BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

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Construction Hazards Screening Analysis

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Preclosure Safety Analysis

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There are no attachments to this document.	0

RECORD OF REVISIONS

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DISCLAIMER

The calculations contained in this document were developed by Bechtel SAIC Company, LLC (BSC) and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

CONTENTS

Page

FIGURES

Page

TABLES

Page

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ACRONYMS AND ABBREVIATIONS

ACRONYMS

BSC	Bechtel SAIC Company, LLC
CRCF	Canister Receipt and Closure Facility
DOE	U.S. Department of Energy
DIRS	Document Input Reference System
DPC	dual-purpose canister
ECRB	Enhanced Characterization of the Repository Block
ESF	Exploratory Studies Facility
GROA	geologic repository operations area
HLW	high-level radioactive waste
IHF	Initial Handling Facility
IOC	initial operating capability
ITS	important to safety
LHD	load-haul dump
MGR	monitored geologic repository
RF	Receipt Facility
SNF	spent nuclear fuel
SSC	structure, system, or component
TAD	transportation, aging, and disposal
TBM	tunnel boring machine
TEV	transport and emplacement vehicle
WHF	Wet Handling Facility

ABBREVIATIONS

ft	foot
gal	gallon
in.	inch

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1. PURPOSE

The purpose of this analysis is to identify potential construction hazards and/or initiating events at the repository that could result in event sequences that produce radiological exposures to workers or offsite individuals during the preclosure period. Hazards from construction-related activities are applicable to the repository during the preclosure period because construction of the full geologic repository operations area (GROA) is not scheduled to be completed prior to the commencement of emplacement operations. Hazards and/or initiating events identified by this analysis will be considered, if required, in the preclosure safety analysis for event sequence identification, event sequence categorization, and the determination of doses resulting from potential releases of radioactive material. It should be noted that external hazards (events that originate outside or external to the repository, including weather-related hazards) are not considered in this analysis.

It is intended that this analysis will meet the requirements of NUREG-1804, *Yucca Mountain Review Plan, Final Report* (Ref. 2.3.2, Section 2.1.1.3 [DIRS 163274]) for the determination of the potential for construction hazards that must be included as event sequence initiators in the development of event sequences for the repository.

This analysis only considers issues related to preclosure radiological safety. Issues important to waste isolation as related to the impact from construction activities will be considered, if required, in the repository performance assessment.

2. REFERENCES

2.1 PROCEDURES/DIRECTIVES

2.1.1 BSC (Bechtel SAIC Company) 2007. *Quality Management Directive*. QA-DIR-10, Rev. 2. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20080103.0002. [DIRS 184596]

2.1.2 EG-PRO-3DP-G04B-00037, Rev. 10. *Calculations and Analyses*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071018.0001. [CDIS 54620]

2.1.3 IT-PRO-0011, Rev. 7. *Software Management*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070905.0007. [CDIS 53898]

2.1.4 LS-PRO-0201, Rev 5. *Preclosure Safety Analysis Process*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20071010.0021. [CDIS 54505]

2.2 DESIGN INPUTS

2.2.1 BSC 2005. *Potential Loss of Subsurface Isolation Barrier and Consequence Analysis*. 800-KMC-VU00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050830.0012; ENG.20080116.0003. [DIRS 174874]

2.2.2 BSC 2007. *Baseline/Funding Change Proposal, Fiscal Year 2007*. YMP AWP Revision. Baseline Change Proposal. YMP-2007-001, Rev. 1. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20070308.0112. [DIRS 178867]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.2 is suitable for use in this analysis. The information in this change proposal is relevant for use in this analysis because it presents information that corresponds to the repository design and operations that will be presented in the license application.

2.2.3 BSC 2007. *Basis of Design for the TAD Canister-Based Repository Design Concept*. 000-3DR-MGR0-00300-000-001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071002.0042; ENG.20071108.0002; ENG.20071109.0001; ENG.20071120.0023; ENG.20071126.0049; ENG.20071214.0009; ENG.20071213.0005; ENG.20071227.0018; ENG.20080207.0004; ENG.20080212.0003.

2.2.4 BSC 2008. *Geologic Repository Operations Area Aging Pad Site Plan*. 170-C00-AP00-00101-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ENG.20080129.0005. [DIRS 184922]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.4 is suitable for use in this analysis. This drawing is relevant for use in this analysis because it presents information that corresponds to the repository design that will be presented in the license application.

2.2.5 BSC 2008. *Geologic Repository Operations Area North Portal Site Plan*. 100-C00-MGR0-00501-000 REV 00F. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080125.0007. [DIRS 184864]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.5 is suitable for use in this analysis. This drawing is relevant for use in this analysis because it presents information that corresponds to the repository design that will be presented in the license application.

2.2.6 The reference corresponding to this reference number has been superseded. In accordance with procedural requirements, the reference is not listed as a design input. The information in the reference is relevant for intended use in this analysis because it corresponds to the operational steps and design that are presented in the license application. The source of the superseded document is stated in the text where the information is used.

2.2.7 BSC 2007. *Repository System Codes*. 000-30X-MGR0-01200-000-00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071101.0022. [DIRS 182471]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.7 is suitable for use in this analysis. The information in this reference is relevant for use in this analysis because it presents information that corresponds to the repository design and operations that will be presented in the license application.

2.2.8 BSC 2007. *Site Fire Hazard Analysis*. 000-M0A-FP00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070814.0003. [DIRS 181993]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.8 is suitable for use in this analysis. The information in this analysis is relevant for use in this analysis because it presents information that corresponds to the repository design and operations that will be presented in the license application.

2.2.9 The reference corresponding to this reference number has been superseded. In accordance with procedural requirements, the reference is not listed as a design input. The information in this engineering study is relevant for intended use in this analysis because it corresponds to the operational steps and design that are presented in the license application. The source of the superseded document is stated in the text where the information is used.

2.2.10 BSC 2007. *Subsurface Construction Methods*. 800-KMR-MGR0-00100-000-002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071116.0008. [DIRS 182905]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.10 is suitable for use in this analysis. The information in this engineering study is relevant for use in this analysis because it presents information that corresponds to the repository design and operations that will be presented in the license application.

2.2.11 BSC 2007. *Subsurface Construction Strategy*. 800-30R-MGR0-00100-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071106.0035. [DIRS 182570]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.11 is suitable for use in this analysis. The information in this engineering study is relevant for use in this analysis because it presents information that corresponds to the repository design and operations that will be presented in the license application.

2.2.12 BSC 2007. *Subsurface Repository Fire Hazard Analysis*. 800-M0A-FP00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070928.0001; ENG.20071101.0014. [DIRS 180306]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.12 is suitable for use in this analysis. The information in this analysis is relevant for use in this analysis because it presents information that corresponds to the repository design and operations that will be presented in the license application.

2.2.13 DOE (U.S. Department of Energy) 2004. *Construction Execution Plan*. 000-PLN-MGR0-00700-000-000. Las Vegas, Nevada: U.S. Department of Energy, Office of Repository Development. ACC: ENG.20040211.0005. [DIRS 168857]

In accordance with Section 3.2.2 of Ref. 2.1.2, Ref. 2.2.13 is suitable for use in this analysis. The information in this reference is relevant for use in this analysis because it presents information that corresponds to the repository design and operations that will be presented in the license application.

2.2.14 Stephans, R.A. and Talso, W.W., eds. 1997. *System Safety Analysis Handbook*. 2nd Edition. Albuquerque, New Mexico: System Safety Society. TIC: 236411. [DIRS 101450]

2.2.15 BSC 2007. *Probabilistic Characterization of Preclosure Rockfalls in Emplacement Drifts*. 800-00C-MGR0-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070329.0009. [DIRS 180415]

2.2.16 BSC 2007. *Waste Package Capability Analysis for Nonlithophysal Rock Impacts*. 000-00C-MGR0-04500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071113.0017. [DIRS 184425]

2.2.17 BSC 2007. *Thermal Responses of TAD and 5-DHLW/DOE SNF Waste Package to a Hypothetical Fire Accident*. 000-00C-WIS0-02900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070220.0008. [DIRS 183720]

2.2.18 BSC 2008. *Industrial/Military Activity-Initiated Accident Screening Analysis*. 000-PSA-MGR0-01500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080204.0006. [DIRS 184975]

2.2.19 BSC 2008. *External Events Hazards Screening Analysis*. 000-00C-MGR0-00500-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080219.0001. [DIRS 180124]

2.3 DESIGN CONSTRAINTS

2.3.1 10 CFR 63. 2007. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. [DIRS 180319]

2.3.2 NRC 2003. *Yucca Mountain Review Plan, Final Report*. NUREG-1804, Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. TIC: 254568. [DIRS 163274]

2.4 DESIGN OUTPUTS

This document may be used as input for other calculations, analyses, and/or other Yucca Mountain Project documents, including the license application.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

There are no assumptions requiring verification in this analysis.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

There are no assumptions not requiring verification in this analysis.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

As determined from Section 2.1.C.1.1 of the *Quality Management Directive* (Ref. 2.1.1 [DIRS 184596]), the activity under which this analysis was developed is subject to the repository quality assurance program requirements because this analysis examines hazards that may be applicable to items important to safety (ITS), as defined by 10 CFR 63.2 (Ref. 2.3.1 [DIRS 180319]), and it is part of the preclosure safety analysis. Therefore, the approved version of this document is designated as "QA: QA." This analysis is prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.2) and LS-PRO-0201, *Preclosure Safety Analysis Process* (Ref. 2.1.4).

4.2 USE OF SOFTWARE

The operating environment used in writing this analysis included the use of Microsoft® Word 2003 software installed on a Dell OptiPlex 745 personal computer. The operating system used on this computer is Microsoft Windows XP Professional. The use of Microsoft Word software is classified as Level 2 software usage per Attachment 12 of *Software Management* (Ref. 2.1.3). No software was used for any calculation in this analysis.

4.3 CRITERIA

Construction activities must be evaluated for potential hazards/events that could lead to event sequences that produce radiological exposures to workers or offsite individuals during the preclosure period. As defined in 10 CFR 63.2 (Ref. 2.3.1 [DIRS 180319]), an event sequence includes one or more initiating events and associated combinations of repository system component failures that could potentially lead to exposure of individuals to radiation (including nuclear criticality). If a structure, system or component (SSC) is relied upon to reduce the frequency or mitigate the consequences of an event sequence it is classified as ITS, as defined in 10 CFR 63.2. Perturbations from normal operations, human errors in operations, human errors during maintenance (preventive or corrective), and equipment malfunctions may initiate an event sequence. The SSCs supporting normal operations (and not relied upon as described previously for event sequences) are identified as non-ITS and are subject to controls imposed by facility management systems. In addition, if an SSC is used solely to reduce normal operating radiation exposure, it is classified as non-ITS.

Category 1 event sequences are those event sequences that are expected to occur one or more times before permanent closure; Category 2 event sequences are other event sequences that have at least one chance in 10,000 of occurring before permanent closure of the repository (Ref. 2.3.1, Section 63.2 [DIRS 180319]). The event sequences that are based on these hazards can be considered to be Beyond Category 2 events if their event sequence frequency is less than 10^{-6} per year. Beyond Category 2 event sequences can be screened from further consideration. The surface facilities are designed for preclosure period of operations 50 years; the preclosure period of operations for the subsurface facilities is 100-years (Ref. 2.2.3, Section 2.2.2.8 [DIRS 182131]).

4.4 METHOD

This hazards screening analysis was performed using the hazard analysis methodologies described in *System Safety Analysis Handbook* (Ref. 2.2.14 [DIRS 101450]). This analysis addresses the hazards and potential initiating events that could potentially result in an event sequence (as defined in Section 4.3) as a result of construction activities. Tables of hazards/events, and potential initiating events are generated by applying a checklist of generic events to the various areas where construction activities will occur. Steps in the analysis process are described in Sections 4.4.1 through 4.4.5.

4.4.1 Step 1: Define the Repository Construction Areas

The first step of the analysis process involves dividing the repository into the various areas for which construction hazards and potential initiating events are identified. These areas are usually defined by specific activities, by facility physical boundaries, or both. The repository architecture is based on *Repository System Codes* (Ref. 2.2.7 [DIRS 182471]). For the purposes of this analysis, the repository has been divided into two specific areas for analysis: the Subsurface Facility and the Surface Facility.

4.4.2 Step 2: Define the Repository Design Configuration and Operations

In the second step of the analysis process, the design configuration and operations of the repository are established and documented for each area where construction activities may occur for use during hazard/potential identification activities (Step 4.4.3).

4.4.3 Step 3: Develop the Generic Events Checklist

The third step of the analysis process involves the generation of a generic checklist of construction hazards/events and potential initiating events. The list is comprised of hazards and events that, if determined to be applicable, could potentially result in radiological hazards or radiological releases (i.e., event sequences). The generic checklist is intended to be a comprehensive list that identifies potential hazards and initiating events that can be used to ensure that a thorough risk-informed treatment of possible events is performed.

4.4.4 Step 4: Determine the Applicability of Generic Events

The fourth step of the analysis process includes a review of the construction areas and the operations in and around these areas, and given the results of the generic checklist, generation of a list of potential events that could result in radiological hazards or initiating events with radiological releases.

4.4.5 Step 5: Events Screening

This process is followed until each area is evaluated using the generic checklists and any or all potential events are identified. The generic event category is screened from further evaluation if no hazards/events are identified for that category. If any potential events are not screened out based on the inability of the potential events to lead to event sequences, they will be compiled in a list as subjects for further evaluation. These events could be considered as event sequences to be analyzed further as part of the preclosure safety analysis supporting the Yucca Mountain construction license application.

The evaluation of the generic hazard/event categories and the postulation of potential events associated with construction activities is performed in Sections 6.4 through 6.8.

5. LIST OF ATTACHMENTS

	Number of Pages
There are no attachments to this document.	0

6. BODY OF CALCULATION

6.1 GENERIC HAZARDS/INITIATING EVENTS CHECKLIST

The development of the generic hazards/initiating events checklist for use in this analysis is based on three hazard evaluation techniques from *System Safety Analysis Handbook* (Ref. 2.2.14 [DIRS 101450]), as follows:

- Energy analysis (p. 3-81)
- Energy trace barrier analysis (p. 3-83)
- Energy trace checklist (p. 3-89).

The checklist used in this analysis is based upon the Stephans and Talso techniques and lists (Ref. 2.2.14 [DIRS 101450]). The checklist contains questions for each generic hazard/initiating event to determine its applicability to a functional area, which is indicated by a positive response (as applicable).

There are six types of generic hazards or initiating events that, if determined to be applicable, could potentially result in an event sequence resulting in radiological hazards or radiological releases. As defined in 10 CFR 63.2 (Ref. 2.3.1 [DIRS 180319]), an event sequence is a series of actions and/or occurrences within the natural and engineered components of the geologic repository operations area that could potentially lead to exposure of individuals to radiation (including nuclear criticality). An event sequence includes one or more initiating events and associated combinations of repository system component failures, including those produced by the action or inaction of operation personnel.

The six types of generic hazards/initiating events include the following (Ref. 2.2.14 [DIRS 101450]):

1. Collision/Crushing
2. Chemical Contamination/Flooding
3. Explosion/Implosion
4. Fire
5. Radiation/Magnetic/Electrical/Fissile
6. Thermal.

Sections 6.1.1 to 6.1.6 describe each of the six types of generic hazards/initiating events (Ref. 2.2.14 [DIRS 101450]).

6.1.1 Collision/Crushing

Categories:

1. Uncontrolled mass/force. Examples include: Excessive velocity or acceleration of mass, inadvertent operation of appendage, failure of primary/secondary structure, tumbling (or tipped-over) mass, uncontrolled robot, or uncontrolled fixed rotating equipment, falls, drops.

2. Protrusions into pathways. Examples include: Extended appendages, protruding structural elements, or improperly placed equipment.

Applicability to Functional Area of Design:

- Is kinetic or potential energy present?
- Can the kinetic or potential energy be released in an unplanned way?
- Can the release of kinetic or potential energy interact with the waste form?

6.1.2 Chemical Contamination/Flooding

Note: Chemical Contamination/Flooding is not normally a direct potential threat to the waste form; it is usually a contributing cause of another generic hazard/initiating event.

Categories:

1. Reactions. Examples include: Release of chemicals or materials that react with system materials causing system deterioration. The released materials may foster electrolytic reactions, galvanic reactions, stress corrosion, or oxidation.

2. Off-Gassing. Examples include: Release of volatile/condensable materials.

3. Venting. Examples include: Leaking or venting of materials, gases, or liquids.

4. Debris/Leaks. Examples include: Small loose/free parts, flaking, leaking fluids or flooding, dirt or dust, or oxidized materials (e.g., metal rust).

5. Flooding. Examples include: Water, water ingress leading to the potential for criticality.

Applicability to Functional Area of Design:

Applicability to Category 1: Reactions

- Are corrosive or reactive chemicals or materials present?
- Can these chemicals or materials be released?
- Can the chemicals or materials interact with the waste form?

Applicability to Category 2: Off-Gassing

- Are volatile or condensable materials present?
- Can these materials be released?
- Can these materials interact with the waste form?

Applicability to Category 3: Venting

- Is there potential for venting materials in the area?
- Can the materials interact with the waste form?

Applicability to Category 4: Debris and Leaks

- Is there potential for debris or leaks in the area?
- Can the debris or fluids interact with the waste form?

Applicability to Category 5: Flooding

- Are sources of water present in the area?
- Is there a potential to release the water?
- Can the released water interact with the waste form with potential for criticality?

6.1.3 Explosion/Implosion

Note: This event is normally accompanied by shrapnel or other high velocity debris.

Categories:

1. Pressure Energy Release. Examples include: Damage, failure, or rupture of pressurized containers or components and release of gases, implosion of containers, vessels, or enclosed structural volumes.

2. Electrical Energy Release. Examples include: Overloading, shorts, faults, arcs, static charge, electrical component failure, battery overcharge or overdischarge, out-of-phase source connection, shooting objects, or fire.

3. Chemical Energy Release. Examples include: Chemical dissociation or reactions, fire internal to confined volumes, adiabatic detonation, or ignition of confined flammable gases.

4. Mechanical Equipment. Examples include: Rotating equipment disintegration due to overspeed.

Applicability to Functional Area of Design:

- Are pressure, electrical, chemical, or mechanical energy sources present?
- Can an event occur that results in an explosion or implosion energy release?
- Can the released energy impact the waste form directly?

6.1.4 Fire

A fire must have ignition, fuel, and oxidizer sources:

1. Ignition Sources. Examples include: Electrical faults, shorts, arcs, chemical reactions, hot surfaces, small flames, or catalytic reaction (also see Section 6.1.3, Explosion/Implosion).

2. Fuel and Oxidizer Sources. Examples include: Flammable materials (solids and liquids) and flammable atmospheres (gases), in addition to the presence of an oxidizing environment from ambient atmosphere or other chemical agents (also see Section 6.1.2, Chemical Contamination/Flooding).

Categories: Not Applicable

Applicability to Functional Area of Design:

- Are fuel, oxidizers, and ignition sources present?
- Is there sufficient fuel and oxidizer to sustain a fire?
- Can fire interact with the waste form?

6.1.5 Radiation/Magnetic/Electrical/Fissile

Categories:

1. Ionizing. Examples include: Radioactive materials, X-rays, high-voltage radio frequency equipment, or corona.

2. Non-Ionizing. Examples include: Electromagnetic interference or radio frequency.

3. Magnetic. Examples include: Permanent magnets and electromagnetic devices.

4. Nuclear Particles. Examples include: Ion, electron beams, or radioactive materials.

5. Laser Light. Examples include: High energy laser beams and accompanying energy forms such as heat.

6. Fissile Material. Examples include: Uranium-233, uranium-235 and plutonium-239.

Applicability to Functional Area of Design:

- Are radiation, magnetic, or electrical energy sources present external to the waste form? Is fissile material present?
- Is a mechanism present to release radioactive, magnetic, or electrical energy?
- Can the release of radiation, magnetic, or electrical energy interact with the waste form?
- Can fissile material be arranged in a manner that could result in criticality?

6.1.6 Thermal

Note: Also see Fire (Section 6.1.4).

Category:

Heat. This category accommodates any heat energy source with sufficient energy to have an impact on the waste form.

Applicability to Functional Area of Design:

- Are external heat energy sources present?
- Can heat energy be released?
- Can the heat energy affect the waste form?

Section 6.3 identifies the hazards and initiating events associated with construction activities at the repository during the preclosure period.

6.2 APPLICABILITY OF GENERIC EVENTS TO FUNCTIONAL AREAS

The repository was subdivided into two functional areas for the purpose of identifying and documenting the hazards and potential initiating events associated with repository construction activities. The two functional areas considered in this analysis are the Subsurface Facility and the Surface Facility (taken as a whole).

6.3 IDENTIFICATION OF HAZARDS AND POTENTIAL INITIATING EVENTS

The following approach, using the listed subsections, was used in Sections 6.5 through 6.8 to document potential hazards and potential initiating events:

Area Description/Process Description: Establishes the baseline description of the repository functional area and process description. Information is used to gain an understanding of the expected use of the functional area.

Generic Event Category Applicability: Summarizes the results from the applicability assessment for each of the following generic events:

- Collision/Crushing
- Chemical Contamination/Flooding
- Explosion/Implosion
- Fire
- Radiation/Magnetic/Electrical/Fissile
- Thermal.

Potential Events: Identifies the specific events based on the potential for interaction.

6.4 REPOSITORY DEVELOPMENT

The repository will be developed and operated in the following five phases:

1. Site characterization
2. Construction (development)
3. Operations (waste emplacement and postemplacement)
4. Closure
5. Postclosure.

Site characterization, the initial phase, is not part of the scope of this document. The postclosure phase, which occurs after the repository is closed, is also not part of the scope of this document. The operations phase will begin after the construction phase has started. The operations phase will be concurrent with construction activities for several decades and will continue several years after the completion of the construction phase. Construction and operations will take place in phases, starting with the facilities required to conduct initial operating capability. More facilities will be constructed and brought online to eventually achieve full operating capability. The surface facilities will be removed from service as waste receipt ramps down. The closure phase begins at the end of the operations phase. Inherent to construction and operations is the startup of facilities. Startup includes startup of individual systems and verification of the interaction of systems to achieve the desired process outcome (Ref. 2.2.9, Section 3.0; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

The construction phase includes:

- Transition of the Exploratory Studies Facility (ESF) to repository facilities (a programmatic change in status)

- Construction of surface facilities

- Refurbishment of ESF openings
- Excavation and equipping of the Subsurface Facility
- Collection of data to support performance confirmation or other required test activities.

Construction will begin several years before the start of waste receipt and emplacement. Construction of the underground facility will continue during most of the operations phase (Ref. 2.2.9, Section 3.1; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

When construction and emplacement activities are concurrent, the construction portion of the Subsurface Facility will be under the control of the subsurface construction manager, and the emplacement portion will be under control of the operations manager. On the surface, the construction and operations organizations are physically separated. The construction and operations facilities will be located at different access portals to the emplacement level of the repository. The facilities associated with operations will be located near the North Portal, and operations personnel and equipment will access the subsurface through the North Portal and ramp (Figure 1). The facilities and operations associated with construction will be located at the South Portal. Construction personnel and equipment will access the subsurface through the South Portal (and, in following years, through the North Construction Portal). The functions of the construction and operation organizations are separated in the subsurface by the placement of isolation barriers between the development and emplacement sides of the Subsurface Facility (Ref. 2.2.9, Section 3.1.1; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

6.5 SUBSURFACE FACILITY DEVELOPMENT

6.5.1 Steps 1 and 2: Subsurface Facility Area Description/Process Description

The current Subsurface Facility layout design includes a potential maximum total of 108 emplacement drifts located in four waste emplacement panels, as shown in Figure 1. The Subsurface Facility is comprised of the following major features: portals, access mains, ramps, exhaust mains, shafts, raises, turnouts, and emplacement drifts. In addition to these specific features, other features to be present include performance confirmation facilities (observation drift and alcoves), civil infrastructure, equipment, utilities, communications, safeguards and security, and miscellaneous support and safety systems such as refuge stations.

The repository layout was designed to take advantage of existing subsurface Yucca Mountain Project excavations. Subsurface openings excavated during the characterization phase of the Yucca Mountain Project will become part of the permanent repository after improvements have been implemented to bring those structures to the higher standards of the repository. The first emplacement panel to be constructed (Panel 1) is also the smallest, consisting of six emplacement drifts. The drifts in Panel 1 will receive waste packages from the Initial Handling Facility (IHF) and the first Canister Receipt and Closure Facility (CRCF). One or two of the emplacement drifts in this panel will be designated as thermally accelerated test drifts and will be used as part of the Performance Confirmation Program. The balance of the emplacement drifts (Panels 2, 3, and 4) will be developed concurrently with waste emplacement operations, involving waste packages from the IHF and the CRCFs.

Separation will be maintained between the development area and the emplacement areas by the use of temporary isolation barriers, separate underground access portals, and administrative controls, thus providing separate access, safeguards and security, transportation, and ventilation systems for the two areas (Ref. 2.2.9, Section 2.2; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]). The subsurface ventilation system is discussed in Section 6.5.12; the use of isolation barriers is discussed in Section 6.5.13.

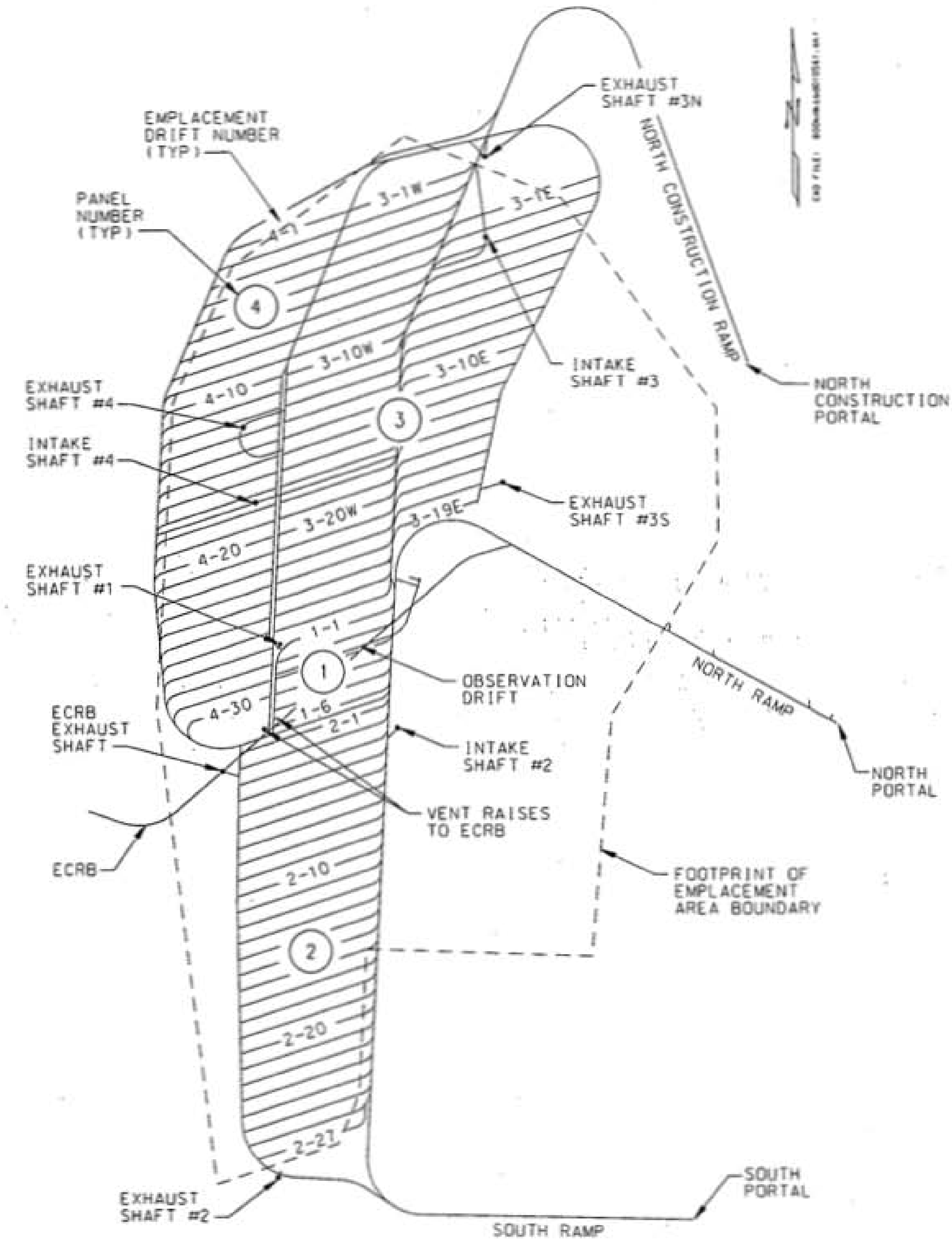
6.5.2 North Portal, South Portal, North Ramp, and South Ramp

One subsurface access portal will be required for waste emplacement, and a separate subsurface access portal will be required for construction. The North Portal will be used as the access for waste emplacement operations, although a portion of the construction activities may initially use the North Portal and North Ramp until they are refurbished and used exclusively for emplacement operations. Construction use and refurbishment of the North Ramp will be coordinated with surface construction activities as schedules for Surface Facility completion and emplacement are finalized. Some utilities in the North Ramp may be used during the construction of the Panel 1 emplacement drifts. After the Panel 1 construction operations have been completed, the construction utilities and ventilation ducting will be removed. Construction utilities will then be installed through the South Portal.

These utilities will include the electrical power to be used by the tunnel boring machines (TBMs), drill jumbos, rock bolters, ventilation fans, and lighting. Other utilities will include water lines for construction purposes and subsequent discharge, compressed air lines, communication systems, and monitoring systems. Surface systems that provide these utility services will be in place as part of the construction infrastructure. A conveyor system may be used to remove muck (defined as the earth and rock removed during the tunnel-boring) out the South Ramp, but due to dust concerns the current strategy envisions using railcars. Railcars from Panels 1 and 2 will be dumped at the South Portal site by using rapid dump machinery (Ref. 2.2.11, Section 5.7 [DIRS 182570]).

6.5.3 North Construction Portal and North Construction Ramp

The North Construction Portal and the North Construction Ramp (Figure 1) will be built approximately 10 years after construction has commenced. The infrastructure and systems at the North Construction Portal will be similar to the systems used at the South Portal (Ref. 2.2.11, Section 5.8 [DIRS 182570]).



NOTE: ECRB = Enhanced Characterization of the Repository Block.

Source: Ref. 2.2.11, Figure 4.1.2-1 [DIRS 182570]

Figure 1. Subsurface Facilities – Phased Panel Arrangement

6.5.4 Panel Sequencing

The proposed panel construction sequence that will meet the requirement for staged development of the repository (including excavation, construction, and emplacement activities) follows (Ref. 2.2.11, Section 6.1 [DIRS 182570]):

- Panel 1
- Panel 2
- Panel 3E and Panel 3W
- Panel 4 (some drifts excavated concurrently with Panel 3 work).

Typical subsurface excavation and construction cycle activities include the following (Ref. 2.2.11, Section 6.2 [DIRS 182570]):

- Excavation using TBMs, roadheaders, raiseboring, or drilling and blasting (described in Sections 6.5.8 and 6.5.9)

- Muck removal using railcars, load-haul dumps (LHDs), conveyors, skip hoisting, etc.

- Ground support inspection and installation activities involving rock bolts, perforated steel sheets, etc.

- Ventilation system installation and operation to provide for isolation of development activities from emplacement activities

- Development of transportation system operations for personnel, equipment, and materials handling

- Utilities installation, including electrical systems, water lines, communications, and monitoring systems

- Equipment installation activities for emplacement system rail lines, inverts, and ventilation equipment.

6.5.5 Panel 1

Construction will start with Panel 1 since this location is easily accessed from the ESF North Ramp and the main drift (Figures 1 and 2). This panel will require the least amount of development work, time, and expense. Panel 1 will also require the least amount of ventilation preparation. Excavation and construction of emplacement drifts will proceed from north to south in Panel 1. Panel 1 has a total of six emplacement drifts and one exhaust shaft. It is expected that half of the panel, three emplacement drifts, will be commissioned when waste emplacement in Panel 1 begins (Ref. 2.2.11, Section 6.1 [DIRS 182570]).

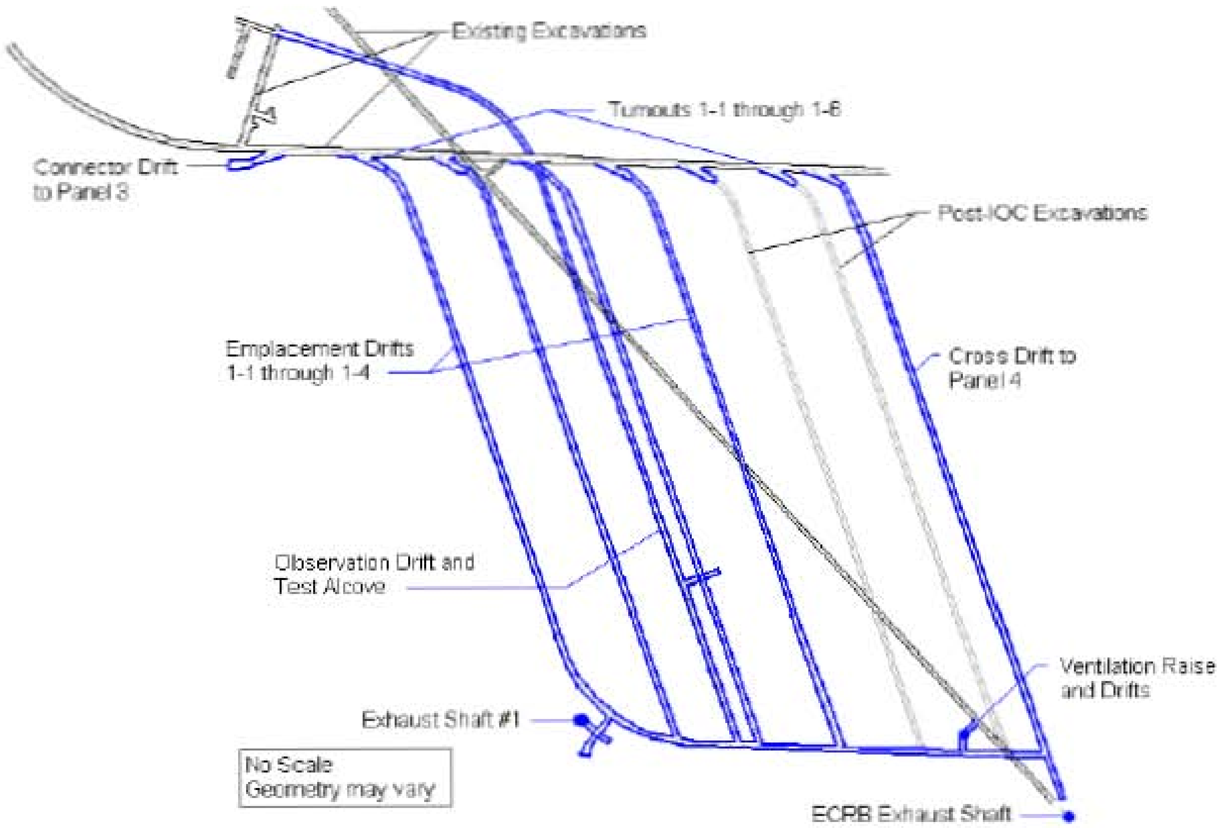
The North Ramp will be used as the initial access for Panel 1 excavation activities. Intake ventilation for initial Panel 1 construction will be through the North Ramp. Muck from the various excavations in Panel 1 will travel out through the South Ramp to a designated surface storage area. Some muck could be hoisted to the surface (as described later in this section); this aspect of the construction operations will depend on the muck haulage strategy devised by the subsurface subcontractor (Ref. 2.2.11, Section 7.1 [DIRS 182570]).

Excavation of Panel 1 will begin with the starter tunnel for emplacement drift 1-1 or the starter tunnel for the Enhanced Characterization of the Repository Block (ECRB) Cross-Drift (identified as 'Existing Excavations' in Figure 2) to Panel 4. Muck from the heading will be removed with underground loaders. When the starter tunnel excavation is completed, an 18-ft TBM will be used to excavate the drift. Muck from the TBM excavations will probably be removed by railcars, although the subsurface subcontractor may elect to install a conveyor system. All underground drifts will be mapped geologically and anomalies, if any, will be addressed. Emplacement drift 1-1 and all of the Panel 1 Exhaust Main will be excavated by an 18-ft TBM in a single drive that originates in the access main (Figures 1 and 2). After completing the drive to the intersection point of the ECRB Cross-Drift and Panel 4, the TBM will be removed and excavation will commence on emplacement drift 1-2. The excavation sequence will be repeated until the final drift in Panel 1, emplacement drift 1-6, is completed (Ref. 2.2.11, Section 7.1 [DIRS 182570]).

Two short access drifts will be excavated from the Panel 1 exhaust main. One will provide access to the bottom of exhaust shaft 1, and the other will extend to the bottom of the construction vent raise to the ECRB Cross-Drift. These access drifts will be drilled and blasted (as described in Section 6.5.9), with the muck being removed by an underground loader. The construction vent raise to the ECRB Cross-Drift will be excavated using raiseboring techniques (as described in Section 6.5.8.3). This muck will be removed by an underground loader. Exhaust shaft 1 to the surface could be excavated using raisebore techniques, or it could be excavated using conventional shaft-sinking methods. In conventional shaft-sinking methods, the muck is hoisted to the surface. When the raisebore method is used, the muck is removed through the underground. The final excavation for Panel 1 will be the performance confirmation observation drift and its alcove. This drift will be excavated by drill-and-blast methods or through the use of a roadheader, using an underground loader for muck removal (Ref. 2.2.11, Section 7.1 [DIRS 182570]).

6.5.6 Panel 2

Panel 2 will be the next panel excavated. This panel will also be accessed from the main drift. After the exhaust main has been constructed, the excavation and construction of emplacement drifts will proceed in Panel 2 from north to south. This panel will have a total of 27 emplacement drifts and one intake shaft. Panel 2 will have a dedicated exhaust shaft on the south end of the panel. Panel 2 will share the ECRB exhaust shaft with Panels 3 and 4, once those panels are excavated (Ref. 2.2.11, Section 6.1 [DIRS 182570]).



NOTE: ECRB = Enhanced Characterization of the Repository Block; IOC = initial operating capability.

Source: Ref. 2.2.11, Figure A1.1-1 [DIRS 182570]

Figure 2. Repository Panel 1

Muck from the various excavations in Panel 2 is expected to travel out of the South Ramp to a designated surface storage area. The exception to this strategy will be the muck from the ventilation shafts; this muck may be hoisted to the surface. Alternatively, the subsurface subcontractor may install a muck-skip system in one of the shafts for muck removal through the shaft. This method would result in a substantial reduction in the amount of muck that would pass through the South Ramp, thereby minimizing the quantity of dust generated by muck removal (Ref. 2.2.11, Section 7.1 [DIRS 182570]).

Excavation of Panel 2 will begin with the starter tunnel near the south end of the main drift using a 25-ft TBM. The exhaust main excavation will continue around Panel 2 until it intersects the ECRB Cross-Drift (identified as 'Existing Excavations' in Figure 2) at Panel 4. The 25-ft TBM would then be removed from Panel 2. All muck produced from this TBM will be removed by railcars or a conveyor belt. The Panel 2 turnouts will be excavated with a roadheader or through the use of drill-and-blast methods, and the muck will be removed by underground loaders (Ref. 2.2.11, Section 7.1 [DIRS 182570]).

As the excavation on the turnouts progresses, the 18-ft TBMs will be used to excavate the emplacement drifts in Panel 2. One plan foresees requiring two TBMs to excavate the emplacement drifts. Muck from the emplacement drifts will be removed using railcars. It is expected that emplacement drifts will be completed in groups of approximately five drifts. Construction personnel will erect isolation barriers (as described in Section 6.5.13), and the completed set of drifts will be turned over to operations. Operations personnel will remove the isolation barrier on the emplacement side after startup testing and checkout of all systems has been completed. As long as the isolation barrier on the emplacement side of the turned over area is still functioning, construction personnel can assist with troubleshooting and punch list items. However, as soon as the emplacement operations personnel remove the isolation barrier and activate the construction side isolation barrier, construction access ends. The isolation barrier will be taken to the surface through the North Portal by operations personnel. It will be checked for radiation and then delivered to the subsurface subcontractor at the South Portal or North Construction Portal for reuse. Additional excavations will be made for the three shaft access drifts that will connect to the three ventilation shafts that serve Panel 2. The shaft access drifts will be excavated using a roadheader or through the use of drill-and-blast methods and will be mucked with underground loaders. The shafts may be excavated using conventional shaft sinking techniques; the muck from each shaft will be hoisted to the surface. However, the raisebore process (described in Section 6.5.8.3), followed by a slashing process to obtain the full shaft size, may alternatively be used to excavate any of these shafts (Ref. 2.2.11, Section 7.1 [DIRS 182570]).

6.5.7 Panels 3W, 3E, and 4

Panel 3E and Panel 3W will be the next panels excavated. These panels will share a common access main, and the emplacement drifts will be excavated alternately from south to north. Substantially more development will be needed to prepare these panels and their associated emplacement drifts as compared to the time required to complete Panel 2 or Panel 1. More time will be required for the startup and completion of the North Construction Portal and the North Construction Ramp, the completion of five ventilation shafts, and the excavation of access and exhaust mains that must be constructed before emplacement can begin. The North Construction

Portal will support construction activities for Panel 3E and Panel 3W. The emplacement drifts for these two panels will be excavated alternating from the east side to the west side, advancing from the south to the north. These panels will have a combined total of 45 emplacement drifts. Panel 4 will be the last panel excavated, although part of the panel will be excavated concurrently with Panel 3. Construction activities for Panel 4 are not as extensive as those needed for Panel 3E and Panel 3W. However, for reasons regarding ventilation isolation, muck haulage, and construction access, Panel 4 will be finished last. The emplacement drifts in Panel 4 will be emplaced from the south end to the north end. This panel will have a total of 30 drifts (Ref. 2.2.11, Section 6.1 [DIRS 182570]).

When the exhaust main in Panel 2 is completed, excavation of the North Construction Portal and the North Construction Ramp will begin. Excavations for Panel 3W, Panel 3E, and Panel 4 will use the North Construction Ramp to remove the excavated muck to a designated storage area near the North Construction Portal. The shafts on the north end of the repository could potentially also be utilized for muck removal, personnel access, or material transport. The 25-ft TBM(s) will excavate the access and exhaust mains in these panels. Muck from the 25-ft TBM(s) will be removed using conveyor belts, railcars, and shaft skips (a platform raised and lowered in a vertical shaft). Muck excavated by the 18-ft TBMs from the emplacement drifts in these panels will be removed by railcars. All turnouts will be excavated by drill-and-blast methods or roadheaders and will be mucked by underground loaders. The shafts will be excavated and mucked similarly to the shafts described in Panel 2. The schedule for developing and completing these panels will be coordinated with the schedule for loading waste packages in the CRCFs, waste package emplacement rates, and rates for sending waste to the Surface Aging Facility (Ref. 2.2.11, Section 7.1 [DIRS 182570]).

6.5.8 Proposed Excavation Equipment

Constructing the subsurface repository will require using a large variety of equipment. Mining and underground construction equipment is designed for excavating horizontal openings, vertical shafts or raises, and inclined drifts or ramps. The primary horizontal development excavations will be the emplacement drifts, the turnouts, and the main drifts. The portals and ramps, the observation drift, and the support excavations will have varying degrees of inclination from essentially no incline (flat) to a grade of approximately five percent. The main vertical development excavations will be the ventilation shafts and ventilation raises (Ref. 2.2.10, Section 6.0 [DIRS 182905]).

Mechanical excavation will be the primary excavation method for much of the repository. This method includes the use of a TBM for long horizontal drives and raiseboring for the applicable vertical development. Alternatively, in nonemplacement headings where ground conditions or dimensional constraints are not favorable for mechanical excavation, drill-and-blast techniques may be used. Roadheaders may be used as mechanical excavation tools when rock conditions permit (Ref. 2.2.10, Section 6 [DIRS 182905]).

The major types of equipment needed to accomplish the excavation and construction methods planned for the repository are described in the following sections.

6.5.8.1 TBMs

A TBM is an electrically powered mechanical excavator that will be used to excavate the majority of the subsurface repository. The TBM creates a circular opening by advancing a cutterhead through the rock. The cutterhead rotates across the full diameter of the excavation normal to the axis of the drive. The cutterhead has multiple disc cutters that engage the rock face and initiate tensile failure in the rock as the TBM applies force by thrusting forward. The TBM thrust reaction can originate from the grippers that engage the side walls or ribs, or the reaction can be transmitted to concrete segments or steel sets behind the machine. The rock fractures into chips that are scooped up into buckets built into the rotating cutterhead and channeled to a conveyor and removed away from the rock face. The emplacement drifts will be excavated with an 18-ft diameter TBM. The Panel 1 exhaust main will be a continuation of the TBM drive from emplacement drift 1-1 and will also have an excavated diameter measuring 18 ft. Most of the remaining perimeter development for the repository emplacement area will be excavated with 25-ft diameter TBMs. The excavated muck will move through the TBM on a primary muck conveyor and will be discharged onto a secondary conveyor called a bridge conveyor. The bridge conveyor will carry the muck over the trailing gear for disposal into either muck cars or onto a main conveyor. The TBM is the lead piece of equipment in a series of support components called the trailing gear. The trailing gear is towed by the TBM and may ride on the construction rail that is installed as the TBM advances. Water will be used at the disc cutters to suppress the release of dust into the work environment (Ref. 2.2.10, Section 6.1 [DIRS 182905]).

6.5.8.2 Roadheaders

A roadheader is a mechanical excavator that is significantly more mobile than a TBM and can be used to excavate short access drifts, alcoves, shaft stations, turnouts, and starter tunnels. The roadheader is an electric hydraulic machine and requires a power center with transformers and switchgear. A trailing cable provides the power directly to the roadheader. Roadheaders can be used in the same areas as drill-and-blast operations if the rock type is amenable to excavation with a roadheader. Roadheaders are generally more effective in softer rock types since the mass and energy needed to break harder rock are not always available on a roadheader. The roadheader breaks the rock by initiating tensile failure by applying a rotating cutterhead with multiple picks against the rock face. The roadheader is crawler mounted, and the cutterhead is on an extended boom. The cutting action is performed by engaging the cutterhead in a series of sweeps across the rock face, as opposed to the full-face excavation of the TBM. As a result, a roadheader can easily construct a flat floor, and the excavation profile of the crown can be configured as an arch or made relatively flat. The boom passes the cutterhead across the rock face in a row and column pattern starting at the base of the excavation and moving upward. The cutterhead has carbide picks that are rotated against the face and break off chips of rock. The broken rock falls to the invert and is gathered onto a loading apron. The muck, fed onto a conveyor that passes through the center of the roadheader, is elevated, and then discharged off the tail of the conveyor. The muck is loaded into haulage equipment for transport to the surface. Haulage equipment may include underground haulage trucks, shuttle cars, or underground front-end loaders known as LHDs. Dust generated during excavation will initially be controlled with water sprays at the cutterhead picks, and residual dust will be captured in the dust collector. The residual dust will be removed at an interception point ahead of the operator compartment through an exhaust duct that transports the dust-laden air to a scrubber (Ref. 2.2.10, Section 6.2 [DIRS 182905]).

6.5.8.3 Raiseboring

A raisebore drill machine may be used to excavate raises or shafts. The raisebore drill is a mechanical excavator that produces a smooth vertical excavation. In conventional raiseboring, the raisebore drill is set up at the surface or upper level of two levels to be connected. The raiseboring process is a two-pass method that requires access to both the top and the bottom horizon of the vertical shaft or raise. The raisebore drill, set up on the top horizon, drills a small diameter pilot hole to the lower horizon with a drill bit attached to a drill string linked to the raisebore drill. At the breakthrough into the lower horizon, the pilot bit is removed, and a larger diameter reamer head is attached to the drill string. The reamer head is raised to the top horizon with the power of the raisebore drill. The reamer head rotates across the full diameter of the excavation normal to the axis of pull. The reamer head has multiple disc cutters that engage the rock face and initiate tensile failure in the rock as the raisebore drill applies force by pulling upwards. The rock cuttings that are produced during the reaming fall to the lower horizon, where they are removed using an LHD. The basic design of a raisebore drill consists of base plates and support beams to anchor the machine, thrust cylinders to apply feed pressure or lift as required, an electric motor, and a rotation head. The raisebore drill machine can be mounted on a crawler to facilitate mobility. Drive motor power is provided by electrical switchgear, and hydraulic power is used to raise and lower the derrick and manipulate the rod handler. The machine is controlled and monitored from an operator panel. Raiseboring is only possible where ground conditions are relatively competent since the shaft or raise must be self-supporting until ground support can be installed. Ground support is not installed until after the entire excavation has been completed. A steel liner can be lowered from the top horizon, or a concrete liner can be cast in place from the top down (Ref. 2.2.10, Section 6.3 [DIRS 182905]).

6.5.9 Drill-and-Blast Technique

The drill-and-blast technique is the alternative excavation method to mechanical excavation to be used in the nonemplacement headings. The activities that are performed as part of the drill-and-blast process include drilling the rock face, charging and blasting the holes, removing the muck, and installing the ground support. The first step of this process involves marking the drill pattern on the face of the excavation. After the drill pattern is established, an LHD may be needed to clean the drift floor at the face to locate the bottom holes of the drill pattern. Prior to drilling, the face is examined, and previous blast holes, if present, are inspected for residual explosives. Water is used for dust suppression. Water is injected at the bit face through a hollow tube in the drill steel to wet down the dust produced during the drilling. Upon completion of the drilling, explosives are loaded, blast holes are detonated, and muck is removed with an LHD. The cycle continues with installation of the ground support. Regardless of what method is used to drill the blast holes for the drill-and-blast excavation, the holes must be loaded with explosives and then detonated to fracture the rock. There are many different explosive types available that can be loaded into the blast holes using a variety of methods. Explosive charges contain at least two parts: a detonator and the primary explosive component. Detonators are used since they produce a relatively small detonation that has sufficient energy to ignite the primary explosive.

The primary explosive is powerful, but it is less sensitive and usually requires a detonator to ignite it. The detonator is ignited by an electrical charge or from explosive cord material.

After the explosives are detonated remotely, work will not resume in the blast area until a postblast examination addressing potential blast-related hazards has been conducted by an experienced person. When returning to the blast site, the crew will spray water on the muck pile and spray water on the blasted area from a safe distance. An examination will be made of the ground conditions, and loose material that can be accessed safely will be barred down. The removal of the muck will be accomplished through the use of an LHD. The crew will wet down the area and examine the ground conditions while they are removing the muck. Muck will be taken to a waiting haul truck or railcar, or it may be transported to a shaft loading pocket, a conveyor system hopper, or another transfer or storage location (Ref. 2.2.10, Section 6.4 [DIRS 182905]).

6.5.10 Ancillary Underground Construction Equipment

Muck removal and ground support installation are the two major components of the excavation cycle that supplement the rock-breaking component. With mechanical excavators such as the TBMs or the roadheaders, ground support activities are usually incorporated into the excavation process with onboard ground support installation equipment. Muck removal is integrated into the excavation cycle to produce a process of continuous excavation, mucking, and ground support installation. Ancillary equipment will be needed to assist in constructing emplacement drift inverts, erecting bulkheads, moving broken muck, and performing a variety of other tasks. This equipment could include underground loaders, muck cars or haul trucks, man lifts, utility vehicles, underground cranes, compactors, and graders (Ref. 2.2.10, Section 6.5 [DIRS 182905]).

6.5.11 Development Transportation

Development transportation provides the means of delivering personnel, equipment, and materials to the underground construction areas in a safe and timely manner. An efficient method of transportation will be achieved by the use of manually operated diesel locomotives on a 36-in. construction rail system. The existing rail in the ESF South Ramp could potentially be upgraded and may be used to support construction activities to the extent possible. A dual-track railroad system or a single-track railroad system with passing sections in the mains will enable traffic to flow efficiently for continuous and expeditious construction.

Development transportation for a portion of the Panel 1 construction effort may utilize the North Portal until the North Ramp is refurbished and equipped to handle waste packages. After that time construction personnel, equipment, and materials will enter the subsurface through the South Portal or via shafts. Subsurface construction use of the North Portal pad and the North Ramp will be scheduled and coordinated with the construction of the surface nuclear facilities in the vicinity of the North Portal.

Portions of Panel 1 and all of Panel 2 will be developed using transportation through the South Ramp and South Portal. When Panel 2 is sufficiently developed to accept waste packages, the North Construction Portal will have been completed, and construction personnel, equipment, and materials will enter the subsurface through the North Construction Portal or vertical shafts on the north end of the repository.

Transportation equipment will include locomotives, personnel cars, equipment cars, specialized cars for the delivery of concrete or shotcrete, and railcars to be used for muck removal. Other equipment may include vehicles that have been modified to travel either on or off the rails. The amount of work occurring during construction will require a well-regulated and coordinated traffic control system for dispatching personnel, equipment, and materials (Ref. 2.2.11, Section 6.8 [DIRS 182570]).

6.5.12 Subsurface Ventilation System

Mechanical ventilation will be used during the repository construction and emplacement operational periods to provide fresh air to the subsurface through the use of fans and ducting equipment. Primary construction ventilation will be provided by routing air from the intake shafts or portals, circulating it across the construction areas, and venting it through exhaust shafts or portals. Secondary construction ventilation will be provided by auxiliary fans and ducting for all areas where flow-through ventilation is not used, such as in development headings, rescue chambers, storage alcoves, and workshop areas (Ref. 2.2.11, Section 6.7 [DIRS 182570]).

The ventilation system will also remove water from the host rock by evaporation and will remove potential contaminants such as silica dust, radon, blasting fumes, engine exhaust smoke, and diesel particulates to meet air quality requirements (Ref. 2.2.9, Section 3.2.5; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

Two distinct ventilation networks will be employed to isolate the construction operations from the waste emplacement operations: the development ventilation system and the emplacement ventilation system. The development ventilation system will incorporate a forced-fan installation to provide positive-pressure ventilation through the construction air splits. The exhaust air from the emplacement ventilation system could become radiologically contaminated. For this reason the emplacement ventilation system will be separated from the construction development ventilation system. Moveable isolation barriers and doors (described in Section 6.5.13) will be placed at key locations to further assist in segregating development activities from emplacement activities. The isolation barriers will prevent unauthorized entry into emplacement areas, and detectors will automatically alarm if unauthorized entry is detected. However, the primary function of the isolation barriers is to control ventilation. The direction of any potential air leakage through the isolation barriers will be from the development side to the emplacement side of the subsurface repository (Ref. 2.2.11, Section 6.7 [DIRS 182570]). In addition, as air passes over the emplaced waste packages, it will be heated and it will expand. The emplacement drift exhaust volume will, therefore, be higher than the intake volume due to thermal expansion. The air will also pick up moisture from the wall rock if moisture is available. The airflow will travel to the exhaust main, where it will then be exhausted to the surface through the exhaust shaft (Ref. 2.2.9, Section 3.2.5; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

There will always be some degree of leakage between the emplacement and development sides of the repository, regardless of how substantially the ventilation systems are constructed. The emplacement ventilation system will supply air to the emplacement side of the repository through the use of exhaust fans located at the collar of the exhaust shafts, while the construction ventilation system will utilize fans forcing ventilation down the intake shafts (Ref. 2.2.11, Section 6.7 [DIRS 182570]). The system will maintain the air pressure on the development side at least 0.1 in. of water gauge greater than the air pressure on the emplacement side (Ref. 2.2.11, Table 4.2-1, Requirement Number 22.2.1.6 [DIRS 182570]). In this configuration of these two systems, all leakage will occur in the direction toward the emplacement side, thus ensuring that the air in the development area will inherently remain uncontaminated and that any potential contamination in the emplacement area of the repository will remain there (Ref. 2.2.11, Section 6.7 [DIRS 182570]).

6.5.13 Isolation Barriers

The ventilation system will use fire-rated isolation barriers located in the access mains and exhaust mains to separate areas of emplacement from areas being constructed. The following types of barriers will be used in the repository (Ref. 2.2.9, Section 3.1.7; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]):

- Type A—Moveable barrier between the development and emplacement ventilation systems that does not permit emergency egress
- Type B—Moveable barrier between the development and emplacement ventilation systems that permits emergency egress
- Type C—Permanent barrier between intake airflow and exhaust airflow.

During the construction phase, Type A and Type B isolation barriers will be installed in the access and exhaust mains to separate the construction ventilation from the emplacement ventilation. The isolation barriers are temporary and are moved as the construction effort progresses. The Type B isolation barrier contains an airlock door for emergency egress for escape purposes.

A Type C isolation barrier will be installed between the intake air and exhaust air flow paths, ensuring that access to high-radiation and high-temperature areas is not possible and that exhaust airflow does not recirculate. Access ports for the deployment of remotely operated vehicles may be made available at some Type C barriers. Type C barriers are permanent; they will remain in place for the entire ventilation period after final emplacement. Bulkheads for temporary and permanent barriers will be of the same approximate size and will have interchangeable parts (Ref. 2.2.9, Section 3.1.7; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

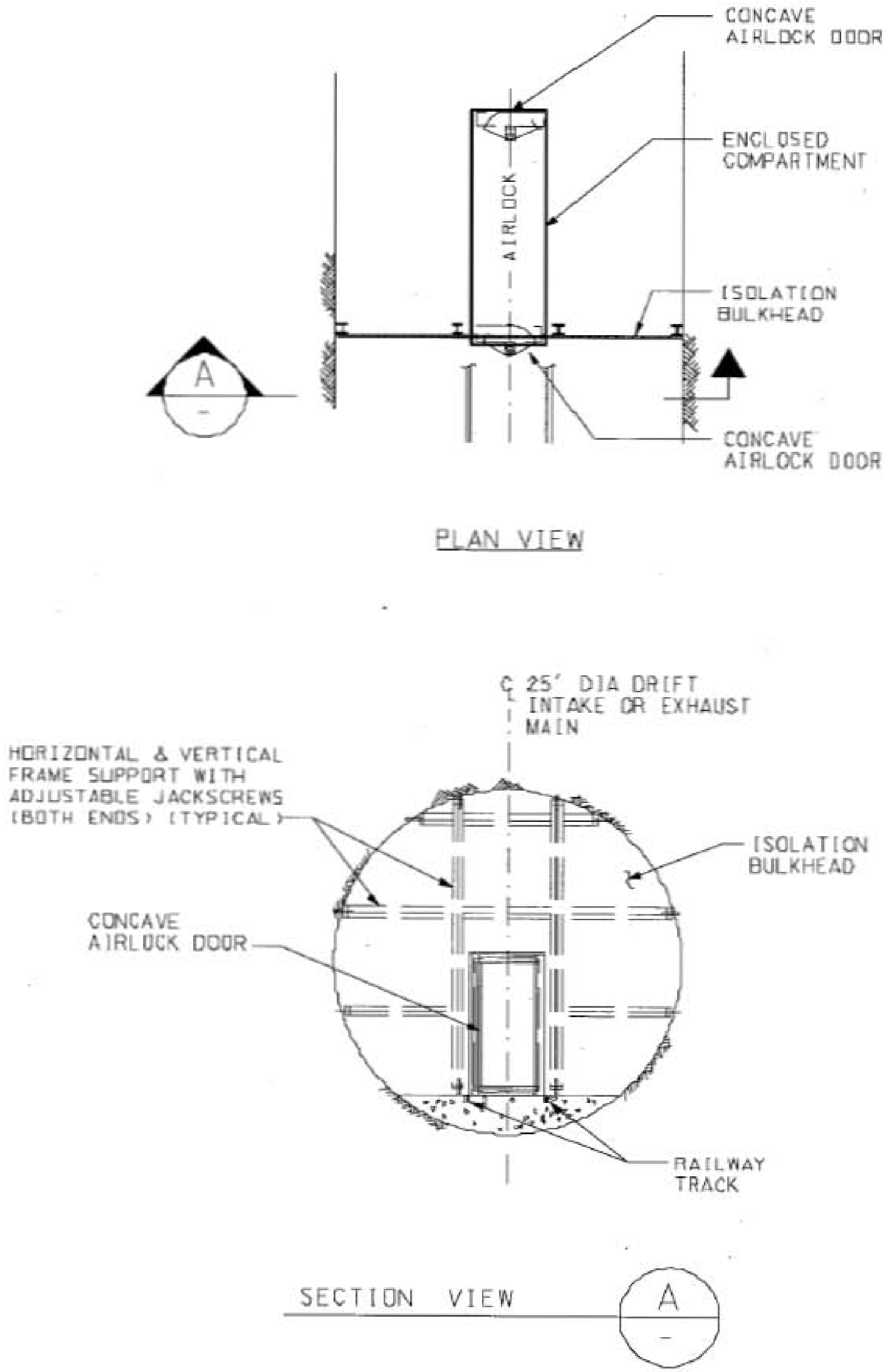
In a typical panel, each isolation barrier structure will consist of a bulkhead and an airlock chamber (Figure 3). In Figure 3, the concave doors are oriented toward the construction side of the isolation barrier, where the higher ventilation pressure keeps the doors closed. Section A in Figure 3 is cut through the development side, looking toward the emplacement side. The length of the airlock chamber will be dependent on the specific application (Ref. 2.2.9, Section 3.1.7; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

The location of the isolation barriers in the access mains will also be coordinated with the location of the electrical equipment alcoves such that there will be no impact to their intended functions. A set of barriers will typically consist of two Type A barriers in the exhaust main and two Type B barriers in the access main, located at directly opposite sides of the emplacement panel (Ref. 2.2.9, Section 3.1.7; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

As an example, if five emplacement drifts have been completed, the development activities for those five emplacement drifts will include construction of the access main invert structure, rail installation, and installation of electrical equipment up to and past the first set of isolation barriers. The first set of isolation barriers will separate the emplacement activities in the first five drifts from the development activities in the rest of this panel. Commissioning for emplacement begins when the first set of isolation barriers is in place and sealed. Emplacement drift excavation activities can continue beyond this set of barriers (Ref. 2.2.9, Section 3.1.7; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

The installation of a second set of isolation barriers will be initiated at a location on the development side of the set of the five emplacement drifts; however, this set of isolation barriers will be left open or partly completed to allow for construction equipment and personnel traffic. Similar to the case of the first five drifts, completion of the second set of emplacement drifts will include completion of the access main invert structure and installation of rail and utilities up to and past the second set of isolation barriers. This sequencing will allow the second set of barriers to be closed, sealed, and made ready for use. The second set of emplacement drifts will then be commissioned for use. This operation will be carried out in accordance with safeguard and security requirements. At that time, the first set of isolation barriers will no longer be needed and will be removed, reconditioned, and relocated to the intended location for the third set of barriers. Removal of the isolation barriers will take place inside a commissioned emplacement area. This activity will be limited to dismantlement and will not include demolition or dust-generating activities.

The bulkheads for the isolation barriers will be constructed by bolting modules together to a structural framework. There will be little interaction with emplacement activities, and radiological exposure will be minimal. After the second set of isolation barriers has been sealed and the second set of emplacement drifts has been commissioned for emplacement, construction activities will continue on a third set of emplacement drifts.



Source: Ref. 2.2.9, Figure 2; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]

Figure 3. Type B Isolation Bulkhead Arrangement

Components from the first set of isolation barriers that have been removed will then be reconditioned and reinstalled at the intended location for the third set of barriers. This process will then be repeated until the panel is completed (Ref. 2.2.9, Section 3.1.7; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

The isolation barriers will prevent the normal passage of personnel from the emplacement side of the repository to the development or construction side. Likewise, construction personnel will not be allowed to pass through the barriers under normal conditions. The barriers will be sealed around the edges to prevent and minimize the passage of dust or vapors to the emplacement side. Leakage is expected across the bulkhead since the construction side is required to have a differential pressure of 0.1 in. water gauge higher than the emplacement side (Ref. 2.2.10, Section 8.4 [DIRS 182905]).

The emplacement side of the isolation barriers will be monitored to ensure that the level of particulate matter, vapors, water, and other airborne residues (such as diesel smoke or blasting fumes) are within allowable limits. If construction residues leaking to the emplacement side exceed predetermined limits, additional sealing and shotcreting can be performed on the construction side. The isolation barriers may be located down gradient from the construction side of the subsurface, so water detection may also be required on both sides of the barrier (Ref. 2.2.10, Section 8.4 [DIRS 182905]).

6.5.14 Infrastructure

To support the subsurface construction strategy, infrastructure must already be in place or be installed concurrently with subsurface construction without interfering or delaying excavation work. Key infrastructure items include electrical power, water distribution, a concrete batch plant, and communication systems. Existing infrastructure (i.e., the ESF and the North Portal) will be upgraded to support construction and emplacement (Ref. 2.2.11, Section 5.5 [DIRS 182570]).

A concrete batch plant will be needed to efficiently conduct underground construction work. The most efficient strategy is to have a dedicated batch plant for the underground construction work located near a portal, though more distant batch plants, or batch plants shared with other subcontractors, may be suitable. Additionally, construction access routes (such as roads and rail lines) that provide access to site areas (e.g., portals, shafts, surface support facilities) will need to be established. Facilities and storage yards for subcontractors and their supplies will also be constructed or developed (Ref. 2.2.11, Section 5.5 [DIRS 182570].)

The rail system on the emplacement side of the repository will be located in the North Ramp, the access mains, and turnouts. In developing the first set of emplacement drifts in a panel, the rail system will be constructed to extend through the first set of isolation barriers. After construction of the first set of emplacement drifts, but prior to turnover of the drifts to the startup organization, the rail system will be extended through the second set of isolation barriers. This sequence of construction will be followed until the entire panel is constructed (Ref. 2.2.9, Section 3.1.8; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV

00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

6.5.15 Utilities

The principal utilities to be carried in the access mains are electric power and communications. Electric power will be required to power the transport and emplacement vehicle (TEV) during the emplacement operations. Electric power will also be required for lighting, communications, instrumentation, operation of ventilation dampers, and operation of drift doors. During construction of the first set of emplacement drifts in any given panel, the utilities will be installed and will be energized up to the first isolation barrier. They will not penetrate the barrier (with the exception of emergency communications) such that the isolation of the construction and emplacement utilities can be maintained. During this construction period, the utilities will be installed (but not activated) between the first and second isolation barriers. After the first set of emplacement drifts is turned over from construction to the startup organization and the first isolation barrier is removed, the utilities will be activated up to the remaining barrier. This sequence will continue until the entire panel is constructed (Ref. 2.2.9, Section 3.1.8; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

Utilities necessary for initial excavation and construction work will be installed after the ground support has been installed. These utilities will include electrical power cabling, communications, lighting, water supply lines, wastewater discharge lines, and ventilation ducts. Utilities will be routed through the portals and ramps or down ventilation shafts to provide the service to subsurface construction areas requiring a particular service. Alternative, additional, or redundant utility routes will be provided when needed in the event that a primary route is unavailable. When the initial excavation work is completed, the utilities used for construction will be removed such that the final ground support, invert ballast, and other permanent emplacement systems can be installed (Ref. 2.2.11, Section 6.9 [DIRS 182570]).

After completing the Panel 1 construction, in addition to the utilities, the construction ventilation ducting will be removed from Panel 1. Construction utilities will be installed through the South Portal, including the electrical power to be used by the TBMs, the drill jumbos, the rock bolters, the ventilation fans, and lighting. Other utilities include water lines for construction purposes and subsequent discharge, compressed air lines, communication system, and monitoring system (Ref. 2.2.11, Section 5.7 [DIRS 182570]).

Fire protection will be integrated into all stages of excavation and construction. Equipment will be procured and designed with onboard fire suppression systems or devices. Fire extinguishing equipment will be available to assist in fighting incipient-stage fires. Visual and audible alarms will be placed such that their signal can be detected or observed by subsurface personnel. Full service fire and rescue capabilities will be available to support subsurface activities during all stages of construction (Ref. 2.2.11, Section 6.11 [DIRS 182570]). No fire water distribution system will be installed in the subsurface emplacement side of the repository (Ref. 2.2.12, Section 6.1.2.1 [DIRS 180306]).

6.6 POTENTIAL SUBSURFACE EVENT SEQUENCE IDENTIFICATION

6.6.1 Steps 3 and 4: Generic Event Applicability and Potential Subsurface Construction-Related Events

Table 1 lists the applicability of generic hazards to the subsurface construction activities; Table 2 lists the potential events for each applicable category. These tables are based on an evaluation of the activities slated to occur during construction operations associated with the Subsurface Facility, the equipment and utilities slated to be present during the construction phase, and the hazards that may be present in the repository such that a hazard or event leads to a potential event sequence.

Table 1. Generic Hazard/Event Applicability to the Subsurface Construction Activities

Generic Hazard/Event Category	Is Generic Hazard/Event Applicable?
Collision/Crushing	None identified that affect/interact with a waste form leading to an event sequence
Chemical Contamination/Flooding	Yes, Flooding
Explosion/Implosion	Yes
Fire	Yes
Radiation/Magnetic/Electrical/Fissile	Yes, Radiation
Thermal	Yes (see Fire)

Source: Original

Table 2. Potential Events for the Subsurface Construction Activities

Generic Hazard/Event Category	Potential Event
Chemical Contamination/Flooding	SS.1 Flooding due to a pipe break, valve failure, etc. in the Subsurface Facility affects the emplacement side of the repository.
Explosion/Implosion	SS.2 Intended or unintended detonation of explosives on the construction (development) side of the repository affects the emplacement side of the repository.
Fire, Thermal	SS.3 Diesel fuel fire/explosion associated with subsurface development equipment, including locomotives, affects the emplacement side of the repository. SS.4. Electrical fire associated with subsurface development equipment or other equipment affects the emplacement side of the repository. SS.5 Transient combustible fire in the development side of the subsurface facilities affects the emplacement side of the repository.

Table 2. Potential Events for the Subsurface Construction Activities (Continued)

Generic Hazard/Event Category	Potential Event
Radiation	SS.6 Radiation exposure of a Subsurface Facility worker on the development side of the repository due to radioactive shine from the emplacement side of the repository. SS.7 Radiation exposure of a Subsurface Facility worker on the development side of the repository due to exposure to activated air from the emplacement side of the repository. SS.8 Radiation exposure of a Subsurface Facility worker on the development side of the repository due to exposure to detached and/or lofted surface contamination from waste packages located on the emplacement side of the repository.

Source: Original

Note: SS = Subsurface.

6.6.2 Step 5: Analysis of Identified Potential Event Sequences/Events Screening

6.6.2.1 Collision/Crushing

After Panel 1 has been completed, emplacement activities will occur in this portion of the Subsurface Facility while Panel 2 is under construction, as described previously. Waste packages containing waste forms will either have been emplaced in a drift or else will be in transit inside a TEV to a drift. Isolation barriers will separate the development (construction) and emplacement portions of the Subsurface Facility. During construction of the first set of emplacement drifts in any given panel, the utilities will be installed and will be energized up to the first isolation barrier. The utilities will not penetrate the barrier (with the exception of emergency communications) such that isolation of the development and emplacement utilities can be maintained. During this construction period, the utilities will be installed (but not activated) between the first and second isolation barriers (Ref. 2.2.9, Section 3.1.8; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]). In developing the first set of emplacement drifts in a panel, the rail system will be constructed to extend through the first set of isolation barriers. After construction of the first set of emplacement drifts, but prior to turnover of the drifts to the startup organization, the rail system will be extended through the second set of isolation barriers. This sequence of construction will be followed until the entire panel is constructed (Ref. 2.2.9, Section 3.1.8; BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. [DIRS 179331]).

Due to the separation (through the use of isolation barriers) and distance between emplacement operations and development (construction) activities (as part of normal operational/construction activities), no event sequences have been identified in which a collision or crushing hazard associated with subsurface construction could lead to an event sequence. If, due to a rail switching error (or other malfunction or error), a transport and emplacement vehicle (TEV) loaded with a waste package were to approach the construction side of the repository (on the available rail system), there would be no electrical power beyond the first isolation barrier available such that the TEV could transport a waste package into/through the second isolation barrier and into the construction portion of the Subsurface Facility. Regardless, no collision/crushing activities originating on the development (construction) portion of the Subsurface Facility have been identified that could lead to an event sequence involving high-level radioactive waste (HLW) present in sealed waste packages on the emplacement side of the Subsurface Facility.

6.6.2.2 Chemical Contamination/Flooding

6.6.2.2.1 SS.1. Flooding due to a pipe break, valve failure, etc. in the Subsurface Facility affects the emplacement side of the repository

Construction utilities will be installed through the South Portal, including water lines for construction purposes and subsequent discharge (Ref. 2.2.11, Section 5.7 [DIRS 182570]). Water will be used at the TBM disc cutters to suppress the release of dust into the work environment (Ref. 2.2.10, Section 6 [DIRS 182905]). In addition to dust suppression, water will also be used to wash blasting residues from the walls of excavated openings such as turnouts (Ref. 2.2.10, Section 4.3.1 [DIRS 182905]). When excavation work is completed in a panel, the utilities (including water lines as well as wastewater discharge lines) used for construction will be removed so that the final ground support, invert ballast, and other permanent emplacement systems can be installed (Ref. 2.2.11, Section 6.9 [DIRS 182570]). In addition, no fire water distribution system will be installed in the subsurface emplacement side of the repository (Ref. 2.2.12, Section 6.1.2.1 [DIRS 180306]). Therefore, if flooding were to occur in the Subsurface Facility during construction (concurrent with a failure or overwhelming of the wastewater discharge line), this event could only occur in the development (construction) portion of the repository. Due to the separation (through the use of isolation barriers) and distance between emplacement operations (including waste packages placed in drifts and waste packages in a loaded TEV) and development (construction) activities (as part of normal operational/construction activities), no event sequences have been identified (such as event SS.1) in which a flooding hazard/event associated with a pipe break/failure, etc. could lead to an event sequence involving HLW present in sealed waste packages on the emplacement side of the Subsurface Facility.

6.6.2.3 Explosion/Implosion

6.6.2.3.1 SS.2. Intended or unintended detonation of explosives on the construction (development) side of the repository affects the emplacement side of the repository

Due to the hardness of the rock at Yucca Mountain and the required design features to be excavated, it will be necessary to use explosives and blasting agents during construction of the repository. Any use of explosives will be designed and controlled to ensure that there is no impact on concurrent emplacement operations. The use of explosives will be carefully monitored, and ground vibration measurements will confirm that there are no adverse effects in emplacement areas. Explosive vibrations can travel thousands of feet through rock. Blasts on the construction side of the repository will be detectable in emplacement areas. However, the effects will be negligible and will be controlled. If needed, temporary bulkheads, blast mats, sandbag-type structures, or other features will be used to control the impacts from explosive use. A number of excavations requiring explosives use will be constructed prior to initiating emplacement operations. At least six turnouts, over 3,300 ft of observation drift and test alcoves, at least two shaft stations and associated access drifts, vertical shafts, and other openings will be excavated by drill-and-blast methods prior to any waste package emplacement operations. The experience gained in these blasting operations will ensure that explosive use can be predicted and controlled after the isolation barriers have been activated and emplacement operations begin. The timing of blasts will be coordinated with repository emplacement operations. This coordination would be primarily for information purposes only. Explosive charges and detonations will be conducted according to an approved design and will be timed and controlled to ensure that there are no adverse impacts on the emplacement side of the isolation barriers. After a blast has occurred, there may be some immediate indication on the emplacement side that a blast has occurred, such as a small transient vibration or minor loosening of dust. Because of the manner that blast waves travel through rock, it is not feasible to totally eliminate the sound or faint vibration of a blast from reaching the emplacement side of the repository (Ref. 2.2.10, Section 4.3.1 [DIRS 182905]). The subsurface isolation bulkheads will be designed to accommodate the maximum credible pressure differential from events such as ventilation failure or blasting (Ref. 2.2.13, Section 2.23 [DIRS 168857]).

Explosives will be stored in approved magazines. Explosives will be transported in approved containers and will be handled in accordance with applicable safety and health regulations. Precautions will be taken to ensure that the use of explosives does not adversely affect ITS systems (e.g., waste packages, the TEV) in emplacement areas (Ref. 2.2.11, Section 5.7 [DIRS 182570]).

Construction activities will be sufficiently isolated from emplacement activities such that potential missiles caused by the detonation of explosives will not initiate an event sequence. Due to the separation (through the use of isolation barriers) and distance between development (construction) operations and emplacement activities (as part of normal operational/construction activities), no event sequences have been identified in which an explosion associated with subsurface development (e.g., drill-and-blast activities, unintended detonation, event SS.2) could lead to an event sequence involving HLW present in sealed waste packages on the emplacement side of the Subsurface Facility.

6.6.2.4 Fire, Thermal

6.6.2.4.1 SS.3. Diesel fuel fire/explosion associated with subsurface development equipment, including locomotives, affects the emplacement side of the repository

6.6.2.4.2 SS.4. Electrical fire associated with subsurface development equipment or other equipment affects the emplacement side of the repository

6.6.2.4.3 SS.5. Transient combustible fire in the development side of the subsurface facilities affects the emplacement side of the repository

The Subsurface Facility fire area boundaries will be a function of the subsurface repository construction chronology. Initially, during the development phase, the Subsurface Facility will be comprised of one fire area. When waste emplacement begins, the Subsurface Facility will be divided into two fire areas: the development fire area and the emplacement fire area. These two fire areas will be physically separated by the isolation barriers. Finally, after the completion of the development (construction) activities, the repository will revert to one fire area after the isolation barriers are removed. The isolation barriers at the development/emplacement fire area interface will have a minimum fire-resistance rating of 3 hours with equivalently rated openings, dampers, and penetration seals. The development and emplacement fire areas are considered separate and distinct fire areas. The effects of fire contamination from one fire area to the other are adequately addressed by the barrier design constraints (Ref. 2.2.12, Section 4.4.1 [DIRS 180306]).

A mix of diesel-powered and electrically-powered equipment will be used in the subsurface development activities. The TBMs are electrically-powered mechanical excavators that will be used to excavate the majority of the subsurface repository. The roadheaders are electric-hydraulic machines that require a power center with transformers and switchgear. Trailing cables will provide the power directly to the roadheaders. The raisebore drill machine drive motor power will be provided by electrical switchgear, and hydraulic power will be used to raise and lower the derrick and manipulate the rod handler.

Ancillary equipment will be needed to assist in constructing emplacement drift inverts, erecting bulkheads, moving broken muck, and performing a variety of other tasks. This equipment could include underground loaders, muck cars or haul trucks, man lifts, utility vehicles, underground cranes, compactors, and graders. Much of this equipment will be powered by diesel engines. Development transportation equipment used to deliver personnel, equipment, and materials to the underground construction areas will include diesel-powered locomotives. Other equipment may include vehicles that have been modified to travel either on or off the rails.

Electrically powered equipment presents low fire hazards. Diesel-powered equipment presents higher fire hazards due to hot internal combustion engines and onboard diesel fuel storage tanks (Ref. 2.2.12, Section 6.3.1.3.2.1 [DIRS 180306]). As previously mentioned, no fire water distribution system will be installed in the subsurface emplacement side of the repository (Ref. 2.2.12, Section 6.1.2.1 [DIRS 180306]). Construction utilities, including the water supply, will be removed upon completion of the construction of each panel prior to turnover for emplacement operations. However, full-service fire and rescue capabilities will be available to support subsurface activities during all stages of construction. Equipment will be procured and designed with onboard fire suppression systems or devices. Fire extinguishing equipment will be available to assist in fighting incipient-stage fires (Ref. 2.2.11, Section 6.11 [DIRS 182570]).

Transient combustible materials are those combustible materials that are not permanently installed in a given fire area. Transient combustible materials primarily include waste materials generated from plant operations and maintenance activities. The control of combustible materials is an essential element of the defense-in-depth approach to fire protection. Prior to operations, an active administrative control program will be implemented to control the quantity of combustible materials permitted in a given fire zone. The program will be based on the combustible fuel loading and the findings of the fire hazards analysis for a given fire zone (Ref. 2.2.12, Section 6.1.3.4 [DIRS 180306]). In addition, low- (or reduced-) hazard materials will be used in the subsurface. Fire-resistant hydraulic fluids, hydraulic hoses, fiberoptics, and electric-cable insulation will be used to the maximum extent possible. Sealed bearings on mobile equipment will be used, primarily for environmental containment, thus reducing the exposure of greases (Ref. 2.2.12, Section 6.3.1.6.1.1 [DIRS 180306]). Therefore, the probability of a transient fire will be greatly reduced.

The probability of fire exposure from the development fire area encroaching into the emplacement fire area is very remote. The isolation barriers between fire areas are fire rated, and the ventilation systems will operate totally independently from each other (Ref. 2.2.12, Section 6.3.1.5 [DIRS 180306]). Construction activities will be sufficiently isolated from emplacement activities such that a diesel fire or explosion, an electrical fire, or a fire associated with transient combustibles in the development (construction) portion of the repository will not initiate an event sequence. Therefore, due to the separation (through the use of fire-rated isolation barriers) and distance between development (construction) operations and emplacement activities, the presence of fire suppression equipment and fire extinguishment capabilities, and controls to be put in place to control the presence of combustible materials (as part of normal operational/construction activities), no event sequences have been identified (including events SS.3, SS.4, and SS.5) in which a fire in the development (construction) portion of the Subsurface Facility could lead to an event sequence involving HLW present in sealed waste packages on the emplacement side of the Subsurface Facility.

6.6.2.5 Radiation

6.6.2.5.1 SS.6 Radiation exposure of a Subsurface Facility worker on the development side of the repository due to radioactive shine from the emplacement side of the repository

6.6.2.5.2 SS.7 Radiation exposure of a Subsurface Facility worker on the development side of the repository due to exposure to activated air from the emplacement side of the repository

6.6.2.5.3 SS.8 Radiation exposure of a Subsurface Facility worker on the development side of the repository due to exposure to detached and/or lofted surface contamination from waste packages located on the emplacement side of the repository

No fire-water distribution system will be installed in the subsurface emplacement side of the repository (Ref. 2.2.12, Section 6.1.2.1 [DIRS 180306]). Therefore, with no identified sequences involving breached waste packages and the introduction of water (or any other moderator) due to development (construction) activities, criticality in the emplacement portion of the repository has been eliminated from consideration in this analysis.

Radon is a naturally occurring gas in the subsurface environment. Concentrations of radon vary depending on the geology, the level of excavation activity, and the amount of ventilation provided to the area. Radon can be controlled several ways. Radon can be suppressed in the rock surrounding an excavation by using a blowing ventilation system or by applying a barrier such as shotcrete or a liner. Since radon is water soluble, it can be controlled by using water to keep ventilated openings damp. Also, by keeping dust levels low, the risk of radon inhalation is reduced since radon attaches to dust particles. Monitors will be installed to collect data to be used for assessing radon concentrations (Ref. 2.2.11, Section 6.13 [DIRS 182570]). Radon inhalation is not regulated by the U.S Nuclear Regulatory Commission; radon inhalation is a mining/occupational hazard. Underground miners will be aware of the radiation hazards on the emplacement side of the isolation barriers, but the construction effort will not be overly impacted by radiation concerns (Ref. 2.2.11, Section 4.3.5 [DIRS 182570]).

Due to the quantity of air circulating through the ventilation system, concentrations of radon, silica, nuisance dust, diesel particulate matter, and other hazardous gases or particulates will be diluted to levels that are below permissible exposure limits. Fumes produced by blasting will also be removed by the ventilation system. The ventilation system will be monitored to ensure that discharges to the surface do not exceed air quality permitted levels for total dust. The extensive use of dust collectors and wet scrubbers may be needed to meet environmental discharge restrictions (Ref. 2.2.11, Section 6.7 [DIRS 182570]).

Construction activities will be sufficiently isolated from emplacement activities such that radioactive shine from the emplacement side of the repository will not affect workers on the development side of the repository. In addition, as described in Section 6.3.2.1, if due to a rail switching error (or other malfunction or error), a TEV loaded with a waste package were to approach the construction side of the repository (on the available rail system), there would be no electrical power beyond the first isolation barrier available such that the TEV could transport a waste package into or through the second isolation barrier and into the construction portion of the Subsurface Facility (potentially leading to a worker dose if the worker were in close enough proximity to the TEV/waste package).

The development ventilation subsystem provides airflow to the development operations (provided by a forcing fan system). The emplacement ventilation subsystem provides airflow to the emplacement operations (exhausting fan system). This configuration provides air pressure in the development side at a higher pressure than on the emplacement side. This air pressure differential will prevent infiltration of air from the emplacement side of the repository to the development side. The isolation barriers that separate the development and emplacement ventilation systems are configured as two stand-alone steel structures with access door airlocks (Ref. 2.2.1, Section 4.3.1 [DIRS 174874]). If power is lost to the development ventilation system (blowing), the emplacement system (exhausting) would maintain a pressure differential across the isolation barrier. Conversely, in the event power is lost to the emplacement system (exhausting), the development system (blowing) would maintain a pressure differential across the isolation barrier. If power is lost to both systems, the natural ventilation pressure will maintain the desired flow-through pattern (Ref. 2.2.1, Section 6.1.2 [DIRS 174874]). The natural ventilation pressure in an emplacement drift is created by waste packages heating the air, which creates a change in density and an imbalance between the intake and exhaust system after the first 120 m of drift is filled or after approximately one year of operation (Ref. 2.2.1, Section 6.2.3 [DIRS 174874]).

If power were to be lost during the warmer months, there may not be enough of a temperature difference to provide the natural ventilation pressure. From an operations practice, if power were lost to the main fans, personnel would evacuate from the underground. However, if an airflow reversal were to occur under these unlikely circumstances during simultaneous construction and waste emplacement phases of the subsurface repository operation, the worker dose would be negligible (0.18 mrem) compared to the regulatory limit of 100 mrem/year. It should be noted that this dose would be due to the release of activated air and dust and the radioactive contamination suspended from emplaced waste packages and not from a waste package breach (Ref. 2.2.1, Section 7 [DIRS 174874]).

Through the use of isolation barriers, detection systems, and management of the work force, sufficient mitigation will be provided such that repository emplacement-side radiation is not considered a construction hazard. Underground miners will be aware of the radiation hazards on the emplacement side of the isolation barriers, but the construction effort will not be overly impacted by radiation concerns (Ref. 2.2.11, Section 4.3.5 [DIRS 182570]). Due to the separation (through the use of isolation barriers) and distance between development (construction) operations and emplacement activities (as part of normal operational/construction activities), no event sequences (including events SS.6, SS.7, and SS.8) have been identified in which radiation-related hazards or events in the development (construction) portion of the Subsurface Facility could lead to an event sequence resulting in significant exposure of construction workers.

6.7 SURFACE FACILITIES DEVELOPMENT

As discussed previously, construction of the full GROA is not scheduled to be completed prior to the initiation of emplacement operations. Schedules have been developed for the design, construction, testing, and initial operation of the facilities to support waste receipt (Ref. 2.2.2 [DIRS 178867]). The surface handling facilities are not scheduled to be completed at the same time as the emplacement drifts, which (as mentioned previously) will be developed as needed rather than all drifts being completed prior to the start of operations. However, consistent with 10 CFR 63.41(a)(1) and (2) (Ref. 2.3.1 [DIRS 180319]), those SSCs that have been identified as ITS and necessary to permit initial receipt and emplacement capability of the waste forms will be installed and startup-tested prior to the initial receipt of waste. Startup testing will include the surface, subsurface, and interconnecting ITS SSCs, as well as the sufficient number of subsurface emplacement drifts to support initial operations.

6.7.1 Steps 1 and 2: Surface Facility Area Description/Process Description

6.7.1.1 Phased Construction Schedule

As described in Section 6.4, the repository will be constructed in well-defined and manageable construction phases. In the first construction phase (Phase 1), those facilities required for the initial operating capability will be constructed. The full operating capability is achieved by the completion of the subsequent three construction phases (Phases 2, 3, and 4) (Ref. 2.2.5 [DIRS 184864]).

The objective of Phase 1 is to achieve the capability to start repository operations, including the development of those assets necessary to achieve a reasonable ramp-up of operations during the first several years of waste receipt. The objective of the subsequent three phases is to develop full operational capability for the receipt and emplacement of the inventory of spent nuclear fuel (SNF) and HLW currently authorized by law for the repository. In addition, a phased construction approach will provide an opportunity for implementing lessons learned on subsequently constructed facilities. Figures 4 and 5 illustrate the Aging Facility and Surface Facility layouts, respectively. Table 3 presents the legend for this illustration, as well as the list of facilities to be completed in each phase.

6.7.1.2 Initial Operating Capability

The initial operating capability of the repository is provided by the construction of surface facilities and their support facilities and systems that include all necessary functional capabilities to receive, package, and emplace a limited throughput of canistered SNF and HLW and individual commercial SNF assemblies.

6.7.1.2.1 Initial Operating Capability Facilities

As illustrated in Table 3, the following facilities are scheduled for completion to support the repository initial operating capability (Ref. 2.2.3, Section 2.2.1 [DIRS 182131]):

- Surface nuclear handling facilities:
  - IHF
  - CRCF 1
  - Wet Handling Facility (WHF)
  - Initial capacity of the Aging Facility.
- Balance of Plant surface facilities that provide infrastructure services:
  - Low-Level Waste Facility
  - Cask Receipt Security Station
  - Utilities Facility and cooling tower
  - Evaporation pond
  - Emergency Diesel Generator Facility
  - Standby Diesel Generator Facility
  - Switchyard and switchgear facility
  - Central Security Station
  - Railcar and truck buffer areas
  - Fire water facilities (central and east)
  - Helicopter pad
  - Stormwater retention pond
  - Septic tank and leach field

  - Heavy Equipment Maintenance Facility
  - Central Control Center Facility
  - Warehouse and Non-Nuclear Receipt Facility
  - Warehouse, central receiving, and yard storage areas
  - Fire, rescue, and medical facility
  - Administration Facility
  - Diesel fuel oil storage
  - Administration security stations
  - Craft shops, vehicle maintenance, and fueling stations.

- Subsurface emplacement drifts 1 to 4 in Panel 1 (Figure 1), including one drift to be thermally accelerated under the Performance Confirmation Program for monitoring host-rock near-field coupled processes. In addition, one observation drift associated with the first thermally accelerated drift is included in this phase of subsurface development. Ventilation for the subsurface will be developed in a phased manner to support emplacement operations (Ref. 2.2.3, Sections 2.2.1, 2.2.2 [DIRS 182131]).

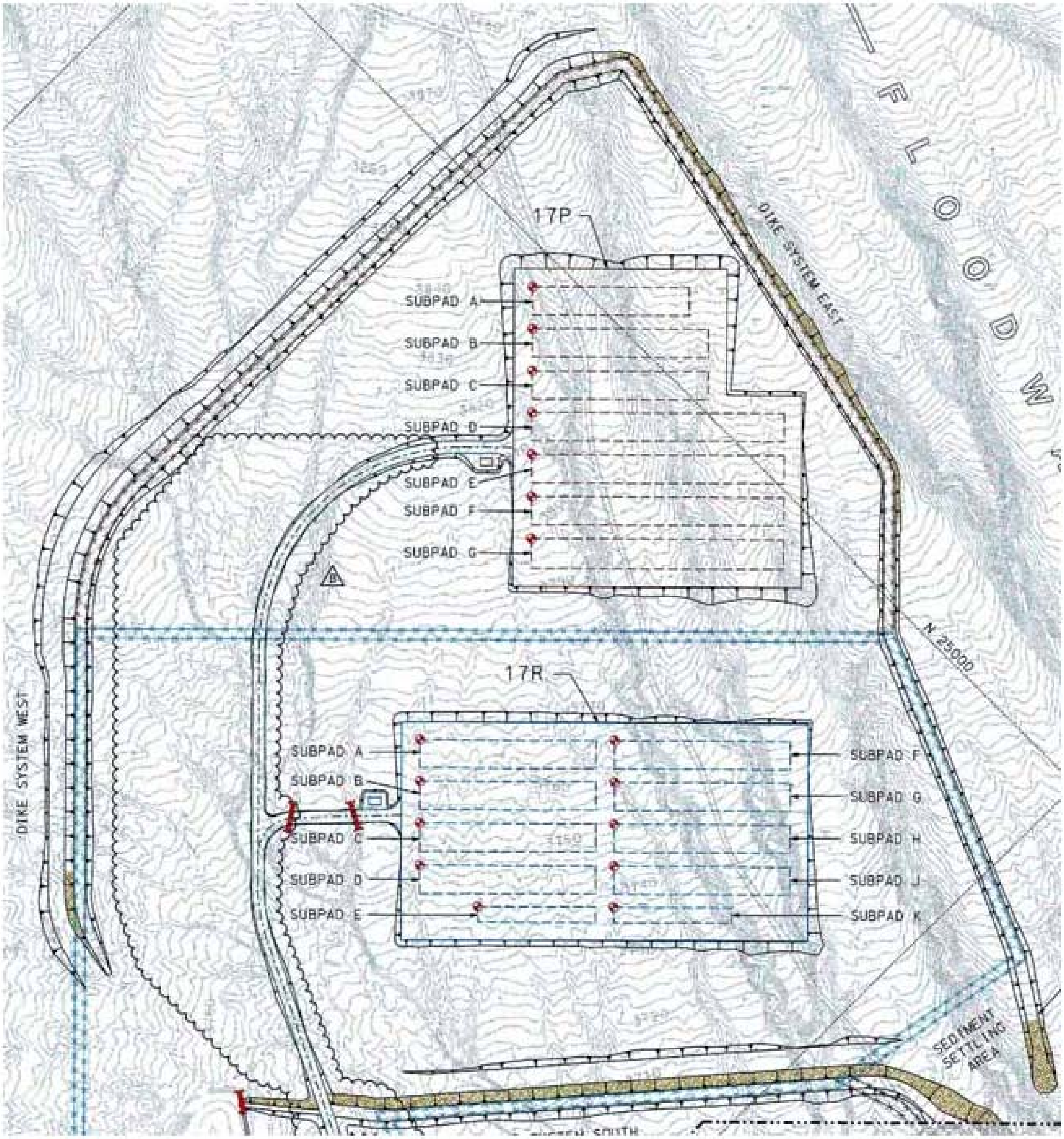
The major facilities are described in the following subsections.

6.7.1.2.2 IHF

The IHF is a transfer facility that will receive shipments of naval SNF canisters and (potentially, once the inventory of naval SNF is emplaced) U.S. Department of Energy (DOE) HLW canisters by rail. The naval SNF canisters (and, potentially, HLW canisters) will be transferred into waste packages and will subsequently be sealed and loaded into the shielded TEV in preparation for emplacement. The waste packages will then be transported to the Subsurface Facility for emplacement (Ref. 2.2.3, Section 3 [DIRS 182131]).

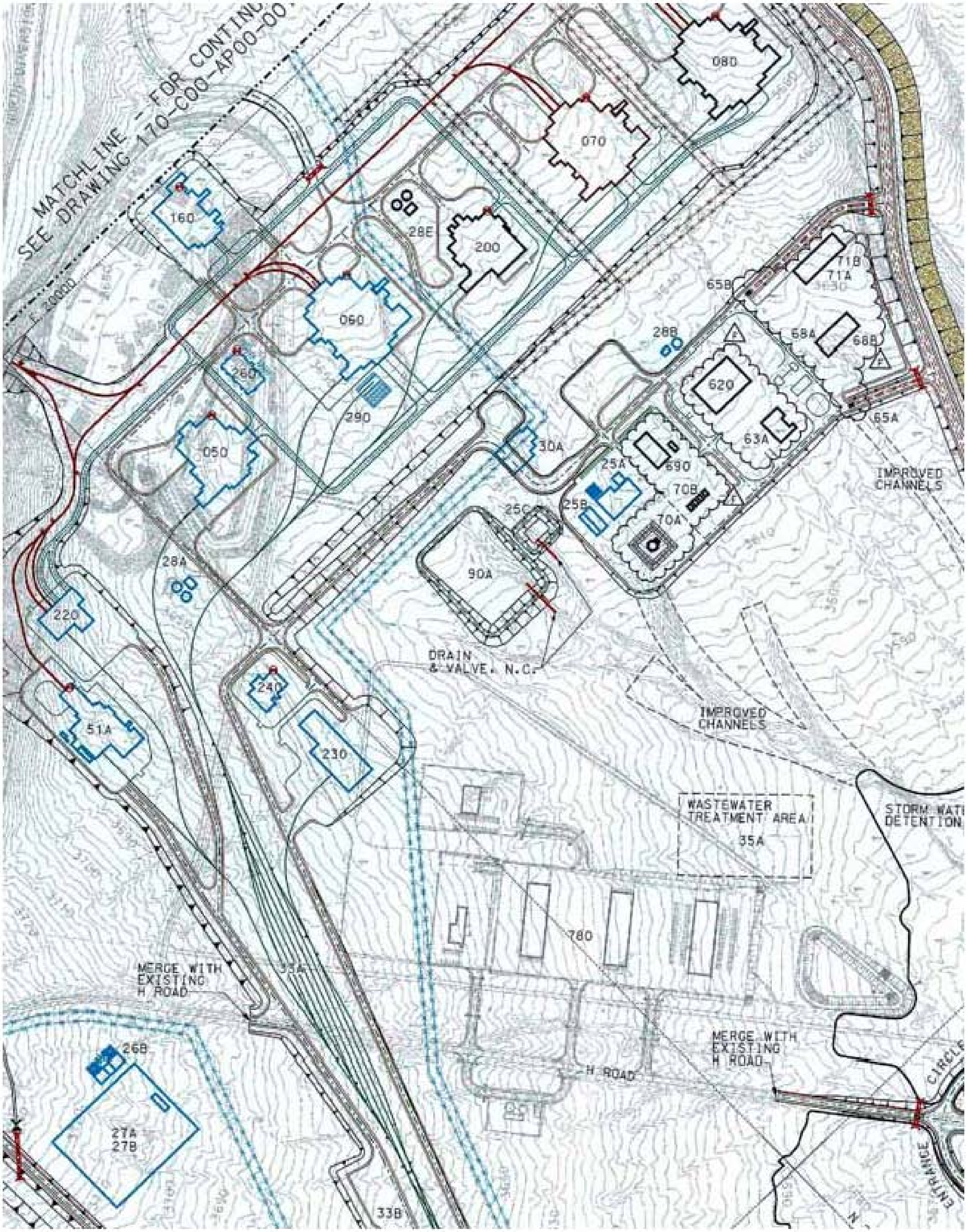
6.7.1.2.3 CRCF 1, Panel 1, Initial Aging

CRCF 1 will accommodate the necessary functional capabilities to receive (by truck or rail), package, and emplace HLW canisters; DOE SNF canisters; and transportation, aging, and disposal (TAD) canisters holding commercial SNF assemblies. Handling features will also be available to transfer TAD canisters (and dual-purpose canisters (DPCs), if necessary) into overpacks for aging. CRCF 1 will also receive loaded aging overpacks holding TAD canisters returning from the Aging Facility and will transfer their contents into waste packages. Uncanistered SNF will not be handled in CRCF 1 (nor in the subsequently constructed CRCF 2 or CRCF 3). Waste packages will be filled with either a TAD canister or a predetermined HLW/DOE canister configuration and will be sealed. The waste packages will then be loaded into the TEV and transported to the Subsurface Facility for emplacement.



Source: Ref. 2.2.4 [DIRS 184922]

Figure 4. Aging Facility Arrangement Illustrating Phased Construction



Source: Ref. 2.2.5 [DIRS 184864]

Figure 5. Surface Facility Arrangement

Table 3. Phased Construction Schedule and Surface Facility Legend

LEGEND			
Initial Operating Capability			
Phase 1			
050	Wet Handling Facility	26D	Emergency Diesel Generator Facility
060	Canister Receipt and Closure Facility 1	27A	Switchyard (138 kV)
51A	Initial Handling Facility	27B	13.8 kV Switchgear Facility
17K	Aging Pad R	28A	Fire Water Facility (Central)
160	Low-Level Waste Facility	28B	Fire Water Facility (East)
220	Heavy Equipment Maintenance Facility	30A	Central Security Station
230	Warehouse and Non-Nuclear Receipt Facility	30B	Cask Receipt Security Station
240	Central Control Center Facility	33A	Railcar Staging Area
25A	Utilities Facility	33B	Truck Staging Area
25B	Cooling Tower	35A	Septic Tank and Leach Field
25C	Evaporation Pond	66A	Helicopter Pad
26B	Standby Diesel Generator Facility		
Full Operating Capability			
Phase 2			
200	Receipt Facility	68A	Warehouse/Central Receiving
28C	Fire Water Facility (South)	68B	Materials/Yard Storage
28E	Fire Water Facility (North)	690	Vehicle Maintenance and Motor Pool
620	Administration Facility	70A	Diesel Fuel Oil Storage
63A	Fire, Rescue, and Medical Facility	70B	Fueling Stations
65A	Administration Security Station	71A	Craft Shops
65B	Administration Security Station	71B	Equipment/Yard Storage
Phase 3			
070	Canister Receipt and Closure Facility 2	17L	Aging Pad P
Phase 4			
080	Canister Receipt and Closure Facility 3	30C	North Perimeter Security Station

Source: Ref. 2.2.4 [DIRS 184922], Ref. 2.2.5 [DIRS 184864]

Aging Pad R will be constructed to support the initial operating capability. This aging pad will provide space for aging overpacks holding either a TAD canister or a DPC (Ref. 2.2.3, Section 4 [DIRS 182131]).

6.7.1.2.4 WHF

The WHF is designed to receive rail and truck shipments of both uncanistered SNF assemblies in transportation casks and SNF assemblies sealed in DPCs carried in transportation casks. The DPCs may also be received from the Aging Facility and Receipt Facility (RF) (when completed for full operating capability) in aging overpacks carried by the site transporter. The WHF is designed to repackage uncanistered SNF assemblies or SNF assemblies from the DPCs into TAD canisters while submerged in a wet handling pool. Once sealed, the TAD canister will be transported in an aging overpack to either the Aging Facility or to a CRCF for transfer to a waste package prior to emplacement (Ref. 2.2.3, Section 5 [DIRS 182131]).

6.7.1.2.5 Infrastructure Utilities

The site contains existing infrastructure and utilities that support the existing facilities. This infrastructure includes roads, electrical power, water, sewer, and communications. The existing infrastructure will be modified to support the construction and the operation of the repository; however, such modifications will not be made before the U.S. Nuclear Regulatory Commission authorizes repository construction. Infrastructure that will be developed to support repository operations is identified with each phase as it is to be developed and is included in the construction schedule (Ref. 2.2.3, Section 9 [DIRS 182131]).

The following infrastructure is planned to be developed off site:

- A rail line
- Communication system improvements
- Electric power transmission lines.

The following infrastructure is planned to be developed within the site, primarily to support construction activities; however, the electrical power system, roads, and the rail line will also support operations (Ref. 2.2.13, Section 2.6 [DIRS 168857]):

- Construction workforce shops, offices, warehouses, and laydown yards near the North Portal and South Portal
- Qualified borrow pits and concrete batch plants
- Raw materials and engineered fill stockpiles
- Raw water supplies and delivery system
- A wastewater collection and control system
- An electrical power transmission line and switchyard for construction
- An ESF muck pile and undocumented fill, relocated away from the North Portal area
- Removal of existing North Portal structures and facilities
- An access road from off site
- A rail line from off site.

6.7.1.3 Full Operating Capability – Phase 2

6.7.1.3.1 RF

To increase throughput capabilities, repository full operating capability requires the construction of additional high-throughput handling facilities similar to those developed for repository initial operating capability. The three operable Phase 1 handling facilities will be augmented in Phase 2 by an RF that is designed to receive rail casks containing commercial waste canisters, to prepare the casks for transfer, and then to transfer these canisters to an aging overpack for movement to other surface facilities, including the Aging Facility (Ref. 2.2.3, Section 6 [DIRS 182131]).

6.7.1.3.2 Balance of Plant Facilities

Additional Balance of Plant facilities are included in Phase 2 to support full capacity operations. The following Balance of Plant surface facilities that provide infrastructure services are scheduled for completion in Phase 2 to support the first increment of full operating capability (Ref. 2.2.5 [DIRS 184864]):

- Warehouse, central receiving, and yard storage areas
- Fire water facility (north and south)
- Fire, rescue, and medical facility
- Administration Facility
- Diesel fuel oil storage
- Administration security stations
- Craft shops, vehicle maintenance, and fueling stations
- Visitors Center (to be sited later).

6.7.1.3.3 Subsurface Facility

As described previously, in the subsurface the remainder of Panel 1 and Panel 2 will be constructed. The construction of Panels 3 and 4 will be ongoing throughout this and subsequent phases.

6.7.1.4 Full Operating Capability – Phase 3

The following additional handling facilities are scheduled for completion in Phase 3 to support the second increment of full operating capability:

- CRCF 2
- Aging Pad P of the Aging Facility.

6.7.1.5 Full Operating Capability – Phase 4

CRCF 3 is scheduled for completion in Phase 4 to support the final increment of full operating capability.

Additionally, the North Perimeter Security Station will be added in Phase 4 for additional control of access to the GROA from the north.

6.7.2 Waste Receipt and Emplacement

Emplacement operations are projected to span up to approximately 50 years (Ref. 2.2.3, Section 2.2.2.7 [DIRS 182131]). Throughout emplacement operations the development of the emplacement drifts is scheduled to support receipt rates.

6.7.3 Surface Construction Methodology

The surface construction methodology will include the application of proven construction methods and techniques into the work processes. These methods and techniques have demonstrated safety, cost, and schedule savings (Ref. 2.2.13, Section 2.3.1 [DIRS 168857]). The construction methodology to be applied for the construction of the surface facilities will be a composite of construction methods that include stick-built (all pieces assembled at site), site preassembly, and modularization structures. The magnitude of craft labor hours to be required within the construction period will encourage the exploitation of preassembly and modularization, although existing highway and railroad accessibility will determine the extent of modularization. Preassembly and modular construction will allow more construction activities to proceed in parallel. More construction activities will occur offsite and thereby reduce the craft labor needed in the field and reduce the calendar time required for plant construction.

A component of the construction methodology will be the management and coordination of stick-built, preassembly, and modular construction in multiple work areas. The site will be organized into an area concept for the purpose of detailed planning and execution of the work. The construction of the surface facilities will follow a series of activities, including (but not limited to) the following (Ref. 2.2.13, Section 2.3 [DIRS 168857]):

- Performing a field survey
- Site preparation and earthwork activities
- Concrete placement
- Pouring of concrete
- Installation of piping
- Erection of structural steel
- Installation of mechanical equipment
- Installation of electrical equipment and systems
- Instrumentation and control equipment installation.

Temporary construction fencing plans and details will be designed to isolate environmentally sensitive areas and to aid with security measures. The layout of permanent and temporary fencing will be designed to minimize impacts during the transition phase from construction to operations. On the surface, operations and construction will be physically separated by a perimeter intrusion detection and assessment system fence and by radiologically restricted area fences that extend beyond this fence. The installation of the security fencing will be accomplished to support each operating phase of the project, while leaving all nonoperating areas accessible for construction. Areas adjacent to building foundations will be developed to permit access of heavy-haul equipment and cranes. This backfill operation will be performed in a phased approach (Ref. 2.2.13, Section 2.3.1.2 [DIRS 168857]).

As the repository transitions into the construction phase, activities required to transition into construction operations will commence. This transition will focus on infrastructure modifications and demolition. Design modifications will be required to ensure that service is maintained to facilities that will be occupied during construction. Prior to demolition, utilities supplying abandoned facilities will be de-energized and isolated. Surface construction activities will include (but not be limited to) providing permanent power necessary to support construction; upgrading the existing water system; constructing haul roads to borrow pits for backfill and aggregate; implementing the construction site security program; and locating, constructing, and certifying concrete batch plants and an ice plant (Ref. 2.2.13, Section 2.6.1 [DIRS 168857]).

As described previously, the current repository schedule will require performing construction activities and nuclear waste repository operations concurrently. Construction will be performed in phases; therefore, it will be necessary to separate these activities to ensure the safety and security of project personnel. During detailed design, consideration will be given to achieving this separation by designing independent systems for repository operations and construction. This work would include designing sufficient space separations for activities that have a potential to impact operations. Areas of concern include security requirements, crane movements, routing of utility sources, and ensuring no exposure to construction personnel. Boundaries will be designed to isolate personnel movement between nuclear operations and construction areas (Ref. 2.2.13, Section 2.23 [DIRS 168857]).

6.8 POTENTIAL SURFACE EVENT SEQUENCE IDENTIFICATION

6.8.1 Steps 3 and 4: Generic Event Applicability and Potential Surface Construction-Related Events

Table 4 lists the applicability of generic hazards to the surface construction activities; Table 5 lists the potential events for each applicable category. These tables are based on an evaluation of the activities slated to occur during construction operations associated with the Surface Facility, the equipment and utilities slated to be present during the construction phase, and the hazards that may be present such that a hazard or event leads to a potential event sequence.

Table 4. Generic Hazard/Event Applicability to the Surface Construction Activities

Generic Hazard/Event Category	Is Generic Hazard/Event Applicable?
Collision/Crushing	Yes
Chemical Contamination/Flooding	None identified that affect/interact with a waste form
Explosion/Implosion	Yes (Fire, Table 5)
Fire	Yes
Radiation/Magnetic/Electrical/Fissile	Yes, Radiation/Fissile
Thermal	Yes (Fire, Table 5)

Source: Original

Table 5. Potential Events for the Surface Construction Activities

Generic Event Category	Potential Event
Collision/Crushing	S.1. Impact on a loaded horizontal transportation cask, a loaded horizontal shielded transfer cask, a loaded aging overpack, or a loaded waste package during construction operations.
Explosion	S.2. Detonation of explosive gases used as part of construction activities (e.g., welding gases, propane).
Fire, Thermal	S.3. Diesel fuel fire/explosion associated with construction equipment S.4. Electrical fire associated with construction equipment or other Surface Facility equipment S.5. Transient combustible fire S.6. Fire involving facilities under construction.
Radiation	S.7. Radiation exposure of a construction worker, facility worker, or the offsite public (e.g., due to equipment failure, loss of shielding) resulting from construction activities.
Fissile	S.8. Criticality involving a loaded transportation cask, a loaded horizontal transportation cask, a loaded horizontal shielded transfer cask, a loaded aging overpack, or a loaded waste package due to activities associated with surface construction.

Source: Original

Note: S = Surface.

6.8.2 Step 5: Analysis of Identified Potential Event Sequences/Events Screening

6.8.2.1 Collision/Crushing

6.8.2.1.1 S.1. Impact on a loaded horizontal transportation cask, a loaded horizontal shielded transfer cask, a loaded aging overpack, or a loaded waste package during construction operations

While surface construction operations are underway, SNF will be present at the surface facilities during the following activities and locations in the following configurations (Ref. 2.2.6, Sections 1 and 3; BSC 2007. *Geologic Repository Operations Area, Surface Facilities Concept of Operations*. 000-30R-MGR0-03000-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070531.0002. [DIRS 182580]):

- Inside a transportation cask during delivery operations to the repository or repository facilities
- Inside a transportation cask during staging in the railcar buffer area or truck buffer area
- During processing within a Surface Facility

- In a sealed waste package during transit in a TEV from the IHF or from a CRCF to the subsurface
- Contained in a TAD canister or a DPC inside an aging overpack, being carried by a site transporter in transit to or returning from the Aging Facility
- Contained in a TAD canister or a DPC inside an aging overpack situated on an aging pad at the Aging Facility
- Contained in a DPC inside an horizontal aging module at the Aging Facility
- Contained in a DPC inside a transportation cask or horizontal transfer cask on a horizontal positioning trailer being pulled by a yard tractor, in transit to or returning from a horizontal aging module at the Aging Facility.

The GROA surface facilities are locations where nuclear waste contents are unloaded and packaged for aging or emplacement. Railcars and truck trailers carrying transportation casks will enter the GROA through the Preliminary Inspection Area. Site roads and rail lines will extend to all nuclear processing surface facilities, warehouses, and parking and staging areas. Nonsecurity vehicles and rail traffic will stay more than 20 ft from any security fencing. The GROA rail yard will include multiple rail spurs for queuing and staging incoming loaded casks and staging outbound emptied casks and other commercial vehicles. Casks in queuing and storage will have impact limiters attached and will meet 10 CFR Part 71 transportation safety requirements (Ref. 2.2.6, Section 3.2.4; BSC 2007. *Geologic Repository Operations Area, Surface Facilities Concept of Operations*. 000-30R-MGR0-03000-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070531.0002. [DIRS 182580]).

The TEV is a heavily shielded, remotely operated vehicle that will carry a loaded waste package from the waste package loadout areas in the IHF and the CRCFs to the subsurface emplacement drifts. The TEV will lift and carry the loaded waste package close to the ground such that any drop or collision would not result in damage or radioactive release. The TEV will operate on rails that will run the length of the North Ramp, the access main, and into each turnout and emplacement drift (Ref. 2.2.6, Sections 3.1.11 and 3.2.7; BSC 2007. *Geologic Repository Operations Area, Surface Facilities Concept of Operations*. 000-30R-MGR0-03000-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070531.0002. [DIRS 182580]).

Site transporters will be site-only, heavy-duty, crawler-type vehicles that will engage and lift aging overpacks and will move them in the vertical orientation back and forth between surface facilities and site aging facilities. They are sized to prevent accidental tipover events. Site transporters will be large, heavy, slow-moving vehicles designed for travel on paved and unpaved surfaces and will be sufficiently maneuverable to allow for accurate positioning of the aging overpack (Ref. 2.2.6, Sections 3.1.10 and 3.2.7; BSC 2007. *Geologic Repository Operations Area, Surface Facilities Concept of Operations*. 000-30R-MGR0-03000-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070531.0002. [DIRS 182580]).

A horizontal positioning trailer will be a site-only trailer suitable for handling a U.S. Nuclear Regulatory Commission–certified horizontal DPC transportation cask and a site-only horizontal aging module shielded transfer cask that will be suitable for placing and retrieving horizontally handled DPCs. The horizontal DPCs will be transported from the RF to the horizontal aging module located at the site Aging Facility (Figure 4). The trailer will be moved at slow speeds using one or more heavy-duty yard tractors. Retrieved DPCs will be transferred to the WHF, where the DPCs will be opened and unloaded.

As described previously, construction of surface facilities will be accomplished in stages such that transfer and emplacement operations can begin before construction of surface facilities is complete. Therefore, separation will be maintained between waste transfer and emplacement activities and activities that support surface construction or subsurface excavation. The erection of temporary physical barriers to separate construction activities from the rest of the site activities is an effective and common method of reducing, if not eliminating, interactions. In addition, administrative controls provide a means of preventing interactions.

Although potential event S.1 postulates a collision/crushing or impact hazard/event, no hazard or event has been identified in which a construction activity could present a collision/crushing event that could result in an impact to a transportation cask, aging overpack, horizontal transfer cask, or waste package. Construction activities will not occur in the vicinity of (and will be separated by a security fence and/or barrier from) the Preliminary Inspection Area, the Site Security Gate, the rail yard and truck trailer staging areas, any operating surface facilities, and the roads and rails leading to those facilities upon which HLW may travel. In addition, barriers will separate construction activities from the rails where the TEV will travel, as well as the road leading to the Aging Facility that the site transporter and horizontal transfer trailer/yard tractor will travel.

Due to the separation of construction activities and operation activities (through the use of barriers and fences) and the distance between these operation activities, the locations where SNF will be found on the Surface Facility, and construction activities (as part of normal operational/construction activities), no event sequences have been identified in which a collision/crushing hazard/event could lead to an event sequence. Information pertaining to the separation distances between the surface facilities is presented in Section 6.8.2.4.

6.8.2.2 Chemical Contamination/Flooding

No hazards or events associated with surface construction activities involving chemical contamination/flooding were identified such that these hazards or events could potentially lead to an event sequence. Again, the use of barriers and the distances between construction activities and locations where HLW may be present on the Surface Facility will preclude such an event sequence.

6.8.2.3 Explosion/Implosion

6.8.2.3.1 S.2. Detonation of explosive gases used as part of construction activities (welding gases, propane, etc.)

Prior to operations, an active combustible control program will be implemented to control the quantity and placement of combustibles at the GROA. Storage of liquid and gaseous combustibles will comply with the applicable National Fire Protection Agency codes and standards. Consequently, the storage of these materials will not adversely impact site operations (Ref. 2.2.8, Section 6.1.2.5.4 [DIRS 181993]). The storage and use of explosives will conform to the applicable regulations, codes, and standards (Ref. 2.2.8, Section 6.1.3 [DIRS 181993]).

Due to the separation of construction activities and operation activities (through the use of barriers and fences) and the distance between these operation activities, the locations where SNF will be found on the surface GROA, and construction activities (as part of normal operational/construction activities), no event sequences have been identified (including potential event S.2) in which an explosion hazard/event could lead to an event sequence.

Fire-related explosions are considered in Section 6.8.2.4.

6.8.2.4 Fire/Thermal

6.8.2.4.1 S.3. Diesel fuel fire/explosion associated with construction equipment

6.8.2.4.2 S.4. Electrical fire associated with construction equipment or other Surface Facility equipment

6.8.2.4.3 S.5. Transient combustible fire

6.8.2.4.4 S.6. Fire involving facilities under construction

The repository surface facilities are subdivided into separate fire areas for the purpose of limiting the spread of fire, protecting personnel, and limiting the consequential damage to the facility. Determination of fire area boundaries are based on the consideration of the following items (Ref. 2.2.8, Section 6.1.2.4 [DIRS 181993]):

- Types, quantities, density, and location of combustible materials
- Location and configuration of equipment
- Consequences of inoperable equipment
- Location of fire detection and suppression systems
- Personnel safety and exit requirements.

With one exception, the repository surface facilities will be separated from other facilities by a minimum distance of approximately 100 ft. The exception is a noncombustible cooling tower, which will be located approximately 50 ft to the south of the Utilities Facility (Figure 5). A minimum separation distance of 30 ft is required per International Building Code. Therefore, the separation distance between the GROA surface facilities adequately precludes a fire from propagating between facilities (Ref. 2.2.8, Section 6.1.2.5 [DIRS 181993]).

Fossil-fueled vehicles represent a transient exposure fire threat (such as potential event S.3). However, these vehicles will be required to be provided with portable fire extinguishers. Authorized personnel may operate government-furnished vehicles within close proximity to some of the surface facilities. These vehicles could contain up to 100 gal of fuel (Ref. 2.2.8, Section 6.1.2.5.2 [DIRS 181993]). Construction vehicles, including earth-moving equipment, cranes, large trucks, and other light-duty vehicles will be used as part of the construction activities associated with the surface facilities. Large earth-moving equipment such as scrapers, bulldozers, all-terrain dump vehicles, excavators, and large-capacity front-end loaders would expedite the earthwork schedule (Ref. 2.2.13, Section 2.13.5 [DIRS 168857]). However, these vehicles will be used only in areas where construction will take place, separated by barriers from areas where HLW is transported or staged.

Industrial/Military Activity-Initiated Accident Screening Analysis (Ref. 2.2.18, Attachment A [DIRS 184975]) contains an explosion analysis for a 50,000 gallon diesel fuel bulk storage tank. This analysis concluded that the safe overpressure distance for the 54-lb TNT-equivalent detonation of this tank is conservatively estimated to be approximately 170 ft. Surface construction vehicles, including fuel trucks used to carry fuel to the construction vehicles, will hold a quantity of fuel significantly smaller than the 50,000 gallon bulk storage tank, thereby requiring a safe overpressure distance of much less than 170 ft. By maintaining separation distances between construction vehicles and refueling trucks carrying diesel fuel and SNF/HLW in the Surface Facility, and through the use of travel routes that maintain safe separation distances, no blast or explosion associated with construction activities have been identified that could lead to an event sequence. Although these travel routes have not yet been defined, Figure 5 indicates that ample space to accomplish a safe distance is available.

As discussed previously, transient combustible materials are those combustible materials that are not permanently installed in a given fire area. Transient combustible materials primarily include waste materials generated from plant operations and combustibles introduced during maintenance activities. The control of transient combustible materials will be an essential element of the defense-in-depth approach to fire protection. As part of the fire protection procedures and practices, prior to operations, an active administrative control program will be implemented to control the quantities of combustibles allowed in a given fire area (Ref. 2.2.8, Section 6.1.2.5.4 [DIRS 181993]).

Construction activities will be sufficiently isolated from emplacement activities that an electrical fire or diesel fuel fire associated with development equipment will not initiate an event sequence (such as potential events S.3 and S.4). Also, construction activities will be sufficiently isolated from emplacement activities that a transient combustible fire associated with construction activities (such as event S.5) will not initiate an event sequence. Although there will be large quantities of materials that could potentially burn if a facility under construction were to be involved in a fire, there is sufficient distance between fire areas and SNF to be located on the GROA such that an event sequence would not occur due to potential event S.6. In addition, firefighting capability will exist to extinguish any fire associated with construction activities.

Therefore, due to the separation of construction activities and operation activities (through the use of barriers and fences) and the distance between these operation activities, the locations where SNF will be found on the surface GROA, and construction activities (as part of normal operational/construction activities), no event sequences have been identified in which a fire or fire-related explosion associated with construction activities could lead to an event sequence.

6.8.2.5 Radiation

6.8.2.5.1 S.7. Radiation exposure of a construction worker, facility worker, and/or the offsite public (due to equipment failure, loss of shielding, etc.) resulting from construction activities

Activities in proximity to SNF located anywhere on the Surface Facility will be monitored to ensure that there is a continuous operation of shielding equipment without loss of function. The SNF on the Surface Facility will be contained in transportation casks, in sealed waste packages inside TEVs, in canisters inside aging overpacks, in DPCs inside horizontal transfer casks or transportation casks in transit to or from a horizontal aging module or it will be situated on an aging pad in an aging overpack or horizontal aging module (Ref. 2.2.6, Sections 1.3 and 3; BSC 2007. *Geologic Repository Operations Area, Surface Facilities Concept of Operations*. 000-30R-MGR0-03000-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070531.0002. [DIRS 182580]). Due to the separation of construction activities and operation activities (through the use of barriers and fences) and the distance between these operation activities, the locations where SNF (contained in the previously mentioned casks, canisters, and overpacks) will be found on the surface GROA, and construction activities (as part of normal operational/construction activities), no event sequences have been identified (such as potential event S.7) in which a hazard or event could lead to an event sequence involving a radiation exposure.

6.8.2.6 Fissile

6.8.2.6.1 S.8. Criticality involving a loaded transportation cask, a loaded horizontal transportation cask, a loaded horizontal shielded transfer cask, a loaded aging overpack, or a loaded waste package due to activities associated with surface construction

Construction activities pose much less of a challenge to the waste containers holding HLW and SNF than the internal and external events (including criticality events) analyzed in the preclosure safety analysis. Because of large separation distances, construction activity cannot cause mechanical or thermal challenges to waste forms that are not considered and bounded by the preclosure safety analysis criticality and event sequence analyses.

Potential event S.8 is similar to potential event S.1 in that a construction activity is postulated to impact or affect SNF located in the surface GROA. No addition event sequences have been identified in which an impact hazard or event (with optimal moderation) could lead to an event sequence involving a criticality.

7. RESULTS AND CONCLUSIONS

Through the use of hazard analysis methodologies described in the *System Safety Analysis Handbook* (Ref. 2.2.14 [DIRS 101450]), hazards and potential initiating events that could potentially result in an event sequence are identified. Tables of hazards, events, and potential initiating events are generated by applying a checklist of generic events to the various areas where construction activities will occur, as described in Sections 6.4 and 6.5.

As stated in Section 4.4.1, for the purposes of this analysis, the repository has been divided into two specific areas for evaluation: the Subsurface Facility and the Surface Facility.

The only source of radiological material that could potentially be released in the Subsurface Facility will be the SNF and HLW sealed inside the waste packages in the emplacement drifts or in a TEV traveling to an emplacement drift. Section 6.6 describes potential hazards associated with construction in the Subsurface Facility. It is concluded that construction activities on the development (construction) portion of the Subsurface Facility will not lead to an event sequence due to the separation (through the use of isolation barriers) and distance between emplacement operations and development (construction). It should be noted that the only potential threat to a waste package in an emplacement drift or in a TEV significant enough to lead to an event sequence is from a rockfall. *Probabilistic Characterization of Preclosure Rockfalls in Emplacement Drifts* (Ref. 2.2.15 [DIRS 180415]) identifies the bounding rockfall for the subsurface; it has been demonstrated in *Waste Package Capability Analysis for Nonlithophysal Rock Impacts* (Ref. 2.2.16 [DIRS 184425]) that this rockfall will not result in a waste package breach.

As described in Section 6.8.2.1.1, waste forms on the surface will be located in the surface facilities, on the aging pads, in the truck and railcar buffer areas, in transit between these areas, or in transit between the surface facilities and the subsurface. While in transit, waste forms are either in transportation casks in a 10 CFR Part 71 configuration (with impact limiters and personnel barrier in place), in aging overpacks, in horizontal shielded transfer casks, or in a waste package in a TEV. Section 6.8 provides a discussion of potential hazards associated with construction activities in the Surface Facility. It is concluded that surface construction activities will not lead to an event sequence due to the separation of construction and operation activities (through the use of barriers and fences) and the distance between construction and operation activities. Waste forms located inside the surface facilities will be protected from construction activities by the facility structures. For waste forms located outside of a facility, any fire associated with construction activities is bounded by the fire analyzed in *Thermal Responses of TAD and 5-DHLW/DOE SNF Waste Package to a Hypothetical Fire Accident* (Ref. 2.2.17, Section 7 [DIRS 183720]). This analysis demonstrates that a waste package containing a TAD canister or five DOE SNF/HLW canisters can withstand being totally immersed in a flame of temperature equal to at least 800°C, for a period of 30 minutes, without breach or exceeding required fuel temperatures.

No blast that could lead to an event sequence is predicted from any activity associated with surface construction operations. As stated in Section 6.8, the storage and use of explosives will conform to the applicable regulations, codes, and standards (Ref. 2.2.8, Section 6.1.3 [DIRS 181993]). By utilizing standoff distances, fencing, and barriers between surface construction areas and any location on the surface where SNF/HLW could potentially be located, any potential explosion from construction activities is bounded by the results of the analysis performed for the diesel fuel bulk storage tank and the distance calculated to reach a safe overpressure (Ref. 2.2.18, Attachment A [DIRS 184975]).

External Events Hazards Screening Analysis (Ref. 2.2.19, Attachment A [DIRS 180124]) provides an assessment of external hazards and their applicability to the repository, including high winds and tornados. This analysis considers the transport of construction material via winds or tornados and the potential for structural damage from tornado or straight-wind missiles. In *External Events Hazards Screening Analysis* it is concluded that at the low tornado and straight-wind speeds expected at the repository site, no heavy (typically damaging) missiles would be generated and lightweight construction missiles (e.g. 2 in. × 4 in. beams) have a frequency of damage less than 1×10^{-4} over the preclosure period. Therefore, no event sequence has been identified from these external hazards.

Since each of the identified potential events in this analysis were screened out based on the inability of these events to lead to event sequences, no events for further evaluation were identified. No events associated with this analysis are required to be considered as additional event sequences to be analyzed further as part of the preclosure safety analysis supporting the Yucca Mountain construction license application. This analysis only considers preclosure radiological safety issues associated with construction activities.

This analysis was performed in accordance with the requirements of NUREG-1804, *Yucca Mountain Review Plan, Final Report* (Ref. 2.3.2, Section 2.1.1.3 [DIRS 163274]) for the determination of the potential for construction hazards that must be included as event sequence initiators in the development of event sequences for the repository.