperature (Fischer 1997) is approximately,

$$T = 23.5°\ C = 296.7°\ K$$

using these values in equation (III-1) gives for the relative humidity,

$$RH = 0.990.$$

ATTACHMENT IV

COMPARISON OF ADVECTIVE AND DIFFUSIVE TRANSPORT MECHANISMS IN THE NEAR-FIELD

(6 PAGES)

COMPARISON OF ADVECTIVE AND DIFFUSIVE TRANSPORT MECHANISMS IN THE NEAR-FIELD

The near-field, as used in this discussion, refers to the native rock within about 7.6 m (or about one ESF tunnel diameter) of the potential repository waste emplacement drifts. Potential waste emplacement drifts are assumed to lie a minimum of 37 m from the ESF (see Section 9.2). The current conceptual repository design locates waste emplacement drifts at the same elevation as the ESF in the primary emplacement area west of the ESF and at an elevation that is about 100 m below the ESF in the optional emplacement area to the east of the ESF. Due to the uncertainties in the conceptual repository design, however, the relative elevation of the waste emplacement drifts with respect to the ESF is not assumed to be fixed because further scientific analysis, performance assessment, and engineering design may alter the current conceptual design for waste emplacement. Therefore, water movement from the ESF to potential waste emplacement locations is assumed to be possible.

Water that enters the geosphere from the ESF will either migrate relatively quickly through fractures to elevations below potential emplacement areas, slowly migrate through the rock matrix at or near the potential repository elevations, or flow through some combination of these two flow paths. Water that enters and remains in the fractures, however is assumed to migrate to lower lithologic units, perched water bodies, or the saturated zone prior to potential waste emplacement. Water films along fracture surfaces may be slow to drain, however this water is expected to be absorbed into the rock matrix. Therefore, only water that enters the rock matrix is expected to have the opportunity to interact with the near-field potential repository environment.

Radionuclides released from waste packages will migrate to the near-field geosphere through an EBS material that supports waste packages into the surrounding rock. The material that may be used as part of the EBS to support the waste packages has not been selected, however, crushed tuff and concrete have been proposed. Diffusive transport is assumed to be analogous in the rock matrix and EBS because molecular diffusion rates appear to be independent of the material (CRWMS M&O 1995h, p. 6-24), only dependent on the volumetric water content of the material. Advective transport in the EBS is expected to be driven by the local fracture and matrix advective transport processes. Fracture flow in the near-field is expected to be independent of local increases in matrix saturation near potential waste emplacement locations.

Radionuclides that escape the EBS will either enter the surrounding rock matrix or fractures through aqueous or gas-phase transport mechanisms. Of the many different types of radionuclides contained in the waste, only three may have significant movement in the gas-phase. However, the introduction of water through ESF activities could only increase water saturation (decrease gas saturation), which would reduce gas-phase transport via advection or diffusion. Therefore, the influence of ESF water discharge on gas-phase processes is not considered further.

Under the current hydrologic conditions, the fractures are expected to be relatively non-conductive to water except for transient infiltration events that move through fractures (CRWMS M&O 1995h, p. 7-7). Radionuclides dissolved in the aqueous phase may enter the geosphere directly through fractures if fracture flow directly intercepts waste emplacement areas. However, the water saturation in the rock matrix immediately surrounding potential emplacement drifts (near-field) is expected to have a negligible effect on much larger-scale transient flow events through fractures into emplacement drifts. Therefore, the primary effect of increased water saturation in the near-field environment is on aqueous radionuclide transport through the rock matrix.

Fracture spacing in the Tptpln averages 0.74 m (CRWMS M&O 1996ac, p. 13). Therefore, radionuclide transport over distances on the order of one m could be important if radionuclides enter the matrix locally but are transported through the far-field unsaturated zone primarily via fracture flow.

The remainder of this Attachment concerns the relative magnitudes of advective and diffusive transport through the Tptpln rock matrix over distances of one m.

Aqueous radionuclides that enter the rock matrix in the near-field can move to fractures through a combination of two transport mechanisms: bulk flow (advection) and molecular diffusion. Measurements using a wide variety of materials over a broad range of volumetric water contents suggest that the bulk effective diffusion coefficient, D_e, for an unretarded, dilute, dissolved constituent is primarily a function of the fractional volumetric water content, θ. These measurements have been analyzed and reduced to the following functional relationship (CRWMS M&O 1995h, p. 6-24):

$$D_e(\theta) = \theta \ 10^{[1.898 \log(100\theta) - 8.255]} \qquad \text{(IV-1)}$$

where D_e is given in units of square centimeters per second (cm^2/sec). Simplifying equation (IV-1) and converting the units of D_e to square meters per second (m^2/sec) gives:

$$D_e(\theta) = 3.47536 \times 10^{-9} \ (\theta)^{2.898} \qquad \text{(IV-2)}$$

The volumetric water content, θ, may be expressed in terms of the porosity, ϕ, and the water saturation, S_w:

$$\theta = \phi \ S_w \qquad \text{(IV-3)}$$

For the Tptpln, the average value of ϕ for the rock matrix is found to be 0.13 (CRWMS M&O 1996ac, p. 13), giving

$$\theta = 0.13 \ S_w \qquad \text{(IV-4)}$$

Using equation (IV-4), equation (IV-2) may be given as the following function of the micropore saturation:

$$D_e(S_w) = 9.4017 \times 10^{-12} \ S_w^{2.898} \qquad \text{(IV-5)}$$

An estimate for the travel time for diffusive transport, T_D, over a length scale associated with the fracture spacing, L_{FS}, is (Fischer et al. 1979, p. 13),

$$T_D = \frac{L_{FS}^2}{D_e(S_w)} \qquad \text{(IV-6)}$$

The effective hydraulic conductivity, K_e for unsaturated flow of water may be represented using

$$K_e\,(S_n) = K_s \ S_n^{1/2} \left(1 - \left(1 - S_n^{\frac{\beta}{\beta-1}}\right)^{1-\frac{1}{\beta}}\right)^2 \qquad \text{(IV-7)}$$

the following relationship with normalized, fractional water saturation, S_n (van Genuchten 1980):

where K_s is the saturated hydraulic conductivity, β is the shape factor, and S_n is given by:

$$S_n = \frac{S_w - S_r}{1 - S_r} \qquad \text{(IV-8)}$$

where S_r is the residual water saturation. For the Tptpln, the following average values have been computed from available measurements (CRWMS M&O 1996ac, p. 13), $K_s = 1.87 \times 10^{-11}$ m/s, $\beta = 1.748$, and $S_r = 0.05$. Using these values, the expression for K_e becomes:

$$K_e(S_w) = 1.91858 \times 10^{-11} (S_w - 0.05)^{1/2} (1 - (1 - 1.12737 (S_w - 0.05)^{2.33726})^{0.42785})^2 \qquad \text{(IV-9)}$$

The advective flux of water per unit area, q_A, may be estimated using Darcy's law,

$$q_A(S_w) = -K_e(S_w) \nabla \left(\frac{p_c(S_w)}{\rho_w g} - z \right) \qquad \text{(IV-10)}$$

The maximum water flux, q_A, under an equilibrated saturation distribution (spatially uniform saturation) is given by:

$$q_A(S_w) \approx K_e(S_w) \qquad \text{(IV-11)}$$

The advective velocity for transport is then estimated using,

$$V_A \approx \frac{K_e(S_w)}{\phi\, S_w} \qquad \text{(IV-12)}$$

An estimate of the travel time for advective transport, T_A, over a length scale associated with the fracture spacing, L_{FS}, is

$$T_A = \frac{\phi\, S_w\, L_{FS}}{K_e(S_w)} \qquad \text{(IV-13)}$$

The ratio of advective to diffusive travel times, T_A/T_D may be computed using equations (IV-6) and (IV-13), giving:

$$\frac{T_A}{T_D} \approx \frac{\phi \ S_w \ D_e \ (S_w)}{K_e (S_w) \ L_{FS}} \qquad \text{(IV-14)}$$

This ratio may be used to indicate which, if either, transport mechanism may dominate the movement of radionuclides through the near-field rock matrix. A large value of the ratio (>> 1) indicates diffusive dominated transport, while a small value for the ratio (<< 1) indicates advective dominated transport. For computations using this ratio, assume that L_{FS} is one m. The ratio is found to range from about 0.4 to 0.06 over a saturation range of 0.74 to 1. Given the approximate treatment of the transport expressions, the ratio does not conclusively identify either transport mechanism as dominant. Therefore, the sensitivity of both advection and diffusion to water saturation must be considered.

ATTACHMENT V

NATURAL VARIABILITY IN THE NEAR-FIELD AQUEOUS DIFFUSIVE TRANSPORT POTENTIAL UNDER AMBIENT CONDITIONS RELATIVE TO AVERAGE AQUEOUS DIFFUSIVE TRANSPORT POTENTIAL UNDER ELEVATED SATURATION CONDITIONS

(8 PAGES)

NATURAL VARIABILITY IN THE NEAR-FIELD AQUEOUS DIFFUSIVE TRANSPORT POTENTIAL UNDER AMBIENT CONDITIONS RELATIVE TO AVERAGE AQUEOUS DIFFUSIVE TRANSPORT POTENTIAL UNDER ELEVATED SATURATION CONDITIONS

As described in Attachment IV, the aqueous diffusive travel time, T_D, is inversely proportional to the bulk diffusion coefficient, D_e:

$$T_D \approx \frac{L_{FS}^2}{D_e(\theta)} \quad \text{(V-1)}$$

where θ is the volumetric water content (fraction of the bulk volume occupied by water) and L_{FS} is the fracture spacing. The fracture spacing was argued to be the relevant transport distance to assess changes to the potential repository performance in the near-field. The expression for D_e, in units of cm²/sec, as a function of water content is (CRWMS M&O 1995h, p. 6-24):

$$D_e(\theta) = \theta \; 10^{[1.898 \log(100\theta) - 8.255]} \quad \text{(V-2)}$$

An analysis of the experimental data for aqueous diffusion coefficients in geologic materials found that the mathematical expression for D_e, including its variability, at a given water content could be represented by the following (CRWMS M&O 1995h):

$$D_e(\theta) = \theta \; 10^{[b \log(100\theta) + a + \varepsilon]} \quad \text{(V-3)}$$

where (Atkins 1996)

$$a = -8.255 + 0.04997 \, g_{rn1}$$

$$b = 1.897 - 0.04153 \, g_{rn1} + 0.02075 \, g_{rn2} \quad \text{(V-4)}$$

$$\varepsilon = 0.296 \; g_{rn3}$$

and g_{rni} are standard Gaussian random numbers.

The variability in water content in the Tptpln is estimated from the average and standard deviation for water content in this geologic unit given in CRWMS M&O 1996ac. Because water content is a measurement that is physically restricted to lie between 0 and 1, the probability distribution of these values are assumed to be represented by the beta distribution. The beta distribution, a two-parameter distribution with a minimum of 0 and maximum of 1, is written in the form:

$$p_d(x;\gamma,\omega) = \frac{1}{B(\gamma,\omega)} x^{(\gamma-1)} (1-x)^{(\omega-1)} \qquad \text{(V-5)}$$

where p_d is the probability density at the value of x, γ and ω are parameters, and $B(\gamma,\omega)$ is a normalizing factor such that the integral of p_d over the entire range of x (from 0 to 1) is equal to 1. The average and variance of the distribution is given by the following (Abramowitz and Stegun 1972, p. 930):

$$\text{mean} \equiv \mu_{bd} = \frac{\gamma}{\gamma+\omega} \qquad \text{(V-6)}$$

$$\text{variance} \equiv \sigma_{bd}^2 = \frac{\gamma\,\omega}{(\gamma+\omega)^2\,(\gamma+\omega+1)} \qquad \text{(V-7)}$$

The parameters γ and ω are calculated from equations (V-6) and (V-7) given known values for the mean and variance. The mean and variance for water content in the Tptpln geologic unit may be estimated from the measured values of water content given in CRWMS M&O 1996ac. The mean and variance for these data are $\mu_{bd} = 0.095115$ and $\sigma_{bd}^2 = 0.0014078$, respectively. Using these values for μ_{bd} and σ_{bd}^2, we find $\gamma = 5.7201$ and $\omega = 54.418$. A similar calculation may be done for the porosity, ϕ. The mean and variance for the porosity in the Tptpln geologic unit given in CRWMS M&O 1996ac are $\mu_{bd} = 0.12714$ and $\sigma_{bd}^2 = 0.0018713$, respectively. Using these values, we find $\gamma = 7.4132$ and $\omega = 50.894$ for porosity. The porosity will be used here to calculate the statistical properties of diffusive travel time under saturated conditions. The values are summarized in Table V-1.

A method to compute random values of the water content, θ, may be derived from the cumulative probability integral:

$$P(\theta;\gamma,\omega)=\int_0^{\theta}\frac{1}{B(\gamma,\omega)}\,x^{(\gamma-1)}\,(1-x)^{(\omega-1)}\,dx \qquad \text{(V-8)}$$

Numerical values for this integral may be computed using the following series expansion for *P* (Abramowitz and Stegun 1972, p. 944):

$$P(\theta;\gamma,\omega)=\frac{\theta^{\gamma}(1-\theta)^{\omega}}{\gamma\,B(\gamma,\omega)}\left\{1+\sum_{n=0}^{\infty}\frac{B(\gamma+1,n+1)}{B(\gamma+\omega,n+1)}(\theta)^{n+1}\right\} \qquad \text{(V-9)}$$

The series converges faster for smaller values of θ. For larger values of θ, the following relationship is used (Abramowitz and Stegun 1972, p. 944):

$$P(\theta;\gamma,\omega)=1-P(1-\theta;\omega,\gamma) \qquad \text{(V-10)}$$

Therefore, for θ greater than 0.5, the following series converges more rapidly than equation (V-9):

$$P(\theta;\gamma,\omega)=1-\frac{\theta^{\omega}(1-\theta)^{\gamma}}{\omega\,B(\omega,\gamma)}\left\{1+\sum_{n=0}^{\infty}\frac{B(\omega+1,n+1)}{B(\gamma+\omega,n+1)}(1-\theta)^{n+1}\right\} \qquad \text{(V-11)}$$

The function denoted by *B* is given by the following relationship (Abramowitz and Stegun 1972, p. 258):

$$B(\gamma,\omega)=\frac{\Gamma(\gamma)\,\Gamma(\omega)}{\Gamma(\gamma+\omega)} \qquad \text{(V-12)}$$

where Γ is the gamma function defined by (Abramowitz and Stegun 1972, p. 255)

$$\Gamma(z)=\int_0^\infty t^{z-1}e^{-t}\,dt \qquad \text{(V-13)}$$

Numerical evaluation of the gamma function is performed using the following polynomial approximation (Abramowitz and Stegun 1972, p. 257)

$$\Gamma(z)=\sum_{n=0}^{8} b_n(z-1)^n \qquad \text{(V-14)}$$

where $b_0 = 1$ and the other values of b_n are given in Abramowitz and Stegun 1972, p. 257. The maximum error quoted for this approximation to the gamma function is 3×10^{-7}.

Practical computations of the infinite series expressions in equations (V-9) and (V-11) require truncation of the series at some finite number of terms. A comparison with tabular values is possible using the following relationship (Abramowitz and Stegun 1972, p. 945):

$$Q(F_P|2\omega,2\gamma)=P(\theta;\gamma,\omega) \qquad \text{(V-15)}$$

where

$$\theta=\frac{\gamma}{\gamma+\omega F_P} \qquad \text{(V-16)}$$

Because tabular values of Q are limited to the range of 0.001 to 0.5, the following additional relationship is needed:

$$Q(F_{1-P}|2\gamma,2\omega)=1-Q(F_P|2\omega,2\gamma) \qquad \text{(V-17)}$$

where F_P and F_{1-P} denote the values of F for cumulative probabilities of P and 1-P, respectively. Therefore, using equations (V-10) and (V-15), equation (V-17) becomes:

$$Q(F_{1-P}|2\gamma,2\omega)=P(1-\theta;\omega,\gamma) \qquad \text{(V-18)}$$

with the corresponding relationship for equation (V-16) being,

$$1-\theta = \frac{\omega}{\omega + \gamma\, F_{1-P}} \qquad \text{(V-19)}$$

or, solving equation (V-19) for θ gives,

$$\theta = \frac{\gamma\, F_{1-P}}{\omega + \gamma\, F_{1-P}} \qquad \text{(V-20)}$$

Therefore, values of θ interpolated from values generated by the series expansions in equations (V-9) and (V-11) may be compared with tabular results using equations (V-18) and (V-20). For example, given values of γ and ω and setting the cumulative probability, $P(\theta;\gamma,\omega) = 0.999$, and therefore, $P(1-\theta;\omega,\gamma) = 0.001$, tables for Q may be used to determine F_{1-P}, which, using equation (V-20), may be used to determine θ. Computations using equations (V-9) and (V-11) were carried out for 1001 values of θ and φ between 0 and 1 at intervals of 0.001. The value of θ or φ at some particular value of cumulative probability was linearly interpolated from these values. Comparison calculations for porosity and water content are given below for a cumulative probability of 0.999.

Comparison for $Q = P =$ 0.999.	γ	ω	F_{1-P} interpolated from Table 26.9 in Abramowitz and Stegun 1972	θ from equation (V-20)	θ series expansion - equation (V-9)
Water Content	5.7201	54.418	3.149	0.24869	0.24581
Porosity	7.4132	50.894	2.885	0.29589	0.29302

The above comparison indicates that 110 terms in the series gives values for θ and φ with relative errors of about 1.2 percent and 0.97 percent, respectively. The nature of the series expansion guarantees that smaller values of θ will give even more accurate results. Therefore 110 terms in the expansion provides sufficiently accurate values of θ and φ.

The distribution of the cumulative probability, *P*, is uniform over the range 0 to 1. Uniform pseudorandom numbers are generated using a commercially available software routine. The software used is a multiplicative congruential generator called RND included in the Lahey Fortran Compiler, F77L-EM/32 FORTRAN 77 Version 5.01 for the 80386/80486; (Copyright© 1988-1992, Lahey Computer Systems, Inc.). The generator produces values between 0.0 and 1.0 and has a fixed period of 2^{38}.

The mean and variance of the ambient aqueous diffusion coefficient are estimated by generating a sequence of random values of the aqueous diffusion coefficient based on equations (V-3) and (V-4) for the diffusion coefficient, equations (V-9), (V-10), and (V-11) for the water content, and the Lahey Compiler uniform pseudorandom number generator, RND. For saturated conditions, the random values of the water content are generated using equations (V-9), (V-10), and (V-11) for the porosity. The resulting diffusive travel time is then computed using equation (V-1) with a fracture spacing of one m. The travel times are treated as a log-normal distribution and reported in terms of the geometric mean and standard deviation. The values given in Table V-1 indicate that, for 1,000,000 samples, the geometric mean travel time at ambient conditions is about 10,600 years and the one-sigma value below the mean is about 2,640 years. The geometric mean travel time for 1,000,000 samples under saturated conditions is 4,290 years. Therefore, the change in the average diffusive travel time due to complete saturation of the matrix lies within one-standard deviation of the mean diffusive travel time under ambient conditions. These values indicate the relatively broad variability of the aqueous diffusive travel time under ambient conditions in comparison with the changes in the mean aqueous diffusive travel time resulting from an increase in water saturation from ambient levels to near-saturated conditions. Therefore, it is expected that near-field diffusion of aqueous radionuclides will not be noticeably influenced by local saturation increases from existing conditions.

Table V-1

Statistical Parameters:

	μ_{bd}	σ_{bd}^2	Υ	ω
Water Content	0.095115	0.0014078	5.7201	54.418
Porosity	0.12714	0.0018713	7.4132	50.894

Table V-2

Statistical Results

Ambient Conditions:

number of random samples	geometric mean travel time (years)	geometric standard deviation	travel time one standard deviation below the mean (years)
10,000	10,700	4.04	2,640
100,000	10,600	4.02	2,630
1,000,000	10,600	4.01	2,640

Saturated Conditions:

number of random samples	geometric mean travel time (years)
10,000	4,320
100,000	4,290
1,000,000	4,290

ATTACHMENT VI

NATURAL VARIABILITY IN THE NEAR-FIELD AQUEOUS ADVECTIVE TRANSPORT POTENTIAL UNDER AMBIENT CONDITIONS RELATIVE TO AVERAGE AQUEOUS ADVECTIVE TRANSPORT POTENTIAL UNDER ELEVATED SATURATION CONDITIONS

(9 PAGES)

NATURAL VARIABILITY IN THE NEAR-FIELD AQUEOUS ADVECTIVE TRANSPORT POTENTIAL UNDER AMBIENT CONDITIONS RELATIVE TO AVERAGE AQUEOUS ADVECTIVE TRANSPORT POTENTIAL UNDER ELEVATED SATURATION CONDITIONS

As described in Attachment IV, the aqueous advective travel time, T_A, is inversely proportional to the effective hydraulic conductivity, K_e:

$$T_A \approx \frac{\phi \, S_w \, L_{FS}}{K_e \, (S_w)} \tag{VI-1}$$

where S_n is the normalized water saturation, S_w is the water saturation (fraction of the pore volume occupied by water) and S_r is the residual water saturation. The natural variation in advective flux potential may be attributed to variations in K_e.

The expression for K_e, given by equation (IV-7), is

$$K_e \, (S_n) = K_s \, S_n^{\frac{1}{2}} \left(1 - \left(1 - S_n^{\frac{\beta}{\beta - 1}} \right)^{1 - \frac{1}{\beta}} \right)^2 \tag{VI-2}$$

where

$$S_n = \frac{S_w - S_r}{1 - S_r} \tag{VI-3}$$

and K_s is the saturated hydraulic conductivity and β is the van Genuchten shape factor (van Genuchten 1980). The variability in advective water flux depends on the variability of K_s, β, S_r, and (for ambient conditions) S. The variability in these values may be estimated from the mean and standard deviations of measurements given in CRWMS M&O 1996ac. K_s and β have a semi-infinite range, whereas S_r and S are limited to values between 0 and 1. The log-normal distribution is used to represent the probability density function for parameters with a semi-infinite range and the beta distribution is used to represent the probability density function for parameters with a finite range. The beta distribution is discussed in detail in Attachment V. The mean and variance for S and S_r and their translation into parameters for the beta distribution are given in Table VI-1. The series expansions used in Attachment V were implemented for S and S_r

using 150 terms. As done in Attachment V, computations using equations (V-9) and (V-11) were carried out for 1001 values of S and S_r between 0 and 1 at intervals of 0.001. The value of S or S_r at some particular value of cumulative probability was linearly interpolated from these values. A check on the accuracy of these calculations may be done as described in Attachment V. The following table gives the results of this comparison:

Comparison for $Q = P =$ 0.999	Y	ω	F_{1-P} interpolated from Table 26.9 in Abramowitz and Stegun 1972	S_r from equation (V-20)	S_r series expansion - equation (V-9)
Residual Water Saturation	0.65304	12.439	12.471	0.39567	0.31163

The large relative error found here for the residual saturation, about 21 percent, is thought to be due to interpolation over values of F_{1-P} tabulated in Abramowitz and Stegun 1972 that have a coarse spacing for this range of parameters. The tabulated values have a finer spacing for these parameters given a cumulative probability of 0.95.

Comparison for $Q = P =$ 0.95	Y	ω	F_{1-P} interpolated from Table 26.9 in Abramowitz and Stegun 1972	S_r from equation (V-20)	S_r series expansion - equation (V-9)
Residual Water Saturation	0.65304	12.439	3.982	0.17291	0.16603

At the 0.95 cumulative probability level, better agreement is found, with a relative error of about 4 percent. Therefore the large relative error found for the 0.999 cumulative probability level is believed to be due to inaccuracies introduced by the coarse spacing of the tabulated values in Abramowitz and Stegun 1972.

Comparison for $Q = P = 0.5$	γ	ω	F_P interpolated from Table 26.9 in Abramowitz and Stegun 1972	S from equation (V-16)	S series expansion - equation (V-9)
Water Saturation	5.6975	2.0032	0.89124	0.76141	0.76136

The water saturation values are found to compare quite favorably between saturations computed from tabulated values and the series expansion. The relative error in this case is only 0.0066 percent.

Comparison for $Q = P = 0.999$	γ	ω	F_{1-P} interpolated from Table 26.9 in Abramowitz and Stegun 1972	S from equation (V-20)	S series expansion - equation (V-11)
Water Saturation	5.6975	2.0032	47.515	0.99265	0.99265

The comparison is still good for a cumulative probability of 0.999, having a relative error of less than 0.001 percent.

Values of ambient saturation and residual saturation are sampled independently, because there is no information available to determine if a correlation may exist. Both distributions span the entire range of 0 to 1, although the shapes of the two probability density distributions will generally lead to a random value of S_w that is larger than the value of S_r. However, it is possible to select a value of S_r that is larger than S_w, which is not reasonable for the ambient system.

Therefore, if the random number generation sequence does generate a value of S_r that is larger than the value of S_w, the value of S_r is regenerated using a new random number until the ordering $S_w < S_r$ is obtained.

The saturated hydraulic conductivity, K_s, and the shape factor, β, both have a semi-infinite range. Lacking specific information on their total distributions, these parameters are modeled using a log-normal distribution, given by

$$p_d(x;\mu_g,\sigma_g)=\frac{1}{\sqrt{2\pi}\,x\ln\sigma_g}\exp\left\{\frac{-(\ln x-\ln\mu_g)^2}{2(\ln\sigma_g)^2}\right\} \qquad \text{(VI-4)}$$

where μ_g and σ_g are the geometric mean and geometric standard deviation, respectively (Bickel and Doksum 1977). This is equivalent to a Gaussian probability density function for $\ln x$, having a mean of $\ln \mu_g$ and a standard deviation of $\ln \sigma_g$. If we let

$$g_{rn}=\frac{\ln x-\ln\mu_g}{\ln\sigma_g} \qquad \text{(VI-5)}$$

then the probability density function may be written as

$$p_d(g_{rn})=\frac{1}{\sqrt{2\pi}}\exp\left\{\frac{-g_{rn}^2}{2}\right\} \qquad \text{(VI-6)}$$

which is the probability density function for a normalized Gaussian random variable, g_{rn}. Rearranging equation (VI-5) to solve for x in terms of g_{rn} gives

$$x=\mu_g\sigma_g^{g_{rn}} \qquad \text{(VI-7)}$$

A random value of x may be computed from the above relationship, given known values of the geometric mean and geometric standard deviation and a normalized Gaussian random variable, g_{rn}.

Normalized Gaussian random numbers may be computed from the complementary cumulative probability integral of the Gaussian probability density function (Abramowitz and Stegun 1972):

$$P(g_{rn}) = \frac{1}{\sqrt{2\pi}} \int_{g_{rn}}^{\infty} \exp\left(-t^2/2\right) dt \qquad \text{(VI-8)}$$

The numerical value of g_{rn} may be evaluated using an approximation to the inverse function, $g_{rn}(p)$ given by the following for $0 < p \leq 0.5$ (Abramowitz and Stegun 1972):.

$$g_{rn} = \sigma - \frac{c_0 + c_1\sigma + c_2\sigma^2}{1 + d_1\sigma + d_2\sigma^2 + d_3\sigma^3} \qquad \text{(VI-9)}$$

where

$c_0 = 2.515517$; $c_1 = 0.802853$; $c_2 = 0.010328$

$d_1 = 1.432788$; $d_2 = 0.189269$; $d_3 = 0.001308$

$$\sigma = \sqrt{\ln\left(p^{-2}\right)} \qquad \text{(VI-10)}$$

where $p = P(g_{rn})$ is the cumulative probability. The quoted maximum error for this method is 4.5×10^{-4}. For $0.5 < p < 1$, equations (VI-9) and (VI-10) are modified to,

$$g_{rn} = \frac{c_0 + c_1\sigma + c_2\sigma^2}{1 + d_1\sigma + d_2\sigma^2 + d_3\sigma^3} - \sigma \qquad \text{(VI-11)}$$

$$\sigma = \sqrt{\ln\left\{(1-p)^{-2}\right\}} \qquad \text{(VI-12)}$$

The distribution of the cumulative probability, P, is uniform over the range 0 to 1. Uniform pseudorandom numbers are generated using a Lahey Fortran Compiler System function RND. Further description and statistical tests of RND are given in Attachment V.

The log-normal distribution covers the range from 0 to ∞. This is consistent with the range for K_s, however, values for β range from 1 to ∞. Therefore, random values for a "shifted" shape factor, $\xi = \beta - 1$, are generated using a log-normal distribution and values for the geometric mean and standard deviation of ξ. Random values of β are given by

$$\beta = \xi + 1. \qquad \text{(VI-13)}$$

Table VI-1 gives values for the geometric means and standard deviations of K_s and ξ.

The hydraulic conductivity is assumed to be perfectly correlated over distances on the order of one m. This assumption is based on a spatial correlation analyses of porosity (Rautman and Robey 1994, p. 2513), which indicate correlation lengths of 60 m in the Topopah Spring Member of the Paintbrush Tuff (which encompasses the Tptpln lithologic unit). The mean and variance of the ambient effective hydraulic conductivity is estimated by generating a sequence of random values of the effective hydraulic conductivity based on equation (VI-2). Random values for the water saturation, residual water saturation and porosity are computed using the method for generating random values from a beta distribution discussed in Attachment III using values for γ and ω given in Table VI-1. A random normalized saturation is computed using equation (VI-2). Random values for the saturated hydraulic conductivity are generated using equation (VI-7) and the geometric mean and standard deviation for saturated hydraulic conductivity given in Table VI-1. Random values for the "shifted" shape factor are generated using equation (VI-7) and the geometric mean and standard deviation for the "shifted" shape factor given in Table VI-1. A value for the shape factor is then computed using equation (VI-13). Normalized Gaussian random numbers are computed using the method given above (equations (VI-9) through (VI-12)) and uniform pseudorandom numbers are generated using the Lahey Compiler uniform pseudo-random number generator, RND (see Attachment V). The resulting advective travel times are then computed using equation (VI-1) with a fracture spacing of one m.

The travel times are treated as a log-normal distribution and reported in terms of the geometric mean and standard deviation. The values in Table VI-2 indicate that, for 1,000,000 samples, the geometric mean advective travel time at ambient conditions is 4,510 years and the one-sigma value below the mean is 301 years. The geometric mean advective travel time, for 1,000,000 samples at a specified water saturation of 0.99, is 358 years. At saturated conditions, the geometric mean advective travel time drops to a value of 203 years based on a simulation using 1,000,000 samples. Therefore, the change in the average advective travel time due to water saturation increased to a value of 0.99 (mean ambient water saturation is 0.74) lies within one-standard deviation of the mean advective travel time under ambient conditions. These values indicate the relatively broad variability of the advective travel time under ambient conditions in comparison with the changes in the mean advective travel time resulting from an increase in water saturation from ambient levels to near-saturated conditions. Therefore, it is expected that

EBS releases via aqueous advection will not be noticeably influenced by local saturation increases to near-saturated conditions.

Table VI-1

Statistical Parameters:

	μ_{bd}	σ_{bd}^2	Y	ω
Porosity	0.12714	0.0018713	7.4132	50.894
Water Saturation	0.73986	0.022121	5.6975	2.0032
Residual Water Saturation	0.049879	0.0033628	0.65304	12.439

	μ_g	σ_g
Saturated Hydraulic Conductivity	1.8708×10^{-11} (m/s)	6.7027
Shifted Shape Parameter	0.70153	1.6055

Table VI-2

Statistical Results:

Ambient Conditions (Water Saturation of 0.74)

number of random samples	geometric mean travel time (years)	geometric standard deviation	travel time one standard deviation below the mean (years)
10,000	4,510	15.2	298
100,000	4,490	15.1	297
1,000,000	4,510	15.0	301

Water Saturation of 0.99:

number of random samples	geometric mean travel time (years)
10,000	357
100,000	359
1,000,000	358

Water Saturation of 1:

number of random samples	geometric mean travel time (years)
10,000	197
100,000	203
1,000,000	203

ATTACHMENT VII

ENHANCED FAR-FIELD TRANSPORT OF A TRACER IN ESF-ADDED WATER BETWEEN POTENTIAL WASTE EMPLACEMENT ZONES AND THE WATER TABLE

(14 PAGES)

ENHANCED FAR-FIELD TRANSPORT OF A TRACER IN ESF-ADDED WATER BETWEEN POTENTIAL WASTE EMPLACEMENT ZONES AND THE WATER TABLE

Consider an initially saturated zone lying directly below the ESF main drift excavation, which extends down a distance L. This "pulse" of water will migrate under the effects of gravity and capillary forces. Consider the vertical motion only, because we are concerned here with movement from potential waste emplacement locations to the water table. According to the one-dimensional mass conservation equation, coupled with Darcy's law, the saturation distribution will evolve as described by the following expression (Bear 1972, pp. 488, 496):

$$\phi \frac{\partial S_w}{\partial t} + \frac{\partial}{\partial z} K \left(1 - \frac{\partial \psi}{\partial z} \right) = 0 \qquad \text{(VII-1)}$$

where

$\phi \equiv$ porosity

$S_w \equiv$ water saturation

$K \equiv K(S_w) \equiv$ effective hydraulic conductivity

$\psi \equiv \psi(S_w) \equiv$ water pressure head

$z \equiv$ vertical coordinate, positive downward, zero at the ESF

$t \equiv$ time

The relative contributions of gravitational and capillary driving forces are difficult to determine quantitatively. At the leading edge of a water pulse, gravitational and capillary-driven flow processes will both act to enhance transport to the water table. However, at the trailing edge capillary-driven flow will "backflow" vertically upwards while the gravity-driven flow process will continue toward the water table. An important simplification to be used here is that the flow and transport may be approximated ignoring the effects of capillary driven flow or, in equation (VII-1),

$$\frac{\partial \psi}{\partial z} \ll 1 \qquad \text{(VII-2)}$$

This will clearly be true in the long-time limit as capillary pressure gradients decay. Using this approximation, equation (VII-1) may be written as:

$$\frac{\partial S_w}{\partial t}+\frac{1}{\phi}\frac{dK}{dS_w}\frac{\partial S_w}{\partial z}=0 \qquad \text{(VII-3)}$$

The solution to the given flow equation may be derived in a useable form for transport calculations if the effective hydraulic conductivity is approximated as a quadratic function of water saturation, i.e.,

$$K(S_w)=K_s(aS_w^2+bS_w) \qquad \text{(VII-4)}$$

where K_s is the saturated hydraulic conductivity. The solution for the flow field using equations (VII-3) and (VII-4) may be obtained using the following relationships derived for the position of the saturation front, x_f.

The characteristic form for equation (VII-3) is (Whitham 1974, p. 20):

$$\frac{dS_w}{dt}=0 \qquad \text{(VII-5)}$$

along

$$\frac{dz}{dt}=\frac{1}{\phi}\frac{dK}{dS_w} \qquad \text{(VII-6)}$$

The interpretation of this form is that the saturation is constant along characteristic lines defined by equation (VII-6), whose slope is a function of the constant saturation associated with the line. Therefore, a solution may be constructed from initial values of S_w and z at time equal zero. At time zero, let $z=\xi$. Integration of equation (6) gives the following (Whitham 1974, p. 20):

$$z(\xi,t)=\xi+f(\xi)t$$

$$f(\xi)=\frac{1}{\phi}\frac{dK}{dS_w} \qquad \text{(VII-7)}$$

and $S_w \equiv S_w(\xi)$. The function f may be interpreted as a wave velocity for the constant-saturation characteristics. A saturation discontinuity occurs when characteristic lines cross. The saturation discontinuity physically is a high-saturation gradient zone created by a situation where higher saturation (and higher velocity, f) characteristics enter a region occupied by lower saturation characteristics. The kinematic wave model, as expressed in equation (VII-3), approximates this high-saturation gradient zone as a sharp discontinuity. The location of the discontinuity may be obtained for an initial "square wave" saturation profile using an expression derived in Whitham 1974 (p. 47).

$$\frac{1}{2}(f_2-f_0)^2 t=\int_{\xi_2}^{L}(f-f_0)\,d\xi \qquad \text{(VII-8)}$$

Here, f_2 is the value of f at ξ_2, which is the initial coordinate of the characteristic that arrives at time t at the saturation discontinuity (originating from the saturation pulse region between 0 and L). f_0 is the characteristic wave velocity at ambient saturation, S_0. For small times, ξ_2 is greater than 0 and $S_w=1$. Let f_s be the value of f at $S_w=1$. Equation (VII-8) then gives:

$$\frac{1}{2}(f_s-f_0)^2 t=(L-\xi_2)(f_s-f_0) \qquad \text{(VII-9)}$$

Solving for ξ_2 gives

$$\xi_2=L-\frac{1}{2}(f_s-f_0)t \qquad \text{(VII-10)}$$

Substituting equation (VII-10) into the expression for z in equation (VII-7) and recognizing that $f(\xi_2)=f_s$ gives the following:

$$z_f = L + \frac{1}{2}(f_s + f_0)t \qquad \text{(VII-11)}$$

where z_f is the position of the saturation discontinuity at time t. At larger times, $\xi_2 = 0$, therefore equation (VII-8) gives:

$$f(\xi_2) = f_0 + \left\{\frac{2L}{t}(f_s - f_0)\right\}^{\frac{1}{2}} \qquad \text{(VII-12)}$$

Again, substituting equation (VII-12) into the expression for z in equation (VII-7) gives:

$$z_f = f_0 t + \{2Lt(f_s - f_0)\}^{\frac{1}{2}} \qquad \text{(VII-13)}$$

The intersection of the two expressions for z_f may be obtained by equating equations (VII-11) and (VII-13) to find they cross at:

$$z_f = \frac{2Lf_s}{f_s - f_0}$$

$$t_f = \frac{2L}{f_s - f_0} \qquad \text{(VII-14)}$$

Behind the front, the characteristics form an expansion fan given by the following:

$$z = f(S_w)t \qquad \text{(VII-15)}$$

In front of the saturation discontinuity and behind the expansion fan lies undisturbed fluid in which the characteristics are:

$$z = \xi + f_0 t \qquad \text{(VII-16)}$$

These relationships are shown in Figure VII-1 on a characteristics diagram for the flow process.

The transport of a dissolved substance of concentration, C (defined as the mass of dissolved substance per unit volume of solution), is described by the following material balance expression (Bear 1972, p. 487):

$$\phi \frac{\partial (S_w C)}{\partial t} + \frac{\partial (K C)}{\partial z} = 0 \qquad \text{(VII-17)}$$

Expanding the partial derivatives in equation (VII-17) and using equation (VII-3) gives:

$$\phi S_w \frac{\partial C}{\partial t} + K \frac{\partial C}{\partial z} = 0 \qquad \text{(VII-18)}$$

Putting equation (VII-18) in characteristic form gives:

$$\frac{dC}{dt} = 0 \qquad \text{(VII-19)}$$

along

$$\frac{dz}{dt} = \frac{K}{\phi S_w} \qquad \text{(VII-20)}$$

Using equation (VII-4) for K in equation (VII-20) gives:

$$\frac{dz}{dt} = \frac{K_s}{\phi} (a S_w + b) \qquad \text{(VII-21)}$$

Consider a tracer of some concentration, C_0, that is initially located at $z = L$. Integrating equation (VII-22) for the tracer characteristic path from $z = L$ to some point z within the initially saturated zone (see Figure VII-1) gives:

$$z = L + \frac{K_s}{\phi}(a+b)t \qquad \text{(VII-22)}$$

Note that in equation (VII-22), $S_w = 1$. This equation for the tracer characteristic path applies until the path exits the zone of saturated flow, when

$$t = \frac{z}{f_s} = \frac{z}{\frac{K_s}{\phi}(2a+b)} \qquad \text{(VII-23)}$$

where f_s has been evaluated using equations (VII-4) and (VII-7) at $S_w = 1$. Substituting equation (VII-23) for t in equation (VII-22) gives:

$$z_l = L + \frac{(a+b)}{(2a+b)} z_l \qquad \text{(VII-24)}$$

where z_l is the value of z where the tracer characteristic crosses the saturated zone boundary line (see Figure VII-1) into the expansion fan region. Solving equation (VII-24) for z_l gives:

$$z_l = (2 + \frac{b}{a})L \qquad \text{(VII-25)}$$

Substituting equation (VII-25) for z_l into equation (VII-22) for z, gives the value of t_l, the time when the characteristic leaves the saturated zone:

$$t_l = \frac{L\phi}{K_s a} \qquad \text{(VII-26)}$$

To find the characteristic path through the expansion fan, first combine equation (VII-15) for f and equations (VII-4) and (VII-7) for f, to give:

$$\frac{K_s}{\phi}(2aS_w+b)=\frac{z}{t} \quad \text{(VII-27)}$$

Solving equation (VII-27) for $\frac{K_s a S_w}{\phi}$ gives:

$$\frac{K_s a S_w}{\phi}=\frac{1}{2}\left(\frac{z}{t}-\frac{K_s b}{\phi}\right) \quad \text{(VII-28)}$$

Substituting equation (VII-28) into equation (VII-21) gives:

$$\frac{dz}{dt}=\frac{1}{2}\left(\frac{z}{t}+\frac{K_s b}{\phi}\right) \quad \text{(VII-29)}$$

Let $F=\frac{z}{t}$ or $z=tF$, then

$$\frac{dz}{dt}=t\frac{dF}{dt}+F \quad \text{(VII-30)}$$

Equating the expressions for $\frac{dz}{dt}$ in equations (VII-29) and (VII-30) and using $F=\frac{z}{t}$ gives,

$$t\frac{dF}{dt}+F=\frac{1}{2}\left(F+\frac{K_s b}{\phi}\right) \quad \text{(VII-31)}$$

or, upon rearrangement gives

$$\frac{dF}{d[\ln(t)]} + \frac{F}{2} = \frac{K_s b}{2\phi} \qquad \text{(VII-32)}$$

and letting $y = \ln(t)$ gives,

$$\frac{dF}{dy} + \frac{F}{2} = \frac{K_s b}{2\phi} \qquad \text{(VII-33)}$$

Equation (VII-33) may be integrated by using an integrating factor,

$$\frac{d}{dy}(F e^{y/2}) = \frac{K_s b e^{y/2}}{2\phi} \qquad \text{(VII-34)}$$

Integrating equation (VII-34) between (F_1, y_1), which are evaluated at (z_1, t_1) and a general point (F, y), we find:

$$F = F_1 \exp\left\{ \frac{y_1 - y}{2} \right\} + \frac{K_s b}{\phi} \left\{ 1 - \exp\left\{ \frac{y_1 - y}{2} \right\} \right\} \qquad \text{(VII-35)}$$

Substituting for y, y_1, F, and F_1 in equation (VII-35), we find

$$z = z_1 \left\{ \frac{t}{t_1} \right\}^{\frac{1}{2}} + \frac{K_s bt}{\phi} \left\{ 1 - \left\{ \frac{t_1}{t} \right\}^{\frac{1}{2}} \right\} \qquad \text{(VII-36)}$$

Equation (VII-36) is valid until the concentration characteristic enters the undisturbed flow zone from the expansion fan at z_2, t_2. The equation for the trailing edge characteristic between the expansion fan and the undisturbed flow region is given by equation (VII-16) for a characteristic emanating from the origin, $\xi = 0$, or

$$z_2 = f_0 t_2 \qquad \text{(VII-37)}$$

Substituting equation (VII-37) into equation (VII-36) for z_2 and solving for t_2 gives:

$$t_2 = \frac{1}{t_1}\left\{ \frac{\dfrac{z_1 \phi}{K_s b t_1} - 1}{\dfrac{f_0 \phi}{K_s b t_1} - \dfrac{1}{t_1}} \right\}^2 \qquad \text{(VII-38)}$$

Using equations (VII-25) and (VII-26) to evaluate $\frac{z_1 \phi}{K_s b t_1}$, and equations (VII-4) and (VII-7) to evaluate $\frac{f_0 \phi}{K_s b}$, we find for equation (VII-38),

$$t_2 = \frac{t_1}{S_0^2} = \frac{L \phi}{K_s a S_0^2} \qquad \text{(VII-39)}$$

And from equation (VII-39), with f_0 given by equations (VII-4) and (VII-7), we find for z_2,

$$z_2 = \left(2 + \frac{b}{a S_0} \right) \frac{L}{S_0} \qquad \text{(VII-40)}$$

The time to arrive at position z_2 starting from $\xi = L$ in an undisturbed flow is computed from equation (VII-20) at a uniform saturation, S_0, or

$$z_2 = L + \frac{K(S_0)}{\phi\, S_0}\, t \qquad \text{(VII-41)}$$

Using equation (VII-4) for K and solving for t gives:

$$t = \frac{\phi\, L}{K_s\, a\, S_0^2} \left\{ 1 + \frac{1 - S_0}{1 + \dfrac{b}{a\, S_0}} \right\} \qquad \text{(VII-42)}$$

To make these calculations, the effective hydraulic conductivity function, equation (VII-4), must be fit to the van Genuchten model (van Genuchten 1980),

$$K(S_w) = K_s\, S_n^{\frac{1}{2}} \left\{ 1 - \left\{ 1 - S_n^{\frac{\beta}{\beta - 1}} \right\}^{1 - \frac{1}{\beta}} \right\}^2 \qquad \text{(VII-43)}$$

where

$$S_n = \frac{S_w - S_r}{1 - S_r} \qquad \text{(VII-44)}$$

A conservative fit of the quadratic model, equation (4), with the van Genuchten model, equations (VII-43) and (VII-44) is made by forcing the quadratic model to equal the van Genuchten model at the endpoints of the saturation range in question, i.e., at $S_w = 0.74$ and $S_w = 1$, where 0.74 is the ambient saturation of the current potential emplacement zone (CRWMS M&O 1996ac, p. 13). Using this fitting method the coefficients a and b are found to be $a = 3.5907$, $b = -2.5907$. The quadratic model is found to be conservative, as shown in Figure VII-2 in that the effective hydraulic conductivities at intermediate saturations, $0.74 < S_w < 1$ are higher for the quadratic model than the van Genuchten model.

Using values for the Tptpln from CRWMS M&O 1996ac (p. 13) and $L = 37$ m (Attachment IV) gives $t_2 = 4145$ years and $z_2 = 51.25$ m. The undisturbed travel time through the unsaturated zone is computed using the following sum:

$$t_r = \sum_{i=1}^{4} \frac{D_i \phi_i S_{wi}}{K(S_{wi})} \qquad \text{(VII-45)}$$

where D_i is the distance of travel in unit I, ϕ_i is the porosity of unit I, S_{wi} is the undisturbed water saturation in unit I, and $K(S_{wi})$ is the effective hydraulic conductivity in unit I as calculated from equations (VII-43) and (VII-44). The four units are the Tptpln, Tptpv2, Tptpv1&2, and Tac, as given in CRWMS M&O 1996ac. The value of D_l is 61 - 37 m = 24 m. The distance between potential emplacement (and the ESF) with the Tptpv3 averages 61 m and the tracer is initiated 37 m downstream at the head of the disturbed saturation zone. The undisturbed travel time through the unsaturated zone is found to be 285,000 years.

For the disturbed travel time, the tracer transport period while in the disturbed flow zone is t_2, 4,145 years. After this time the tracer exists the disturbed flow zone at a distance of 50 m from the ESF, or 61 - 51.25 m = 9.75 m from the Tptpv3 unit. A disturbed travel time is computed using the value of t_2 for the enhanced transport period added to equation (47), with D_l = 9.75 m. The disturbed travel time through the unsaturated zone is found to be 242,000 years.

Figure VII-1 Characteristic Diagram for Propagation of a Saturation Pulse and Tracer Transport

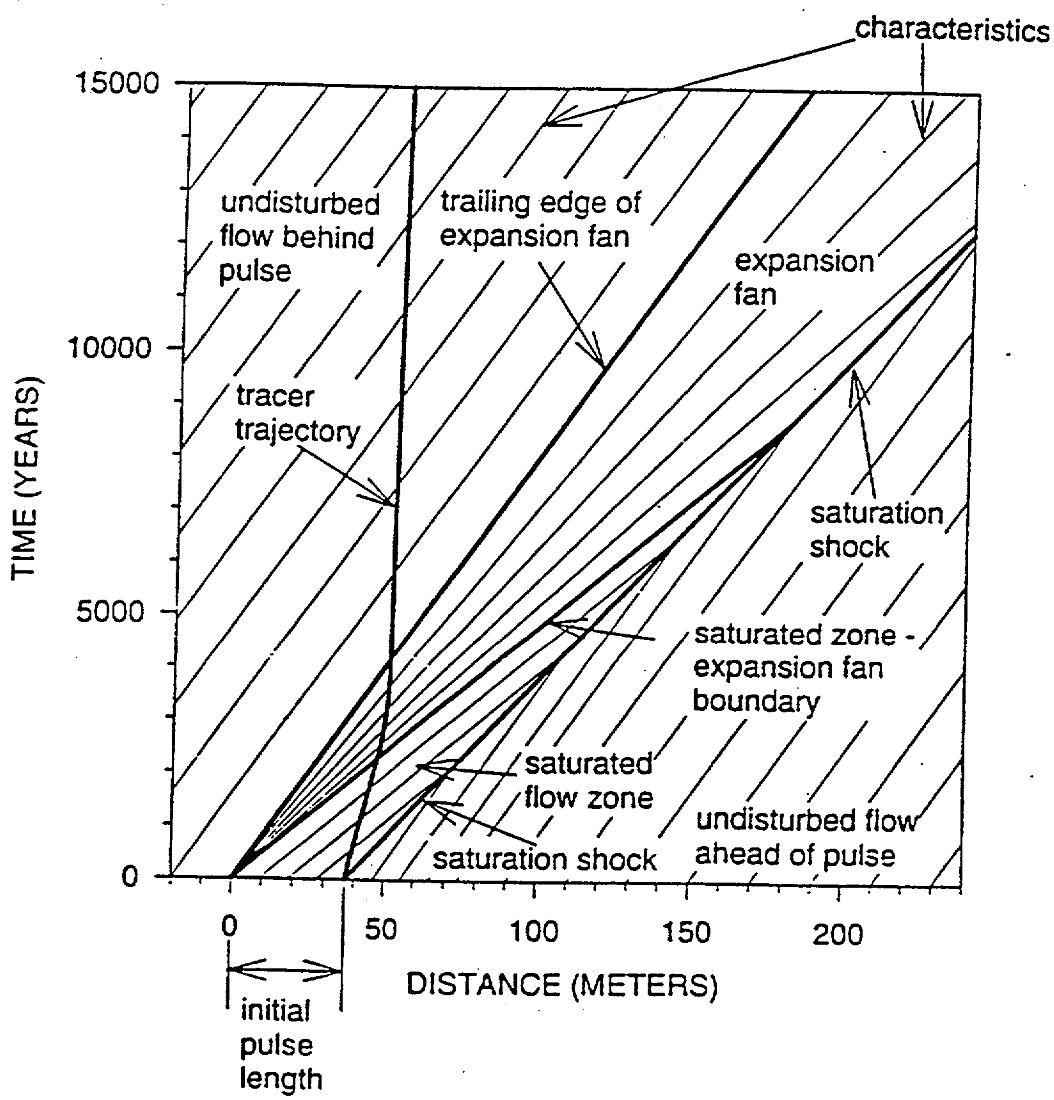
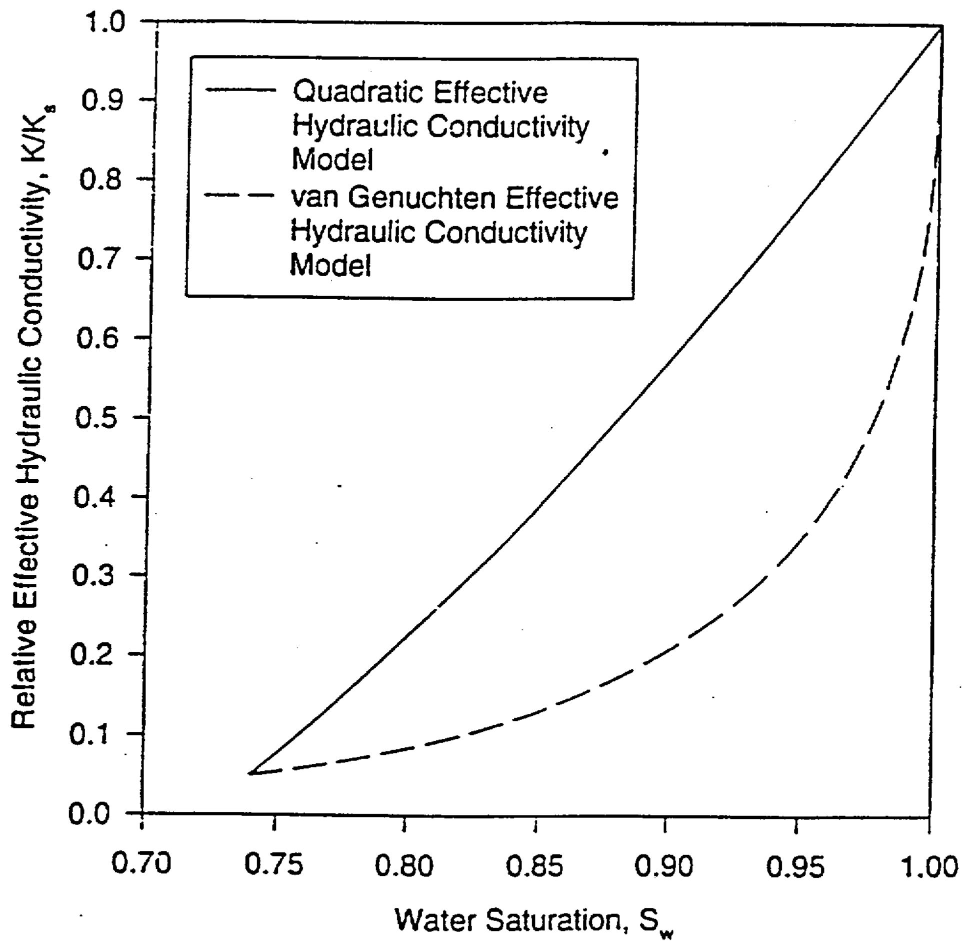


Figure VII-2 Endpoint of Quadratic Effective Hydraulic Conductivity Model to a van Genuchten Model



ATTACHMENT VIII

EVAPORATION AND REMOVAL OF WATER BY THE VENTILATATION SYSTEM

(13 PAGES)

EVAPORATION AND REMOVAL OF WATER BY THE VENTILATATION SYSTEM

The ventilation system for the ESF is a negative pressure system, in which exhaust fans at the portals draw external air into the tunnel from the North Portal and discharge air out the South Portal and through a ventilation pipe to the North Portal. The native underground atmosphere, or rock gas, carries a high relative humidity, which can be shown to be about 99 percent for natural conditions in the TSw2. The outside atmosphere is much more variable with respect to relative humidity, however, and is typically much less humid than the native rock gas. The presence of free water on surfaces in the tunnel such as the concrete inverts will, given sufficient exposure, evaporate into the ventilation stream. In this attachment, a conceptual model for evaporation and transport in the ventilation stream is used to estimate the rate of evaporation as a function of distance into the ESF.

The ventilation flow in the ESF is sufficiently large to be considered turbulent (see below). In addition, the differences in air pressure between the North Portal and the excavation face are extremely small in comparison with atmospheric pressure (see below), therefore the air flow process may be modeled using incompressible flow theory. The velocity profile for turbulent flow in a circular, rough-walled conduit may be computed from the following relations (Daily and Harleman 1973, p. 272):

$$\frac{u}{u_*} = 2.5 \ln \left\{ \frac{y}{k_s} \right\} + 8.5 \qquad \text{(VIII-1)}$$

where

$y \equiv$ distance from the tunnel wall
$k_s \equiv$ wall roughness
$u_* \equiv$ shear velocity
$u \equiv$ flow velocity at position y

The shear velocity is related to the average flow velocity by the following (Daily and Harleman 1973, pp. 229 and 264):

$$u_* = \sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{f}{8}}\, V \qquad \text{(VIII-2)}$$

where

$\tau_0 \equiv$ flow shear stress at the tunnel wall
$\rho \equiv$ air density

$$V = \frac{Q}{A} \qquad \text{(VIII-3)}$$

$Q \equiv$ volumetric flow rate
$A \equiv$ tunnel cross-sectional area

and

$f \equiv$ pipe friction factor

The shear stress in a turbulent flow, τ, is commonly modeled using the following constitutive relationship (Vanoni 1975, p. 72),

$$\tau = \varepsilon_m \frac{d(\rho u)}{dy} \qquad \text{(VIII-4)}$$

where

$\varepsilon_m \equiv$ turbulent diffusivity for momentum (turbulent kinematic eddy viscosity)

The distribution of shear stress across the flow is linear (Vanoni 1975, p. 75)

$$\frac{\tau}{\tau_0} = \frac{R - y}{R} \qquad \text{(VIII-5)}$$

where

$R \equiv$ pipe radius

Given an incompressible flow, ρ may be taken as a constant. Rearranging equation (VIII-4) gives for ε_m,

$$\varepsilon_m = \frac{\tau}{\rho} \left\{ \frac{du}{dy} \right\}^{-1} \qquad \text{(VIII-6)}$$

Substituting for u using equation (VIII-1) and for τ using equation (VIII-2) and (VIII-5) gives,

$$\varepsilon_m = 0.4\, u_*\; y\; \frac{R - y}{R} \qquad \text{(VIII-7)}$$

The diffusivity for mass in a turbulent flow is related to the diffusivity for momentum by the turbulent Schmidt number, *Sc*, (Daily and Harleman 1973, p. 431)

$$\varepsilon_s = \frac{\varepsilon_m}{Sc} \qquad \text{(VIII-8)}$$

The turbulent Schmidt number is about 0.7 (Daily and Harleman 1973, p. 431). Therefore,

$$\varepsilon_s = \frac{4}{7}\, u_*\; y\; \frac{R - y}{R} \qquad \text{(VIII-9)}$$

Then, using equation (VIII-2) for u_*, equation (VIII-9) becomes

$$\varepsilon_s = \frac{\sqrt{2f}}{7}\; V\; y\; \frac{R - y}{R} \qquad \text{(VIII-10)}$$

The turbulent mass diffusivity, ε_s, is found to be a function of distance from the tunnel wall, y. As $y \to 0$, $\varepsilon_s \to 0$, therefore, near the tunnel wall molecular diffusion becomes important. Let the total mass diffusivity be the sum of molecular and turbulent diffusion processes,

$$\varepsilon_t = \varepsilon_s + D_m \qquad \text{(VIII-11)}$$

where

$\varepsilon_t \equiv$ total mass diffusivity
$D_m \equiv$ molecular diffusivity

Substituting for ε_s using equation (VIII-10), equation (VIII-11) becomes,

$$\varepsilon_t = \frac{\sqrt{2f}}{7}\; V\; y\; \frac{R - y}{R} + D_m \qquad \text{(VIII-12)}$$

Material balance for steady-state vapor transport in the tunnel may be modeled using the following steady-state form of the advection-diffusion equation (Fischer et al. 1979, p. 71), written in a cylindrical coordinate system,

$$u \frac{\partial \rho_v}{\partial x} - \frac{1}{R-y} \frac{\partial}{\partial y} \left\{ \varepsilon_t \, (R-y) \frac{\partial \rho_v}{\partial y} \right\} = 0 \qquad \text{(VIII-13)}$$

where

$\rho_v \equiv$ water vapor mass density
$x \equiv$ distance along the tunnel.

The combination of a nonlinear spatial distribution of the mass diffusivity, equation (VIII-12), and a nonlinear velocity profile, equation (VIII-1), makes an exact evaluation of the mass transport process difficult. An approximate solution may be obtained by assuming that the cross-section variations in the longitudinal transport term are small, i.e.,

$$u \frac{\partial \rho_v}{\partial x} \approx V \frac{d \overline{\rho_v}}{d x} \qquad \text{(VIII-14)}$$

where

$$\overline{\rho_v} = \frac{1}{R} \int_0^R \rho_v \, dy \qquad \text{(VIII-15)}$$

and let

$$q_v = V \frac{d \overline{\rho_v}}{d x} \qquad \text{(VIII-16)}$$

Using equations (VIII-14) and (VIII-16), equation (VIII-13) becomes

$$\frac{1}{(R-y)} \frac{\partial}{\partial y}\left\{ \varepsilon_t (R-y) \frac{\partial \rho_v}{\partial y} \right\} = q_v \qquad \text{(VIII-17)}$$

Integrate equation (VIII-17) from y to R to give,

$$-\varepsilon_t (R-y) \frac{\partial \rho_v}{\partial y} = \frac{(R-y)^2}{2} q_v + g(x) \qquad \text{(VIII-18)}$$

Where $g(x)$ is an arbitrary function of x. However, $g(x) = 0$ for $\frac{\partial \rho_v}{\partial y}$ to be bounded at $y = R$.

Rearranging equation (VIII-18) to solve for $\frac{\partial \rho_v}{\partial y}$ and using equation (VIII-12) for ε_t gives,

$$\frac{\partial \rho_v}{\partial y} = \frac{-(R-y)}{\frac{\sqrt{2f}}{7} \frac{V}{R} y (R-y) + D_m} \left\{ \frac{q_v}{2} \right\} \qquad \text{(VIII-19)}$$

The roots of the denominator of the right-hand side of equation (VIII-19), y_1 and y_2, are given by,

$$y_1 = \frac{R}{2} \left\{ 1 + \sqrt{1 + \frac{28 D_m}{\sqrt{2f} \; V R}} \right\} \qquad \text{(VIII-20)}$$

$$y_2 = \frac{R}{2} \left\{ 1 - \sqrt{1 + \frac{28 D_m}{\sqrt{2f} \; V R}} \right\} \qquad \text{(VIII-21)}$$

In terms of these roots, equation (VIII-19) may be expressed as,

$$\frac{\partial \rho_v}{\partial y} = \frac{-7 R q_v}{2\sqrt{2f}\ V} \frac{(y-R)}{(y-y_1)(y-y_2)} \qquad \text{(VIII-22)}$$

Equation (VIII-22) may be expanded for integration over y to the following expression,

$$\frac{\partial \rho_v}{\partial y} = \frac{-7 R q_v}{2\sqrt{2f}\ V} \frac{1}{(y_1-y_2)} \left\{ \frac{y-R}{y-y_1} - \frac{y-R}{y-y_2} \right\} \qquad \text{(VIII-23)}$$

Integrating equation (VIII-23) from 0 to y gives,

$$\rho_v - \rho_{vs} = \frac{-7 R q_v}{2\sqrt{2f}\ V} \frac{1}{(y_1-y_2)} \left\{ \int_0^y \frac{\xi - R}{\xi - y_1} d\xi - \int_0^y \frac{\xi - R}{\xi - y_2} d\xi \right\} + g(x) \qquad \text{(VIII-24)}$$

where ρ_{vs} is the density of water vapor at saturated conditions, i.e., a relative humidity of 100 percent, and $g(x)$ is an arbitrary function of x. However, to satisfy the boundary condition $\rho_v = \rho_{vs}$ at $y = 0$, $g(x) = 0$. This boundary condition is used because a saturated water vapor condition is expected next to the tunnel inverts after application of dust control water.

The integrals in equation (VIII-24) have a generic solution of the form,

$$\int_0^y \frac{\xi - R}{\xi - y_i} d\xi = y + (y_i - R) \ln\left(1 - \frac{y}{y_i}\right) \qquad \text{(VIII-25)}$$

where y_i is either y_1 or y_2. Substituting this relation for each of the integrals in equation (VIII-24) gives,

$$\rho_v - \rho_{vs} = \tag{VIII-26}$$

$$\frac{-7R\,q_v}{2\sqrt{2f}\;V}\,\frac{1}{(y_1-y_2)}\left\{ y_1 \ln(1-\frac{y}{y_1}) - y_2 \ln(1-\frac{y}{y_2}) + R \ln\left\{\frac{(1-\frac{y}{y_1})}{(1-\frac{y}{y_2})}\right\}\right\}$$

The integrated version of ρ_v defined in equation (VIII-15) may be computed from equation (VIII-26),

$$\overline{\rho_v} = \rho_{vs} - \tag{VIII-27}$$

$$\frac{7\,q_v}{2\sqrt{2f}\;V}\,\frac{1}{(y_1-y_2)}\int_0^R\left\{ y_1 \ln(1-\frac{y}{y_1}) - y_2 \ln(1-\frac{y}{y_2}) + R \ln\left\{\frac{(1-\frac{y}{y_1})}{(1-\frac{y}{y_2})}\right\}\right\}dy$$

Equation (VIII-27) may be reduced using the following generic integral expression,

$$\int_0^R \ln(1-\frac{y}{y_i})\,dy = (R-y_i)\ln(1-\frac{R}{y_i}) - R \tag{VIII-28}$$

where y_i is again either y_1 or y_2. Using equation (VIII-28) in for each of the integrals in equation (VIII-27) gives,

$$\rho_v = \rho_{vs} - B\,q_v \tag{VIII-29}$$

where

$$B = \frac{7}{2\sqrt{2f}\quad V}\ \frac{1}{(y_1 - y_2)}\ \mathrm{x}$$

(VIII-30)

$$\left\{ (R-y_2)\left\{ (R-y_2)\ln(1-\frac{R}{y_2})-R \right\} -(y_1-R)\left\{ (y_1-R)\ln(1-\frac{R}{y_1})+R \right\} \right\}$$

Substituting equation (VIII-16) for q_V into equation (VIII-29) and rearranging gives,

$$\frac{d\overline{\rho_v}}{dx} = \frac{1}{BV}\,(\rho_{vs} - \overline{\rho_v}) \qquad \text{(VIII-31)}$$

Equation (VIII-31) may be solved to give,

$$\overline{\rho_v} = \rho_{vs} - (\rho_{vs} - \overline{\rho_{v0}})\exp\left\{\frac{-x}{BV}\right\} \qquad \text{(VIII-32)}$$

The rate of evaporative removal of water, q_V, is equal to the net longitudinal transport due to the assumed steady-state conditions. The net longitudinal advective flux of water vapor is computed from the derivative of equation (VIII-32) with respect to x multiplied by the volumetric flow rate of air in the tunnel, VA, i.e.,

$$Q_v = AV\frac{d\overline{\rho_v}}{dx} = \frac{A}{B}\,(\rho_{vs} - \overline{\rho_{v0}})\exp\left\{\frac{-x}{BV}\right\} \qquad \text{(VIII-33)}$$

where Q_V is given in units of mass per unit length and time.

Specific calculations will be used to confirm the first two assumption given above, i.e., the flow is turbulent and the changes in air density due to flow are small compared with the average density. For the specific calculations, the following representative values will be used:

$R = 3.81$ m
$k_S = 0.2$ m (see Section 6.5)

$V = 1$ m/s
$T = 23.5°$ C (Fischer 1997)

$\nu = 1.535 \times 10^{-5}$ m²/sec
$D_m = 2.5 \times 10^{-5}$ m²/sec (Batchelor 1967, p. 594)

where ν is the kinematic viscosity of air. The wall roughness dimension, k_s, is taken to be the width of a steel set, 8 inches, or about 0.2 m. The Reynolds number for the flow, *Re,* may be computed from the following

$$Re = \frac{2VR}{\nu} \qquad \text{(VIII-34)}$$

Using values for *V*, *R*, and ν gives $Re = 4.96 \times 10^5$. The relative roughness for the flow is defined by $\frac{k_s}{2R}$, which has a value of 0.0262. Using these values, the pipe friction diagram (Daily and Harleman 1973, p. 275) indicates that the flow is turbulent and in the fully rough flow regime. The friction factor, *f*, may be computed from the following expression (Daily and Harleman 1973, p. 272),

$$\frac{1}{\sqrt{f}} = -0.8686 \ln \left\{ \frac{k_s}{2R} \right\} + 1.14 \qquad \text{(VIII-35)}$$

which gives a value of 0.054 for *f*. The pressure loss in the flow is given by (Daily and Harleman 1973, p. 265)

$$p_0 - p_L = \rho_a f \frac{L}{R}\frac{V^2}{4} + \rho_a g (h_L - h_0) \qquad \text{(VIII-36)}$$

where

$\rho_a \equiv$ density of air at North Portal
$L \equiv$ flow path length (tunnel length)
$g \equiv$ gravitational acceleration
$p_0 \equiv$ air pressure at the North Portal
$p_L \equiv$ air pressure at the tunnel face
$h_0 \equiv$ elevation at the North Portal
$h_L \equiv$ elevation at the tunnel face.

Because $h_L < h_0$ for nearly the entire excavation, the elevation factor may be conservatively ignored. The air density may be estimated from the ideal gas law (Houghton 1977, p. 3),

$$\rho_a = \frac{p}{R_s T} \quad \text{(VIII-37)}$$

where R_S is the specific gas constant for air, 287.05 J/(kg-K) (Houghton 1977, p. 164).

The average atmospheric pressure at Yucca Flat is about 26.01 in Hg (CRWMS M&O 1997w, Section 1.3, p. 4), or 8.8×10^4 N/m^2 and the average air temperature is 54.9° F (CRWMS M&O 1997w, Section 1.3, p. 3), or 286° K. Using equation (VIII-37), the air density is approximately 1.07 kg/m^3.

The maximum pressure difference is computed from equation (VIII-36) neglecting gravitational effects and using the maximum tunnel length of about 8000 m. Therefore, the pressure difference is found to be,

$$p_0 - p_L = 30 \text{ N/m}^2 \quad \text{(VIII-38)}$$

This pressure is about 0.03 percent of the average air pressure at Yucca Flat. Because pressure and density are linearly related (see equation (VIII-37)), this translates to a density change due to the ventilation flow of about 0.03 percent of the average air density. Therefore, the pressure changes due to the ventilation flow will have a negligible effect on air density.

To compute evaporation rates, the average water vapor density at the North Portal, $\overline{\rho_{v0}}$, is required. The value of $\overline{\rho_{v0}}$ is computed from the relative humidity and temperature data available in Wang 1998. The least favorable evaporation conditions identified in Wang 1998 are near the portal entrance for January. The average temperature is 17.4° C and the average relative humidity is 27.5 percent. The saturated water vapor density is computed based on this average temperature (Reynolds and Perkins 1977, p. 622), which is found to be 0.01468 kg/m^3. Accounting for the relative humidity, the initial water vapor density is found to be

$$\overline{\rho_{v0}} = 0.004043 \text{ kg/m}^3 \quad \text{(VIII-39)}$$

with

$$\rho_{vs} = 0.01468 \text{ kg/m}^3 \quad \text{(VIII-40)}$$

Values of y_1 and y_2 may be calculated from equations (VIII-20) and (VIII-21). Here we use a ventilation rate of 120,000 cubic feet of air per minute (CRWMS M&O 1998g), which for a 3.81 m radius tunnel, is equivalent to a velocity of 1.24 m/s. Using these values, we obtain

$$y_1 = 3.81043 \qquad \text{(VIII-41)}$$

$$y_2 = -4.28753 \times 10^{-4} \qquad \text{(VIII-42)}$$

Given these values for y_1 and y_2, equation (VIII-30) may be used to compute B,

$$B = 264.8\ s \qquad \text{(VIII-43)}$$

The rate of water removal, Q_v, is computed using equation (VIII-33)

$$Q_v = 1.830 \times 10^{-3} \exp\left\{\frac{-x}{328.4}\right\} \mathrm{kg/(m\text{-}s)} \qquad \text{(VIII-44)}$$

On a daily time-basis, this is

$$Q_v = 158.3\ \exp\left\{\frac{-x}{328.4}\right\} \mathrm{kg/(m\text{-}day)} \qquad \text{(VIII-45)}$$

The concrete inverts are about 3.4 m wide. Therefore, the fraction of the wall occupied by the inverts is about 3.4 m / (2π*3.81 m), or 0.142. Scaling equation (VIII-45) by this factor gives the rate of water removal from the inverts, Q_{vi},

$$Q_{vi} = 22.5\ \exp\left\{\frac{-x}{328.4}\right\} \mathrm{kg/(m\text{-}day)} \qquad \text{(VIII-46)}$$

The evaporative removal rate of water, Q_{vi}, will decrease to a value of 0.76 kg/(m-day) at a distance of about 1100 m. If ventilation is increased to 248,000 cubic feet of air per minute, a similar calculation shows that the allowable wetted distance of invert is 1440 m.

A similar calculation may be used to include use of dust control water in the TTF. In this case, we consider a wetted tunnel upstream of the TTF to determine what quantity of water may be used in the main drift such that there is sufficient evaporation for removal of dust control water from the TTF. The section of tunnel upstream of the TTF has a higher ventilation rate, 179,000 cubic feet of air per minute (CRWMS M&O 1998g; 1998h), and therefore the velocity is 1.85 m/s. For example, say that there is an 730 m length of main drift wetted for dust control just upstream of the TTF. The water vapor density entering the TTF may be computed from equation (VIII-32), giving a value of 0.01340 kg/m^3. The TTF effective "radius" is 2.5 m (CRWMS M&O 1996n) and its ventilation rate is 47,500 cubic feet of air per minute (CRWMS M&O 1998i). If we make the same calculation as before (i.e. using equations (VIII-20), (VIII-21), (VIII-30), (VIII-33), and (VIII-35)), and use the TTF values for radius, ventilation rate, and an initial water vapor density of 0.01340 kg/m^3, we find:

$$Q_{vittf} = 1.88 \ \exp\left\{ \frac{-x}{186.9} \right\} \text{kg}/(\text{m-day}) \qquad \text{(VIII-47)}$$

The length of the TTF is about 170 m (CRWMS M&O 1996n), so the evaporation rate under these worst-case conditions at 170 m is 0.76 kg/m-day. Therefore the combined length of invert in the TS Loop and the TTF is 900 m. A simple operating rule may be derived from this calculation: a cumulative length of tunnel of 900 m may be treated with dust control water (including any use of dust control water in the TTF) at a rate of 0.76 kg/m-day. The 900 m can be anywhere in the TS Loop or TTF.