OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. ☒ Analysis — Check all that apply

Type of Analysis	☒ Engineering ☐ Performance Assessment ☐ Scientific
Intended Use of Analysis	☒ Input to Calculation ☒ Input to another Analysis or Model ☒ Input to Technical Document ☒ Input to other Technical Products

Describe use:

Provide input to the Site Recommendation Consideration Report and provide a basis for the Subsurface Facility and Emplacement Drift System Description Documents.

3. ☐ Model — Check all that apply

Type of Model	☐ Conceptual Model ☐ Abstraction Model ☐ Mathematical Model ☐ System Model ☐ Process Model
Intended Use of Model	☐ Input to Calculation ☐ Input to another Model or Analysis ☐ Input to Technical Document ☐ Input to other Technical Products

Describe use:

4. Title:

Site Recommendation Subsurface Layout

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-SFS-MG-000001 REV 00

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VULCAN v3.4 design work throughout the analysis completed by A.F. Linden.
Ventilation design work in Attachment IV completed by A.F. Linden.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD
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Site Recommendation Subsurface Layout

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ACRONYMS

AML	areal mass loading
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
CPA	controlled project assumption
CSNF	Commercial Spent Nuclear Fuel
CQ	Conventional Quality
DHLW	Defense High-Level Waste
DOE	U.S. Department of Energy
DSNF	Defense SNF
ECRB	Enhanced Characterization of the Repository Block
ESF	Exploratory Studies Facilities
HLW	High-level Waste
IPWF	Immobilized Plutonium Waste Form
MCO	Multi-Canister Overpacks
MGR	Monitored Geologic Repository
MGR PDD	Project Description Document
MTHM	metric tons initial heavy metal
MTU	metric tons of uranium
OD	observation drift
PTn	Thermal/Mechanical Unit: Lower Tiva Canyon Member, Yucca Mountain and Pah Canyon Members, Upper Topopah Spring Member, non welded ashflows and bedded tuffs
PWR	Pressurized Water Reactor
QA	quality affecting
QARD	*Quality Assurance Requirements and Description*
QL	Quality Level
RHH	repository host horizon

ACRONYMS

SDD	System Description Document
SNF	Spent Nuclear Fuel
SR	Site Recommendation
SSCs	Systems, structures, and components
STA	Station
TBD	to-be-determined
TBM	tunnel boring machine
TBV	to-be-verified
tptpll	Geologic/Lithologic Stratigraphy: lower lithophysal zone of the crystal poor Topopah Spring Tuff
tptpln	Geologic/Lithologic Stratigraphy: lower nonlithophysal zone of the crystal poor Topopah Spring Tuff
tptpmn	Geologic/Lithologic Stratigraphy: middle lithophysal zone of the crystal poor Topopah Spring Tuff
tptrv1	Geologic/Lithologic Stratigraphy: densely welded subzone of the vitric zone in the crystal rich member of the Topopah Spring Tuff
TSw1	Thermal/Mechanical Unit: Topopah Spring Member, welded, devitrified ashflows, lithophysal (alternating lithophysae-rich and lithophysae-poor ashflows)
TSw2	Thermal/Mechanical Unit: Topopah Spring Member, welded, devitrified ashflows, nonlithophysal (sparsely distributed lithophysae)
VPI	vertical point of intersection
WP	waste package

1. PURPOSE

The purpose of this analysis is to develop a Subsurface Facility layout that is capable of accommodating the statutory capacity of 70,000 metric tons of uranium (MTU), as well as an option to expand the inventory capacity, if authorized, to 97,000 MTU. The layout configuration also requires a degree of flexibility to accommodate potential changes in site conditions or program requirements. The objective of this analysis is to provide a conceptual design of the Subsurface Facility sufficient to support the development of the *Subsurface Facility System Description Document* (CRWMS M&O 2000e) and the *Emplacement Drift System Description Document* (CRWMS M&O 2000i). As well, this analysis provides input to the Site Recommendation Consideration Report.

The scope of this analysis includes:

- Evaluation of the existing facilities and their integration into the Subsurface Facility design.

- Identification and incorporation of factors influencing Subsurface Facility design, such as geological constraints, thermal loading, constructibility, subsurface ventilation, drainage control, radiological considerations, and the Test and Evaluation Facilities.

- Development of a layout showing an available area in the primary area sufficient to support both the waste inventories and individual layouts showing the emplacement area required for 70,000 MTU and, if authorized, 97,000 MTU.

This analysis has been prepared in accordance with the Development Plan (CRWMS M&O 1999a), which was prepared in accordance with AP-2.13Q, *Technical Product Development Planning.*

Most of this analysis was supported by the VULCAN v3.4 software program, which was used for developing the subsurface layouts. The VULCAN v3.4 software program is unqualified (see Section 3) and, as such, the results extracted from VULCAN v3.4 are considered to-be-verified (TBV) and tracked with TBV-4208.

2. QUALITY ASSURANCE

This analysis has been determined to be quality affecting (QA) in accordance with Civilian Radioactive Waste Management System Management and Operating Contractor procedure QAP-2-0, *Conduct of Activities*, because the information in this analysis affects the design of a Quality-Listed item. The procedure QAP-2-0, *Conduct of Activities* has been superceded by AP-2.16Q, *Activity Evaluation.* The activity evaluation preformed under QAP-2-0, *Conduct of Activities,* is still considered valid. Therefore, this analysis is subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) document (DOE 2000). This analysis was prepared in accordance with the procedure *Analyses and Models*, AP-3.10Q and is covered by the *Subsurface Facility System WP# 12012124M5* Activity Evaluation (CRWMS M&O 1999b).

Systems, structures, and components (SSCs) discussed in this report have been evaluated in accordance with QAP-2-3, *Classification of Permanent Items*. The classification analysis relevant to this analysis is the *Classification of the MGR Subsurface Facility System* (CRWMS M&O 1999c). The results of the QA classification (CRWMS M&O 1999c, Section 7.1, Table 1) are provided in Table 1.

Table 1. Subsurface Facility System QA Classification

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

Source: CRWMS M&O 1999c, Table 1

The following classification categories are specified by QAP-2-3, *Classification of Permanent Items,* to meet the requirements of Section 2 of the QARD (DOE 2000) and have been defined in the *Classification of the MGR Subsurface Facility System* (CRWMS M&O 1999c, p. 6) as follows:

> **"Quality Level 1 (QL-1)**–Those SSCs whose failure could directly result in a condition adversely affecting public safety. These items have a high safety or waste isolation significance.
>
> **Quality Level 2 (QL-2)**–Those SSCs whose failure or malfunction could indirectly result in a condition adversely affecting public safety, or whose direct failure would result in consequences in excess of normal operational limits. These items have a low safety or waste isolation significance.
>
> **Quality Level 3 (QL-3)**–Those SSCs whose failure or malfunction would not significantly impact public or worker safety, including those defense-in-depth design features intended to keep doses as low as reasonably achievable. These items have a minor impact on public and worker safety and waste isolation.
>
> **Conventional Quality (CQ)**–Those SSCs not meeting any of the criteria for Quality Levels 1, 2, or 3. Conventional quality items are not subject to the requirements of the QARD."

In order to ensure accuracy and completeness of the information generated by this analysis, access to the information on the personal computer and UNIX workstation was controlled with password protection. The personal computer files were stored on the network 'H' drive, which was backed up daily by the Enterprise Server Team Department. The Unix workstation files were stored on a local hard disk, which was backed up daily on a DLT tape drive (CRWMS M&O #116961), labeled and stored locally. The backups were stored for four weeks, then recycled through the backup system. When the work was complete, the files were transferred to floppy disk, appropriately labeled, and verified by examining the file listing. The floppy disk was hand carried to Engineering Document Control (EDC) for transfer to the Records Processing Center. During the process of checking the document, accuracy and completeness of the data placed in the Records Processing Center was verified against the information contained in this analysis.

3. COMPUTER SOFTWARE AND MODEL USAGE

Much of the work detailed in this analysis involved the use of the VULCAN software product, Version 3.4 (CRWMS M&O 1999h). This software is a geology and mine engineering computer design system developed by Maptek. The VULCAN v3.4 software is installed on a Silicon Graphics Octane workstation running the IRIX 6.5 operating system (CRWMS M&O #116980).

Based on a special dispensation granted by the U.S. Department of Energy (DOE) Project Operations Review Board, some software that is required to support Site Recommendation (SR) products may be used prior to full qualification. The requirements of this special use are detailed in procedure AP-SI.1Q, *Software Management*, Section 5.11. Qualification of the VULCAN v3.4 software product was in process at the start of this analysis, but because of the size and complexity of the software system; the necessary qualification could not be completed in time. Therefore, since this analysis will support the SR, the Interim Use of Unqualified Software to Support SR Products, Section 5.11 of AP-SI.1Q, was used to control the use of the VULCAN v3.4 software.

In accordance with AP-SI.1Q, Section 5.11, a *Software Activity Plan, Document Number 10044-SAP-3.4-00* was developed for the VULCAN v3.4 software. The VULCAN v3.4 software is controlled by Software Configuration Management under Software Activity Number LV-1999-001 (VULCAN V3.4) and Software Tracking Number 10044-3.4-00. The software was released under a Software User Request and installed on the above-identified workstation. The VULCAN v3.4 software (tracked with TBV-4647) and the technical products developed from it are designated as TBV in accordance with procedure AP-3.15Q, *Managing Technical Product Inputs*.

The VULCAN v3.4 software was selected to develop the repository plans within the geological framework for SR as documented in the Software Activity Plan. After the VULCAN v3.4 software is qualified and baselined in accordance with procedure AP-SI.1Q, the computer runs will be repeated and output compared with the runs developed with the unqualified software to determine any impacts to this analysis and to remove the TBV status of the VULCAN v3.4 results.

4. INPUTS

All technical product input and sources of the input used in the development of this analysis are documented in this section. The qualification status of the input is indicated, as well as the documentation for TBV or to-be-determined (TBD) data, in accordance with AP-3.15Q, *Managing Technical Product Inputs*.

4.1 DATA AND PARAMETERS

Parameters are scientific data, performance assessment data, or technical engineering information that represent physical or chemical properties. A parameter consists of an assigned variable name, and is generally represented by a value or range of values. The following subsections will outline the parameters used in the preparation of this analysis.

4.1.1 Geologic Volume Available for Potential Repository Siting

The geologic volume available for potential repository siting at the Yucca Mountain location is documented in the report *Determination of Available Repository Siting Volume within the Characterized Area for Site Recommendation* (CRWMS M&O 2000c). The model of the geology of Yucca Mountain, the VULCAN GFM 3.1 Representation (DTN: MO0003MWDVUL03.002) was used as input into VULCAN v3.4 (see Section 3) and is tracked with TBV-4187 since VULCAN v3.4 is an unqualified software program. This available volume for repository siting will be discussed in Sections 6.1 and 6.2.2.

4.1.2 Surface-Based Boreholes

The surface-based boreholes, also referred to as point features, of the Yucca Mountain Project are documented in the Technical Data Management System (DTN: MO0002COV00084.001). These boreholes include holes that are considered qualified and some that are considered non-qualified. All of the boreholes used are listed in Attachment III. The discussion of the surface-based boreholes is located in Section 6.2.6 and Attachment III.

4.1.3 Waste Package Inventory

The "Approach to Implementing the Site Recommendation Design Baseline" (Stroupe 2000, Attachment 1, p. 1) states that the SR design must accommodate the waste package (WP) inventory for 70,000 MTU in accordance with the design input transmittal *Waste Package and DOE Canister Inventory* (CRWMS M&O 2000a). The WP inventory, which includes the WP quantities, heat outputs, and the outer length of the WP, for the Truncated Case herein referred to as the 70,000 MTU (TBV-4183), is outlined in Table 2 (CRWMS M&O 2000a, Item 2, pp. 3 and 5). The WP inventory for the Full Inventory Case, if authorized, herein referred to as the 97,000 MTU (TBV-4186) is outlined in Table 3 (CRWMS M&O 2000a, Item 2, pp. 4 and 6).

The average heat outputs are discussed as part of the thermal design and operational interface in Section 6.2.3.2 and 6.2.3.3. The WPs and their lengths, as part of the emplacement capacity, will be discussed in Sections 6.3.1, 6.4, and 6.4.1.

4.1.4 Commercial Spent Nuclear Fuel for the 97,000 MTU Case, If Authorized

The 97,000 MTU case, if authorized, includes approximately 83,800 MTU (83,791.49 MTU) of Commercial Spent Nuclear Fuel (CSNF) (CRWMS M&O 2000d, p. 27). This input is used in Section 6.4.1.

Table 2. Waste Package Inventory for the 70,000 MTU Case

WP Description		Number of WPs by WP Type	Average Heat Output/Package (kW)	WP Outer Length (m)
21 PWR[a]	Absorber Plates	4,299	11.330	5.06
	Control Rods	95	3.260	5.06
12 PWR	Absorber Plates Long	163	8.970	5.54
44 BWR[b]	Absorber Plates	2,831	7.000	5.06
24 BWR	Absorber Plates	84	0.540	5.00
5 IPWF[c]		95	2.450	3.48
5 DHLW[d] Short/1 DOE SNF[e] Short		1,052	2.575	3.48
5 DHLW Long/1 DOE SNF Long		1,406	2.575	5.11
2 MCO[f]/2 DHLW Short		149	1.230	5.11
5 HLW[g] Long/1 DSNF[h] Short		126	2.575	5.11
HLW Long Only		584	2.450	5.11
Naval	Short	200	3.100	5.32
	Long	100	3.100	5.96
TOTAL		11,184		

Source: CRWMS M&O 2000a, Item 2, pp. 3 and 5

[a] Pressurized Water Reactor (PWR)
[b] Boiling Water Reactor (BWR)
[c] Immobilized Plutonium Waste Form (IPWF)
[d] Defense High-level Waste (DHLW)
[e] Spent Nuclear Fuel (SNF)
[f] Multi-Canister Overpacks (MCO)
[g] High-level Waste (HLW)
[h] Defense SNF (DSNF)

Table 3. Waste Package Inventory for the 97,000 MTU Case, If Authorized

WP Description		Number of WPs by WP Type	Average Heat Output/Package (kW)	WP Outer Length (m)
21 PWR	Absorber Plates	5,690	11.330	5.06
	Control Rods	106	3.260	5.06
12 PWR	Absorber Plates Long	293	8.970	5.54
44 BWR	Absorber Plates	3,732	7.000	5.06
24 BWR	Absorber Plates	98	0.540	5.00
5 IPWF		127	2.450	3.48
5 DHLW Short/1 DOE SNF Short		1,403	2.575	3.48
5 DHLW Long/1 DOE SNF Long		1,874	2.575	5.11
2 MCO/2 DHLW Short		199	1.230	5.11
5 HLW Long/1 DSNF Short		167	2.575	5.11
HLW Long Only		780	2.450	5.11
Naval	Short	200	3.100	5.32
	Long	100	3.100	5.96
TOTAL		14,769		

Source: CRWMS M&O 2000a, Item 2, pp. 4 and 6

4.1.5 Existing Facilities

The Exploratory Studies Facility (ESF) and the East-West Cross Drift, also known as the Enhanced Characterization of the Repository Block (ECRB), will be incorporated into the Subsurface Facility repository layout. The following subsections outline the defining parameters of the ESF and East-West Cross Drift that are used in this analysis.

4.1.5.1 Exploratory Studies Facility

The existing ESF opening will be incorporated into the potential Subsurface Facility repository layout. The design and arrangement of the ESF, including gradients, coordinates, elevations, and azimuths, are illustrated in Figure 1 (CRWMS M&O 1996, p. 27). These parameters are used in Sections 5.2.7.2, 6, and 6.2.1.1.

4.1.5.2 East-West Cross Drift

The existing East-West Cross Drift, herein referred to as the ECRB, is incorporated into the Subsurface Facility repository layout. The design and arrangement of the ECRB is illustrated in Figure 2 (CRWMS M&O 1998a, Figure 1, and Attachment I) for reference only. The ECRB design as described below was outlined in the *East-West Cross Drift and Starter Tunnel Layout Analysis* (CRWMS M&O 1998a, pp. 12 and 14) and is used as input to the layout.

The grade of the excavated invert for the starter tunnel is +0.5 percent. The starter tunnel departs from the North Ramp at a 45-degree angle, which is an azimuth of 253.9747 degrees and terminates at Station (STA) 00+26.400 meters. The elevation at the breakout from the North Ramp was calculated at 1,083.423 meters and the elevation of the start of the bored tunnel at launch at 1,083.842 meters. The starter tunnel is initially mined up to approximately STA 00+14.200 meters. A 305-millimeter offset exists between the starter tunnel's excavated invert and the bored invert. The ECRB drift is a 5.0-meter diameter bored tunnel that starts at the end of the starter tunnel STA 00+26.400 meters and proceeds along an azimuth of 253.9747 degrees to the beginning of the first horizontal circular curve at STA 1+82.454 meters. The tunnel continues along the horizontal curve to the end of the curve at STA 3+15.401 meters. The tunnel proceeds along an azimuth of 229.0000 degrees to STA 3+25.401 meters at which point VPI #1 (vertical point of intersection) was located. The drift then continues at a +1.86 percent slope along 229.0000 degrees azimuth to the location of VPI #2 at STA 7+72.661 meters. VPI #2 is located at the plan view intersection of the ECRB and the East Main drift centerlines. VPI #2 is located at an elevation of 1,093.592 meters. From this point, the drift slopes at a +1.48 percent and continues along the 229.0000 degrees azimuth to the location of VPI #3 at STA 16+02.05 meters. VPI #3 is located at an elevation of 1,105.931 meters. The drift continues, from this point, at a slope of +0.886 percent and 229.0000 degrees azimuth to the beginning of the second horizontal curve at STA 23+20.763 meters. The drift continues along the curve at +0.886 percent slope to VPI #4 located at STA 24+67.146 meters. VPI #4 elevation is 1,113.597 meters. The drift then continues from this point at a slope of –3.0 percent to the end of the horizontal curve #2 located at STA 26+40.158 meters. From the end of curve #2, the drift continues at a –3.0 percent slope along a 289.0000 degrees azimuth to the terminal end of the drift located at STA 28+23.066 meters. The invert elevation at the terminal point is 1,102.919 meters. These parameters are used in Section 6.2.1.3.

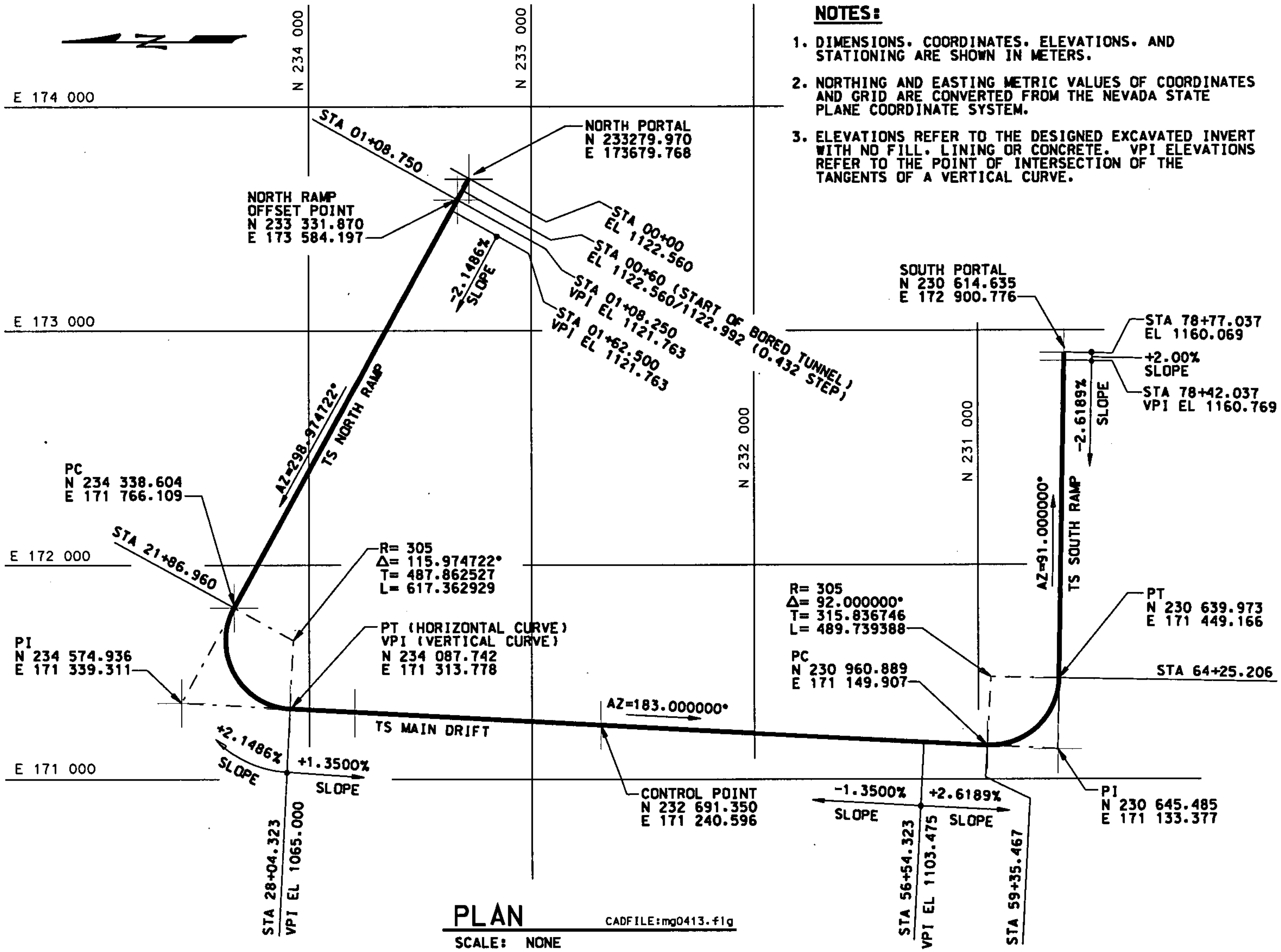
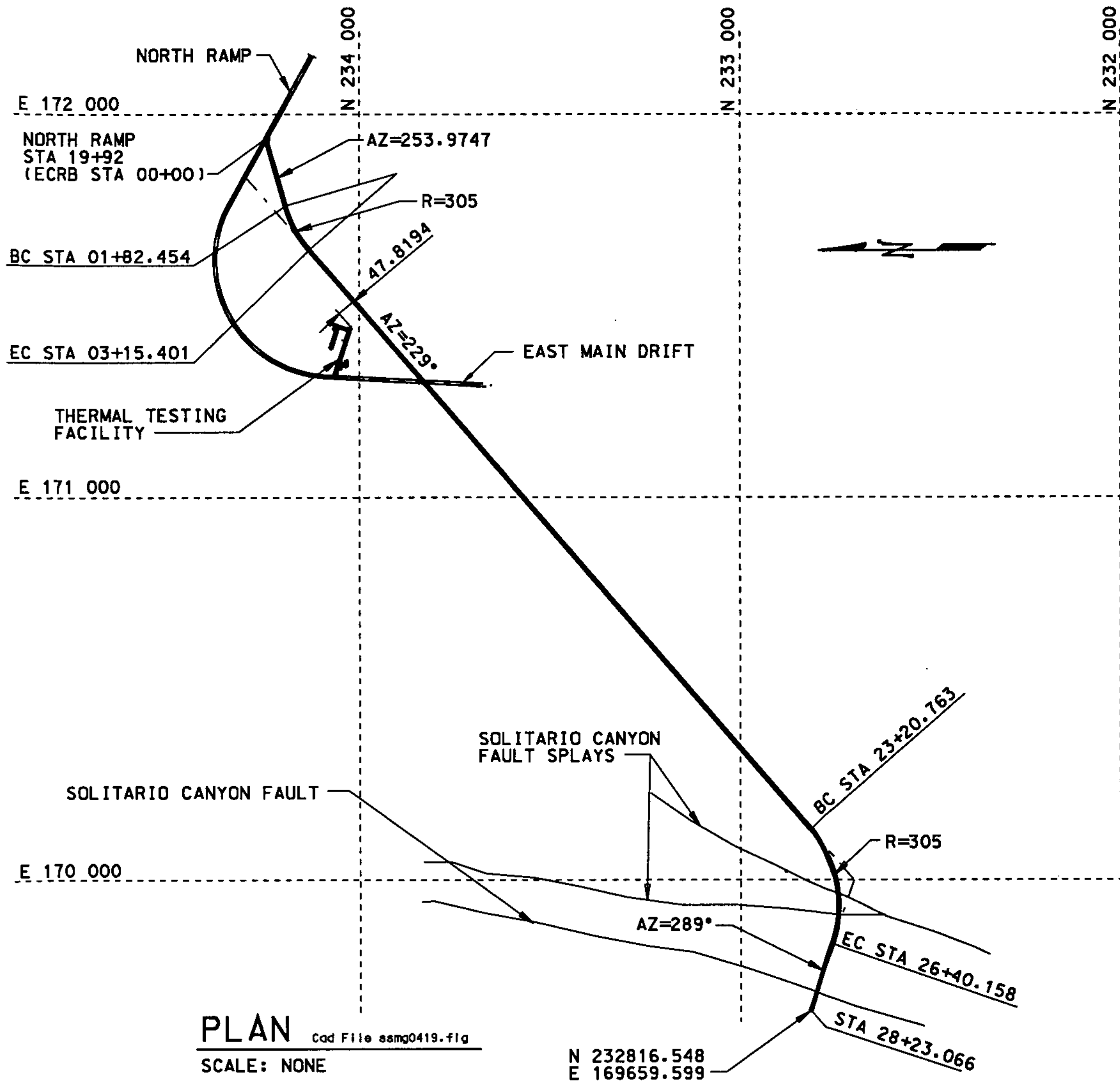


Figure 1. Exploratory Studies Facility



NOTES:

1. DIMENSIONS, COORDINATES, ELEVATIONS, AND STATIONING ARE SHOWN IN METERS.
2. NORTHING AND EASTING METRIC VALUES OF COORDINATES AND GRID ARE CONVERTED FROM THE NEVADA STATE PLANE COORDINATE SYSTEM.
3. ELEVATIONS REFER TO THE DESIGNED EXCAVATED INVERT WITH NO FILL, LINING, AND CONCRETE. VPI ELEVATIONS REFER TO THE POINT OF INTERSECTION OF THE TANGENTS OF A VERTICAL CURVE.

Figure 2. Enhanced Characterization of the Repository Block

4.1.6 Thermal Interface Inputs

A number of inputs for analyzing the interface between the Subsurface Facility and the overall subsurface thermal-loading concept are required. These inputs are documented in the following sections.

4.1.6.1 Ventilation Model Results

The Thermal Design and Operational Interface, Section 6.1.4, used output from the *Ventilation Model* (CRWMS M&O 2000l). The decay of the linear heat load is shown in Table 4 and the heat removed per drift segment and time period is shown in Table 5. This information was used to calculate the heat removal rate from the emplacement drifts after 30 and 50 years of continuous ventilation in Section 6.2.3.4.

Table 4. Decay of the Linear Heat Load

Time (years)	Percentage Decay of All CSNF WP(%)	All WP Linear Heat Load (kW/m)
0.01	100.00	1.5473
1	96.99	1.5008
5	87.93	1.3605
10	79.35	1.2278
15	72.23	1.1177
20	66.23	1.0248
26	59.89	0.9266
30	56.11	0.8682
40	48.24	0.7464
50	41.94	0.6490

Source: CRWMS M&O 2000l, p. II-4

Table 5. Heat Removed per Time Period and Drift Segment

Time Step (year)	Heat Removal Rate (q-rm) in Individual Segment, kW					
	0 – 100 m	100 – 200 m	200 – 300 m	300 – 400 m	400 – 500 m	500 – 600 m
0.0001	56.31	56.31	56.31	56.31	56.31	56.31
1	92.16	77.08	64.46	53.91	45.09	37.71
5	105.36	98.79	91.64	84.27	76.92	69.78
10	98.55	96.11	93.22	89.85	86.07	82.00
15	90.35	88.78	87.13	85.32	83.30	81.13
20	83.04	81.78	80.50	79.18	77.77	76.34
26	76.22	75.22	74.21	73.16	72.07	70.98
30	70.66	69.77	68.87	67.96	67.04	66.11
40	64.13	63.62	63.03	62.42	61.76	61.09
50	55.97	55.95	55.82	55.63	55.40	55.09

Source: CRWMS M&O 2000l, pp. IV-20 – IV-36

4.1.6.2 ANSYS Thermal Calculation

The tabular summaries from *ANSYS Thermal Calculations in Support of Waste, Quantity, Mix and Throughput Study* (CRWMS M&O 1999g) is a source of input for this analysis. The tables listed in Table 6 have been used throughout Section 6.2.3.

Table 6. ANSYS Thermal Calculation Inputs

Input Source	Section Used In
CRWMS M&O 1999g, Table 6-2, p. 38	Section 6.2.3.5
CRWMS M&O 1999g, Table 6-3, p. 39	Sections 6.2.3.6, and 6.2.3.10
CRWMS M&O 1999g, Tables 5-2 and 5-3, pp. 22 and 23	Section 6.2.3.10

4.1.6.3 Postclosure Peak Drift Wall Temperatures

For closure 30 years after emplacement of the last waste package, the postclosure peak drift wall temperature is 192.51 degrees Celsius, occurring 17.02 years after closure (TBV-4708). This information is documented in the input transmittal *Postclosure Peak Drift Wall Temperatures* (CRWMS M&O 2000n, Item 1). This input provides updated ANSYS calculations to reflect heat removal by the ventilation system directly from the drift wall and waste package.

4.1.6.4 NUFT Input for Quarter Pillar Temperature

Information generated using NUFT 3.0, as documented in the input transmittal *Repository Subsurface Design Manager's Request for Thermal-Hydrology Simulations of Pillar Conditions* (CRWMS M&O 2000f) shows that the 1/4 pillar temperature remains below 96 degrees Celsius for the 1.45 kW/m thermal load with 15 years of continuous ventilation. This information is discussed in Section 6.2.3.7.

4.1.6.5 Thermal Induced Ground Movement

The *Repository Ground Support Analysis for Viability Assessment* study (CRWMS M&O 1998c) described the expected ground movement as a result of the 85 MTU/acre areal mass load for the Viability Assessment repository design. In the Viability Assessment repository design, the unsupported non-emplacement drift vertical deflection ranges from 3 mm to 10 mm and the maximum horizontal deflection is approximately 15 mm (CRWMS M&O 1998c, Section 7.6.2.1.2, p. 74). This information is discussed in Section 6.2.3.12.

4.1.7 Ventilation Interface Inputs

A number of inputs for analyzing the interface between the Subsurface Facility and the subsurface ventilation system are required. These inputs are documented in the following sections.

4.1.7.1 Effective Areas of Ventilation Airways

The effective areas i.e., the unobstructed cross-sectional area within an opening for the ventilation airways are documented in *Calculation of Effective Areas of Subsurface Openings During Emplacement Mode* (CRWMS M&O 1999f, p. 50) as outlined in Table 7.

Table 7. Effective Areas of Ventilation Airways

Heading Type	Effective Area (m^2)
Access Mains (7.62-meter diameter)	36.17
Performance Confirmation Observation Drifts (Test and Evaluation Facilities) and Cross-block Drifts (5.5-meter diameter)	19.63

Source: CRWMS M&O 1999f, p. 50

This information is used in Attachment IV, Section IV.1.

4.1.7.2 Opening and Fixtures Geometry

The opening and fixtures geometry are documented in *Calculation of Effective Areas of Subsurface Openings During Emplacement Mode* (CRWMS M&O 1999f) and are given in Table 8.

Table 8. Opening and Fixture Geometry

Parameter	Description and Value	Reference Citation
Invert Geometry	The angle between the drift centerline and the outermost part of the invert is 34.9 degrees, based on an inside-opening radius of 3.51 meters.	CRWMS M&O 1999f, pp. 27 and 30
Track Gauge	Standard 1.44m gauge track	CRWMS M&O 1999f, p. 30
Area of 7.62 meter lined opening	The open area in a main is 38.7 m^2	CRWMS M&O 1999f, p. 27
Area of rails	0.0145 m^2	CRWMS M&O 1999f, p. 19
Area of light fixtures	0.1 m^2	CRWMS M&O 1999f, p. 19
Area of Utilities	0.474 m^2	CRWMS M&O 1999f, p. 28
Height of rail tie	0.1 meters	CRWMS M&O 1999f, p. 20
Height of the invert	0.933 meters	CRWMS M&O 1999f, p. 30
Lining Thickness in Mains	0.300 meters thick	CRWMS M&O 1999f, p. 30
Invert area above the ground support	1.73 m^2	CRWMS M&O 1999f, p. 28

This information is used in Attachment IV, Sections IV.3 and IV.7.

4.1.7.3 Exhaust Air Temperature Profiles

Table 9 outlines the maximum exhaust air temperature profiles at the ventilation raise based on a ventilation drift split of 600 meters.

Table 9. Maximum Exhaust Air Temperature Profiles at Ventilation Raise

Waste Package Heat Output (kW/m)	Emplacement Drift Ventilation Airflow (m^3)	Average Air Temperature at Ventilation Raise (degree Celsius)	Reference Source
1.2 kW/m	15	53.3	CRWMS M&O 1999g, Table I-14, p. I-18
1.4 kW/m	15	58.0	CRWMS M&O 1999g, Table II-8, p. II-9
1.6 kW/m	15	62.7	CRWMS M&O 1999g, Table III-8, p. III-11

Note: The average air temperature at the ventilation raise has been rounded up from the source document.

This information is used in Attachment IV, Section IV.2.

4.1.7.4 Thermal Expansion

The volume of the ventilation air expands as it passes through the emplacement drifts due to the thermal output of the WPs. Charles' Law for Thermal Expansion (Hartman et al. 1997, pp. 22 and 23) is used to calculate this effect.

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

where V = volume of a gas,
T = absolute temperature in degrees Kelvin
(degrees Kelvin = degrees Celsius + 273.15)

This information is used in Attachment IV, Section IV.2.

4.1.8 Exploratory Studies Facility Opening Size and Equipment Envelope

The ESF opening was excavated with a tunnel boring machine (TBM) with a diameter of 7.62 meters in accordance with the *Exploratory Studies Facility Design Requirement* (YMP 1996, p. 3-69). This information is used in Section 6.2.1.1.

4.2 CRITERIA

As described by Section 4.3.4, the requirements or constraints on this analysis will include those outlined in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000j), herein referred to as the MGR PDD. The MGR PDD Section 5 is not intended to be cited directly by design analyses, however, since the cited system description documents have not yet been updated to reflect the revised criteria, an exception has been made.. The primary source of criteria for this analysis is the *Subsurface Facility System Description Document* (CRWMS M&O 2000e), herein referred to as the Subsurface Facility SDD.

Criteria from the *Subsurface Ventilation System Description Document* (CRWMS M&O 2000b), herein referred to as the Subsurface Ventilation SDD, the *Emplacement Drift System Description Document* (CRWMS M&O 2000i), herein referred to as the Emplacement Drift SDD, and the *Waste Emplacement/Retrieval System Description Document* (CRWMS M&O 2000h), herein referred to as the Waste Emplacement/Retrieval SDD were also used as sources of design criteria.

4.2.1 System Performance Criteria

The following subsections outline the system performance criteria used in this analysis for the development of the subsurface layout.

4.2.1.1 Waste Inventory Requirement

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.1) states that the system shall be capable of accommodating:

- 86,700 metric tons initial heavy metal (MTHM), i.e., MTU of commercial SNF;
- 2,502 MTU DOE SNF (which includes 65 MTHM naval SNF);
- 19,333 defense HLW canisters (which includes IPWF); and
- 302 commercial HLW canisters.

In addition, the MGR PDD (CRWMS M&O 2000j, Sections 5.1.4.1 and 5.1.4.2) states that the Monitored Geologic Repository (MGR) shall:

- accommodate up to 70,000 MTU or equivalent, including 63,000 MTU of CSNF,
- not preclude the capability (by adding additional components and features) of accommodating up to 97,000 MTU or equivalent, and
- not preclude the capability of accommodating up to 115,000 MTU or equivalent to show flexibility of the design.

The MGR PDD (CRWMS M&O 2000j, Sections 5.2.3 and 5.2.4) provides the WP inventories that represent "not to exceed" values for each WP category. The note (CRWMS M&O 2000j, Sections 5.2.3 and 5.2.4) for the WP inventories state:

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

The WP inventory for the design basis, the 70,000 MTU case is shown in Table 10 (CRWMS M&O 2000j, Table 5-5) and the WP inventory for the maximum subsurface emplacement, the 97,000 MTU case is shown in Table 11 (CRWMS M&O 2000j, Table 5-6).

Table 10. Design Basis Waste Package Inventory

Type of WP	WP Length (m)	Average Heat Output/Package (kW)	Quantity
21 PWR AP (Absorber Plates)	5.06	11.330	4,500
21 PWR CR (Control Rods)	5.06	3.260	100
12 PWR AP Long	5.54	8.970	170
44 BWR AP	5.06	7.000	3,000
24 BWR AP	5.00	0.540	90
5 IPWF	3.48	2.450	100
5 DHLW Short/1 DOE SNF Short	3.48	2.575	1,100
5 DHLW Long/1 DOE SNF Long	5.11	2.575	1,500
2 MCO/2 DHLW	5.11	1.230	160
5 HLW Long/1 DOE SNF Short	5.11	2.575	130
HLW Long Only	5.11	2.450	600
Naval Short	5.32	3.100	210
Naval Long	5.96	3.100	110

Table 11. Waste Package Inventory for Maximum Subsurface Emplacement

Type of WP	WP Length (m)	Average Heat Output/Package (kW)	Quantity
21 PWR AP	5.06	11.330	5,700
21 PWR CR	5.06	3.260	110
12 PWR AP Long	5.54	8.970	300
44 BWR AP	5.06	7.000	3,750
24 BWR AP	5.00	0.540	100
5 IPWF	3.48	2.450	130
5 DHLW Short/1 DOE SNF Short	3.48	2.575	1,410
5 DHLW Long/1 DOE SNF Long	5.11	2.575	1,880
2 MCO/2 DHLW	5.11	1.230	200
5 HLW Long/1 DOE SNF Short	5.11	2.575	170
HLW Long Only	5.11	2.450	800
Naval Short	5.32	3.100	210
Naval Long	5.96	3.100	110

The WP inventory for SR is described in Section 4.1.3.

The repository reference capacity of 70,000 MTU will be discussed in Sections 6.3 and 6.3.1 and the capacity of 97,000 MTU, should it be authorized, will be discussed in Sections 6.2, 6.4, and 6.4.1.

4.2.1.2 Waste Package Quantities and Lengths

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.2) states that the system shall accommodate emplacement of the WPs listed in Table 12.

Although these WP characteristics have been provided in the Subsurface Facility SDD, the WP lengths and quantities for SR are documented as a parameter in Section 4.1.3.

The WP quantities and lengths are discussed in Section 6.3.1.

Table 12. Proposed Waste Packages and Characteristics

Waste Package Type	Number of Waste Packages	Outer Length (m)
21 PWR	4,411	5.335
12 PWR	489	5.335
12 PWR ST	156	5.871
44 BWR	2,841	5.657
24 BWR	92	5.657
HLW/DSNF Co-Disposal	1,377	5.367
HLW Separate	0	3.790
DSNF Separate	694	4.985
Navy SNF	285	6.165
Immobilized Plutonium/HLW Co-Disposal	318	not specified

Source: CRWMS M&O 2000e, Section 1.2.1.2

4.2.1.3 Emplacement Drift Diameter

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.3) and the MGR PDD (CRWMS M&O 2000j, Section 5.2.5) states that the system shall size the emplacement drifts with a nominal diameter of 5.5 meters.

The emplacement drift diameter will be discussed as part of the emplacement drift description in Sections 6.2.1.2, 6.2.3.7, 6.3.2.2, and 6.4.2.2.

4.2.1.4 Waste Package Spacing

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.4) states that the system shall allow for an average WP spacing. The waste package spacing is considered TBD and is tracked with TBD-3791.

The MGR PDD (CRWMS M&O 2000j, Section 5.2.10) states that the emplacement drifts shall be line loaded with WPs spaced with a nominal distance of 10 centimeters between the ends of adjacent WPs. (In this context, the "ends" of the WPs include any skirts or other structures that extend beyond the lid of the WP). The maximum linear heat load shall be 1.5 kW/m, averaged over a fully loaded emplacement drift at the time of completion of loading an entire emplacement drift.

The WP spacing will be addressed as part of the emplacement area definition in Sections 6.2.3.2, 6.3.1, and 6.4.1. The maximum linear heat load is addressed in Section 6.2.3.2.

4.2.1.5 Emplacement Drift Spacing

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.5) and the MGR PDD (CRWMS M&O 2000j, Section 5.2.1) states that the system shall space the emplacement drifts 81 meters center-to-center.

The emplacement drift spacing will be discussed in Sections 6.2.1.2, 6.2.3.7, 6.3.1, and 6.4.1.

4.2.1.6 Limit Water Inflow in Ramps

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.6) states that the system shall provide an upward grade of at least 1 percent for at least the first 10 meters of the entrance ramps from the surface.

The limiting of water inflow in the ramps will be addressed in Section 6.2.5 as part of the overall drainage scheme of the subsurface layout.

4.2.1.7 Orientation of Emplacement Drifts

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.7) states that the system shall orient emplacement drifts at least 30 degrees from dominant joint orientations.

The orientation of the emplacement drifts will be addressed as part of the emplacement area definition in Sections 6.2.1.2, and 6.2.2.2.

4.2.1.8 Test and Evaluation Program

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.1.8) states that the system shall provide drifts and alcoves for implementation of the Test and Evaluation Program. The drifts and alcoves shall have the characteristics shown in Table 13.

Table 13. General Performance Characteristics–Test and Evaluation Facilities

Quantity	Performance Monitoring: Minimum of three (3) monitoring areas with one observation drift (OD) and a minimum of six (6) alcoves for each area. Postclosure Simulation: One Engineered Barrier System interaction test area and one Near Field Response test area, consisting of two (2) simulated emplacement drifts, one (1) OD and three (3) alcoves per area. Test areas may share the same OD. Specialized Test Areas: Ten (10) seepage alcoves. Two (2) seismic monitoring niches. One (1) ramp-seal test alcove. Two (2) shaft-seal test alcoves and one (1) connecting shaft. Other Test Alcoves: Not yet specified.
Size	Based on equipment / instrument envelope and ventilation duct requirements.

Table 10. General Performance Characteristics–Test & Evaluation Facilities (Continued)

Grade	Performance Monitoring: Observation drifts are to be oriented parallel to emplacement drift horizon within 1% grade of target slope and sufficient to provide drainage. Alcoves sloped to provide drainage to ODs. Postclosure Simulation: Observation drift(s) are to be oriented parallel to simulated drifts within 1% grade of target slope and sufficient to provide drainage. Alcoves sloped to provide drainage to ODs. Specialized Test Areas: For seepage alcoves, grade sufficient to provide drainage. For seismic monitoring niches, grade sufficient to provide drainage. For ramp-seal test alcove, slope shall be representative of access mains. For shaft-seal test area, alcove shall slope sufficient to provide drainage, and shaft shall be vertical. Other Test Alcoves: Sufficient to provide drainage.
Length	Performance Monitoring: Observation drifts for performance monitoring shall, at a minimum, span the width of the emplacement area where they are located. Alcoves shall be of sufficient length to extend from the OD and provide coverage of the area between adjacent emplacement drifts, and two drift diameters on outer sides of the emplacement drifts. Postclosure Simulation: Simulated Emplacement drifts shall be a minimum of 600m long to provide for 2 segment tests and buffer areas. Observation drifts shall provide access for monitoring along the entire length of the associated drift. Specialized Test Areas: For seepage alcoves, alcoves shall be a minimum of 20m in length, and located outside the mechanical-hydrological zone of influence of adjacent excavations. For seismic monitoring niches, niches shall be of sufficient depth to accommodate drilling of monitoring holes within niche without impact to traffic in other tunnels and drifts, and sufficient to house data acquisition system and associated electronics. For ramp-seal test alcove, length shall be sufficient to contain representative seal and sufficient additional length to isolate seal test area from other tunnels and drift, and house related instrumentation and data acquisition systems.

Table 10. General Performance Characteristics–Test & Evaluation Facilities (Continued)

Length (continued)	Shaft-seal test alcove, test area shall be vertical and access alcoves of sufficient length to isolate seal test area from other tunnels and drifts and house related instrumentation and data acquisition systems. Other Test Alcoves: As required for testing.
Arrangement	Performance Monitoring: Observation drifts are to be located above or below repository horizon so as to not significantly impact the thermal-mechanical-hydrological response of the emplacement drifts. Location above or below the horizon shall be varied to provide both conditions over the range of ODs. Postclosure Simulation: Simulated emplacement drifts shall be at grades representative of emplacement drifts. Observation drifts to be located below the simulated drifts so as to not significantly impact the thermal-mechanical-hydrological response of the simulated drifts. Specialized Test Areas: Seepage alcoves shall be located along access mains and performance monitoring ODs. Seismic monitoring alcoves/niches shall be arranged to be located off access mains at opposing ends of the repository configuration. Ramp seal test area shall be arranged to be located off the south access main. Shaft seal test area shall be arranged to be located off the south access main. Other alcoves: Alcoves shall be arranged as required.
Location	Performance Monitoring: One test area and associated OD shall be located so to monitor first emplacement drifts containing waste. Remaining ODs and test areas shall be located to provide access to varying rock mass conditions, including areas with differing rock stratigraphy, fracture density, and expected percolation rates. Observation drifts shall provide flexibility in locating specific test areas. Postclosure Simulation: Test areas shall be located in rock conditions representative of the repository horizon. Test area may be located in areas outside the siting area designated as suitable for emplacement or as can be accommodated within the siting area.

Table 10. General Performance Characteristics–Test & Evaluation Facilities (Continued)

Location (continued)	Specialized Test Areas: Seepage alcoves shall be located to provide access to varying rock mass conditions, including areas with differing rock stratigraphy, fracture density, and expected percolation rates. Seismic monitoring alcoves/niches shall be located in areas with different rock mass characteristics at repository depth. Ramp seals test shall be located in similar rock mass conditions as repository ramps. Shaft seal test shall to be located in similar rock mass conditions as repository shafts. Other alcoves: Not yet specified.

Source: CRWMS M&O 2000e, Section 1.2.1.8

The Test and Evaluation Facility requirement will be discussed in Section 6.2.1.3.

4.2.2 Nuclear Safety Criteria

The MGR must comply with applicable provisions of the Code of Federal Regulations (CFR) "Standards for Protection Against Radiation" (10 CFR 20) as outlined in Section 4.3.3. The following nuclear safety criteria are specified in the Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1, pp. 14 and 15).

4.2.2.1 Unrestricted Access Radiation Level Limit

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.1) states that the system shall ensure subsurface areas requiring unrestricted access can be maintained at radiation levels less than or equal to 2.5 mrem per hour.

Radiological safety will be discussed in Section 6.2.7.

4.2.2.2 Restricted Access Radiation Level Limit

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.2) states that the system shall ensure subsurface areas requiring restricted access can be maintained at radiation levels less than or equal to 100 mrem per hour.

Radiological safety will be discussed in Section 6.2.7.

4.2.2.3 Locating Surface Openings

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.3) states that the system shall locate the entrance of all surface openings to the Subsurface Facility outside of the probable maximum flood areas as depicted in *Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion* (YMP 1995, Figure 2.6.2-1). The location of the surface openings will be addressed as part of the ventilation design and operational interface in Sections 6.2.4 and 6.2.5.

4.2.2.4 Minimum Geologic Standoffs to Repository Openings

The input transmittal for the *Preliminary Water Table Standoff Criterion* (CRWMS M&O 2000k, Section 1.2.2.1.4) states that the system shall accommodate the minimum standoffs identified in Table 14. Repository openings that are placed within these standoff distances shall be approved per site impact analysis.

Table 14. Repository Opening Standoffs

Geologic Areas	Standoff Distance
Top of the present day water table	160 meters from the closest edge of the emplacement drifts (TBV-359)
Main trace of Type I fault zone	60 meters from the closest edge of repository openings (TBV-359)

Source: CRWMS M&O 2000k, Section 1.2.2.1.4

The geological standoff distances are addressed in Sections 6.2.2 and 6.2.2.1.

4.2.2.5 Geologic Standoff Distances for Waste Packages

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.5) states that the system shall accommodate a 15 meter standoff between WPs and Type I faults and a 5-meter standoff between WPs and splays associated with Type I faults. It is also noted that the standoff distances used in the SDD are for establishing usable drift length only. These distances do not specify final WP standoff distances.

The geological standoff distances from the WPs to Type I faults are addressed in Section 6.2.2.1.

4.2.2.6 Standoff Distance to Surface-Based Boreholes

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.6) states that the system shall allow at least a 5-meter standoff from the edge of the WPs to the perpendicular projection of the centerline of a surface-based borehole if the borehole intercepts the drift or comes within 5 meters of the edge of the drift.

The standoff distances for surface-based boreholes will be addressed as part of the emplacement area definition in Section 6.2.6 and Attachment III.

4.2.2.7 Drainage

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.7) states that the system shall provide a repository grade such that overall water drainage and accumulation is away from emplacement areas.

The overall drainage scheme of the subsurface layout will be discussed in Section 6.2.5.

4.2.2.8 Location of the Repository Emplacement Area

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.8) states that the system shall limit the emplacement areas to within the lower part of the lithophysal zone of the TSw1 unit and the entire TSw2 unit. The TSw1 unit is a thermal/mechanical unit, described as the Topopah Spring Member, with welded, devitrified ashflows and lithophysal (alternating lithophysae-rich and lithophysae-poor ashflows). The TSw2 unit is also a thermal/mechanical unit and is described as the Topopah Spring Member with welded, devitrified ashflows and nonlithophysal (sparsely distributed lithophysae).

The location of the potential repository emplacement area is addressed in Sections 6.2.2 and 6.5.2.

4.2.2.9 Minimum Overburden Thickness

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.1.9) states that the system shall locate the subsurface emplacement level at least 200 meters below the directly overlying ground surface (TBV-619).

The minimum overburden thickness is addressed in Sections 6.2.2 and 6.5.2.

4.2.3 Non-Nuclear Safety Criteria

The MGR SSCs must be designed and fabricated using good engineering principles, with particular attention to system safety. The following non-nuclear safety criteria are specified by the Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.2, p. 15).

4.2.3.1 Escapeways

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.2.1) states that the system shall have two or more separate, properly maintained escapeways to the surface from the lowest levels which are so positioned that damage to one shall not lessen the effectiveness of the others. A method of refuge shall be provided while a second opening to the surface is being developed.

All non-nuclear safety concerns will be addressed in Section 6.2.8.

4.2.3.2 Refuge Chambers

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.2.2) states that a method of refuge shall be provided for every employee who cannot reach the surface from his working place, through at least two separate escapeways, within a time limit of one hour when using the normal exit method (i.e., walking). These refuge chambers must be positioned such that the employee can reach one of them within 30 minutes from the time the workplace is left.

All non-nuclear safety concerns will be addressed in Section 6.2.8.

4.2.3.3 Travel Time to Reach Refuge Chamber

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.2.2.3) states that travel times for exiting or reaching a refuge chamber shall be based on a maximum rate for personnel travel of 2,100 meters in 30 minutes.

All non-nuclear safety concerns will be addressed in Section 6.2.8.

4.2.4 System Interfacing Criteria

The Subsurface Facility interfaces with various other systems. The following interfacing criteria have been specified by the Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4, pp. 16 and 17).

4.2.4.1 Subsurface Ventilation System

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.1) states that the system layout shall accommodate the Subsurface Ventilation System design criteria.

The ventilation requirements and incorporation of the ventilation openings in the subsurface layout will be discussed in Section 6.2.4.

4.2.4.2 Gradients

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.2) states that the system shall be designed so the grades of the South Ramp, emplacement drifts, and other openings providing rail transport do not exceed 2.7 percent, 1.0 percent, and 2.5 percent, respectively.

The gradient constraints will be discussed as part of the layout description in Sections 6.2.1.1 and 6.2.5.

4.2.4.3 Opening Sizes

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.3) states that the system shall size the excavated openings, as a minimum, to accommodate the required operating envelopes while allowing for ground control installation, variations in tunnel dimensions and alignment, and tunnel deformation (based on repository preclosure life). The diameter of the emplacement drifts has been determined to be 5.5 meters.

The opening sizes will be discussed as part of the layout constructibility in Section 6.2.1.1.

4.2.4.4 Zeolitized Layer Temperature Limit

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.4) states that the system shall be designed to accommodate the Emplacement Drift System's maximum constraint for the zeolitized layer within the Calico Hills.

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.3.2) states that the system shall limit the temperature of zeolite layers located 170 meters or further beneath the emplacement area horizon to less than 90 degrees Celsius (TBV-286).

The temperature limits will be addressed as part of the thermal strategy in Section 6.2.3.10.

4.2.4.5 Soil Surface Temperature Change

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.5) states that the system shall be designed to accommodate a limit on the temperature change, at 45 centimeters below the soil surface, to 2 degrees Celsius above the established naturally occurring pre-emplacement average annual ground surface temperature within the footprint of the MGR. The MGR footprint is defined as that area directly above emplaced WPs and extending 500 meters horizontally beyond the edge of emplaced WPs (TBV-617).

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.3.3) states that the system shall limit the change in temperature, at 45 centimeters below the soil surface, to 2 degrees Celsius above what the established naturally occurring pre-emplacement average annual ground surface temperature is in the area directly above the emplaced WPs and extending 500 meters beyond the edge of the emplaced WPs (TBV-617).

The temperature limits will be addressed as part of the thermal strategy in Section 6.2.3.11.

4.2.4.6 Temperature Limit on the PTn Geologic Unit

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.6) states that the system shall accommodate the Emplacement Drift System's temperature constraint for the PTn geologic unit. The PTn geologic unit is a thermal/mechanical unit described as the Lower Tiva Canyon Member, Yucca Mountain and Pah Canyon Members, Upper Topopah Spring Member, with non-welded ashflows and bedded tuffs.

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.3.4) states that the system shall limit the temperature of the PTn geologic unit to less than 96 degrees Celsius (TBV-0322).

The temperature limits will be addressed as part of the thermal strategy in Section 6.2.3.10.

4.2.4.7 Opening Orientations

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.7) states that the system shall orient access drifts, mains, and ramps etc., as needed to support waste emplacement and potential retrieval operations in the emplacement drift.

The opening orientations will be addressed as part of the layout constructibility in Section 6.2.1.1.

4.2.4.8 Uplift Limit of the TSw1 Unit

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.8) states that the system shall accommodate the Emplacement Drift System's uplift limit of the TSw1 thermomechanical unit.

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.3.5) states that the system shall be designed such that the differential uplift measured between the top of the TSw1 thermomechanical unit above the repository and the TSw1 thermomechanical unit at the preclosure controlled area boundary is less than 1 meter (TBV-618).

The uplift limit will be addressed as part of the thermal strategy in Section 6.2.3.12.

4.2.4.9 Interface with the Subsurface Excavation System

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.4.9) states that the system shall interface with the Subsurface Excavation System for the location of construction openings (e.g., TBM Assembly/Disassembly Chambers, etc.).

The interface with the subsurface excavation system is discussed in Section 6.2.9.

4.2.4.10 Emplacement Drift and Turnout Interface

A difference in elevation of 0.8 meters between the bottom of the turnout and the bottom of the emplacement drift (CRWMS M&O 2000h, Section 1.2.4.7) shall be accommodated. This is the result of the need to excavate a step in the launching chamber to allow TBM excavation of the emplacement drift.

This criterion is needed to ensure the Waste Emplacement/Retrieval System is able to negotiate the change in elevation between the bottom of the turnout and the bottom of the emplacement drift, which is located at the emplacement drift dock.

This criterion is addressed in Section 6.2.1.2.

4.2.4.11 Opening Curvatures

The Subsurface Facility shall accommodate the Waste Emplacement Transportation System Curvatures outlined in Table 15 (CRWMS M&O 2000h, Section 1.2.4.6). This criterion is needed to define the interface between the Subsurface Emplacement Transportation System, the Subsurface Facility System, and the Waste Emplacement/Retrieval System. The minimum radius of curvature that the track makes will limit the design of the equipment that rides on top of the tracks. The radius of curvature for the ramps and mains is limited by the muck conveyor usage during construction. This criterion supports the waste emplacement and retrieval operations as required in Section 4.2.4.7. This criterion is addressed in Sections 6.2.1.1 and 6.2.1.2.

Table 15. Subsurface Waste Emplacement Transportation System Curvatures

Location	Minimum Radius
Ramps and Mains	305 meters (TBV-253)
On the Surface and Within Emplacement Drift Turnouts	20 meters (TBV-253)

Source: CRWMS M&O 2000h, Section 1.2.4.6

4.2.4.12 Air Temperature for Human Access

It is assumed that exhaust air that exceeds a dry bulb temperature of 48 degrees Celsius (TBV-0321) will be isolated from areas requiring human access. This assumption is based on the ventilation system criterion to limit the maximum dry bulb temperature to 48 degrees Celsius for subsurface areas during human access (CRWMS M&O 2000b, Section 1.2.1.3).

This criterion is addressed in Section 6.2.4 and Attachment IV, Section IV.3.

4.2.4.13 Preclosure Time Periods

The MGR PDD (CRWMS M&O 2000j, Section 5.1.1.1 and CRWMS M&O 2000m) states that the MGR design shall allow the repository to be closed as early as 30 years after emplacement of the last WP contingent upon meeting the remainder of the thermal requirements. The MGR shall include provisions that support a deferral of closure for up to 300 years from initiation of waste emplacement, with appropriate monitoring and maintenance.

This criterion is addressed in Section 6.2.3.4.

4.2.4.14 Waste Package Maximum Thermal Output

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.4.4) and the MGR PDD (CRWMS M&O 2000j, Section 5.2.13) states that the system shall accommodate a maximum WP thermal output of 11.8 kW at the time of emplacement.

This criterion is addressed in Section 6.2.3.3.

4.2.4.15 Waste Package Heat Removal During Preclosure

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.4.5) and the MGR PDD (CRWMS M&O 2000j, Section 5.1.3.1) states that the system shall accommodate the removal of 70 percent of the heat generated by WPs by the Subsurface Ventilation System during the preclosure period.

This criterion is addressed in Section 6.2.3.4.

4.2.4.16 Not Used

4.2.4.17 Preclosure Emplacement Drift Wall Temperature

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.1.3) states that the system shall limit the emplacement drift wall temperature to 96 degrees Celsius or less during the preclosure period.

This criterion is addressed in Section 6.2.3.5.

4.2.4.18 Postclosure Pillar Temperature

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.1.4) states that if the MGR is closed between 50 years and 125 years after emplacement of the initial WP, the system shall limit the temperature of 50 percent of the pillar width to 96 degrees Celsius or less during the postclosure period.

This criterion is addressed in Section 6.2.3.7.

4.2.4.19 Postclosure Emplacement Drift Wall Temperature Goal

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.1.5) states that if the MGR is closed at 125 years after emplacement of the initial WP or later, the system shall limit the temperature of the emplacement drift walls to 96 degrees Celsius or less during the postclosure period. The MGR PDD (CRWMS M&O 2000j, Section 5.1.5) states as a performance goal that the emplacement drift wall temperature should remain below 96 degrees Celsius following repository closure, based on nominal/expected values of repository closure. Since the MGR PDD states this is only a goal, it is not necessary to show compliance with the SDD criterion.

This criterion is addressed in Section 6.2.3.6.

4.2.4.20 Maximum Postclosure Emplacement Drift Wall Temperature

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.3.1) states that the system shall limit the emplacement drift wall temperature to less than 200 degrees Celsius during the postclosure period (TBV-287).

This criterion is addressed in Section 6.2.3.8.

4.2.4.21 TSw1 Thermomechanical Unit Differential Uplift Rate

The Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.3.6) states that the system shall be designed such that the differential uplift measured between the ground surface above the repository and the ground surface at the preclosure controlled area boundary is less than 0.5 cm/year (TBV-618).

This criterion is addressed in Section 6.2.3.13.

4.3 CODES AND STANDARDS

The primary source of codes and standards for this analysis is the Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.6).

4.3.1 Occupational Safety and Health Standards

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.6.1) states that the system shall comply with the applicable provisions of "Occupational Safety and Health Standards" (29 CFR 1910).

Applicable safety and health standards will be addressed as part of the repository constructibility discussion in Section 6.2.8.

4.3.2 Safety and Health Regulations for Construction

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.6.2) states that the system shall comply with the applicable provisions of "Safety and Health Regulations for Construction" (29 CFR 1926).

Applicable safety and health regulations will be addressed as part of the repository constructibility discussion in Section 6.2.8.

4.3.3 Standards for Protection Against Radiation

The MGR must comply with the applicable provision of "Standards for Protection Against Radiation" (10 CFR 20). This standard as it relates to the Subsurface Facility is discussed in Sections 4.2.2 and 6.2.7.

4.3.4 Monitored Geologic Repository Project Description Document

The Subsurface Facility SDD (CRWMS M&O 2000e, Section 1.2.6.3) states that the system shall comply with the applicable assumptions contained in the MGR PDD (CRWMS M&O 2000j).

Applicable sections of the MGR PDD (CRWMS M&O 2000j) will be addressed with various criteria (see Section 4.2) and various assumptions (see Section 5.1).

5. ASSUMPTIONS

An assumption is considered a statement or proposition that is taken to be true or representative in the absence of direct confirming data or evidence. The assumptions used in this analysis are identified and explained in this section.

5.1 CONTROLLED PROJECT ASSUMPTIONS

The following assumptions from the MGR PDD (CRWMS M&O 2000j) have been incorporated into this analysis as required in Section 4.3.4.

5.1.1 Waste Package Shielding

The MGR PDD (CRWMS M&O 2000j, Controlled Project Assumption (CPA) 019) states that WP containment barriers will provide sufficient shielding for protection of WP materials from radiation-enhanced corrosion. Individual WPs will not provide any additional shielding for personnel protection. Additional shielding for personnel protection will be provided by the subsurface and surface waste handling SSCs, including the WP transporter (TBV-1014). This assumption will be required to discuss the layout of the emplacement drift turnouts.

Radiological safety will be discussed in Section 6.2.7.

5.1.2 Emplacement Drift Entrance

The MGR PDD (CRWMS M&O 2000j, CPA 021) states that doors are required at entrances to emplacement drifts (TBV-1016). This assumption will be required in the discussion regarding the layout of the emplacement drift turnouts.

The turnout requirements and incorporation of emplacement drift doors will be discussed in Section 6.2.1.2 and 6.2.7.

5.1.3 Modular Design and Construction Capability

The MGR PDD (CRWMS M&O 2000j, CPA 023) states that the MGR will be designed in a manner that will permit modular design and/or construction in stages such that maximum annual funding requirements could be reduced. This will facilitate the start of operations at the repository after the initial construction stage and continuation of operations concurrently with subsequent construction stages. The amount of modular design or construction staging would be selected based on funding and schedule constraints.

The construction capability will be discussed as part of the layout constructibility in Section 6.2.9.1.

5.1.4 Subsurface Configuration for Water Drainage

The MGR PDD (CRWMS M&O 2000j, CPA 026) states that the repository subsurface layout will be configured for post-closure water drainage such that:

- Water entering an emplacement drift can drain directly into the surrounding host rock without draining along the drift for collection in a centralized location. (This assumption does not encompass general flooding of the facility) (TBV-1021).
- Drifts above the emplacement level will not have direct connection to an emplacement drift such that water entering the over-lying drift could flow by gravity through a man-made opening into the underlying emplacement drifts (TBV-1021).
- Drifts above the emplacement level will be configured to slope so that any water entering the drift can flow, by gravity, away from the emplacement area (TBV-1021).

The drainage of the subsurface layout will be addressed in Section 6.2.5.

5.2 OTHER ASSUMPTIONS

Other assumptions used in this analysis that are not documented in the MGR PDD (CRWMS M&O 2000j) are identified and explained in this section. These initial use assumptions will only be considered TBV if it has been determined that the assumption is critical to the conclusions of this analysis. Each statement for an initial use assumption will contain a justification of the input status.

5.2.1 Empty Drifts During Emplacement

It is assumed that a certain number of special use drifts will be excavated within the pillar of two adjacent emplacement drifts and will be left empty during emplacement operations. These drifts are excavated within the pillar of adjacent emplacement drifts so as not to impact the required emplacement area. Some of the empty drifts will be cross-block drifts for ventilation, monitoring, emergency egress, and/or the Test and Evaluation program. These will be located to split the repository block into similarly sized areas. Other empty drifts will be standby emplacement drifts for possible temporary relocation of emplaced WPs. These drifts will be located within the first half of the emplacement drifts to be available early in the emplacement process. This assumption will not be considered TBV since the number of empty drifts excavated between adjacent emplacement drifts does not affect the total area required for emplacement of the specified WP inventories. The incorporation of standby and cross-block drifts is discussed in Section 6.2.1.2.

5.2.2 Contingency Area

Two different allowances have been included in the layout. It is assumed that an allowance of 2 percent of the required emplacement drift length will be excavated in addition to the required length of emplacement drift. This area is planned to be excavated to allow for additional space if needed during emplacement for variances in the WP inventory. It is assumed that an additional 10 percent contingency is included in the conceptual layout. This contingency will only be excavated to allow for unexpected circumstances such as conditions found during development that prevent the intended emplacement area from being used due to unexpected ground conditions. This assumption will not be considered TBV since the impact is not critical to the total area allocation for emplacement of the WP inventories. The incorporation of the excavation allowance and the contingency area is discussed in Sections 6.3, 6.3.1, 6.4, and 6.4.1.

5.2.3 Emplacement Drift Turnout Configuration

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

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

It is assumed that the straight portion at the end of the turnout is 24 meters. This straight portion of the turnout accommodates the setup and launch of the TBM as well as provides a docking area for the WP transporter for unloading of the WP in line with the emplacement drift. The WP transporter with the transfer dock is approximately 22 meters long (CRWMS M&O 2000g, p. 30).

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

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

It is assumed that the turnout profile is 8 meters wide with an arch from spring line to spring line, and 7 meters high at the crown. This turnout profile is based on the straight portion of the turnout specified for the VA subsurface layout (CRWMS M&O 1997a, p. 89) and is assumed to be adequate for the TBM launch and WP transporter activities in the turnout.

These assumptions are not considered TBV since configuration of the emplacement drift turnouts does not affect the total area required for emplacement of the specified WP inventories. This assumption was used in the configuration of the emplacement drift turnout as illustrated in Figure 4 and discussed in Sections 6.2.1.2, 6.2.7, and Attachment I.

5.2.4 Maximum Length of Drift Split

A maximum emplacement drift split length of 600 meters is assumed and any emplacement length in excess of 600 meters will be considered unusable space. The basis of this restriction is the thermal analysis of the effect of continuous ventilation on the temperature of rock adjacent to the emplacement drifts. The assumed effective length of ventilating airflow in an emplacement drift is 600 meters (CRWMS M&O 1999g, p. 19). This assumption will not be considered TBV since the restriction on the useable emplacement length of an emplacement drift does not affect the total area required for emplacement of the specified WP inventories such that the conclusions of this analysis are impacted.

The restriction of the useable emplacement drift split is incorporated into the layout in Attachments I and IV.

5.2.5 Pillar Requirements

A pillar between perpendicular crossing drifts is assumed to be a minimum of 10 meters from crown to invert. A pillar for drifts running parallel is assumed to be a minimum of three diameters, using the maximum diameter of the largest drifts, from centerline-to-centerline. This assumption does not include pillar requirements for the emplacement drifts since the emplacement drift spacing has been set at 81 meters center-to-center (see Section 4.2.1.5). This assumption will not be considered TBV since the assignment of minimum pillar requirements does not affect the total area required for emplacement of the specified WP inventories.

The incorporation of the minimum pillar requirements in developing the layout is discussed in Section 6.2.1.1.

5.2.6 Physical Standoff Distance to the Ventilation Raise

Ventilation raises are located in each emplacement drift to channel exhaust air to the Exhaust Main. A physical standoff distance of 2 meters is assumed, measured from the centerline of the ventilation raise to the end of the nearest emplaced WP. This standoff distance should minimize interference with the ventilation airflow and/or radiological monitoring around the ventilation raise. This assumption will not be considered TBV since the assignment of this standoff distance does not affect the total area required for emplacement of the specified WP inventories.

The incorporation of the physical standoff distance to the ventilation raise is discussed in Attachment I.

5.2.7 Ventilation Strategy Assumptions

A number of assumptions are required to integrate the subsurface layout with the overall ventilation strategy for the potential repository. These assumptions are documented in the following sections.

5.2.7.1 Minimum Airflow Velocity

The minimum airflow velocity for openings requiring human access during normal operations is assumed be 1 meter per second (McPherson 1993, p. 295). This value is based on a typical minimum design airflow velocity requirement from industry, as outlined in *Subsurface Ventilation and Environmental Engineering*. This assumption will not be considered TBV since the assignment of the minimum airflow velocity does not impact the area required for emplacement of the specified WP inventories.

This assumption is used in Attachment IV, Section IV.1.

5.2.7.2 Subsurface Openings Supporting Ventilation

The primary subsurface openings supporting ventilation are assumed to be driven by a 7.62-meter diameter TBM. This sizing of the ventilation openings is consistent with other access openings (see Section 4.1.5.1) to minimize the sizes of TBMs required to construct the repository. This assumption will not be considered TBV since the size of the support openings does not affect the area required for emplacement of the specified WP inventories. Some secondary openings may be developed by roadheader or conventional drill and blast methods.

This assumption is used in Attachment IV, Sections IV.1 and IV.3.

5.2.7.3 Ventilation Shaft Size

It is assumed that all the ventilation shafts will be excavated the same diameter based on the largest shaft size necessary to support the subsurface ventilation system. This assumption is used to standardize the equipment size required for shaft excavation. This assumption will not be considered TBV since the size of support openings does not affect the total area required for emplacement of the specified WP inventories.

This assumption is used in Attachment IV, Section IV.7.

5.2.7.4 Air Velocity Constraints

It is assumed that the air velocity constraints for the subsurface ventilation airflows, as listed in Table 16, are sufficient for the purposes of this analysis in determining opening sizes. These constraints are based on the typical industry maximum velocities found in *Subsurface Ventilation and Environmental Engineering* (McPherson 1993, Table 9.1, p. 295). This assumption will not be considered TBV since the air velocity constraints only affect the size of the support openings and do not affect the total area required for emplacement of the specified WP inventories.

This assumption is used throughout Attachment IV.

Table 16. Air Velocity Constraints

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

Source: McPherson 1993, p. 295, Table 9.1

5.2.7.5 Human Access In The Exhaust Main

It is assumed that human access will be required in the Exhaust Main in order to service ventilation controls and monitoring equipment located at the bottom of the ventilation raises. This assumption will not be considered TBV since the function of the support openings does not affect the total area required for emplacement of the specified WP inventories. This assumption is used in Section 6.2.4 and Attachment IV, Section IV.3.

5.2.7.6 Ventilation Stopping

It is assumed that a typical mine stopping, a physical barrier used for separating ventilation airflow is approximately 0.2 meters thick. This mine stopping is typical for the mining industry (Hartman et al. 1997, p. 463) where permanent or long-term control of airflow is required. This assumption will not be considered TBV as the use and function of the stopping does not affect the total area required for emplacement of the specified WP inventories.

This assumption is used to provide a thickness for the partition wall in the Exhaust Main as discussed in Attachment IV, Section IV.3.

5.2.7.7 Invert Area For Ventilation Openings

It is assumed that the inverts for all 7.62-meter diameter excavations will be the same as the invert for the ramps and mains. This invert design has a larger cross-sectional area than the other, as outlined in Table 17, and will bound the maximum airflow volume in the drift. This assumption will not be considered TBV since the fixtures within the support openings do not affect the total area required for emplacement of the specified WP inventories.

This assumption is used in Attachment IV, Section IV.3.

Table 17. Invert Areas

Invert Type	Cross-Sectional Area (m^2)	Reference Source
Exhaust Main	0.603	CRWMS M&O 1999f, pp. 31 and 32
Ramps and Mains	1.73	CRWMS M&O 1999f, pp. 27 and 28

5.2.7.8 Intake Shaft Accesses

It is assumed that the intake shafts are connected to the East and West Mains by a shaft access to support the overall ventilation system. This allows supply intake air to be distributed to both the East and West Mains and, subsequently, to the emplacement drifts. This assumption will not be considered TBV since the configuration of these support openings does not affect the total area required for emplacement of the specified WP inventories.

This assumption is used in Attachment IV, Section IV.1.

5.2.7.9 Exhaust Shaft Accesses

It is assumed that the exhaust shafts that are utilized to their full capacity will be connected to the Exhaust Main with two access drifts. These two exhaust shaft access drifts will aid in minimizing the size of the accesses and help maximize the airflow volume supplied to the exhaust shaft. This assumption will not be considered TBV since the configuration of these support openings does not affect the total area required for emplacement of the specified WP inventories.

This assumption is used in Attachment IV, Sections IV.4.2 and IV.5.2.

5.2.7.10 Ventilation Raises

It is assumed that the ventilation raises that support the Subsurface Ventilation System are excavated at 2 meters in diameter. This ventilation raise size is based on the *Repository Subsurface Layout Configuration Analysis* (CRWMS M&O 1997a, p. 78) and is still applicable to the current concept of the subsurface layout. This assumption does not impact the design of the emplacement area and therefore will not be designated as TBV.

This assumption is used in Section 6.2.4.

5.2.7.11 Shaft Sumps

It is assumed that all ventilation shafts will be excavated with a 5-meter deep sump at the bottom. The sump provides a place for water entering the Subsurface Facility to collect for subsequent pumping to surface. This assumption does not impact the design of the emplacement area and, therefore, will not be considered TBV.

This assumption is used in Sections 6.3.2.3, 6.3.2.4, 6.3.2.5, 6.4.2.3, 6.4.2.4, and 6.4.2.5.

5.2.7.12 Ambient Air Temperature Entering Emplacement Drift

An ambient air temperature of 25 degrees Celsius entering the emplacement drift is assumed. This air temperature was the basis of the calculations for the thermal analysis (CRWMS M&O 1999g, Table I-14, p. I-18). This assumption does not impact the design of the emplacement area and, therefore, will not be considered TBV.

This assumption is used in Attachment IV, Section IV.2.

6. ANALYSIS/MODEL

This analysis develops the overall subsurface layout and identifies design and operational interfaces for the Subsurface Facility. This section of the analysis reviews and demonstrates the incorporation of factors influencing the repository layout, such as design criteria, geological constraints, and the incorporation of existing facilities.

A planning layout is developed in Section 6.2 consistent with the usable three-dimensional spatial boundaries within the geology of Yucca Mountain incorporating the ESF (see Section 4.1.5.1), at the primary area elevation. The planning layout was then used as a basis to determine specific layouts for the capacity scenarios as discussed in Sections 6.3 and 6.4.

6.1 DESIGN METHODOLOGY

The design of the planning layout and, subsequently, the 70,000 MTU and 97,000 MTU layouts (if authorized) were developed using the VULCAN v3.4 software (see Section 3). The geological model for Yucca Mountain, the Geologic Framework Model 3.1, as documented in the *Determination of Available Repository Siting Volume within the Characterized Area for Site Recommendation* (see Section 4.1.1) was used as input into VULCAN v3.4. Using the geological model as a basis, the planning layout was developed in three dimensions using the centerlines of the excavations (CRWMS M&O 2000aa). The Geologic Framework Model 3.1 was developed for this type of design application. The development of the planning layout was based on the inputs listed in Section 4 and the assumptions listed in Section 5, as described in Section 6.2. VULCAN v3.4 was used throughout this analysis to extract information such as the geological information of the proposed repository openings (see Section 6.2.2) and the excavation quantities specified in Sections 6.3 and 6.4. The subsurface layouts, for both the planning layout (see Section 6.2) and the lower block (see Section 6.5.1) are contained in ".dxf" files in the Records Processing Center (CRWMS M&O 2000aa and CRWMS M&O 2000bb).

6.2 DEVELOPMENT OF THE PLANNING LAYOUT

The approach to developing the conceptual design for SR was to evaluate the available three-dimensional volume within the repository host horizon (RHH) at the primary area elevation. This approach to the conceptual design positions the emplacement area within the RHH, at the primary area elevation and utilizes the geology of the area while maintaining all geologic constraints. The geologic constraints are discussed in more detail in Section 6.2.2.

The planning layout was also developed with an emplacement area sufficient to accommodate the 70,000 MTU WP inventory, with the capability of supporting a 97,000 MTU WP inventory, if it is authorized (see Section 4.2.1.1).

A description of the planning layout and a discussion of influencing factors that affect the Subsurface Facility are discussed in the following sections.

6.2.1 Layout Description

The planning layout consists of various types of openings with different functions and design considerations. The following sections provide a description of the planning layout, as it was developed three-dimensionally in VULCAN v3.4. For reference, the planning layout is illustrated in Figure 3 and details of the heading lengths and gradients are detailed in Attachment II.

6.2.1.1 Ramps and Mains

The ESF opening is located such that it can become an integral part of the Subsurface Facilities (see Section 4.1.5.1). The ramps in the ESF provide access to the specified available site volume at gradients that accommodate rail transportation (see Section 4.2.4.2), where the North Ramp is at an approximate grade of –2.15 percent and the South Ramp is at an approximate grade of -2.62 percent. The available site volume is discussed further in Section 6.2.2.

The entire main drift of the ESF lies within the available site volume. It is situated near the upper bound of the available site volume and provides the eastern boundary for the planning layout. It thereby becomes the East Main in the planning layout, as illustrated in Figure 3. The ESF main drift, with a gradient of +1.35 percent to the north, is within the gradient requirements for accommodating rail transportation (see Section 4.2.4.2).

The ESF opening was excavated with a TBM to a diameter of 7.62 meters in accordance with the *Exploratory Studies Facility Design Requirement* (see Section 4.1.8). This opening size should be sufficient to allow waste emplacement operations and have the allowance necessary for ground control installation, variations in tunnel dimensions and alignment and tunnel deformations (see Section 4.2.4.3). However, an evaluation of the equipment envelope will require an analysis of the impacts of all aspects of the construction and emplacement operations. The perimeter mains for the planning layout will also be excavated with a TBM to a diameter of 7.62 meters (see Section 5.2.7.2) to provide integration of the ESF openings with the Subsurface Facility design.

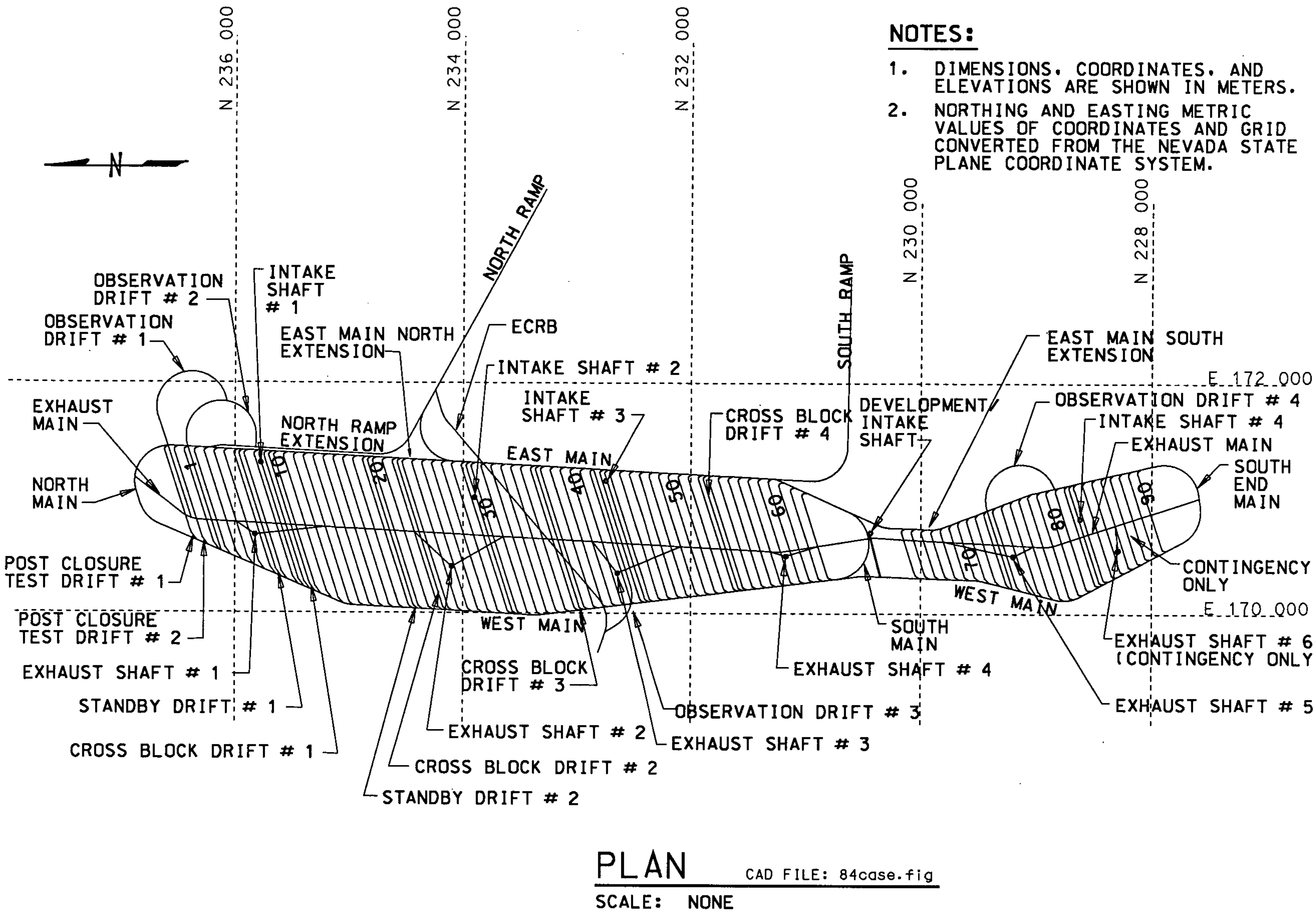


Figure 3. Subsurface Facility Planning Layout

The outermost boundaries of potential repository block to the north, south and west were established by locating the perimeter mains of the repository block within the limits of the three-dimensional spatial boundary as established by VULCAN v3.4, while maximizing the emplacement area within the defined block, as illustrated in Figure 3. The East and West Mains, including the East Main North and South Extensions will be used primarily for waste emplacement operations as access to the emplacement drifts. As such, the West Main has been oriented with respect to the East Main and the East Main extensions to support waste emplacement and potential retrieval operations (see Section 4.2.4.7).

The North, South, and South End Mains have been configured between the East and West Mains in order to provide access from one side of the repository block to the other. This type of access across the repository block will provide flexibility of movement for the WP transporter during waste emplacement operations.

A North Ramp Extension is provided to the north end of the repository block as a bypass from the North Ramp to allow concurrent waste emplacement operations and continued Subsurface Facility development. Concurrent emplacement and development operations are further discussed in Section 6.2.9.1. The extension to the north end of the planning layout is parallel to the East Main Extension with a centerline-to-centerline plan distance of approximately 24.5 meters between the openings. This pillar size is in excess of the assumed stable pillar size of three diameters from centerline-to-centerline (see Section 5.2.5).

The perimeter mains have also been configured such that any opening curvature radius within the mains and any transition from main to main are 305 meters. This opening radius dictates the curvature radius of the tracks and allows integration of the emplacement and retrieval equipment (see Section 4.2.4.11).

The Exhaust Main is required to receive the airflow from the subsurface openings and direct that flow to the surface via the exhaust shafts. It is situated below the repository elevation and extends from the north end of the block to the extreme south end. A minimum pillar of 10 meters is allowed between the Exhaust Main and the overlying openings. This pillar allowance is assumed to provide stability of the ground left between the Exhaust Main and the other repository openings (see Section 5.2.5). The Exhaust Main is graded in the vicinity of the South Main to allow intersection of the two headings and to provide accesses into the Exhaust Main from the South Main. The gradients in all sections of the Exhaust Main are less than 2.5 percent to allow rail transportation within the opening (see Section 4.2.4.2). The configuration and design concepts for the Exhaust Main are discussed further in Section 6.2.4.

6.2.1.2 Emplacement Area

The emplacement drifts will be excavated between the East Main and the West Main. This configuration will allow access into the emplacement drifts from either side during emplacement operations. The drifts will be excavated with an azimuth of 252 degrees; the preferred drift orientation (CRWMS M&O 1999d, p. 26) in order to position the emplacement drifts at least 30 degrees from the dominant joint orientations of the RHH (see Section 4.2.1.7).

The emplacement drifts will be excavated with a nominal diameter of 5.5 meters as required (see Section 4.2.1.3). The emplacement drifts are to be spaced at 81 meters center-to-center (see Section 4.2.1.5). This arrangement allows drainage of thermally mobilized water between the emplacement drifts and increases the independence of the individual emplacement drifts. With this drift spacing, the planning layout can accommodate 92 drifts in the primary area. These drifts provide approximately 86,777 meters of available emplacement drift, excluding the two Test and Evaluation postclosure test drifts as shown in Attachment I, Table I-1. The Test and Evaluation Facilities, including the use of the first two drifts in the emplacement area, are discussed in Section 6.2.1.3.

The emplacement area in the planning layout is bounded by a set of coordinates that represent the theoretically last emplaced WP in the drift. The last emplaced WP in the emplacement drift is assumed to be 1.5 meters from the start of the emplacement drift (see Section 5.2.3). A list of these boundary coordinates for the emplacement area is located in Attachment V.

Acreage Available in the Planning Layout–The total emplacement drift length and the drift spacing can be used to calculate the total available acreage in the planning layout.

$$\text{Acreage} = \frac{L_a \text{ (meters)} \times \text{DS (meters)}}{43{,}560 \ \text{ft}^2/\text{acre}} \times \frac{1}{0.0929 \ \text{m}^2/\text{ft}^2}$$

Where:
L_a = available emplacement drift length (meters) and
DS = drift spacing (meters).

When:
L_a = 86,777 meters (see Attachment I, Table I-1) and
DS = 81.0 meters (see Section 4.2.1.5),

$$\text{Acreage} = \frac{86{,}777 \text{ meters} \times 81 \text{ meters}}{43{,}560 \ \text{ft}^2/\text{acre}} \times \frac{1}{0.0929 \ \text{m}^2/\text{ft}^2}$$

$$\text{Acreage} = 1{,}736.9 \text{ acres}$$

The Subsurface Facility planning layout with 90 emplacement drifts, excluding the two Test and Evaluation postclosure test drifts, has approximately 1,737 acres available within the primary area.

Emplacement Drift Turnouts–A transition from the East and West Mains into the emplacement drifts is required to support emplacement operations and accommodate the waste emplacement equipment. The emplacement drift turnouts will function as this transition from the Mains into the emplacement drifts and support activities such as the TBM launch for emplacement drift excavation and WP transporter unloading and transfer of the WPs to the emplacement gantry.

The configuration of the turnout requires the integration of a number of activities and operations, and a discussion of these factors is necessary. For reference, a typical turnout is illustrated in

Figure 4. The entrance to the turnout must provide for a stable intersection with the main. It is assumed that a 30-degree approach angle from the main into the turnout, along with a minimum pillar thickness of 4 meters at the nose of the pillar, will provide the required stability (see Section 5.2.3).

One of the functions of the turnout is to aid in reducing the radiation levels in the East and West Mains. The direct line of radiation, the line-of-sight from the last emplaced WP in the emplacement drift, can increase the radiation levels in the East and West Mains. The theoretically last emplaced WP in the emplacement drift is assumed to be 1.5 meters from the start of the emplacement drift (see Section 5.2.3) and the projection of the direct line of radiation from this last WP will have a minimum assumed standoff distance of 4.5 meters from the nose of the pillar (see Section 5.2.3). This is assumed to be sufficient to prevent the direct line of radiation from entering the mains. Radiological safety is further discussed in Section 6.2.7.

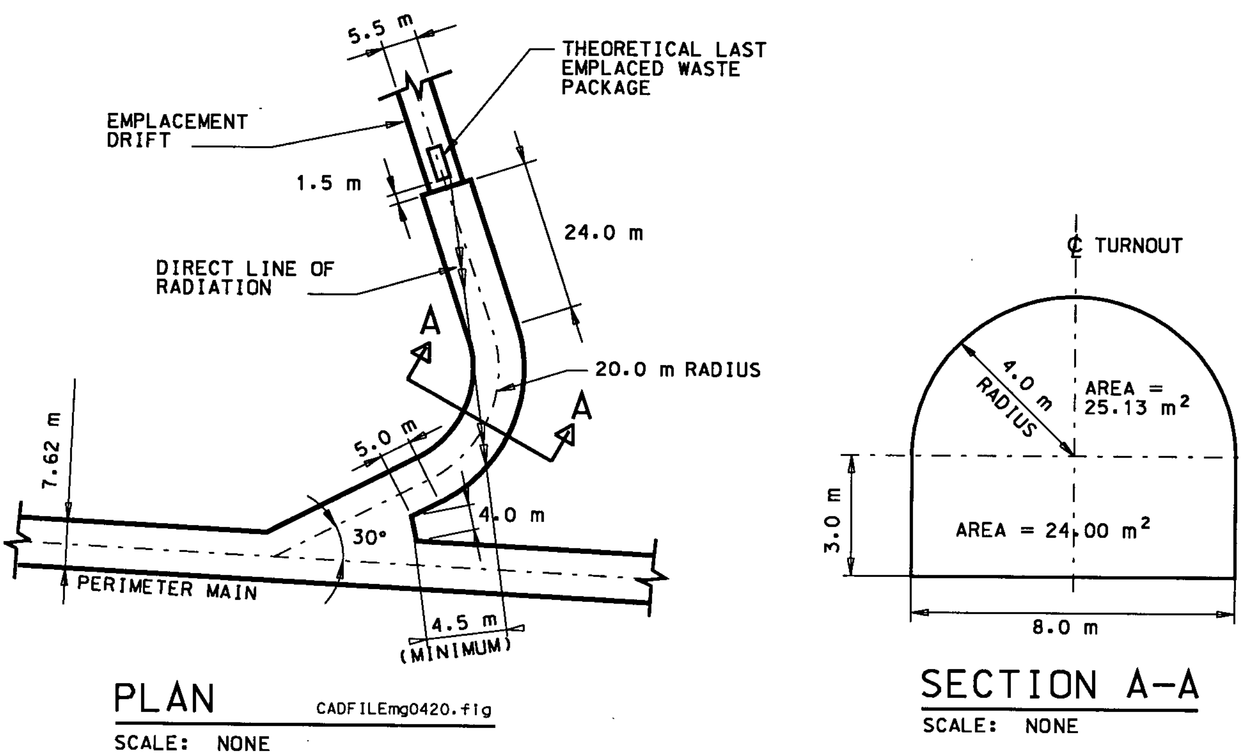


Figure 4. Typical Turnout Configuration

The emplacement drift turnout must also accommodate the placement and offsets of doors at the entrance of the emplacement drift (see Section 5.1.2). These doors are necessary to restrict personnel access to emplacement drifts after WPs have been emplaced and to limit radiation exposure in the turnouts and mains. The turnouts have been configured to allow installation of two sets of doors if required. A two-door system has the potential to provide ventilation flow control through the turnout and into the emplacement drift, since the doors can act as an airlock. The first door will be located at the entrance to the turnout. It is assumed that a minimum straight portion of 5 meters from the nose of the pillar to the curved section of the turnout will be required to accommodate installation of the door (see Section 5.2.3). An allowance has also been made for installation of a second door at the entrance to the emplacement drift.

The emplacement drift turnout must also accommodate the WP transporter. A number of parameters within the turnout must be set by the physical constraints of the WP transporter. The curvature radius within the turnout is 20 meters to accommodate the minimum radius which the transporter can negotiate (see Sections 4.2.4.11). A difference in elevation of 0.8 meters between the interface of the bottom of the turnout and the bottom of the emplacement drift has also been used. This elevation step is required for interfacing with the transporter design for unloading the WP (see Section 4.2.4.10). In addition, a straight portion beyond the curve of the turnout must be incorporated to ensure adequate allowance for the WP transporter to dock and unload the WP. It is assumed that a straight portion of 24 meters is adequate (see Section 5.2.3) for these purposes.

The profile of the emplacement drift turnout is 8 meters wide with an arch from spring-line to spring-line, and 7 meters high at the crown as illustrated in Figure 4 (see Section 5.2.3).

The length of the turnout depends on the change in azimuth between the centerline of the perimeter main and the centerline of the emplacement drift. As the angle between the main and the emplacement drift gets larger, the turnout length increases. The lengths of the turnouts are discussed further in Sections 6.3.2.2 and 6.4.2.2. The variances in the turnout gradients change with the turnout length, but are configured such that any water encountered within the turnout will drain out to the main. The overall drainage scheme for the planning layout is further discussed in Section 6.2.5.

Standby and Cross-Block Drifts–It is assumed that a number of drifts excavated in the pillar of adjacent emplacement drifts will be left empty during emplacement operations (see Section 5.2.1). These drifts will serve two purposes. First, the cross-block drifts will be left empty to facilitate ventilation, emergency egress, and possibly to assist in the Test and Evaluation program. The cross-block drifts will also be one of the paths for cool, fresh air to get to the Exhaust Main service side (see Section 6.2.4). The Test and Evaluation program may also use the cross-block drifts to monitor the adjacent emplacement drifts. The cross-block drifts are located between Emplacement Drifts 9 and 10, Emplacement Drifts 22 and 23, Emplacement Drifts 36 and 37 and Emplacement Drifts 53 and 54.

The standby drifts will be left empty for temporary relocation of WPs, if necessary. If, for some reason, the WPs must be removed from a loaded emplacement drift, the standby drifts will serve as receiving locations instead of removing the WPs back to the surface. Relocated WPs can remain in the standby drifts on a temporary basis and must moved to a permanent location, depending on the situation that caused the relocation. The standby drifts are located between Emplacement Drifts 6 and 7 and Emplacement Drifts 19 and 20.

6.2.1.3 Test and Evaluation Program

A Test and Evaluation program will be required within the Subsurface Facility (see Section 4.2.1.8). This Test and Evaluation program, part of the Performance Confirmation Plan will operate during both Construction and the Development to confirm that the design objective, the long-term isolation of waste in the Subsurface Facility, is accomplished. The Test and Evaluation program will require a number of facilities for performance monitoring, postclosure simulations, and specialized test areas. The location of the Test and Evaluation Facilities within the planning layout is illustrated in Figure 3. Only major facilities (ODs and test drifts) are shown. Smaller facilities, such as alcoves, are not designed at this time.

The performance monitoring facility will require a minimum of three monitoring areas with one OD and a minimum of six alcoves for each area (see Section 4.2.1.8).

Four performance monitoring ODs will be located within the primary area. The first performance monitoring OD is located between Drifts 3 and 4 of the planning layout (see Figure 3). The ECRB can be established as an integral part of the Test and Evaluation program and will be used as the second performance monitoring OD. The ECRB is located above the potential repository horizon at a location that provides access to the central area of the emplacement area for the Test and Evaluation Program alcoves (see Section 4.1.5.2). The ECRB will provide access to the third performance monitoring OD located between Drifts 44 and 45. The fourth performance monitoring OD will be placed between Drifts 75 and 76 of the planning layout.

These performance monitoring ODs are located above the repository horizon to provide access for monitoring of preclosure conditions in the near-field environment. Along with each of the ODs, a number of testing alcoves will be required. The locations of these alcoves will be specified in future analyses.

A postclosure simulation facility will be located within the primary area (see Section 4.2.1.8). The first two drifts within the emplacement block will be designated as the two simulation drifts. The postclosure simulation drifts need to be a minimum of 600 meters in length to provide for two segment tests (see Section 4.2.1.8), therefore, only the east side of the reserved drifts will be used. An OD to monitor the postclosure simulation drifts is located between the drifts below the repository horizon. Along with the ODs, a number of testing alcoves will be required. The locations of these alcoves will be specified in future analyses.

Additional specialized test areas will be required within the Subsurface Facility (see Section 4.2.1.8). These test areas include seepage measurement alcoves, seismic monitoring alcoves, ramp-seal test alcoves, and shaft-seal test alcoves. These specialized alcoves will require specific testing locations that will provide the varying conditions needed for the test. The location of these alcoves does not affect the conceptual Subsurface Facility layout and will be addressed in future analyses.

6.2.2 Geological Constraints

The geology dictates the siting and configuration of the potential repository. The site geology defines the physical three-dimensional spatial boundaries of the Subsurface Facility and the available repository siting volume has been identified in *Determination of Available Repository Siting Volume within the Characterized Area for Site Recommendation* (see Section 4.1.1). The geological model developed in this report was used as input to VULCAN v3.4. The software was then used to extract geologic information with respect to the planning layout from the *Subsurface Facility Planning Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000aa).

As shown in Figure 5, the planning layout is located such that the closest edge of the emplacement drifts are placed a minimum of 160 meters from the top of the present day water table (see Section 4.2.2.4). This allowance assists both the engineered and natural barriers to work in combination to limit the possible annual dose released from the repository by providing a standoff from the water table. In addition, the emplacement area is located at least 200 meters below the directly overlying ground surface (see Section 4.2.2.9). The identified limits for repository siting include limiting the emplacement areas to within the characterized area, locating the emplacement level at least 200 meters below the directly overlying ground surface (see Section 4.2.2.9), and providing minimum standoffs from the top of the groundwater table and the main trace of Type I faults (see Section 4.2.2.4). The identification and classification of Type I faults are discussed in more detail in Section 6.2.2.1.

The geologic boundaries as they relate to the planning layout in a plan view are shown in Figure 5. The figure shows a visual representation of where the groundwater table and overburden contour limit the extent of the planning layout. The figure also shows a representation, as depicted by VULCAN v3.4, of the rock units in which the three-dimensional planning layout will be situated.

The repository footprint is located entirely within the lower part of the TSw1 unit and the entire TSw2 unit of the characterized area (see Section 4.2.2.8). The excavation percentages of the potential repository in each of the geologic rock units are listed in Table 18. The tptpll rock unit is the lower lithophysal zone of the crystal-poor Topopah Spring Tuff, the tptpln rock unit is the lower nonlithophysal zone of the crystal-poor Topopah Spring Tuff, and the tptpmn rock unit is the middle lithophysal zone of the crystal-poor Topopah Spring Tuff. These excavation volumes were extracted from *Subsurface Facility Planning Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000aa) using VULCAN v3.4 and the percentages were then calculated.

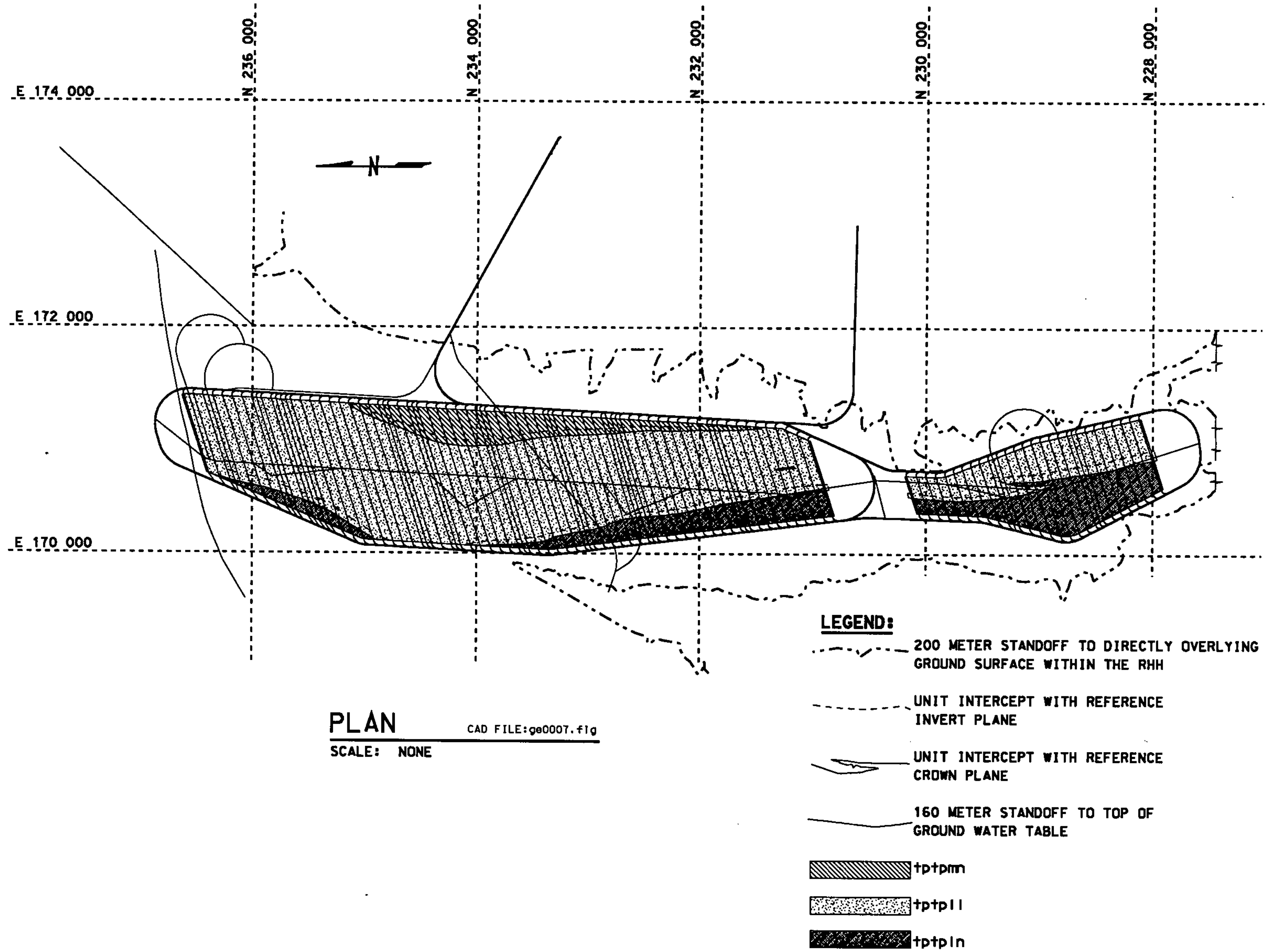


Figure 5. Planning Layout with Geologic Boundaries

Table 18. Percentage of Excavation in Various Rock Units

Area	Percent Excavation in Geologic Unit							
	tptpmn		tptpll		tptpln		Total	
	Volume (m³)	%	Volume (m³)	%	Volume (m³)	%	Volume (m³)	%
Emplacement Drifts 1 through 58	2,562,522	8.5	24,268,439	80.4	3,345,030	11.1	30,175,991	100.0
Emplacement Drifts 1 through 63	2,562,522	8.0	25,406,877	79.6	3,935,238	12.3	31,904,638	99.9[a]
Emplacement Drifts 64 through 90		0.0	3,419,377	46.2	3,984,786	53.8	7,404,163	100.0
Total Primary Area	2,562,522	6.5	28,826,255	73.3	7,920,025	20.1	39,308,801	99.9[a]

[a] Does not total 100 percent due to rounding.

6.2.2.1 Faults

The report NUREG-1451, *Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository* (McConnell et al. 1992, p. 5) defines Type I faults as

> "Faults or fault zones that are subject to displacement and of sufficient length and located such that they may affect repository design and/or performance. As such, they should be investigated in detail. Only faults that are determined to be Type I are of regulatory concern, because it is those faults, both inside and outside the controlled area, that may require consideration in repository design, or could have an effect on repository performance, or could provide significant input into models used to assess repository performance."

Fault displacement hazard results have indicated two sites, Bow Ridge and Solitario Canyon, that have a higher hazard of fault displacement, as indicated in Table 19 (CRWMS M&O 1998b, pp. 4-7 to 4-9).

Table 19. Calculated Fault Displacements

Fault	Displacement for 10^{-4} Annual Probability	Displacement for 10^{-5} Annual Probability	Type I Fault
Bow Ridge	< 1 cm	12 cm	Yes
Solitario Canyon	< 1 cm	30 cm	Yes
Drill Hole Wash	< 1 cm	< 1 cm	No
Ghost Dance	< 1 cm	< 1 cm	No
Sundance	< 1 cm	< 1 cm	No

Source: CRWMS M&O 1998b, pp. 4-7 to 4-9

The only Type I fault identified in the immediate area of the repository is the Solitario Canyon fault, which defines the western edge of the repository, using a 60-meter standoff (see Section 4.2.2.4). The Bow Ridge Fault is not in the immediate area of the repository and, therefore, will not impact the subsurface layout. Although Ghost Dance Fault and Abandoned Wash Fault are in the vicinity of the Subsurface Facility, these faults have not been identified as Type I faults. Since the faults in the vicinity of the repository have not been classified as Type I, geologic standoff-distances to emplaced WPs (see Section 4.2.2.5) will not be required. Figure 6 identifies the faults, located in the vicinity of the repository block, and their relative locations to the repository blocks as depicted by VULCAN v3.4.

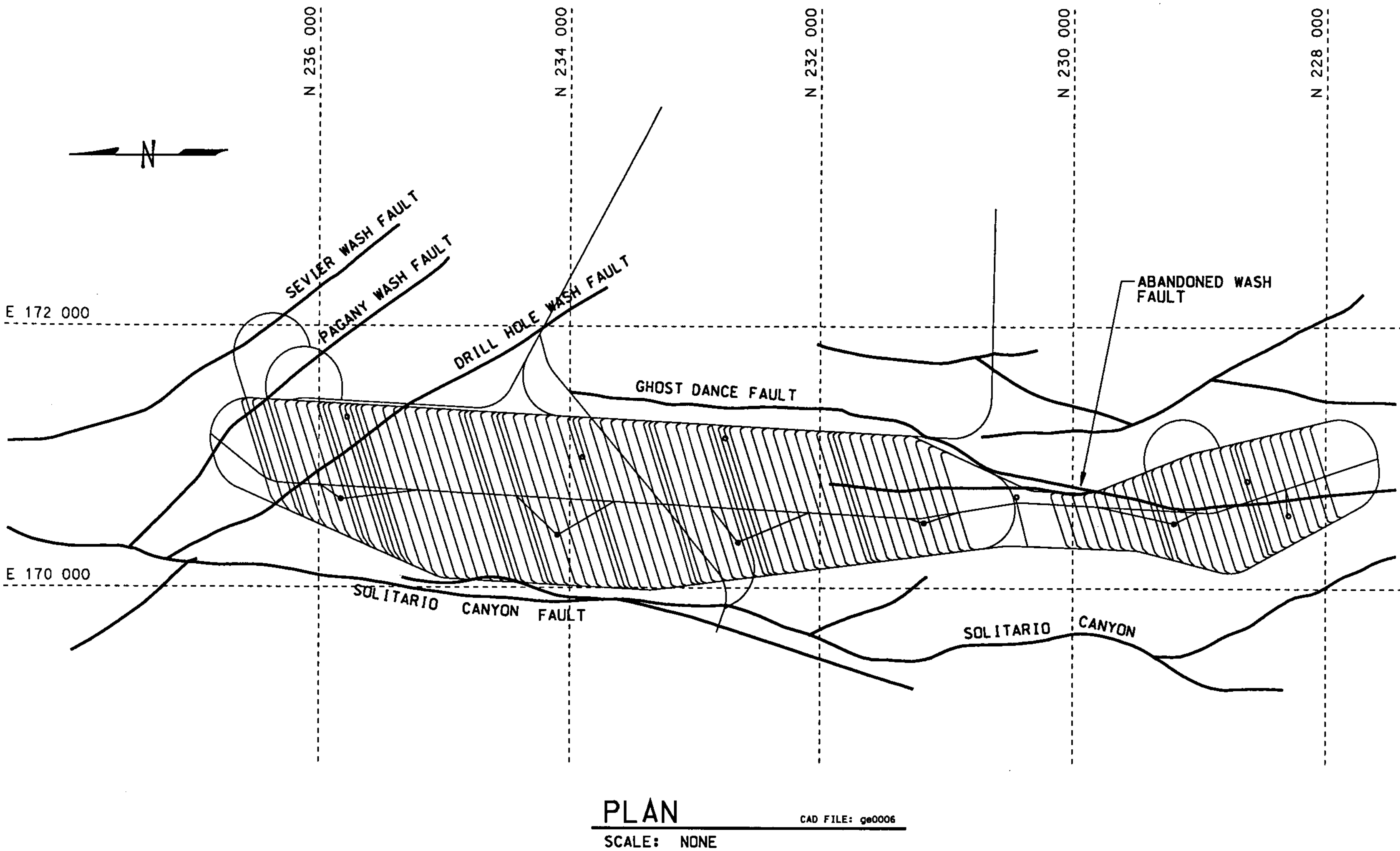


Figure 6. Geologic Faults Locations

6.2.2.2 Rock Mass Jointing

Rock mass joints are natural occurring fractures that are usually planar and frequently occur in parallel sets. Joint planes introduce a strong directional weakness that increases the potential for the formation of blocky ground and, therefore, the orientation of the joint sets is important to drift stability. It has been determined that the emplacement drifts should be oriented at least 30 degrees from dominant joint orientations (see Section 4.2.1.7). Based on the dominant joint orientation and a minimum offset criterion of 30 degrees between the joint strike and drift orientation, a reorientation of the emplacement drifts to an azimuth of 252 degrees was suggested in *TBV-361 Resolution Analysis: Emplacement Drift Orientation* (see Section 6.2.1.2). This emplacement drift orientation will be used in the configuration of the Subsurface Facility as shown in the planning layout (see Figure 3).

6.2.3 Thermal Design and Operational Interface

The thermal design of the emplacement drifts interfaces with the Subsurface Facility and Subsurface Ventilation Systems. The spacing and location of emplaced WPs and the control of heat from the WPs are aspects of the thermal loading performance. The following sections outline the thermal modeling and analysis supporting the Subsurface Facility and Subsurface Ventilation Systems.

6.2.3.1 Assumptions Used to Describe the Thermal Model

The *ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study* (CRWMS M&O 1999g, p. 19) used several assumptions that formed the basis for that calculation and are important to be recognized in the discussion of the thermal strategy for this document.

The ANSYS assumptions include the following:

- Emplacement drifts are located in the Tptpll geologic unit
- Spacing between the WPs is 10 centimeters
- Waste inventory is loaded into all of the emplacement drifts simultaneously
- Initial heat load is generated from the total inventory
- Representative emplacement drift in the model is 600 meters in length.

It was assumed that the waste inventory is emplaced in 24 years and is followed by an additional 26 years of preclosure ventilation. This results in closure at 50 years, after initial waste emplacement.

6.2.3.2 Average Thermal Load

The repository emplacement drift average thermal load is calculated based on a 10-centimeter spacing between the WPs as specified by the criterion for the WP spacing (see Section 4.2.1.4). The heat output for the 70,000 MTU and 97,000 MTU inventories have been calculated using input from Section 4.1.3 and are shown in Table 20. The total heat outputs for each inventory was calculated by determining the heat outputs associated with each WP type (i.e., multiply the WP quantity by the heat output per WP for each WP type) and then the individual heat outputs per WP type were summed. The 70,000 MTU waste inventory applies 79,772.46 kW (see Table 20) of heat over 56,222 meters (see Section 6.3.1) of emplacement drift for an average thermal load of 1.42 kW/m to the repository emplacement drifts. The 97,000 MTU waste inventory applies 105,5883.61 kW (see Table 20) of heat over 74,214.2 meters (see Section 6.4.1) of emplacement drift for an average thermal load of 1.43 kW/m to the repository emplacement drifts. An average thermal load of 1.45 kW/m was selected to bound the 1.42 kW/m for the 70,000 MTU case and the 1.43 kW/m for the 97,000 MTU case. This bounding value of 1.45 kW/m satisfies the requirement for a maximum linear heat load of 1.5 kW/m (see Section 4.2.1.4).

Table 20. Heat Output Calculations

WP Description		Heat Output per WP (kW)	70,000 MTU Inventory		97,000 MTU Inventory	
			WP Quantities	Heat Output (kW)	WP Quantities	Heat Output (kW)
21 PWR	Absorber Plates	11.330	4,299	48,707.67	5,690	64,467.70
21 PWR	Control Rods	3.260	95	309.70	106	345.56
12 PWR	Absorber Plates Long	8.970	163	1,462.11	293	2,628.21
44 BWR	Absorber Plates	7.000	2,831	19,817.00	3,732	26,124.00
24 BWR	Absorber Plates	0.540	84	45.36	98	52.92
5 IPWF		2.450	95	232.75	127	311.15
5 DHLW Short/1 DOE SNF Short		2.575	1,052	2,708.90	1,403	3,612.73
5 DHLW Long/1 DOE SNF Long		2.575	1,406	3,620.45	1,874	4,825.55
2 MCO/2 DHLW Short		1.230	149	183.27	199	244.77
5 HLW Long/1 DSNF Short		2.575	126	324.45	167	430.03
HLW Long Only		2.450	584	1,430.80	780	1,911.00
Naval	Short	3.100	200	620.00	200	620.00
Naval	Long	3.100	100	310.00	100	310.00
TOTALS			11,184	79,772.46	14,769	105,883.62

Note: WP heat outputs and inventories are documented in Section 4.1.3

6.2.3.3 Maximum Thermal Output of a Waste Package

In the designated waste inventory, the 21 PWR absorber plate WP has the highest average WP heat output of 11.330 kW (see Section 4.1.3). The maximum WP thermal output is restricted to 11.8 kW at the time of emplacement (see Section 4.2.4.14). The WP inventory and WP loading must be controlled to produce a maximum thermal output of 11.330 kW + 0.47 kW to stay within the design criterion.

6.2.3.4 Heat Removal by the Ventilation System

The MGR ventilation system must remove 70 percent of the heat generated by the waste during the preclosure period (see Section 4.2.4.15). The preclosure period is described as closing as early as 30 years after emplacement of the last WP (see Section 4.2.4.13).

The rate of heat removed by the ventilation system must be calculated for both a ventilation period of 50 years and 30 years of continuous ventilation. These calculations will represent the heat removal rates for the first and last emplacement drifts respectively.

Table 21 outlines the summary of the heat removal rates calculated for a 600 meter long emplacement drift with a continuous ventilation rate of 15 m^3/s. Table 22 outlines the calculations of the heat generated from the WPs in an emplacement drift. Table 23 outlines the calculation of the heat removed by the ventilation system.

Table 21. Summary of Heat Removal Rates

Time After Emplm't, Year	Heat Removal Rate (q-rm) in Individual Segment, kW						Total Rate of Heat Removal from 600m drift (kW)
	0 - 100 m	100 - 200 m	200 - 300 m	300 - 400 m	400 - 500 m	500 - 600 m	
	[a]	[b]	[c]	[d]	[e]	[f]	[g=a+b+c+d+e+f]
0							0.00
0.0001	56.31	56.31	56.31	56.31	56.31	56.31	337.86
1	92.16	77.08	64.46	53.91	45.09	37.71	370.41
5	105.36	98.79	91.64	84.27	76.92	69.78	526.76
10	98.55	96.11	93.22	89.85	86.07	82.00	545.80
15	90.35	88.78	87.13	85.32	83.30	81.13	516.01
20	83.04	81.78	80.50	79.18	77.77	76.34	478.61
26	76.22	75.22	74.21	73.16	72.07	70.98	441.86
30	70.66	69.77	68.87	67.96	67.04	66.11	410.41
40	64.13	63.62	63.03	62.42	61.76	61.09	376.05
50	55.97	55.95	55.82	55.63	55.40	55.09	333.86

Source: Heat Removal Rates from Section 4.1.6.1

Table 22. Heat Generated from WPs in an Emplacement Drift

Time Step, Year	Thermal Decay (%)	Rate of Heat Generation (kW/m)	Rate of Heat Generation (kW/600m)	Average Rate of Heat Generation (kW/600m)	Heat (Energy) Generation (GJ/600m)
	[h]	[i]	[j = 600 x i]	[k] average [j] over time	[l = [k]*([Current Time Step]-[Previous Time Step]) *[365*24*3,600 seconds/year]
0	100	1.5473	928.38		
0.01	100	1.5473	928.38	928.38	2.93
1	96.99	1.5008	900.48	914.43	28,834.58
5	87.93	1.3605	816.30	858.39	108,280.75
10	79.35	1.2278	736.68	776.49	122,436.94
15	72.23	1.1177	670.62	703.65	110,951.53
20	66.23	1.0248	614.88	642.75	101,348.82
26	59.89	0.9412	564.72	589.8	111,599.60
30	56.11	0.8682	520.92	542.82	68,473.49
40	48.24	0.7464	447.84	484.38	152,754.08
50	41.94	0.6490	389.40	418.62	132,016.00

Source: Thermal Decay and Rate of Heat Generation from Section 4.1.6.1

Table 23. Heat Removed by the Ventilation System

Time Step, Year	Total Rate of Heat Removal from 600m drift (kW)	Average Rate of Heat Removal (kW)	Heat (Energy) Removal (GJ/600m)
	[g] see Table 21	[m] average [g] over time	[n] [m]*([Current Time Step]-[Previous Time Step])*[365*24*3,600 seconds/year]
0	0.00	0.00	
0.0001	337.86	168.93	0.53
1	370.41	354.14	11,167.04
5	526.76	448.59	56,586.94
10	545.80	536.28	84,560.63
15	516.01	530.91	83,713.89
20	478.61	497.31	78,415.84
26	441.86	460.24	87,084.77
30	410.41	426.14	53,755.00
40	376.05	393.23	124,009.01
50	333.86	354.96	111,940.19

The total heat generated by the WPs is 651,928.64 GJ and 936,698.72 GJ for 30 years and 50 years of continuous ventilation respectively. The total heat removed by the ventilation system is 455,284.64 GJ and 691,233.84 GJ for 30 years and 50 years of continuous ventilation respectively.

The heat removal percentage is calculated as the heat removed by the ventilation system divided by the heat generated from the WPs, then this ratio is multiplied by 100. This results in a heat removal percentage of 70 percent and 74 percent for 30 years and 50 years of continuous ventilation respectively. This indicates that the first emplacement drift will receive approximately 74 percent heat removal and the last emplacement drift will receive approximately 70 percent heat removal. The overall repository average heat removal percentage can then be calculated as 72 percent, which satisfies the criterion stating the ventilation system must remove 70 percent of the heat generated by the waste with a preclosure period of 50 years.

6.2.3.5 Preclosure Maximum Drift Wall Temperature

The design of the emplacement drift system must limit the emplacement drift wall temperature to 96 degrees Celsius or less during the preclosure period (see Section 4.2.4.17). The peak drift wall temperature during preclosure, with 15 m^3/s airflow rate, is 79 degrees Celsius at a thermal loading of 1.4 kW/m. With a 1.6 kW/m thermal load, the peak drift wall temperature is 87 degrees Celsius (CRWMS M&O 1999g, Table 6-2, p. 38) as documented in Section 4.1.6.2. Since a thermal load of 1.45 kW/m for emplacement drifts is bounded by these limits, this shows that the criterion of the preclosure drift wall temperature not exceeding 96 degrees Celsius can be met.

6.2.3.6 Postclosure Maximum Drift Wall Temperature Goal

The performance goal for the postclosure emplacement drift wall temperature (see Section 4.2.4.19) states that the emplacement drift wall temperature should remain below 96 degrees Celsius following repository closure, based on nominal/expected values of repository closure. Figure 7 illustrates the drift wall temperature with respect to years of continuous ventilation for the 1.4 kW/m thermal load case with 70 percent heat removal (CRWMS M&O 1999g, Table 6-3, p. 39) as documented in Section 4.1.6.2. The SR design with a thermal load of 1.45 kW/m would result in a higher drift wall temperature than that for a thermal loading of 1.4 kW/m. This would indicate that the post closure drift wall temperature would remain at 96 degrees Celsius with approximately 175 years of continuous ventilation. The current design indicates a preclosure period of 50 years, and therefore this goal has not been achieved.

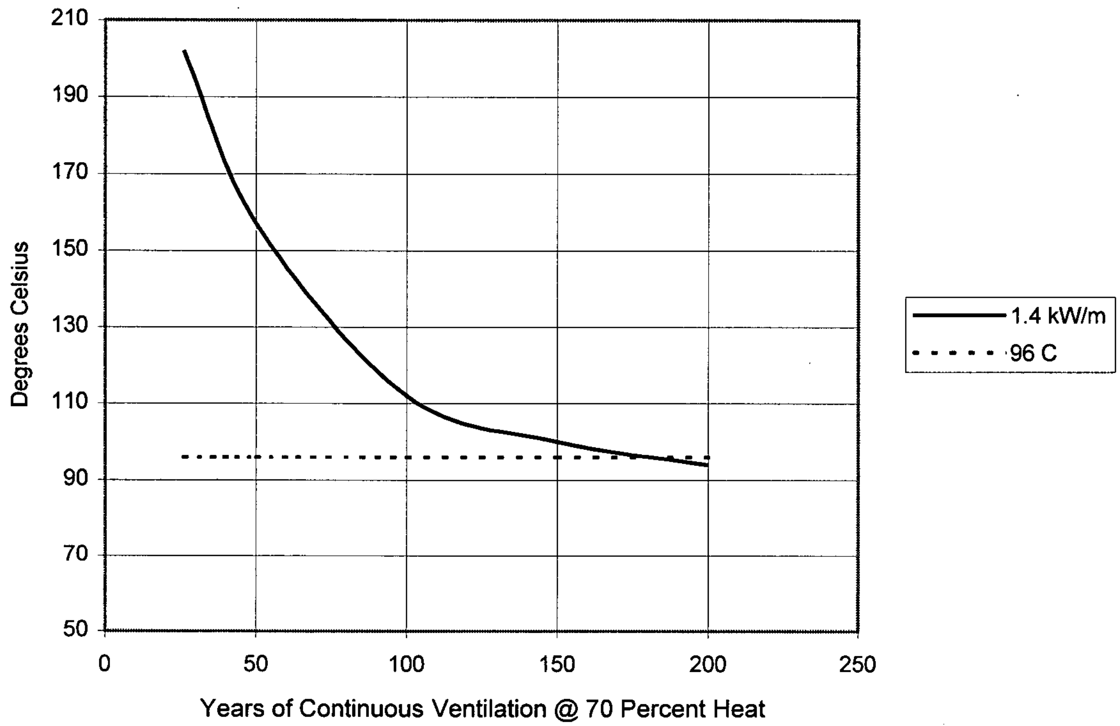


Figure 7. Peak Drift Wall Temperature With Respect to Continuous Ventilation

6.2.3.7 Postclosure Maximum Quarter Pillar Temperature

During the postclosure period, the temperature of 50 percent of the pillar width must be limited to less than or equal to 96 degrees Celsius (see Section 4.2.4.18). The 50-percent pillar width can be described in the following manner. Given that the emplacement drift diameter is nominally 5.5 meters (see Section 4.2.1.3) and the nominal emplacement drift spacing is 81 meters (see Section 4.2.1.5), it follows that the pillar width is 75.5 meters. Therefore, one-half of the pillar width, the area of interest, is 37.75 meters. This area is located in the center portion of the pillar. As a result, the radial distance from the emplacement drift wall to the ¼ pillar interface is 18.9 meters. Information generated using NUFT 3.0 shows that the ¼ pillar temperature remains below 96 degrees Celsius for the 1.45 kW/m thermal load with 15 years of continuous ventilation (see Section 4.1.6.4) and, therefore, the criterion can be satisfied.

6.2.3.8 Postclosure Maximum Drift Wall Temperature

The maximum allowable drift wall temperature for the postclosure period is not to exceed 200 degrees Celsius (see Section 4.2.4.10). The input transmittal *Postclosure Peak Drift Wall Temperatures*, as documented in Section 4.1.6.3, shows that the peak drift wall temperature would be approximately 193 degrees Celsius for closure after 30 years of continuous preclosure ventilation in the 1.45 kW/m thermal load and 70 percent of the WP heat removed case. The criterion for keeping the drift wall temperature below 200 degrees Celsius during the postclosure period is satisfied.

6.2.3.9 Not Used

6.2.3.10 Thermal Load on Geologic Units

The temperature of the zeolite layers, located 170 meters or further beneath the emplacement area horizon, is not to exceed 90 degrees Celsius (see Section 4.2.4.4). In addition, the temperature of the PTn geologic unit is required to be less than 96 degrees Celsius (see Section 4.2.4.6). Using the information from the *ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study* (CRWMS M&O 1999g, Table 6-3, p. 39) as documented in Section 4.1.6.2, a trend can be established to evaluate these requirements.

The most extreme rock temperatures modeled for removal of 70 percent of the heat generated by the waste is within the pillar of adjacent emplacement drifts and the maximum temperatures occur at 26 years of continuous ventilation. For the 1.4 kW/m thermal load, the intercept values for the drift wall temperature are 202 degrees Celsius and at the drift wall; at 7.5 meters into the pillar, the temperature is 116 degrees Celsius; and at the mid-pillar distance of 40.5 meters, the temperature is 99 degrees Celsius. Similarly, for the 1.6 kW/m thermal load, the temperature values are 229, 130, and 107 degrees Celsius, respectively. Figure 8 shows the curve plot.

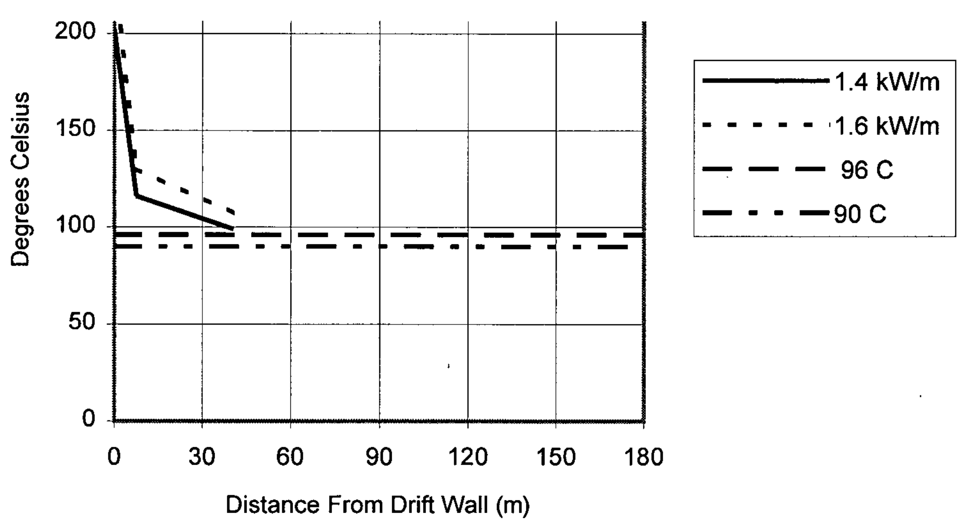


Figure 8. Peak Rock Temperature Gradient

By observation, the trend for the 1.4 kW/m thermal load indicates that the temperature gradient intersects the 96 degrees Celsius threshold at approximately 48 meters. Similarly, for the 1.6 kW/m thermal load, this distance is 57 meters. A thermal load of 1.45 kW/m for the emplacement drifts would be bounded by these limits. The PTn geologic unit is approximately 165 meters above the repository horizon (CRWMS M&O 1999g, Table 5-2, p. 22, Table 5-3, p. 23) as documented in Section 4.1.6.2. Therefore, the criterion of limiting the temperature to 96 degrees Celsius in the PTn geologic unit should be satisfied.

The same approach is applied to the zeolite layer using the same curve but examining the distances for a rock temperature of 90 degrees Celsius. By observation, the trends for 1.4 kW/m thermal load indicate that the temperature gradient crosses the 90 degrees Celsius threshold at approximately 57 meters. Similarly, for the 1.6 kW/m thermal load the distance is 68 meters. A thermal load of 1.45 kW/m for emplacement drifts would be bounded by these limits. Since the zeolite layer is located approximately 170 meters beneath the emplacement area horizon, the zeolite layer temperature should not exceed 90 degrees Celsius.

6.2.3.11 Permissible Temperature Change Below Soil Surface

The change in temperature, at 45 centimeters below the soil surface above the potential repository, is to be limited to 2 degrees Celsius above what was established as the naturally occurring pre-emplacement average annual ground surface temperature. Specifically, this is in the area directly above the emplaced WPs and extends 500 meters beyond the edge of the emplaced WPs (see Section 4.2.4.5). Analyses have not yet been completed that address this criterion.

6.2.3.12 TSw1 Thermomechanical Unit Differential Uplift

The MGR must be designed such that the differential uplift measured between the top of the TSw1 thermomechanical unit above the repository and the TSw1 thermomechanical unit at the preclosure controlled area boundary is less than 1 meter (see Section 4.2.4.8). It can be inferred, with reasonable confidence, that differential uplift in the TSw1 will be less than 1 meter. This is based on the *Repository Ground Support Analysis for Viability Assessment* study (CRWMS M&O 1998c). This analysis described the expected ground movement as a result of the 85 MTU/acre areal mass load for the Viability Assessment repository design. In the Viability Assessment repository design, the unsupported non-emplacement drift vertical deflection ranges from 3 mm to 10 mm and the maximum horizontal deflection is approximately 15 mm (see Section 4.1.6.5). Since the areal mass load of the SR repository design is significantly lower at approximately 56 MTU/acre (see Sections 6.3.1 and 6.4.1), it can be expected that the ground deflection will not exceed the differential uplift limit in the TSw1 geologic unit.

6.2.3.13 TSw1 Thermomechanical Unit Differential Uplift Rate

The system shall be designed such that the differential uplift measured between the ground surface above the repository and the ground surface at the preclosure controlled area boundary is less than 0.5 cm/year (see Section 4.2.4.21). Based on the discussion presented in

Section 6.2.3.12 it would be unlikely that this measurable uplift will be of concern, but further analyses will need to be completed for confirmation.

6.2.4 Ventilation Design and Operational Interface

The overall ventilation strategy dictates the ventilation airway sizes for the Subsurface Facility. This section will discuss the ventilation system interfaces with the subsurface layout as detailed in Attachment IV and addresses the interfacing criterion outlined in Section 4.2.4.1.

In order to support the 15 m^3/s (see Section 6.2.3.4) airflow volume to each emplacement drift split, four intake shafts (see Section IV.5.1), one Development/Intake Shaft (see Section IV.5.1), and six exhaust shafts (see Section IV.5.2) are required in the planning layout (see Figure 3). The intake shafts and the Development/Intake Shaft are required to supply ventilation air to the subsurface areas in addition to the air supplied by the North and South Ramps.

The intake shafts and exhaust shafts are located in the Emplacement Area within the pillar of adjacent emplacement drifts. The intake shafts are connected to the East and West Mains via an intake shaft access to distribute the ventilation air to each side of the emplacement drifts (see Section IV.1). The exhaust shafts are connected to the Exhaust Main via two exhaust shaft accesses (see Section IV.6). A Development/Intake Shaft is located in the vicinity of the South Main and is connected to the South Main and West Main via two access drifts. The shafts have been located at the coordinates listed in Table 24 such that the shaft collars are outside the probable maximum flood areas (see Section 4.2.2.3) and avoid steep terrain that would require extensive earth moving for pad and road construction. A more detailed shaft siting analysis may be required to confirm the shaft collar locations.

The shafts have been sized at an excavated diameter of 8 meters (see Attachment IV, Section IV.7) to accommodate the required airflow volumes for the subsurface operations. The repository ventilation system design will be addressed in other analyses.

Table 24. Shaft Coordinates

Description	Northing (m)	Easting (m)
Intake Shaft 1	235,775	171,300
Intake Shaft 2	233,900	171,000
Intake Shaft 3	232,750	171,150
Intake Shaft 4	228,625	170,825
Development/Intake Shaft	230,450	170,700
Exhaust Shaft 1	235,825	170,675
Exhaust Shaft 2	234,100	170,400
Exhaust Shaft 3	232,650	170,350
Exhaust Shaft 4	231,175	170,500
Exhaust Shaft 5	229,050	170,550
Exhaust Shaft 6	228,300	170,550

Ventilation raises located in the emplacement drifts, cross-block drifts, standby drifts, and Test and Evaluation Facility headings, will connect the headings to the Exhaust Main below the repository. A raise bore machine will be used to excavate the raises to a diameter of 2 meters (see Section 5.2.7.10) from the crown of the Exhaust Main to the upper headings. The raises serve as ventilation airways for emplacement operations and for Test and Evaluation Program activities.

The Exhaust Main can be partitioned in order to separate the heated exhaust air exiting the emplacement drifts from the cooler service air exiting from headings such as the Test and Evaluation Facilities, the standby drifts, and the cross-block drifts (see Attachment IV, Section IV.3). Since the WPs will only be temporarily located in the standby drifts, the exhaust air from these drifts will be lower than that of an emplacement drift This partitioning of the Exhaust Main may be necessary since it is assumed that personnel access will be required to service the ventilation controls (see Section 5.2.7.5) and the exhaust air exceeding 48 degrees Celsius needs to be isolated from areas requiring personnel access (see Section 4.2.4.12). One side of the Exhaust Main can accommodate the ventilation controls at the emplacement drift raises as well as exhausting the cooler service air. This side of the Exhaust Main is referred to as the service side. The other side of the Exhaust Main can exhaust the heated air exiting the emplacement drifts and the postclosure test drifts. This side of the Exhaust Main is referred to as the exhaust side.

6.2.4.1 Simultaneous Development and Emplacement Operations

For some period of time, the Subsurface Facility is concurrently developed while the emplacement operations are ongoing. The concept of ventilating both the development side and the emplacement side is similar to the concepts developed in the *Overall Development and Ventilation Systems* (CRWMS M&O 1997b, Sections 7.7 and 7.8) and is further discussed in this section as it applies to the planning layout.

The ventilation system during this overlap period will be composed of two separate systems: the development-side ventilation system and the emplacement-side ventilation system. An isolation barrier will physically separate the two systems. The development side ventilation system is a positive pressure system, where air is blown into the development side through the Development/Intake Shaft and from there, to the working areas. The development air is then exhausted out the South Ramp.

While development is on going, both the Development/Intake Shaft and the South Ramp will be required for the development ventilation system; these cannot be used by the emplacement-side ventilation system to supply air to the emplacement areas. The emplacement-side ventilation system is a negative pressure system, where the air is drawn into the emplacement side through the intake shafts and the North Ramp. The East and West Mains then distribute the air to the emplacement drifts from the main intake airways. The airflow in each emplacement drift travels from the East and West Mains to a central raise into the Exhaust Main, and from there, out to the exhaust shafts. On the development side, the fans are located at the intake (Development/Intake Shaft) and on the emplacement side, the fans are located at the exhaust (the exhaust shafts).

6.2.4.2 Emplacement Ventilation

The subsurface openings are configured in such a manner that the ventilation intake air enters an emplacement drift from two directions, referred to as drift splits, and exhausts through a ventilation raise into the Exhaust Main. The subsurface openings or headings requiring ventilation have been separated into drift splits as listed in Table 25.

Table 25. Drift Splits Requiring Ventilation

Heading Description	Number of Drift Splits	
	70,000 MTU Case	97,000 MTU Case
ECRB	2	2
Test and Evaluation Facility ODs	5	7
Standby Drifts	4	4
Cross-block Drifts	6	8
Test and Evaluation Facility Postclosure Test Drifts	2	2
Emplacement Drifts	104	160
Contingency	12	20

The emplacement intake air enters the Subsurface Facility through an intake shaft, or ramp and is split between two intake shaft accesses with a 7.62-meter excavated diameter (see Section IV.1). The intake air then splits into the East and West Mains and subsequently, a 15 m^3/s airflow volume (see Section 6.2.3.4) enters each emplacement drift from both the east side and west side. The emplacement drift airflow then exhausts through a ventilation raise into the Exhaust Main, with an excavated opening diameter of 7.62 meters (see Section IV.3). From the Exhaust Main, the air enters one of two exhaust shaft accesses with an opening profile of 8 meters wide by 8.5 meters high (see Section IV.6) and exits the Subsurface Facility through an exhaust shaft.

The detailed airflow distribution for the Subsurface Facility is further discussed in Attachment IV, Sections IV.4 and IV.5.

6.2.5 Drainage Control

A number of factors affecting the overall drainage pattern of the Subsurface Facility must be incorporated into the repository layout. These factors are:

- The ramps providing access to the Subsurface Facility must have an initial upward grade of at least one percent for at least the first 10 meters of the entranceway (see Section 4.2.1.6) to limit water inflow into the ramp and, subsequently, into the Subsurface Facility.

- The entrance to all surface openings to the Subsurface Facility must be located outside the probable maximum flood areas (see Section 4.2.2.3).

- The overall grading of the Subsurface Facility openings must provide drainage control such that any accumulation of water is away from the emplacement areas (see Section 4.2.2.7).

- Water entering the emplacement drifts will be allowed to drain directly into the surrounding host rock without having to drain along the drift for collection in a centralized area (see Section 5.1.4).

The first two requirements provide against the possibility of surface floodwater entering the Subsurface Facility. The existing North and South Ramps are the only ramp accesses to the Subsurface Facility. The South Ramp has been designed and excavated to provide a 2 percent gradient for a minimum of 10 meters (33 feet) inside the tunnel to preclude the introduction of Probable Maximum Flood storm water to the subsurface (CRWMS M&O 1996, p. I-3). The North Ramp starter tunnel, STA 00+00 to STA 00+60, as shown in Figure 1, has been excavated at a flat grade and a step up of 0.432 meters. Although the North Ramp starter tunnel does not physically have a minimum grade of one percent, the invert and finishing work in the tunnel can accommodate this requirement. The locations of the remaining surface openings, namely the ventilation shafts are discussed in Section 6.2.4.

The overall grading of the Subsurface Facility, excluding the emplacement drifts, diverts any water entering the Facility away from the emplacement drifts and to the shaft sumps for removal to the surface during preclosure, as shown in Figure 9. The gradients in all sections of the mains and ramps have also been configured to allow rail transportation within the opening (see Section 4.2.4.2). The actual grades within the subsurface openings are documented in Attachment II. The 0.8-meter step at the transition of the emplacement drift and the turnout (see Section 6.2.1.2) also prevents water inflow into the emplacement drifts.

The assumption for having water in the emplacement drifts drain directly into the host rock (see Section 5.1.4) indicates that the emplacement drifts are excavated at a zero percent gradient.

6.2.6 Surface-Based Boreholes

There are 15 surface-based boreholes in the vicinity of the planning layout (see Section 4.1.2 and Attachment III). The locations of the borehole collars are shown in Figure 10. The design of the layout must allow at least a 5-meter standoff from the edge of the WPs to the perpendicular projection of the centerline of a surface-based borehole if the borehole intercepts the drift or comes within 5 meters of the edge of the drift (see Section 4.2.2.6). In order to determine the perpendicular projection of the borehole at the repository elevation, deviation surveys for these boreholes are required. Since these deviation surveys are not available at this time, this requirement cannot be fully addressed in this analysis. The maximum impact this criterion could have on the emplacement area definition as outlined in this analysis is 150 meters (15 boreholes with 5 meter standoffs to two WPs) of unusable emplacement drift length that is currently included in the design. This equates to approximately 0.2 percent of the 86,777 meters (see Section 6.2.1.2) of available emplacement drift length in the planning layout (150 meters divided by 86,777 meters, multiplied by 100). Future analyses using the actual borehole deviation surveys will determine the actual impact of this criterion on the Subsurface Facility design.

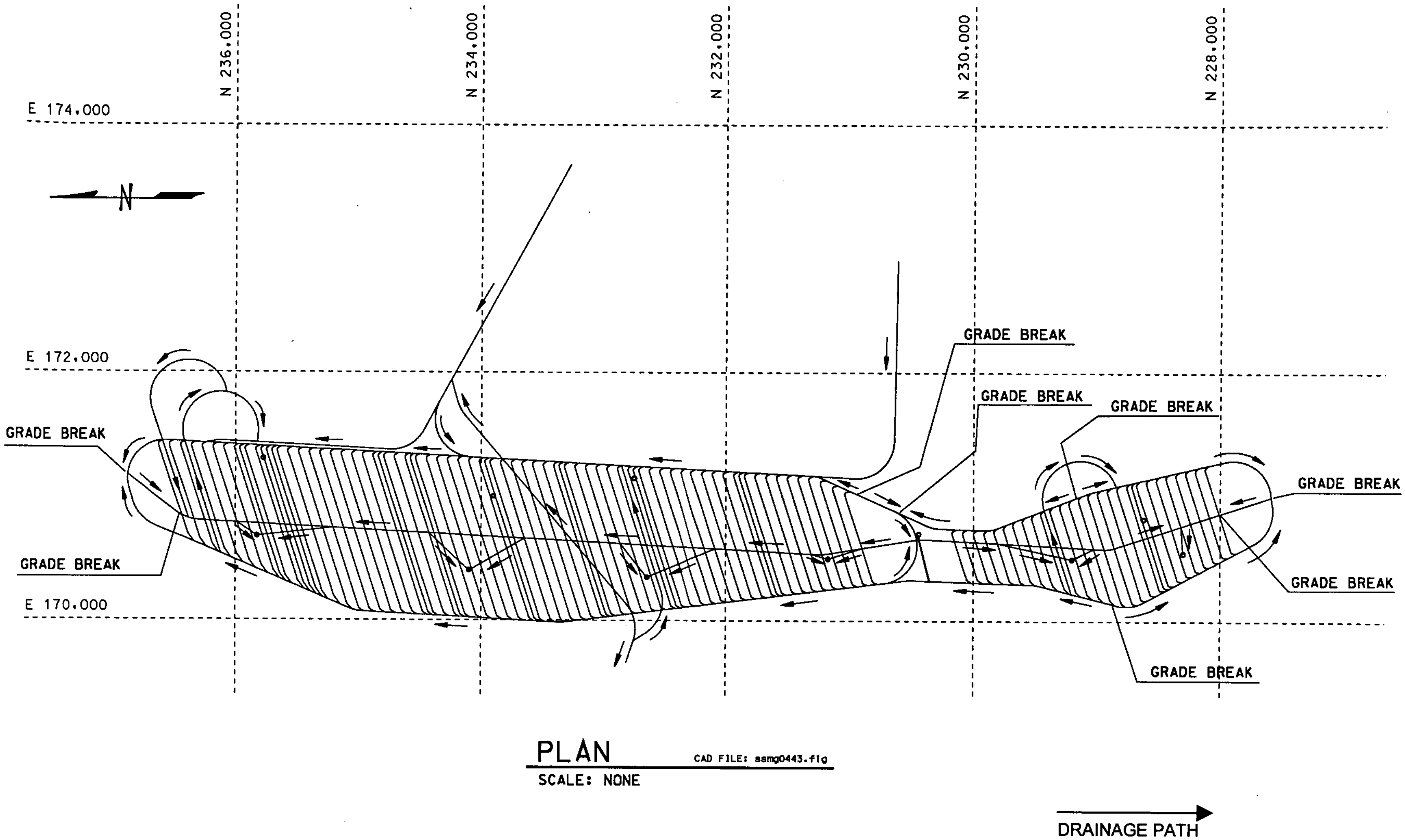


Figure 9. Overall Drainage Pattern

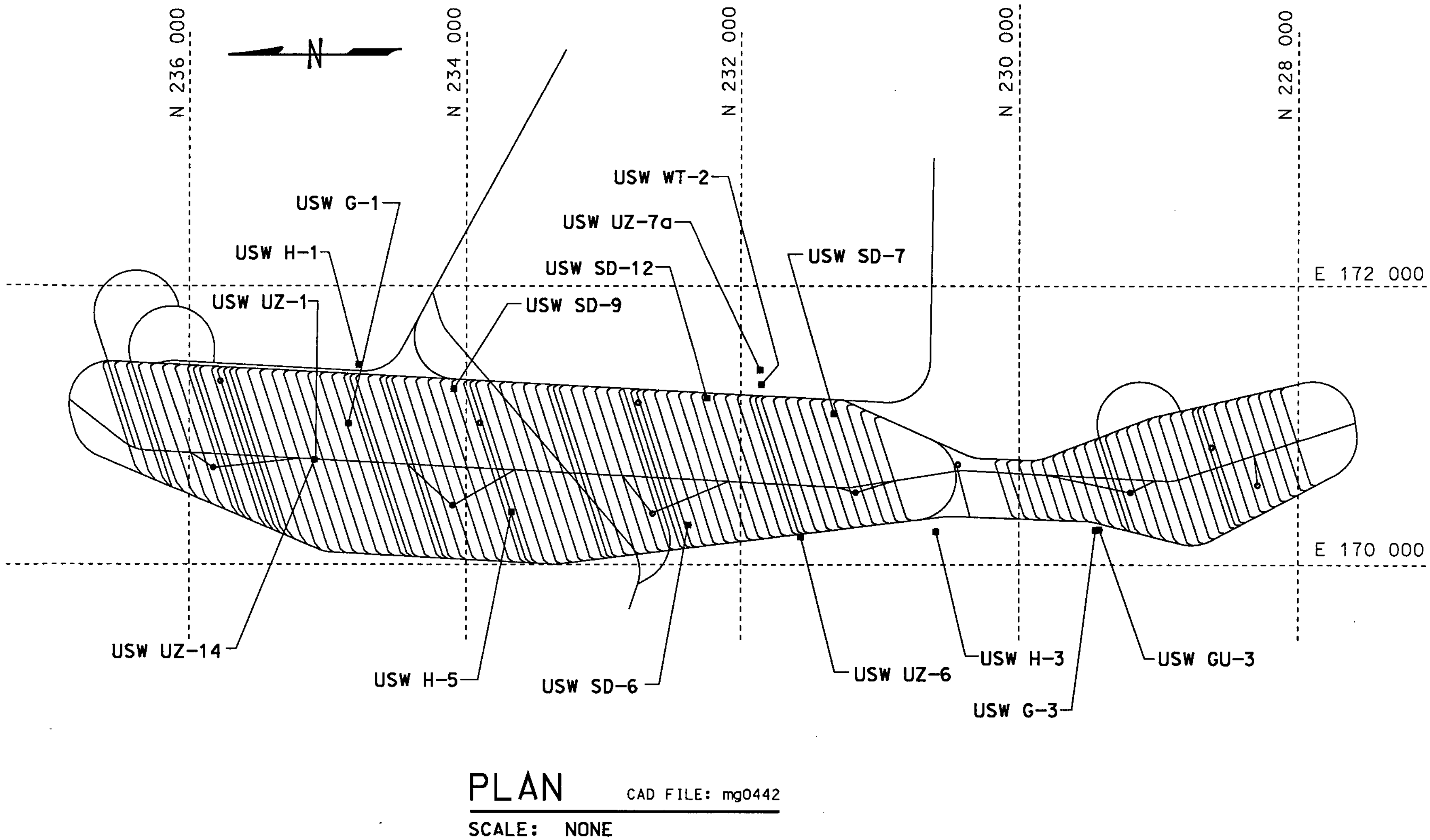


Figure 10. Site Characterization Boreholes

6.2.7 Radiological Safety

Radiological safety is one of the most important aspects of the repository and the MGR must comply with the applicable provisions of the "Standard for Protection Against Radiation" (10 CFR 20) (see Section 4.3.3). Since personnel will be frequently travelling in the mains, potential radiological exposure should be kept as low as reasonably achievable. Since individual WPs will not provide sufficient shielding for personnel protection (see Section 5.1.1), the turnouts have been configured to aid in increasing radiological protection in the mains. The turnout configuration has been designed to eliminate the direct line of radiation from entering the main (see Section 5.2.3). The length of the turnout also provides an increase in radiological protection, as distance is one of the best sources of protection. A typical turnout is illustrated in Figure 4, showing the design configuration and elimination of the direct line of radiation entering the main.

Emplacement drift doors are also located within the emplacement drift turnouts (see Section 5.1.2). These doors serve to limit personnel access to the emplacement drifts after waste has been emplaced in a drift. The placement of the doors in the emplacement drift turnout is discussed in more detail in Section 6.2.1.2.

The Exhaust Main is partitioned to separate the heated exhaust air exiting the emplacement drifts from the cooler service air exiting from headings such as the Test and Evaluation Facilities and the cross-block drifts (see Section 6.2.4). The ventilation controls from the emplacement drift ventilation raises are accessed through the service side of the Exhaust Main. This arrangement in the Exhaust Main serves to isolate personnel from the exhaust from the emplacement drifts.

Although the unrestricted radiation level (see Section 4.2.2.1) and the restricted-access radiation level (see Section 4.2.2.2) have not yet been determined and will be calculated in future analyses, it is not anticipated that these calculations will adversely impact the design of the Subsurface Facility.

6.2.8 Non-Nuclear Safety

The design, construction, and development of the Subsurface Facility is governed by two occupational health and safety standards, the "Occupational Safety and Health Standard" (29 CFR 1910) and the "Safety and Health Regulations for Construction" (29 CFR 1926); see Sections 4.3.1 and 4.3.2. The applicability of, and adherence to, these standards will be addressed in future analyses.

The layout of the Subsurface Facility is required to provide two or more separate, properly maintained escapeways to the surface from the lowest levels that are so positioned that damage to one escapeway will not lessen the effectiveness of the others (see Section 4.2.3.1). The existing North and South Ramps provide the minimum required escape routes from the primary area to the surface.

Within the Subsurface Facility, personnel refuge chambers will also be required (see Section 4.2.3.2). Personnel refuge chambers can serve multiple personnel functions other than emergency refuge, such as first aid stations, temporary offices, and lunchrooms. These personnel refuge chambers will be located at a maximum of 2,100 meters from an adjacent personnel refuge chamber or the nearest escapeway such that personnel can reach a refuge chamber within 30 minutes (see Section 4.2.3.3). The location and specifics of the personnel refuge chamber design and locations within the Subsurface Facility do not affect the design of the overall Subsurface Facility and will be addressed in future analyses.

6.2.9 Constructibility

The layout is influenced by practical limitations imposed by the operating requirements and performance characteristics of the equipment and methods selected for construction of the repository. The size, configuration, and operating requirements of the construction equipment will provide restrictions on the size and shape of the excavated openings and the general arrangements possible for the layout (see Section 4.2.4.9).

The construction methods and equipment, construction sequence, and equipment productivity must be considered to ensure the overall constructibility of the planned layout. The layout design seeks to minimize the number and size of the openings needed to accommodate waste emplacement operations and to utilize completed drifts in an efficient manner to help the construction process. This section discusses the planned construction approach and its influence on the repository layout.

The excavation methods for developing the Subsurface Facilities are outlined in the Summary of the Subsurface Excavation SDD (CRWMS M&O 1999e, p. 5). The excavation methods include mechanical excavation (using TBMs, roadheaders, raise-borers, and drills), although drilling and blasting methods may be used for special applications. The main ESF openings, the North Ramp, Main Drift, and South Ramp were excavated by a 7.62-meter diameter TBM (see Section 6.2.1). Similar methods will be used for repository construction and development, although drill and blast methods may be used. These methods will be strictly limited to areas where mechanical methods are clearly impractical. The majority of the repository openings will be excavated by TBM, which require long and relatively straight tunnels for efficient operation. Both the 7.62-meter and the 5.5-meter TBMs will be designed for transportation through completed tunnels.

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

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

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

6.2.9.1 Construction Sequence

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

The construction phase will include partial excavation of the mains on the north end of the repository block, excavation of the ventilation shafts required to support the first panel of several emplacement drifts and ventilation raises that will accommodate the initial emplacement requirements and support continued development. Isolation airlocks will be erected after the first panel of emplacement drifts is finished to allow simultaneous emplacement and development operations to proceed. Emplacement operations will use the first panel of emplacement drifts on the north side of the isolation airlocks while the next panel of emplacement drifts, ventilation raises and the supporting main drift excavation is under development on the south side of the airlocks. As a panel of emplacement drifts is completed, a new set of isolation airlocks will be erected, the completed panel turned over to emplacement operations, and the previous set of isolation airlocks dismantled. As each new panel is being developed, only sufficient excavation is completed to support turnover of the next emplacement panel. In this way, the Facility will be constructed in a manner that will permit construction in stages such that the maximum annual funding requirements could be reduced (see Section 5.1.3). This will also facilitate the start of operations concurrently with subsequent construction stages.

6.3 70,000 MTU LAYOUT DESCRIPTION

The MGR will be required to accept 70,000 MTHM or equivalent of SNF/HLW for disposal in the primary area of the repository (see Section 4.2.1.1). The 70,000 MTU Layout for SR is based on the planning layout as described in Section 6.2. For reference, the 70,000 MTU Layout for SR is illustrated in Figure 11.

The 70,000 MTU Layout for SR will occupy the emplacement area up to Emplacement Drift 58 on the planning layout, which extends from the extreme north of the repository block to the South Main. The required emplacement area calculations and details for the 70,000 MTU Layout can be found in Section 6.3.1. The main drift excavation for this layout includes the North Main, North Ramp Extension, East Main North Extension, and the South Main. The East Main South Extension, West Main, and Exhaust Main will only be excavated up to the South Main. Details of the main drifts and the design concepts have been outlined in Section 6.2.1.1.

The emplacement area will consist of 51 emplacement drifts for emplacement of the required WP inventory, with Emplacement Drift 52 being excavated to accommodate an excavation allowance to account for possible variances in the WP inventory (see Section 5.2.2). Also included in the layout is a contingency area. Emplacement drifts will only be excavated in this area if the intended emplacement area cannot be used due to unexpected ground conditions (see Section 5.2.2) or for larger waste stream variations. This contingency area consists of Emplacement Drifts 53 through 58. Details of the emplacement drifts and the design concepts have been outlined in Section 6.2.1.2.

The required emplacement length calculated to accommodate the WP inventory is 56,222 meters, which indicates approximately 1,125 acres at an areal mass loading (AML) of approximately 56 MTU/acre, as calculated in Section 6.3.1.

Within the emplacement area, five standby and cross-block drifts will be excavated in this scenario. The two standby drifts from the planning layout will be excavated between Emplacement Drifts 6 and 7 and between Emplacement Drifts 19 and 20. Only three of the cross-block drifts will be required, and located between Emplacement Drifts 9 and 10, between Emplacement Drifts 22 and 23, and between Emplacement Drifts 36 and 37, as shown in Figure 11. The details of the design concepts for the standby and cross-block drifts have been outlined in Section 6.2.1.2.

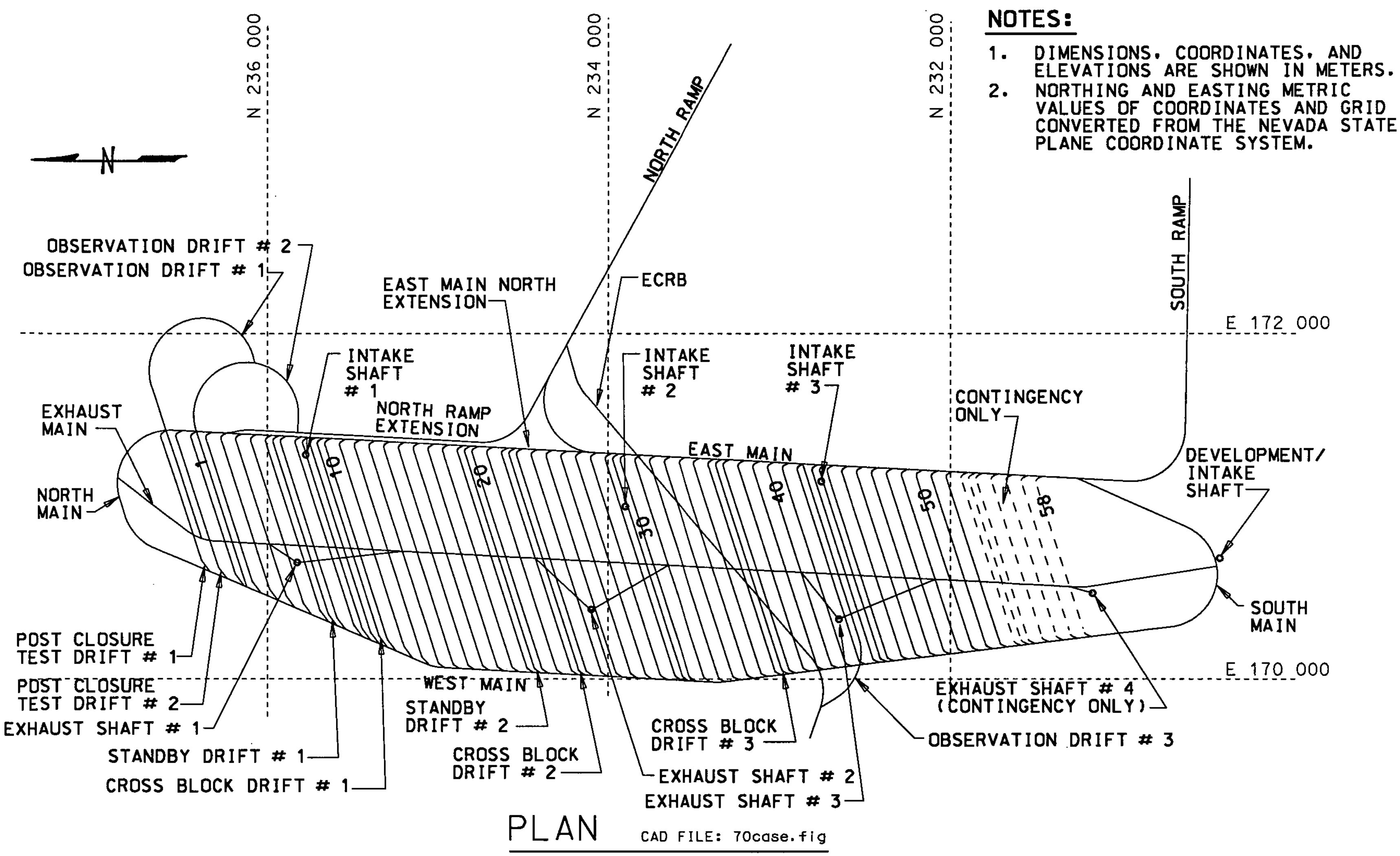


Figure 11. 70,000 MTU Layout for Site Recommendation

The Test and Evaluation Facility for the 70,000 MTU layout will consist of the postclosure test drifts on the north end of the repository with their ODs, and the performance monitoring Observation Drifts 2 and 3, along with the ECRB. Details and functions of the Test and Evaluation Facilities have been outlined in Section 6.2.1.3.

Three intake shafts are required to supply the necessary ventilation flow rates to the Subsurface Facility for the 70,000 MTU Case, in addition to the North and South Ramps (see Section 6.2.4). The locations of the intake shafts are listed in Table 26.

Table 26. Intake Shaft Locations for the 70,000 MTU Case

Intake Shaft Number	Northing (m)	Easting (m)
1	235,775	171,300
2	233,900	171,000
3	232,750	171,150

The Development Shaft, located in the vicinity of the South Main, provides intake airflow for the construction and development operations in the Subsurface Facility (see Section 6.2.4), and will not be required after construction is completed. The Development Shaft is located at 230,450 meters north and 170,700 meters east. Only Access 1 for the Development Shaft will need to be excavated in the 70,000 MTU layout since the second access as shown in the planning layout provides an airway into the West Main beyond the South Ramp, which is not required in this scenario.

Three exhaust shafts are required to exhaust emplacement side air from the Subsurface Facility for the 70,000 MTU Case (see Section 6.2.4). The locations of the exhaust shafts are listed in Table 27.

Table 27. Exhaust Shaft Locations for the 70,000 MTU Case

Exhaust Shaft Number	Northing (m)	Easting (m)
1	235,825	170,675
2	234,100	170,400
3	232,650	170,350
4 (Contingency Only)	231,175	170,500

Exhaust Shaft 4, considered as a contingency in the 70,000 MTU layout, will only be required in the event that excavation within the contingency area makes it necessary to support the additional ventilation capacity.

6.3.1 Emplacement Area Determination

The WP inventory for SR as listed in Table 2 (see Section 4.1.3) will be used for defining the emplacement area as opposed to the proposed WP characteristics presented in Section 4.2.1.2, since the values listed in Table 2 are the basis for the Technical Baseline (Stroupe 2000, Attachment 1, p. 1).

The WPs will be emplaced in a line-loaded configuration (see Section 4.2.1.4) and this will dictate the method of calculating the required emplacement length. The total length of the WPs is calculated by multiplying the total number of WPs with the weighted average WP length, shown in Table 28.

The WP total length is calculated by multiplying the total number of WPs (11,184) and the weighted average WP length (4.927 meters).

WP Total Length = 11,184 WPs × 4.927 meters per WP

WP Total Length = 55,103.6 meters

The total WP spacing is calculated by multiplying the total number of WPs (11,184) and the WP spacing of 0.1 meters (see Section 4.2.1.4).

Total WP Spacing = 11,184 WPs × 0.1 meters per WP
Total WP Spacing = 1,118.4 meters

The required emplacement length is calculated by adding the WP total length (55,103.6 meters) and the total WP spacing (1,118.4 meters) to get 56,222.0 meters.

Table 28. Total Length of Waste Packages for the 70,000 MTU Case

WP Description[a]		Number of WPs by WP Type[b]	WP Type Fraction of Total[c]	WP Outer Length (m)[d]	Contribution to Weighted Average WP Length (m)[e]
21 PWR	Absorber Plates	4,299	0.384	5.06	1.945
	Control Rods	95	0.008	5.06	0.043
12 PWR	Absorber Plates Long	163	0.015	5.54	0.081
44 BWR	Absorber Plates	2,831	0.253	5.06	1.281
24 BWR	Absorber Plates	84	0.008	5.00	0.038
5 IPWF		95	0.008	3.48	0.030
5 DHLW Short/1 DOE SNF Short		1,052	0.094	3.48	0.327
5 DHLW Long/1 DOE SNF Long		1,406	0.126	5.11	0.642
2 MCO/2 DHLW Short		149	0.013	5.11	0.068
5 HLW Long/1 DSNF Short		126	0.011	5.11	0.058
HLW Long Only		584	0.052	5.11	0.267
Naval	Short	200	0.018	5.32	0.095
	Long	100	0.009	5.96	0.053
TOTAL		11,184[f]	1.000		4.927[g]

Notes:
[a] WP descriptions defined in Section 4.1.3
[b] Number of WPs by WP type defined in Section 4.1.3
[c] WP fraction of total is calculated as the number of WPs, by WP Type, divided by the total number of WPs (see Note [f])
[d] Outer WP length defined in Section 4.1.3
[e] Contribution to weighted average WP length is calculated by multiplying the WP type fraction of total (see Note [c]) with the outer WP length (see Note [d])
[f] Total number of WPs is the summation of the number of WPs by WP type (see Note [b])
[g] Weighted average WP length is the summation of contributions to the weighted average WP length (see Note [e])

By examining the available area in the planning layout as outlined in Attachment I, Table I-1, it can be seen that 51 emplacement drifts, not including the 2 drifts for use as the postclosure simulation drifts (see Section 6.2.1.3), will be required for emplacement of 70,000 MTU of waste as illustrated in Figure 11.

Two percent of the required emplacement drift length will be excavated in addition to the required 51 emplacement drifts to ensure flexibility of the layout and to account for possible anomalies in the waste inventory (see Section 5.2.2). This excavation allowance equates to an additional 1,124.4 meters, for a total of 57,346.4 meters, and extends the excavation out to Emplacement Drift 52. This additional drift, although it will be excavated, will not be used for further emplacement area calculations.

A 10 percent contingency area (see Section 5.2.2) will be accommodated within the repository layout. The contingency is calculated as 10 percent of the required emplacement drift length, or an additional 5,622.2 meters. The contingency area will encompass emplacement drifts 53 through 58, for a total of 63,089.5 meters of available emplacement drift (see Attachment I).

The required emplacement drift length and the drift spacing can be used to calculate the total available acreage in the layout:

$$\text{Acreage} = \frac{L_r\,(\text{m}) \;\times\; DS\,(\text{m})}{43{,}560\ \text{ft}^2/\text{acre}} \times \frac{1}{0.0929\ \text{m}^2/\text{ft}^2}$$

Where: L_r = required emplacement drift length (m) and
DS = drift spacing (m).

When: L_r = 56,222.0 meters and
DS = 81.0 meters (see Section 4.2.1.5),

$$\text{Acreage} = \frac{56{,}222.0\ \text{meters} \;\times\; 81\ \text{meters}}{43{,}560\ \text{ft}^2/\text{acre}} \times \frac{1}{0.0929\ \text{m}^2/\text{ft}^2}$$

$$\text{Acreage} = 1{,}125.3\ \text{acres}$$

The layout supporting the 70,000 MTU will require approximately 1,125 acres to accommodate the waste inventory.

The AML is calculated with the amount of MTU from commercial SNF only. The AML of the repository layout can then be calculated as:

$$\text{AML} = \frac{\text{Commercial SNF (MTU)}}{\text{Acreage}}$$

Where: Commercial SNF = 63,000 MTU (see Section 4.2.1.1)
Acreage = 1,125 acres

$$\text{AML} = \frac{63{,}000\ \text{MTU}}{1{,}125\ \text{acres}}$$

$$\text{AML} = 56.0\ \text{MTU}/\text{acre}$$

The repository layout to support the 70,000 MTU waste stream has an AML of 56 MTU/acre.

The 70,000 MTU layout must also be evaluated with respect to the design basis WP inventory (see Section 4.2.1.1). This WP inventory represents "not to exceed" values for each WP category that applies to the capability of the subsurface emplacement. The required length of emplacement drift is calculated, based on these not to exceed values and compared to the planning layout discussed in Section 6.2. The total length of WPs is calculated by multiplying the total number of WPs with the WP length plus the gap length of 0.1 meters (see Section 4.2.1.4), as shown in Table 29.

Table 29. Required Emplacement Length for Design Basis Inventory

Type of WP	WP Length (m)	WP Length Plus Gap (m)	Quantity	Contribution to Required Emplacement Length (m)
21 PWR AP	5.06	5.16	4,500	23,220.0
21 PWR CR	5.06	5.16	100	516.0
12 PWR AP Long	5.54	5.64	170	958.8
44 BWR AP	5.06	5.16	3,000	15,480.0
24 BWR AP	5.00	5.10	90	459.0
5 IPWF	3.48	3.58	100	358.0
5 DHLW Short/1 DOE SNF Short	3.48	3.58	1,100	3,938.0
5 DHLW Long/1 DOE SNF Long	5.11	5.21	1,500	7,815.0
2 MCO/2 DHLW	5.11	5.21	160	833.6
5 HLW Long/1 DOE SNF Short	5.11	5.21	130	677.3
HLW Long Only	5.11	5.21	600	3,126.0
Naval Short	5.32	5.42	210	1,138.2
Naval Long	5.96	6.06	110	666.6
			11,770	59,186.5

By examining the available area within the planning layout as outlined in Attachment I, Table I-1, it can be seen that 54 emplacement drifts, not including the 2 drifts for use as the postclosure test drifts (see Section 6.2.1.3), will be required for emplacement of the "not to exceed" design basis inventory. This indicates that the subsurface facility is capable of accommodating the "not to exceed" design basis WP inventory.

6.3.2 Excavation Quantities

The excavation quantities were extracted from the *Subsurface Planning Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000aa) using VULCAN v3.4 for the various subsurface headings and will be discussed in the following sections.

The lengths of the headings are expressed in slope length. The slope length of a heading refers to the actual length excavated at the specified gradient of the heading.

The opening profile areas are outlined in Table 30. The circular openings have been calculated as πr^2, where r is the radius of the opening and π is defined as 3.14. The horseshoe profile openings have been calculated based on ½ the circular area for the top portion plus the rectangular area on the bottom portion.

Table 30. Excavated Opening Areas

Opening Profile	Opening Size (meters)				Area (m^2)	Comments
	Diameter	Radius	Width	Height		
Circular	7.62	3.81	--	--	45.60	
Circular	5.5	2.75	--	--	23.76	
Circular	8.0	4.0	--	--	50.27	
Circular	2.0	1.0	--	--	3.14	
Horseshoe	--	--	8.0	7.0	49.13	Refer to Figure 4 for profile details
Horseshoe	--	--	8.0	8.5	61.13	Refer to Attachment IV, Section IV.6 for profile details

6.3.2.1 Perimeter Mains and Exhaust Main

The perimeter mains and Exhaust Main are excavated at a diameter of 7.62 meters (see Section 6.2.1). The excavated cross-sectional area of these headings is 45.6 m^2. The lengths of the perimeter mains and the Exhaust Main, as well as the bank volumes, are outlined in Table 31.

Table 31. Excavation Quantities for the Main Drifts – 70,000 MTU Case

Heading Designation	Point Designations (see Attachment II)		Slope Length (m)	Shape of Opening	Profile (m)	Area (m^2)	Volume (m^3)
	From Point	To Point					
North Ramp			Existing	Circular	7.62	45.60	Existing
East Main			Existing	Circular	7.62	45.60	Existing
South Ramp			Existing	Circular	7.62	45.60	Existing
North Ramp Extension	36	2	2,003.7	Circular	7.62	45.60	91,368.7
East Main North Extension	1	3	2,500.0	Circular	7.62	45.60	114,000.0
North Main	3	7	1,256.8	Circular	7.62	45.60	57,310.1
West Main	7	15	5,744.6	Circular	7.62	45.60	261,953.8
South Main	15	18	793.4	Circular	7.62	45.60	36,179.0
Exhaust Main	5	16	6,542.2	Circular	7.62	45.60	298,324.3
East Main South Extension	28	20	689.7	Circular	7.62	45.60	31,450.3
Total			19,530.4				890,586.2

6.3.2.2 Emplacement Drifts

The emplacement drifts are excavated at a diameter of 5.5 meters (see Section 4.2.1.3). The excavated cross-sectional area of these heading is 23.76 m^2. The lengths of the emplacement drifts, as well as the bank volume, are outlined in Table 32.

The emplacement drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high, as previously illustrated in Figure 4. The cross-sectional area of the turnouts is 49.13 m^2 (see Figure 4). The lengths of the turnouts, as well as the bank volume, are outlined in Table 33.

Table 32. Excavation Quantities for Emplacement Drift – 70,000 MTU Case

Drift Number	Length (m)	Volume (m^3)
1	781.1	18,558.9
2	820.4	19,492.7
3	859.7	20,426.5
4	899.0	21,360.2
5	938.3	22,294.0
6	977.7	23,230.2
7	1,017.0	24,163.9
8	1,056.3	25,097.7
9	1,095.6	26,031.5
10	1,134.9	26,965.2
11	1,174.3	27,901.4
12	1,230.0	29,224.8
13	1,263.5	30,020.8
14	1,263.5	30,020.8
15	1,263.5	30,020.8
16	1,263.5	30,020.8
17	1,263.5	30,020.8
18	1,263.5	30,020.8
19	1,263.5	30,020.8
20	1,263.5	30,020.8
21	1,263.5	30,020.8
22	1,263.5	30,020.8
23	1,263.5	30,020.8
24	1,263.5	30,020.8
25	1,263.5	30,020.8
26	1,263.5	30,020.8
27	1,263.5	30,020.8
Subtotal	30,936.8	735,058.4

Drift Number	Length (m)	Volume (m^3)
28	1,263.5	30,020.8
29	1,263.5	30,020.8
30	1,263.5	30,020.8
31	1,263.5	30,020.8
32	1,263.8	30,027.9
33	1,248.5	29,664.4
34	1,233.1	29,298.5
35	1,217.8	28,934.9
36	1,202.4	28,569.0
37	1,187.1	28,205.5
38	1,171.7	27,839.6
39	1,156.4	27,476.1
40	1,141.1	27,112.5
41	1,125.7	26,746.6
42	1,110.4	26,383.1
43	1,095.0	26,017.2
44	1,079.7	25,653.7
45	1,064.3	25,287.8
46	1,049.0	24,924.2
47	1,033.6	24,558.3
48	1,018.3	24,194.8
49	1,002.9	23,828.9
50	987.6	23,465.4
51	972.2	23,099.5
52	956.9	22,735.9
Subtotal	28,371.5	674,106.8

Total Length 59,308.3 meters
Total Volume 1,409,165.2 m^3

Table 33. Excavation Quantities for Turnouts – 70,000 MTU Case

Turnout Description	Quantity	Centerline Length (m)	Total Length (m)	Excavation Volume (m^3)	Total Volume (m^3)
East Main Turnouts					
Turnouts 1 through 52	52	79.5	4,134.0	3,905.8	203,103.4
West Main Turnouts					
Turnouts 1 through 11	11	110.9	1,219.9	5,448.5	59,933.7
Turnout 12	1	93.2	93.2	4,578.9	4,578.9
Turnouts 13 through 31	19	75.6	1,436.4	3,714.2	70,570.3
Turnouts 32 through 52	21	72.9	1,530.9	3,581.6	75,213.1
Total	104		8,414.4		413,399.5

6.3.2.3 Intake Shafts

The intake shaft accesses will be excavated at a diameter of 7.62 meters (see Section 6.2.4), and a cross-sectional area of 45.60 m^2. The intake shaft access turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 8.5 meters high, similar to the exhaust shaft accesses (see Section 6.2.4), with a cross-sectional area of 61.13 m^2. The intake shafts will be excavated with a diameter of 8 meters (see Attachment IV), and a cross-sectional area of 50.27 m^2. The intake shafts will be excavated from the surface to the repository elevation, and will include a sump at the bottom, excavated 5 meters deep (see Section 5.2.7.11). The lengths of the intake shafts and the associated headings with the bank volume are outlined in Table 35 and Table 34.

Table 34. Excavation Quantities for Intake Shafts – 70,000 MTU Case

Shaft Number	Shaft Length (m)	Shaft Sump (m)	Shaft Volume (m^3)
1	386.4	5.0	19,675.7
2	321.9	5.0	16,433.3
3	275.4	5.0	14,095.7
Totals	983.7	15.0	50,204.6

Table 35. Excavation Quantities for Intake Shaft Accesses and Turnouts –70,000 MTU Case

Shaft Number	Access Length (m)	Volume (m^3)	East Turnout		West Turnout	
			Length (m)	Volume (m^3)	Length (m)	Volume (m^3)
1	1,076.0	49,065.6	79.5	4,859.8	75.6	4,621.4
2	1,263.5	57,615.6	79.5	4,859.8	75.6	4,621.4
3	1,087.3	49,580.9	79.5	4,859.8	72.9	4,456.4
Totals	3,426.8	156,262.1	238.5	14,579.5	224.1	13,699.2

6.3.2.4 Development/Intake Shaft

The Development/Intake Shaft Access 1 will be excavated with a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.2.4), with a cross-sectional area of 61.13 m^2. The Development Shaft will be excavated to a diameter of 8 meters (see Attachment IV), and a cross-sectional area of 50.27 m^2. The Development/Intake Shaft will be excavated from the surface to the repository elevation, and, includes a 5-meter deep sump at the bottom (see Section 5.2.7.11). The lengths of the Development Shaft and associated headings with the bank volume are outlined in Table 37 and Table 36.

Table 36. Excavation Quantities for Development Shaft – 70,000 MTU Case

Shaft Length (m)	Shaft Sump (m)	Shaft Volume (m^3)
282.7	5.0	14,462.7

Table 37. Excavation Quantities for Development Shaft Access – 70,000 MTU Case

Access Number	Access Length (m)	Volume (m^3)
1	16.9	1,033.1

6.3.2.5 Exhaust Shafts

The exhaust shaft accesses will be excavated with a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.2.4), with a cross-sectional area of 61.13 m^2. The exhaust shafts will be excavated to a diameter of 8 meters (see Attachment IV) and a cross-sectional area of 50.27 m^2. The exhaust shafts will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom (see Section 5.2.7.11). The lengths of the exhaust shafts and the associated headings, including the bank volume, are outlined in Table 39 and Table 38.

Table 38. Excavation Quantities for Exhaust Shafts – 70,000 MTU Case

Shaft Number	Shaft Length (m)	Shaft Sump (m)	Shaft Volume (m^3)
1	447.5	5.0	22,747.2
2	447.4	5.0	22,742.1
3	425.5	5.0	21,641.2
Total	1,320.4	15.0	67,130.6

Table 39. Excavation Quantities for Exhaust Shaft Accesses – 70,000 MTU Case

Shaft Number	Access #1 Length (m)	Access #1 Volume (m^3)	Access #2 Length (m)	Access #2 Volume (m^3)
1	194.8	11,908.1	621.8	38,010.6
2	445.1	27,209.0	522.6	31,946.5
3	346.8	21,199.9	607.2	37,118.1
Total	986.7	60,317.0	1,751.6	107,075.3

6.3.2.6 Emplacement Drift Ventilation Raises

The emplacement drift ventilation raises channel the exhaust air from the emplacement drifts to the Exhaust Main, service side where ductwork directs the air to the exhaust side (see Section 6.2.4). The raises will be excavated to a diameter of 2 meters (see Section 6.2.4) and a cross-sectional area of 3.14 m^2. The lengths of the ventilation raises, including the bank volume, are outlined in Table 40.

Table 40. Excavation Quantities for Ventilation Raises – 70,000 MTU Case

Drift Number	Length (m)	Volume (m^3)	Drift Number	Length (m)	Volume (m^3)
1	16.3	51.2	28	16.9	53.1
2	16.7	52.4	29	16.9	53.1
3	17.1	53.7	30	16.8	52.8
4	17.3	54.3	31	16.8	52.8
5	17.3	54.3	32	16.8	52.8
6	17.2	54.0	33	16.8	52.8
7	17.2	54.0	34	16.8	52.8
8	17.2	54.0	35	16.7	52.4
9	17.2	54.0	36	16.7	52.4
10	17.2	54.0	37	16.7	52.4
11	17.2	54.0	38	16.7	52.4
12	17.1	53.7	39	16.7	52.4
13	17.1	53.7	40	16.6	52.1
14	17.1	53.7	41	16.6	52.1
15	17.1	53.7	42	16.6	52.1
16	17.1	53.7	43	16.6	52.1
17	17.0	53.4	44	16.6	52.1
18	17.0	53.4	45	16.6	52.1
19	17.0	53.4	46	16.5	51.8
20	17.0	53.4	47	16.5	51.8
21	17.0	53.4	48	16.5	51.8
22	17.0	53.4	49	16.5	51.8
23	16.9	53.1	50	16.3	51.2
24	16.9	53.1	51	16.1	50.6
25	16.9	53.1	52	15.9	49.9
26	16.9	53.1			
27	16.9	53.1			
Subtotal	459.9	1,444.1	Subtotal	415.2	1,303.7

Total length 875.1 meters
Total volume 2,747.8 m^3

6.3.2.7 Standby Drifts

The standby drifts are excavated at a diameter of 5.5 meters (see Section 6.2.1.2). The excavated cross-sectional area of these headings is 23.76 m^2. The standby drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.3.2.2), with a cross-sectional area of 49.13 m^2. The standby drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, with a cross-sectional area of 3.14 m^2. The lengths of the standby drifts and the associated headings, including the bank volumes, are outlined in Table 41.

Table 41. Excavation Quantities for Standby Drifts – 70,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)	East Turnout	
			Length (m)	Volume (m^3)
1	997.3	23,695.8	79.5	3,905.8
2	1263.5	30,020.8	79.5	3,905.8
Totals	2,260.8	53,716.6	159.0	7,811.7

Drift Number	West Turnout		Raise Length (m)	Raise Volume (m^3)
	Length (m)	Volume (m^3)		
1	110.9	5,448.5	17.2	54.0
2	75.6	3,714.2	17.0	53.4
Totals	186.5	9,162.7	34.2	107.4

6.3.2.8 Cross-Block Drifts

The cross-block drifts are excavated at a diameter of 5.5 meters (see Section 6.2.1.2). The excavated cross-sectional area of these headings is 23.76 m^2. The cross-block drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.3.2.2), with a cross-sectional area of 49.13 m^2. The cross-block drifts also require ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, and a cross-sectional area of 3.14 m^2. The lengths of the cross-block drifts and associated headings, including the bank volume, are outlined in Table 42.

Table 42. Excavation Quantities for Cross-Block Drifts – 70,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)	East Turnout	
			Length (m)	Volume (m^3)
1	1,115.3	26,499.5	79.5	3,905.8
2	1,263.5	30,020.8	79.5	3,905.8
3	1,194.8	28,388.4	79.5	3,905.8
Totals	3,573.6	84,908.7	238.5	11,717.5

Drift Number	West Turnout		Raise Length (m)	Raise Volume (m^3)
	Length (m)	Volume (m^3)		
1	110.9	5,448.5	17.2	54.0
2	75.6	3,714.2	17.0	53.4
3	72.9	3,581.6	16.7	52.4
Totals	259.4	12,744.3	50.9	159.8

6.3.2.9 Test and Evaluation Facility Drifts

This section will briefly describe the Test and Evaluation Facility headings.

6.3.2.9.1 Postclosure Test Drifts

The postclosure test drifts will be excavated to a diameter of 5.5 meters (see Section 6.2.1.3), and a cross-sectional area of 23.76 m^2. The postclosure test drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.3.2.2), with a cross-sectional area of 49.13 m^2. The postclosure test drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, and a cross-sectional area of 3.14 m^2. The lengths of the postclosure test drifts and the associated headings with the bank volume are outlined in Table 43.

Table 43. Excavation Quantities for Postclosure Test Drifts – 70,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)	East Turnout	
			Length (m)	Volume (m^3)
1	697.2	16,565.5	77.0	3,783.0
2	741.7	17,622.8	79.5	3,905.8
Totals	1,438.9	34,188.3	156.5	7,688.8
Drift Number	West Turnout		Raise Length (m)	Raise Volume (m^3)
	Length (m)	Volume (m^3)		
1	110.9	5,448.5	15.6	49.0
2	110.9	5,448.5	15.9	49.9
Totals	221.8	10,897.0	31.5	98.9

6.3.2.9.2 Observation Drifts

The ODs will be excavated to a diameter of 5.5 meters (see Section 6.2.1.3), and a cross-sectional area of 23.76 m^2. The ODs also requires ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, and a cross-sectional area of 3.14 m^2. The lengths of the ODs and the associated headings, including the bank volume, are outlined in Table 44 and Table 45.

Table 44. Excavation Quantities for Observation Drifts – 70,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)
1	1,931.2	45,885.3
2	2,103.1	49,969.7
3	1,567.9	37,253.3
Total	5,602.2	133,108.3

Table 45. Excavation Quantities for Observation Drift Raises – 70,000 MTU Case

Description		Raise Length (m)	Raise Volume (m^3)
From	To		
OD #2	Exhaust Main	35.7	112.1
OD #2	West Main	14.8	46.5
OD #3	Exhaust Main	39.3	123.4
OD #3	East Main	15.0	47.1
OD #3	West Main	26.6	83.5
ECRB	Exhaust Main	55.4	174.0
ECRB	West Main	35.6	111.8
Total		222.4	698.3

6.4 97,000 MTU INVENTORY CASE

The MGR must be designed to be capable of accommodating 86,700 MTHM of commercial SNF for disposal in the repository (see Section 4.2.1.1). The current Technical Baseline indicates that the expansion option must accommodate a 97,000 MTU waste inventory, if authorized, including all fuel types and the corresponding WP inventory as outlined in Section 4.1.3. The 97,000 MTU Layout for SR is based on the planning layout as described in Section 6.2. For reference the 97,000 MTU Layout for SR is illustrated in Figure 12.

The 97,000 MTU Layout for SR, if authorized, will occupy the total area indicated in the planning layout based on the required emplacement area calculations and details for the 97,000 MTU Layout located in Section 6.4.1. The details for the main drifts and the design concepts have been outlined in Section 6.2.1.1. The emplacement area will consist of 78 emplacement drifts for emplacement of the required WP inventory, with Emplacement Drifts 79 and 80 being excavated to account for possible variances in the WP inventory (see Section 5.2.2). Also included in the layout is a contingency area which consists of a number of emplacement drifts that will only be excavated if the intended emplacement area cannot be used due to unexpected ground conditions (see Section 5.2.2) or for larger waste stream variations. This contingency area consists of Emplacement Drifts 81 through 90. Details of the emplacement drifts and the design concepts have been outlined in Section 6.2.1.2.

The required emplacement length calculated to accommodate the 97,000 MTU WP inventory, if authorized, is approximately 74,214 meters, which is approximately 1,485 acres, at an AML of approximately 56 MTU/acre as calculated in Section 6.4.1.

Within the emplacement area, six standby and cross-block drifts will be excavated. The two standby drifts from the planning layout will be excavated in this scenario, and will be located between Emplacement Drifts 6 and 7 and between Emplacement Drifts 19 and 20. All four of the cross-block drifts will be required: between Emplacement Drifts 9 and 10, between Emplacement Drifts 22 and 23, between Emplacement Drifts 36 and 37, and between Emplacement Drifts 53 and 54, as shown in Figure 12. The details of the design concepts for the standby and cross-block drifts have been outlined in Section 6.2.1.2.

The Test and Evaluation Facility for the 97,000 MTU layout, if authorized, will consist of the postclosure test drifts on the north end of the repository with its OD, and all performance monitoring ODs from the planning layout, along with the ECRB. Details and functions of the Test and Evaluation Facilities have been outlined in Section 6.2.1.3.

Four intake shafts are required to supply the required ventilation flow rates to the Subsurface Facility for the 97,000 MTU Case, if authorized, in addition to the North and South Ramps (see Section 6.2.4). The locations of the intake shafts are listed in Table 46.

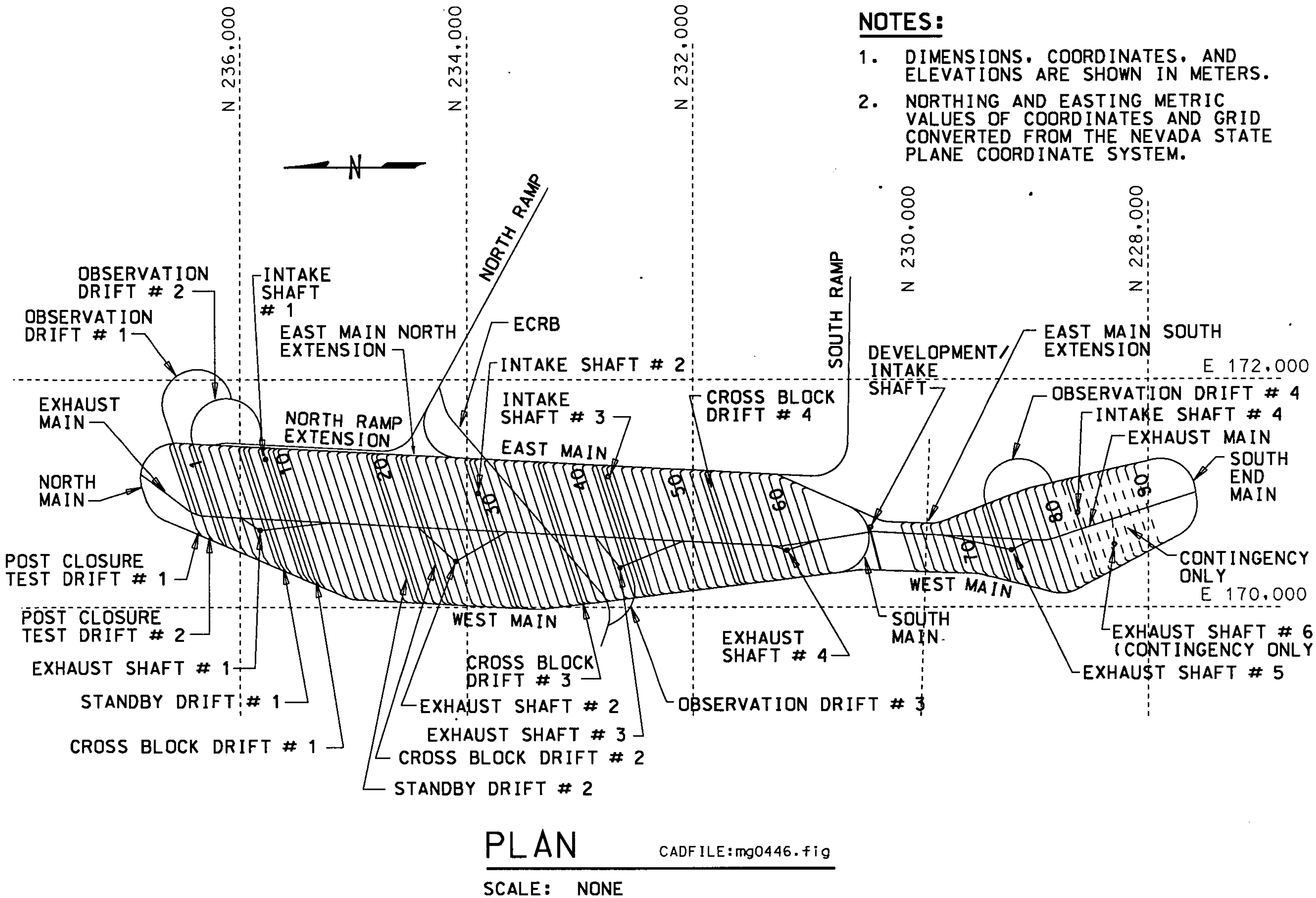


Figure 12. 97,000 MTU Layout for Site Recommendation

Table 46. Intake Shaft Locations for the 97,000 MTU Case

Intake Shaft Number	Northing (m)	Easting (m)
1	235,775	171,300
2	233,900	171,000
3	232,750	171,150
4	228,625	170,825

The Development/Intake Shaft, located in the vicinity of the South Main provides intake airflow for the construction and development operations in the Subsurface Facility (see Section 6.2.4). The Development/Intake Shaft is located at 230,450 meters north and 170,700 meters east.

Five exhaust shafts are required to exhaust air from the Subsurface Facility for the 97,000 MTU Case (see Section 6.2.4). The locations of the exhaust shafts are listed in Table 47.

Table 47. Exhaust Shaft Locations for the 97,000 MTU Case

Exhaust Shaft Number	Northing (m)	Easting (m)
1	235,825	170,675
2	234,100	170,400
3	232,650	170,350
4	231,175	170,500
5	229,050	170,550
6 (Contingency Only)	228,300	170,550

Exhaust Shaft 6, considered for contingency in the 97,000 MTU layout, will only be required if excavation within the contingency area deems it necessary to support the additional ventilation capacity.

The design concepts used to determine these shaft quantities are outlined in Section 6.2.4 and calculated in Attachment IV.

6.4.1 Emplacement Area Determination

The WP inventory for SR as listed in Table 3 (see Section 4.1.3) will be used to define the emplacement area for the option of 97,000 MTU, if it is authorized.

The WPs will be emplaced in a line-loaded configuration (see Section 4.2.1.4) and this will dictate the method of calculating the required emplacement length. The total length of the WPs is calculated by multiplying the total number of WPs with the weighted average WP length, shown in Table 48.

Table 48. Total Length of Waste Packages for the 97,000 MTU Case

WP Description[a]		Number of WPs by WP Type[b]	WP Type Fraction of Total[c]	WP Outer Length (m)[d]	Contribution to Weighted Average WP Length (m)[e]
21 PWR	Absorber Plates	5,690	0.385	5.06	1.949
	Control Rods	106	0.007	5.06	0.036
12 PWR	Absorber Plates Long	293	0.020	5.54	0.110
44 BWR	Absorber Plates	3,732	0.253	5.06	1.279
24 BWR	Absorber Plates	98	0.007	5.00	0.033
5 IPWF		127	0.009	3.48	0.030
5 DHLW Short/1 DOE SNF Short		1,403	0.095	3.48	0.331
5 DHLW Long/1 DOE SNF Long		1,874	0.127	5.11	0.648
2 MCO/2 DHLW Short		199	0.013	5.11	0.069
5 HLW Long/1 DSNF Short		167	0.011	5.11	0.058
HLW Long Only		780	0.053	5.11	0.270
Naval	Short	200	0.014	5.32	0.072
	Long	100	0.007	5.96	0.040
TOTAL		14,769[f]	1.000		4.925[g]

Notes:
[a] WP descriptions defined in Section 4.1.3
[b] Number of WPs by WP type defined in Section 4.1.3
[c] WP fraction of total is calculated as the number of WPs by WP Type divided by the total number of WPs (see Note [f])
[d] Outer WP length defined in Section 4.1.3
[e] Contribution to weighted average WP length is calculated by multiplying the WP type fraction of total (see Note [c]) with the outer WP length (see Note [d])
[f] Total number of WPs is the summation of the number of WPs by WP type (see Note [b])
[g] Weighted average WP length is the summation of contribution to weighted average WP length (see Note [e])

The WP total length is calculated by multiplying the total number of WPs (14,769) and the weighted average WP length (4.925 meters).

$$\text{WP Total Length} = 14{,}769 \text{ WPs} \times 4.925 \text{ meters per WP}$$

$$\text{WP Total Length} = 72{,}737.3 \text{ meters}$$

The total WP spacing is calculated by multiplying the total number of WPs (14,769) by the WP spacing of 0.1 meters (see Section 4.2.1.4).

$$\text{Total WP Spacing} = 14{,}769 \text{ WPs} \times 0.1 \text{ meters per WP}$$
$$\text{Total WP Spacing} = 1{,}476.9 \text{ meters}$$

The required emplacement length is calculated by adding the WP total length (72,737.3 meters) and the total WP spacing (1,476.9 meters) to get 74,214.2 meters.

By examining the available area in the planning layout as outlined in Attachment I, Table I-1, it can be seen that 78 emplacement drifts, not including the 2 drifts for use as the postclosure simulation drifts (see Section 6.2.1.3), will be required for emplacement of the waste inventory for 97,000 MTU, if it is authorized.

Two percent of the required emplacement drift length will be excavated in addition to the required 78 emplacement drifts to ensure flexibility of the layout and to account for possible anomalies in the waste inventory (see Section 5.2.2). This excavation allowance equates to an additional 1,484.3 meters, a total of 75,698.5 meters, and extends the excavation out to Emplacement Drift 80. These additional drifts, although they will be excavated, will not be used for further emplacement area calculations.

A 10-percent contingency area (see Section 5.2.2) will be accommodated within the repository layout. The contingency is calculated as 10 percent of the required emplacement drift length, an additional 7,421.4 meters. The contingency area will encompass Emplacement Drifts 81 through 90 for a total of 83,476.8 meters of available emplacement drift (see Attachment I).

The required emplacement drift length and the drift spacing can be used to calculate the total available acreage in the layout.

$$\text{Acreage} = \frac{L_r\,(m) \times DS\,(m)}{43{,}560\ ft^2/acre} \times \frac{1}{0.0929\ m^2/ft^2}$$

Where: L_r = required emplacement drift length (m) and
DS = drift spacing (m).

When: L_r = 74,214.2 meters and
DS = 81.0 meters (see Section 4.2.1.5),

$$\text{Acreage} = \frac{74{,}214.2\ \text{meters} \times 81\ \text{meters}}{43{,}560\ ft^2/acre} \times \frac{1}{0.0929\ m^2/ft^2}$$

Acreage = 1,485.5 acres

The layout supporting the 97,000 MTU inventory, if authorized, will require approximately 1,485 acres to accommodate the waste inventory.

The AML is calculated with the amount of MTU from commercial SNF only. The AML of the repository layout can then be calculated as:

$$AML = \frac{\text{Commercial SNF (MTU)}}{\text{Acreage}}$$

Where: Commercial SNF = 83,800 MTU (see Section 4.1.4)
Acreage = 1,485 acres

$$AML = \frac{83{,}800 \text{ MTU}}{1{,}485 \text{ acres}}$$

$$AML = 56.4 \ \text{MTU}/\text{acre}$$

The repository layout to support the 97,000 MTU waste stream, if authorized, has an AML of approximately 56 MTU/acre.

The 97,000 MTU layout must also be evaluated with respect to the WP inventory for maximum subsurface emplacement (see Section 4.2.1.1). This WP inventory represents "not to exceed" values for each WP category that applies to the capability of the subsurface emplacement. The required length of emplacement drift is calculated, based on these not to exceed values and compared to the planning layout discussed in Section 6.2. The total length of WPs is calculated by multiplying the total number of WPs with the WP length plus the gap length of 0.1 meters (see Section 4.2.1.4), as shown in Table 49.

Table 49. Required Emplacement Length for Maximum Subsurface Emplacement

Type of WP	WP Length (m)	WP Length Plus Gap (m)	Quantity	Contribution to Required Emplacement Length (m)
21 PWR AP	5.06	5.16	5,700	29,412.0
21 PWR CR	5.06	5.16	110	567.6
12 PWR AP Long	5.54	5.64	300	1,692.0
44 BWR AP	5.06	5.16	3,750	19,350.0
24 BWR AP	5.00	5.10	100	510.0
5 IPWF	3.48	3.58	130	465.4
5 DHLW Short/1 DOE SNF Short	3.48	3.58	1,410	5,047.8
5 DHLW Long/1 DOE SNF Long	5.11	5.21	1,880	9,794.8
2 MCO/2 DHLW	5.11	5.21	200	1,042.0
5 HLW Long/1 DOE SNF Short	5.11	5.21	170	885.7
HLW Long Only	5.11	5.21	800	4,168.0
Naval Short	5.32	5.42	210	1,138.2
Naval Long	5.96	6.06	110	666.6
			14,870	74,740.1

By examining the available area within the planning layout as outlined in Attachment I, Table I-1, it can be seen that 79 emplacement drifts, not including the 2 drifts for use as the postclosure test drifts (see Section 6.2.1.3), will be required for emplacement of the "not to exceed" maximum subsurface emplacement inventory. This indicates that the subsurface facility is capable of accommodating the WP inventory for the "not to exceed" maximum subsurface emplacement.

6.4.2 Excavation Quantities

The excavation quantities were extracted from the *Subsurface Planning Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000aa) using VULCAN v3.4 for the various subsurface headings and will be discussed in the following sections.

The lengths of the headings are expressed in slope length. The slope length of a heading refers to the actual length excavated at the specified gradient of the heading.

The excavated opening areas were calculated in Section 6.3.2 and will be used throughout this section of the analysis.

6.4.2.1 Perimeter Mains and Exhaust Main

The perimeter mains and Exhaust Main are excavated at a diameter of 7.62 meters (see Section 6.2.1). The excavated cross-sectional area of these headings is 45.6 m^2. The lengths of the perimeter mains and the Exhaust Main, as well as the bank volume, are outlined in Table 50.

Table 50. Excavation Quantities for the Main Drifts – 97,000 MTU Case

Heading Designation	Point Designations (see Attachment II)		Slope Length (m)	Shape of Opening	Profile (m)	Area (m^2)	Volume (m^3)
	From Point	To Point					
North Ramp			Existing	Circular	7.62	45.60	Existing
East Main			Existing	Circular	7.62	45.60	Existing
South Ramp			Existing	Circular	7.62	45.60	Existing
North Ramp Extension	36	2	2,003.7	Circular	7.62	45.60	91,368.7
East Main North Extension	1	3	2,500.0	Circular	7.62	45.60	114,000.0
North Main	3	7	1,256.8	Circular	7.62	45.60	57,310.1
West Main	7	24	8,727.3	Circular	7.62	45.60	397,964.9
South Main	15	18	793.4	Circular	7.62	45.60	36,179.0
Exhaust Main	5	26	9,480.5	Circular	7.62	45.60	432,310.8
East Main South Extension	28	20	3,334.6	Circular	7.62	45.60	152,057.8
South End Main	24	28	1,263.2	Circular	7.62	45.60	57,601.9
Total			29,359.5				1,338,793.2

6.4.2.2 Emplacement Drifts

The emplacement drifts are excavated at a diameter of 5.5 meters (see Section 4.2.1.3). The excavated cross-sectional area of these headings is 23.76 m^2. The lengths of the emplacement drifts, as well as the bank volume, are outlined in Table 51.

The emplacement drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high, as previously illustrated in Figure 4. The cross-sectional area of the turnouts is 49.13 m^2. The lengths of the emplacement drift turnouts, as well as the bank volume, are outlined in Table 52.

Table 51. Excavation Quantities for Emplacement Drift – 97,000 MTU Case

Drift Number	Length (m)	Volume (m^3)
1	781.1	18,558.9
2	820.4	19,492.7
3	859.7	20,426.5
4	899.0	21,360.2
5	938.3	22,294.0
6	977.7	23,230.2
7	1,017.0	24,163.9
8	1,056.3	25,097.7
9	1,095.6	26,031.5
10	1,134.9	26,965.2
11	1,174.3	27,901.4
12	1,230.0	29,224.8
13	1,263.5	30,020.8
14	1,263.5	30,020.8
15	1,263.5	30,020.8
16	1,263.5	30,020.8
17	1,263.5	30,020.8
18	1,263.5	30,020.8
19	1,263.5	30,020.8
20	1,263.5	30,020.8
21	1,263.5	30,020.8
22	1,263.5	30,020.8
23	1,263.5	30,020.8
24	1,263.5	30,020.8
25	1,263.5	30,020.8
26	1,263.5	30,020.8
27	1,263.5	30,020.8
Subtotal	30,936.8	735,058.4

Drift Number	Length (m)	Volume (m^3)
28	1,263.5	30,020.8
29	1,263.5	30,020.8
30	1,263.5	30,020.8
31	1,263.5	30,020.8
32	1,263.8	30,027.9
33	1,248.5	29,664.4
34	1,233.1	29,298.5
35	1,217.8	28,934.9
36	1,202.4	28,569.0
37	1,187.1	28,205.5
38	1,171.7	27,839.6
39	1,156.4	27,476.1
40	1,141.1	27,112.5
41	1,125.7	26,746.6
42	1,110.4	26,383.1
43	1,095.0	26,017.2
44	1,079.7	25,653.7
45	1,064.3	25,287.8
46	1,049.0	24,924.2
47	1,033.6	24,558.3
48	1,018.3	24,194.8
49	1,002.9	23,828.9
50	987.6	23,465.4
51	972.2	23,099.5
52	956.9	22,735.9
53	941.5	22,370.0
54	926.2	22,006.5
Subtotal	30,239.2	718,483.4

Drift Number	Length (m)	Volume (m^3)
55	910.8	21,640.6
56	895.5	21,277.1
57	880.1	20,911.2
58	864.8	20,547.6
59	849.4	20,181.7
60	834.1	19,818.2
61	796.2	18,917.7
62	739.0	17,558.6
63	681.8	16,199.6
64	333.5	7,924.0
65	333.5	7,924.0
66	333.5	7,924.0
67	335.4	7,969.1
68	352.8	8,382.5
69	384.7	9,140.5
70	415.4	9,869.9
71	458.5	10,894.0
72	513.4	12,198.4
73	568.3	13,502.8
74	623.1	14,804.9
75	678.0	16,109.3
76	732.8	17,411.3
77	787.7	18,715.8
78	845.4	20,086.7
79	861.4	20,466.9
80	848.1	20,150.9
Subtotal	16,857.2	400,527.1

Total Length 78,033.2 meters
Total Volume 1,854,068.8 m^3

Table 52. Excavation Quantities for Turnouts – 97,000 MTU Case

Turnout Description	Quantity	Centerline Length (m)	Total Length (m)	Excavation Volume (m^3)	Total Volume (m^3)
East Main Turnouts					
Turnouts 1 through 60	60	79.5	4,770.0	3,905.8	234,350.1
Turnouts 61 through 63	3	86.9	260.7	4,269.4	12,808.2
Turnouts 64 through 66	3	79.2	237.6	3,891.1	11,673.3
Turnout 67	1	74.1	74.1	3,640.5	3,640.5
Turnout 68	1	70.3	70.3	3,453.8	3,453.8
Turnouts 69 through 77	9	71.9	647.1	3,532.4	31,792.0
Turnouts 78 through 80	3	74.4	223.2	3,655.3	10,965.8
West Main Turnouts					
Turnouts 1 through 11	11	110.9	1,219.9	5,448.5	59,933.7
Turnout 12	1	93.2	93.2	4,578.9	4,578.9
Turnouts 13 through 31	19	75.6	1,436.4	3,714.2	70,570.3
Turnouts 32 through 63	32	72.9	2,332.8	3,581.6	114,610.5
Turnouts 64 through 69	6	75.2	451.2	3,694.6	22,167.5
Turnout 70	1	76.3	76.3	3,748.6	3,748.6
Turnouts 71 through 77	7	84.1	588.7	4,131.8	28,922.8
Turnout 78	1	75.6	75.6	3,714.2	3,714.2
Turnout 79	1	73.2	73.2	3,596.3	3,596.3
Turnout 80	1	75.7	75.7	3,719.1	3,719.1
Total	160		12,706.0		624,245.8

6.4.2.3 Intake Shafts

The intake shaft accesses will be excavated to a diameter of 7.62 meters (see Section 6.2.4), and a cross-sectional area of 45.60 m^2. The intake shaft access turnouts will be excavated to a horseshoe-shaped profile of 8 meters wide and 8.5 meters high, similar to the exhaust shaft accesses (see Section 6.2.4), with a cross-sectional area of 61.13 m^2. The intake shaft will be excavated to a diameter of 8 meters (see Attachment IV), and a cross-sectional area of 50.27 m^2. The intake shafts will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom, (see Section 5.2.7.11). The lengths of the intake shafts and the associated headings, including the bank volume, are outlined in Table 54 and Table 53.

Table 53. Excavation Quantities for Intake Shafts – 97,000 MTU Case

Shaft Number	Shaft Length (m)	Shaft Sump (m)	Shaft Volume (m^3)
1	386.4	5.0	19,675.7
2	321.9	5.0	16,433.3
3	275.4	5.0	14,095.7
4	289.2	5.0	14,789.4
Totals	1,272.9	20.0	64,994.1

Table 54. Excavation Quantities for Intake Shaft Accesses and Turnouts – 97,000 MTU Case

Shaft Number	Access Length (m)	Volume (m^3)	East Turnout		West Turnout	
			Length (m)	Volume (m^3)	Length (m)	Volume (m^3)
1	1,076.0	49,065.6	79.5	4,859.8	75.6	4,621.4
2	1,263.5	57,615.6	79.5	4,859.8	75.6	4,621.4
3	1,087.3	49,580.9	79.5	4,859.8	72.9	4,456.4
4	794.6	36,233.8	74.0	4,523.6	75.7	4,627.5
Totals	4,221.4	192,495.8	312.5	19,103.1	299.8	18,326.8

6.4.2.4 Development/Intake Shaft

The Development Shaft provides intake airflow for the construction and development operations in the Subsurface Facility (see Section 6.2.4). The Access 1 of the Development/Intake Shaft will be excavated to a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.2.4), with a cross-sectional area of 61.13 m^2. The Access 2 of the Development/Intake Shaft will be excavated to a diameter of 7.62 meters (see Section 6.2.4), and a cross-sectional area of 45.60 m^2. The Development/Intake Shaft will be excavated to a diameter of 8 meters (see Attachment IV), and a cross-sectional area of 50.27 m^2. The Development/Intake Shaft will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom, (see Section 5.2.7.11). The lengths of the Development Shaft and associated headings, including the bank volume, are outlined in Table 56 and Table 55.

Table 55. Excavation Quantities for Development Shaft – 97,000 MTU Case

Shaft Length (m)	Shaft Sump (m)	Shaft Volume (m^3)
282.7	5.0	14,462.7

Table 56. Excavation Quantities for Development/Intake Shaft Accesses – 97,000 MTU Case

Access Number	Access Length (m)	Volume (m^3)
1	16.9	1,033.1
2	389.0	17,738.4
Totals	405.9	18,771.5

6.4.2.5 Exhaust Shafts

The exhaust shaft accesses will be excavated in a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.2.4), with a cross-sectional area of 61.13 m^2. The exhaust shafts will be excavated to a diameter of 8 meters (see Attachment IV), and a cross-sectional area of 50.27 m^2. The exhaust shafts will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom (see Section 5.2.7.11). The lengths of the exhaust shafts and the associated headings, including the bank volume, are outlined in Table 57 and Table 58.

Table 57. Excavation Quantities for Exhaust Shaft Accesses – 97,000 MTU Case

Shaft Number	Access #1 Length (m)	Access #1 Volume (m^3)	Access #2 Length (m)	Access #2 Volume (m^3)
1	194.8	11,908.1	621.8	38,010.6
2	445.1	27,209.0	522.6	31,946.5
3	346.8	21,199.9	607.2	37,118.1
4	138.4	8,460.4	290.4	17,752.2
5	617.5	37,747.8	196.1	11,987.6
Total	1,742.6	106,525.1	2,238.1	136,815.1

Table 58. Excavation Quantities for Exhaust Shafts – 97,000 MTU Case

Shaft Number	Shaft Length (m)	Shaft Sump (m)	Shaft Volume (m^3)
1	447.5	5.0	22,747.2
2	447.4	5.0	22,742.1
3	425.5	5.0	21,641.2
4	361.5	5.0	18,424.0
5	346.5	5.0	17,669.9
Total	2,028.4	25.0	103,224.4

6.4.2.6 Ventilation Raises

The emplacement drift ventilation raises channel the exhaust air from the emplacement drifts to the Exhaust Main, service side where ductwork directs the airflow to the exhaust side (see Section 6.2.4). The raises will be excavated to a diameter of 2 meters (see Section 6.2.4), and a cross-sectional area of 3.14 m^2. The lengths of the ventilation raises, including the bank volume, are outlined in Table 59.

6.4.2.7 Standby Drifts

The standby drifts are excavated at a diameter of 5.5 meters (see Section 6.2.1.2). The excavated cross-sectional area of these headings is 23.76 m^2. The standby drift turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.3.2.2), with a cross-sectional area of 49.13 m^2. The standby drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, and a cross-sectional area of 3.14 m^2. The lengths of the standby drifts and the associated headings, including the bank volumes, are outlined in Table 60.

Table 59. Excavation Quantities for Ventilation Raises – 97,000 MTU Case

Drift Number	Length (m)	Volume (m^3)	Drift Number	Length (m)	Volume (m^3)	Drift Number	Length (m)	Volume (m^3)
1	16.3	51.2	28	16.9	53.1	55	15.4	48.4
2	16.7	52.4	29	16.9	53.1	56	15.2	47.7
3	17.1	53.7	30	16.8	52.8	57	15.0	47.1
4	17.3	54.3	31	16.8	52.8	58	14.8	46.5
5	17.3	54.3	32	16.8	52.8	59	14.7	46.2
6	17.2	54.0	33	16.8	52.8	60	14.6	45.8
7	17.2	54.0	34	16.8	52.8	61	14.5	45.5
8	17.2	54.0	35	16.7	52.4	62	14.2	44.6
9	17.2	54.0	36	16.7	52.4	63	13.9	43.6
10	17.2	54.0	37	16.7	52.4	64	13.9	43.6
11	17.2	54.0	38	16.7	52.4	65	14.8	46.5
12	17.1	53.7	39	16.7	52.4	66	15.7	49.3
13	17.1	53.7	40	16.6	52.1	67	16.6	52.1
14	17.1	53.7	41	16.6	52.1	68	17.4	54.6
15	17.1	53.7	42	16.6	52.1	69	18.3	57.5
16	17.1	53.7	43	16.6	52.1	70	19.2	60.3
17	17.0	53.4	44	16.6	52.1	71	20.1	63.1
18	17.0	53.4	45	16.6	52.1	72	21.1	66.3
19	17.0	53.4	46	16.5	51.8	73	22.0	69.1
20	17.0	53.4	47	16.5	51.8	74	23.0	72.2
21	17.0	53.4	48	16.5	51.8	75	23.9	75.0
22	17.0	53.4	49	16.5	51.8	76	24.9	78.2
23	16.9	53.1	50	16.3	51.2	77	25.2	79.1
24	16.9	53.1	51	16.1	50.6	78	24.7	77.6
25	16.9	53.1	52	15.9	49.9	79	24.2	76.0
26	16.9	53.1	53	15.8	49.5	80	23.5	73.8
27	16.9	53.1	54	15.6	48.9			
Subtotal	459.9	1,444.1	Subtotal	446.6	1,402.3	Subtotal	480.8	1,509.7

Total Length 1,387.3 meters
Total Volume 4,356.1 m^3

Table 60. Excavation Quantities for Standby Drifts – 97,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)	East Turnout	
			Length (m)	Volume (m^3)
1	997.3	23,695.8	79.5	3,905.8
2	1,263.5	30,020.8	79.5	3,905.8
Totals	2,260.8	53,716.6	159.0	7,811.7

Drift Number	West Turnout		Raise Length (m)	Raise Volume (m^3)
	Length (m)	Volume (m^3)		
1	110.9	5,448.5	17.2	54.0
2	75.6	3,714.2	17.0	53.4
Totals	186.5	9,162.7	34.2	107.4

6.4.2.8 Cross-Block Drifts

The cross-block drifts are excavated at a diameter of 5.5 meters (see Section 6.2.1.2). The excavated cross-sectional area of these headings is 23.76 m^2. The cross-block drift turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.3.2.2), with a cross-sectional area of 49.13 m^2. The cross-block drifts also require ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, and a cross-sectional area of 3.14 m^2. The lengths of the cross-block drifts and associated headings, including the bank volume, are outlined in Table 61.

Table 61. Excavation Quantities for Cross-Block Drifts – 97,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)	East Turnout	
			Length (m)	Volume (m^3)
1	1,115.3	26,499.5	79.5	3,905.8
2	1,263.5	30,020.8	79.5	3,905.8
3	1,194.8	28,388.4	79.5	3,905.8
4	933.8	22,187.1	79.5	3,905.8
Totals	4,507.4	107,095.8	318.0	15,623.3
Drift Number	West Turnout		Raise Length (m)	Raise Volume (m^3)
	Length (m)	Volume (m^3)		
1	110.9	5,448.5	17.2	54.0
2	75.6	3,714.2	17.0	53.4
3	72.9	3,581.6	16.7	52.4
4	72.9	3,581.6	15.7	49.3
Totals	332.3	16,325.9	66.6	209.1

6.4.2.9 Test and Evaluation Facility Drifts

This section will briefly describe the Test and Evaluation Facility headings.

6.4.2.9.1 Postclosure Test Drifts

The postclosure test drifts will be excavated to a diameter of 5.5 meters (see Section 6.2.1.3), and a cross-sectional area of 23.76 m^2. The postclosure test drift turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.3.2.2), with a cross-sectional area of 49.13 m^2. The cross-block drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, and a cross-sectional area of 3.14 m^2. The lengths of the postclosure test drifts and the associated headings, including the bank volume, are outlined in Table 62.

Table 62. Excavation Quantities for Postclosure Test Drifts – 97,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)	East Turnout	
			Length (m)	Volume (m^3)
1	697.2	16,565.5	77	3,783.0
2	741.7	17,622.8	79.5	3,905.8
Totals	1,438.9	34,188.3	156.5	7,688.8
Drift Number	West Turnout		Raise Length (m)	Raise Volume (m^3)
	Length (m)	Volume (m^3)		
1	110.9	5,448.5	15.6	49.0
2	110.9	5,448.5	15.9	49.9
Totals	221.8	10,897.0	31.5	98.9

6.4.2.9.2 Observation Drifts

The ODs will be excavated to a diameter of 5.5 meters (see Section 6.2.1.3), and a cross-sectional area of 23.76 m^2. The ODs also require ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.2.4.2), similar to the emplacement drift raise, and a cross-sectional area of 3.14 m^2. The lengths of the ODs and the associated headings, including the bank volume, are outlined in Table 63 and Table 64.

Table 63. Excavation Quantities for Observation Drifts – 97,000 MTU Case

Drift Number	Drift Length (m)	Volume (m^3)
1	1,931.2	45,885.3
2	2,103.1	49,969.7
3	1,567.9	37,253.3
4	1,668.3	39,638.8
Total	7,270.5	172,747.1

Table 64. Excavation Quantities for Observation Drift Raises – 97,000 MTU Case

Description		Raise Length (m)	Raise Volume (m^3)
From	To		
OD #2	Exhaust Main	35.7	112.1
OD #2	West Main	14.8	46.5
OD #3	Exhaust Main	39.3	123.4
OD #3	East Main	15.0	47.1
OD #3	West Main	26.6	83.5
ECRB	Exhaust Main	55.4	174.0
ECRB	West Main	35.6	111.8
OD #4	Exhaust Main	40.3	126.5
OD #4	West Main	13.6	42.7
Total		276.3	867.6

6.5 EXPANSION AREAS AND POTENTIAL SITING OPTIONS

The flexibility of the SR planning layout with respect to expansion and potential siting options is discussed in the following sections.

6.5.1 Expansion Areas

The design of the repository must not preclude the capability of expansion and accommodation of a waste inventory of up to 115,000 MTU or equivalent (see Section 4.2.1.1). An area located to the east of the planning layout, at a lower elevation is available for this expansion (CRWMS M&O 2000bb). This siting area is referred to as the lower block. The development of this lower block area was approached in a similar manner as the design of the planning layout discussed in Section 6.2. The layout of the lower block was based on the applicable inputs listed in Section 4 and the assumptions listed in Section 5 and only encompassed sufficient area as to show the expansion capability of the current SR layouts. Consequently, the layout of the lower block was fully integrated with the design of the planning layout. The lower block layout is located approximately 40 meters and 130 meters below the elevation of the planning layout on the north and south ends of the primary block, respectively. The lower block, as illustrated in Figure 13 can accommodate 52 emplacement drifts with approximately 62,400 meters of available emplacement drift (see Attachment VI).

For reference, details of the main drift lengths and gradients of the lower block layout are contained in Attachment VI. In addition, Attachment VI lists a set of bounding coordinates for the emplacement area contained within the lower block.

6.5.2 Potential Siting Options

Additional repository siting area may be available at the elevation of the SR layouts when the TSw1 upper lithophysal unit is used with potentially less than 200 meters of overburden (Stroupe 2000, Attachment 2, p. 2). This siting alternative requires relaxing of two criteria.

- The criterion that requires the emplacement area to be located within the lower part of the lithophysal zone of the TSw1 unit and the entire TSw2 unit (see Section 4.2.2.8).
- The criterion that requires the subsurface emplacement area to be located at least 200 meters below the directly overlying ground surface (see Section 4.2.2.9).

Removal of these criteria may allow additional siting area to the east of the Subsurface Planning Layout (see Figure 3). The area to the north of the planning layout is bounded by the 100-meter standoff from the top of the groundwater table (see Section 4.2.2.4). Solitario Canyon fault and the bottom of the RHH form the western boundary of the layout. The southern extent of the characterized area restricts the southern limits of the planning layout.

Five overburden limits were considered, specifically siting the emplacement area 180, 160, 140, 120, or 100 meters below the overlying ground surface. These limits are illustrated in Figure 14.

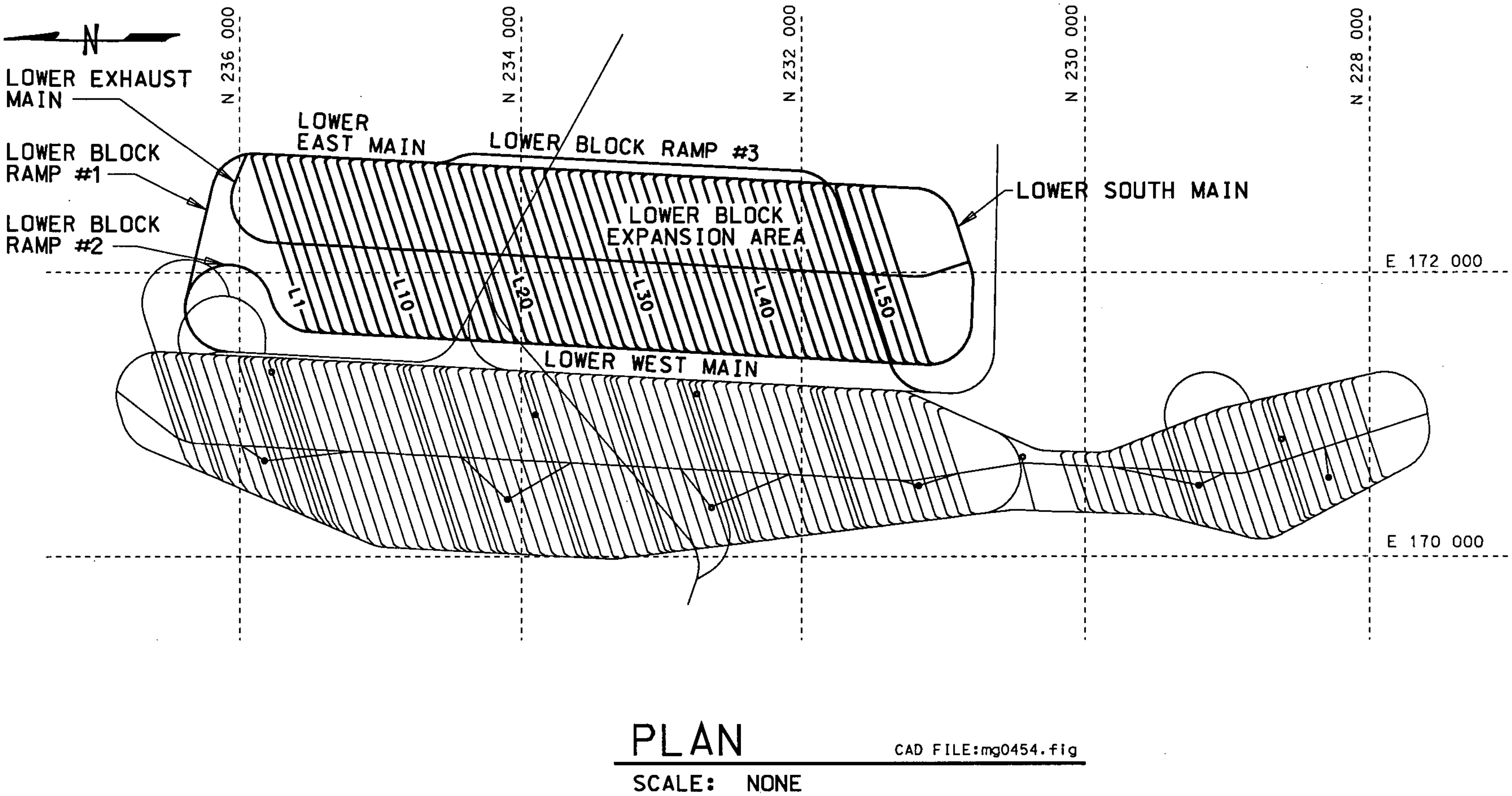


Figure 13. Lower Block Expansion Layout

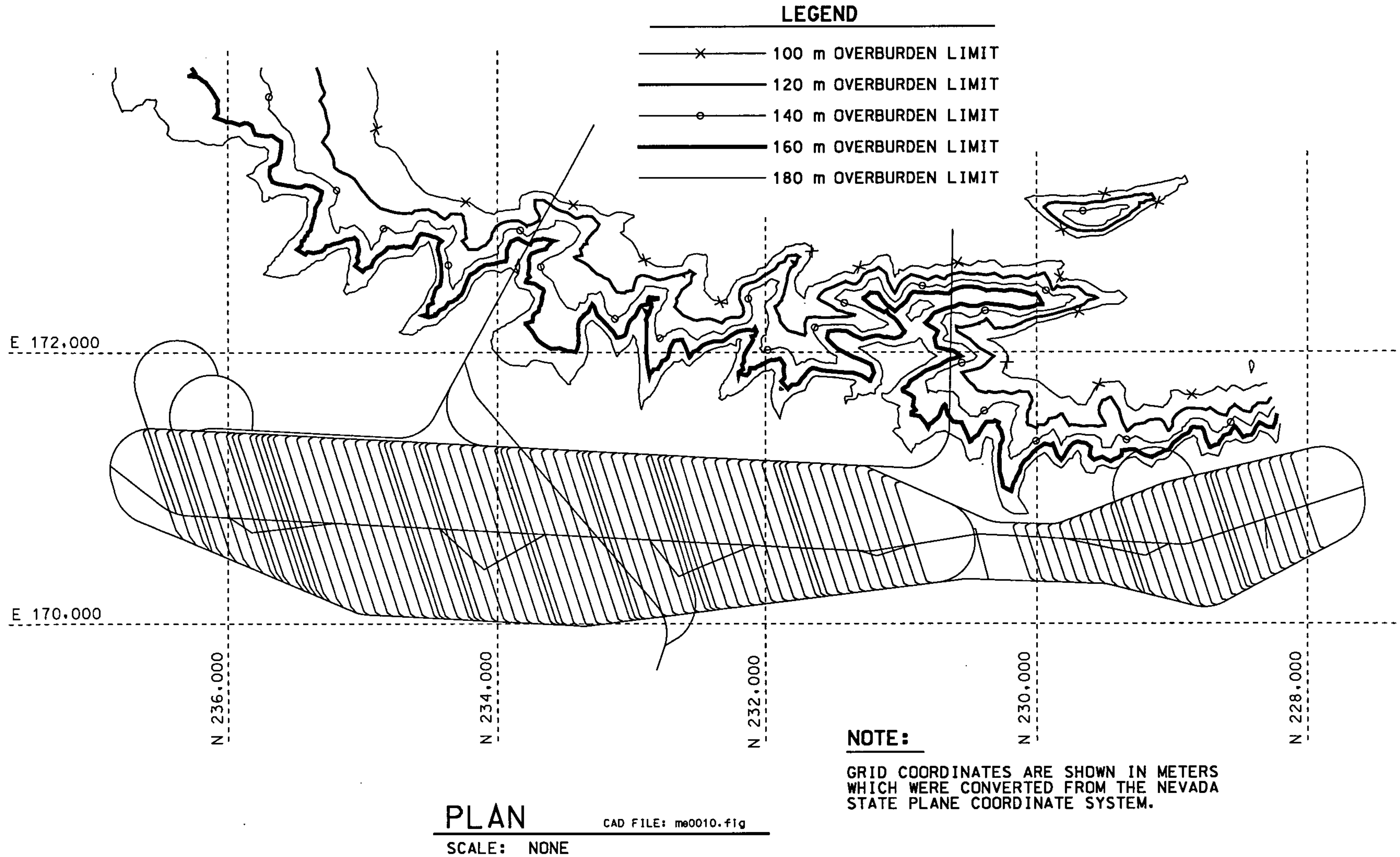


Figure 14. Potential Siting Options Under Various Overburden Limits

In addition to examining the overburden limit, the location of the rock units to the east of the Ghost Dance fault must also be examined. The top of the RHH, which is the top of the lower part of the TSw1 unit as well as the top of the TSw1, excluding the crystal –rich member, vitric zone, densely welded subzone (tptrv1) are identified. These two limits are superimposed on the overburden limits in Figure 15.

In order to evaluate the relaxing the overburden criterion or the criterion which specifies the geologic units in which the emplacement area is located, both the overburden limits and the geology must be considered together.

First by examining the relaxation of the overburden criterion in Figure 14, it can be seen that an increasingly larger area can be gained as the 100-meter overburden limit is approached. Secondly, the criterion requiring the emplacement area to be located within specific rock units must also be re-evaluated as illustrated in Figure 15. Without changing the criterion for locating the emplacement area within specific rock units, additional siting area cannot be realized by relaxing the overburden limit.

The maximum alternative siting area would be achieved by relaxing the overburden limit, such that the emplacement area could be located within 100 meters of the directly overlying ground surface and for the most part the emplacement area would be located within the TSw1 geologic unit.

The SR layouts for both the 70,000 MTU and the 97,000 MTU cases are located within the current siting criteria requirements (see Sections 6.3.1 and 6.4.1).

In the event that the 97,000 MTU waste inventory were to be expanded or the thermal loading strategy modified, additional emplacement area would be required. The potential siting option of relaxing the overburden and rock unit criteria should be considered as an alternative to locating additional emplacement area below the current SR footprint. Relaxing of these criteria would provide the use of area at the same elevation as the main repository horizon and will benefit operations by eliminating the use of internal ramp systems necessary for developing areas below the SR repository horizon.

Layouts for the potential siting areas have not been developed since they are outside the scope of this analysis. Further design work will be required to define and develop useable emplacement area layouts within this potential siting area should relaxing of the siting criteria be authorized.

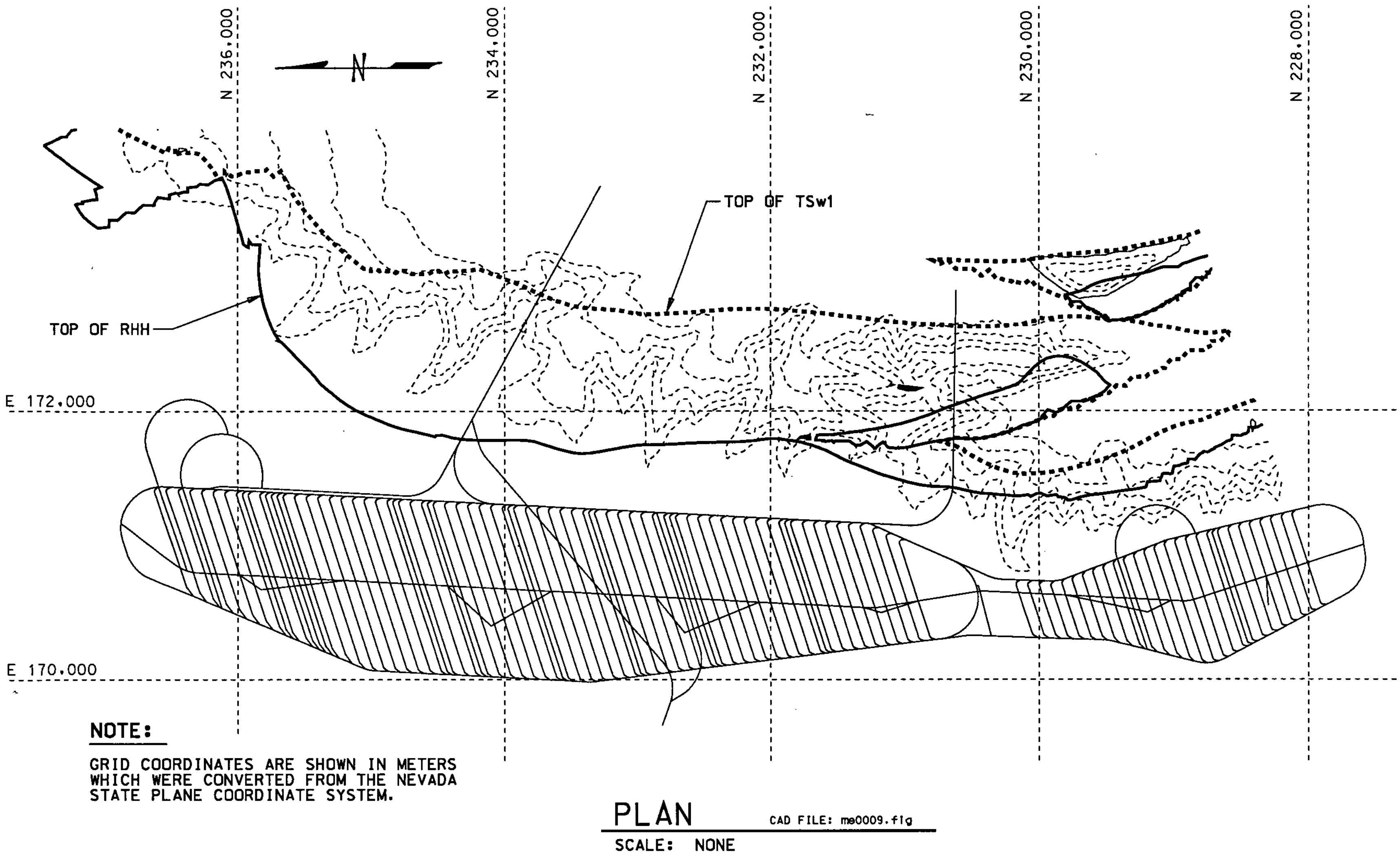


Figure 15. Potential Siting Options Under Varying Geology

7. CONCLUSIONS

A planning layout has been developed, consistent with the usable three-dimensional spatial boundaries within the geology of Yucca Mountain and includes the existing ESF. This planning layout as shown in Figure 3 (CRWMS M&O 2000aa) was then used as a basis for specifying specific layouts for the 70,000 MTU and 97,000 MTU WP inventories.

A thermal analysis of the emplacement drifts was required for specifying the spacing and location of emplaced WPs, and the control of heat from the WPs (see Section 6.2.3). The repository emplacement drift average thermal load was calculated based on a 10-centimeter spacing between WPs. The 70,000 MTU WP inventory has an average thermal load of 1.42 kW/m in the repository emplacement drifts. The 97,000 MTU WP inventory has an average thermal load of 1.43 kW/m in the repository emplacement drifts. A thermal load of 1.45 kW/m was used to approximate these values (1.42 and 1.43 kW/m).

The Subsurface Ventilation System must remove 70 percent of the heat generated by the WPs during the preclosure period as mandated by the Emplacement Drift SDD (CRWMS M&O 2000i, Section 1.2.4.5) as documented in Section 4.2.4.15. It has been determined that with a continuous ventilation rate of 15 m^3/s, an overall average of 72 percent of the heat generated by the WPs is removed by the ventilation system during the preclosure period (see Section 6.2.3.4).

Radiological safety is one of the most important aspects of the repository and the MGR must comply with applicable standards (see Section 6.2.7). Design considerations in the emplacement drift turnouts have been incorporated to aid in increasing radiological protection in the mains. In addition, the Exhaust Main is partitioned to isolate personnel from the exhaust air exiting the emplacement drifts.

The layout is influenced by practical limitations imposed by the operating requirements and performance characteristics of the equipment and methods for construction of the repository. The size, configuration, and operating requirements of the construction equipment were taken into consideration to provide restriction on the size and shape of the excavated opening and the general arrangements possible for the layout (see Section 6.2.9).

The SR layouts for both the 70,000 MTU and 97,000 MTU WP inventories are located within the available site volume as estimated from current geologic information (see Section 6.2.2). If the available site volume were to change, the impact to the layouts would have to be determined and modification to the layouts would need to be done to accommodate the changes.

The ESF is integrated into the Layouts for SR (see Section 6.2.1.1). The North Ramp will become the access for the emplacement side of the subsurface repository, and the South Ramp will become the access for the development side. The ESF Main Drift will become the East Main. All other subsurface repository openings will be developed from the ESF. The size and configuration of the ESF is sufficient to provide clearance for repository construction and emplacement operations.

The Layouts for SR facilitate preclosure and postclosure water drainage away from the emplacement drifts, by sloping the subsurface openings away from the emplacement area along the mains to drainage areas at the ventilation shaft sumps (see Section 6.2.5). The emplacement drifts have been designed with a flat gradient. This allows any water entering the emplacement drifts to drain directly into the surrounding rock without draining along the drift for collection into a centralized location. The step at the emplacement drift - turnout interface prevents water inflow to the emplacement drifts as well.

7.1 70,000 MTU LAYOUT FOR SITE RECOMMENDATION

The MGR is required to accept 70,000 MTU of SNF/HLW for disposal in the primary area of the repository. The 70,000 MTU Layout for SR supports this WP inventory (see Section 6.3.1). The 70,000 MTU Layout (see Figure 11) for SR will require 58 emplacement drifts. Emplacement Drifts 1 through 51 are required for emplacement of the WP inventory. Emplacement Drift 52 is excavated as an allowance for possible variances in the waste stream. Emplacement Drifts 53 through 58 are contingency drifts that will only be excavated in the event that conditions during development of the repository are found to be such that the intended emplacement area cannot be used due to unexpected ground conditions.

The required emplacement length to accommodate the 70,000 MTU Layout for SR is 56,222 meters, which needs approximately 1,125 acres for an AML of approximately 56 MTU/acre (see Section 6.3.1).

Within the emplacement area, five standby and cross-block drifts will be excavated within the pillars of adjacent emplacement drifts. The two standby drifts will be located within the first half of the emplacement drifts to be available early on for possible relocation of WPs. The three cross-block drifts will serve possible ventilation, monitoring, emergency egress, and/or Test and Evaluation program functions.

The Test and Evaluation Facility for the 70,000 MTU layout will consist of the two postclosure test drifts on the north end of the repository with the OD, and the performance monitoring Observation Drifts 2 and 3, along with the ECRB.

The Subsurface Ventilation System was analyzed within this document to determine the number of openings and respective sizes required to support the continuous ventilation rate of 15 m^3/s (see Section 6.3). In addition to the North and South Ramps, three intake shafts are required to supply the needed ventilation flow rates to the Subsurface Facility for the 70,000 MTU case. The Development Shaft, located in the vicinity of the South Main provides intake airflows for the construction and development operations in the Subsurface Facility and will not be required after construction and development is complete. Three exhaust shafts are required to exhaust air from the Subsurface Facility for the 70,000 MTU case. Exhaust Shaft 4, considered contingency only, will only be required in the event that excavation within the contingency area makes it necessary to support additional ventilation capacities.

7.2 97,000 MTU LAYOUT FOR SITE RECOMMENDATION

The MGR is also required to design for a WP inventory of 97,000 MTU of SNF/HLW, if authorized, for disposal in the primary area of the repository. The 97,000 MTU Layout for SR (see Figure 12) supports this WP inventory (see Section 6.4.1). The 97,000 MTU Layout for SR will require 90 emplacement drifts. Emplacement Drifts 1 through 78 are required for emplacement of the WP inventory. Emplacement Drifts 79 and 80 are excavated as an allowance for possible variances in the waste stream. Emplacement Drifts 81 through 90 are contingency drifts that will only be excavated in the event that conditions during development of the repository are found to be such that the intended emplacement area cannot be used due to unexpected ground conditions or for larger waste stream variations.

The required emplacement length for the 97,000 MTU Layout for SR calculated to accommodate the WP inventory is approximately 74,214 meters, which needs approximately 1,485 acres for an AML of approximately 56 MTU/acre (see Section 6.4.1).

Within the emplacement area, six standby and cross-block drifts will be excavated within the pillars of adjacent emplacement drifts. The two standby drifts will be located within the first half of the emplacement drifts to be available early on for possible relocation of WPs. The four cross-block drifts will perform possible ventilation, monitoring, emergency egress, and/or Test and Evaluation program functions.

The Test and Evaluation Facility for the 97,000 MTU layout will consist of the two postclosure test drifts on the north end of the repository with the OD, and the performance monitoring Observation Drifts 2, 3, and 4, along with the ECRB.

The Subsurface Ventilation System was analyzed within this document to determine the number of openings and respective sizes required to support the continuous ventilation rate of 15 m^3/s (see Section 6.4). In addition to the North and South Ramps, four intake shafts are required to supply the needed ventilation flow rates to the Subsurface Facility for the 97,000 MTU case. The Development/Intake Shaft, located in the vicinity of the South Main provides intake airflows for the construction and development operations in the Subsurface Facility and will be required as an intake shaft after construction and development is complete. Five exhaust shafts are required to exhaust air from the Subsurface Facility for the 97,000 MTU case. Exhaust Shaft 6, considered contingency only, will only be required in the event that excavation within the contingency area makes it necessary to support additional ventilation capacities.

7.3 EXPANSION CAPABILITIES OF THE SITE RECOMMENDATION LAYOUTS

The design of the repository must not preclude the capability of expansion and accommodation of a waste inventory of up to 115,000 MTU or equivalent. An area located to the east of the planning layout, at a lower elevation is available for this expansion (CRWMS M&O 2000bb) as discussed in Section 6.5. This siting area is referred to as the lower block. The layout of the lower block only encompassed sufficient area as to show the expansion capability of the current SR layouts. Consequently, the layout of the lower block was fully integrated with the design of the planning layout. The lower block layout is located approximately 40 meters and 130 meters below the elevation of the planning layout on the north and south ends of the primary block, respectively.

7.4 TO-BE-VERIFIED IMPACTS

The TBVs identified in Sections 4 and 5 are carried through to the outputs of this analysis as outlined in Table 65. In addition, the layouts for SR were developed using the VULCAN v3.4 software (CRWMS M&O 2000aa), that is considered unqualified and, therefore, the results of the layouts for SR are considered TBV. These results will be tracked with TBV-4208. The output of this analysis cannot be used for construction, procurement, or fabrication.

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

Table 65. To-Be-Verified Impacts

TBV Number	Description	Impact
TBV-0253	305 meter ramps and mains minimum radius – subsurface waste emplacement transportation system curvatures.	This minimum turning radius was used to configure the subsurface layout (see Section 6.2.1.1).
TBV-0286	The maximum acceptable temperature of the zeolites beneath the emplacement area needs to be determined along with the vertical distance from the emplacement area to the average top of the zeolite layer.	The thermal analysis used this constraint for defining the overall thermal output of the emplacement drifts (see Section 6.2.3.10).
TBV-0287	The requirements for the maximum temperature at the boundary of the emplacement drift needs to be determined in order to limit the thermal and thermomechanical response of the host rock and surrounding strata and groundwater system.	The thermal analysis used this constraint for defining the overall thermal output of the emplacement drifts (see Section 6.2.3.8).
TBV-0321	Criteria for maximum temperature for human access	This criterion was used as a basis for partitioning the Exhaust Main (see Section 6.2.4).
TBV-0322	The requirements limiting the temperature of the PTn geologic unit to less than 115 degrees Celsius need to be verified.	The thermal analysis used this constraint for defining the overall thermal output of the emplacement drifts (see Section 6.2.3.10).
TBV-0359	The repository opening standoff distances from the water table and Type I faults.	These constraints set the physical boundaries of the emplacement area (see Section 6.2.2).
TBV-0617	Temperature change at 45 centimeters below the soil surface to 2 degrees Celsius above the established naturally occurring pre-emplacement average annual ground surface.	The thermal analysis used this constraint for defining the overall thermal output of the emplacement drifts (see Section 6.2.3.11).
TBV-0618	The rate of uplift and total uplift of the repository overburden that will prevent damage to the natural barrier above the repository.	The thermal analysis used this constraint for defining the overall thermal output of the emplacement drifts (see Section 6.2.3.12 and Section 6.2.3.13).
TBV-0619	200 meter overburden.	This constraint sets a physical boundary of the emplacement area (see Section 6.2.2).

Table 65. To-Be-Verified Impacts (Continued)

TBV Number	Description	Impact
TBV-1014	Confirm the License Application Design Selection process that shielding for personnel protection will be provided on the surface and subsurface waste handling SSCs including the WP transporter rather than on the individual WPs.	The emplacement drift turnouts were configured to aid in reducing the direct line of radiation from an unshielded WP (see Section 6.2.1.2).
TBV-1016	Confirm that the doors are to be required at the entrances to emplacement drifts as the means to control personnel access and also serve as a ventilation damper	The emplacement drift turnouts have been configured to allow installation of doors (see Section 6.2.1.2).
TBV-1021	Confirm criteria on the Subsurface Configuration for water drainage to help minimize the opportunities for water to contact WPs after closure.	The emplacement drifts have been assigned a flat gradient to accommodate this criteria (see Section 6.2.1.2).
TBD-3791	The average WP spacing	The average minimum WP spacing of 0.1 meters was confirmed with the thermal analyses (see Section 6.2.3).
TBV-4183	WP inventory for 70,000 MTU	This inventory was used to calculate the required emplacement area for the 70,000 MTU Layout for SR (see Section 6.3.1).
TBV-4186	WP inventory for 97,000 MTU	This inventory was used to calculate the required emplacement area for the 97,000 MTU Layout for SR (see Section 6.4.1).
TBV-4187	VULCAN v3.4 model of the Yucca Mountain geology.	This information was used as the basis for the subsurface layout (see Section 6.1).
TBV-4208	VULCAN v3.4 three-dimensional representation of the planning layout and the lower block.	Results of this analysis.
TBV-4647	VULCAN v3.4 software	Use of unqualified software.
TBV-4708	Postclosure Peak Drift Wall Temperatures	This input transmittal provided information to show compliance with a thermal criterion (see Section 6.2.3.8)

7.5 CRITERION COMPLIANCE

Various design criteria were used in the process of completing this analysis. Other criteria, which have been discussed in the analysis, may not have been fully addressed and, therefore, were not met. A list of the criteria discussed in this analysis is presented in Table 66 with indications of where the discussion is located as well as whether the criteria was fully met.

Table 66. Criteria Summation

Criterion	Description	Criterion Documentation in Section	Criterion Discussion Located in Section	Adherence to Criteria
CRWMS M&O 2000e, Section 1.2.1.1	Waste Inventory Requirement	4.2.1.1	6.3.1, and 6.4.1	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.1.2	WP Quantities and Lengths	4.2.1.2	6.3.1	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.1.3	Emplacement Drift Diameter	4.2.1.3	6.2.1.2, 6.2.3.7, 6.3.2.2, and 6.4.2.2	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.1.4	WP Spacing	4.2.1.4	6.2.3.2, 6.3.1, and 6.4.1	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.1.5	Emplacement Drift Spacing	4.2.1.5	6.2.1.2, 6.2.3.7, 6.3.1, and 6.4.1	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.1.6	Limit Water Inflow in Ramps	4.2.1.6	6.2.5	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.1.7	Orientation of Emplacement Drifts	4.2.1.7	6.2.1.2 and 6.2.2.2	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.1.8	Test and Evaluation Program	4.2.1.8	6.2.1.3	Criterion has been met for major facilities. Details of minor facilities have not yet been included in the layout.
CRWMS M&O 2000e, Section 1.2.2.1.1	Unrestricted Access Radiation Level Limit	4.2.2.1	6.2.7	This criterion has not been evaluated at this time, however it is not anticipated that this calculation will adversely impact the design of the Subsurface Facility.
CRWMS M&O 2000e, Section 1.2.2.1.2	Restricted Access Radiation Level Limit	4.2.2.2	6.2.7	This criterion has not been evaluated at this time. It is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. It will be revisited when full operational aspects of the repository are available.
CRWMS M&O 2000e, Section 1.2.2.1.3	Locating surface Openings	4.2.2.3	6.2.4 and 6.2.5	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.2.1.4	Minimum Geologic Standoffs to Repository Openings	4.2.2.4	6.2.2 and 6.2.2.1	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.2.1.5	Geologic Standoff Distances for WPs	4.2.2.5	6.2.2.1	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.2.1.6	Standoff Distance to Surface Drilled Boreholes	4.2.2.6	6.2.6	This criterion has not been evaluated at this time because it requires knowledge of specific borehole locations. Potential impacts associated with applying this criterion have been discussed and contingency emplacement space provided.

Table 66. Criteria Summation (Continued)

Criterion	Description	Criterion Documentation in Section	Criterion Discussion Located in Section	Adherence to Criteria
CRWMS M&O 2000e, Section 1.2.2.1.7	Drainage	4.2.2.7	6.2.5	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.2.1.8	Location of the Repository Emplacement Area	4.2.2.8	6.2.2	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.2.1.9	Minimum Overburden Thickness	4.2.2.9	6.2.2	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.2.2.1	Escapeways	4.2.3.1	6.2.8	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.2.2.2	Refuge Chambers	4.2.3.2	6.2.8	This criterion has not been evaluated at this stage. The details of the locations and specifics of the personnel refuge chambers do not affect the design of the Subsurface Facility and will be addressed in the future.
CRWMS M&O 2000e, Section 1.2.2.2.3	Travel Time to Reach Refuge Chamber	4.2.3.3	6.2.8	This criterion has not been evaluated at this stage. The details of the locations and specifics of the personnel refuge chambers do not affect the design of the Subsurface Facility and will be addressed in the future.
CRWMS M&O 2000e, Section 1.2.4.1	Subsurface Ventilation System	4.2.4.1	6.2.4	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.4.2	Gradients	4.2.4.2	6.2.1.1 and 6.2.5	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.4.3	Opening Sizes	4.2.4.3	6.2.1.1	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.4.4 and CRWMS M&O 2000i, Section 1.2.3.2	Zeolitized Layer Temperature Limit	4.2.4.4	6.2.3.10	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.4.5 and CRWMS M&O 2000i, Section 1.2.3.3	Soil Surface Temperature Change	4.2.4.5	6.2.3.11	This criterion has not been evaluated. Analyses to verify that the layouts for SR will meet this criterion will be conducted in the future.
CRWMS M&O 2000e, Section 1.2.4.6 and CRWMS M&O 2000i, Section 1.2.3.4	Temperature Limit on the PTn Geologic Unit	4.2.4.6	6.2.3.10	Criterion has been met.
CRWMS M&O 2000e, Section 1.2.4.7	Opening Orientations	4.2.4.7	6.2.1.1	Criterion has been met.

Table 66. Criteria Summation (Continued)

Criterion	Description	Criterion Documentation in Section	Criterion Discussion Located in Section	Adherence to Criteria
CRWMS M&O 2000e, Section 1.2.4.8 and CRWMS M&O 2000i, Section 1.2.3.5	Uplift Limit of the TSw1 Unit	4.2.4.8	6.2.3.12	Criterion has been met. It is expected that the ground deflection will not exceed the differential uplift limit in the TSw1 geologic unit.
CRWMS M&O 2000e, Section 1.2.4.9	Interface with the Subsurface Excavation System	4.2.4.9	6.2.9	Criterion has been met.
CRWMS M&O 2000h, Section 1.2.4.7	Emplacement Drift and Turnout Interface	4.2.4.10	6.2.1.2	Criterion has been met.
CRWMS M&O 2000h, Section 1.2.4.6	Opening Curvatures	4.2.4.11	6.2.1.1 and 6.2.1.2	Criterion has been met.
CRWMS M&O 2000b, Section 1.2.1.3	Air Temperature for Human Access	4.2.4.12	6.2.4	Criterion has been met.
CRWMS M&O 2000j, Section 5.1.1.1	Preclosure and Postclosure Time Periods	4.2.4.13	6.2.3.4	Criterion has been met.
CRWMS M&O 2000i, Section 1.2.4.4	WP Maximum Thermal Output	4.2.4.14	6.2.3.3	Criterion has been met.
CRWMS M&O 2000i, Section 1.2.4.5	WP Heat Removal During Preclosure	4.2.4.15	6.2.3.4	Criterion has been met.
CRWMS M&O 2000i, Section 1.2.1.3	Preclosure Emplacement Drift Wall Temperature	4.2.4.17	6.2.3.5	Criterion has been met.
CRWMS M&O 2000i, Section 1.2.1.4	Postclosure Pillar Temperature	4.2.4.18	6.2.3.7	Criterion has been met.
CRWMS M&O 2000i, Section 1.2.3.1	Postclosure Emplacement Drift Wall Temperature	4.2.4.20	6.2.3.8	Criterion has been met.
CRWMS M&O 2000i, Section 1.2.3.6	TSw1 Thermomechanical Unit Differential Uplift Rate	4.2.4.21	6.2.3.13	This criterion has not been evaluated. Analyses to verify that the layouts for SR will meet this criterion will be conducted in the future.
CRWMS M&O 2000e, Section 1.2.6.1	Occupational Safety and Health Standards	4.3.1	6.2.8	This criterion has not been evaluated. Analyses to verify that the layouts for SR will meet this criterion will be conducted in the future.

Table 66. Criteria Summation (Continued)

Criterion	Description	Criterion Documentation in Section	Criterion Discussion Located in Section	Adherence to Criteria
CRWMS M&O 2000e, Section 1.2.6.2	Safety and Health Regulations for Construction	4.3.2	6.2.8	This criterion has not been evaluated. Analyses to verify that the layouts for SR will meet this criterion will be conducted in the future.
CRWMS M&O 2000e, Section 1.2.2	Standards for Protection Against Radiation	4.3.3	4.2.2 and 6.2.7	This criterion has not been evaluated. Analyses to verify that the layouts for SR will meet this criterion will be conducted in the future.
CRWMS M&O 2000e, Section 1.2.6.3	Monitored Geologic Repository Project Description Document	4.3.4	4.2 and 5.1	Criterion has been met.

8. INPUTS AND REFERENCES

8.1 DOCUMENTS CITED

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8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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29 CFR 1910. Labor: Occupational Safety and Health Standards. Readily Available

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ATTACHMENT I

AVAILABLE EMPLACEMENT DRIFT LENGTH FOR THE PLANNING LAYOUT

ATTACHMENT I

AVAILABLE EMPLACEMENT DRIFT LENGTH FOR THE PLANNING LAYOUT

The length of the emplacement drifts represented in Table I-1 is from the door of the emplacement drift on the east side to the door of the emplacement drift on the west side as extracted from the *Subsurface Planning Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000aa) using VULCAN v3.4. The operational standoff distance is the distance from the door of the emplacement drift to the last WP emplaced in the drift is 1.5 meters on each end of the emplacement drift (see Section 5.2.3). A total operational standoff distance of 3.0 meters is therefore applied to each emplacement drift The ventilation standoff is a physical standoff established to minimize the interference of the ventilation airflow and/or radiological monitoring around the ventilation raise (see Section 5.2.6). The other unusable length accounts for the maximum effective emplacement length of 600 meters in a drift split (see Section 5.2.4). Any drift that would have a drift split in excess of 600 meters is decreased accordingly. The drift length available for emplacement is the usable length of each Emplacement Length. The usable length is calculated as the excavation lengths of each drift less the total standoff lengths and the unusable length for each drift (see Table I-1). The cumulative usable emplacement lengths are also shown in Table I-1. The 90 emplacement drifts provide approximately 83,477 meters of available emplacement drift length.

Table I-1. Available Emplacement Drift Length for Planning Layout

Drift Number	Length (m)	WP Standoff[a] (m)	Vent Standoff[b] (m)	Other Unusable Length[c] (m)	Available Emplacement Drift Length (m)	Cumulative Available Emplacement Drift Length (m)	Comments
PC 1	697.2	3.0	4.0	690.2	0.0	0.0	
PC 2	741.7	3.0	4.0	734.7	0.0	0.0	
1	781.1	3.0	4.0	0.0	774.1	774.1	
2	820.4	3.0	4.0	0.0	813.4	1,587.5	
3	859.7	3.0	4.0	0.0	852.7	2,440.2	
4	899.0	3.0	4.0	0.0	892.0	3,332.2	
5	938.3	3.0	4.0	0.0	931.3	4,263.5	
6	977.7	3.0	4.0	0.0	970.7	5,234.2	
7	1,017.0	3.0	4.0	0.0	1,010.0	6,244.2	
8	1,056.3	3.0	4.0	0.0	1,049.3	7,293.5	
9	1,095.6	3.0	4.0	0.0	1,088.6	8,382.1	
10	1,134.9	3.0	4.0	0.0	1,127.9	9,510.0	
11	1,174.3	3.0	4.0	0.0	1,167.3	10,677.3	
12	1,230.0	3.0	4.0	23.0	1,200.0	11,877.3	see Note [c]
13	1,263.5	3.0	4.0	56.5	1,200.0	13,077.3	see Note [c]
14	1,263.5	3.0	4.0	56.5	1,200.0	14,277.3	see Note [c]
15	1,263.5	3.0	4.0	56.5	1,200.0	15,477.3	see Note [c]
16	1,263.5	3.0	4.0	56.5	1,200.0	16,677.3	see Note [c]
17	1,263.5	3.0	4.0	56.5	1,200.0	17,877.3	see Note [c]
18	1,263.5	3.0	4.0	56.5	1,200.0	19,077.3	see Note [c]
19	1,263.5	3.0	4.0	56.5	1,200.0	20,277.3	see Note [c]
20	1,263.5	3.0	4.0	56.5	1,200.0	21,477.3	see Note [c]
21	1,263.5	3.0	4.0	56.5	1,200.0	22,677.3	see Note [c]
22	1,263.5	3.0	4.0	56.5	1,200.0	23,877.3	see Note [c]
23	1,263.5	3.0	4.0	56.5	1,200.0	25,077.3	see Note [c]
24	1,263.5	3.0	4.0	56.5	1,200.0	26,277.3	see Note [c]
25	1,263.5	3.0	4.0	56.5	1,200.0	27,477.3	see Note [c]
26	1,263.5	3.0	4.0	56.5	1,200.0	28,677.3	see Note [c]
27	1,263.5	3.0	4.0	56.5	1,200.0	29,877.3	see Note [c]
28	1,263.5	3.0	4.0	56.5	1,200.0	31,077.3	see Note [c]
29	1,263.5	3.0	4.0	56.5	1,200.0	32,277.3	see Note [c]
Subtotal	34,902.7	93.0	124.0	2,408.4	32,277.3		

Table I-1. Available Emplacement Drift Length for Planning Layout (Continued)

Drift Number	Length (m)	WP Standoff[a] (m)	Vent Standoff[b] (m)	Other Unusable Length[c] (m)	Available Emplacement Drift Length (m)	Cumulative Available Emplacement Drift Length (m)	Comments
30	1,263.5	3.0	4.0	56.5	1,200.0	33,477.3	see Note [c]
31	1,263.5	3.0	4.0	56.5	1,200.0	34,677.3	see Note [c]
32	1,263.8	3.0	4.0	56.8	1,200.0	35,877.3	see Note [c]
33	1,248.5	3.0	4.0	41.5	1,200.0	37,077.3	see Note [c]
34	1,233.1	3.0	4.0	26.1	1,200.0	38,277.3	see Note [c]
35	1,217.8	3.0	4.0	10.8	1,200.0	39,477.3	see Note [c]
36	1,202.4	3.0	4.0	0.0	1,195.4	40,672.7	
37	1,187.1	3.0	4.0	0.0	1,180.1	41,852.8	
38	1,171.7	3.0	4.0	0.0	1,164.7	43,017.5	
39	1,156.4	3.0	4.0	0.0	1,149.4	44,166.9	
40	1,141.1	3.0	4.0	0.0	1,134.1	45,301.0	
41	1,125.7	3.0	4.0	0.0	1,118.7	46,419.7	
42	1,110.4	3.0	4.0	0.0	1,103.4	47,523.1	
43	1,095.0	3.0	4.0	0.0	1,088.0	48,611.1	
44	1,079.7	3.0	4.0	0.0	1,072.7	49,683.8	
45	1,064.3	3.0	4.0	0.0	1,057.3	50,741.1	
46	1,049.0	3.0	4.0	0.0	1,042.0	51,783.1	
47	1,033.6	3.0	4.0	0.0	1,026.6	52,809.7	
48	1,018.3	3.0	4.0	0.0	1,011.3	53,821.0	
49	1,002.9	3.0	4.0	0.0	995.9	54,816.9	
50	987.6	3.0	4.0	0.0	980.6	55,797.5	
51	972.2	3.0	4.0	0.0	965.2	56,762.7	
52	956.9	3.0	4.0	0.0	949.9	57,712.6	
53	941.5	3.0	4.0	0.0	934.5	58,647.1	
54	926.2	3.0	4.0	0.0	919.2	59,566.3	
55	910.8	3.0	4.0	0.0	903.8	60,470.1	
56	895.5	3.0	4.0	0.0	888.5	61,358.6	
57	880.1	3.0	4.0	0.0	873.1	62,231.7	
58	864.8	3.0	4.0	0.0	857.8	63,089.5	
59	849.4	3.0	4.0	0.0	842.4	63,931.9	
Subtotal	67,015.5	183.0	244.0	2,656.6	63,931.9		

Table I-1. Available Emplacement Drift Length for Planning Layout (Continued)

Drift Number	Length (m)	WP Standoff[a] (m)	Vent Standoff[b] (m)	Other Unusable Length[c] (m)	Available Emplacement Drift Length (m)	Cumulative Available Emplacement Drift Length (m)	Comments
60	834.1	3.0	4.0	0.0	827.1	64,759.0	
61	796.2	3.0	4.0	0.0	789.2	65,548.2	
62	739.0	3.0	4.0	0.0	732.0	66,280.2	
63	681.8	3.0	4.0	0.0	674.8	66,955.0	
64	333.5	3.0	4.0	0.0	326.5	67,281.5	
65	333.5	3.0	4.0	0.0	326.5	67,608.0	
66	333.5	3.0	4.0	0.0	326.5	67,934.5	
67	335.4	3.0	4.0	0.0	328.4	68,262.9	
68	352.8	3.0	4.0	0.0	345.8	68,608.7	
69	384.7	3.0	4.0	0.0	377.7	68,986.4	
70	415.4	3.0	4.0	0.0	408.4	69,394.8	
71	458.5	3.0	4.0	0.0	451.5	69,846.3	
72	513.4	3.0	4.0	0.0	506.4	70,352.7	
73	568.3	3.0	4.0	0.0	561.3	70,914.0	
74	623.1	3.0	4.0	0.0	616.1	71,530.1	
75	678.0	3.0	4.0	0.0	671.0	72,201.1	
76	732.8	3.0	4.0	0.0	725.8	72,926.9	
77	787.7	3.0	4.0	0.0	780.7	73,707.6	
78	845.4	3.0	4.0	0.0	838.4	74,546.0	
79	861.4	3.0	4.0	0.0	854.4	75,400.4	
80	848.1	3.0	4.0	0.0	841.1	76,241.5	
81	826.7	3.0	4.0	0.0	819.7	77,061.2	
82	805.3	3.0	4.0	0.0	798.3	77,859.5	
83	784.0	3.0	4.0	0.0	777.0	78,636.5	
84	762.6	3.0	4.0	0.0	755.6	79,392.1	
85	741.2	3.0	4.0	0.0	734.2	80,126.3	
86	719.8	3.0	4.0	0.0	712.8	80,839.1	
87	698.5	3.0	4.0	0.0	691.5	81,530.6	
88	677.1	3.0	4.0	0.0	670.1	82,200.7	
89	655.7	3.0	4.0	0.0	648.7	82,849.4	
90	634.4	3.0	4.0	0.0	627.4	83,476.8	
Subtotal	86,777.4	276.0	368.0	2,656.6	83,476.8		

Notes:

[a] An operational standoff distance of 3 meters to the WP is used (see Section 5.2.3)

[b] A total physical standoff distance of 4 meters about the ventilation raise is used (see Section 5.2.6)

[c] The maximum length of a drift split is restricted to 600 meters (see Section 5.2.4)

ATTACHMENT II

PLANNING LAYOUT DETAILS

ATTACHMENT II

PLANNING LAYOUT DETAILS

The VULCAN v3.4 software program provides a three dimensional design of the subsurface layout to be prepared. In order to provide specific information about the planning layout as illustrated in Figure 3, key reference points within the layout are used to describe the lengths and grades of the various subsurface openings.

Figure II-1 presents a set of reference points within the Subsurface Facility. The definitions of these reference points are listed in Table II-1, complete with the coordinates and elevations.

The details of the subsurface openings lengths and grades, corresponding to the reference points presented in Figure II-1 and outlined in Table II-1, are presented in Table II-2. The information in this attachment was extracted from the *Subsurface Planning Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000aa) using VULCAN v3.4.

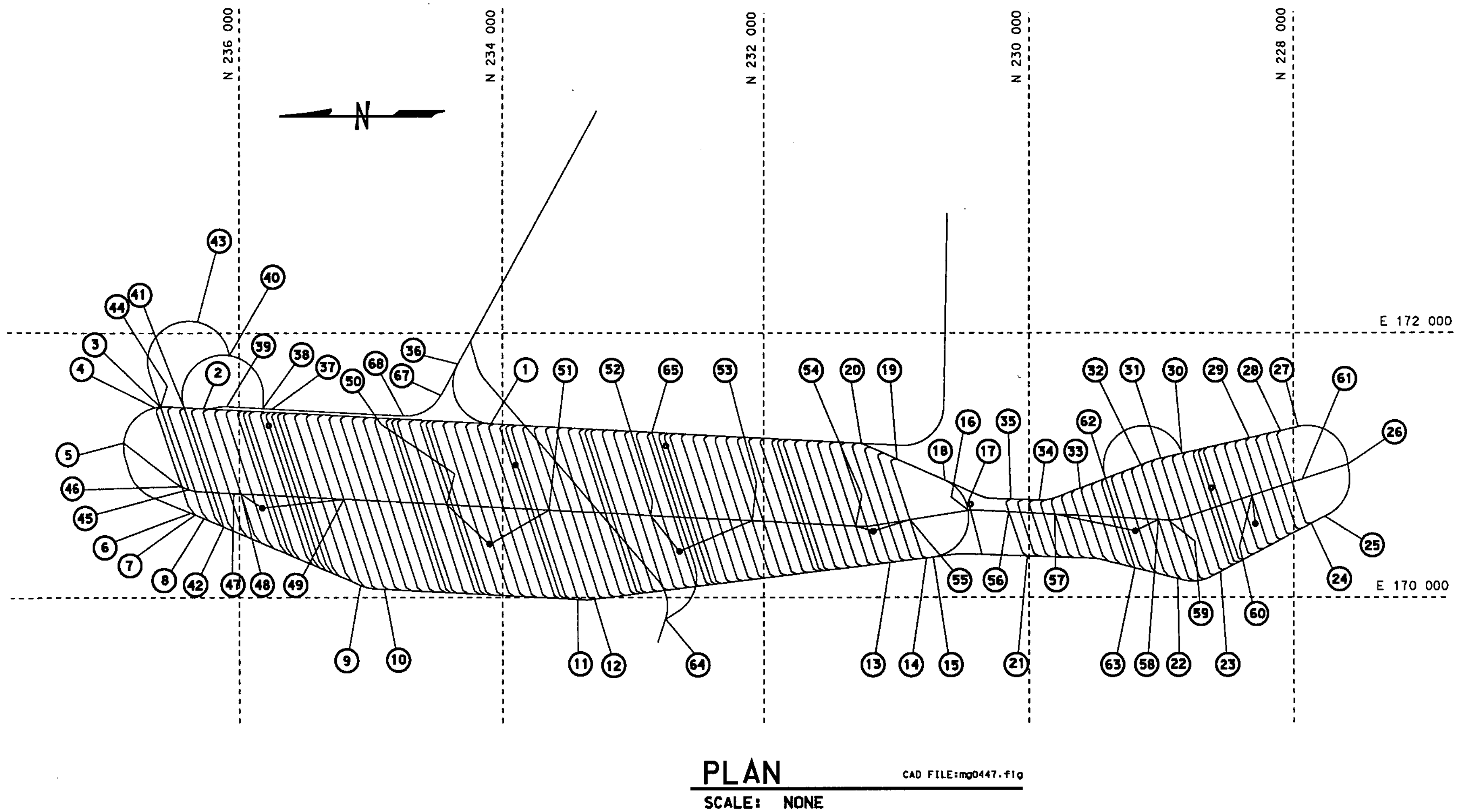

Figure II-1. Planning Layout Details

Table II-1. Point Designation Definitions

Point Designation	Description	Northing (m)	Easting (m)	Elevation (m)
1	Bottom of northern curve of the ESF loop	234,087.742	171,313.778	1,065.000
2	Intersection of the East Main North Extension and the North Ramp Extension	236,265.995	171,427.935	1,035.553
3	Intersection of the centerline of the east turnout of Post Closure Test Drift #1 and the East Main North Extension	236,584.156	171,441.857	1,031.253
4	Grade break in the North Main	236,624.569	171,435.799	1,030.700
5	Intersection of the North Main and the Exhaust Main	236,862.588	171,169.724	1,022.806
6	Grade break in the North Main	236,365.524	170,638.542	1,030.700
7	Intersection of the centerline of the west turnout of Post Closure Test Drift #1 and the West Main	236,332.334	170,624.454	1,031.079
8	Grade break in the West Main	236,266.730	170,596.606	1,031.828
9	Grade break in the West Main	235,081.200	170,093.379	1,045.884
10	Grade break in the West Main	234,900.977	170,062.952	1,048.226
11	Grade break in the West Main	233,428.032	169,985.759	1,068.139
12	Grade break in the West Main	233,300.734	169,987.157	1,069.896
13	Grade break in the West Main	231,048.457	170,263.702	1,102.106
14	Intersection of the centerline of the west turnout for Emplacement Drift # 63 and the West Main	230,771.546	170,297.702	1,105.592
15	Intersection of the South Main and the West Main	230,720.853	170,303.926	1,106.230
16	Intersection of the Exhaust Main and the South Main	230,456.966	170,655.489	1,096.782
17	Intersection of access to the Contingency Development Shaft and the South Main	230,466.350	170,695.826	1,097.404
18	Intersection of the East Main South Extension and the South Main	230,633.968	170,885.284	1,101.316
19	Intersection of the centerline of the east turnout for Emplacement Drift # 63 and the East Main South Extension	230,993.486	171,045.352	1,105.895
20	Intersection of the East Main and East Main South Extension	231,263.998	171,165.792	1,103.173
21	Intersection of the West Main and the centerline of the west turnout of Emplacement Drift # 64	230,011.802	170,311.217	1,110.757
22	Grade break in the West Main	228,879.123	170,140.217	1,116.515
23	Grade break in the West Main	228,554.967	170,191.053	1,112.270
24	Intersection of the West Main and the centerline of the west turnout of Emplacement Drift #90	227,866.605	170,557.062	1,099.796
25	Grade break in the South End Main	227,763.800	170,611.724	1,097.933

Table II-1. Point Designation Definitions (Continued)

Point Designation	Description	Northing (m)	Easting (m)	Elevation (m)
26	Intersection of the South End Main and the Exhaust Main	227,587.993	171,005.323	1,086.317
27	Grade break in the South End Main	227,963.024	171,291.286	1,097.711
28	Intersection of the East Main South Extension and the centerline of the east turnout of Emplacement Drift # 90	228,097.714	171,260.190	1,099.908
29	Grade break in the East Main South Extension	228,335.390	171,205.318	1,103.785
30	Intersection of the East Main South Extension and the contingency Test and Evaluation Program Observation Drift #4	228,843.773	171,087.949	1,112.230
31	Grade break in the East Main South Extension	229,004.654	171,050.806	1,114.526
32	Grade break in the East Main South Extension	229,158.348	170,999.582	1,116.515
33	Grade break in the East Main South Extension	229,612.690	170,825.177	1,113.650
34	Grade break in the East Main South Extension	229,923.676	170,733.806	1,111.898
35	Intersection of the East Main South Extension and the centerline of the east turnout of Emplacement Drift # 64	230,135.984	170,741.220	1,110.836
36	Top of northern curve of the ESF loop	234,338.604	171,766.109	1,078.265
37	Point on the North Ramp Extension	235,749.672	171,425.374	1,045.061
38	Intersection of the North Ramp Extension and the Test and Evaluation Program Observation Drift #2	235,821.357	171,429.131	1,043.581
39	Grade break in the North Ramp Extension	236,093.936	171,443.416	1,037.950
40	Intersection of the Test and Evaluation Program Observation Drift # 2 and Observation Drift # 1	236,073.430	171,831.000	1,047.091
41	Point in the Test and Evaluation Program Observation Drift #2 where it crosses over the East Main North Extension	236,411.572	171,435.564	1,051.205
42	End of the Test and Evaluation Program Observation Drift # 2	236,118.539	170,533.703	1,055.947
43	Grade break in the Test and Evaluation Program Observation Drift # 1	236,313.235	172,084.816	1,038.259
44	Point in the Test and Evaluation Program Observation Drift #1 where it crosses under the East Main North Extension	236,583.958	171,441.873	1,015.755
45	Intersection of the Exhaust Main and the Test and Evaluation Program Observation Drift # 1	236,380.351	170,815.233	1,009.698
46	Grade break in the Exhaust Main	236,431.576	170,837.746	1,009.200
47	Grade break in the Exhaust Main	236,040.048	170,786.317	1,012.740

Table II-1. Point Designation Definitions (Continued)

Point Designation	Description	Northing (m)	Easting (m)	Elevation (m)
48	Intersection of the Exhaust Main and Access #1 to Exhaust Shaft #1	235,986.790	170,783.526	1,013.470
49	Intersection of the Exhaust Main and Access #2 to Exhaust Shaft #1	235,206.995	170,742.658	1,024.169
50	Intersection of the Exhaust Main and Access #1 to Exhaust Shaft #2	234,427.200	170,701.791	1,034.867
51	Intersection of the Exhaust Main and Access #2 to Exhaust Shaft #2	233,647.406	170,660.924	1,045.565
52	Intersection of the Exhaust Main and Access #1 to Exhaust Shaft #3	232,867.610	170,620.057	1,056.263
53	Intersection of the Exhaust Main and Access #2 to Exhaust Shaft #3	232,087.816	170,579.189	1,066.961
54	Intersection of the Exhaust Main and Access #1 to Exhaust Shaft #4	231,308.021	170,538.322	1,079.157
55	Intersection of the Exhaust Main and Access #2 to Exhaust Shaft #4	230,897.576	170,585.703	1,085.630
56	Grade break in the Exhaust Main	230,150.688	170,646.112	1,090.532
57	Intersection of the Exhaust Main and Access #1 to Exhaust Shaft #5	229,804.113	170,627.949	1,088.659
58	Intersection of the Exhaust Main and Access #2 to Exhaust Shaft #5	229,024.318	170,587.081	1,084.445
59	Grade break in the Exhaust Main	228,950.000	170,583.207	1,084.041
60	Intersection of the Exhaust Main and Access to Exhaust Shaft #6 (Contingency Shaft)	228,316.759	170,768.533	1,079.850
61	Grade break in the Exhaust Main	227,931.581	170,893.685	1,077.285
62	Point in the Contingency Test and Evaluation Program Observation Drift #4 where it crosses over the East Main South Extension	229,423.381	170,897.846	1,132.464
63	End of the Contingency Test and Evaluation Program Observation Drift # 4	229,203.490	170,221.090	1,136.022
64	Intersection of the ECRB and the start of the Test and Evaluation Program Observation Drift #3	232,755.308	169,837.596	1,108.566
65	End of the Test and Evaluation Program Observation Drift # 3	232,859.174	171,249.391	1,104.228
66	NOT USED			
67	Top of the curve in the North Ramp Extension	234,469.347	171,529.950	1,072.697
68	Bottom of the curve in the North Ramp Extension	234,752.146	171,373.096	1,065.666

Table II-2. Planning Layout Details

From Point	To Point	Slope Length (m)	Plan Length (m)	Grade (%)
1	2	2,181.4	2,181.2	-1.35
2	3	359.5	359.5	-1.35
3	4	40.9	40.9	-1.35
4	5	381.4	381.4	-2.07
5	6	798.4	798.4	0.99
6	7	36.1	36.1	1.05
7	8	70.3	70.3	1.05
8	9	1,287.9	1,288.0	1.09
9	10	184.2	184.2	1.27
10	11	1,475.1	1,475.0	1.35
11	12	127.6	127.6	1.38
12	13	2,269.4	2,269.2	1.42
13	14	279.0	279.0	1.25
14	15	51.1	51.1	1.25
15	16	491.0	490.9	-1.92
16	17	41.5	41.4	1.50
17	18	260.9	260.8	1.50
18	19	393.6	393.5	1.16
19	20	296.1	296.1	-0.92
15	21	710.8	710.8	0.64
21	22	1,151.5	1,151.5	0.50
22	23	340.7	340.7	-1.25
23	24	779.7	779.6	-1.60
24	25	116.4	116.4	-1.60
25	26	471.2	471.1	-2.47
26	27	537.4	537.2	2.12
27	28	138.2	138.2	1.59
28	29	244.0	243.9	1.59
29	30	521.8	521.8	1.62
30	31	165.1	165.1	1.39
31	32	162.3	162.3	1.23
32	33	486.7	486.7	-0.59
33	34	326.7	326.7	-0.54

Table II-2. Planning Layout Details (Continued)

From Point	To Point	Slope Length (m)	Plan Length (m)	Grade (%)
34	35	212.4	212.4	-0.50
35	18	525.9	525.9	-1.81
36	37	1,610.0	1,609.7	-2.06
37	38	71.8	71.8	-2.06
38	39	273.0	273.0	-2.06
39	2	173.4	173.3	-1.38
38	40	531.6	531.6	0.66
40	41	623.2	623.2	0.66
41	42	948.3	948.3	0.50
40	43	371.9	371.8	-2.38
43	44	900.4	900.2	-2.50
44	45	658.9	658.9	-0.92
5	46	544.4	544.2	-2.50
46	45	56.0	56.0	0.89
45	47	342.4	342.3	0.89
47	48	53.3	53.3	1.37
48	49	780.9	780.9	1.37
49	50	780.9	780.9	1.37
50	51	780.9	780.9	1.37
51	52	780.9	780.9	1.37
52	53	780.9	780.9	1.37
53	54	781.0	780.9	1.56
54	55	414.4	414.4	1.56
55	16	446.2	446.1	2.50
16	56	306.9	306.8	-2.04
56	57	347.1	347.1	-0.54
57	58	780.9	780.9	-0.54
58	59	74.4	74.4	-0.54
59	60	662.6	662.0	-0.63
60	61	405.0	405.0	-0.63
61	26	361.4	361.3	2.50
30	62	956.7	956.5	2.12
62	63	711.6	711.6	0.50
64	65	1,567.9	1,567.9	-0.28
36	67	270.0	269.9	-2.06
67	68	340.9	340.8	-2.06
68	37	999.1	998.9	-2.06

ATTACHMENT III

SURFACE-BASED BOREHOLES

ATTACHMENT III

SURFACE-BASED BOREHOLES

The Subsurface Facility must allow at least a 5-meter standoff from the edge of the WPs to the perpendicular projection of the centerline of a surface-based borehole if the borehole intercepts the drift or comes within 5 meters of the edge of the drift (see Section 4.2.2.6).

The point features of the Yucca Mountain Project boreholes are documented in the Technical Data Management System as indicated in Section 4.1.2. These boreholes include holes that are considered qualified and some that are considered non-qualified. The boreholes are listed in Table III-1. The coordinates of the boreholes are expressed in Nevada State Plane Feet, the collar elevation is expressed in feet above sea level, and the total depth is expressed in feet from the collar elevation.

In order to determine which boreholes may affect the subsurface layout, the boreholes listed in Table III-1 must be converted to Nevada State Plane Meters, meters above sea level, and depth in meters. This conversion is easily accomplished knowing that 3.2808 feet equals 1 meter. The boreholes can then be sorted to determine which fall within the Northing and Easting boundaries of the planning layout, as well as pass through the plane of the repository itself.

The planning layout as illustrated in Figure 3 can be bounded by 227,750 meters north, 236,900 meters north, 169,950 meters east, and 171,500 meters east. These Northing and Easting boundaries are used to eliminate any boreholes that are not in the vicinity of the Subsurface Facility.

The repository horizon in the primary area lies within a lower elevation of 1,022 meters and an upper elevation of 1,120 meters. The highest elevation of 1,120 meters will be used as a discriminator to eliminate those boreholes that do not pass through the repository horizon.

The boreholes listed in Table III-2 have been determined to be within the vicinity of the Subsurface Facility and pass through the repository horizon using the discriminators listed above.

The discussion of integrating the surface-based boreholes with the Subsurface Facility is further discussed in Section 6.2.6.

Table III-1. Surface-Based Boreholes

Borehole Identifier	Elevation (feet)	Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
U-5 Seismic #1	3,868.360	140.00	668,101.062	749,607.375	Q
U-5 Seismic #2	3,867.050	140.00	668,123.188	749,624.438	Q
USW Seismic-1	5,101.780	200.00	560,432.562	778,958.812	Q
USW Seismic-2	5,106.740	200.00	560,362.625	779,090.562	Q
USW Seismic-3	5,111.460	200.00	560,268.312	779,266.625	Q
USW Seismic-4	5,114.020	200.00	560,173.000	779,442.625	Q
USW Seismic-5	5,121.310	200.00	560,079.500	779,619.125	Q
USW Seismic-7	5,141.700	200.00	559,891.312	779,972.000	Q
USW Seismic-8	5,153.020	200.00	559,796.438	780,147.625	Q
USW Seismic-9	5,161.690	200.00	559,702.125	780,320.500	Q
USW Seismic-10	5,171.210	200.00	559,604.688	780,502.250	Q
USW Seismic-11	5,179.400	200.00	559,513.500	780,677.312	Q
USW Seismic-12	5,185.200	200.00	559,419.688	780,851.438	Q
USW Seismic-13	5,085.570	200.00	560,645.812	778,560.750	Q
USW Seismic-14	5,076.100	200.00	560,740.750	778,383.250	Q
USW Seismic-15	5,063.910	200.00	560,834.062	778,209.062	Q
USW Seismic-16	5,051.360	200.00	560,928.875	778,033.250	Q
USW Seismic-17	5,039.540	200.00	561,023.938	777,856.625	Q
USW Seismic-18	5,027.610	200.00	561,118.000	777,681.250	Q
USW Seismic-19	5,014.410	200.00	561,211.625	777,504.375	Q
U-25 Seismic #20	3,357.000	140.00	593,171.938	747,172.875	Q
U-25 Seismic #21	3,524.580	140.00	569,427.625	746,906.312	Q
U-25 Seismic #22	2,947.370	140.00	581,268.500	718,335.000	Q
U-25 Seismic #23	3,215.660	140.00	580,246.688	741,126.062	Q
U-25 Seismic #24	3,554.120	140.00	580,907.250	769,057.312	Q
U-25 TC #1	3,753.740	30.00	612,897.750	756,483.875	Q
U-25 TC #2	3,753.790	30.00	612,899.125	756,486.312	Q
U-25 TCi #1	3,790.120	5.00	613,452.750	756,777.062	Q
U-25 TCi #2	3,790.110	5.00	613,451.125	756,779.250	Q
U-25 TCi #3	3,790.050	5.00	613,436.438	756,783.000	Q
U-25 TCi #4	3,790.110	5.00	613,438.750	756,784.375	Q
U-26 Seismic #1	3,847.750	140.00	629,834.125	746,151.312	Q
U-29 Seismic #1	3,877.830	142.00	585,139.938	791,869.125	Q
U-30 Seismic #1	4,754.400	142.00	604,819.938	837,368.812	Q
U-30 Seismic #2	4,751.880	140.00	604,800.625	837,375.375	Q
UE-1 m	4,478.130	514.00	657,843.125	825,408.688	Q
UE-1 n	4,483.230	5.00	657,761.875	825,330.250	Q
UE-1 o	4,480.070	5.00	657,757.000	825,418.688	Q
UE-1 p	4,231.960	782.00	662,294.250	826,268.812	Q
UE-16 c	4,726.530	144.00	644,558.875	844,957.688	Q
UE-16 d	4,685.820	2,321.00	646,567.812	844,877.312	Q
UE-16 f	4,651.450	1,479.00	648,842.125	832,352.938	Q
UE-17 a	4,696.630	1,214.00	645,992.500	846,138.062	Q
UE-17 b	4,783.340	256.50	646,471.500	849,216.250	Q
UE-17 c	4,833.450	586.00	650,048.000	857,444.438	Q
UE-17 d	4,680.730	398.00	647,789.188	847,189.000	Q
UE-17 e	4,934.250	3,000.00	646,448.812	853,205.000	Q
UE-17 f	4,929.900	100.00	646,032.375	853,321.625	Q

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
UE-17 g	4,929.750	104.00	646,515.312	853,291.750	Q
UE-17 SI #1	4,931.860	110.00	646,487.750	853,331.250	Q
UE-17 SI #2	4,931.880	92.50	646,488.125	853,333.125	Q
UE-17 SI #3	4,931.840	115.00	646,489.750	853,330.812	Q
UE-17 SI #4	4,931.890	92.50	646,485.812	853,331.438	Q
UE-17 SI #5	4,931.880	83.50	646,488.438	853,335.062	Q
UE-17 SI #6	4,931.870	80.00	646,491.750	853,330.438	Q
UE-17 SI #7	4,931.850	82.50	646,487.062	853,327.188	Q
UE-17 SI #8	4,931.880	77.50	646,484.500	853,328.938	Q
UE-17 SI #8a	4,931.870	60.00	646,478.812	853,324.812	Q
UE-17 SI #9	4,931.880	80.00	646,483.812	853,331.812	Q
UE-17 SI #10	4,931.880	84.50	646,489.062	853,338.000	Q
UE-17 SI #11	4,931.840	82.50	646,486.562	853,324.188	Q
UE-17 SI #11a	4,931.790	60.00	646,485.875	853,320.312	Q
UE-17 SI #12	4,931.880	77.50	646,480.938	853,332.312	Q
UE-17 SI #13	4,931.880	84.50	646,489.688	853,342.000	Q
UE-17 SI #14	4,931.890	80.00	646,498.562	853,329.188	Q
UE-17 SI #15	4,931.890	77.50	646,476.812	853,333.062	Q
UE-17 SI #16	4,931.290	84.00	646,495.438	853,374.438	Q
UE-17 TH #1	4,931.980	80.00	646,479.188	853,343.438	Q
UE-17 TH #2	4,931.980	80.00	646,477.938	853,345.188	Q
UE-17 TH #3	4,931.840	80.00	646,478.812	853,349.188	Q
UE-17 TH #4	4,931.770	80.00	646,491.750	853,352.625	Q
UE-17 TH #5	4,931.800	80.00	646,492.000	853,354.562	Q
UE-22 ARMY #1	3,153.350	1,945.00	684,772.938	670,903.125	Q
UE-25 a #1	3,935.350	2,501.00	566,349.875	764,901.000	Q
UE-25 a #3	4,548.900	2,530.00	602,940.688	769,318.938	Q
UE-25 a #4	4,102.040	500.00	564,471.875	767,972.375	Q
UE-25 a #5	4,060.570	487.00	564,755.188	766,956.438	Q
UE-25 a #6	4,053.270	500.00	564,500.875	765,899.875	Q
UE-25 a #7	4,005.580	1,002.00	565,468.312	766,250.000	Q
UE-25 b #1	3,939.280	4,003.00	566,416.188	765,244.312	Q
UE-25 c #1	3,708.490	3,000.00	569,680.562	757,096.750	Q
UE-25 c #2	3,714.090	3,000.00	569,633.938	756,849.625	Q
UE-25 c #3	3,714.410	3,000.00	569,554.938	756,910.875	Q
UE-25 h #1	3,407.590	400.00	574,462.312	748,352.688	Q
UE-25 J-11	3,443.060	1,329.00	611,768.000	740,968.750	Q
UE-25 J-11Prime	3,441.940	220.00	611,821.812	740,890.938	Q
UE-25 J-12	3,129.840	1,139.00	581,012.062	733,508.250	Q
UE-25 J-13	3,317.400	3,498.00	579,647.938	749,202.000	Q
UE-25 JF #3	3,098.420	1,298.00	581,179.438	730,875.375	Q
UE-25 NRG #2	3,800.370	294.00	569,162.438	765,763.750	Q
UE-25 NRG #2a	3,780.550	266.00	569,001.062	765,699.938	Q
UE-25 NRG #2b	3,801.400	330.00	569,214.562	765,765.250	Q
UE-25 NRG #2c	3,801.170	151.00	569,189.750	765,771.688	Q
UE-25 NRG #2d	3,792.050	170.20	569,132.312	765,825.125	Q
UE-25 NRG #3	3,823.330	330.00	568,316.125	766,250.625	Q
UE-25 NRG #4	4,099.480	726.00	566,820.000	767,080.188	Q

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
UE-25 NRG #5	4,106.660	1,350.00	564,769.875	767,889.625	Q
UE-25 ONC #1	3,815.110	1,540.00	568,092.875	759,257.250	Q
UE-25 p #1	3,654.530	5,923.00	571,484.438	756,172.562	Q
UE-25 RF #1	3,688.600	145.00	570,890.125	762,190.562	Q
UE-25 RF #2	3,657.850	52.00	570,335.125	758,800.812	Q
UE-25 RF #3b	3,661.370	111.00	571,066.062	765,695.750	Q
UE-25 RF #4	3,637.060	306.00	572,063.312	762,091.625	Q
UE-25 RF #7	3,756.080	150.00	571,171.062	768,804.750	Q
UE-25 RF #7a	3,756.500	153.00	570,268.812	768,768.750	Q
UE-25 RF #8	3,785.700	128.00	568,790.188	765,631.375	Q
USW SR-1	3,051.310	0.00	559,339.062	721,817.875	Q
USW SR-2	3,051.150	0.00	559,333.312	721,809.688	Q
USW SR-3	3,046.650	0.00	559,246.625	721,823.000	Q
UE-25 UZ #4	3,940.050	411.00	566,140.125	768,715.688	Q
UE-25 UZ #5	3,952.830	405.00	566,136.125	768,593.125	Q
UE-25 UZ #16	4,000.480	1,696.20	564,857.500	760,535.125	Q
UE-25 UZN #1	3,995.430	50.00	565,224.438	769,329.750	Q
UE-25 UZN #2	3,947.070	50.00	566,113.688	768,606.375	Q
UE-25 UZN #3	3,940.820	15.00	566,119.438	768,631.438	Q
UE-25 UZN #4	3,942.510	30.00	566,127.125	768,664.375	Q
UE-25 UZN #5	3,943.530	50.00	566,134.188	768,690.188	Q
UE-25 UZN #6	3,938.770	45.00	566,136.812	768,706.500	Q
UE-25 UZN #7	3,939.870	45.00	566,141.375	768,724.938	Q
UE-25 UZN #8	3,938.340	45.00	566,146.625	768,743.812	Q
UE-25 UZN #9	3,941.130	40.00	566,156.062	768,782.375	Q
UE-25 UZN #10	4,038.710	99.00	564,744.562	769,869.312	Q
UE-25 UZN #12	3,908.250	50.00	566,695.188	768,651.500	Q
UE-25 UZN #13	3,821.470	65.00	568,255.188	768,025.438	Q
UE-25 UZN #14	3,824.380	55.00	568,233.062	767,968.000	Q
UE-25 UZN #18	4,018.900	61.00	565,246.625	766,472.812	Q
UE-25 UZN #19	4,025.490	40.00	564,570.812	763,689.562	Q
UE-25 UZN #20	4,027.360	41.00	564,579.438	763,760.625	Q
UE-25 UZN #21	4,027.980	42.00	564,591.375	763,806.812	Q
UE-25 UZN #22	4,029.300	95.00	564,604.875	763,881.062	Q
UE-25 UZN #23	4,043.760	35.00	564,545.688	763,973.750	Q
UE-25 UZN #28	3,958.920	26.00	565,319.812	763,092.062	Q
UE-25 UZN #29	3,973.360	35.00	565,173.312	762,613.812	Q
UE-25 UZN #30	3,959.530	35.00	565,232.875	762,048.188	Q
UE-25 UZN #56	3,960.250	60.00	565,480.125	760,394.688	Q
UE-25 UZN #60	3,893.040	35.00	566,567.125	759,757.938	Q
UE-25 UZN #63	3,942.210	60.00	566,169.625	768,837.250	Q
UE-25 UZN #85	3,337.060	80.00	577,568.250	750,715.812	Q
UE-25 UZN #97	3,959.030	60.00	565,320.625	763,094.562	Q
UE-25 UZNC #1	3,928.610	5.00	566,159.000	764,671.500	Q
UE-25 UZNC #2	3,928.710	5.00	566,157.312	764,669.562	Q
UE-25 WT #3	3,379.230	1,142.00	573,385.188	745,995.562	Q
UE-25 WT #4	3,835.680	1,580.00	568,038.312	768,511.938	Q
UE-25 WT #5	3,558.030	1,330.00	574,249.750	761,826.688	Q
UE-25 WT #6	4,313.270	1,258.00	564,523.625	780,576.125	Q

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
UE-25 WT #12	3,525.760	1,308.00	567,011.812	739,726.688	Q
UE-25 WT #13	3,385.860	1,154.00	578,842.250	756,885.188	Q
UE-25 WT #14	3,529.670	1,310.00	575,210.188	761,651.375	Q
UE-25 WT #15	3,552.560	1,360.00	579,806.250	766,117.000	Q
UE-25 WT #16	3,971.260	1,709.00	570,395.125	774,420.188	Q
UE-25 WT #17	3,687.090	1,450.00	566,212.000	748,421.500	Q
UE-25 WT #18	4,384.000	2,043.00	564,854.625	771,167.250	Q
UE-29 UZN #91	3,949.340	94.00	585,341.375	797,275.812	Q
UE-29 UZN #92	3,670.680	120.00	583,559.000	778,010.125	Q
UE-29 a #1	3,984.200	215.00	585,575.250	797,730.000	Q
UE-29 a #2	3,984.640	1,383.00	585,547.500	797,745.750	Q
US-25 #4	3,800.040	50.00	567,853.438	762,458.312	Q
US-25 #5	3,799.210	52.00	567,853.438	762,433.000	Q
US-25 #6	3,782.770	52.00	568,551.750	762,378.562	Q
US-25 #7	3,782.820	52.00	568,551.250	762,355.125	Q
US-25 #8	3,756.330	52.00	569,332.188	762,317.438	Q
US-25 #9	3,757.870	50.00	569,328.625	762,284.250	Q
US-25 #10	3,722.990	50.00	570,113.438	762,251.000	Q
US-25 #11	3,722.910	52.00	570,109.188	762,227.375	Q
US-25 #12	3,687.790	52.00	570,894.250	762,189.312	Q
US-25 #13	3,686.990	52.00	570,891.312	762,168.312	Q
US-25 #14	3,653.100	50.00	571,675.000	762,137.250	Q
US-25 #15	3,653.870	50.00	571,671.875	762,106.125	Q
US-25 #16	3,619.340	50.00	572,452.812	762,048.688	Q
US-25 #17	3,575.270	50.00	573,629.375	761,985.562	Q
US-25 #19	3,498.600	50.00	576,242.625	761,747.125	Q
US-25 #21	3,842.000	50.00	578,542.938	761,629.125	Q
U-25 TC #3	3,763.620	45.00	613,080.188	756,807.188	Q
U-25 TC #4	3,764.700	45.00	613,095.625	756,861.188	Q
U-25 TC #5	3,762.790	0.00	613,077.750	756,795.250	Q
USW G-1	4,350.150	6,000.00	561,001.062	770,501.625	Q
USW G-2	5,097.270	6,602.00	560,503.938	778,825.938	Q
USW G-3	4,856.090	5,031.00	558,483.312	752,779.625	Q
USW G-4	4,166.130	3,001.00	563,081.750	765,807.500	Q
USW GA-1	5,186.950	551.00	559,246.812	779,367.188	Q
USW GU-3	4,856.700	5,031.00	558,501.625	752,690.000	Q
USW H-1	4,274.190	600.00	562,388.438	770,254.812	Q
USW H-3	4,866.470	4,000.00	558,451.875	756,542.000	Q
USW H-4	4,096.170	4,004.00	563,911.375	761,644.500	Q
USW H-5	4,851.350	4,000.00	558,908.438	766,634.125	Q
USW H-6	4,270.790	4,002.00	554,074.938	763,299.438	Q
USW NRG-6	4,092.120	1,100.00	564,187.000	766,726.500	Q
USW NRG-7a	4,207.170	1,513.00	562,984.000	768,880.125	Q
USW SD-7	4,472.000	2,675.10	561,240.250	758,949.875	Q
USW SD-9	4,272.640	2,223.00	561,818.000	767,998.500	Q
USW SD-12	4,342.820	2,166.30	561,605.625	761,956.562	Q
USW UZ-1	4,424.730	1,270.00	560,221.562	771,277.375	Q
USW UZ-6	4,925.170	1,887.00	558,325.000	759,730.188	Q
USW UZ-6s	4,949.160	519.00	558,050.688	759,909.312	Q

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
USW UZ-7	4,169.130	207.00	562,911.625	760,837.000	Q
USW UZ-7a	4,228.280	770.00	562,269.812	760,692.750	Q
USW UZ-8	4,226.730	57.00	562,293.750	760,763.188	Q
USW UZ-13	4,816.110	430.00	558,489.312	751,953.062	Q
USW UZ-14	4,425.400	2,207.00	560,141.562	771,309.812	Q
USW UZ-N11	5,221.790	84.40	559,020.938	780,573.938	Q
USW UZ-N15	5,107.810	59.90	559,551.750	778,090.562	Q
USW UZ-N16	5,114.980	60.00	559,626.000	778,150.812	Q
USW UZ-N17	5,125.750	59.82	559,995.125	778,224.125	Q
USW UZ-N24	4,226.520	75.00	562,054.438	768,005.625	Q
USW UZ-N25	4,333.990	59.00	561,219.125	768,430.438	Q
USW UZ-N26	4,383.810	35.00	561,023.250	768,757.375	Q
USW UZ-N27	4,857.270	202.42	558,871.750	771,569.375	Q
USW UZ-N31	4,151.840	192.60	562,751.938	764,245.625	Q
USW UZ-N32	4,156.180	207.40	562,799.625	764,302.625	Q
USW UZ-N33	4,329.160	75.00	561,192.188	770,070.125	Q
USW UZ-N34	4,321.120	84.10	561,251.375	770,158.750	Q
USW UZ-N35	4,245.370	175.00	562,309.938	762,264.000	Q
USW UZ-N36	4,640.370	59.82	563,582.688	773,899.500	Q
USW UZ-N37	4,121.120	271.33	563,713.500	767,499.125	Q
USW UZ-N38	4,146.890	89.40	563,343.875	767,466.312	Q
UE-25 UZN #39	3,768.220	125.00	617,277.750	755,133.062	Q
USW UZ-N40	4,079.700	35.00	564,221.438	766,176.188	Q
USW UZ-N41	4,117.810	37.00	563,521.062	765,867.750	Q
USW UZ-N42	4,179.300	40.00	562,858.625	765,729.125	Q
USW UZ-N43	4,149.500	45.00	563,263.625	765,997.500	Q
USW UZ-N44	4,161.700	36.00	563,139.500	766,192.938	Q
USW UZ-N45	4,130.200	45.00	563,429.250	765,977.250	Q
USW UZ-N46	4,500.660	99.00	559,747.938	772,262.188	Q
USW UZ-N47	4,480.410	86.00	559,783.750	771,967.562	Q
USW UZ-N48	4,211.080	35.00	562,413.812	760,835.938	Q
USW UZ-N49	4,228.250	36.00	562,322.062	760,861.438	Q
USW UZ-N50	4,172.770	20.00	562,911.938	760,776.938	Q
USW UZ-N51	4,168.620	20.00	562,909.562	760,861.750	Q
USW UZ-N52	4,171.850	25.00	562,908.938	760,894.938	Q
USW UZ-N53	4,053.860	234.70	564,237.250	760,096.250	Q
USW UZ-N54	4,044.070	244.72	564,262.188	760,271.938	Q
USW UZ-N55	4,070.600	255.30	564,248.250	760,502.875	Q
USW UZ-N57	4,183.660	118.90	560,829.812	755,164.500	Q
USW UZ-N58	4,179.230	118.80	560,862.188	755,240.375	Q
USW UZ-N59	4,177.710	118.80	560,888.375	755,321.250	Q
USW UZ-N61	4,182.170	118.90	560,893.938	755,375.938	Q
USW UZ-N62	4,881.950	60.00	558,302.688	757,125.188	Q
USW UZ-N64	4,789.380	60.04	559,435.500	765,728.125	Q
USW UZ-N65	4,372.320	50.00	562,537.625	758,627.312	Q
USW UZ-N66	4,357.940	50.00	561,881.688	758,433.875	Q
USW UZ-N67	3,918.220	25.00	563,799.250	753,635.562	Q
USW UZ-N68	3,923.250	55.00	564,006.125	753,963.688	Q
USW UZ-N69	3,916.960	35.00	564,402.000	754,462.500	Q

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
USW UZ-N70	4,541.820	35.00	560,165.000	769,250.750	Q
USW UZ-N71	4,924.660	52.00	558,405.938	761,025.688	Q
USW UZ-N72	4,864.400	30.00	558,645.938	761,071.625	Q
USW UZ-N73	4,781.620	30.00	558,945.562	761,052.938	Q
USW UZ-N74	4,903.280	37.00	558,560.125	761,361.938	Q
USW UZ-N75	4,798.650	37.00	559,076.000	761,462.250	Q
USW UZ-N76	4,795.530	40.00	559,067.438	761,356.875	Q
USW UZ-N77	3,902.950	50.00	554,397.312	755,526.875	Q
USW UZ-N78	4,182.020	30.00	556,262.688	757,558.438	Q
USW UZ-N79	4,154.410	32.00	556,334.125	757,733.688	Q
USW UZ-N80	4,331.230	52.00	557,201.375	757,635.000	Q
USW UZ-N81	4,064.410	70.00	555,595.375	757,807.562	Q
USW UZ-N82	3,974.220	40.00	554,689.938	757,498.750	Q
USW UZ-N83	4,157.260	70.00	556,349.250	760,624.938	Q
USW UZ-N84	4,111.470	45.00	555,888.000	760,717.062	Q
USW UZ-N86	4,172.290	30.00	556,460.500	760,615.375	Q
USW UZ-N87	4,111.420	45.00	555,887.250	760,714.250	Q
USW UZ-N88	4,201.650	30.00	556,551.250	760,797.938	Q
USW UZ-N89	4,089.460	45.00	555,588.750	760,611.250	Q
USW UZ-N90	4,089.340	45.00	555,587.438	760,609.250	Q
USW UZ-N93	4,924.030	40.00	558,321.000	759,584.062	Q
USW UZ-N94	4,925.860	30.00	558,236.688	759,723.312	Q
USW UZ-N95	4,928.700	20.00	558,172.625	759,898.750	Q
USW UZ-N96	4,893.080	35.00	558,403.375	759,445.562	Q
USW UZ-N98	4,223.720	75.00	562,083.750	767,996.500	Q
USW VH-1	3,160.050	2,501.00	533,625.000	743,356.375	Q
USW VH-2	3,197.080	4,000.00	526,264.500	748,321.062	Q
USW WT-1	3,939.750	1,689.00	563,739.188	753,942.125	Q
USW WT-2	4,268.230	2,060.00	561,924.000	760,661.562	Q
USW WT-7	3,926.240	1,610.00	553,891.625	755,570.562	Q
USW WT-10	3,685.770	1,412.00	553,302.312	748,771.562	Q
USW WT-11	3,589.100	1,446.00	558,376.688	739,071.312	Q
UE-25 SPT #1	3,945.900	0.00	566,219.312	765,089.875	Q
USW UNK-2	3,925.910	0.00	553,793.812	755,580.062	Q
USW SRS-13	3,062.310	0.00	528,364.688	740,508.500	Q
USW SRS-11	2,998.000	202.30	522,693.000	737,205.000	Q
USW SRS-201	3,173.000	200.00	534,016.000	743,815.000	Q
USW SRS-203	3,364.000	152.00	539,831.000	747,042.000	Q
USW SRS-207	3,782.000	194.20	550,960.000	753,855.000	Q
USW SRS-208.5a	4,244.000	0.00	556,764.000	757,559.000	Q
USW SRS-208.5b	4,244.000	0.00	556,764.000	757,559.000	Q
USW SRS-211a	4,160.000	0.00	555,676.000	762,157.000	Q
USW SRS-211b	4,160.000	0.00	555,676.000	762,157.000	Q
USW SRS-300	3,703.000	201.70	538,298.000	766,510.000	Q
USW SRS-302a	4,160.000	0.00	555,676.000	762,157.000	Q
USW SRS-302b	4,160.000	0.00	555,676.000	762,157.000	Q
UE-25 SRS #307r	3,661.000	0.00	570,958.000	756,207.000	Q
UE-25 SRS #311	3,356.000	0.00	577,865.000	755,087.000	Q
US-25 #3	3,620.000	52.00	572,455.000	762,075.000	Q

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
USW SRS-1	2,663.000	201.30	498,514.000	717,226.000	Q
USW SRS-3	2,670.000	202.40	503,010.000	721,851.000	Q
USW SRS-5	2,736.000	200.00	507,380.000	726,590.000	Q
USW SRS-7	2,954.000	0.00	511,921.000	730,880.000	Q
USW SRS-9	2,939.000	0.00	517,012.000	733,911.000	Q
UE-25 RF #9	3,671.700	106.00	570,642.688	765,945.625	NQ
UE-25 RF #10	3,669.700	60.00	570,229.062	765,307.125	NQ
US-25 #1	4,258.500	53.00	565,422.750	762,630.500	NQ
US-25 #2	4,316.200	53.00	566,430.125	762,402.375	NQ
US-25 #18	3,545.000	50.00	574,709.250	761,895.500	NQ
US-25 #20	3,485.000	50.00	577,174.688	761,613.375	NQ
UE-25 RF #11	3,665.400	78.00	570,433.625	765,621.500	NQ
UE-25 G #7	0.000	0.00	566,090.688	724,585.375	NQ
USW G-5	0.000	0.00	563,008.438	781,929.750	NQ
USW G-6	0.000	0.00	548,924.062	778,721.312	NQ
UE-25 PH #1a	0.000	0.00	569,303.250	766,000.562	NQ
UE-25 PH #1b	0.000	0.00	569,303.250	766,000.562	NQ
USW V-1	0.000	0.00	518,001.469	729,600.125	NQ
USW V-2	0.000	0.00	578,906.938	683,721.312	NQ
USW V-3	0.000	0.00	549,338.438	656,876.438	NQ
USW V-4	0.000	0.00	546,412.875	654,950.938	NQ
USW SD-11	0.000	0.00	558,315.188	758,175.000	NQ
USW SD-10	0.000	0.00	561,799.938	765,499.688	NQ
UE-25 SD #8	0.000	0.00	564,603.062	762,799.438	NQ
UE-25 SD #5	0.000	0.00	564,969.438	764,630.625	NQ
USW SD-4	0.000	0.00	562,800.500	764,264.562	NQ
USW SD-3	0.000	0.00	559,174.562	764,609.438	NQ
USW SD-2	0.000	0.00	559,799.688	767,700.688	NQ
USW SD-1	0.000	0.00	561,298.500	769,199.562	NQ
UE-25 RF #12	0.000	0.00	569,905.062	764,563.375	NQ
UE-25 RF #6	0.000	0.00	570,051.438	764,934.500	NQ
USW SRG-1	0.000	0.00	567,189.688	756,609.000	NQ
USW SRG-2	0.000	0.00	564,934.250	756,699.500	NQ
USW SRG-3	0.000	0.00	563,301.000	757,165.125	NQ
USW SRG-4	0.000	0.00	561,799.375	757,675.625	NQ
USW SRG-5	0.000	0.00	558,315.188	758,175.000	NQ
USW UZ-10	0.000	0.00	561,123.688	750,138.938	NQ
UE-25 WT #19	0.000	0.00	589,972.688	747,978.125	NQ
UE-25 WT #20	0.000	0.00	565,140.938	728,303.500	NQ
UE-25 UZ #9	0.000	0.00	564,751.062	760,600.000	NQ
UE-25 UZP #1/2	0.000	0.00	569,199.188	730,400.438	NQ
USW H-7	0.000	0.00	558,652.625	762,290.500	NQ
USW UZ-11	0.000	0.00	556,613.188	757,399.375	NQ
USW UZ-12	0.000	0.00	556,055.000	757,399.625	NQ
USW UZ-2	0.000	0.00	558,180.125	759,769.000	NQ
USW UZ-3	0.000	0.00	558,220.625	759,624.625	NQ
USW WT-21	0.000	0.00	550,327.500	760,085.688	NQ
USW WT-22	0.000	0.00	528,373.312	778,858.125	NQ
UE-25 FM #1	0.000	0.00	581,694.688	766,450.688	NQ

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
USW WT-9	0.000	0.00	557,642.188	769,476.500	NQ
USW WT-23	0.000	0.00	559,597.375	772,549.688	NQ
USW WT-8	0.000	0.00	557,052.000	762,283.062	NQ
UE-25 FM #2	0.000	0.00	583,497.750	782,300.188	NQ
UE-25 UZ #15	0.000	0.00	558,327.562	759,731.812	NQ
UE-25 UZ #9b	0.000	0.00	564,849.312	760,600.250	NQ
UE-25 UZ #9a	0.000	0.00	564,800.188	760,600.125	NQ
UE-25 FM #3	0.000	0.00	572,400.062	776,000.438	NQ
UE-25 RF #3	3,657.700	151.00	571,098.938	765,574.562	NQ
UE-25 RF #5	3,813.700	122.00	568,096.625	759,198.375	NQ
USW G-8	0.000	0.00	589,974.938	747,979.562	NQ
USW sei-101	0.000	0.00	518,361.188	750,233.750	NQ
USW sei-102	0.000	0.00	520,948.406	748,899.625	NQ
USW sei-103	0.000	0.00	523,975.906	747,567.500	NQ
USW sei-104	0.000	0.00	527,001.375	746,285.688	NQ
USW sei-105	0.000	0.00	530,036.062	745,034.750	NQ
USW sei-106	0.000	0.00	533,185.125	743,644.062	NQ
USW sei-202	0.000	0.00	536,933.438	745,458.250	NQ
USW sei-203	0.000	0.00	539,792.500	747,100.812	NQ
USW sei-204	0.000	0.00	542,720.750	748,600.812	NQ
USW sei-205	0.000	0.00	545,424.688	750,475.688	NQ
USW sei-206	0.000	0.00	548,208.812	752,281.500	NQ
USW sei-207	0.000	0.00	551,012.875	753,964.000	NQ
USW sei-208	0.000	0.00	553,910.688	755,506.750	NQ
USW sei-210	0.000	0.00	560,492.375	759,085.062	NQ
USW sei-211	0.000	0.00	563,782.562	760,396.438	NQ
UE-25 sei #212	0.000	0.00	567,096.312	762,001.188	NQ
USW sei-300	0.000	0.00	538,287.062	766,675.500	NQ
USW sei-301	0.000	0.00	553,789.688	763,838.875	NQ
USW sei-302	0.000	0.00	555,748.188	762,326.250	NQ
USW sei-303	0.000	0.00	557,884.562	760,191.938	NQ
USW sei-304	0.000	0.00	560,492.375	759,085.062	NQ
USW sei-305	0.000	0.00	563,074.062	757,796.500	NQ
UE-25 sei #306	0.000	0.00	568,612.125	757,474.875	NQ
UE-25 sei #307	0.000	0.00	570,935.812	755,094.812	NQ
UE-25 sei #308	0.000	0.00	573,436.125	756,183.062	NQ
UE-25 sei #401	0.000	0.00	570,170.500	753,062.562	NQ
UE-25 sei #402	0.000	0.00	570,930.750	756,197.438	NQ
UE-25 sei #403	0.000	0.00	573,078.812	758,763.812	NQ
UE-25 sei #404	0.000	0.00	574,640.312	761,791.188	NQ
UE-25 sei #405	0.000	0.00	576,541.062	762,269.875	NQ
UE-25 sei #406	0.000	0.00	578,474.000	764,783.312	NQ
UE-25 sei #407	0.000	0.00	580,117.812	767,598.750	NQ
UE-25 sei #501	0.000	0.00	575,152.500	746,480.438	NQ
UE-25 sei #502	0.000	0.00	576,372.750	749,508.375	NQ
UE-25 sei #503	0.000	0.00	577,438.562	752,573.438	NQ
UE-25 sei #504	0.000	0.00	578,119.562	755,831.938	NQ
UE-25 sei #505	0.000	0.00	578,432.938	759,524.062	NQ
UE-25 sei #506	0.000	0.00	576,538.875	762,268.500	NQ

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
UE-25 sei #507	0.000	0.00	574,469.250	764,843.188	NQ
UE-25 sei #510	0.000	0.00	570,335.562	773,559.312	NQ
UE-25 sei #511	0.000	0.00	569,026.875	776,679.312	NQ
UE-25 sei #512	0.000	0.00	566,600.500	778,941.188	NQ
USW sei-513	0.000	0.00	563,990.125	780,902.938	NQ
USW sei-514	0.000	0.00	561,459.875	783,083.125	NQ
USW sei-515	0.000	0.00	559,068.438	785,222.188	NQ
USW sei-516	0.000	0.00	557,528.375	786,778.562	NQ
UE-25 UZ #4a	0.000	0.00	566,138.375	768,716.250	NQ
UE-25 UZ #5a	0.000	0.00	566,134.188	768,591.250	NQ
USW UZ-8a	0.000	0.00	562,292.625	760,762.438	NQ
UE-25 PTH #2	3,641.730	0.00	571,147.438	764,947.000	NQ
UE-25 PTH #3	3,642.280	0.00	571,098.312	764,946.875	NQ
USW WT-25	0.000	0.00	553,603.562	788,691.375	NQ
USW WT-26	0.000	0.00	553,673.438	752,287.250	NQ
USW WT-27	0.000	0.00	524,360.500	800,774.188	NQ
UE-25 PTH #1	3,640.270	0.00	571,198.750	764,947.125	NQ
UE-25 PTH #4	3,639.610	0.00	571,096.375	764,845.500	NQ
UE-25 PTH #5	3,639.560	0.00	571,147.688	764,847.000	NQ
UE-25 PTH #6	3,638.230	0.00	571,199.000	764,847.125	NQ
UE-25 PSF #7	3,641.010	0.00	571,152.000	764,895.625	NQ
USW NRG-5a	0.000	0.00	564,769.875	767,889.500	NQ
USW NRG-7	4,209.400	0.00	563,006.688	768,846.500	NQ
USW NRG-8c	0.000	0.00	568,704.938	766,032.438	NQ
USW NRG-8b	0.000	0.00	568,801.062	765,978.500	NQ
USW NRG-8a	0.000	0.00	568,988.688	765,927.625	NQ
UE-25 NRG #2e	0.000	0.00	569,102.812	765,822.312	NQ
USW SRS-102	0.000	0.00	520,948.406	748,899.625	NQ
USW SRS-104	0.000	0.00	527,001.375	746,285.688	NQ
USW SRS-106	0.000	0.00	533,185.125	743,642.688	NQ
USW SRS-205	0.000	0.00	525,425.062	750,475.375	NQ
USW SRS-205a	0.000	0.00	525,425.062	750,475.375	NQ
USW SRS-205b	0.000	0.00	525,425.062	750,475.375	NQ
USW SRS-211	0.000	0.00	563,474.188	760,540.125	NQ
USW SRS-302	0.000	0.00	555,748.188	762,327.625	NQ
USW SRS-305	0.000	0.00	563,203.750	757,705.125	NQ
USW SRG-3a	0.000	0.00	563,350.125	757,165.250	NQ
USW SRS-305a	0.000	0.00	563,176.938	757,705.062	NQ
USW SRS-305b	0.000	0.00	563,230.562	757,705.188	NQ
UE-25 BS #1	0.000	0.00	570,441.875	765,016.062	NQ
UE-25 BS #2	0.000	0.00	570,450.875	764,989.688	NQ
UE-25 BS #3	0.000	0.00	570,372.625	765,032.562	NQ
UE-25 BS #4	0.000	0.00	570,319.000	765,061.562	NQ
UE-25 PL #1	0.000	0.00	571,487.000	763,092.500	NQ
UE-25 PL #2	0.000	0.00	571,513.750	763,106.500	NQ
UE-25 PL #3	0.000	0.00	571,473.500	763,142.500	NQ
UE-25 PL #4	0.000	0.00	570,966.625	764,060.562	NQ
UE-25 PL #5	0.000	0.00	570,955.438	764,082.750	NQ
UE-25 PL #6	0.000	0.00	570,942.000	764,104.938	NQ

Table III-1. Surface-Based Boreholes (Continued)

Borehole Identifier	Elevation (feet)	Total Depth (feet)	Easting (feet)	Northing (feet)	Qualification Status
UE-25 PL #7	0.000	0.00	570,894.875	764,192.312	NQ
UE-25 PL #8	0.000	0.00	570,881.438	764,214.500	NQ
UE-25 PL #9	0.000	0.00	570,868.000	764,236.625	NQ
UE-25 PL #10	0.000	0.00	570,441.875	765,016.062	NQ
UE-25 PL #11	0.000	0.00	570,450.875	764,989.688	NQ
UE-25 PL #12	0.000	0.00	570,435.250	764,998.000	NQ
UE-25 PL #13	0.000	0.00	570,372.625	765,032.562	NQ
UE-25 PL #14	0.000	0.00	570,348.062	765,046.375	NQ
UE-25 PL #15	0.000	0.00	570,319.000	765,061.562	NQ
Unknow Unknown	0.000	0.00	562,368.688	760,709.312	NQ
USW sei-201	0.000	0.00	534,039.688	743,907.375	NQ
USW SP-5a	3,368.900	0.00	538,653.375	751,454.875	NQ
USW SP-5b	3,366.100	0.00	538,763.875	751,426.875	NQ
U-12 g	6,114.000	0.00	637,708.000	881,027.000	NQ
USW SD-13	0.000	0.00	560,872.000	773,837.000	NQ
UE-20 PM #2	5,586.000	8,782.00	528,664.812	944,583.250	NQ
UE-20 PM #1	6,558.000	7,858.00	575,885.625	921,109.250	NQ
UE-12 DOL	0.000	0.00	638,611.375	886,664.875	NQ
U-15 k	5,168.000	857.00	677,459.000	903,088.000	NQ
UE-3 TWE	4,934.000	3,000.00	695,991.375	839,984.625	NQ
UE-27 TWF	4,143.000	3,400.00	661,206.938	731,855.750	NQ
USW TW-3	3,477.000	1,860.00	736,937.000	750,189.000	NQ
USW TW-5	3,050.000	926.00	607,632.000	687,231.000	NQ
USW TW-4	0.000	1,500.00	755,786.000	669,497.000	NQ
UE-16 b	4,894.060	361.00	646,345.000	839,498.000	Q
UE-20 c	6,283.000	4,800.00	556,763.000	903,204.000	NQ
UE-18 t	5,201.000	2,600.00	598,394.000	865,793.000	NQ
UE-25 RF #13	3,671.030	0.00	570,720.119	765,500.041	Q
USW SD-6ST1	4,905.400	0.00	558,652.625	762,290.500	NQ
USW WT-24	4,900.280	0.00	562,329.905	776,703.061	Q
U-20 f	6,117.000	4,202.00	551,857.000	917,825.000	NQ
UE-15 d	4,586.000	6,001.00	682,084.000	895,709.000	NQ
UE-19 c	7,033.000	8,489.00	601,027.000	917,000.000	NQ
UE-2 WW #2	4,470.000	3,422.00	668,720.000	880,000.000	NQ
UE-5 WW #5a	3,093.000	910.00	707,514.000	738,361.000	NQ
UE-5 WW #5b	3,092.000	900.00	704,263.000	747,359.000	NQ
UE-5 WW #5c	3,081.000	1,200.00	705,888.000	742,860.000	NQ
UE-18 WW #8	5,695.000	5,499.00	609,999.000	879,468.000	NQ
UE-6 WW c	3,921.000	1,701.00	692,061.000	790,082.000	NQ
UE-6 WW c #1	3,921.000	1,707.00	692,132.000	790,011.000	NQ
USW SD-6	4,905.320	2,541.00	558,607.680	762,421.390	Q
UE-25 NRG #1	3,754.600	150.00	569,803.350	765,359.030	Q
UE-20f	6,116.000	0.00	552,007.000	917,825.000	NQ

Source: DTN: MO0002COV00084.001

Table III-2. Surface-Based Boreholes in the Vicinity of the Subsurface Facility

Borehole Identifier	Elevation		Total Depth		Borehole Bottom Elevation (meters)	Easting		Northing		Qualification Status
	feet	meters	feet	meters		feet	meters	feet	meters	
USW G-1	4,350.150	1,325.942	6,000.00	1,828.822	-502.88	561,001.062	170,995.203	770,501.625	234,851.751	Q
USW G-3	4,856.090	1,480.154	5,031.00	1,533.467	-53.31	558,483.312	170,227.783	752,779.625	229,450.020	Q
USW GU-3	4,856.700	1,480.340	5,031.00	1,533.467	-53.13	558,501.625	170,233.365	752,690.000	229,422.702	Q
USW H-1	4,274.190	1,302.789	600.00	182.882	1,119.91	562,388.438	171,418.080	770,254.812	234,776.522	Q
USW H-3	4,866.470	1,483.318	4,000.00	1,219.215	264.10	558,451.875	170,218.201	756,542.000	230,596.806	Q
USW H-5	4,851.350	1,478.709	4,000.00	1,219.215	259.49	558,908.438	170,357.363	766,634.125	233,672.923	Q
USW SD-12	4,342.820	1,323.708	2,166.30	660.296	663.41	561,605.625	171,179.476	761,956.562	232,247.184	Q
USW SD-6	4,905.320	1,495.160	2,541.00	774.506	720.65	558,607.680	170,265.691	762,421.390	232,388.866	Q
USW SD-7	4,472.000	1,363.082	2,675.10	815.380	547.70	561,240.250	171,068.108	758,949.875	231,330.735	Q
USW SD-9	4,272.640	1,302.317	2,223.00	677.579	624.74	561,818.000	171,244.209	767,998.500	234,088.789	Q
USW UZ-1	4,424.730	1,348.674	1,270.00	387.101	961.57	560,221.562	170,757.609	771,277.375	235,088.203	Q
USW UZ-14	4,425.400	1,348.878	2,207.00	672.702	676.18	560,141.562	170,733.224	771,309.812	235,098.089	Q
USW UZ-6	4,925.170	1,501.210	1,887.00	575.165	926.05	558,325.000	170,179.529	759,730.188	231,568.577	Q
USW UZ-7a	4,228.280	1,288.795	770.00	234.699	1,054.10	562,269.812	171,381.923	760,692.750	231,861.970	Q
USW WT-2	4,268.230	1,300.972	2,060.00	627.896	673.08	561,924.000	171,276.518	760,661.562	231,852.463	Q

ATTACHMENT IV

VENTILATION INTERFACE CALCULATIONS

ATTACHMENT IV

VENTILATION INTERFACE CALCULATIONS

In order to determine the number of shafts required to support the subsurface layout, the limitations of the intake and exhaust airflow openings must be examined.

IV.1 Intake Airflow Opening Limitations

A single intake shaft will feed through intake shaft accesses to both the East Main and the West Main (see Section 5.2.7.8) and as illustrated in Figure IV-1. The access mains are excavated as 7.62-meter diameter TBM openings (see Section 5.2.7.2)

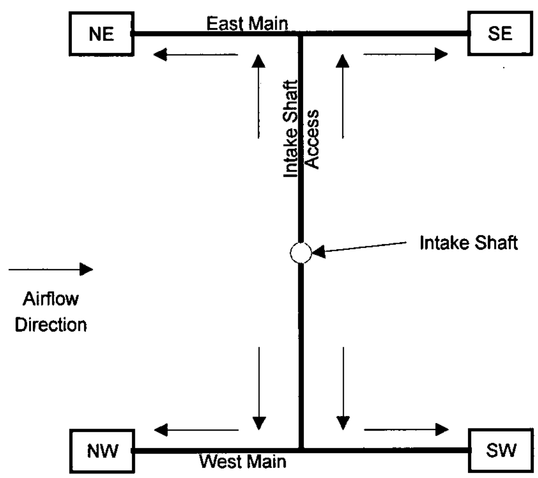

Figure IV-1. Intake Shaft and Access General Arrangement

Maximum Intake Shaft Access Airflow Volume-The maximum airflow volume that can be accommodated in each of the intake shaft access openings, feeding to either the East or West Main and the South Ramp, is 289.36 m^3/s as calculated below.

$$V = A \times v$$

Where:	V	=	airflow volume (m^3/s),
	A	=	Opening cross-sectional area (m^2), and
	v	=	airflow velocity (m/s).
When:	A	=	36.17 m^2 (see Section 4.1.7.1), and
	v	=	8 m/s (see Section 5.2.7.4),

$$V = 36.17\,m^2 \times 8\,m/s$$

$$V = 289.36\,m^3/s$$

Intake Shaft Maximum Airflow Volume and Minimum Effective Area-Since the shaft feeds two access drifts, one to the East Main and the other to the West Main, the maximum airflow volume required per intake shaft would be twice the maximum access drift airflow volume, or 578.72 m^3/s. This in turn dictates the minimum effective intake shaft area, the unobstructed area within the opening, of 28.94 m^2, required to support the intake airflow volume as calculated below.

$$A = \frac{V}{v}$$

When: $V = 578.72\ m^3/s$, and
$v = 20$ m/s (see Section 5.2.7.4),

$$A = \frac{578.72\ m^3/s}{20\ m/s}$$

$$A = 28.94\ m^2$$

North Ramp, East Main, and West Main Maximum Airflow Volume-The North Ramp, East and West Mains can each accommodate a maximum airflow volume of 217.02 m^3/s in one direction as calculated below.

$$V = A \times v$$

When: $A = 36.17\ m^2$ (see Section 4.1.7.1), and
$v = 6$ m/s (see Section 5.2.7.4),

$$V = 36.17\ m^2 \times 6\ m/s$$

$$V = 217.02\ m^3/s$$

Cross-block and Test and Evaluation Facility Minimum Airflow Volume-The minimum design airflow volume that can be accommodated in the cross block and Test and Evaluation facility drift splits is 19.63 m^3/s as calculated below.

$$V = A \times v$$

When: $A = 19.63\ m^2$ (see Section 4.1.7.1), and
$v = 1$ m/s (see Section 5.2.7.1),

$$V = 19.63\ m^2 \times 1\ m/s$$

$$V = 19.63\ m^3/s$$

IV.2 Thermal Expansion

The overall heat output of the WPs is approximately 1.45 kW/m (see Section 6.2.3.2) and the intake air to the emplacement drifts will expand because it will be heated as it passes the WPs. The anticipated exhaust air temperature can be interpolated from Figure IV-2. This figure represents temperature profiles of the exhaust air at various overall WP heat output values for an emplacement drift ventilation rate of 15 m^3/s along a 600 meter (see Section 5.2.4) long emplacement drift (see Section 4.1.7.3).

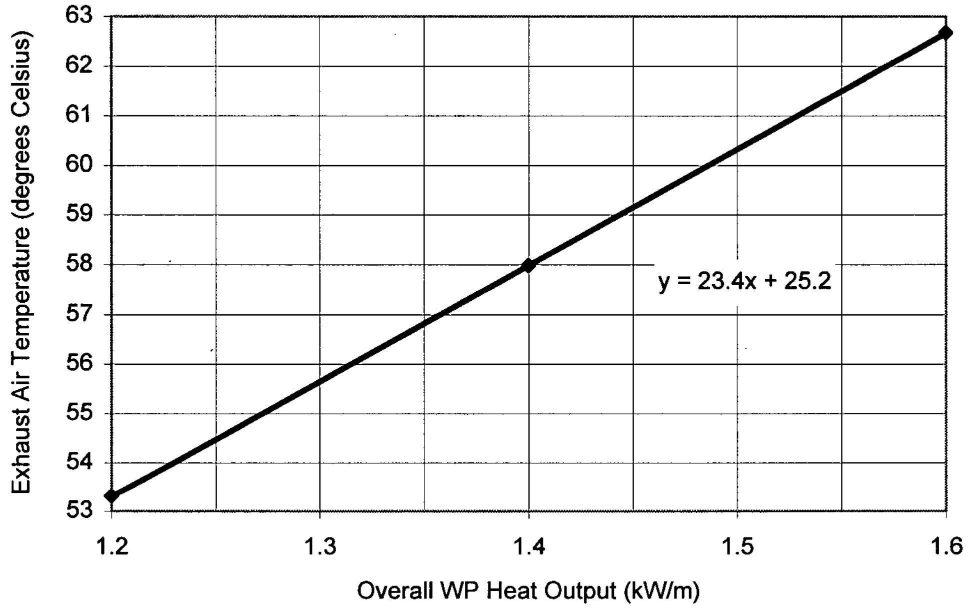

Figure IV-2. Overall Heat Output versus Exhaust Air Temperature

Based on the trend line, the approximate exhaust air temperature from the emplacement drift at a overall WP heat output of 1.45 kW/m and a ventilation airflow rate in the emplacement drift of 15 m^3/s is 59.13 degrees Celsius, as calculated below.

$$y = 23.4x + 25.2$$

Where: y = temperature (° Celsius) and
x = overall WP heat output (kW/m).

Where: x = 1.45 kW/m,

$$y = 23.4(1.45\,\mathrm{kW/m}) + 25.2$$

$$y = 59.13\,°\,\mathrm{Celsius}$$

In order to determine the thermal expansion of the airflow volume, the temperature in degrees Celsius must be converted to degrees Kelvin using the formula indicated in Section 4.1.7.4.

Intake Air Temperature in Kelvin	=	25 ° Celsius (see Section 5.2.7.12) + 273.15
	=	298.15 °Kelvin
Exhaust Air Temperature in Kelvin	=	59.13 °C + 273.15
	=	332.28 °Kelvin

The maximum thermal expansion of the airflow volume per drift split is approximately 16.72 m^3/s as calculated below using Charles' Law of Thermal Expansion (see Section 4.1.7.4).

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Where: V_1 = intake airflow volume,
V_2 = exhaust airflow volume,
T_1 = absolute intake air temperature in °Kelvin, and
T_2 = absolute exhaust air temperature in °Kelvin.

When: V_1 = 15 m^3/s (see Section 6.2.3.4),
T_1 = 298.15 °Kelvin, and
T_2 = 332.28 °Kelvin.

$$\frac{15\ m^3/s}{V_2} = \frac{298.15\,°\ \text{Kelvin}}{332.28\,°\ \text{Kelvin}}$$

$$V_2 = \frac{332.28\,°\ \text{Kelvin} \ \ x \ \ 15\ m^3/s}{298.15\,°\ \text{Kelvin}}$$

$$V_2 = 16.72\ m^3/s$$

IV.3 Exhaust Main

The Exhaust Main will be partitioned to separate the heated exhaust air exiting the emplacement drifts from the cooler service air exiting from drifts such as the Test and Evaluation Facilities, the standby drifts, and the cross-block drifts (see Sections 6.2.1.2 and 4.2.4.12) in the event that human access is required in the Exhaust Main (see Section 5.2.7.5). One side of the Exhaust Main will accommodate the ventilation controls at the emplacement drift raises as well as exhausting the cooler service air. This side of the Exhaust Main will be referred to as the service side. The other side of the Exhaust Main will exhaust the heated air exiting the emplacement drifts and postclosure test drifts. This side will be referred to as the exhaust side. Both sides of the Exhaust Main may require rail, lights, and utilities in the event human access is required (see Section 5.2.7.5). The partition wall, a 0.2-meter thick stopping (see Section 5.2.7.6) will separate the service and exhaust sides of the Exhaust Main.

Exhaust Main Invert-Since both sides of the Exhaust Main will need to accommodate rail transportation, the width of the top of an invert for a 7.62 m main must be calculated as illustrated in Figure IV-3 and as shown below to determine if there is sufficient width to support the stopping and two sets of rail. The width of the invert for the Exhaust Main will be calculated based on the invert size specified for the ramps and mains (see Section 5.2.7.7) in order to bound the maximum airflow volume in the drift.

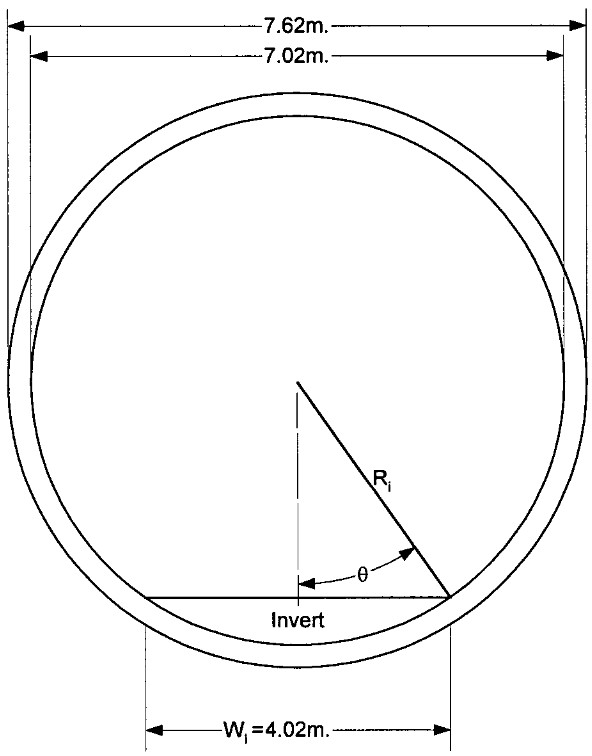

Figure IV-3. Typical Exhaust Main With Invert

$$W_I = 2 \times [\text{Sin}(\theta) \times R_i]$$

Where: W_I = Invert width (m),
θ = Angle between drift centerline and outermost part of invert (degrees), and
R_i = Inside-opening radius (m).

When: θ = 34.9 degrees (see Section 4.1.7.2),
R_i = 3.51 meters (see Section 4.1.7.2).

$$W_I = 2 \times [\mathrm{Sin}(34.9°) \times 3.51 \text{ meters}]$$

$$W_I = 4.02 \text{ meters}$$

There should be sufficient space on each side of the Exhaust Main to accommodate a typical rail gauge of 1.44 meters (see Section 4.1.7.2) since the invert width in each side of the Exhaust Main is 1.91 meters as calculated below.

$$\text{Invert Width, Each Side} = \frac{W_I - W_S}{2}$$

Where: W_I = Invert Width (m) and
W_S = Width of Stopping (m).

Where: W_I = 4.02 meters and
W_S = 0.2 meters (see Section 5.2.7.6).

$$\text{Invert Width, Each Side} = \frac{4.02 \text{ meters} - 0.2 \text{ meters}}{2}$$

$$\text{Invert Width, Each Side} = 1.91 \text{ meters}$$

Obstruction Areas in the Exhaust Main-The effective area of both the exhaust side and the service side of the Exhaust Main must be calculated to determine the airflow volumes that can be accommodated. In order to determine the effective area, the areas of the obstructions within the openings must be calculated.

The area of the ventilation stopping (partition wall) is 1.28 m^2 as calculated below.

$$H_{stopping} = \text{Opening diameter (m)} - \text{Lining thickness (m)} - \text{Invert height (m)}$$

Where: $H_{stopping}$ = Height of the Stopping (m).

When: Opening diameter = 7.62 meters (see Section 5.2.7.2),
Lining thickness = 0.3 meters (see Section 4.1.7.2), and
Invert height = 0.933 meters (see Section 4.1.7.2).

$$H_{stopping} = 7.62 \text{ meters} - 0.3 \text{ meters} - 0.933 \text{ meters}$$

$$H_{stopping} = 6.39 \text{ meters}$$

$$A_{stopping} = W_{stopping} \times H_{stopping}$$

Where: $A_{stopping}$ = Area of the Stopping (m^2),
$W_{stopping}$ = Width of the Stopping (m), and
$H_{stopping}$ = Height of the Stopping (m).

When: $W_{stopping}$ = 0.2 meters (see Section 5.2.7.6), and
$H_{stopping}$ = 6.39 meters.

$$A_{stopping} = 0.2 \text{ meters} \times 6.39 \text{ meters}$$

$$A_{stopping} = 1.28 \text{ m}^2$$

The area occupied by the tie is 0.19 m^2 as calculated below.

$$A_{tie} = \text{Invert Width, Each Side} \times H_{tie}$$

Where: A_{tie} = Area of the tie (m^2) and
H_{tie} = Height of the tie (m).

When: W_{tie} = 1.91 meters and
H_{tie} = 0.1 meters (see Section 4.1.7.2).

$$A_{tie} = 1.91 \text{ meters} \times 0.1 \text{ meters}$$

$$A_{tie} = 0.19 \text{ m}^2$$

Exhaust Side-The effective area of the exhaust side of the Exhaust Main is 17.07 m^2 as calculated below.

The total area, excluding obstructions is one-half of the opening area with the invert and the stopping area as calculated below.

$$TA_{exhaust} = \frac{A_{opening} - A_{invert} - A_{stopping}}{2}$$

Where: $TA_{exhaust}$ = Total area of exhaust side (m^2),
$A_{opening}$ = Area of the opening (m^2),
A_{invert} = Area of the invert (m^2), and
$A_{stopping}$ = Area of stopping (m^2).

When: $A_{opening}$ = 38.7 m^2 (see Section 4.1.7.2),
A_{invert} = 1.73 m^2 (see Section 4.1.7.2), and
$A_{stopping}$ = 1.28 m^2.

$$TA_{exhaust} = \frac{38.7\,m^2 - 1.73\,m^2 - 1.28\,m^2}{2}$$

$$TA_{exhaust} = 17.85\,m^2$$

The Effective area for the exhaust side can now be calculated as the total area less all of the obstruction areas.

$$EA_{exhaust} = TA_{exhaust} - \left(A_{tie} + A_{rails} + A_{utilities} + A_{light}\right)$$

Where:	$EA_{exhaust}$	=	Effective area of exhaust side (m^2),
	$TA_{exhaust}$	=	Total area of exhaust side (m^2),
	A_{tie}	=	Area of rail tie (m^2),
	A_{rails}	=	Area of rails (m^2),
	$A_{utilities}$	=	Area of utilities (m^2), and
	A_{light}	=	Area of light fixture (m^2).

When:	$TA_{exhaust}$	=	17.85 m^2,
	A_{tie}	=	0.19 m^2,
	A_{rails}	=	0.0145 m^2 (see Section 4.1.7.2),
	$A_{utilities}$	=	0.474 m^2 (see Section 4.1.7.2), and
	A_{light}	=	0.1 m^2 (see Section 4.1.7.2).

$$EA_{exhaust} = 17.85\,m^2 - \left(0.19\,m^2 + 0.0145\,m^2 + 0.474\,m^2 + 0.1\,m^2\right)$$

$$EA_{exhaust} = 17.07\,m^2$$

The exhaust side of the Exhaust Main can support an airflow volume of 136.56 $m^{3/s}$ in one direction as calculated below.

$$Volume_{exhaust} = A_{exhaust} \times Velocity_{exhaust}$$

When: $Velocity_{exhaust}$ = 8 m/s (see Section 5.2.7.4).

$$Volume_{exhaust} = 17.07\,m^2 \times 8\,m/s$$

$$Volume_{exhaust} = 136.56\,m^3/s$$

The exhaust side of the Exhaust Main can support four drifts exhausting heated air, or eight splits as indicated below.

$$\text{Number of Emplacement Drifts} = \frac{Volume_{exhaust}}{\left(EVolume_{split} \times 2\right)}$$

When: $EVolume_{split}$ = Expanded Volume of Exhaust Air from Heated Drift Split (m^3)

= 16.72 m^3/s (see Section IV.2)

$$\text{Number of Emplacement Drifts} = \frac{136.56\ m^3/s}{(16.72\ m^3/s \ \ x \ \ 2)}$$

Number of Emplacement Drifts = 4.08, or approximately 4

Service Side-The service side of the Exhaust Main contains the control valves from the exhaust raises. The top two meters of the Exhaust Main on the service side will accommodate the control valves from the exhaust raise, since the raise is two meters in diameter. The area that this control valve obstructs in the service side airway is 4.29 m^2 as calculated below.

In order to determine this obstruction area, the area defined by the arc of β degrees (Area 1 plus Area 2) must be calculated, and the area defined as Area 2 and the portion of Area 1 occupied by the stopping are subtracted (see Figure IV-4).

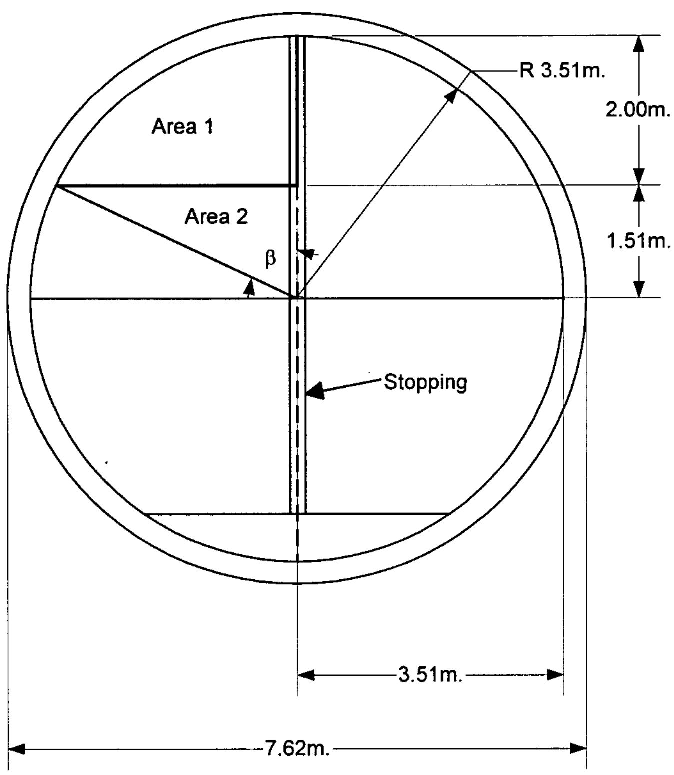

Figure IV-4. Exhaust Side Area Determination

$$\text{Cosine}(\beta) = \frac{1.51 \text{ meters}}{3.51 \text{ meters}}$$

$$\beta = \text{Cosine}^{-1}\left(\frac{1.51 \text{ meters}}{3.51 \text{ meters}}\right)$$

$$\beta = 64.5°$$

The area defined by the arc of β degrees is 6.93 m^2 as calculated below.

$$A_\beta = \pi \times R^2 \times \left(\frac{\beta}{360°}\right)$$

Where: A_β = Area defined by the arc of β degrees (Area 1 plus Area 2)

$$A_\beta = \pi \times (3.51 \text{ meters})^2 \times \left(\frac{64.5°}{360°}\right)$$

$$A_\beta = 6.93 \text{ m}^2$$

In order to determine Area 1, Area 2 must be determined and subtracted from A_β, 6.93 m^2.

$$\text{Area 1} = A_\beta - \text{Area 2}$$

$$\text{Area 1} = A_\beta - \left(\tfrac{1}{2} \times 3.51 \text{ meters} \times 1.51 \text{ meters}\right)$$

$$\text{Area 1} = 6.93 \text{ m}^2 - \left(\tfrac{1}{2} \times 3.51 \text{ meters} \times 1.51 \text{ meters}\right)$$

$$\text{Area 1} = 6.93 \text{ m}^2 - 2.65 \text{ m}^2$$

$$\text{Area 1} = 4.28 \text{ m}^2$$

In order to determine the control valve obstruction area, the portion of Area 1 occupied by the stopping must be subtracted from Area 1, 4.28 m^2.

$$A_{CV} = \text{Area 1} - A_3$$

Where: A_{CV} = Area of the control valve (m^2) and
A_3 = Portion of Area 1 occupied by the stopping (m^2).

$$A_3 = \left(\frac{W_{stopping}}{2} \;\; x \;\; H_{Area\ 1} \right)$$

Where: $H_{Area\ 1}$ = 2 meters (see Figure IV-4).

$$A_3 = \left(\frac{0.2 \text{ meters}}{2} \;\; x \;\; 2 \text{ meters} \right)$$

$$A_{CV} = 4.28\,m^2 - \left(\frac{0.2 \text{ meters}}{2} \;\; x \;\; 2 \text{ meters} \right)$$

$$A_{CV} = 4.08\,m^2$$

The effective area for the service side is 12.99 m^2 and is calculated as the effective area of the exhaust side less the area reserved for the control valves.

$$EA_{service} = EA_{exhaust} - A_{CV}$$

$$EA_{service} = 17.07\,m^2 - 4.08\,m^2$$

$$EA_{service} = 12.99\,m^2$$

The service side can support an airflow volume of 103.92 m^3/s as calculated below.

$$Volume_{service} = A_{service} \;\; x \;\; Velocity_{exhaust}$$

When: $Velocity_{exhaust}$ = 8 m/s (see Section 5.2.7.4).

$$Volume_{service} = 12.99\,m^2 \;\; x \;\; 8\,m/s$$

$$Volume_{service} = 103.92\,m^3/s$$

The service side of the Exhaust Main will be able to accommodate five cross-block, standby, or Test and Evaluation Facility drift splits as calculated below.

$$\text{Number of Splits} = \frac{Volume_{service}}{Volume_{split}}$$

When: $Volume_{split}$ = Volume per Cross-block or Test and Evaluation Drift Split (m^3)

$$= \quad 19.63 \text{ m}^3\text{/s (see Section IV.1)}$$

$$\text{Number of Splits} = \frac{103.92 \text{ m}^3 / \text{s}}{19.63 \text{ m}^3 / \text{s}}$$

$$\text{Number of Splits} = 5.29\text{, or approximately 5}$$

IV.4 70,000 MTU Case

Figure 11 shows the 70,000 MTU Layout for SR. Based on the calculations in Sections IV.1, IV.2, and IV.3, as well as the calculations that follow, there are five intake openings (three shafts and two ramps) and four exhaust shafts in the layout.

IV.4.1 Intake Airflow Volumes

The design airflow volumes that can be accommodated in the intake openings are listed in Table IV-1.

Table IV-1. Intake Opening Design Airflow Volumes – 70,000 MTU Case

Intake Opening Description	Design Airflow Volume (m^3/s)	Section Reference
North Ramp	217.02	Section IV.1
Intake Shaft 1	578.72	Section IV.1
Intake Shaft 2	578.72	Section IV.1
Intake Shaft 3	578.72	Section IV.1
South Ramp	289.36	Section IV.1
TOTAL	2,242.54	

The drift splits requiring ventilation and the total intake airflow volumes required are listed in Table IV-2.

Table IV-2. Required Intake Ventilation Split Airflow Volumes – 70,000 MTU Case

Heading Description	Number of Drift Splits	Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)	Section Reference for Number of Drift Splits	Section Reference for Required Volume
ECRB	2	19.63	39.26	Section 6.2.4.2	Section IV.1
Test and Evaluation Facility ODs	5	19.63	98.15	Section 6.2.4.2	Section IV.1
Standby Drifts	4	15.00	60.00	Section 6.2.4.2	Section 6.2.3.4
Cross-block Drifts	6	19.63	117.78	Section 6.2.4.2	Section IV.1
Test and Evaluation Facility Postclosure Test Drifts	2	15.00	30.00	Section 6.2.4.2	Section 6.2.3.4
Emplacement Drifts	104	15.00	1,560.00	Section 6.2.4.2	Section 6.2.3.4
Contingency	12	15.00	180.00	Section 6.2.4.2	Section 6.2.3.4
TOTAL			2,085.19		

Intake Airflow Volume Allocations-Each intake shaft and ramp is designated by the airflow volumes that must support the intake airflows to specific headings within the Subsurface Facility. The intake ventilation airflow allocations outlined in Table IV-3 to Table IV-7 are depicted in Figure IV-5. The zones shown in Figure IV-5 are used for planning only. Ventilation simulations will provide a more accurate representation of airflow distribution.

The design capacity of the North Ramp is 217.02 m^3/s (see Table IV-1), which can supply intake air to the north end of the repository to Emplacement Drift 3 (see Table IV-3) without violating the velocity constraints in the mains or the ramps as outlined in Sections 5.2.7.4 and IV.1.

Table IV-3. North Ramp Intake Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits	Required Airflow Volume (m^3/s)	Total Volume (m^3)
ECRB	1	19.63	19.63
Test and Evaluation Facility ODs	3	19.63	58.89
Standby Drifts	0	15.00	0.00
Cross-block Drifts	0	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	2	15.00	30.00
Emplacement Drifts	6	15.00	90.00
Contingency	0	15.00	0.00
Total			198.52
Extra Capacity			18.5

The design capacity of Intake Shaft 1 is 578.72 m^3/s (see Table IV-1). Intake Shaft 1 can supply intake air to the repository facilities located between Emplacement Drifts 4 and 19 (see Table IV-4) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1.

Table IV-4. Intake Shaft 1 Intake Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Standby Drifts	1	0	1	0	15.00	15.00	0.00	15.00	0.00
Cross-block Drifts	0	1	0	1	19.63	0.00	19.63	0.00	19.63
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	5	11	5	11	15.00	75.00	165.00	75.0	165.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						90.00	184.63	90.00	184.63
Total per Access						274.63		274.63	
Shaft Total						549.26			
Extra Shaft Capacity						29.46			

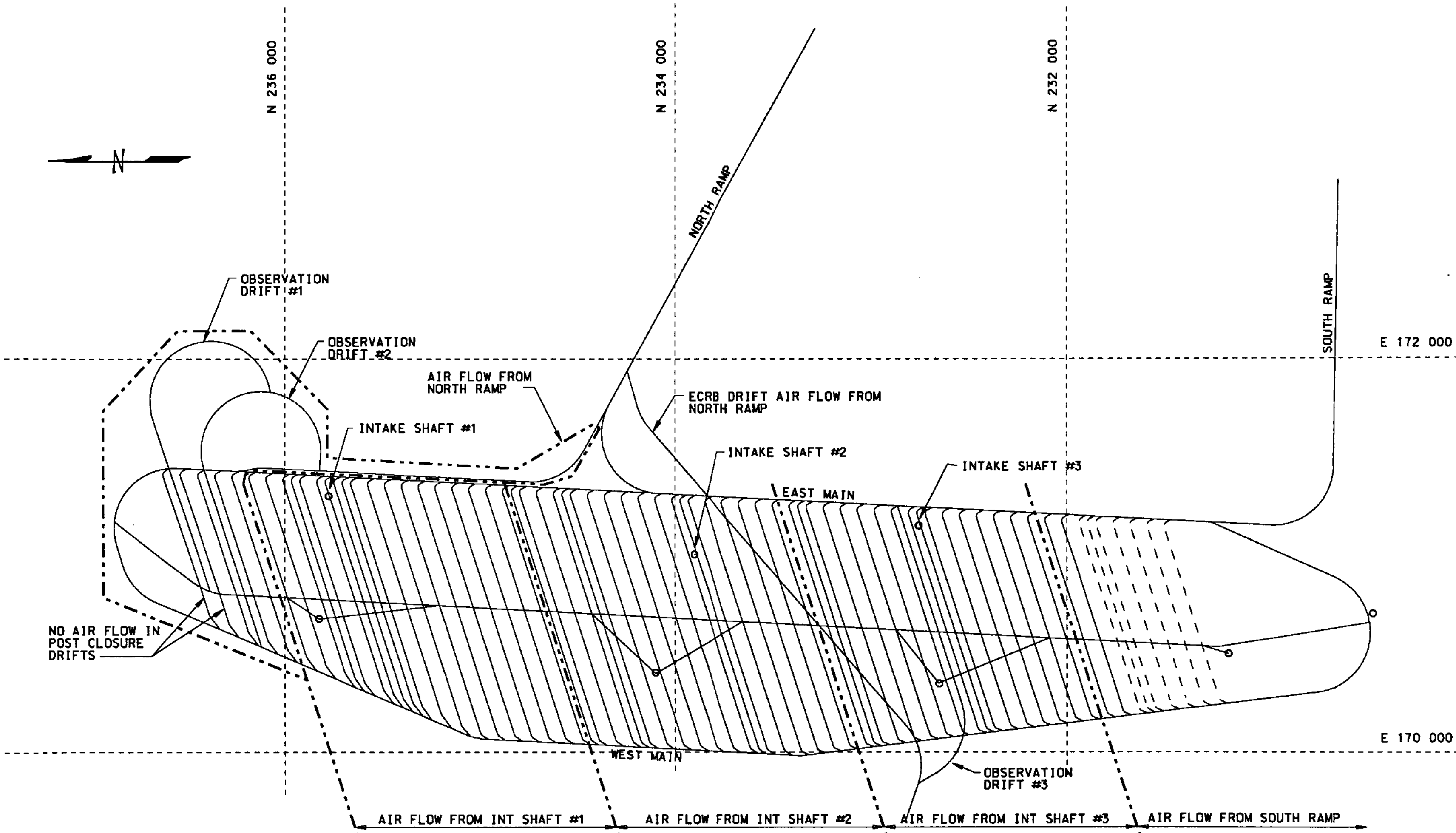

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Figure IV-5. Intake Airflow Volume Allocations – 70,000 MTU Case

The design capacity of Intake Shaft 2 is 578.72 m^3/s (see Table IV-1). Intake Shaft 2 can supply intake air to the repository facilities located between Standby Drift 2 and Emplacement Drift 35 (see Table IV-5) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1.

Table IV-5. Intake Shaft 2 Intake Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Standby Drifts	1	0	1	0	15.00	15.00	0.00	15.00	0.00
Cross-block Drifts	1	0	1	0	19.63	19.63	0.00	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	10	6	10	6	15.00	150.00	90.00	150.00	60.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						184.63	90	184.63	90
Total per Access						274.63		274.63	
Shaft Total						549.26			
Extra Shaft Capacity						29.46			

The design capacity of Intake Shaft 3 is 578.72 m^3/s (see Table IV-1). Intake Shaft 3 can supply intake air to the repository facilities located between Emplacement Drifts 36 and 50 (see Table IV-6) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1.

Table IV-6. Intake Shaft 3 Intake Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	1	0	19.63	0.00	0.00	19.63	0.00
Test and Evaluation Facility ODs	1	0	1	0	19.63	19.63	0.00	19.63	0.00
Standby Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Cross-block Drifts	1	0	1	0	19.63	19.63	0.00	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	7	8	7	15.00	120.00	105.00	120.00	105.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						159.26	105	178.89	105
Total per Access						264.26		283.89	
Shaft Total						548.15			
Extra Shaft Capacity						30.57			

The design capacity of the South Ramp is 289.36 m^3/s (see Table IV-1). South Ramp can supply intake air to the repository facilities located between Emplacement Drifts 51 and 52, as well as the contingency area (see Table IV-7), without violating the velocity constraints in the mains or ramps as outlined in Sections 5.2.7.4 and IV.1.

Table IV-7. South Ramp Intake Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits	Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)
ECRB	0	19.63	0.00
Test and Evaluation Facility ODs	0	19.63	0.00
Standby Drifts	0	15.00	0.00
Cross-block Drifts	0	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	0	15.00	0.00
Emplacement Drifts	4	15.00	60.00
Contingency	12	15.00	180.00
Total			240.00
Extra Capacity			49.36

IV.4.2 Exhaust Airflow Volumes

The drift splits requiring ventilation and the total exhaust airflow volumes required are listed in Table IV-8.

Table IV-8. Required Exhaust Ventilation Split Airflow Volumes – 70,000 MTU Case

Heading Description	Number of Drift Splits	Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)	Section Reference for Number of Drift Splits	Section Reference for Required Volume
ECRB	2	19.63	39.26	Section 6.2.4	Section IV.1
Test and Evaluation Facility ODs	5	19.63	98.15	Section 6.2.4	Section IV.1
Standby Drifts	4	16.72	66.88	Section 6.2.4	Section IV.2
Cross-block Drifts	6	19.63	117.78	Section 6.2.4	Section IV.1
Test and Evaluation Facility Postclosure Test Drifts	2	16.72	33.44	Section 6.2.4	Section IV.2
Emplacement Drifts	104	16.72	1,738.88	Section 6.2.4	Section IV.2
Contingency	12	16.72	200.64	Section 6.2.4	Section IV.2
TOTAL			2,295.03		

Exhaust Airflow Volume Allocations-Airflow volumes are designated to each exhaust shaft and the Exhaust Main to support the exhaust airflows from specific headings within the Subsurface Facility. Each exhaust shaft, utilized to its full capacity, is connected to the Exhaust Main by two accesses (see Section 5.2.7.9). The exhaust ventilation airflow allocations outlined in Table IV-9 to Table IV-12 are depicted in Figure IV- 6. The zones shown in Figure IV- 6 are used for planning only. Ventilation simulations will provide a more accurate representation of airflow distribution.

Exhaust Shaft 1 can support the exhaust air from the north end of the repository through Emplacement Drift 17 (see Table IV-9) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 2 can support the exhaust air from the area between Emplacement Drift 18 through Emplacement Drift 35 and the ECRB (see Table IV-10) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 3 can support the exhaust air from the area between Emplacement Drift 36 through Emplacement Drift 52 and Contingency Drift 1 (see Table IV-11) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 4, which is for contingency only, can support the exhaust air from the area between Contingency Drift 2 through Contingency Drift 6 (see Table IV-12) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

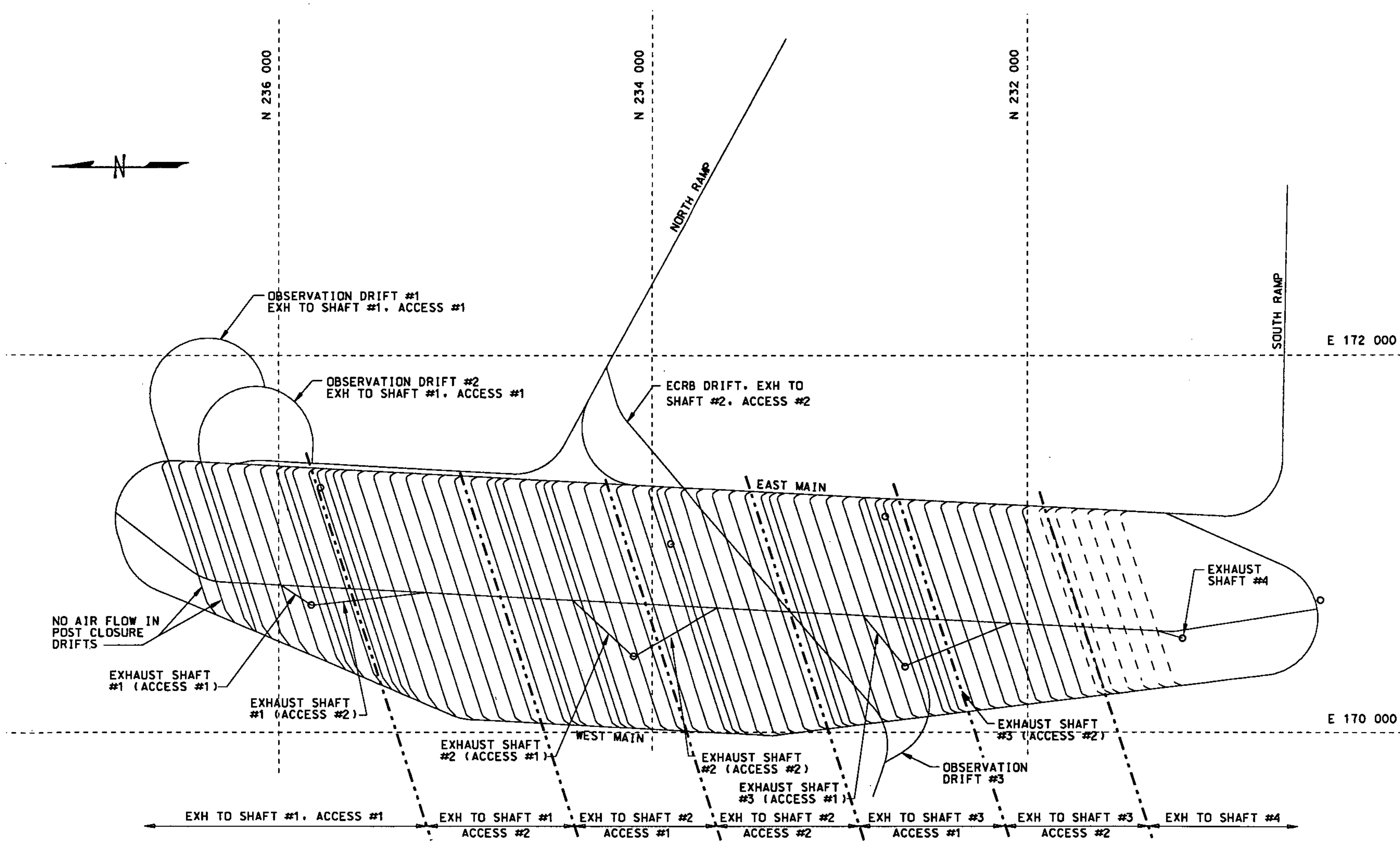

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Figure IV- 6. Exhaust Airflow Volume Allocations – 70,000 MTU Case

Table IV-9. Exhaust Shaft 1 Exhaust Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	3	0	0	0	0	0	19.63	58.89	0.00	0.00	0.00	0.00	0.00
Standby Drifts	0	2	0	0	0	0	16.72	0.00	33.44	0.00	0.00	0.00	0.00
Cross-block Drifts	0	0	0	2	0	0	19.63	0.00	0.00	0.00	39.26	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	2	0	0	0	0	0	16.72	33.44	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	6	8	2	8	8	2	16.72	100.32	133.76	33.44	133.76	133.76	33.44
Contingency	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Total								192.65	167.20	33.44	173.02	133.76	33.44
Total per Access								393.29			340.22		
Shaft Total								733.51					

Table IV-10. Exhaust Shaft 2 Exhaust Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	2	0	19.63	0.00	0.00	0.00	0.00	39.26	0.00
Test and Evaluation Facility ODs	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Standby Drifts	2	0	0	0	0	0	16.72	33.44	0.00	0.00	0.00	0.00	0.00
Cross-block Drifts	0	2	0	0	0	0	19.63	0.00	39.26	0.00	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	8	2	8	8	2	16.72	133.76	133.76	33.44	133.76	133.76	33.44
Contingency	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Total								167.20	173.02	33.44	133.76	173.02	33.44
Total per Access								373.66			340.22		
Shaft Total								713.88					

Table IV-11. Exhaust Shaft 3 Exhaust Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	2	0	0	0	0	19.63	0.00	39.26	0.00	0.00	0.00	0.00
Standby Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Cross-block Drifts	2	0	0	0	0	0	19.63	39.26	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	8	2	8	6	2	16.72	133.76	133.76	33.44	133.76	100.32	33.44
Contingency	0	0	0	0	2	0	16.72	0.00	0.00	0.00	0.00	33.44	0.00
Total								173.02	173.02	33.44	133.76	133.76	33.44
Total per Access									379.48			300.96	
Shaft Total										680.44			

Table IV-12. Exhaust Shaft 4 (Contingency Only) Exhaust Airflow Volume Allocation – 70,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	--	--	--	19.63	0.00	0.00	0.00	--	--	--
Test and Evaluation Facility ODs	0	0	0	--	--	--	19.63	0.00	0.00	0.00	--	--	--
Standby Drifts	0	0	0	--	--	--	16.72	0.00	0.00	0.00	--	--	--
Cross-block Drifts	0	0	0	--	--	--	19.63	0.00	0.00	0.00	--	--	--
Test and Evaluation Facility Postclosure Drifts	0	0	0	--	--	--	16.72	0.00	0.00	0.00	--	--	--
Emplacement Drifts	0	0	0	--	--	--	16.72	0.00	0.00	0.00	--	--	--
Contingency	8	0	2	--	--	--	16.72	133.76	0.00	33.44	--	--	--
Total								133.76	0.00	33.44	--	--	--
Total per Access									167.20			--	
Shaft Total										167.20			

IV.5 97,000 MTU Case

Figure 12 shows the 97,000 MTU Layout for SR. Based on the calculations in Sections IV.1, IV.2, and IV.3, as well as the calculations that follow, there are seven intake openings (five shafts and two ramps) and six exhaust shafts.

IV.5.1 Intake Volumes

The design airflow volumes that can be accommodated in the intake openings are listed in Table IV-13.

Table IV-13. Intake Opening Design Airflow Volumes – 97,000 MTU Case

Intake Opening Description	Airflow Volume (m^3/s)	Section Reference
North Ramp	217.02	Section IV.1
Intake Shaft 1	578.72	Section IV.1
Intake Shaft 2	578.72	Section IV.1
Intake Shaft 3	578.72	Section IV.1
Intake Shaft 4	578.72	Section IV.1
Development/Intake Shaft	578.72	Section IV.1
South Ramp	289.36	Section IV.1
TOTAL	3,399.98	

The drift splits requiring ventilation and the total intake volumes required are listed in Table IV-14.

Table IV-14. Required Intake Ventilation Split Airflow Volumes – 97,000 MTU Case

Heading Description	Number of Drift Splits	Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)	Section Reference for Number of Drift Splits	Section Reference for Required Volume
ECRB	2	19.63	39.26	Section 6.2.4	Section IV.1
Test and Evaluation Facility ODs	7	19.63	137.41	Section 6.2.4	Section IV.1
Standby Drifts	4	15	60.00	Section 6.2.4	Section 6.2.3.4
Cross-block Drifts	8	19.63	157.04	Section 6.2.4	Section IV.1
Test and Evaluation Facility Postclosure Test Drifts	2	15	30.00	Section 6.2.4	Section 6.2.3.4
Emplacement Drifts	160	15	2,400.00	Section 6.2.4	Section 6.2.3.4
Contingency	20	15	300.00	Section 6.2.4	Section 6.2.3.4
TOTAL			3,123.71		

Intake Airflow Volume Allocations-Each intake shaft and ramp is designated by the airflow volumes that must support the intake airflows to specific headings within the Subsurface Facility. The intake ventilation airflow allocations outlined in Table IV-15 to Table IV-21 are depicted in Figure IV-7. The zones shown in Figure IV-7 are used for planning only. Ventilation simulations will provide a more accurate representation of airflow distribution.

The design capacity of the North Ramp is 217.02 m^3/s (see Table IV-13) and can supply intake air to the north end of the repository to Emplacement Drift 3 (see Table IV-15) without violating the velocity constraints in the mains or the ramps as outlined in Sections 5.2.7.4 and IV.1.

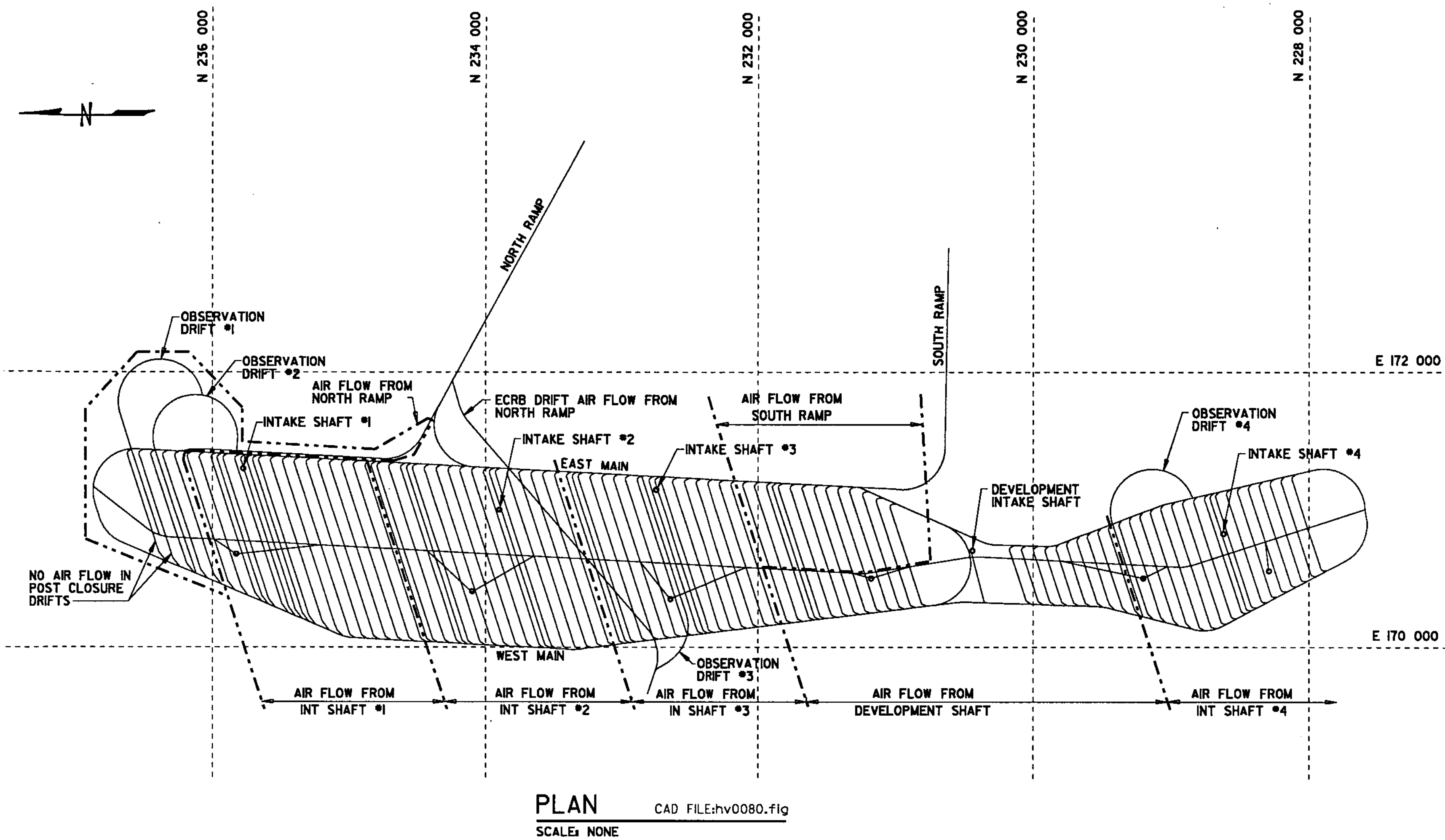

Figure IV-7. Intake Airflow Volume Allocations – 97,000 MTU Case

Table IV-15. North Ramp Intake Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits	Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)
ECRB	1	19.63	19.63
Test and Evaluation Facility ODs	3	19.63	58.89
Standby Drifts	0	15.00	0.00
Cross-block Drifts	0	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	2	15.00	30.00
Emplacement Drifts	6	15.00	90.00
Contingency	0	15.00	0.00
Total			198.52
Extra Capacity			18.5

The design capacity of Intake Shaft 1 is 578.72 m^3/s (see Table IV-13). Intake Shaft 1 can supply intake air to the repository facilities located between Emplacement Drifts 4 and 19 (see Table IV-16) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1.

Table IV-16. Intake Shaft 1 Intake Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Standby Drifts	1	0	1	0	15.00	15.00	0.00	15.00	0.00
Cross-block Drifts	0	1	0	1	19.63	0.00	19.63	0.00	19.63
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	5	11	5	11	15.00	75.00	165.00	75.0	165.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						90.00	184.63	90.00	184.63
Total per Access						274.63		274.63	
Shaft Total						549.26			
Extra Shaft Capacity						29.46			

The design capacity of Intake Shaft 2 is 578.72 m^3/s (see Table IV-13). Intake Shaft 2 can supply intake air to the repository facilities located between Standby Drift 2 and Emplacement Drift 35 (see Table IV-17) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1.

Table IV-17. Intake Shaft 2 Intake Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Standby Drifts	1	0	1	0	15.00	15.00	0.00	15.00	0.00
Cross-block Drifts	1	0	1	0	19.63	19.63	0.00	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	10	6	10	6	15.00	150.00	90.00	150.00	60.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						184.63	90	184.63	90
Total per Access						274.63		274.63	
Shaft Total						549.26			
Extra Shaft Capacity						29.46			

The design capacity of Intake Shaft 3 is 578.72 m^3/s (see Table IV-13). Intake Shaft 3 can supply intake air to the repository facilities located between Emplacement Drifts 36 and 50 (see Table IV-18) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1.

Table IV-18. Intake Shaft 3 Intake Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	1	0	19.63	0.00	0.00	19.63	0.00
Test and Evaluation Facility ODs	1	0	1	0	19.63	19.63	0.00	19.63	0.00
Standby Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Cross-block Drifts	1	0	1	0	19.63	19.63	0.00	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	7	8	7	15.00	120.00	105.00	120.00	105.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						159.26	105	178.89	105
Total per Access						264.26		283.89	
Shaft Total						548.15			
Extra Shaft Capacity						30.57			

The design capacity of the South Ramp is 289.36 m^3/s (see Table IV-13). The South Ramp can supply intake air to the repository facilities located between east side of Emplacement Drifts 51 and 63 (see Table IV-19) without violating the velocity constraints in the mains or ramps as outlined in Sections 5.2.7.4 and IV.1.

Table IV-19. South Ramp Intake Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Standby Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Cross-block Drifts	1	0	0	0	19.63	19.63	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	10	3	0	0	15.00	150.00	45.00	0.00	0.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						169.63	45.00	0.00	0.00
						214.63		0.00	
Ramp Total						214.63			
Extra Ramp Capacity						74.73			

The shaft design capacity of the Development/Intake is 578.72 m^3/s (see Table IV-13). The Development/Intake Shaft can supply intake air to the repository facilities located between west side of Emplacement Drifts 50 and 63 and all of the repository facilities located between Emplacement Drifts 64 and 73 (see Table IV-20) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1.

Table IV-20. Development/Intake Shaft Intake Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Standby Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Cross-block Drifts	0	0	1	0	19.63	0.00	0.00	19.63	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	0	10	13	10	15.00	0.00	150.00	195.00	150.00
Contingency	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Total						0.00	150.00	214.63	150.00
Total per Access						150.00		364.63	
Shaft Total						514.63			
Extra Shaft Capacity						64.09			

The design capacity of Intake Shaft 4 is 578.72 m^3/s (see Table IV-13). Intake Shaft 4 can supply intake air to the repository facilities located between Emplacement Drifts 74 and 80 including the Test and Evaluation Observation Drift 4 and the contingency area (see Table IV-21) without violating the velocity constraints in the mains, shafts, or intake accesses as outlined in Sections 5.2.7.4 and IV.1. The zones shown in Figure IV-7 are used for planning, but when the ventilation network is modeled, the airflows may not be exactly as shown due to free splitting.

Table IV-21. Intake Shaft 4 Intake Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits				Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)			
	NE	SE	NW	SW		NE	SE	NW	SW
ECRB	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	1	0	1	0	19.63	19.63	0.00	19.63	0.00
Standby Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Cross-block Drifts	0	0	0	0	19.63	0.00	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	15.00	0.00	0.00	0.00	0.00
Emplacement Drifts	7	0	7	0	15.00	105.00	0.00	105.00	0.00
Contingency	2	8	2	8	15.00	30.00	120.00	30.00	120.00
Total						154.63	120.00	154.63	120.00
Total per Access						274.63		274.63	
Shaft Total						549.26			
Extra Shaft Capacity						29.46			

IV.5.2 Exhaust Airflow Volumes

The drift splits requiring ventilation and the total exhaust airflow volumes needed are listed in Table IV-22.

Table IV-22. Required Exhaust Ventilation Split Airflow Volumes – 97,000 MTU Case

Heading Description	Number of Drift Splits	Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)	Section Reference for Number of Drift Splits	Section Reference for Required Volume
ECRB	2	19.63	39.26	Section 6.2.4	Section IV.1
Test and Evaluation Facility ODs	7	19.63	137.41	Section 6.2.4	Section IV.1
Standby Drifts	4	16.72	66.88	Section 6.2.4	Section IV.2
Cross-block Drifts	8	19.63	157.04	Section 6.2.4	Section IV.1
Test and Evaluation Facility Postclosure Test Drifts	2	16.72	33.44	Section 6.2.4	Section IV.2
Emplacement Drifts	160	16.72	2,675.20	Section 6.2.4	Section IV.2
Contingency	20	16.72	334.40	Section 6.2.4	Section IV.2
TOTAL			3,443.63		

Exhaust Airflow Volume Allocations-Airflow volumes are designated to each exhaust shaft and the Exhaust Main to support the exhaust airflows from specific headings within the Subsurface Facility. Each Exhaust shaft is connected to the Exhaust Main with two accesses (see Section 5.2.7.9). The exhaust ventilation airflow allocations outlined in Table IV-9 to Table IV-12 are depicted in Figure IV- 8. The zones shown in Figure IV- 8 are used for planning only. Ventilation simulations will provide a more accurate representation of airflow distribution.

Exhaust Shaft 1 can support the exhaust air from the north end of the repository through Emplacement Drift 17 (see Table IV-23) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 2 can support the exhaust air from the area between Emplacement Drift 18 through Emplacement Drift 35 and the ECRB (see Table IV-24) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 3 can support the exhaust air from the area between Emplacement Drift 36 through Emplacement Drift 53 (see Table IV-25) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 4, can support the exhaust air from the area between Emplacement Drift 54 through Emplacement Drift 63 (see Table IV-26) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 5, can support the exhaust air from the area between Emplacement Drift 64 through Emplacement Drift 80 as well as Contingency Drift 1 (see Table IV-27) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

Exhaust Shaft 6, which is for contingency only, can support the exhaust air from the area between Contingency Drift 2 through Contingency Drift 10 (see Table IV-28) without violating the velocity constraints in the Exhaust Main as outlined in Sections 5.2.7.4 and IV.3.

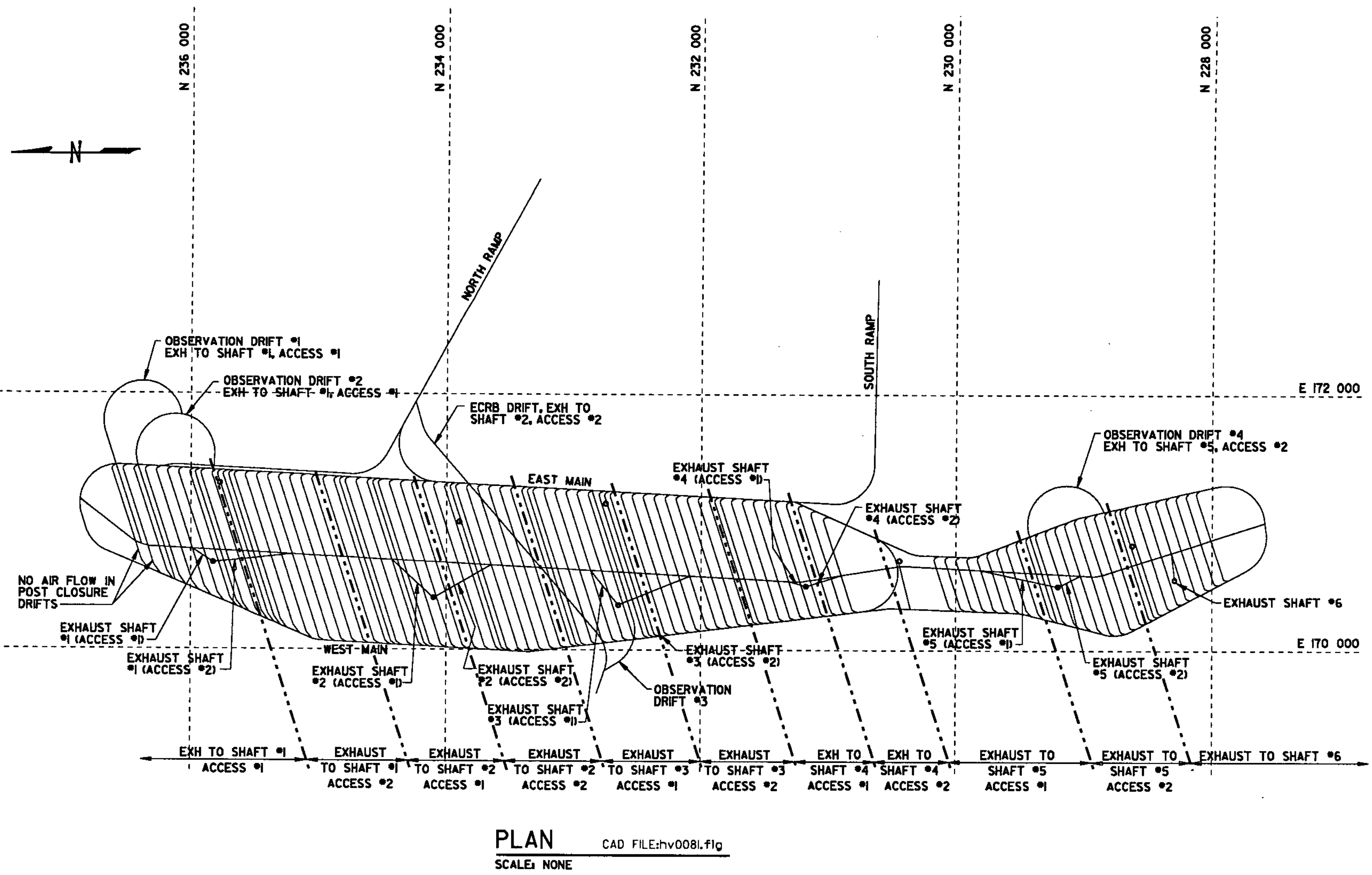

Figure IV- 8. Exhaust Airflow Volume Allocations – 97,000 MTU Case

Table IV-23. Exhaust Shaft 1 Exhaust Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	3	0	0	0	0	0	19.63	58.89	0.00	0.00	0.00	0.00	0.00
Standby Drifts	0	2	0	0	0	0	16.72	0.00	33.44	0.00	0.00	0.00	0.00
Cross-block Drifts	0	0	0	2	0	0	19.63	0.00	0.00	0.00	39.26	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	2	0	0	0	0	0	16.72	33.44	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	6	8	2	8	8	2	16.72	100.32	133.76	33.44	133.76	133.76	33.44
Contingency	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Total								192.65	167.20	33.44	173.02	133.76	33.44
Total per Access								393.29			340.22		
Shaft Total								733.51					

Table IV-24. Exhaust Shaft 2 Exhaust Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	2	0	19.63	0.00	0.00	0.00	0.00	39.26	0.00
Test and Evaluation Facility ODs	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Standby Drifts	2	0	0	0	0	0	16.72	33.44	0.00	0.00	0.00	0.00	0.00
Cross-block Drifts	0	2	0	0	0	0	19.63	0.00	39.26	0.00	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	8	2	8	8	2	16.72	133.76	133.76	33.44	133.76	133.76	33.44
Contingency	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Total								167.20	173.02	33.44	133.76	173.02	33.44
Total per Access								373.66			340.22		
Shaft Total								713.88					

Table IV-25. Exhaust Shaft 3 Exhaust Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	2	0	0	0	0	19.63	0.00	39.26	0.00	0.00	0.00	0.00
Standby Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Cross-block Drifts	2	0	0	0	0	0	19.63	39.26	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	8	2	8	8	2	16.72	133.76	133.76	33.44	133.76	133.76	33.44
Contingency	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Total								173.02	173.02	33.44	133.76	133.76	33.44
Total per Access								379.48			300.93		
Shaft Total								680.41					

Table IV-26. Exhaust Shaft 4 Exhaust Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Standby Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Cross-block Drifts	2	0	0	0	0	0	19.63	39.26	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	4	2	4	0	2	16.72	133.76	66.88	33.44	66.88	0.00	33.44
Contingency	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Total								173.02	66.88	33.44	66.88	0.00	33.44
Total per Access								273.34			100.32		
Shaft Total								373.66					

Table IV-27. Exhaust Shaft 5 Exhaust Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility ODs	0	0	0	2	0	0	19.63	0.00	0.00	0.00	39.26	0.00	0.00
Standby Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Cross-block Drifts	0	0	0	0	0	0	19.63	0.00	0.00	0.00	0.00	0.00	0.00
Test and Evaluation Facility Postclosure Drifts	0	0	0	0	0	0	16.72	0.00	0.00	0.00	0.00	0.00	0.00
Emplacement Drifts	8	8	2	8	6	2	16.72	133.76	133.76	33.44	133.76	100.32	33.44
Contingency	0	0	0	0	2	0	16.72	0.00	0.00	0.00	0.00	33.44	0.00
Total								133.76	133.76	33.44	173.02	133.76	33.44
Total per Access								300.96			340.22		
Shaft Total								641.18					

Table IV-28. Exhaust Shaft 6 (Contingency Only) Exhaust Airflow Volume Allocation – 97,000 MTU Case

Heading Description	Number of Splits						Required Airflow Volume (m^3/s)	Total Airflow Volume (m^3/s)					
	Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct		Acc 1 from North	Acc 1 from South	Acc 1 Direct	Acc 2 from North	Acc 2 from South	Acc 2 Direct
ECRB	0	0	0	--	--	--	19.63	0.00	0.00	0.00	--	--	--
Test and Evaluation Facility ODs	0	0	0	--	--	--	19.63	0.00	0.00	0.00	--	--	--
Standby Drifts	0	0	0	--	--	--	16.72	0.00	0.00	0.00	--	--	--
Cross-block Drifts	0	0	0	--	--	--	19.63	0.00	0.00	0.00	--	--	--
Test and Evaluation Facility Postclosure Drifts	0	0	0	--	--	--	16.72	0.00	0.00	0.00	--	--	--
Emplacement Drifts	0	0	0	--	--	--	16.72	0.00	0.00	0.00	--	--	--
Contingency	8	8	2	--	--	--	16.72	133.76	133.76	33.44	--	--	--
Total								133.76	133.76	33.44	--	--	--
Total per Access								300.96			--		
Shaft Total								300.96					

IV.6 Exhaust Shaft Accesses

The exhaust shaft accesses will be sized to accommodate the maximum potential volume from either the north or the south. The largest volume for both the 70,000 MTU Case and the 97,000 MTU Case is 393.29 m^3 (see Table IV-9 and Table IV-23). The required area of the exhaust shaft accesses is 49.16 m^3 as calculated below.

$$\text{Exhaust Shaft Access Area} = \frac{\text{Volume}}{\text{Velocity}}$$

When: Volume = 393.29 m^3 (see Sections IV.4.2 and IV.5.2) and
Velocity = 8 m/s (see Section 5.2.7.4)

$$\text{Shaft Access Area} = \frac{393.29\ m^3}{8\ m/s}$$

$$\text{Shaft Access Area} = 49.16\ m^2$$

The exhaust shaft accesses will be excavated in a horseshoe-shaped profile of 8 meters wide and 8.5 meters high which has a cross-sectional area of 61.13 m^2 as shown in Figure IV-9. This access size will ensure that the velocity constraints are not exceeded if a 0.3 meter concrete lining is installed in the opening.

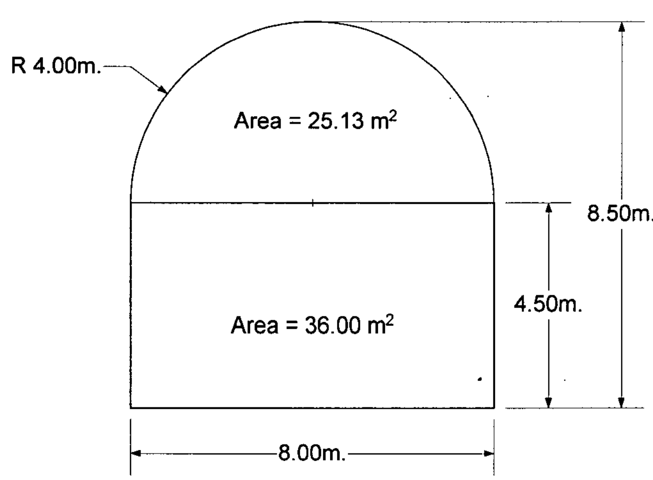

Figure IV-9. Exhaust Shaft Access Profile

IV.7 Shaft Sizes

The largest intake shaft volume of 578.72 m^3 is for Development/Intake Shaft in the 97,000 MTU Case (see Section IV.5.1) and the largest exhaust shaft volume of 733.51 m^3 is for Exhaust Shaft 1 for both the 70,000 MTU and 97,000 MTU Cases (see Section IV.4.2 and Section IV.5.2). To minimize shaft excavation equipment needs, all the ventilation shafts will be excavated to the same diameter (see Section 5.2.7.3). The diameter of the ventilation shafts will be calculated based on the largest shaft volume required, 733.51 m^3.

$$\text{Shaft Area} = \frac{\text{Volume}}{\text{Velocity}}$$

When: Volume = 733.51 m^3 (see Sections IV.4.2 and IV.5.2) and
Velocity = 20 m/s (see Section 5.2.7.4)

$$\text{Shaft Area} = \frac{733.51\ \text{m}^3}{20\ \text{m/s}}$$

$$\text{Shaft Area} = 36.68\ \text{m}^2$$

The minimum inside diameter of the ventilation shafts is 6.83 meters as calculated below.

$$\text{Inside Shaft Diameter} = \sqrt{\frac{4 \times \text{Shaft Area}}{\pi}}$$

$$\text{Inside Shaft Diameter} = \sqrt{\frac{4 \times 36.68\ \text{m}^2}{\pi}}$$

$$\text{Inside Shaft Diameter} = 6.83\ \text{meters}$$

The minimum excavated diameter of the ventilation shafts is 7.43 meters for a lining thickness of 0.3 meters in the shaft (see Section 4.1.7.2).

To account for the installation of utilities, furnishings, as well as the installation of an inspection hoist, the shafts will be excavated to a diameter of 8 meters for the purpose of this analysis.

ATTACHMENT V

BOUNDING COORDINATES OF EMPLACEMENT AREA

ATTACHMENT V

BOUNDING COORDINATES OF EMPLACEMENT AREA

The emplacement area in the planning layout is bounded by a set of coordinates that represent the theoretically last emplaced WP in the drift. The last emplaced WP in the emplacement drift is assumed to be 1.5 meters from the start of the emplacement drift (see Section 5.2.3). Table V-1 lists the boundary coordinates for the emplacement area of the planning layout. Note that the first two drifts listed in Table V-1 are reserved as the postclosure simulation test drifts.

The information in this attachment was extracted from the *Subsurface Planning Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000aa) using VULCAN v3.4.

Table V-1. Bounding Coordinates for Emplacement Area

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
PC1	236,606.073	171,378.875	1,032.437	236,391.550	170,718.641	1,032.437
PC2	236,521.040	171,379.292	1,033.659	236,292.756	170,676.706	1,033.659
1	236,434.396	171,374.751	1,034.831	236,193.962	170,634.770	1,034.831
2	236,347.752	171,370.210	1,036.002	236,095.168	170,592.834	1,036.002
3	236,261.109	171,365.669	1,037.173	235,996.374	170,550.899	1,037.173
4	236,174.465	171,361.129	1,038.345	235,897.579	170,508.963	1,038.345
5	236,087.821	171,356.588	1,039.516	235,798.785	170,467.027	1,039.516
6	236,001.177	171,352.047	1,040.687	235,699.991	170,425.092	1,040.687
7	235,914.533	171,347.506	1,041.858	235,601.197	170,383.156	1,041.858
8	235,827.889	171,342.965	1,043.030	235,502.403	170,341.221	1,043.030
9	235,741.245	171,338.424	1,044.201	235,403.608	170,299.285	1,044.201
10	235,654.601	171,333.884	1,045.372	235,304.814	170,257.349	1,045.372
11	235,567.957	171,329.343	1,046.544	235,206.020	170,215.414	1,046.544
12	235,481.314	171,324.802	1,047.715	235,102.137	170,157.816	1,047.715
13	235,394.670	171,320.261	1,048.886	235,005.154	170,121.454	1,048.886
14	235,308.026	171,315.720	1,050.058	234,918.510	170,116.913	1,050.058
15	235,221.382	171,311.180	1,051.229	234,831.866	170,112.372	1,051.229
16	235,134.738	171,306.639	1,052.400	234,745.222	170,107.831	1,052.400
17	235,048.094	171,302.098	1,053.571	234,658.578	170,103.290	1,053.571
18	234,961.450	171,297.557	1,054.743	234,571.935	170,098.749	1,054.743
19	234,874.806	171,293.016	1,055.914	234,485.291	170,094.209	1,055.914
20	234,788.163	171,288.475	1,057.085	234,398.647	170,089.668	1,057.085
21	234,701.519	171,283.935	1,058.257	234,312.003	170,085.127	1,058.257
22	234,614.875	171,279.394	1,059.428	234,225.359	170,080.586	1,059.428
23	234,528.231	171,274.853	1,060.599	234,138.715	170,076.045	1,060.599
24	234,441.587	171,270.312	1,061.770	234,052.071	170,071.505	1,061.770
25	234,354.943	171,265.771	1,062.942	233,965.427	170,066.964	1,062.942
26	234,268.299	171,261.231	1,064.113	233,878.784	170,062.423	1,064.113
27	234,181.655	171,256.690	1,065.284	233,792.140	170,057.882	1,065.284
28	234,095.012	171,252.149	1,066.456	233,705.496	170,053.341	1,066.456
29	234,008.368	171,247.608	1,067.627	233,618.852	170,048.801	1,067.627
30	233,921.724	171,243.067	1,068.798	233,532.208	170,044.260	1,068.798

Table V-1. Bounding Coordinates for Emplacement Area (Continued)

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
31	233,835.080	171,238.527	1,069.969	233,445.564	170,039.719	1,069.969
32	233,748.436	171,233.986	1,071.141	233,358.817	170,034.860	1,071.141
33	233,661.792	171,229.445	1,072.312	233,276.916	170,044.916	1,072.312
34	233,575.148	171,224.904	1,073.483	233,195.015	170,054.972	1,073.483
35	233,488.504	171,220.363	1,074.655	233,113.114	170,065.029	1,074.655
36	233,401.861	171,215.822	1,075.826	233,031.213	170,075.085	1,075.826
37	233,315.217	171,211.282	1,076.997	232,949.312	170,085.141	1,076.997
38	233,228.573	171,206.741	1,078.169	232,867.411	170,095.197	1,078.169
39	233,141.929	171,202.200	1,079.340	232,785.510	170,105.253	1,079.340
40	233,055.285	171,197.659	1,080.511	232,703.609	170,115.309	1,080.511
41	232,968.641	171,193.118	1,081.682	232,621.708	170,125.366	1,081.682
42	232,881.997	171,188.578	1,082.854	232,539.807	170,135.422	1,082.854
43	232,795.353	171,184.037	1,084.025	232,457.906	170,145.478	1,084.025
44	232,708.710	171,179.496	1,085.196	232,376.005	170,155.534	1,085.196
45	232,622.066	171,174.955	1,086.368	232,294.104	170,165.590	1,086.368
46	232,535.422	171,170.414	1,087.539	232,212.203	170,175.647	1,087.539
47	232,448.778	171,165.874	1,088.710	232,130.301	170,185.703	1,088.710
48	232,362.134	171,161.333	1,089.881	232,048.400	170,195.759	1,089.881
49	232,275.490	171,156.792	1,091.053	231,966.499	170,205.815	1,091.053
50	232,188.846	171,152.251	1,092.224	231,884.598	170,215.871	1,092.224
51	232,102.202	171,147.710	1,093.395	231,802.697	170,225.927	1,093.395
52	232,015.558	171,143.169	1,094.567	231,720.796	170,235.984	1,094.567
53	231,928.915	171,138.629	1,095.738	231,638.895	170,246.040	1,095.738
54	231,842.271	171,134.088	1,096.909	231,556.994	170,256.096	1,096.909
55	231,755.627	171,129.547	1,098.081	231,475.093	170,266.152	1,098.081
56	231,668.983	171,125.006	1,099.252	231,393.192	170,276.208	1,099.252
57	231,582.339	171,120.465	1,100.423	231,311.291	170,286.265	1,100.423
58	231,495.695	171,115.925	1,101.594	231,229.390	170,296.321	1,101.594
59	231,409.051	171,111.384	1,102.766	231,147.489	170,306.377	1,102.766
60	231,322.407	171,106.843	1,103.937	231,065.588	170,316.433	1,103.937

Table V-1. Bounding Coordinates for Emplacement Area (Continued)

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
61	231,228.794	171,080.845	1,105.126	230,983.689	170,326.489	1,105.126
62	231,129.221	171,036.512	1,106.128	230,901.788	170,336.545	1,106.128
63	231,029.648	170,992.179	1,107.130	230,819.887	170,346.601	1,107.130
64	230,161.806	170,680.331	1,112.032	230,059.664	170,365.970	1,112.032
65	230,075.660	170,677.322	1,112.463	229,973.518	170,362.962	1,112.463
66	229,989.514	170,674.314	1,112.894	229,887.373	170,359.954	1,112.894
67	229,903.957	170,673.116	1,113.279	229,801.227	170,356.946	1,113.279
68	229,823.182	170,686.637	1,113.667	229,715.081	170,353.937	1,113.667
69	229,746.888	170,713.951	1,114.115	229,628.935	170,350.929	1,114.115
70	229,671.164	170,743.018	1,114.549	229,543.716	170,350.774	1,114.549
71	229,595.440	170,772.086	1,115.001	229,454.670	170,338.840	1,115.001
72	229,519.716	170,801.154	1,115.479	229,361.994	170,315.734	1,115.479
73	229,443.993	170,830.221	1,115.957	229,269.318	170,292.627	1,115.957
74	229,368.269	170,859.289	1,116.434	229,176.641	170,269.520	1,116.434
75	229,292.545	170,888.357	1,116.912	229,083.965	170,246.413	1,116.912
76	229,216.821	170,917.424	1,117.389	228,991.289	170,223.306	1,117.389
77	229,141.098	170,946.492	1,117.275	228,898.612	170,200.200	1,117.275
78	229,065.285	170,975.285	1,116.251	228,804.965	170,174.104	1,116.251
79	228,986.633	170,995.342	1,115.190	228,721.372	170,178.952	1,115.190
80	228,907.407	171,013.632	1,114.059	228,646.270	170,209.934	1,114.059
81	228,828.182	171,031.923	1,112.851	228,573.648	170,248.548	1,112.851
82	228,748.957	171,050.214	1,111.535	228,501.026	170,287.162	1,111.535
83	228,669.731	171,068.504	1,110.219	228,428.404	170,325.776	1,110.219
84	228,590.506	171,086.795	1,108.903	228,355.782	170,364.389	1,108.903
85	228,511.280	171,105.085	1,107.587	228,283.160	170,403.003	1,107.587
86	228,432.055	171,123.376	1,106.271	228,210.538	170,441.617	1,106.271
87	228,352.829	171,141.667	1,104.955	228,137.916	170,480.231	1,104.955
88	228,273.604	171,159.957	1,103.663	228,065.294	170,518.845	1,103.663
89	228,194.378	171,178.248	1,102.370	227,992.672	170,557.459	1,102.370
90	228,115.153	171,196.539	1,101.078	227,920.050	170,596.072	1,101.078

ATTACHMENT VI

LOWER BLOCK EXPANSION AREA

ATTACHMENT VI
LOWER BLOCK EXPANSION AREA

VI.1 AVAILABLE EMPLACEMENT DRIFT LENGTH IN THE LOWER BLOCK

The length of the emplacement drifts represented in Table VI-1 is from the door of the emplacement drift on the east side to the door of the emplacement drift on the west side as extracted from the *Lower Block Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000bb) using VULCAN v3.4. The operational standoff distance is the distance from the door of the emplacement drift to the last WP emplaced in the drift (see Section 5.2.3). The ventilation standoff is a physical standoff established to minimize the interference of the ventilation airflow and/or radiological monitoring around the ventilation raise (see Section 5.2.6). The other unusable length accounts for the maximum effective emplacement length of 600 meters in a drift split (see Section 5.2.4). Any drift that would have a drift split in excess of 600 meters is decreased accordingly. The drift length available for emplacement is the usable length of each emplacement length. The usable length is calculated as the excavation lengths of each drift less the total standoff lengths and the unusable length for each drift (see Table VI-1). The cumulative usable emplacement lengths are also shown in Table VI-1. The 52 emplacement drifts in the lower block provide approximately 62,400 meters of available emplacement drift length.

Table VI-1. Available Emplacement Drift Length for the Lower Block

Drift Number	Length (m)	WP Standoff[a] (m)	Vent Standoff[b] (m)	Other Unusable Length[c] (m)	Available Emplacement Drift Length (m)	Cumulative Available Emplacement Drift Length (m)
L 1	1,207.0	3.0	4.0	0.0	1,200.0	1,200.0
L 2	1,207.0	3.0	4.0	0.0	1,200.0	2,400.0
L 3	1,207.0	3.0	4.0	0.0	1,200.0	3,600.0
L 4	1,207.0	3.0	4.0	0.0	1,200.0	4,800.0
L 5	1,207.0	3.0	4.0	0.0	1,200.0	6,000.0
L 6	1,207.0	3.0	4.0	0.0	1,200.0	7,200.0
L 7	1,207.0	3.0	4.0	0.0	1,200.0	8,400.0
L 8	1,207.0	3.0	4.0	0.0	1,200.0	9,600.0
L 9	1,207.0	3.0	4.0	0.0	1,200.0	10,800.0
L 10	1,207.0	3.0	4.0	0.0	1,200.0	12,000.0
L 11	1,207.0	3.0	4.0	0.0	1,200.0	13,200.0
L 12	1,207.0	3.0	4.0	0.0	1,200.0	14,400.0
L 13	1,207.0	3.0	4.0	0.0	1,200.0	15,600.0
L 14	1,207.0	3.0	4.0	0.0	1,200.0	16,800.0
L 15	1,207.0	3.0	4.0	0.0	1,200.0	18,000.0
L 16	1,207.0	3.0	4.0	0.0	1,200.0	19,200.0
L 17	1,207.0	3.0	4.0	0.0	1,200.0	20,400.0
L 18	1,207.0	3.0	4.0	0.0	1,200.0	21,600.0
L 19	1,207.0	3.0	4.0	0.0	1,200.0	22,800.0
L 20	1,207.0	3.0	4.0	0.0	1,200.0	24,000.0
L 21	1,207.0	3.0	4.0	0.0	1,200.0	25,200.0
L 22	1,207.0	3.0	4.0	0.0	1,200.0	26,400.0
L 23	1,207.0	3.0	4.0	0.0	1,200.0	27,600.0
L 24	1,207.0	3.0	4.0	0.0	1,200.0	28,800.0
L 25	1,207.0	3.0	4.0	0.0	1,200.0	30,000.0
L 26	1,207.0	3.0	4.0	0.0	1,200.0	31,200.0
L 27	1,207.0	3.0	4.0	0.0	1,200.0	32,400.0
L 28	1,207.0	3.0	4.0	0.0	1,200.0	33,600.0
L 29	1,207.0	3.0	4.0	0.0	1,200.0	34,800.0
L 30	1,207.0	3.0	4.0	0.0	1,200.0	36,000.0
Subtotal	36,210.0	90.0	120.0	0.0	36,000.0	

Table VI-1. Available Emplacement Drift Length for the Lower Block (Continued)

Drift Number	Length (m)	WP Standoff[a] (m)	Vent Standoff[b] (m)	Other Unusable Length[c] (m)	Available Emplacement Drift Length (m)	Cumulative Available Emplacement Drift Length (m)
L 31	1,207.0	3.0	4.0	0.0	1,200.0	37,200.0
L 32	1,207.0	3.0	4.0	0.0	1,200.0	38,400.0
L 33	1,207.0	3.0	4.0	0.0	1,200.0	39,600.0
L 34	1,207.0	3.0	4.0	0.0	1,200.0	40,800.0
L 35	1,207.0	3.0	4.0	0.0	1,200.0	42,000.0
L 36	1,207.0	3.0	4.0	0.0	1,200.0	43,200.0
L 37	1,207.0	3.0	4.0	0.0	1,200.0	44,400.0
L 38	1,207.0	3.0	4.0	0.0	1,200.0	45,600.0
L 39	1,207.0	3.0	4.0	0.0	1,200.0	46,800.0
L 40	1,207.0	3.0	4.0	0.0	1,200.0	48,000.0
L 41	1,207.0	3.0	4.0	0.0	1,200.0	49,200.0
L 42	1,207.0	3.0	4.0	0.0	1,200.0	50,400.0
L 43	1,207.0	3.0	4.0	0.0	1,200.0	51,600.0
L 44	1,207.0	3.0	4.0	0.0	1,200.0	52,800.0
L 45	1,207.0	3.0	4.0	0.0	1,200.0	54,000.0
L 46	1,207.0	3.0	4.0	0.0	1,200.0	55,200.0
L 47	1,207.0	3.0	4.0	0.0	1,200.0	56,400.0
L 48	1,207.0	3.0	4.0	0.0	1,200.0	57,600.0
L 49	1,207.0	3.0	4.0	0.0	1,200.0	58,800.0
L 50	1,207.0	3.0	4.0	0.0	1,200.0	60,000.0
L 51	1,207.0	3.0	4.0	0.0	1,200.0	61,200.0
L 52	1,207.0	3.0	4.0	0.0	1,200.0	62,400.0
Totals	62,764.0	156.0	208.0	0.0	62,400.0	

Notes:

[a] An operational standoff distance of 3 meters to the WP is used (see Section 5.2.3)

[b] A total physical standoff distance of 4 meters about the ventilation raise is used (see Section 5.2.6)

[c] The maximum length of a drift split is restricted to 600 meters (see Section 5.2.4)

VI.2 LOWER BLOCK EXCAVATION QUANTITIES

The opening profiles and the excavation quantities were extracted from the *Lower Block Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000bb) using VULCAN v3.4 for the various subsurface headings and will be discussed in the following sections. The lengths of the headings are expressed in slope length. The slope length of a heading refers to the actual length excavated at the specified gradient of the heading. The excavated opening areas were calculated in Section 6.3.2 and will be used throughout this attachment.

VI.2.1 Emplacement Drifts

The emplacement drifts are excavated at a diameter of 5.5 meters (see Section 4.2.1.3). The excavated cross-sectional area of these headings is 23.76 m^2. The lengths of the emplacement drifts, as well as the bank volume, are outlined in Table VI-2.

Table VI-2. Excavation Quantities for Emplacement Drifts – Lower Block

Drift Number	Length (m)	Volume (m^3)	Drift Number	Length (m)	Volume (m^3)
L1	1,207.0	28,678.32	L27	1,207.0	28,678.32
L2	1,207.0	28,678.32	L28	1,207.0	28,678.32
L3	1,207.0	28,678.32	L29	1,207.0	28,678.32
L4	1,207.0	28,678.32	L30	1,207.0	28,678.32
L5	1,207.0	28,678.32	L31	1,207.0	28,678.32
L6	1,207.0	28,678.32	L32	1,207.0	28,678.32
L7	1,207.0	28,678.32	L33	1,207.0	28,678.32
L8	1,207.0	28,678.32	L34	1,207.0	28,678.32
L9	1,207.0	28,678.32	L35	1,207.0	28,678.32
L10	1,207.0	28,678.32	L36	1,207.0	28,678.32
L11	1,207.0	28,678.32	L37	1,207.0	28,678.32
L12	1,207.0	28,678.32	L38	1,207.0	28,678.32
L13	1,207.0	28,678.32	L39	1,207.0	28,678.32
L14	1,207.0	28,678.32	L40	1,207.0	28,678.32
L15	1,207.0	28,678.32	L41	1,207.0	28,678.32
L16	1,207.0	28,678.32	L42	1,207.0	28,678.32
L17	1,207.0	28,678.32	L43	1,207.0	28,678.32
L18	1,207.0	28,678.32	L44	1,207.0	28,678.32
L19	1,207.0	28,678.32	L45	1,207.0	28,678.32
L20	1,207.0	28,678.32	L46	1,207.0	28,678.32
L21	1,207.0	28,678.32	L47	1,207.0	28,678.32
L22	1,207.0	28,678.32	L48	1,207.0	28,678.32
L23	1,207.0	28,678.32	L49	1,207.0	28,678.32
L24	1,207.0	28,678.32	L50	1,207.0	28,678.32
L25	1,207.0	28,678.32	L51	1,207.0	28,678.32
L26	1,207.0	28,678.32	L52	1,207.0	28,678.32
Subtotal	31,382.0	745,636.32	Subtotal	31,382.0	745,636.32

The total excavated emplacement drift length is 62,764 meters, with a total bank volume of 1,491,272.64 m^3.

VI.2.2 Emplacement Drift Turnouts

The emplacement drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high, as previously illustrated in Figure 4. The cross-sectional area of the turnouts is 49.13m^2. The lengths of the turnouts as well as the bank volumes, are outlined in Table VI-3.

Table VI-3. Excavation Quantities for Turnouts – Lower Block

Turnout Description	Quantity	Centerline Length (m)	Total Length (m)	Excavation Volume per Turnout (m^3)	Total Volume (m^3)
East Main Turnouts					
Turnouts L1 through L52	52	79.5	4,134.0	3,905.84	203,103.68
West Main Turnouts					
Turnouts L1 through L52	52	75.6	3,931.2	3,714.23	193,139.96
Total	104		8,065.2		396,243.64

VI.2.3 Emplacement Drift Raises

The raises will be excavated to a diameter of 2 meters (see Section 6.2.4) and a cross-sectional area of 3.14 m^2. The lengths of the ventilation raises, including the bank volume, are outlined in Table VI-4.

Table VI-4. Excavation Quantities for Ventilation Raises – Lower Block

Drift Number	Length (m)	Volume (m^3)	Drift Number	Length (m)	Volume (m^3)
L1	13.9	43.58	L27	13.9	43.58
L2	13.9	43.58	L28	13.9	43.58
L3	13.9	43.58	L29	13.9	43.58
L4	13.9	43.58	L30	13.9	43.58
L5	13.9	43.58	L31	13.9	43.58
L6	13.9	43.58	L32	13.9	43.58
L7	13.9	43.58	L33	13.9	43.58
L8	13.9	43.58	L34	13.9	43.58
L9	13.9	43.58	L35	13.9	43.58
L10	13.9	43.58	L36	13.9	43.58
L11	13.9	43.58	L37	13.9	43.58
L12	13.9	43.58	L38	13.9	43.58
L13	13.9	43.58	L39	13.9	43.58
L14	13.9	43.58	L40	13.9	43.58
L15	13.9	43.58	L41	13.9	43.58
L16	13.9	43.58	L42	13.9	43.58
L17	13.9	43.58	L43	13.9	43.58
L18	13.9	43.58	L44	13.9	43.58
L19	13.9	43.58	L45	14.0	43.90
L20	13.9	43.58	L46	14.0	43.96
L21	13.9	43.58	L47	14.1	44.27
L22	13.9	43.58	L48	14.2	44.59
L23	13.9	43.58	L49	14.2	44.59
L24	13.9	43.58	L50	14.3	44.90
L25	13.9	43.58	L51	14.4	45.22
L26	13.9	43.58	L52	14.4	45.22
Subtotal	360.9	1,133.16	Subtotal	363.4	1,141.14

The total excavated ventilation raise length is 724.3 meters, with a total bank volume of 2,274.3 m^3.

VI.3 LAYOUT DETAILS FOR THE LOWER BLOCK

The VULCAN v3.4 software program provides a three dimensional design of the subsurface layout. In order to provide specific information about the lower block as illustrated in Figure VI-1, key reference points within the layout are used to describe the lengths and grades of the various subsurface openings.

Figure VI-1 presents a set of reference points within the lower block layout. The definitions of these reference points are listed in Table VI-5, complete with the coordinates and elevations.

The details of the subsurface openings lengths and grades, corresponding to the reference points presented in Figure VI-1 and outlined in Table VI-5, are presented in Table VI-6. The layout details were extracted from the *Lower Block Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000bb) using VULCAN v3.4.

VI.4 BOUNDING COORDINATES FOR THE LOWER BLOCK EMPLACEMENT AREA

The emplacement area in the lower block is bounded by a set of coordinates that represent the theoretically last emplaced WP in the drift. The last emplaced WP in the emplacement drift is assumed to be 1.5 meters from the start of the emplacement drift (see Section 5.2.3). Table VI-7 lists the boundary coordinates for the emplacement area of the lower block. These bounding coordinated were extracted from the *Lower Block Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000bb) using VULCAN v3.4.

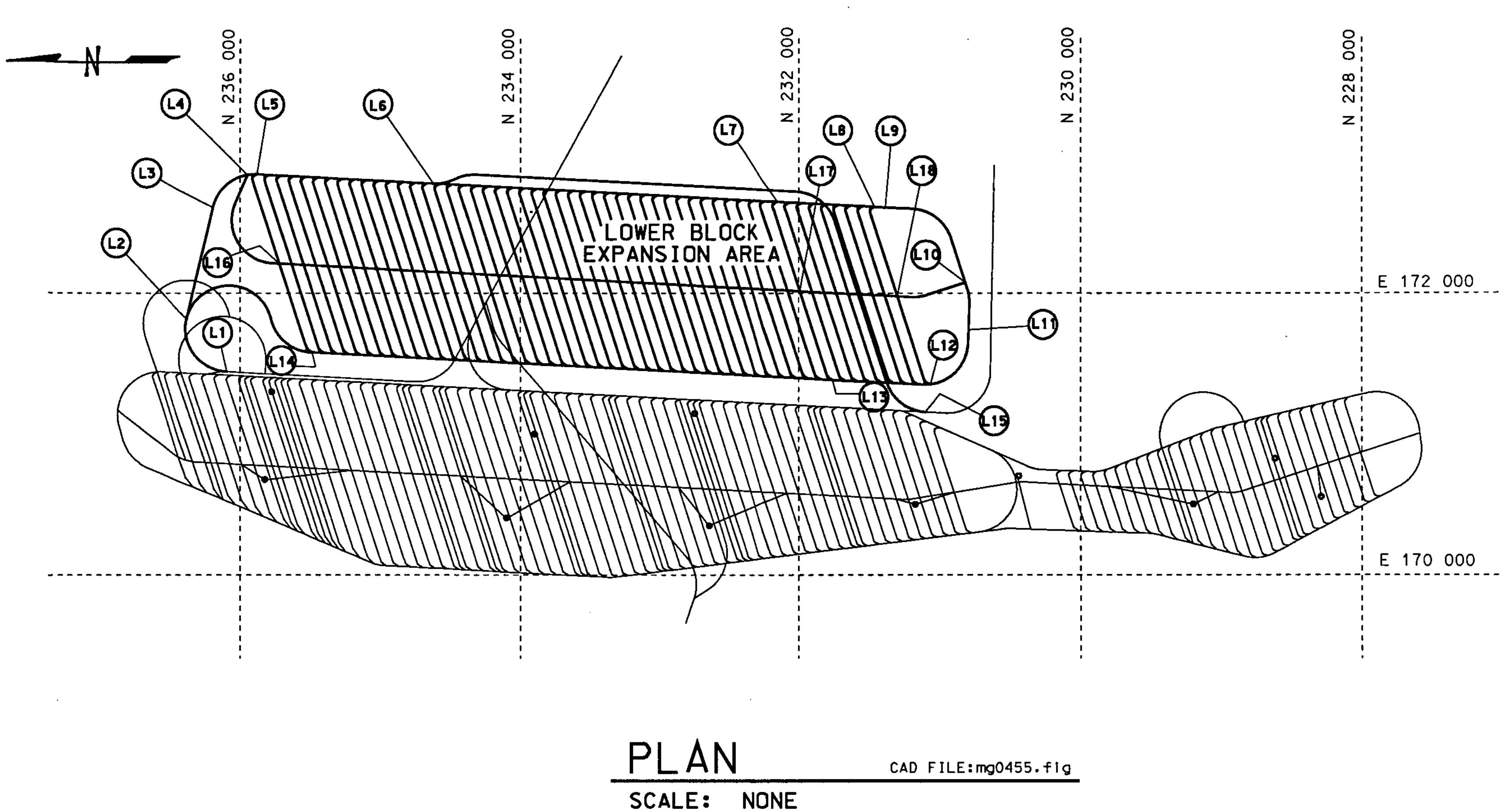

Figure VI-1. Lower Block Details

Table VI-5. Point Designation Definitions for Lower Block

Point Designation	Description	Northing (m)	Easting (m)	Elevation (m)
L 1	Start of Ramp 1 to the lower Block	236,093.936	171,443.416	1,037.950
L 2	Intersection of Ramp 1 to the lower block and Ramp 2 to the lower block	236,375.084	171,816.918	1,026.506
L 3	Grade Break in Ramp 1 to the lower block	236,192.885	172,606.110	1,009.104
L 4	Intersection of Ramp 1 to the lower block and the lower block Exhaust Main	235,948.791	172,837.843	1,004.825
L 5	Intersection of the lower block East Main and the lower block Emplacement Drift 1	235,879.740	172,842.082	1,003.993
L 6	Intersection of the lower block East Main and Ramp 3 to the lower block	234,623.404	172,776.240	994.558
L 7	Grade Break in lower block East Main	232,154.055	172,646.827	976.012
L 8	Intersection of the lower block East Main and the lower block Emplacement Drift 52	231,460.904	172,610.501	974.277
L 9	Grade Break in the lower block South Main	231,386.033	172,606.577	974.090
L 10	Intersection of the lower block South Main and the lower block Exhaust Main	230,818.486	172,075.218	965.904
L 11	Grade Break in the lower block South Main	230,795.195	171,741.019	972.894
L 12	Transition point between the lower block South Main and the lower block West Main	231,065.180	171,353.958	974.207
L 13	Grade Break in the lower block West Main	231,760.456	171,385.575	975.948
L 14	Intersection of the lower block West Main and Ramp 2 to the lower block	235,486.141	171,580.830	1,003.929
L 15	Start of Ramp 3 to the lower block	231,101.269	171,157.263	1,107.156
L 16	Grade Break in the lower block Exhaust Main	235,720.063	172,208.917	983.691
L 17	Grade Break in the lower block Exhaust Main	231,994.378	172,013.663	955.710
L 18	Grade Break in the lower block Exhaust Main	231,301.227	171,977.336	953.442

Table VI-6. Lower Block Layout Details

From Point	To Point	Slope Length (m)	Plan Length (m)	Grade (%)
L1	L2	532.8	532.6	-2.148
L2	L3	810.1	810.0	-2.148
L3	L4	356.6	356.5	-1.200
L4	L5	69.3	69.3	-1.200
L5	L6	1,258.1	1,258.1	-0.750
L6	L7	2,472.8	2,472.7	-0.750
L7	L8	694.1	694.1	-0.250
L8	L9	75.0	75.0	-0.250
L9	L10	887.0	886.9	-0.920
L10	L11	338.3	338.2	2.070
L11	L12	525.4	525.4	0.250
L12	L13	696.3	696.3	0.250
L13	L14	3,730.9	3,730.8	0.750
L14	L2	1,225.7	1,225.5	1.840
L15	L6	4,551.5	4,550.1	-2.470
L4	L16	855.8	855.6	-2.470
L16	L17	3,730.9	3,730.8	-0.750
L17	L18	694.1	694.1	-0.330
L18	L10	498.6	498.5	2.500

Table VI-7. Bounding Coordinates for the Lower Block Emplacement Area

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
1	235,906.091	172,781.453	1,005.191	235,534.035	171,636.381	1,005.191
2	235819.447	172,776.913	1,004.540	235,447.391	171,631.841	1,004.540
3	235,732.803	172,772.372	1,003.890	235,360.747	171,627.300	1,003.890
4	235,646.160	172,767.831	1,003.239	235,274.103	171,622.759	1,003.239
5	235,559.516	172,763.290	1,002.588	235,187.459	171,618.218	1,002.588
6	235,472.872	172,758.749	1,001.937	235,100.815	171,613.677	1,001.937
7	235,386.228	172,754.209	1,001.287	235,014.172	171,609.137	1,001.287
8	235,299.584	172,749.668	1,000.636	234,927.528	171,604.596	1,000.636
9	235,212.940	172,745.127	999.985	234,840.884	171,600.055	999.985
10	235,126.296	172,740.586	999.335	234,754.240	171,595.514	999.335
11	235,039.653	172,736.045	998.684	234,667.596	171,590.973	998.684
12	234,953.009	172,731.505	998.033	234,580.952	171,586.432	998.033
13	234,866.365	172,726.964	997.382	234,494.309	171,581.892	997.382
14	234,779.721	172,722.423	996.732	234,407.665	171,577.351	996.732
15	234,693.077	172,717.882	996.081	234,321.021	171,572.810	996.081
16	234,606.433	172,713.341	995.430	234,234.377	171,568.269	995.430
17	234,519.790	172,708.800	994.780	234,147.733	171,563.728	994.780
18	234,433.146	172,704.260	994.129	234,061.089	171,559.188	994.129
19	234,346.502	172,699.719	993.478	233,974.445	171,554.647	993.478
20	234,259.858	172,695.178	992.827	233,887.802	171,550.106	992.827
21	234,173.214	172,690.637	992.177	233,801.158	171,545.565	992.177
22	234,086.570	172,686.096	991.526	233,714.514	171,541.024	991.526
23	233,999.927	172,681.556	990.875	233,627.870	171,536.484	990.875
24	233,913.283	172,677.015	990.224	233,541.226	171,531.943	990.224
25	233,826.639	172,672.474	989.574	233,454.582	171,527.402	989.574
26	233,739.995	172,667.933	988.923	233,367.939	171,522.861	988.923
27	233,653.351	172,663.392	988.272	233,281.295	171,518.320	988.272
28	233,566.707	172,658.852	987.622	233,194.651	171,513.780	987.622
29	233,480.064	172,654.311	986.971	233,108.007	171,509.239	986.971
30	233,393.420	172,649.770	986.320	233,021.363	171,504.698	986.320

Table VI-7. Bounding Coordinates for the Lower Block Emplacement Area (Continued)

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
31	233,306.776	172,645.229	985.669	232,934.719	171,500.157	985.669
32	233,220.132	172,640.688	985.019	232,848.076	171,495.616	985.019
33	233,133.488	172,636.147	984.368	232,761.432	171,491.075	984.368
34	233,046.844	172,631.607	983.717	232,674.788	171,486.535	983.717
35	232,960.201	172,627.066	983.067	232,588.144	171,481.994	983.067
36	232,873.557	172,622.525	982.416	232,501.500	171,477.453	982.416
37	232,786.913	172,617.984	981.765	232,414.856	171,472.912	981.765
38	232,700.269	172,613.443	981.114	232,328.213	171,468.371	981.114
39	232,613.625	172,608.903	980.464	232,241.569	171,463.831	980.464
40	232,526.981	172,604.362	979.813	232,154.925	171,459.290	979.813
41	232,440.337	172,599.821	979.162	232,068.281	171,454.749	979.162
42	232,353.694	172,595.280	978.511	231,981.637	171,450.208	978.511
43	232,267.050	172,590.739	977.861	231,894.993	171,445.667	977.861
44	232,180.406	172,586.199	977.210	231,808.349	171,441.127	977.210
45	232,093.762	172,581.658	976.993	231,721.706	171,436.586	976.993
46	232,007.118	172,577.117	976.776	231,635.062	171,432.045	976.776
47	231,920.474	172,572.576	976.559	231,548.418	171,427.504	976.559
48	231,833.831	172,568.035	976.342	231,461.774	171,422.963	976.342
49	231,747.187	172,563.495	976.126	231,375.130	171,418.422	976.126
50	231,660.543	172,558.954	975.909	231,288.486	171,413.882	975.909
51	231,573.899	172,554.413	975.692	231,201.843	171,409.341	975.692
52	231,487.255	172,549.872	975.475	231,114.735	171,403.373	975.475