Civilian Radioactive Waste Management System

Management & Operating Contractor

Engineering File - Subsurface Repository

BCA000000-01717-5705-00005 Rev 02, DCN 01

June, 1999

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CHANGE HISTORY

Revision Number	Interim Change No.	Effective Date	Description of Change
00	0	12/30/97	Initial Issue
01	0	03/31/99	Inclusion and incorporation of information and data developed in Addenda: A, B, C, C Supplement, D, E, and F. Appendices revised to include parts of these addenda. Revision of staffing and operating periods are shown in data tables to reflect VA cost data as it differs from earlier cost estimates. Revision of data tables to reflect consumption of water, electricity and other data based on studies related to off-site utilities.
02	0	06/16/99	Revision of text and data to reflect review comments received from YMSCO May 24, 1999.
02	01	06/18/99	Changes on Table 3.1-1 (Summary of Cases) based on assumption added to page 2-2.

- Additional site characterization work will verify that Optional Areas 5, 6, 7, and 8 as illustrated in Figure 3.2-1, are viable areas for nuclear waste storage.
- The same VA design concepts for drifts and ground control will be applicable to the Optional Areas.
- Should emplacement drifts be filled with crushed welded tuff, no additives will be used.
- Emplacement area exhaust ventilation air is assumed to reach 50^0 C.
- For estimating, "Resources Consumed" items and materials were quantified and grouped into appropriate categories.
- Estimates of "Materials Installed" are based on cost estimating input related to the defined case layout and operating data.
- Excavated rock occupies approximately 33% more volume than in-situ volume.
- No diesel is operated underground. While some diesel-powered equipment may be used in special situations, the use of diesel on a regular basis is not planned.
- Solid waste production (5 mt/ employee-year) is related to the total staffing associated with a phase or operation.
- Sanitary waste is assumed to result from staff usage of facilities. A base unit of 50 gallons per employee-day is assumed based on engineering judgement.
- Water that is pumped from the subsurface to the surface facilities is assumed to be 13% of the estimated process water based on ESF experience and calculation.
- For the extended inventory cases listed in Table 3.1-1, the HLW was assumed to be 12,500 MTHM.

66 Table 3.1-1 Summary of Cases

CASE 1)	Disposal Quantities (MTHM) 2)	AREAL MASS LOADING	DRIFT SPACING	AREA (ACRES)	YEARS TO EMPLACE	TOTAL # WASTE PACKAGES	EMPLACEMENT AREA
BASE CASE	63,000 CSNF 4,667 HLW 2,333 DOE SNF	85 MTU/acre	28-meter	740	24 (2010-2033)	10,500	PRIMARY BLOCK (partial)
ALTERNATIVE BASE CASE – INTERMEDIATE THERMAL LOADING	63,000 CSNF 4,667 HLW 2,333 DOE SNF	60 MTU/acre	40-meter	1,050	24 (2010-2033)	10,500	PRIMARY BLOCK (extended)
ALTERNATIVE BASE CASE – LOW THERMAL LOADING	63,000 CSNF 4,667 HLW 2,333 DOE SNF	25 MTU/acre	38-meter	2,520	24 (2010-2033)	10,500	PRIMARY BLOCK (extended), LOWER BLOCK & AREA 5
EXTENDED INVENTORY MODULES 1 & 2b HIGH THERMAL LOADING	105,414 CSNF 12,500 HLW 2,500 DOE SNF (Mod. 1) + 40,000 m3 GTCC & DOE SPAR (Mod.2b)	85 MTU/acre	28-meter	1,240	38 (2010-2047)	17,435	PRIMARY BLOCK (extended) & LOWER BLOCK (partial)
EXTENDED INVENTORY MODULES 1 & 2b INTERMEDIATE THERMAL LOADING	105,414 CSNF 12,500 HLW 2,500 DOE SNF (Mod. 1) + 40,000 m3 GTCC & DOE SPAR (Mod.2b)	60 MTU/acre	40-meter	1,750	38 (2010-2047)	17,435	PRIMARY BLOCK (extended), LOWER BLOCK & AREA 5
EXTENDED INVENTORY MODULES 1 & 2b LOW THERMAL LOADING	105,414 CSNF 12,500 HLW 2,500 DOE SNF (Mod. 1) + 40,000 m3 GTCC & DOE SPAR (Mod.2b)	25 MTU/acre	38-meter	4,200	38 (2010-2047)	17,435	PRIMARY BLOCK (extended), LOWER BLOCK, AREAS 5,6,7, &8

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02	0	06/16/99	Revision of text and data to reflect review comments received from YMSCO May 24, 1999.

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1 INTRODUCTION/BACKGROUND

The Civilian Radioactive Waste Management System (CRWMS) will provide for disposal of spent nuclear fuel (SNF) and high-level waste (HLW) in a mined geologic repository designed to accommodate heavy metal waste amounting to at least 70,000 metric tons. That waste is assumed to include 63,000 metric tons of heavy metal (MTHM) of SNF from commercial nuclear power plants, about 4700 MTHM equivalent HLW from reprocessed defense materials and commercial SNF, and about 2300 MTHM resulting from DOE-managed SNF (DOE SNF) sources. The task assigned to CRWMS is to provide integrated, safe and efficient acceptance, transportation, storage, and disposal of all of these wastes.

Additional to the above defined waste disposal quantities, this engineering file addresses variations in expanded inventories as included in the CRWMS-M&O document titled: *Expanded Environmental Impact Statement Feasibility Assessment* (Sec. 8.2, CRWMS M&O, 1997f, Section 1.4 (pp. 3 & 4))

Revision 01 to the December 1997 issue of the Subsurface Engineering File includes addenda developed and attached to that version during 1998. Issuance of the Viability Assessment of a Repository at Yucca Mountain (VA) in September of 1998 also finalized the VA analyses into a "Base Case" reference document. Addenda incorporated into this Rev 01 engineering file include the following:

- Addendum A - Describes ventilation controls,
- Addendum B - Describes changes in the tables contained in the Engineering File that would be required to reflect a 100-year period available for retrieval,
- Addendum C - Provides an estimate of the radiation exposure of workers in the subsurface repository,
- Addendum D - Committed repository materials,
- Addendum E - 25 MTU/acre thermal loading effects on subsurface environmental data for both the Base and 105,000 MTU CSNF waste inventory cases.
- Addendum F - South Portal Disturbed Area estimate,
- Addendum C Supplement - Supplemental estimate (25 MTU/acre cases only) of the radiation exposure of workers in the subsurface repository.

Along with the above list of addenda, modifications have been made to specific environmental data based on the VA Cost Estimate.

1.1 PURPOSE

The purpose of the Subsurface Engineering File is to supply information to the Environmental Impact Statement (EIS) Contractor. The contractor may use this information to prepare the EIS and evaluate options and alternatives as described in Section 3 of this document.

1.2 SCOPE

The Monitored Geologic Repository (MGR) has three subdivisions: Waste Package, Surface Facilities and Subsurface/Engineered Barrier facilities. This engineering file describes the subsurface part of the MGR which includes components of the Engineered Barrier System and those surface facilities, systems, and operations that are directly related to subsurface activities. The bases for this engineering file are the VA analyses, VA support documents and document existing prior to the VA analyses.

1.3 QUALITY ASSURANCE

The Engineering File - Subsurface Repository (EF) provides bounding design information for the EIS. The EF is not subject to the *Quality Assurance Requirements and Description* Document (QARD) (DOE 1997a) like all EIS work. This determination is documented in the QAP-2-0 activity evaluation, *EIS Support* CRWMS M&O 1996f). This engineering file is, therefore, completed in accordance with PRO-TS-003, *Development of Technical Documents not Subject to QARD Requirements* (CRWMS M&O 1998i.). All data exhibited in this file is considered to be unqualified for any application requiring project QARD controls, requirements and procedures.

1.4 SUBSURFACE FUNCTION

The *MGDS Functional Analysis Document* (CRWMS M&O 1996e, Section 3.1 (pg. 3-1 to 3-10)) defines the functions that must be performed at the Repository to dispose of nuclear waste.

1.5 MGDS PROGRAM PHASES

As depicted on Figure 1.5-1, six phases comprise the evolution of the potential Repository: Site Characterization, Construction, Operations, Monitoring, Closure, and Postclosure (CRWMS M&O 1998f, pp. 3-1 to 3-4). Performance Confirmation is an activity spanning Site Characterization through Closure. It is active in each of these phases to include testing, monitoring and evaluation of various surface, subsurface and engineered barrier systems and components. The above phases are described below:

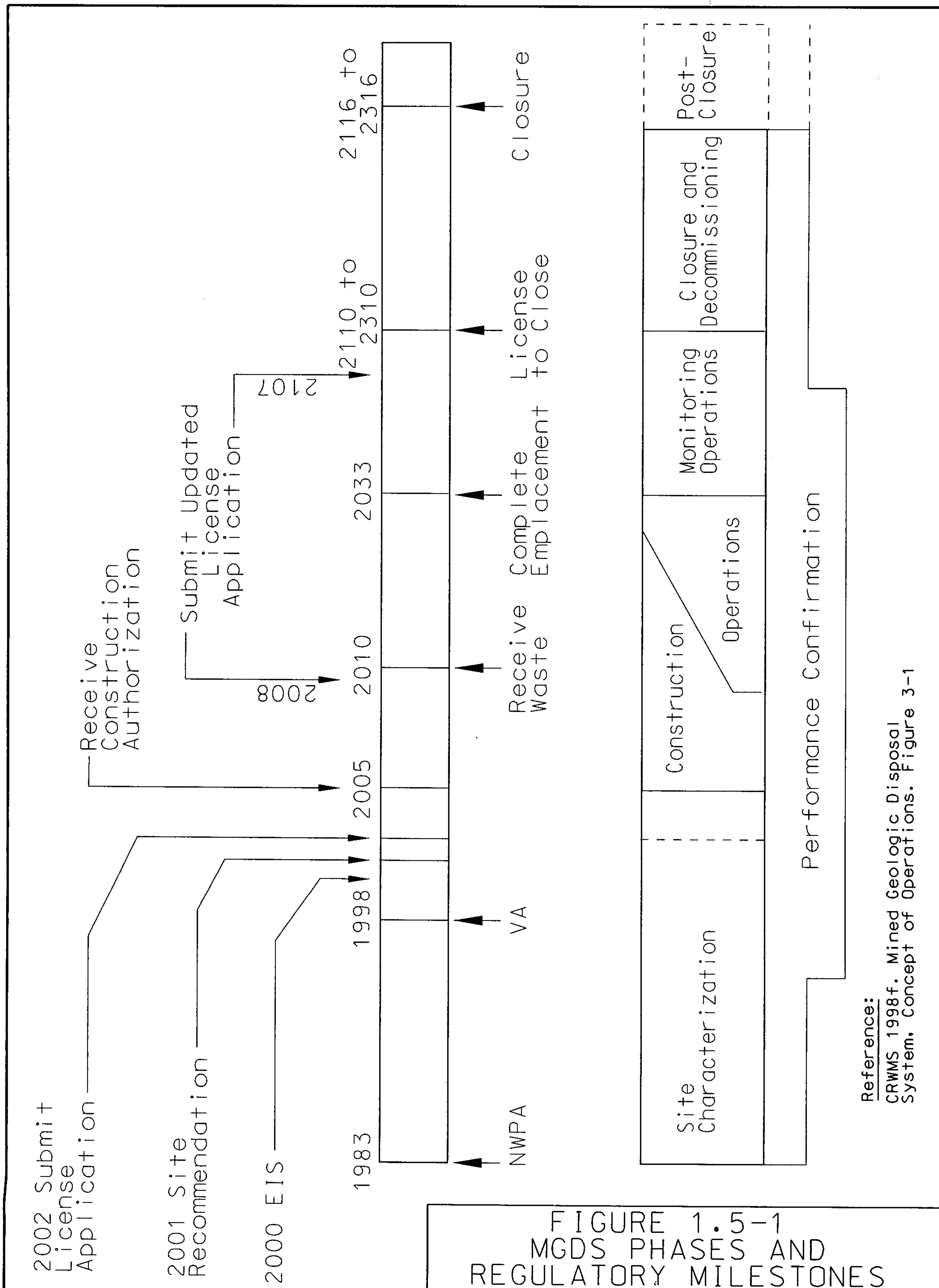


FIGURE 1.5-1
MGDS PHASES AND
REGULATORY MILESTONES

1.5.1 SITE CHARACTERIZATION PHASE

This phase includes those activities associated with gathering and evaluating data to determine the suitability of the site for a geologic repository; predicting the performance of the repository; preparing therepository design; assessing the system performance; and, obtaining a Nuclear Regulatory Commission license. The Exploratory Studies Facility (ESF) that has been constructed includes two underground ramps and a cross-block drift. These facilities will be enhanced during repository construction. The Site characterization Phase ends with the beginning of the Construction Phase in 2005. [CRWMS M&O, 1997g, p. 10 of 32]

1.5.2 CONSTRUCTION PHASE

This phase includes constructing and equipping a portion of the subsurface facility for initial emplacement. Included are refurbishing ESF openings, excavation and equipping of subsurface facilities, gathering data to support predictions of the repository performance, demonstration of some of the repository operations, and preparation of an update to the license application to receive, package and emplace waste (CRWMS M&O, 1998f. p.3-1).

1.5.3 OPERATIONS PHASE

Operation of the subsurface emplacement facilities is scheduled to begin in early 2010 after receiving the amended license to receive and possess nuclear waste. Emplacement of waste will then continue through 2033 (for the Base Case Inventory). Shakedown and startup of the system are expected to commence with emplacement of 38 waste packages in 2010. The annual emplacement rate will increase to approximately 500 waste packages (WPs) in 2015 then average 500 until 2031. Waste receipt will then taper off in 2032 and 2033 (CRWMS M&O 1998b, Key 002 and 003). (CRWMS M&O, 1997g, table 7-1 (pg. 13-17 of 32))

1.5.4 MONITORING OPERATIONS PHASE

The Monitoring Phase will begin when all waste packages have been emplaced. This phase, in earlier documents, was term the "Caretaker" as it includes continuance of performance confirmation activities and maintenance of the subsurface facility. The capability to retrieve the waste packages will be maintained until the NRC approves a license to close the repository . The Monitoring Operations Phase ends when closure begins. Closure is expected to commence 100 years after the beginning of emplacement operations.

1.5.5 CLOSURE AND DECOMMISSIONING PHASE

The Closure Phase will begin after the license amendment to close the repository has been received from the Nuclear Regulatory Commission (NRC). This phase includes closing and sealing the subsurface facilities. Most underground openings not containing waste packages will be filled with an engineered fill assumed to be crushed and sized tuff. Additional surface work (decommissioning) will include removing the surface facilities and returning the site to approximate natural condition, as required. The expected subsurface closure operations are expected to have duration's estimated to be from 4.5 to 24 years depending on the extent of the underground openings.

1.5.6 POST CLOSURE PHASE

During this phase, the engineered and natural barriers will contain and isolate the radioactive waste for thousands of years. This phase will include the capability to provide post-closure monitoring if required or necessary. toring if required or necessary.

2 ASSUMPTIONS

The VA source for documented and controlled assumptions is the *Controlled Design Assumptions* Document (CDA) (CRWMS M&O 1998b).

2.1 CONTROLLED DESIGN ASSUMPTIONS

Assumptions from the *Controlled Design Assumptions Document* (CDA) are not listed in the engineering file. These assumptions are contained in documents referenced. For example, the CDA assumptions that apply to the ventilation system are in the referenced document *Overall Development and Emplacement Ventilation Systems* (CRWMS M&O 1997l, pp. 16-19).

2.2 OTHER ASSUMPTIONS

Assumptions listed in this Subsurface Repository Engineering File are used where a source document cannot be referenced. Assumptions not listed in the CDA or other referenced documents, but needed for this EIS engineering file are as follows:

- Alternate thermal loading case analyses vary emplacement drift spacing while holding waste package spacing in the emplacement drifts as a constant. For the Rev 01, the "Low" thermal loading cases assumed 25 MTU/acre of spent nuclear fuel in place of the 36 MTU/acre used as "Low" in the Rev 00 engineering file. The Rev 02 continues to use 25 MTU/acre.

- The assumed waste package emplacement schedule follows the waste receipt schedule as it appears in CDA Key 003, Table 3-9.

- VA Base Case follows CDA Key 046 assumption that no backfill is placed in the emplacement area. However, a separate backfill design option has been included in this engineering file in Appendix I. Execution of this case would cause waste package retrieval to be very difficult.

- VA Base Case assumes successful waste disposal and closure; however, a required design contingency has been added which involves retrieval of all waste forms and closure of an empty repository.

- To achieve subsurface repository closure, it is assumed that all shafts, ramps, and access mains are filled with processed welded tuff from the surface stockpile including cross-block drifts, ventilation drifts, and performance confirmation drifts.

- Additional site characterization work will verify that Optional Areas 5, 6, 7, and 8 as illustrated in Figure 3.2-1, are viable areas for nuclear waste storage.
- The same VA design concepts for drifts and ground control will be applicable to the Optional Areas.
- Should emplacement drifts be filled with crushed welded tuff, no additives will be used.
- Emplacement area exhaust ventilation air is assumed to reach 50^0 C.
- For estimating, "Resources Consumed" items and materials were quantified and grouped into appropriate categories.
- Estimates of "Materials Installed" are based on cost estimating input related to the defined case layout and operating data.
- Excavated rock occupies approximately 33% more volume than in-situ volume.
- No diesel is operated underground. While some diesel-powered equipment may be used in special situations, the use of diesel on a regular basis is not planned.
- Solid waste production (5 mt/ employee-year) is related to the total staffing associated with a phase or operation.
- Sanitary waste is assumed to result from staff usage of facilities. A base unit of 50 gallons per employee-day is assumed based on engineering judgement.
- Water that is pumped from the subsurface to the surface facilities is assumed to be 13% of the estimated process water based on ESF experience and calculation.

3 EIS CONCEPT ALTERNATIVES AND CASE DEFINITIONS

3.1 THERMAL AND INVENTORY CASES

Three thermal loading cases have been specified implementing alternatives for subsurface conceptual design description and EIS related data calls. The high thermal loading alternative (85 MTU/acre) is based on the Viability Assessment design. The intermediate (60 MTU/acre) and low (25 MTU/acre) thermal loading alternatives are expansions of the VA base case. Additional to these cases, are two variations. One design option is backfilling all emplacement drifts prior to repository closure. The other required design contingency is to retrieve all waste at some point after completion of emplacement but prior to beginning closure operations.

Current controlling documents limit the Yucca Mountain MGDS to 70,000 metric tons of uranium or its equivalent until a second repository is defined (DOE 1998, YMP/CM0025, Rev 03, P.3-1). Geometric and geographic boundaries are capable of extending the capacity of Yucca Mountain to acceptance of all estimated waste. Should the 70,000 MTU limit be removed, as considered in the extended waste inventory cases, then the subsurface portion of the GROA might be extended in area, in excavation and in emplacement time. This Engineering File provides descriptions of the repository layouts required to emplace the waste inventories of 105,414 MTU or more. These inventories are defined in the *Expanded Environmental Impact Statement Feasibility Assessment* (CRWMS M&O, 1997f, Section 3.1 (pg. 11-19)). Case Summaries are shown on Table 3.1-1. The 105,414 MTU modification was requested by the EIS Contractor to replace the 105,000 MTU shown in other revisions of this document.

3.2 GEOLOGIC STORAGE AREAS

The potential blocks available for emplacement are shown on Figure 3.2-1. The Primary (formerly termed "Upper") and Lower blocks have been described in the *Repository Subsurface Layout Configuration Analysis* (CRWMS 1997h, pg. 34 of 109) and have been well characterized. To accommodate the lower thermal cases and the extended inventories expansion areas 5, 6, 7, and 8 (formerly termed: "1a, 1b, 2, 3 and 4") were defined for this engineering file.

The expansion areas 5, 6, 7, and 8 in Figure 3.2-1 have not been characterized to the same extent as have the Primary and Lower Blocks. To bring the level of knowledge of the expansion area to a state equivalent to the Primary and Lower Blocks, additional drilling and surface mapping would be required. The density of drilling required depends upon the characteristics of the geology. If the lateral changes and characteristics of the geology in the expansion area are similar to the main block area, then density of drilling can be similar. It is anticipated that boreholes spaced about 1 to 1.5 km would be sufficient for defining the subsurface stratigraphy. Using this assumption for drilling density, it is anticipated that about 13 boreholes would be required. Approximately two or three of these should be cored to the groundwater table, while the rest could be non-core drilling. With geophysical logs produced for all holes, there would be sufficient stratigraphic control without requiring core from all holes. Samples would be obtained for testing both from the core and from cuttings collected from the non-core holes. Additional tunneling such as extending the south ramp into the area may be required to determine ground support requirements. Because of the rugged terrain, the drill sites would be restricted and significant road building would be required for access.

3.3 ALTERNATE LAYOUTS

Figure 3.3-1 is the layout for the base case. (CRWMS M&O 1997h, Figure 7-1)

Figure 3.3-2 is the layout for 63,000 MTU of CSNF at an areal mass loading (AML) of 60 MTU/acre. Both waste inventories can be emplaced in the Primary Block, however, more area is required for emplacement at 60 MTU/acre because the distance between emplacement drifts is larger.

Figure 3.3-3 is the layout for 63,000 MTU of CSNF emplaced at 25 MTU/acre. As can be seen, when Area 5 is used for emplacement, an additional Emplacement Intake Shaft is required.

Figure 3.3-4 illustrates the layout for emplacement of 105,414 MTU at an AML of 85 MTU/acre. It is the same layout required to emplace waste packages in the Modules 1&2B inventories. The increased number of waste packages in Modules 1&2b comprises non-commercial waste

Defense High Level Waste (DHLW) and Department of Energy/Spent Nuclear Fuel (DOE/SNF) will be emplaced between the commercial spent nuclear fuel (CSNF) waste packages.

Figure 3.3-5 illustrates the layout for emplacement of 105,414 MTU at an AML of 60 MTU/acre. It is also the same as the Modules 1&2b inventory. The increased number of waste packages in modules 1&2b comprises non-commercial waste (DHLW) and (DOE/SNF). The waste will be emplaced between the Commercial Spent Nuclear Fuel (CSNF) waste packages.

Figure 3.3-6 illustrates the layout for emplacement of 105,414 MTU at an AML of 25 MTU/acre. It is also the same as for the Modules 1&2B inventory. Again, the non-commercial spent nuclear fuel waste packages will be placed between the CSNF waste packages. These are the only cases that require all of the expansion areas.

Figures 3.3-2, 3.3-3, 3.3-4, 3.3-5, and 3.3-6 were derived within this engineering file to support the alternative thermal load and waste inventory cases requested under the general purpose defined in Section 1.1.

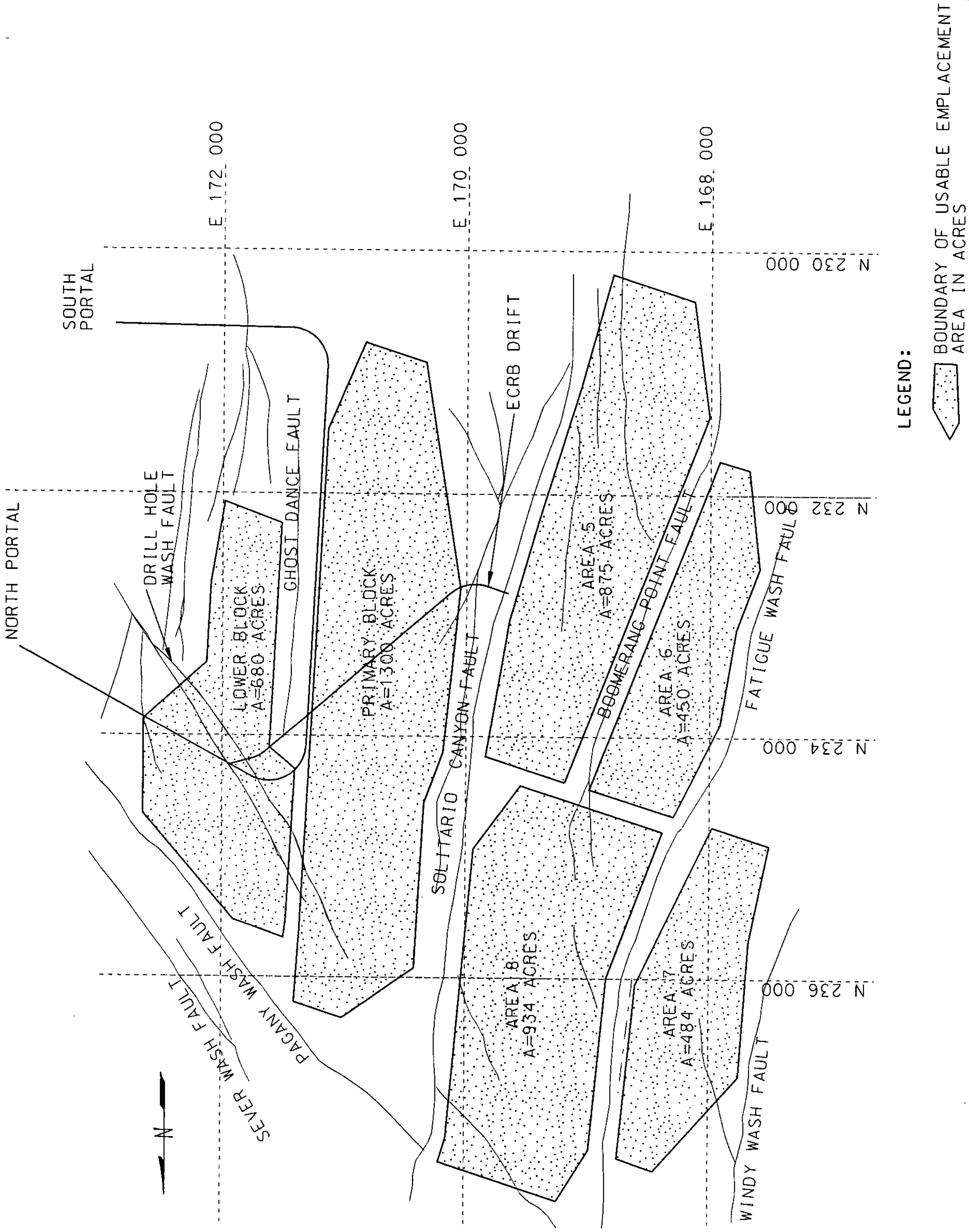
Table 3.1-1 Summary of Cases

CASE 1)	Disposal Quantities (MTHM) 2)	AREAL MASS LOADING	DRIFT SPACING	AREA (ACRES)	YEARS TO EMPLACE	TOTAL # WASTE PACKAGES	EMPLACEMENT AREA
BASE CASE	63,000 CSNF 4,667 HLW 2,333 DOE SNF	85 MTU/acre	28-meter	740	24 (2010-2033)	10,500	PRIMARY BLOCK (partial)
ALTERNATIVE BASE CASE – INTERMEDIATE THERMAL LOADING	63,000 CSNF 4,667 HLW 2,333 DOE SNF	60 MTU/acre	40-meter	1,050	24 (2010-2033)	10,500	PRIMARY BLOCK (extended)
ALTERNATIVE BASE CASE – LOW THERMAL LOADING	63,000 CSNF 4,667 HLW 2,333 DOE SNF	25 MTU/acre	38-meter	2,520	24 (2010-2033)	10,500	PRIMARY BLOCK (extended), LOWER BLOCK & AREA 5
EXTENDED INVENTORY MODULES 1 & 2b HIGH THERMAL LOADING	105,414 CSNF 10,800 HLW 2,500 DOE SNF (Mod. 1) + 40,000 m3 GTCC & DOE SPAR (Mod.2b)	85 MTU/acre	28-meter	1,240	38 (2010-2047)	17,435	PRIMARY BLOCK (extended) & LOWER BLOCK (partial)
EXTENDED INVENTORY MODULES 1 & 2b INTERMEDIATE THERMAL LOADING	105,414 CSNF 10,800 HLW 2,500 DOE SNF (Mod. 1) + 40,000 m3 GTCC & DOE SPAR (Mod.2b)	60 MTU/acre	40-meter	1,750	38 (2010-2047)	17,435	PRIMARY BLOCK (extended), LOWER BLOCK & AREA 5
EXTENDED INVENTORY MODULES 1 & 2b LOW THERMAL LOADING	105,414 CSNF 10,800 HLW 2,500 DOE SNF (Mod. 1) + 40,000 m3 GTCC & DOE SPAR (Mod.2b)	25 MTU/acre	38-meter	4,200	38 (2010-2047)	17,435	PRIMARY BLOCK (extended), LOWER BLOCK, AREAS 5,6,7, &8

Notes:

1) For each case, there are two additional options. One is a required design contingency wherein all waste packages are retrieved (CRWMS M&O 1998b., pg. 3-25) and the other is a design option that includes backfill of the emplacement drifts (CRWMS M&O 1998b., pg. 3-36) For the options with backfill, closure operations begin at the end of the backfill operations and receipt of a license amendment.

2) MTHM = Metric Tons of Heavy Metals contained in Commercial Spent Nuclear Fuel (CSNF) (see Section 9.).



Reference: Appendix F

FIGURE 3.2-1

EMPLACEMENT AREAS

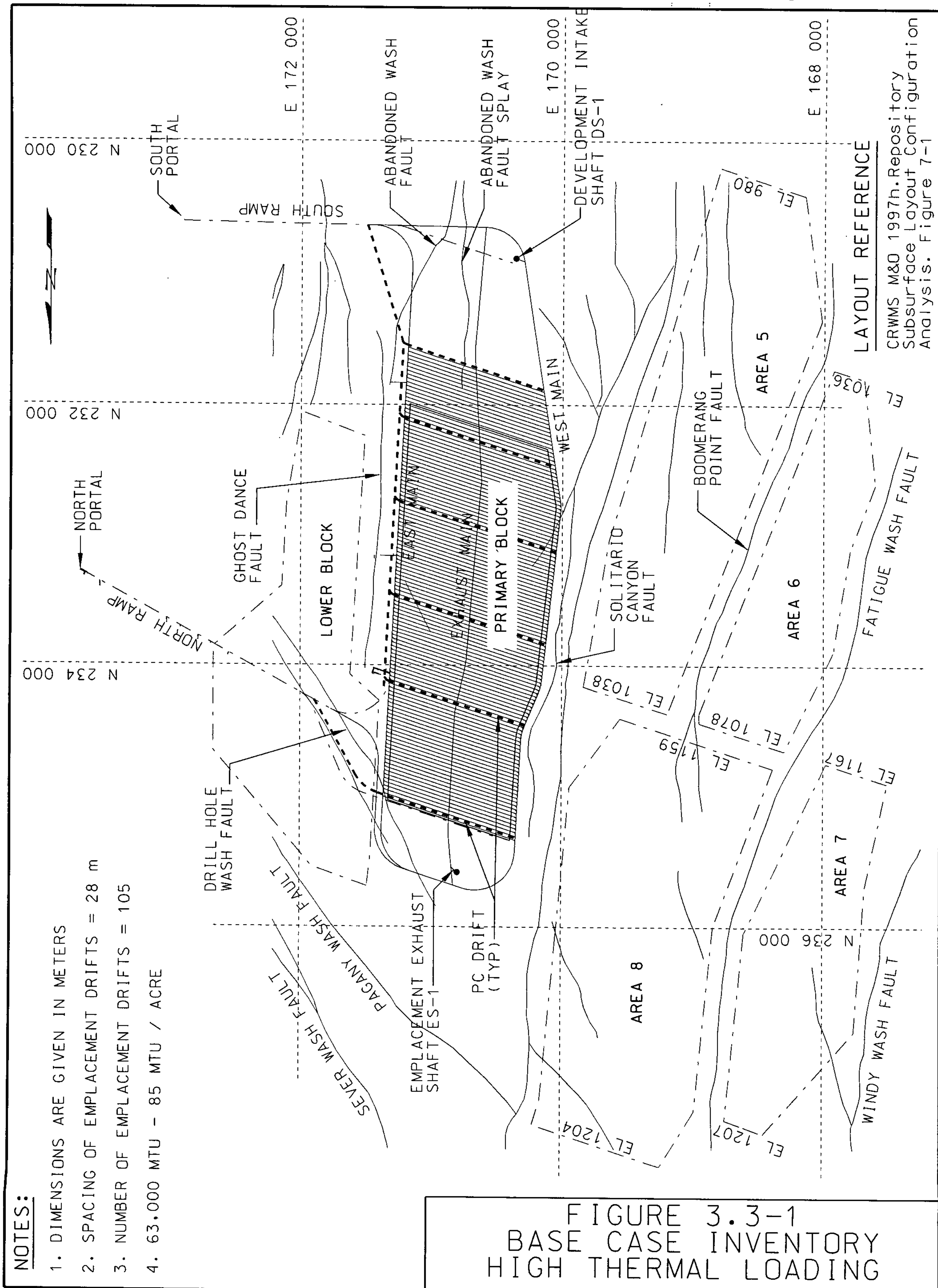
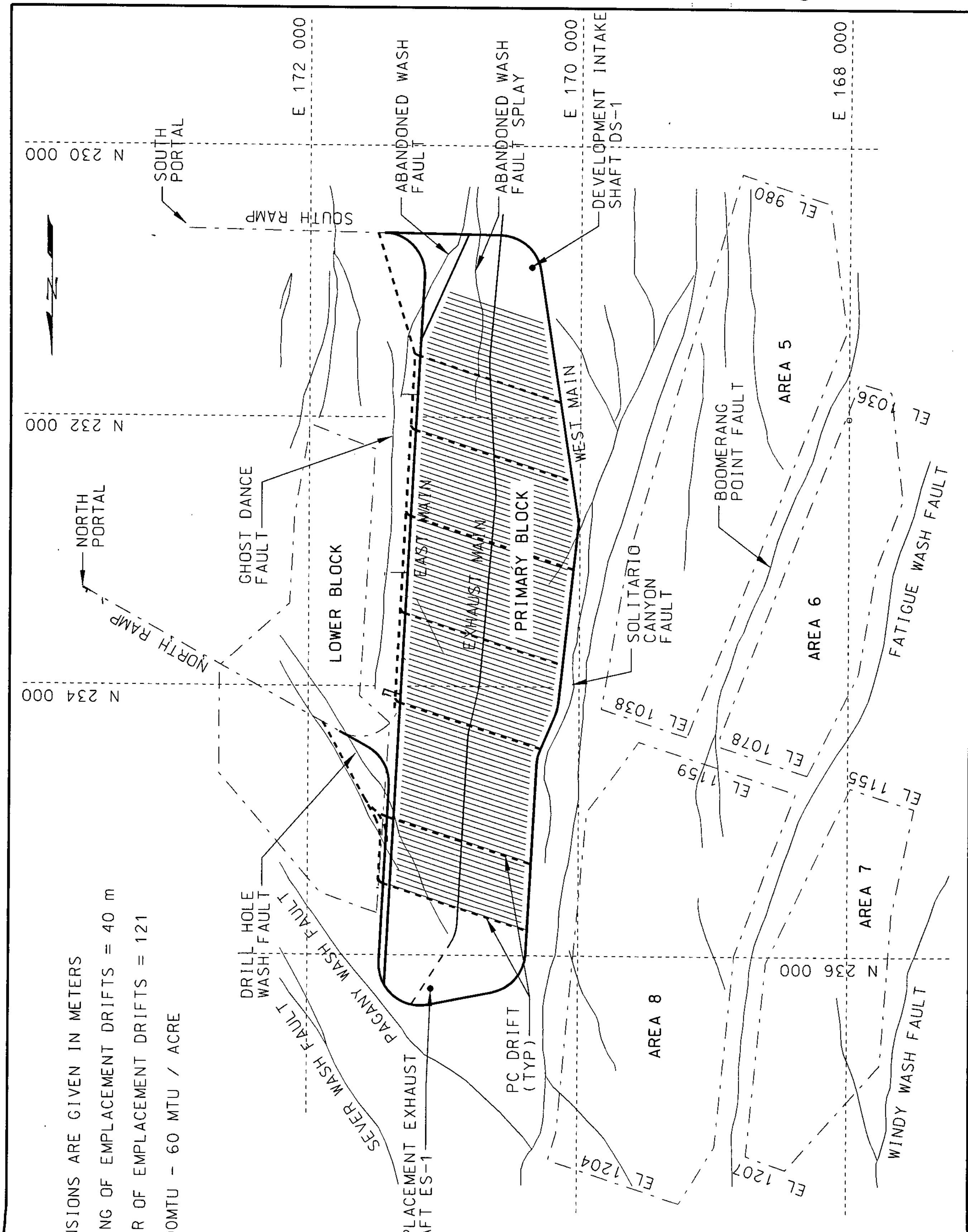


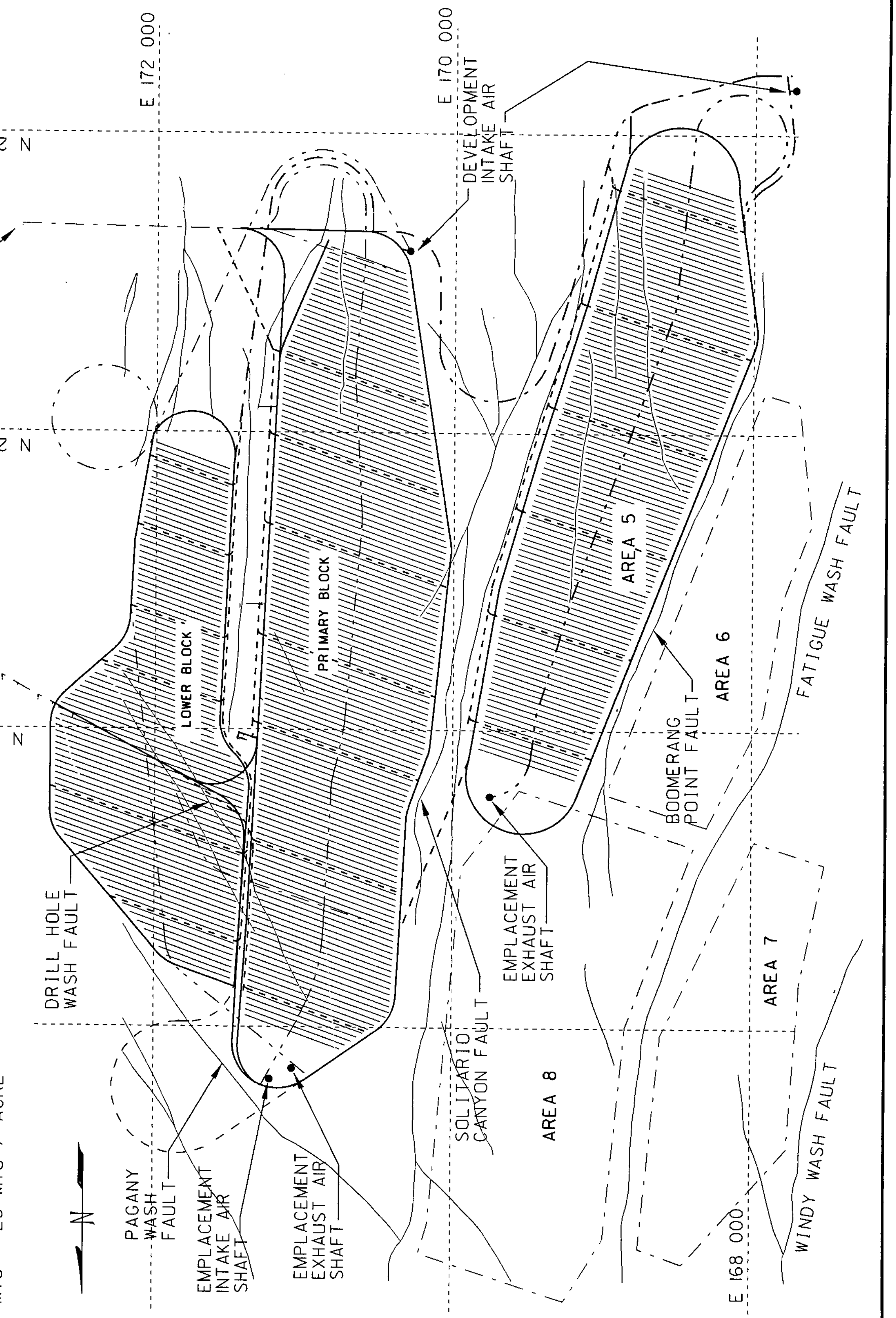
FIGURE 3.3-1
BASE CASE INVENTORY
HIGH THERMAL LOADING



NOTES:

1. DIMENSIONS ARE GIVEN IN METERS
2. SPACING OF EMPLACEMENT DRIFTS = 40 m
3. NUMBER OF EMPLACEMENT DRIFTS = 121
4. 63.000MTU - 60 MTU / ACRE

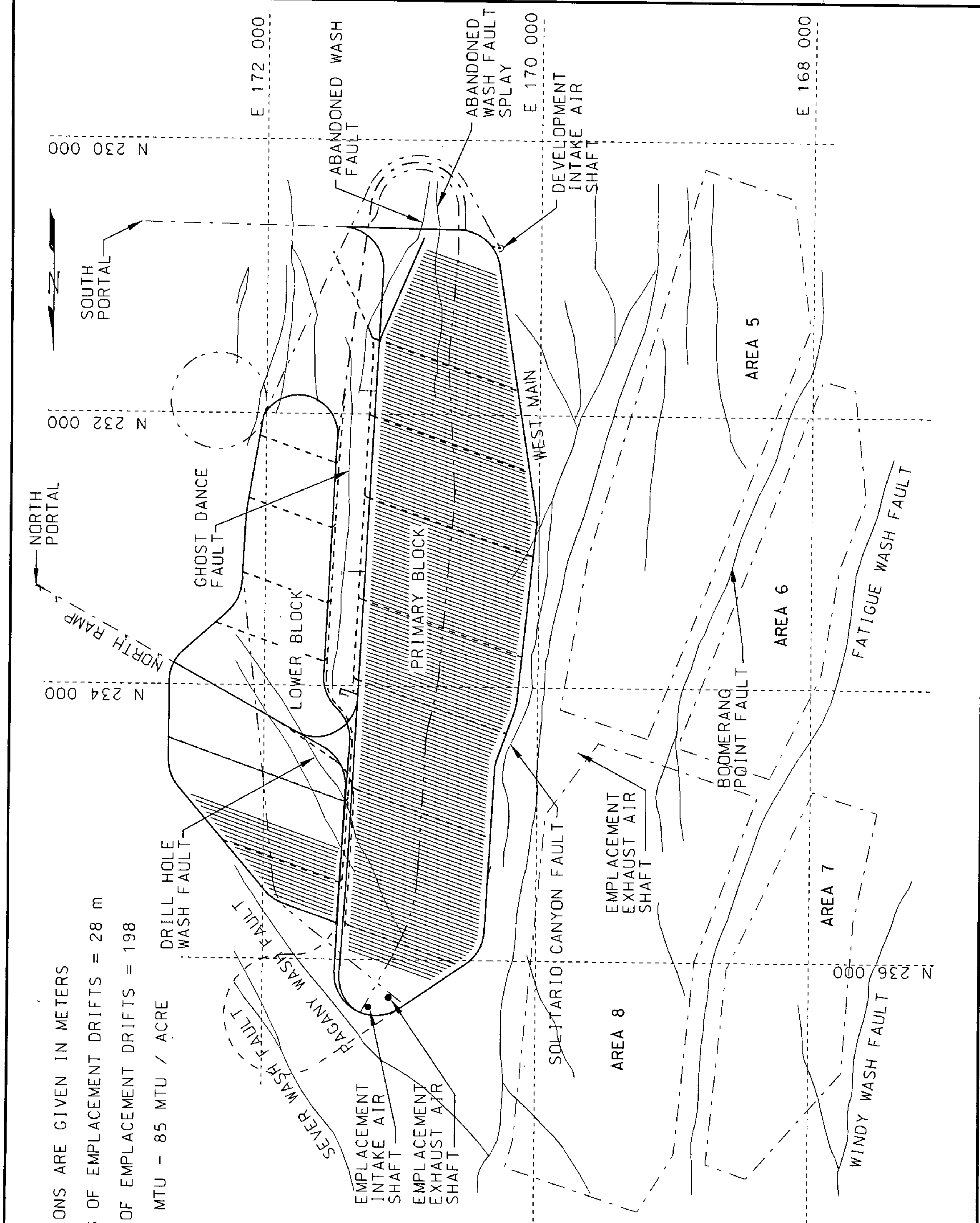
FIGURE 3.3-2
BASE CASE INVENTORY
INTERMEDIATE THERMAL LOADING



NOTES:

1. DIMENSIONS ARE GIVEN IN METERS
2. SPACING OF EMPLACEMENT DRIFTS = 38 m
3. NUMBER OF EMPLACEMENT DRIFTS = 183
4. 63,000 MTU - 25 MTU / ACRE

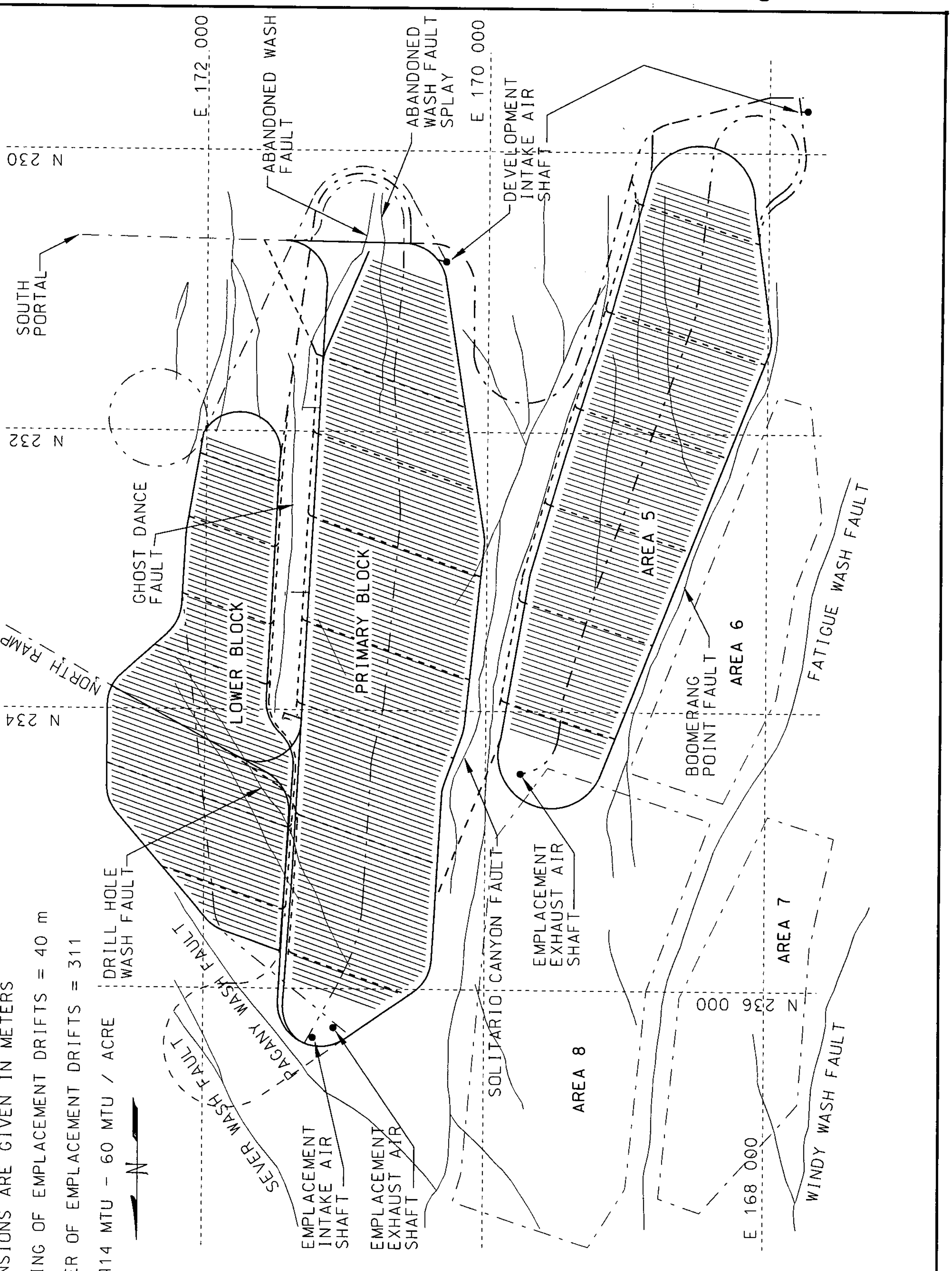
FIGURE 3.3-3
BASE CASE INVENTORY
LOW THERMAL LOADING



NOTES:

1. DIMENSIONS ARE GIVEN IN METERS
2. SPACING OF EMPLACEMENT DRIFTS = 28 m
3. NUMBER OF EMPLACEMENT DRIFTS = 198
4. 105.414 MTU - 85 MTU / ACRE

FIGURE 3.3-4
MODULES 1 & 2b
HIGH THERMAL LOADING



NOTES:

1. DIMENSIONS ARE GIVEN IN METERS
2. SPACING OF EMPLACEMENT DRIFTS = 40 m
3. NUMBER OF EMPLACEMENT DRIFTS = 311
4. 105.414 MTU - 60 MTU / ACRE

FIGURE 3.3-5
MODULES 1 & 2b
INTERMEDIATE THERMAL LOADING

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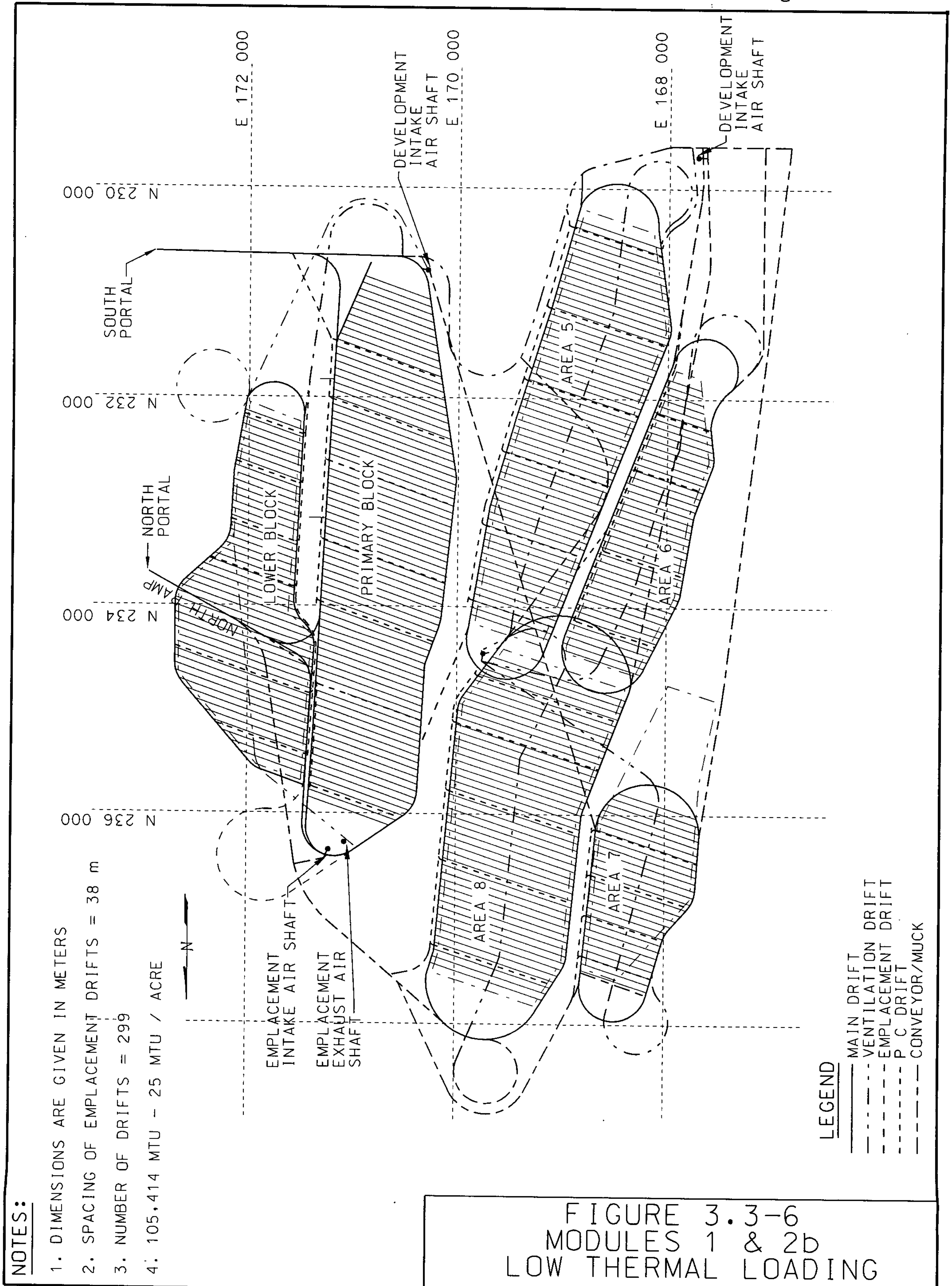

FIGURE 3.3-6
MODULES 1 & 2b
LOW THERMAL LOADING

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4 REFERENCE SUBSURFACE DESIGN DESCRIPTION

4.1 BASIS FOR SUBSURFACE DESIGN

The Viability Assessment, the VA analyses and the other supporting documents provide the bases for this subsurface repository engineering file. Waste inventory and thermal loading alternatives are expansions of VA design features, but the basic approaches are consistent with the VA.

4.2 GENERAL SUBSURFACE DESCRIPTION

The subsurface system includes accesses, alcoves, drifts, and boreholes. This system provides access to the underground, provides for the emplacement of waste, provides a safe and secure work environment, protects waste from natural environments, and guards the engineered barrier system.

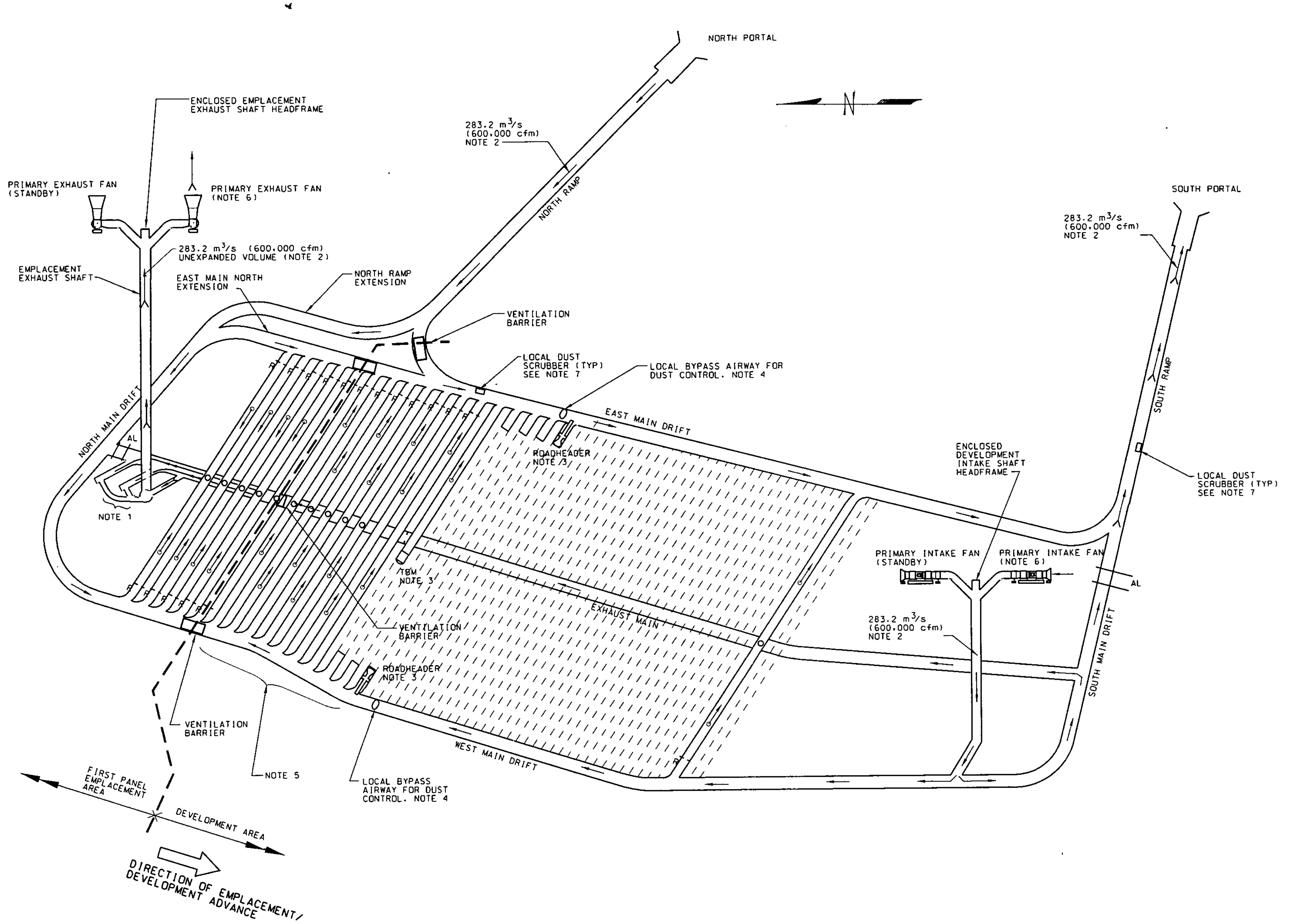
4.3 SUBSURFACE FACILITIES

Following is a description of the major subsurface facilities and equipment. The five major subsurface divisions include the following: underground excavated openings, the Exploratory Studies Facility (ESF), the subsurface utilities, the underground ventilation systems, and the underground shielding equipment/systems.

4.3.1 UNDERGROUND EXCAVATED OPENINGS

Excavated openings include access ramps, subsurface mains, ventilation shafts, emplacement drifts, exhaust mains, alcoves, and ventilation raises. Figure 4.3.1-1 shows a general overview of the subsurface excavated openings including ventilation. Access ramps to the subsurface are 7.62 m in diameter and have been excavated by tunnel boring machines (TBM) s. Repository access includes the North Ramp and South Ramp. These ramps have been excavated as part of the Exploratory Studies Facility (ESF) and will be incorporated into the repository design. The mains (access, waste handling) will also be 7.62 m in diameter and will be excavated by TBMs. For the base case inventory (high thermal loading) the mains will consist of the East main, East Main North Extension, the West main, the North Ramp Extension, and the South Ramp Extension. The East Main has been driven as part of the ESF. The other mains will be excavated as part of repository construction. The South Ramp Extension and North Ramp/North Ramp Extension connector will be excavated by TBM.

For the base case inventory (high thermal loading) two 6.1-m diameter shafts will be excavated for repository ventilation. One shaft will be located at the north end of the repository. One shaft will be located at the south end of the repository.



LEGEND:

- SUPPLY AIR IN DRIFT OR SHAFT
- RETURN AIR IN DRIFT OR SHAFT
- SUPPLY AIR IN DUCT
- RETURN AIR IN DUCT
- UNEXCAVATED
- AL AIRLOCK
- DRIFT REGULATED FLOW
- R REGULATOR
- D DOOR
- L LEAKAGE
- AXIAL FAN W/ SILENCER

NOTES:

1. EXHAUST MAIN DUCTS & STANDBY HEPA FILTERS FOR EMPLACEMENT DRIFT RETURN AIR.
2. NOMINAL MAXIMUM CAPACITY PERFORMANCE.
3. TBM & ROADHEADER FACE VENTILATION.
4. INSTALLED IN PRIMARY AIRWAYS TO BYPASS AIRFLOW DURING INITIAL ROADHEADER CUTTING.
5. FOR CLARITY, NOT ALL EMPLACEMENT/CONSTRUCTION AND CROSS BLOCK DRIFTS ARE SHOWN.
6. PRIMARY EMPLACEMENT AND DEVELOPMENT FAN ARRANGEMENT.
7. LOCAL DUST SCRUBBERS INSTALLED ALONG DRIFTS AS NEEDED.

Reference:
CRWMS M&O 1997l, Overall Development and Emplacement Ventilation Systems. Figure 7.6.2.4

FIGURE 4.3.1-1
EMPLACEMENT VENTILATION

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Emplacement drifts will be 5.5 m in diameter and will be excavated by smaller TBMs. In the main repository block, these drifts will connect the East and West Mains. For a high thermal loading, the spacing between emplacement drifts will be 28-m centerline to centerline. A 7.62-m exhaust main will be developed below the emplacement drift horizon. This drift will run approximately perpendicular to the emplacement drifts and be located midway between the East and West mains. (See Appendix D for details of underground openings.)

4.3.2 SUBSURFACE FACILITIES SUPPORTING UNDERGROUND ACTIVITIES

4.3.2.1 South Portal development support area

The South Portal Development Operations Area covers approximately 36.5 acres, and is located adjacent to the South Portal. The area includes eight structures and various support areas. Facilities are provided to support subsurface development. The South Portal Operations Area will function independently of the emplacement side support area at the North Portal, and will include facilities for personnel support, equipment maintenance, warehousing, material staging, security, and transportation of materials to the subsurface development area. From this operations area, excavated muck from repository development will be transported by overland conveyor to the muck pile.

On completion of repository development, the South Portal Operations Area will be modified for the monitor operations and for possible waste package retrieval should this occur.

The current approach to the South Portal Area disturbance is illustrated in Figure 4.3.2.1-1. It has been extracted from the *Subsurface Construction and Development Analysis,* (CRWMS M&O 1998a, fig. 7-37 (pg. 122 of 130). This inclusive area would cause a surface land disturbance of approximately 36.5 acres. The South Portal facility area will accommodate the following:

- *Covered Lay Down & Storage Area (warehouse)* - is a steel structure (100 m x 40 m) with concrete floor. The two rail tracks (1.44 m gauge) are embedded in a concrete floor to facilitate loading and unloading of rubber tired equipment. Items to be stored in this area include rails, pipes, rockbolts, steel sets, welded wire fabric, ventilation duct, fans, conveyor parts and belt, electric cables, disc cutters and spare parts for the tunnel boring machine, roadheader parts, and steel inverts. The building will have large doors to facilitate access for portable cranes. The warehouse will have a fire water line with an automatic sprinkler system, warehouse office, heating and cooling systems, and electrical power. There will be separate storage areas for the different types of materials.

- *Locomotive and Railcar Repair Shop including Battery Charger Station* - is a steel structure with similar construction to that designed for the North Portal. The battery charger area, however, will be larger to accommodate 10 to 14 battery charging bays.

- *Transformer Yard* - is an open fenced area, 20 m x 20 m, where the 69 kV utility line extended from the North Portal to the South Portal terminates. A transformer will reduce the utility line voltage from 69 kV to 12.47 kV. Two 12.47 kV lines will supply power to the South Portal operations. One line, routed through the South Ramp, will supply the subsurface development operations, and the other line will supply the development side exhaust shaft surface facilities.

- *Air Compressor Building* - is a steel frame building, 20 m x 5 m, with a concrete floor. The air compressor building will be located adjacent to the switch gear and generator building, and will house three electric compressors, each of 43 m^3/min capacity and one diesel standby unit. The building will be equipped with a fire line with automatic sprinklers and a ventilation system.

- *Change House for the Development Crews* - is a steel frame building, 30 m x 25 m, with concrete floor, located adjacent to the portal site offices. The change house will have hot water boilers, cold water lines, showers, lockers for street clothes, and facilities to dry damp work clothes. Separate facilities will be provided for men and women. Wastewater from these facilities will be treated before pumping to the evaporation pond. Should personnel decontamination be needed, those persons affected will use the decontamination facilities at the north portal.

- *Portal Site Offices* – are in a concrete block building, 30 m x 25 m, with a concrete and linoleum floor. This building will house the technical and subsurface development supervisory personnel. In the same building, a dispatch room will track, on each shift, the development activity, materials traffic, and will maintain permanent contact with the underground safety inspector in the event of an emergency.

- *Surface Space for an Optional Tuff Crushing and Screening Plant for Emplacement Drifts or Inverts Backfilling* - this will require an area of 40 m x 40 m, for the crushing and screening plant and where trucks can dump excavated muck from underground development. The tuff will be crushed as needed, sorted, and transported to the subsurface operations in special railcars. If emplacement drifts will be backfilled, crushed material can be transported underground by conveyor. The area will be provided with water and 480 V electrical power utilities. The used water will be collected in a sump where solids will be allowed to settle before pumping to the evaporation pond. No further treatment is anticipated.

- *Aggregate Storage with Optional Feed Conveyor* - will cover an area of 40 m x 20 m, which is enough space for three segregated stockpiles that will be separated by partitions.

- *Concrete Batch Plant* - will occupy an area 30m x 30m, and will include concrete mixers, cement silos, and space for fabricating and curing the tunnel inverts. The area will have a rail track and facilities for loading railcars, a concrete lab, water supply, and 480 V electric power supply. The batch plant will be used to produce concrete for the cast in place concrete liners for main drifts and ramps as well as the pre-cast liners used in the emplacement drifts. The capacity will be approximately 150 cubic yards per hour based upon 3 hours of operation per day. *Concrete Car Clean Out Shed* - this facility will occupy a pad 12 m x 5 m, and will be provided with a spur rail track and high pressure water to wash the concrete cars that travel between the batch plant and tunnel invert fabrication plant. The wastewater will be collected in a sump and treated before discharge to the evaporation pond.

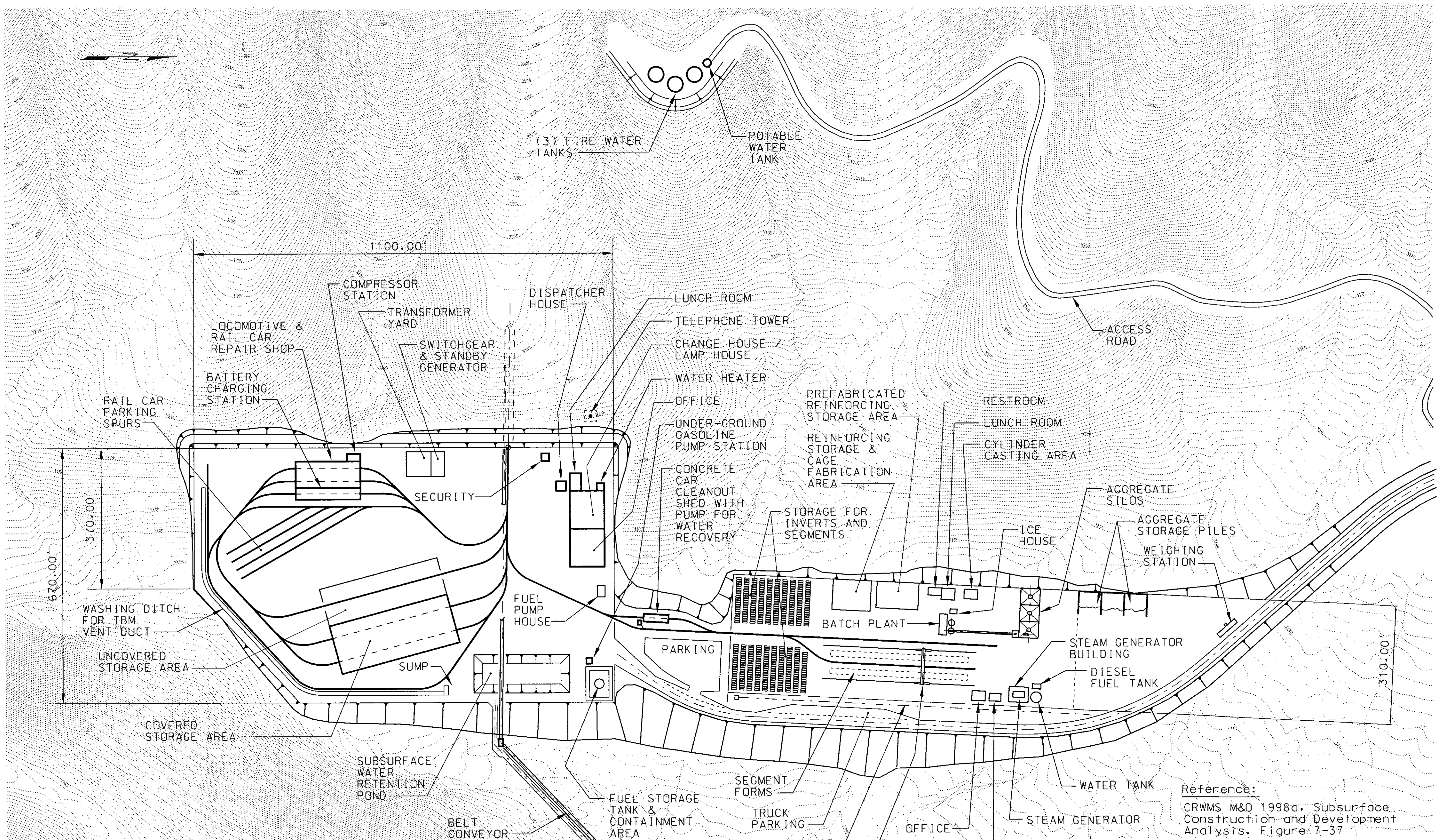
- *Diesel Fuel Storage Tank with Containment Sump* - the area occupied by this tank will be approximately 20 m x 15 m, with a dirt dike capable of containing the diesel fuel if the storage tank ruptures. Diesel fuel will be required for the diesel-powered generator, standby air compressor, and surface rubber tired equipment. There will be a 5 m x 5 m fuel pump house with concrete floor that will be equipped with an automatic fire extinguishing system.

- *Water Storage Tanks* - to satisfy the Standard Review Plan presented in NUREG-0800, the fire water supply will be sized for both the surface and subsurface facilities. Accordingly, two 1,135,500 liter tanks will be installed near the South Portal at an elevation of 1180 m. This gravity water feed system will satisfy the fire protection needs of the surface buildings and facilities. By means of a parallel line, the water storage tanks will fill a smaller tank (227,100 to 378,500 liter capacity) located on the pad. This tank, in tandem with a water pump housed in a 5 m x 5 m building, will feed the 152 mm diameter subsurface water line.

- *Discharge Water Evaporation Pond* - the evaporation pond area will be approximately 75 m x 30 m in area, and will include a 5 m x 5 m pump house. All residual water accumulated from the surface facilities or underground development will be stored in the evaporation pond. This pond will be lined with heavy plastic sheets to prevent ground contamination. Sludge residue will be removed for permanent storage or disposal.

- *Security Station* - there will be two security stations at the South Portal area, at the main gate where traffic is checked in and out, and at the South Portal entrance, to check access to the subsurface. The security buildings will be 5 m x 5 m concrete bricks structures with concrete floors and heat and air conditioning systems. Security personnel will be able to monitor activities throughout the site, and will be familiar with emergency procedures.

- *Truck Unloading Area* - this area will be located adjacent to the covered lay-down and storage area for trucks to unload materials and supplies, including equipment parts and construction materials. Portable cranes, forklifts, and rubber tired transporters will transport materials to the warehouse and storage areas.



Reference:
CRWMS M&O 1998a. Subsurface Construction and Development Analysis. Figure 7-37

FIGURE 4.3.2.1-1
SOUTH PORTAL AREA CONCEPT

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- *Surface Rail Parking Area for Locomotives, Personnel, and Materials Railcars* - two rail tracks will be constructed in the South Portal and the subsurface service main. Outside the portal entrance, the main rail tracks will split on different spurs to access the various buildings and facilities such as the covered lay down and storage area, the maintenance and battery charging shops, the concrete car clean out area, and the batch plant. Spurs will be provided for the standby locomotives; and, personnel and material cars. A minimum 30-m curve radius will be needed for the tracks.

- *Stand-by diesel generator* - will power the vital development systems should off-site power fail.

- *Dispatcher house* - for controlling train movements through the South Ramp and the development facilities.

- *Facilities for washing ventilation ducting* - to remove harmful silica dust prior to reuse.

Figure 4.3.2.1-1 also provides area for concrete fabrication and transportation facilities. These concrete production facilities include the following:

- Concrete Car Clean out Shed
- Storage for inverts and segments
- Areas for segment forms
- Facility for fabricating reinforcing cages
- Concrete batch plant
- Other related facilities

The following surface area estimations were extracted from Addendum F of the engineering file (Rev 00) titled, "South Portal Disturbed Area Estimate." Specific assumptions related to the South Portal Development Area are noted as follows:

a.) With the exception of early E&C Phase activities, all construction and development activities and operations will be conducted through the South Portal. Disturbed surface areas near the South Portal are related to subsurface activities.

b.) The standard emplacement drift ground support will be pre-cast tunnel segments and these segments will be fabricated on the surface and accessible by the South Portal rail system.

c.) All subsurface construction, development and service personnel assigned to the development side of the repository will enter and exit through the South Portal and its facilities under normal conditions.

d.) All mined rock will be transported through the South Ramp and Portal and then be conveyed to the Mined Rock Stockpile. Location and size of the stock pile will be determined by the waste inventory and thermal loading case.

e.) An engineered road will connect the South Portal Area to the main MGDS road serving the North Portal Area.

Should the disturbed areas for shafts be added to the portal area, the following estimates apply:

Base Case (70,000 MTU) High Thermal Loading:

South Portal Area = 36.5 acres

Surface disturbance for two Emplacement and Development Shafts = 6.0 acres

Total Surface Disturbance by Subsurface Construction and Development = 43 acres (rounded)

Stockpile area = 252 acres

Total high thermal base case disturbance estimate = 295 acres

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Base Case (70,000 MTU) Low Thermal Loading:

South Portal Area = 36.5 acres

Surface disturbance for five Emplacement and Development Shafts = 15.0 acres

Total Surface Disturbance from Subsurface Construction/Development = 52 acres (rounded)

Stockpile area = 284 acres

Total base low thermal case disturbance estimate = 336 acres

Extended Inventory Case (105,414 MTU) Low Thermal Loading:

South Portal Area 36.5 acres

Surface disturbance for five Emplacement and Development Shafts 15.0 acres

Total Surface Disturbance from Subsurface Construction and Development = 52 acres (rounded)

Stockpile = 494 acres

Total extended inventory low thermal case disturbance estimate = 550 acres

Section 4.3.2.2 "Emplacement Shaft Operation" describes the following with respect to surface disturbance: "The Emplacement Shaft surface site will occupy an area approximately 80m X 140m " This would create a disturbed area of approximately 3 acres. Section 4.3.2.3 "Development Shaft Operation" describes the following with respect to surface disturbance: "The Development Shaft surface disturbance operations site will require an area similar to the Emplacement Shaft site. ... The shaft area includes a fenced compound of approximately 80m X 160m, with sufficient yard space for operation of mobile equipment and with storage for maintenance supplies." This site would create a disturbed area of approximately 3 acres.

The South Portal area disturbance is constant for all thermal and waste inventory cases. This is because the same functions must be performed during the development processes. The lengths of time when development crews would be active vary with waste inventories and the amounts of materials handled vary with both waste inventories and the thermal loading cases.

Surface disturbance for shaft collars and activities only increases with the addition of shafts. Five shafts are needed in both the Low Thermal cases.

Acreage occupied by mined rock stockpiles depends directly on the amounts of underground opening excavated. Acreage also depends on stockpile design and stacking height.

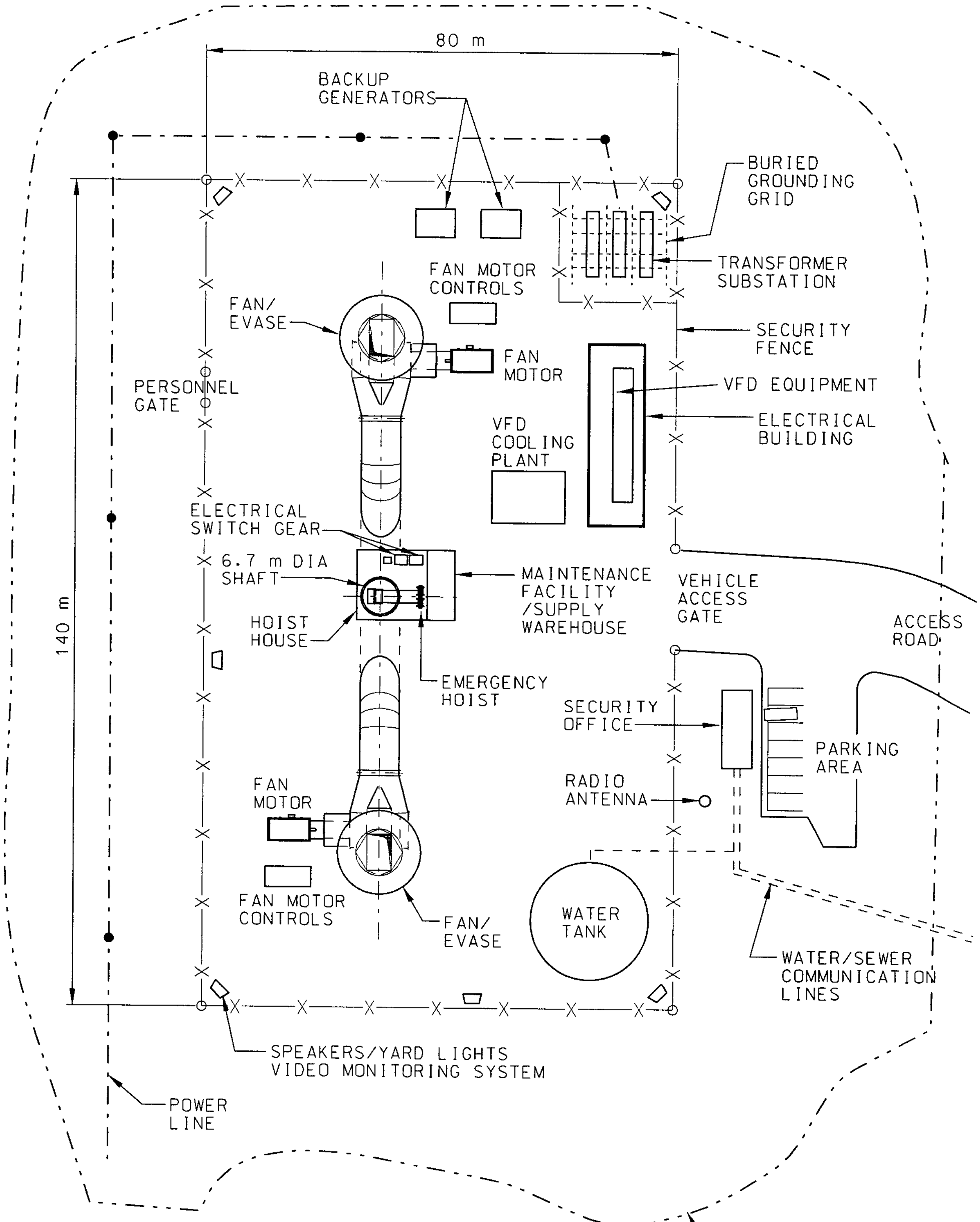
4.3.2.2 Emplacement Shaft Operation

The emplacement and development shaft operation is described in the *Overall Development and Emplacement Ventilation Systems* (CRWMS M&O 1997l, Section 7.8 (p. 85 of 114)) and the *Siting Repository Shafts Analysis* (CRWMS M&O 1997t, pg. 16-18 of 30). Figures 4.3.2.2 - 1 and 4.3.2.2 - 2 show the site and the fans anticipated for emplacement shaft operation. On the emplacement side (for the base case inventory, high thermal load) a single 6.1 m diameter concrete lined shaft will function as the only exhaust airway to the surface while the North Ramp will provide the intake air. The shaft will be excavated to a depth slightly below the Primary Block. The location of the collar on surface will be on the side of a ridge between the Drill Hole and Teacup Washes. The shaft will be under negative pressure, using exhaust fans on the surface to draw air through the subsurface emplacement area and accesses.

The emplacement shaft surface site will occupy an area approximately 80 m x 140 m, and will have fencing, security lights, warning devices, and an occasionally staffed guard station for monitoring entry when work is underway. Sufficient yard space will be provided for operation of rubber tired equipment and a minimal storage area for maintenance supplies. Normally, the site will be unmanned; personnel and materials will be dispatched, as needed, from the North Portal operations area for inspections and maintenance. A building will house the electric-powered inspection hoist and the shaft monitoring equipment, control systems, and cover the shaft collar. A small four to five-man conveyance running on a single guide attached to the shaft wall will be provided for inspections and emergency egress. Doors over the collar will prevent leakage and re-circulation of the exhaust air. There will be two ventilation fans with steel ductwork connecting to the shaft. Each fan will be fitted with an evase to diffuse exhaust air as it leaves the fan.

Upon the unlikely activation of the HEPA Filter System described in Section 4.3.2.10, the filtered air will pass through the Emplacement Exhaust Shaft at 14.2 m^3/sec. This is reduced from the normal operating airflow of 47 m^3/sec. in order to match the filter capacity (CRWMS M&O 1997r. pg. 17). Slowing the rotation of the on-line operating fan located on surface would do this.

Hot air (Approximately 50 degrees C) in the emplacement exhaust shaft make it an undesirable travel way. For this reason entry into this shaft will be limited to inspection and maintenance. In extreme cases only, the shaft could be used for personnel evacuation if no other means is available. Inspections can be carried out by remote controlled equipment, such as a video camera, placed in the shaft conveyance. The concrete lining will require very little maintenance over the life of the repository, but if maintenance were required it would necessitate personnel entering the shaft. For human entry, closing off or diluting hot air from the emplacement drifts and bypassing fresh air from the North Ramp directly into the exhaust shaft will reduce the exhaust air temperature.



Reference:

CRWMS M&O 1997t, Siting Repository Shafts Analysis. Figure 7.2.1

FIGURE 4.3.2.2-1
EMPLACEMENT VENTILATION
SHAFT SURFACE FACILITY PLAN VIEW

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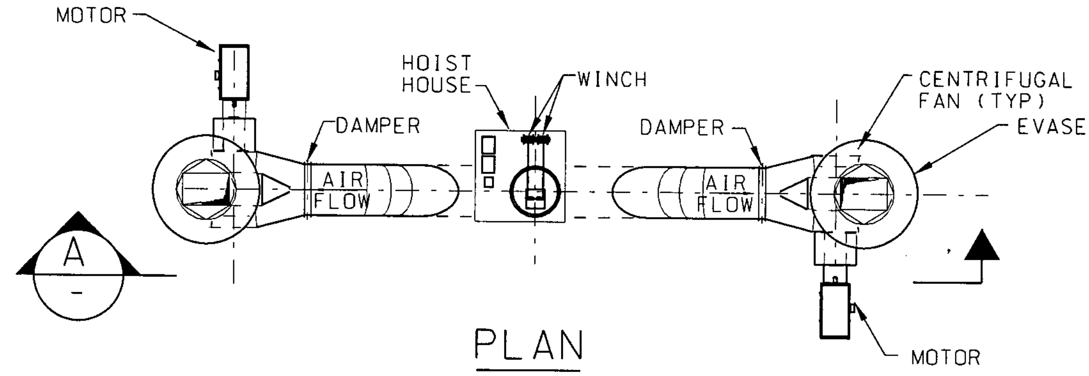
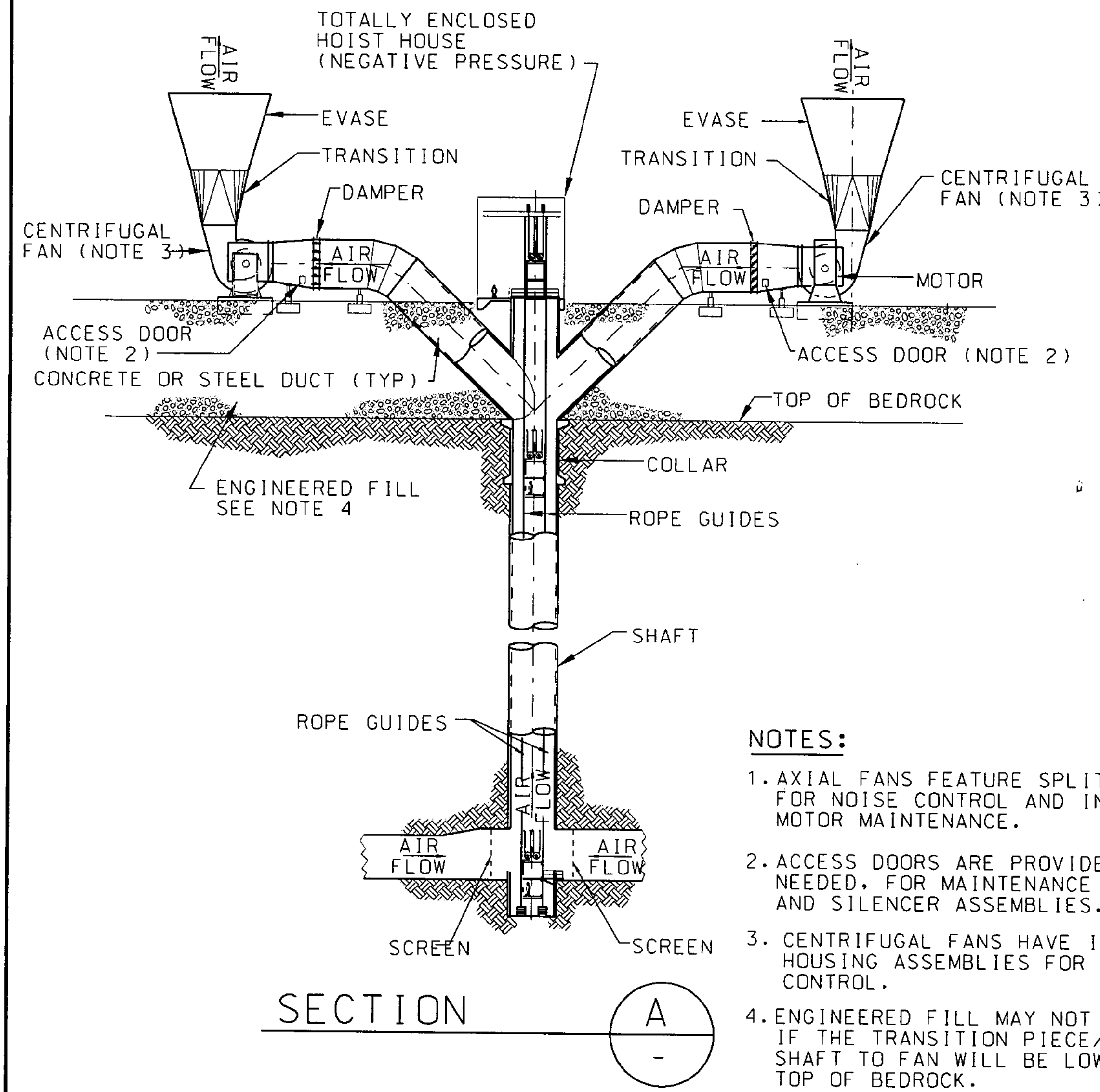




NOTES:

1. AXIAL FANS FEATURE SPLIT FAN HOUSING FOR NOISE CONTROL AND INTERNAL MOTOR MAINTENANCE.
2. ACCESS DOORS ARE PROVIDED, AS NEEDED, FOR MAINTENANCE OF FAN AND SILENCER ASSEMBLIES.
3. CENTRIFUGAL FANS HAVE INSULATED HOUSING ASSEMBLIES FOR NOISE CONTROL.
4. ENGINEERED FILL MAY NOT BE NEEDED IF THE TRANSITION PIECE/DUCT FROM SHAFT TO FAN WILL BE LOWERED TO TOP OF BEDROCK.

Reference:

CRWMS M&O 1997i. Overall Development & Emplacement Ventilation Systems. FIGURE 7.11.1.2

FIGURE 4.3.2.2-2
PRIMARY EMPLACEMENT FAN ARRANGEMENT

The emplacement exhaust shaft surface area will include the following facilities:

- Main Exhaust Fans - Two centrifugal fans each with a capacity of 283.2 m^3/sec, and each driven by a 2,000 horsepower electric motor. One fan will be in continual operation and the other on standby. Fan discharge is through an up-cast evase, approximately 7.62 m in diameter and 12.2 m in height.
- Transformer Station and switchgear - This unit will be of 12.47/4.16/480 V capacity and fed from the North Portal area. The transformer will be located in an open, controlled fenced area.
- Monitoring Instrumentation - Instrumentation will be provided for automatic monitoring of air stream conditions for radiation, air temperature, and particulate/gas content. Other instruments will monitor fan performance, bearing temperature, vibration, motor voltage, current drawn (amperage), and lubrication oil temperature. All instruments will be housed in a building within the shaft compound fenced area.
- Back up generators – This diesel-powered unit will provide emergency power to the above facilities and equipment.

4.3.2.3 Development Shaft operation

For repository development (base case inventory, high thermal loading), a single 6.1 m diameter concrete-lined shaft will function as the development intake air shaft, and the South Ramp will provide the exhaust airway. The shaft will also serve as an emergency escape-way if needed for this purpose.

The development shaft surface operations site will require an area similar to the Emplacement Shaft site (See Figures 4.3.2.3 - 1 and 4.3.2.3 - 2). The surface area includes a fenced compound of approximately 80m x 160m, with sufficient yard space for operation of mobile equipment and with storage for maintenance supplies. A guard station will control access to the shaft area when activities are being performed otherwise the security fence will be prevent access.. Surface fans will force air down the shaft and into the repository block.

During the repository development and emplacement phases, ventilation fans at the shaft collar are required. Exhaust air from the development operations will exhaust directly to the atmosphere through the South Portal. There will be no provisions made for high- efficiency-particulate air filters because the ventilation system design precludes radioactive particulates entering the ventilation air in the development operations.

Hoisting in this shaft will be limited to inspection and maintenance and only in extreme cases for emergency personnel evacuation if no other means are available. Maintenance work is unlikely in both the emplacement and development shaft, but if maintenance is needed the necessary equipment (including a multistage sinking deck, winches, and a larger hoisting system) would be provided by a contractor. The development shaft surface area will include the following facilities:

- Main Intake Fans - The primary fan on the development intake shaft collar is normally in a blowing mode. Air supply is blown into the shaft for subsurface development activities. A standard axial fan will be used. Two fans will be located at the shaft. At any point in time, only one will be in operation. Each fan will have a capacity of 283.2 m^3/sec, and will be driven by a 2,000 horsepower electric motor.

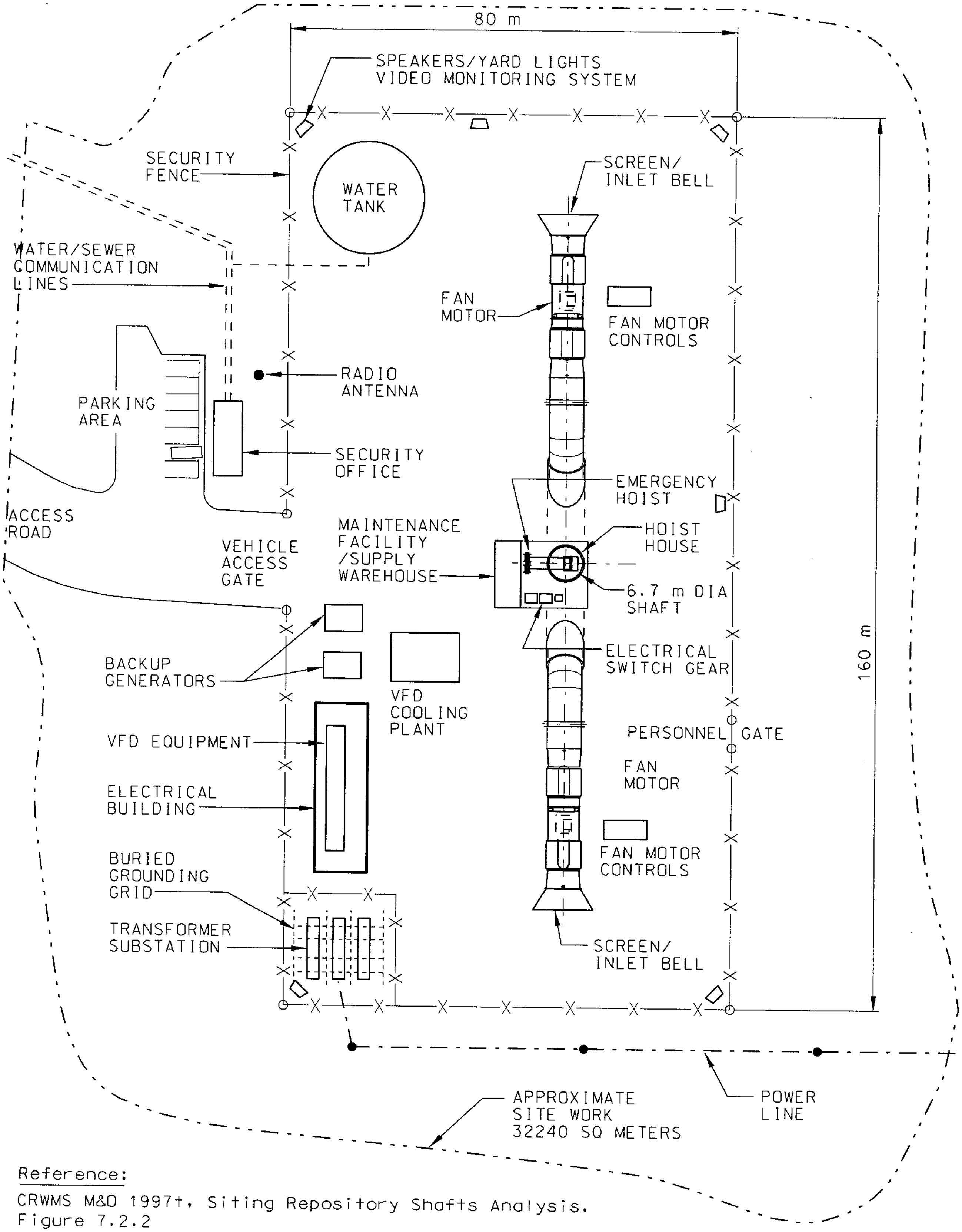
- A headframe and electric-powered emergency hoist capable of carrying four to five workers per trip. This equipment will be housed in a corrugated steel headframe building. This building will contain the shaft conveyance and the monitoring equipment for the shaft.

- The shaft collar will be concrete lined and 6.1 m internal diameter, below the collar a ventilation elbow, also 6.0 m in diameter, will be constructed at 45° to the shaft axis to create a streamlined pathway for the intake air. The ventilation elbow will facilitate entry into the shaft by eliminating ductwork at the collar. The shaft collar will be covered with doors to eliminate air leakage. The doors will be opened when the shaft cage is in use for inspections and in an emergency situation such as hoisting personnel from the underground.

- Monitoring Instrumentation will be provided for monitoring air-stream conditions such as airflow volume and particulates.

- A small building at the site will house the electrical equipment will include a high-voltage disconnect switch to shut off incoming power. It will also house a transformer to reduce the incoming surface voltage to a desired underground feed voltage. A smaller transformer will provide power for site and building lighting, and switchgear for site and building lighting.

- Back up generators



Reference:

CRWMS M&O 1997t, Siting Repository Shafts Analysis. Figure 7.2.2

FIGURE 4.3.2.3-1
DEVELOPMENT VENTILATION
SHAFT SURFACE FACILITY PLAN VIEW

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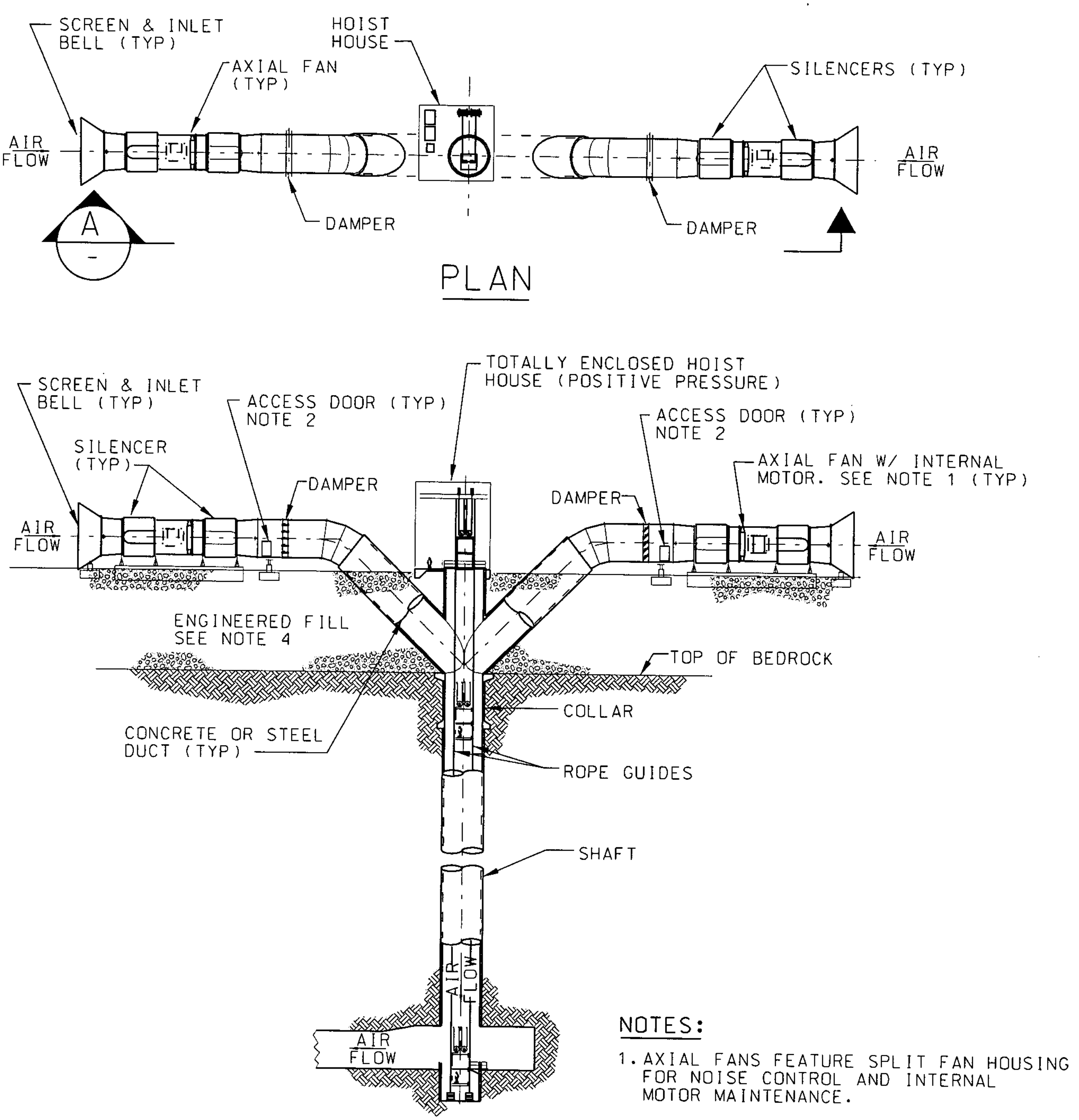

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Reference:

CRWMS M&O 1997i. Overall Development & Emplacement Ventilation Systems. FIGURE 7.11.2.2

FIGURE 4.3.2.3-2
PRIMARY DEVELOPMENT FAN ARRANGEMENT

4.3.2.4 Underground Shielding Equipment/Systems

Underground shielding systems are discussed in detail in: *MGDS Subsurface Radiation Shielding Design Analysis* (Sec. 8.2, CRWMS M&O 1997m, pg. 63-73 of 105). Shadow shields, placed at the ends of the emplacement drifts, are part of this engineered shielding system. The isolation doors, also located at the emplacement drift entrance, prevent human entrance under normal operation. These doors provide some shielding, but are not considered a part of the underground shielding system. Figure 4.3.2.8-1 shows the location of the shadow shields and isolation doors in the emplacement drifts. Shadow shields are constructed of concrete and isolation doors of steel.

4.3.2.5 Underground Closure

The systems for closure consist of constructing concrete seals in all openings to the surface and using fill material (possibly crushed welded tuff) in all mains, ramps and other openings not containing waste packages.

4.3.2.6 Underground Performance Confirmation Systems

The performance confirmation system consists of launch mains used to launch the tunnel boring machines, observation drifts located 15 meters above the perimeter and emplacement drifts, alcoves driven left and right providing a location for instrumentation and boreholes - typically 100 mm in diameter. Ground support in the performance confirmation drifts consists of rockbolts, wire mesh and steel sets as required. This open ground support allows the general area to be mapped.

4.3.2.7 Underground Construction Equipment

Major underground construction equipment consists of tunnel boring machines (TBM), roadheaders, raise boring machines, locomotives, railcars, and loading equipment. The 5.5-m TBMs will be used for emplacement and performance confirmation drift excavation. Roadheaders will be used to excavate turnouts and TBM launch chambers, performance confirmation alcoves and other short excavations. Large tunnel boring machines (7.62-m diameter) will be used for main drifts, ramps and exhaust mains. Equipment used to move the muck between the TBMs and the conveyor in the emplacement drifts consist of side dump railcars and trolley/battery locomotives. Electric powered shuttle cars will load muck from behind the roadheaders and haul it to the conveyor which will haul the broken rock to the South Ramp and then directly to the surface stockpile. Ventilation raises (vertical openings) will be driven using raise-drilling equipment.

To start a TBM on excavation course, its sections are assembled in a pre-excavated launch chamber and launched into its designed alignment. When the excavation is complete, the TBM is disassembled in a pre-excavated chamber and prepared to move to the next location. While mechanical excavation will be used as the predominant method of underground construction, some drill-blast excavation will also be applied where mechanical methods cannot achieve the designed opening.

4.3.2.8 Underground Waste Package Handling Equipment and Emplacement Drift Configuration

The typical configuration of the emplacement drifts and the turnouts connecting the access mains and the emplacement drifts is illustrated in Figure 4.3.2.8-1. Additional to these excavated openings are the following principal components:

- The railroad systems with rails, turnout switches and the trolley system with its conductors, supports, transformers, etc.
- The emplacement drift gantry rail system and powered third rail,
- The isolation doors and their controls for activation,
- The transfer dock.

The underground waste handling equipment consists of a waste package transporter and transporter locomotives, emplacement gantry, and emplacement gantry carrier. The waste package transporter provides shielding as illustrated in Figure 4.3.2.8 -2. It is used to haul the waste packages from the waste handling building to the emplacement drift transfer dock. The transporter is moved by locomotives as shown in Figure 4.3.2.8 - 3. Transporter locomotives can be operated by both manual and remote control.

The emplacement gantry picks up the waste package at the transfer dock in the entry to the emplacement drift, carries the WP to its emplacement location, and lowers the WP onto the WP supports (Figures 4.3.2.8-4 and 4.3.2.8-5). The gantry is designed so that it can lift WPs high enough to emplace them between previously emplaced waste packages. Gantries will be operated totally under remote control.

The emplacement gantry is carried from one emplacement drift to another on a carrier shown in Figure 4.3.2.8 -6. The carrier is required to pick up the gantries at the transfer dock and the track gage in the emplacement drifts is different from in the main drifts.

4.3.2.9 Emplacement Drift Backfill Materials

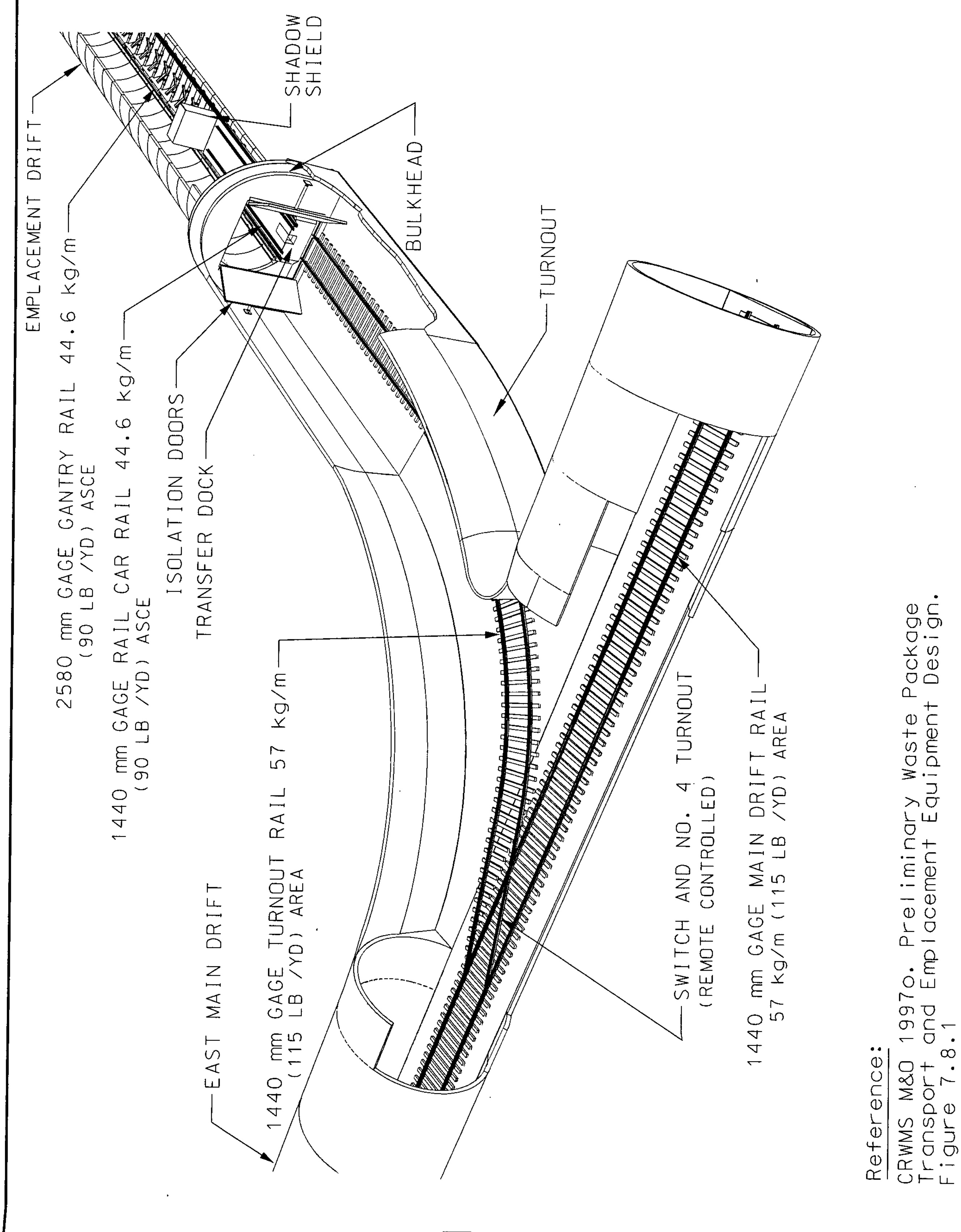
Assumption Section 2.2 (third bullet), of this engineering file, addresses emplacement drift backfill. Backfill material is assumed to be crushed and sized tuff. No additives are mixed with this backfill material. Backfill is described in the *Backfill Strategy and Preliminary Design Analysis* (CRWMS M&O 1997p, pg. 25-26 of 64).

The fifth assumption bullet in Section 2.2 addresses closure of all openings other than emplacement drifts and turnouts. These openings are backfilled with processed material specified for this purpose.

4.3.2.10 Air Filtration System for Potential Radioactive Releases

The document *Air Filtration System for Potential Radiological Releases* (CRWMS 1997r, Section 7.3) describes the operation and design of the system. Return air from the emplacement drifts will pass through in an exhaust duct located in the exhaust drift. The duct is shown in Figure D-8 in Appendix D. The return air from each emplacement drift down casts through the raise into either of two 1.83-m diameter insulated metal ducts. The two metal ducts route the return air to the bottom of the emplacement exhaust shaft for discharge to the surface. In the event of a release of radioactive particulates or gases from a waste package, sensors located in or near the exhaust raise would identify the problem and cause the exhaust air to be routed through banks of high efficiency particulate air (HEPA) filters.

The HEPA filters would be located near the bottom of the exhaust shaft. The valving system in the ventilation duct is shown in Figure 4.3.2.10-1. When activated, the airflow rate would be decreased to 14.2 m^3/second to match the capacity of the HEPA filters. Slowing the exhaust fans located on surface would do this. HEPA filters and adsorber units would be located in the cabinets shown in the figure.



Reference:
CRWMS M&O 1997o. Preliminary Waste Package Transport and Emplacement Equipment Design. Figure 7.8.1

FIGURE 4.3.2.8-1
EMPLACEMENT RAIL SYSTEM
TYPICAL TURNOUT DETAIL

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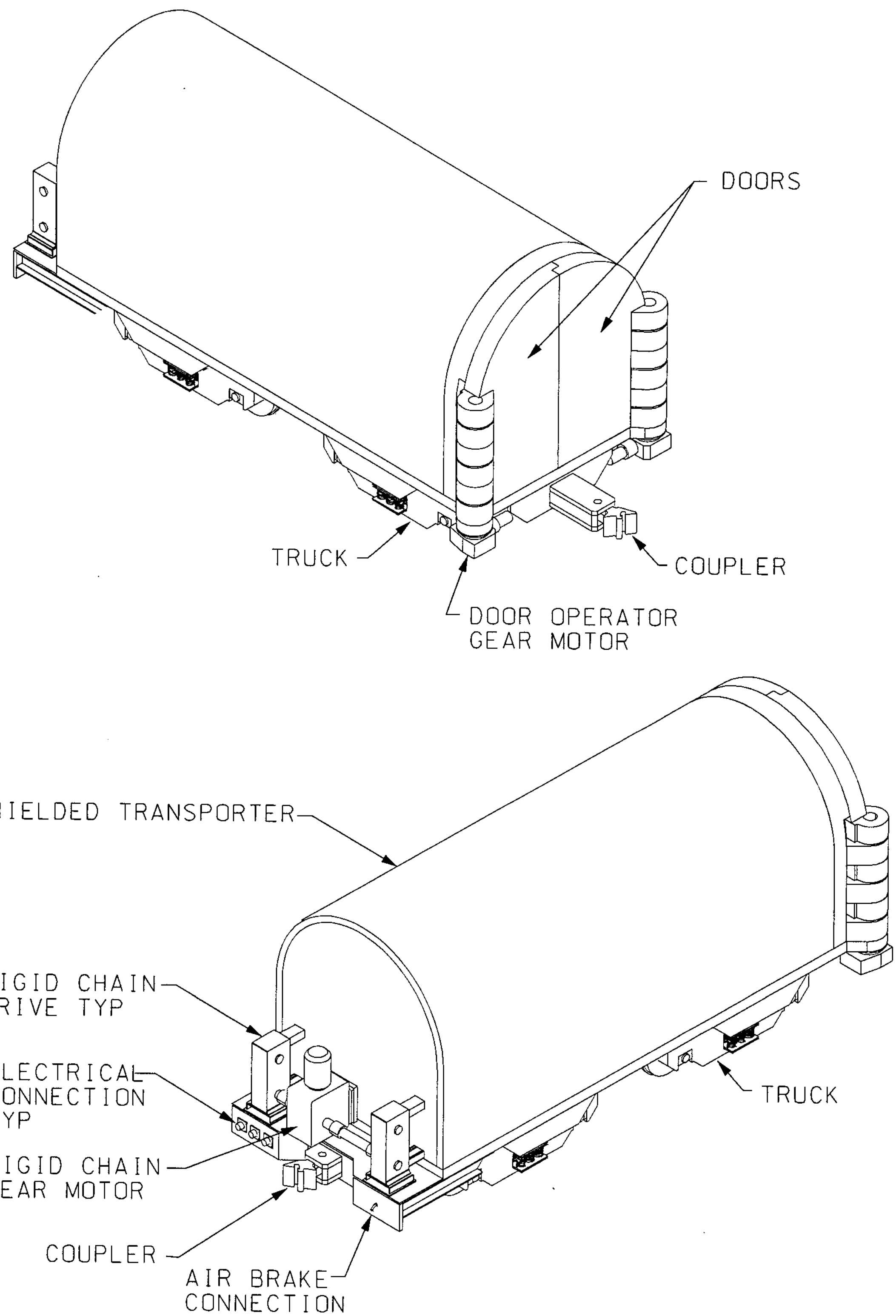

CRWMS M&O 1997o. Preliminary Waste Package Transport and Emplacement Equipment Design. Figure 7.2.1

FIGURE 4.3.2.8-2
WASTE PACKAGE TRANSPORTER ARRANGEMENT

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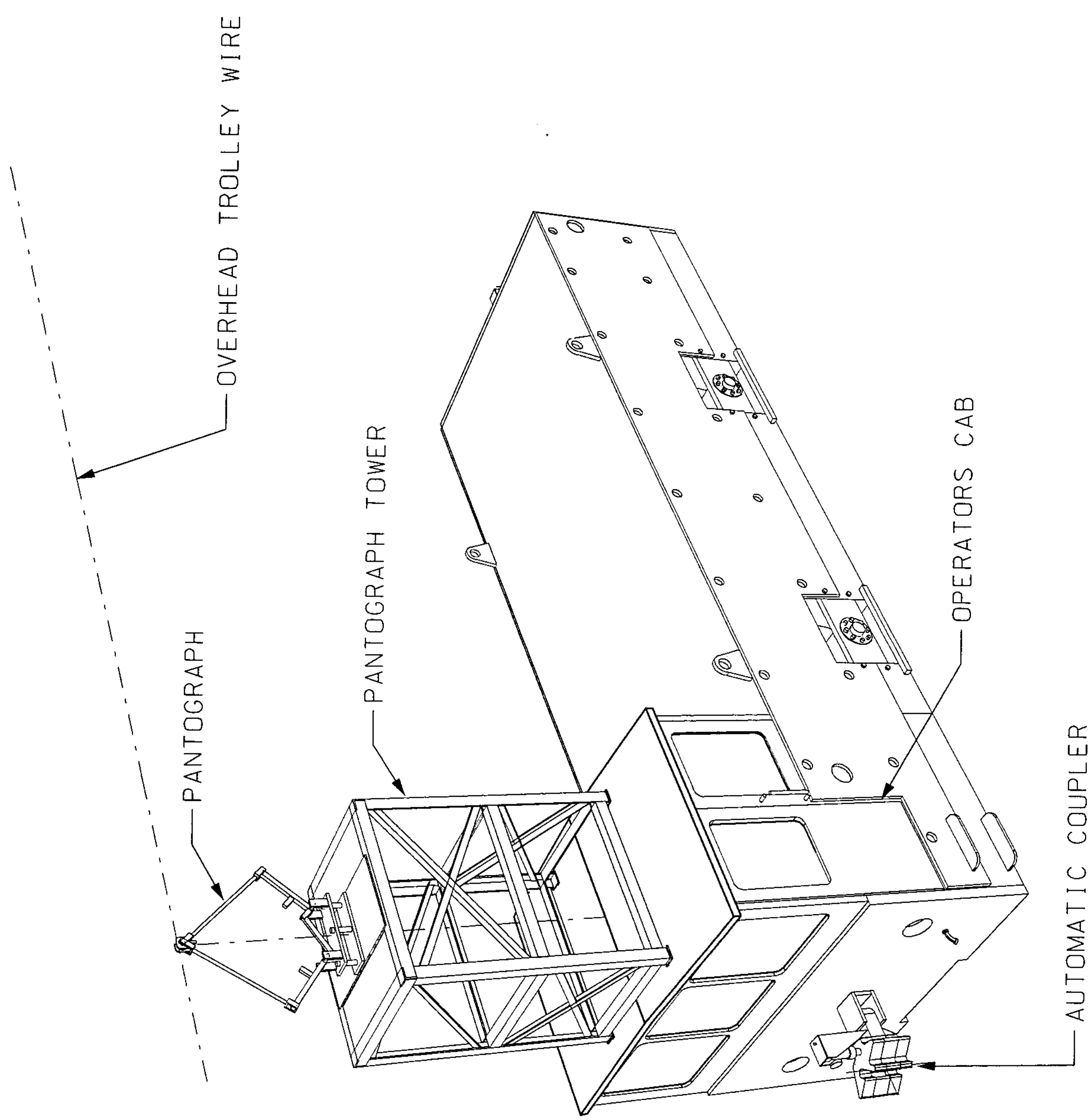
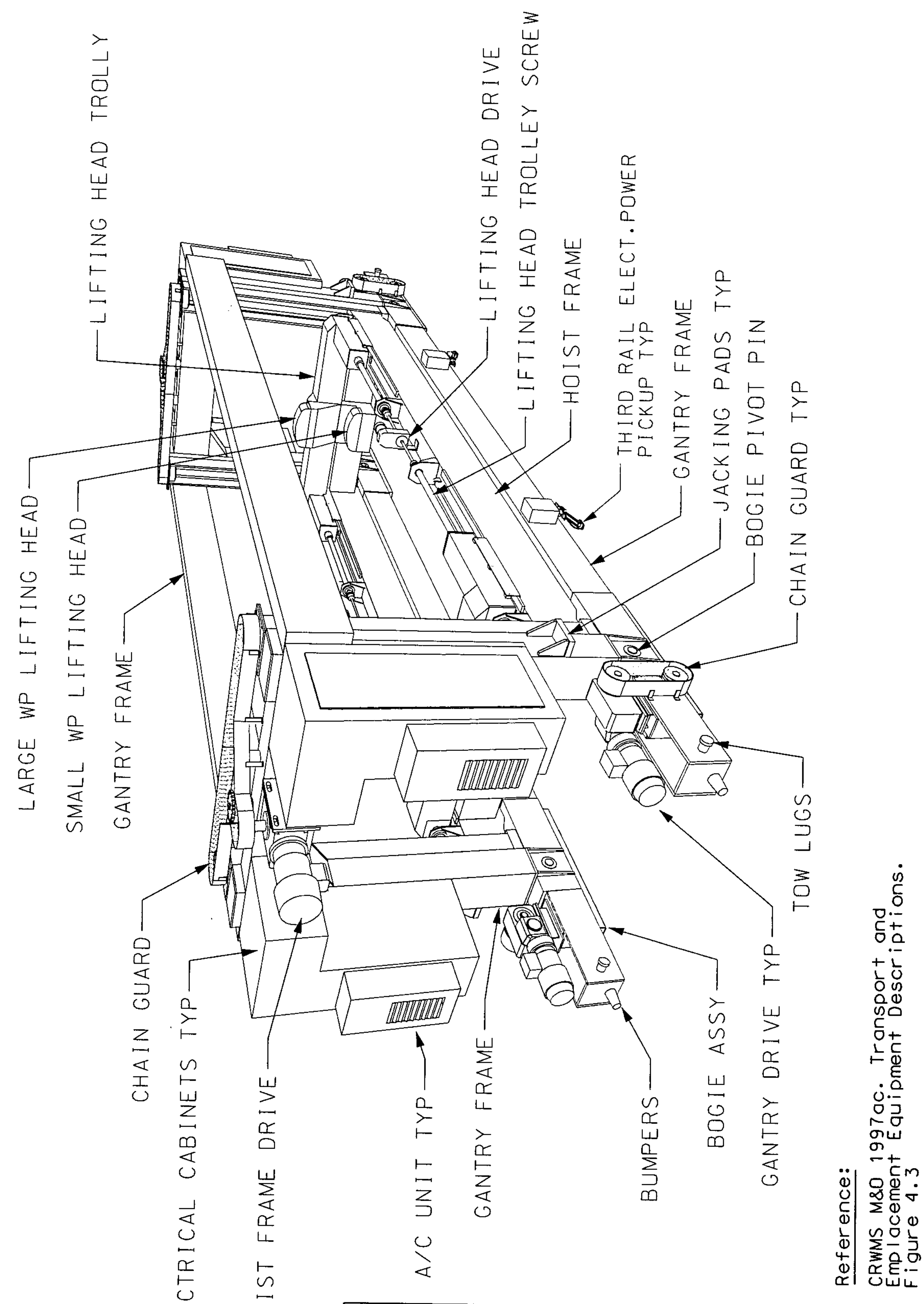


Reference:

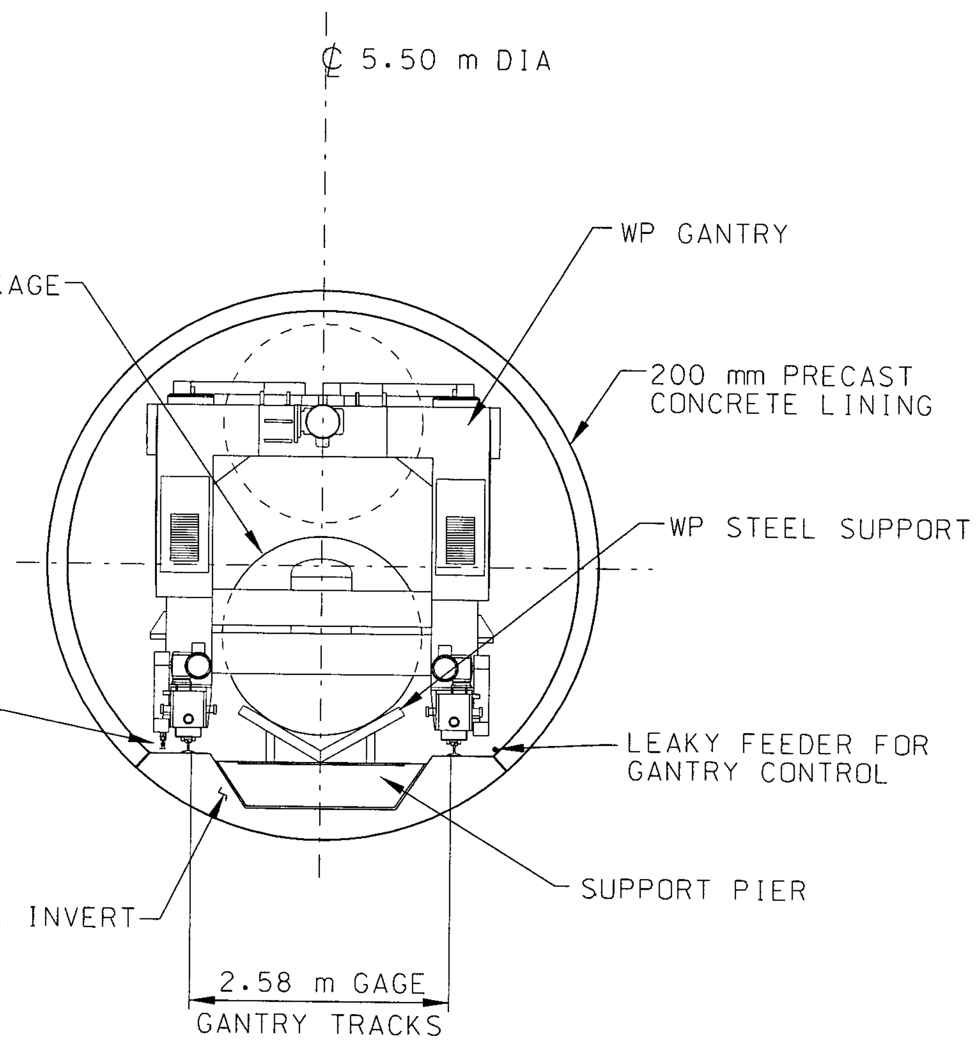
CRWMS M&O 1997o. Preliminary Waste Package Transport and Emplacement Equipment Design. Figure 7.6.1

FIGURE 4.3.2.8-3
TRANSPORT LOCOMOTIVE ARRANGEMENT



Reference:
CRWMS M&O 1997ac. Transport and Emplacement Equipment Descriptions. Figure 4.3

FIGURE 4.3.2.8-4
EMPLACEMENT GANTRY ARRANGEMENT



Reference:
CRWMS M&O 1997h. Repository Subsurface Layout Configuration Analysis. Figure 7-21

FIGURE 4.3.2.8-5
EMPLACEMENT GANTRY
IN OPERATING POSITION

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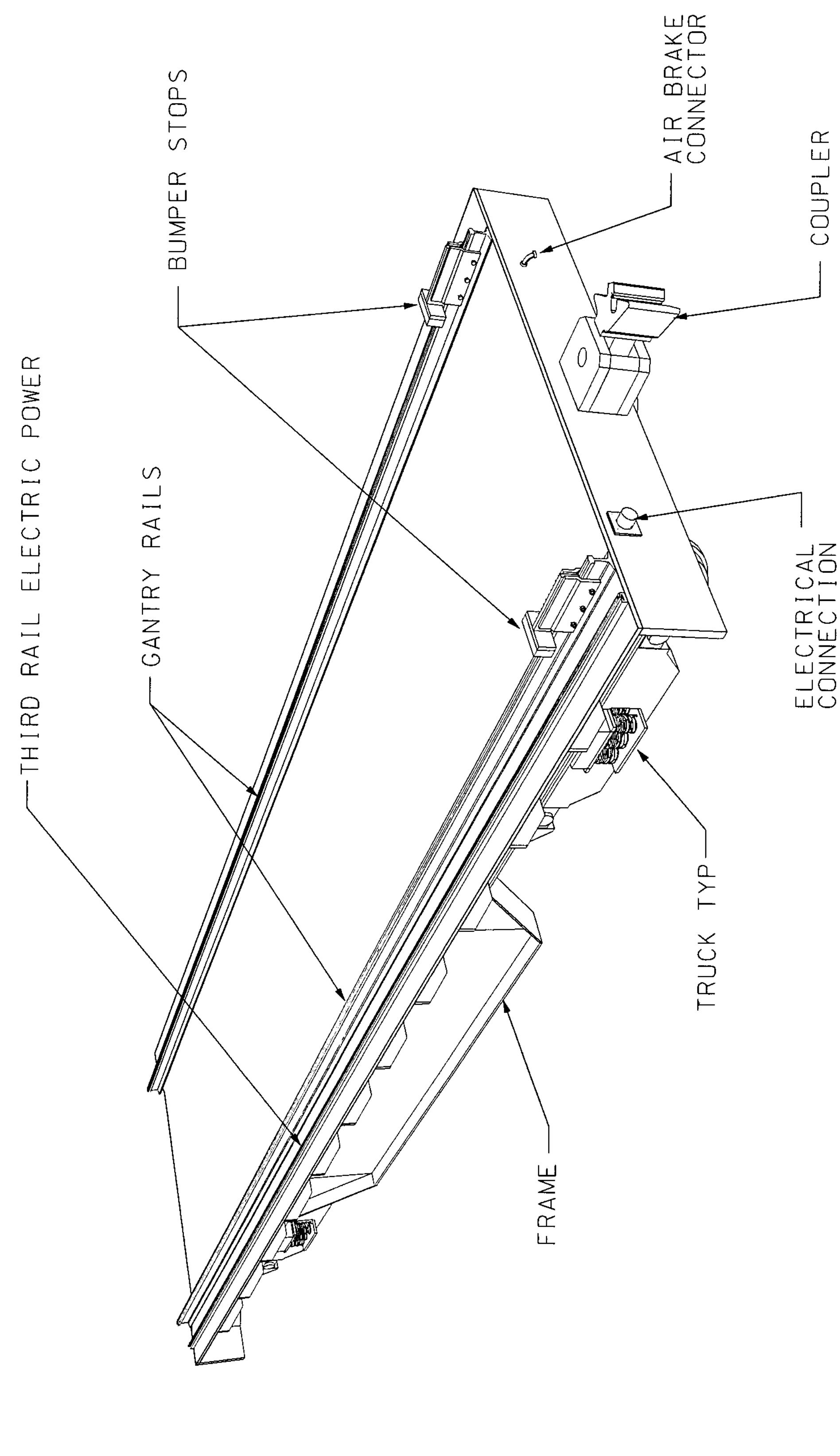
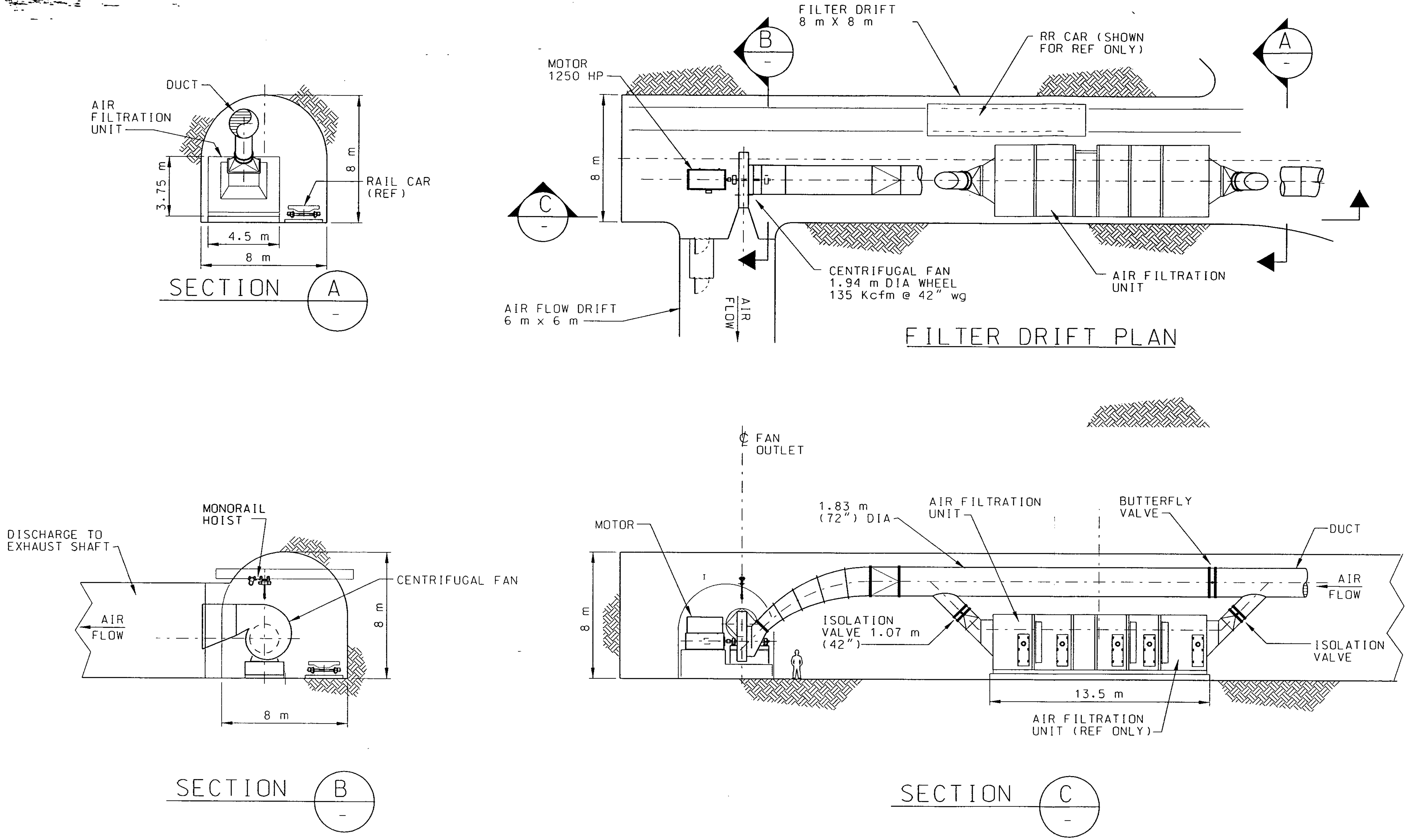


Reference:
CRWMS M&O 1997o. Preliminary Waste Package Transport and Emplacement Equipment Design Figure 7.5.1

FIGURE 4.3.2.8-6
GANTRY CARRIER
ARRANGEMENT



Reference:
CRWMS M&O 1997r. Air Filtration System for Potential Radioactive Releases. Figure 7.5-2

FIGURE 4.3.2.10-1
AIR FILTRATION UNIT
PLAN AND SECTIONS

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4.3.3 EXPLORATORY STUDIES FACILITY (ESF)

Figure 4.3.3 - 1 is a plan view of the Subsurface ESF. The facility consists of approximately 7,900 meters of 7.62-m diameter tunnel and various alcoves. Figure 4.3.3 - 2 shows several representative design cross sections. Sections X and W show the ESF conveyor outside of the ESF tunnel near the North Portal. Cross sections V and K are typical cross sections of the starter tunnel at the North Portal. Cross section G shows the launch chamber (Concrete) used to launch the 7.62-m diameter TBM used to excavate the ESF. Cross section E is typical tunnel during excavation operations. The completed ESF is different as there is only one ventilation duct and it is hung on wire slings in the center of the arch and the walkway as illustrated in the Typical TBM Bore cross section was not installed. Cable hangers rather than cable trays are used to support the electrical cables and an exhaust fan was located on the ventilation stack shown in Cross section V.

The ESF ramps are planned to become the main underground accesses for all repository cases. The TS North Ramp becomes the repository North Ramp which serves as the waste handling ramp to the emplacement area. The TS South Ramp becomes the "Tuff" Ramp for construction and development activities. It servers as the conduit for the mined-rock conveyor and the exhaust ventilation airway. The TS Main Drift becomes the main segment of the repository East Main Access to the emplacement drifts. By incorporating the existing ESF openings into the repository design, there is a savings in schedule, materials and cost.

An E-W Cross Drift of 5.5-m diameter was driven in 1998 to map and verify the condition of the ground in the repository area.

4.3.4 SUBSURFACE UTILITIES

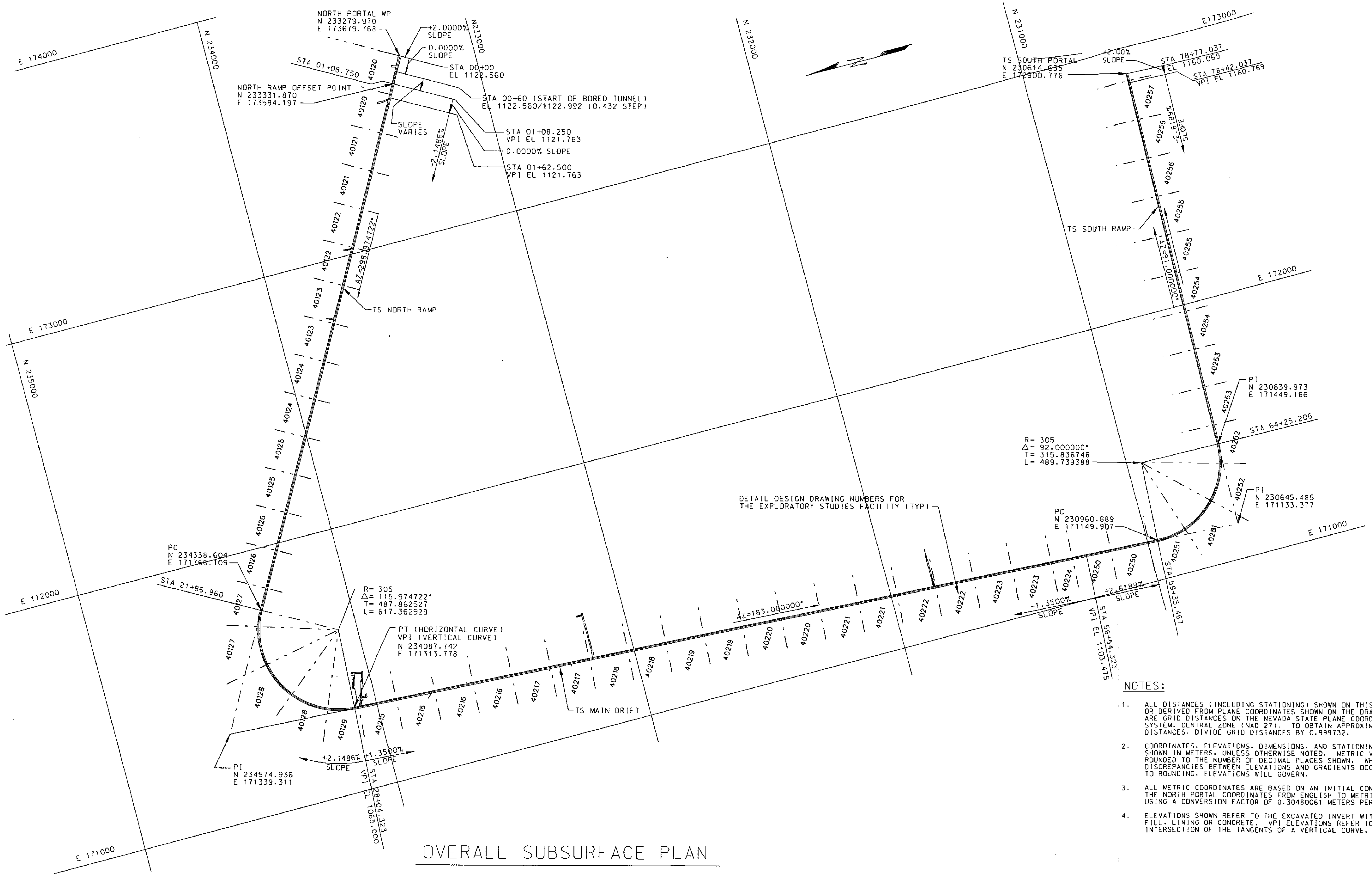
Subsurface utilities will in general be divided between those serving waste disposal and those serving subsurface repository development. The differences will be addressed specifically under each system.

4.3.4.1 Telephone Communications

There will be a telephone system throughout the subsurface repository during the construction, development, emplacement, monitoring, and closure phases. The system will connect to the existing Nevada Test Site (NTS) telephone system.

4.3.4.2 General Lighting

General lighting for the underground will be provided and will meet OSHA, MSHA AND NOSHA codes as part of construction and development. The emplacement-side of the repository will be independently lighted from the development side. There will be no lighting in the emplacement drifts after commissioning has been completed and human access has been restricted.



NOTES:

1. ALL DISTANCES (INCLUDING STATIONING) SHOWN ON THIS DRAWING OR DERIVED FROM PLANE COORDINATES SHOWN ON THE DRAWING ARE GRID DISTANCES ON THE NEVADA STATE PLANE COORDINATE SYSTEM, CENTRAL ZONE (NAD 27). TO OBTAIN APPROXIMATE GROUND DISTANCES, DIVIDE GRID DISTANCES BY 0.999732.
2. COORDINATES, ELEVATIONS, DIMENSIONS, AND STATIONING ARE SHOWN IN METERS, UNLESS OTHERWISE NOTED. METRIC VALUES ARE ROUNDED TO THE NUMBER OF DECIMAL PLACES SHOWN. WHERE DISCREPANCIES BETWEEN ELEVATIONS AND GRADIENTS OCCUR DUE TO ROUNDING, ELEVATIONS WILL GOVERN.
3. ALL METRIC COORDINATES ARE BASED ON AN INITIAL CONVERSION OF THE NORTH PORTAL COORDINATES FROM ENGLISH TO METRIC UNITS, USING A CONVERSION FACTOR OF 0.30480061 METERS PER FOOT.
4. ELEVATIONS SHOWN REFER TO THE EXCAVATED INVERT WITH NO FILL, LINING OR CONCRETE. VPI ELEVATIONS REFER TO THE POINT OF INTERSECTION OF THE TANGENTS OF A VERTICAL CURVE.

Reference:
CRWMS M&O 1996b. ESF Layout Calculation

FIGURE 4.3.3-1
ESF COORDINATE GEOMETRY

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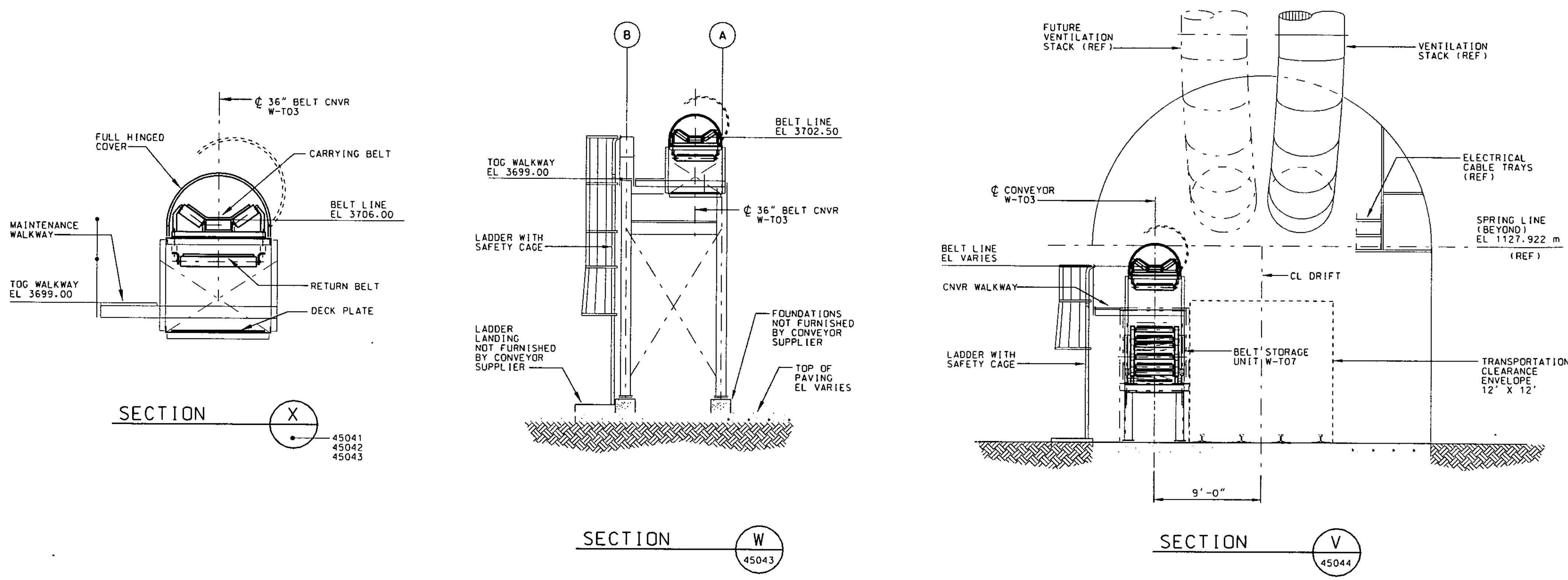

NOTES FOR SECTIONS 'X' 'W' & 'V'

1. CONVEYOR SUPPORT STRUCTURES SUCH AS TRUSSES, BENTS, MAINTENANCE PLATFORMS, WALKWAYS, ETC FURNISHED BY CONVEYOR SUPPLIER.
2. DIMENSIONS ARE IN FEET UNLESS OTHERWISE NOTED.
3. DIMENSIONS HAVE PRECEDENCE OVER SCALE.

NOTES FOR SECTS 'K' 'G' 'E' & 'TYP TBM BORE'

1. CONVEYOR SUPPORTS FURNISHED BY CONVEYOR SUPPLIER.
2. FIRE PROTECTION TO BE AUTOMATIC DRY CHEMICAL EXTINGUISHING SYSTEM. SEE SPECIFICATIONS.
3. DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.
4. DIMENSIONS HAVE PRECEDENCE OVER SCALE.

REFERENCE DRAWINGS

45030	SURFACE & SUBSURFACE - MATERIAL HANDLING - DWG LIST, ABBRS & NOTES
45031	SURFACE & SUBSURFACE - MATERIAL HANDLING - FLOW DIAGRAM
45032	SURFACE CONVEYOR SYSTEM - GENERAL ARRANGEMENT - AREA PLAN
45040	SUBSURFACE CNVR SYSTEM - GENERAL ARRANGEMENT - PLAN

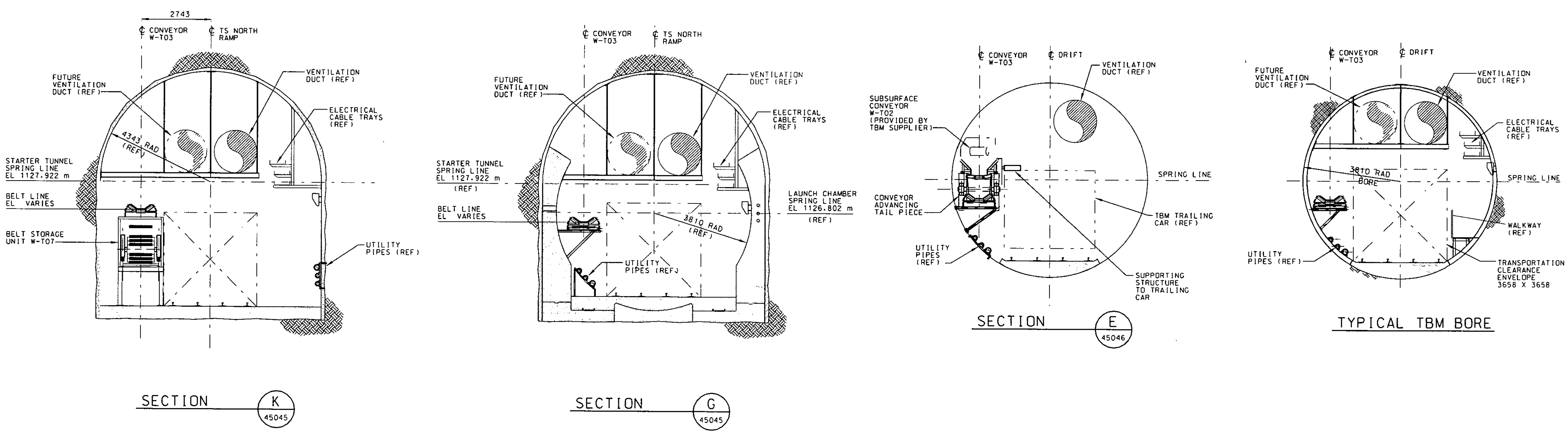

FIGURE 4.3.3-2
E S F CROSS-SECTIONS

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4.3.4.3 Electrical Power

A division of electrical power will be provided at the main repository site substation on the surface. The emplacement-side power will be conducted to the North Portal Facilities and converted to the appropriate specifications. The construction and development power will be conducted to the South Portal substation for conversion to required specifications.

Electrical power for operating TBMs, road headers, muck conveyor systems, ventilation systems, development locomotives, and other development operations will be conducted through the South Ramp for underground distribution.

Electrical power for operating the waste handling locomotives, waste emplacement machines, emplacement side ventilation fans and regulators, mine water pumps, control, monitoring and communication equipment, and powering other systems is conducted through the North Ramp for underground waste emplacement, ventilation and monitoring needs. The electrical system used for the rail system during emplacement is described in *Repository Rail Electrification Analysis* (CRWMS M&O 1997q, Section 7.1 (pg. 20-26 of 66)).

4.3.4.4 Compressed Air

Compressed air for powering rock drills, rock bolters, rail switches, ventilation doors, and maintenance services will be used during in construction. The compressors will be located on surface at the South Portal in the air compressor station. The compressed air will be carried in pipelines hung on the walls of the drifts as shown in the figures in Appendix D.

Compressed air for activating emplacement-side rail switches and opening and closing the emplacement drift isolation doors will be piped from the North Portal air compressor through the North Ramp and be distributed through the repository access mains.

4.3.4.5 Subsurface process water systems

While drifts are being excavated, water will be supplied to the subsurface in pipelines hung on the ribs of the tunnels as shown in the figures in Appendix D. Mostly this process water will be used for controlling rock dust at the mining units and along the conveyor system. It may also be necessary to apply water to other dust sources. Drilling holes for ground support requires water for removing rock cuttings and dust suppression.

There are no processes that require maintenance of water to be piped to the waste emplacement-side of the repository. The small and infrequent amounts of process water needed for such activities as cleanup, can best be served by a mobile car-mount tank.

4.3.4.6 Water removal systems

Process water will be used for dust control as explained in Sections 4.3.4.5 and 4.4.12. Some of that water will be removed from the area with the broken rock, some will evaporate and be removed in the ventilating air. The remainder will be collected in sumps near the point of use. This water will be pumped to South Portal and the subsurface water retention evaporation pond. There a portion will be clarified and reused for dust control. Some will evaporate. Any remaining sludge will be removed at closure for disposal as a waste product.

If water were to enter the repository for some unknown reason, the repository layout is designed so the water will drain out of the emplacement drifts to the main drifts. The water in the main drifts would drain to a low point in the layout where a sump and pumps would be located. In the VA layouts, the East and West Mains are sloped approximately 1.35% downward in a northerly direction consistent with the dip of the Tsw2 geologic unit. The emplacement drifts slope approximately 0.5% downward from the midpoints of the drifts toward the East and West Mains. Water would drain from the emplacement drifts through the main drifts and onto the Emplacement Shaft where a sump and pump station would be located.

The quantity of water used and the amount of water pumped is shown in the tables in Section 6.

4.3.4.7 Fire Suppression Systems

For both excavation operations and emplacement operations, local application dry chemical extinguisher systems would be used. This eliminates systems that would totally flood an area with water or chemicals to extinguish fires.

Mobile equipment would be equipped with manual or automatic systems depending on the need. No fire protection systems would remain in the emplacement drifts during or after waste package emplacement.

4.3.4.8 Subsurface Sanitation Systems

Sanitary, non-hazardous waste produced by people in the subsurface repository will be collected in portable toilets. The portable toilets will be removed from the repository as required and the effluent treated in a plant on surface designed for that purpose. Sanitary waste produced by people in the change house and office facilities at the South Portal will be treated in a plant similar to the one designed for the North Portal area.

The amount of human waste depends on the number of people working underground. The number of people is shown in Section 6.

4.3.4.9 Hazardous or Toxic Wastes

Other waste such as oily rags, solvents, aerosol paint cans, degreasers, battery acid, etc. may be generated in the subsurface. These materials will be disposed of in the surface waste treatment facility or sent off-site to a licensed disposal facility.

4.3.4.10 Health Safety Program

The Health Safety program will monitor, test and manage personnel exposure to hazardous substances and radiation. The program monitors the operational personnel areas for hazardous materials and conditions in both the emplacement and development sides of the repoisitory. The program makes provisions for decontamination for personnel if required.

The program will provide safety training, perform health and safety surveillance and surveys, develop and maintain safety procedures, maintain health records, and manage corrective action for unsafe conditions.

The Health Safety Program will operate in conjunction with the administration system and the medical facility to collect and maintain personnel health data. Health physics laboratories, offices, and calibration shops will be located in the waste handling building controlled area (DOE 1998b., Sec. 4.1.7, Vol. 2). Health Safety facilities related only to non-radiological activities will also be included in the south portal area facilities and in the underground development area (see Section 4.3.2).

4.3.5 UNDERGROUND VENTILATION SYSTEMS

The overall ventilation design is based on delivering effective air velocity to produce adequate air quantity and quality in all subsurface working places and travel ways. Two separated ventilation systems must be used to serve the diverse needs of the waste emplacement and the development sides of the repository areas. Isolation airlocks will partition the access mains and the exhaust mains. For specific emplacement panels, isolation airlocks must be provided in ramps or connections. During the emplacement and monitor operating phases, a pressure differential is maintained between the development and waste emplacement operations. The Isolation Airlocks not only provide a separation but maintain a higher pressure within the development side than the emplacement side. This pressure differential will prevent airborne contaminants from passing into the development side from emplacement operations.

Return air from active emplacement drifts will be contained in an Exhaust Main system away from human contact. For filled panels, return air from each emplaced drift downcasts through raises into metal ducts for normal discharge to surface. Should nuclear contamination be detected by the monitoring system, this air stream may be diverted through HEPA filters to capture these radioactive particles before discharging the air stream.

During the pre-emplacement period construction period the North Ramp can be utilized as the primary intake airway until the Development Intake Shaft has been completed. The South Ramp will be used for exhaust and auxiliary ventilation will be provided to the large TBM driving the South Ramp Extension, South Main and West Main until construction activities have provided ventilation shafts. These perimeter drifts and the Exhaust Main will have ventilation air conducted through duct works via auxiliary fans. Ventilation controls are addressed in Appendix E of this revised engineering file.

The current ventilation design analysis for the Viability Assessment (VA) was described in the *Overall Development and Emplacement Ventilation System* (CRWMS M&O 1997l, Section 7.8 (pp. 67 and 85-90 of 114)). The subsurface ventilation system layout is discussed in the *Repository Subsurface Layout Configuration Analysis*. (CRWMS M&O 1997h, pg. 78-79 of 109)

4.3.5.1 Base Case, High Thermal Loading

See Figure 3.3-1 for Base Case High Thermal subsurface layout's units. Major features of the subsurface ventilation design are illustrated in Figure 4.3.5-1.

In order to support simultaneous development and emplacement, the repository will be divided into two separated systems. After construction of the access and exhaust mains is complete, development of the emplacement drifts will begin. Development will proceed from north to south in discrete panels of drifts. These panels are isolated from the emplacement operations until commissioning to emplacement. Commissioning of these panels is coordinated with emplacement schedules (CRWMS M&O 1997g, table 7-1 (pg. 13-17 of 32).

During emplacement operations, underground openings will receive waste packages in the panels described in Section 4.4.8.1. Physical and functional separation of development and emplacement activities will be maintained using isolation air locks. See Section 4.4.7 for more detail. Ventilation systems consist of subsurface openings, isolation barriers, ducting, fans, a HEPA filter system (if required), and airflow and electronic controls. These systems interface with the surface for air intake and exhaust, electric power, and monitoring.

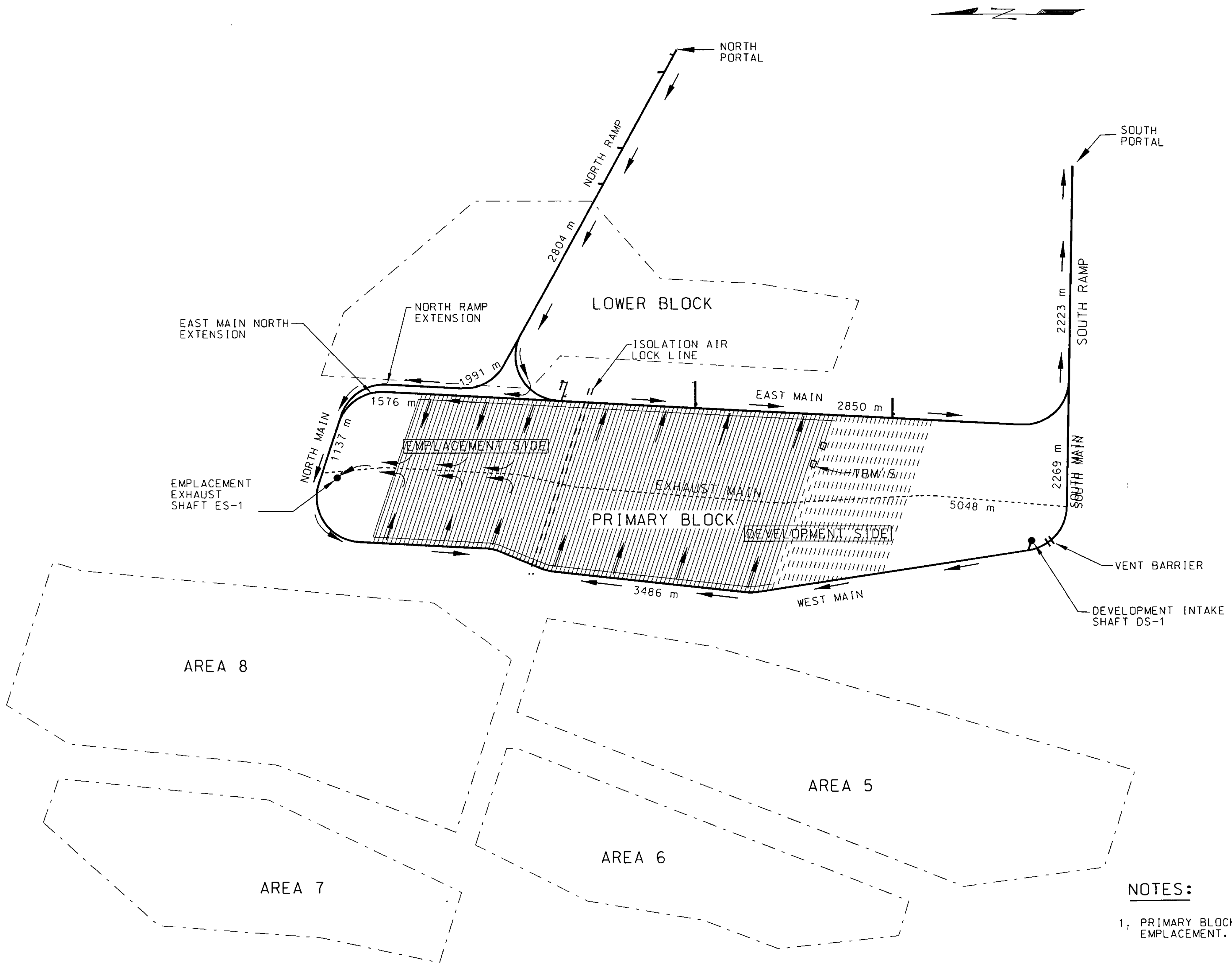
The ventilation system on the subsurface development side of the isolation airlocks operates by forcing air down the Development Shaft, through the access mains and into the active subsurface excavations. Exhaust air from mining is scrubbed at the TBMs then is contained in ducts to the South Ramp. All subsurface construction and development exhaust air passes out the South Ramp to enter the atmosphere. This keeps all excavation and construction emissions, including the dust from conveyor systems, confined to this one point source. Because of the hazardous nature of silica dust, scrubbers and water spray systems operate to keep harmful sized particles from becoming airborne. If the dust becomes airborne, systems such as those described in Section 4.4.12 are provided to keep the concentration of the dust below prescribed threshold limit values. Air pressure on the development side of the isolation airlocks is maintained above atmospheric, by this system, to the point of discharge at the surface. Development-side openings will always be at a greater pressure than will emplacement-side openings. This pressure differential helps to prevent contamination of the development-side openings should an off-normal event in the emplacement side cause a release of airborne radioactive particles.

The ventilation system on the emplacement side pulls air down the North Ramp, through the emplacement area, into the Exhaust Main, up the Emplacement Exhaust Shaft, using fans located at the Emplacement Exhaust Shaft (ES-1) collar. By drawing the emplacement side air through to its point of discharge, air pressure is maintained below atmospheric. This ventilation system increases the pressure differential between emplacement and development sides necessitating the isolation airlocks to be closed at all times. This combination of systems ensures that, in the event that one system shuts down, a pressure differential between development and emplacement will be maintained.

The emplacement intake air is split between East and West Mains. It is regulated to pass through the emplacement drifts (both active and filled). Each emplacement drift discharges air at a mid-point exhaust raise to enter ducts in the Exhaust Main (see Appendix D). Exhaust air from waste filled drifts, under normal conditions; enter ducts as shown in Figure D-8 and D-10. While entering the ducts, the exhaust air is monitored for contamination. Should radioactive contaminants be detected, the air is immediately routed to high efficiency (HEPA) filters. Filtered discharge then mixes with unaffected emplacement side air to enter the Emplacement Exhaust Shaft. Air, that is regulated to pass through empty cross block or emplacement drifts, mixes with the discharging air from the filled and partially filled emplacement drifts prior to entering the bottom of the Emplacement Exhaust Shaft.

Airflow rates for the various underground operations and locations are based on a number of considerations including: the minimum and maximum air velocity constraints, minimum quantity of airflow for underground personnel, high crystobalite and quartz content of the volcanic rock, project imposed limitations on the use of water for dust control, and allowances for air leakage and contingencies.

Ventilation network models (CRWMS M&O 1997l, Section 7.11.2.1 (pg. 106 of 114)) showed the maximum air quantity of approximately 570,000 ft^3/min (269 m^3/s) would be needed for repository development operations during the early stage of simultaneous development and emplacement. As the development and emplacement operations proceed, the need of air quantity for development will decrease while the emplacement air demand will increase. The maximum airflow rate needed for the emplacement side will become about 640,000 ft^3/min (302 m^3/s) in the late stage of simultaneous development and emplacement. The maximum quantity needed for Monitor Phase activities (in this case, for repository Primary Block only) will be approximately 410,000 ft^3/min (194 m^3/s).



NOTES:

1. PRIMARY BLOCK: SIMULTANEOUS DEVELOPMENT AND EMPLACEMENT.

FIGURE 4.3.5-1
HIGH THERMAL BASE CASE
VENTILATION FLOW PATH

Waste filled emplacement drifts will have a regulated average air flow rate of 0.1 m^3/s to allow sampling of emplacement drift air and to prevent the expanded air from backing into the access main. Heated exhaust air from the emplacement drifts is controlled and directed away from human contact through the exhaust duct in the Exhaust Main. This duct will be insulated to reduce heat transfer from the duct to the airflow in the main. General airflow arrangements for the Base Case of 85 MTU/acre are illustrated and discussed in CRWMS M&O 1997l, Section 8 (pg. 110-111 of 114).

After completion of waste emplacement, the main air supplies for the Monitoring Phase operations are as follows:

Area	Main Intake	Main Exhaust
Primary Block	North Ramp & DS-1	Shaft: ES-1

The South Ramp then only is used for exhaust air from the greatly reduced development-side of the repository and part of the P.C. drifts.

4.3.5.2 Intermediate Thermal Base Case

For this intermediate thermal loading scenario, waste emplacement area is expanded in the Primary Block as shown in Figure 3.3-2. The subsurface ventilation scheme of this case, however, will be essentially the same as the Base Case High thermal load (85 MTU/acre). The greatest airflow needs occur during simultaneous development and emplacement. Maximum airflow rates are approximately 570,000 ft^3/min (269 m^3/s) for the development operations, 640,000 ft^3/min (302 m^3/s) for the waste emplacement, and 410,000 ft^3/min (194 m^3/s) for the caretaker operations.

The intake air for the development side of the Primary Block will be brought through the development shaft and directed into the West Main. This fresh air, then, passes through cross block drifts to the East Main for distribution. These cross block drifts would be excavated early in the E&C Phase from the East Main (see Figure 4.3.5-1). Fresh air for emplacement drift headings under excavation is drawn into the ends of these drifts from the East Main using auxiliary fans and ventilation duct. This duct extends to near the TBM cutter head and that operates in suction mode. Dusty air from rock cutting is routed through the TBM's on-board dust scrubbers then directly into the ventilation duct. All exhausting air is ducted to the main return airway to surface. This is the South Ramp for the development side ventilation system. Ventilation intake air for the Primary Block emplacement side system operates as described in Section 4.3.5.1 above.

After completion of waste emplacement, the main air supplies for the Monitoring Phase operations are similar to the High Thermal Case described in Section 4.3.5.1.

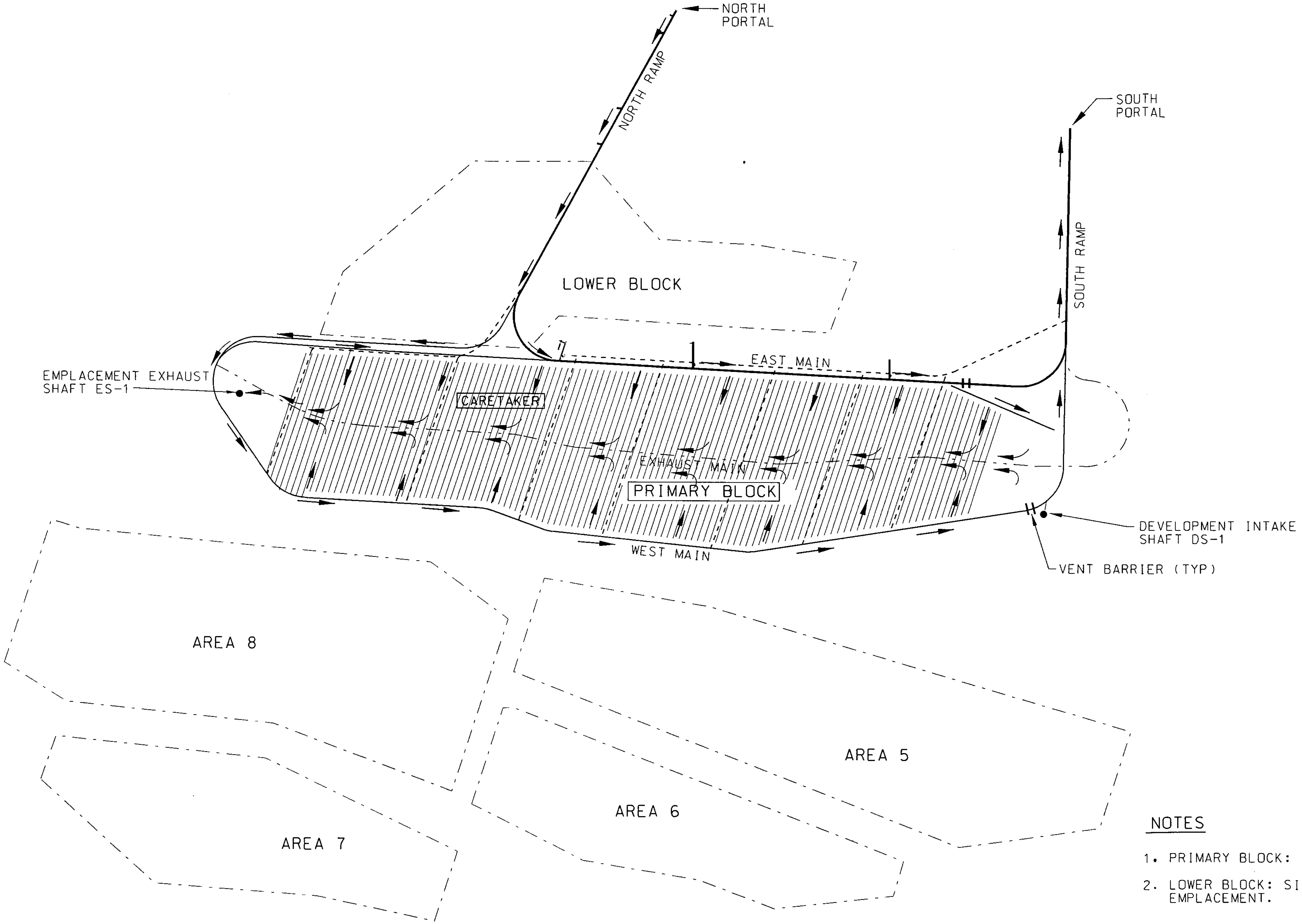
4.3.5.3 Low Thermal Base Case

This emplacement thermal load uses, in sequence, the Primary Block (expanded), Lower Block, and part of Area 5. The highest air quantity will be needed during the simultaneous development and emplacement of Area 5, after both the Primary and Lower Blocks are emplaced with WPs and are in monitoring mode as illustrated in Figure 4.3.5-3. The maximum air flow rates are approximately 820,000 ft^3/min (390 m^3/s) for the caretaker operations in both Primary and Lower Blocks, 640,000 ft^3/min (302 m^3/s) for the waste emplacement in Area 5, and 570,000 ft^3/min (269 m^3/s) for the development operations in Area 5.

The ventilation for the development and emplacement of the Primary Block is similar to that described in Section 4.3.5.1. After completion of waste emplacement in the Primary Block and initial development of the Lower Block, simultaneous development and emplacement in the Lower Block will begin. At this point the maximum air quantity requirements are 570,000 ft^3/min (269 m^3/s) for the development operations in the Lower Block, 410,000 ft^3/min (194 m^3/s) for the caretaker operations in the Primary Block, and 640,000 ft^3/min (302 m^3/s) for the waste emplacement the Lower Block. To meet the requirement of separation of the development and emplacement areas, the intake air for both the Lower Block emplacement area and the caretaker operations in the Primary Block will have to be provided by the North Ramp, if no additional ventilation opening to the surface is added to the system. If total intake airflow of 1,050,000 ft^3/min (496 m^3/s) must travel through the North (Waste) Ramp, the air velocity in the ramp will be over 2,000 ft/min. This velocity exceeds the maximum air velocity limit (1,500 ft/min in the Waste Ramp).

To meet the maximum air velocity requirement and to excavate access ramps and mains in Area 5, a 6.7-meter diameter intake ventilation shaft is added. No ventilation fans are required in this intake shaft. This shaft (ES-3) then supports waste emplacement and the Monitoring Phase operations. It is located near the Emplacement Exhaust Shaft near the northern end of the Primary Block (see Figure 4.3.5-3).

To facilitate simultaneous development and emplacement operations in Area 5 along with the Primary and Lower Blocks in monitoring mode, a second development shaft is needed near the southern end of Area 5 (See Figure 4.3.5-3). The intake air for the development side of Area 5 will be directed to travel from the Development Shaft DS-2 to Ramp #7. Air will travel up Ramp #7 to Area 5 (A5) West Main, across the emplacement area through cross block (ventilation) drifts to the A5 East Main. Fresh air for active TBM emplacement drift headings is drawn from the A5 East Main. Auxiliary fans and ventilation duct, extending from near the TBM cutter head, operate in an exhausting (locally negative pressure) mode. Dust contaminated air is routed through on-board TBM dust scrubbers then into the exhausting ventilation duct. The ductwork extends from the working face to the mains, through Ramp #6 to the South Ramp return airway.



NOTES

1. PRIMARY BLOCK: EMPLACED.
2. LOWER BLOCK: SIMULTANEOUS DEVELOPMENT AND EMPLACEMENT.

FIGURE 4.3.5-2
INTERMEDIATE THERMAL BASE CASE VENTILATION FLOW PATH

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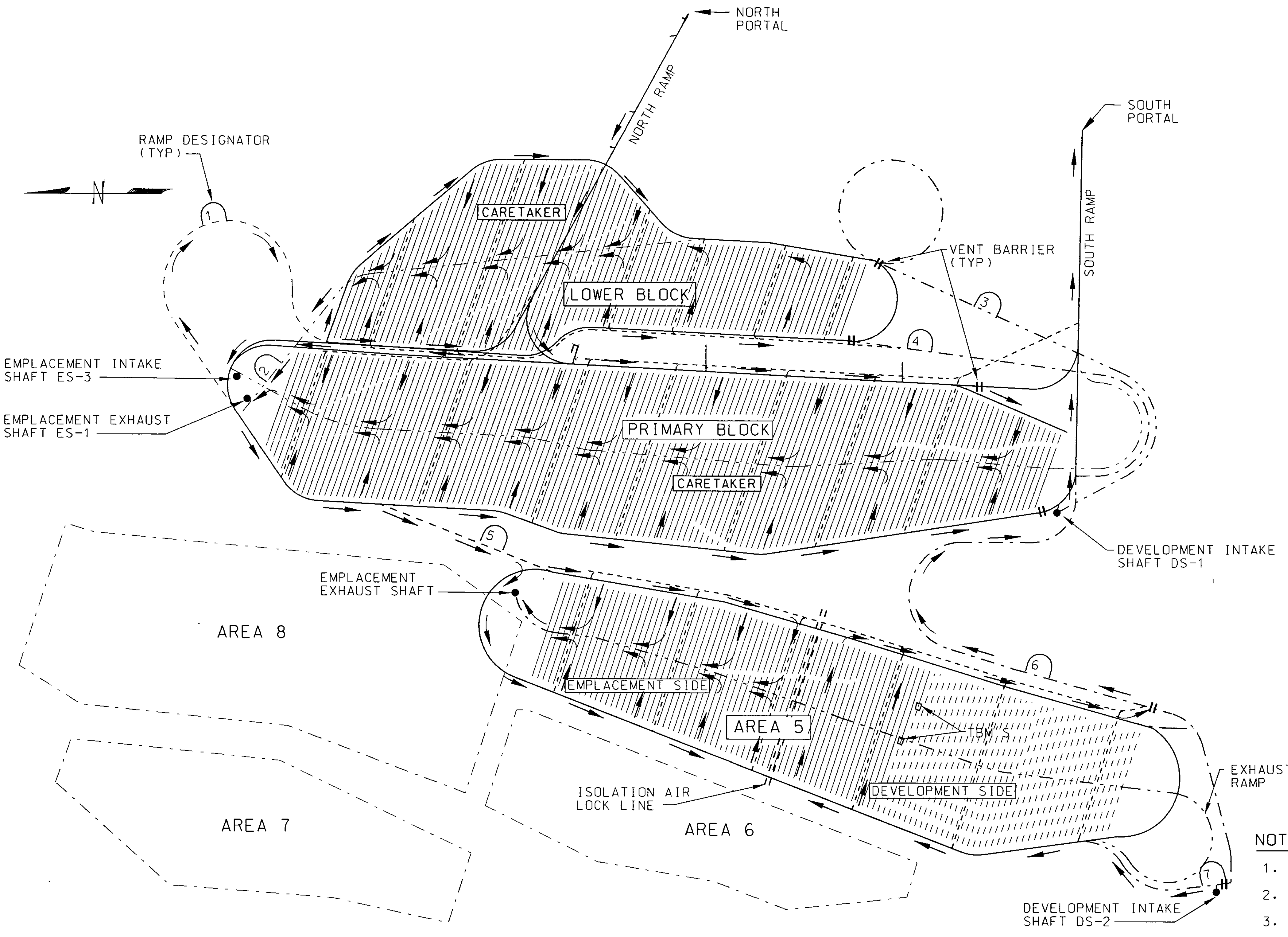


NOTES:

1. PRIMARY BLOCK: EMPLACED.
2. LOWER BLOCK: EMPLACED.
3. AREA 5: SIMULTANEOUS DEVELOPMENT AND EMPLACEMENT.

FIGURE 4.3.5-3
LOW THERMAL BASE CASE
VENTILATION FLOW PATH

The Emplacement Intake Shaft (ES-3) supplies the intake air for the emplacement operations in Area 5. The intake air travels through Ramp # 5 and is then split into the east and west mains of Area 5. It then is regulated through the active, filled and empty, commissioned emplacement drifts. Cross block drifts are maintained empty to allow additional air into the exhaust system. Air in the emplacement drifts passes to mid-drift exhaust raises. It is drawn down through the raises and into ventilation ducts. This exhausting air is monitored for radioactive contamination. It is contained in the main duct until reaching the HEPA filter facility at the Area 5 Emplacement Exhaust Shaft (ES-2). For the monitor phase operations in the Primary, Lower Blocks and Area 5, the main intake air will be provided by both the North Ramp and the Emplacement Intake Shaft (ES-3). Return air (exhaust) will be exhausted through both the initial (ES-1) and the second Emplacement Exhaust Shaft (ES-2).

After completion of waste emplacement, the main air supplies for the Monitoring Phase operations are as follows:

Area	Main Intake	Main Exhaust
Primary Block	North Ramp & DS-1	Shaft: ES-1
Lower Block	North Ramp	Shaft ES-1
Area 5	ES-3 & DS-1	Shaft ES-2

4.3.5.4 High Thermal, Module 1 & 2b Cases

The waste emplacement for these cases will use the Primary Block (expanded) plus additional drifts in the Lower Block, as shown in Figure 3.3-4. The Primary Block ventilation systems are consistent with those described for the Base High and Intermediate Cases. The Lower Block emplacement area is developed in only 24 drifts which allow it to be defined as a single emplacement panel for commissioning and emplacement. No simultaneous development and emplacement activities will overload the air intake capabilities during the waste emplacement operations (see Figure 4.3.5-4).

The intake air during development operations in the Lower Block will be directed to flow from the Development Shaft DS-1 to Ramp #3 then to the L.B. East Main. Because all emplacement drifts will be excavated from the L.B. West Main, fresh air is brought across the emplacement area using the previously excavated cross block drifts. The active TBM emplacement drift headings are ventilated by drawing into the western ends of these drifts using auxiliary fans and ventilation duct extending to near the TBM cutter head. The system operates in an exhausting (locally negative pressure) mode. Dust contaminated air is routed through the TBM dust scrubbers and then directed back to the L.B. West Main.

The duct carrying exhaust air is maintained through Ramp #4 to discharge into the South Ramp (see Figure 4.3.5-4).

The intake air for emplacement operations travels through Ramp # 1 and is then directed to the active emplacement drifts and standby drifts. The exhaust air from the emplacement drifts travels through ventilation ducts (installed in Ramp #2) that are connected to the HEPA filter Facility and to the emplacement exhaust shaft (ES-1).

After completion of waste emplacement, the main air supplies for the Monitoring Phase operations are as follows:

Area	Main Intake	Main Exhaust
Primary Block	North Ramp & DS-1	Shaft: ES-1
Lower Block	North Ramp	Shaft ES-1

4.3.5.5 Intermediate Thermal Module 1 & 2b Cases

The arrangement of the emplacement areas of this case is similar to the case described previously in Section 4.3.5.3 and illustrated in Figure 4.3.5-3. The waste emplacement will use the Primary Block (expanded), Lower Block, and 45 drifts in Area 5. As in the case described in Section 4.3.5.3, the Emplacement Intake Shaft (ES-3) is needed to support simultaneous development and emplacement in Area 5, a second development intake shaft (DS-2) and a second emplacement exhaust shaft (ES-2) is needed to serve Area 5 (see Figure 4.3.5-5).

After completion of waste emplacement, the main air supplies for the Monitoring Phase operations are as follows:

Area	Main Intake	Main Exhaust
Primary Block	North Ramp & DS-1	Shaft: ES-1
Lower Block	North Ramp	Shaft ES-1
Area 5	ES-3 & DS-1	Shaft ES-2

4.3.5.6 Low Thermal Module 1& 2b Cases

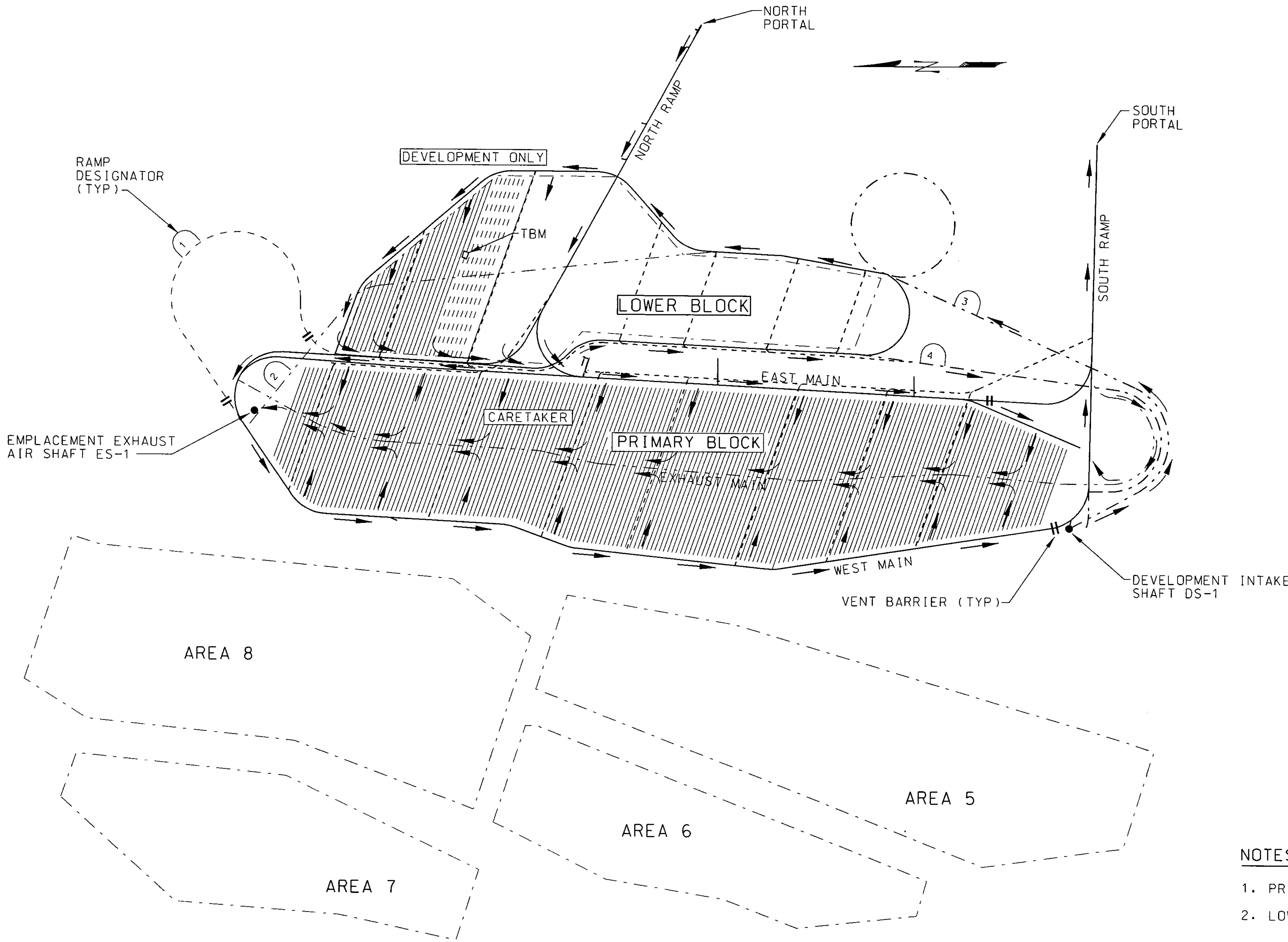
The emplacement zone of this case will contain six areas: the Primary Block (expanded), Lower Block, Areas 5, 6, 7 and 18 drifts in Area 8 as shown in Figure 3.3-6. As described in Section 4.3.5.3 and because of the large number and scattering of ventilated areas, two development shafts (DS-1 & DS-2) are required. For this same reason, two Emplacement Exhaust Shafts (ES-1 & ES-2) are also needed. These four of these shafts will be powered. Also, as described in Section 4.3.5.3, an Emplacement Intake Shaft (ES-3) is needed. Emplacement Exhaust Shaft #2 (ES-2) serves the Emplacement and Monitoring Phases for Areas 5, 6, 7, and 8. The ES-2 Emplacement Exhaust Shaft is similar to ES-1 as it includes a subsurface HEPA filter Facility. See Figure 4.3.5-6 for this period of operation.

The ventilation for the development and emplacement of the Primary Block, Lower Block, and Area 5 will be arranged in the same way as described in Section 4.3.5.3 and illustrated by Figure 4.3.5-4.

During the simultaneous development and emplacement in Area 6 (when the Upper Blocks, Lower Block and Area 5 are in monitoring modes), the intake air for the development side of Area 6 will be directed to travel from the Development Shaft DS-2 to Ramp #8 (see Figure 4.3.5-6). From the top of Ramp #8, air moves through the access mains to the western side of Area 6. Like other block development, the fresh air passes through the emplacement drifts in previously bored cross-block drifts to A6 East Main. Fresh air for excavation is drawn into headings by auxiliary fans and ventilation that operate in an exhausting (locally negative pressure mode). Used air from the TBM cutting, after being scrubbed, passes directly into the ventilation ducts extended through Ramp #9 to discharge into the South Ramp.

The intake air for the emplacement operations in Area 6 enters through Ramp #10 connecting the A5 West Main to the A6 East Main. Fresh emplacement air is regulated through the filled, partially filled, and empty but commissioned emplacement drifts. The exhaust air from the emplacement drifts passes down the ventilation raises to ducts in the A6 Exhaust Main. Exhaust air is monitored for radioactive particles and contained in the ventilation ducts. These ducts continue through the Exhaust Ramp to the ES-2 HEPA filter Facility. Contaminated air is routed through the filters. Uncontaminated air and cleaned air from the filters is coursed through the Emplacement Exhaust Shaft (ES-2) to surface discharge (see Figure 4.3.5-6).

It is planned that the waste emplacement in Area 7 precede emplacement in Area 8 (see Figure 4.3.5-7). During the development of Area 7, the main airflow will be directed to travel from the Development Shaft DS-1 to Ramp #13, up Ramp # 13 to the A7 East Main, where it will be available to enter the emplacement drifts as they are excavated. Exhaust air from excavation is then ducted around Area 7 perimeter drifts to Ramp #12, Ramp #6, and then to discharge in the extended South Ramp.



NOTES:

1. PRIMARY BLOCK: EMPLACED.
2. LOWER BLOCK: DEVELOPMENT ONLY

FIGURE 4.3.5-4
HIGH THERMAL MODULE 1 & 2b CASES
VENTILATION FLOW PATH

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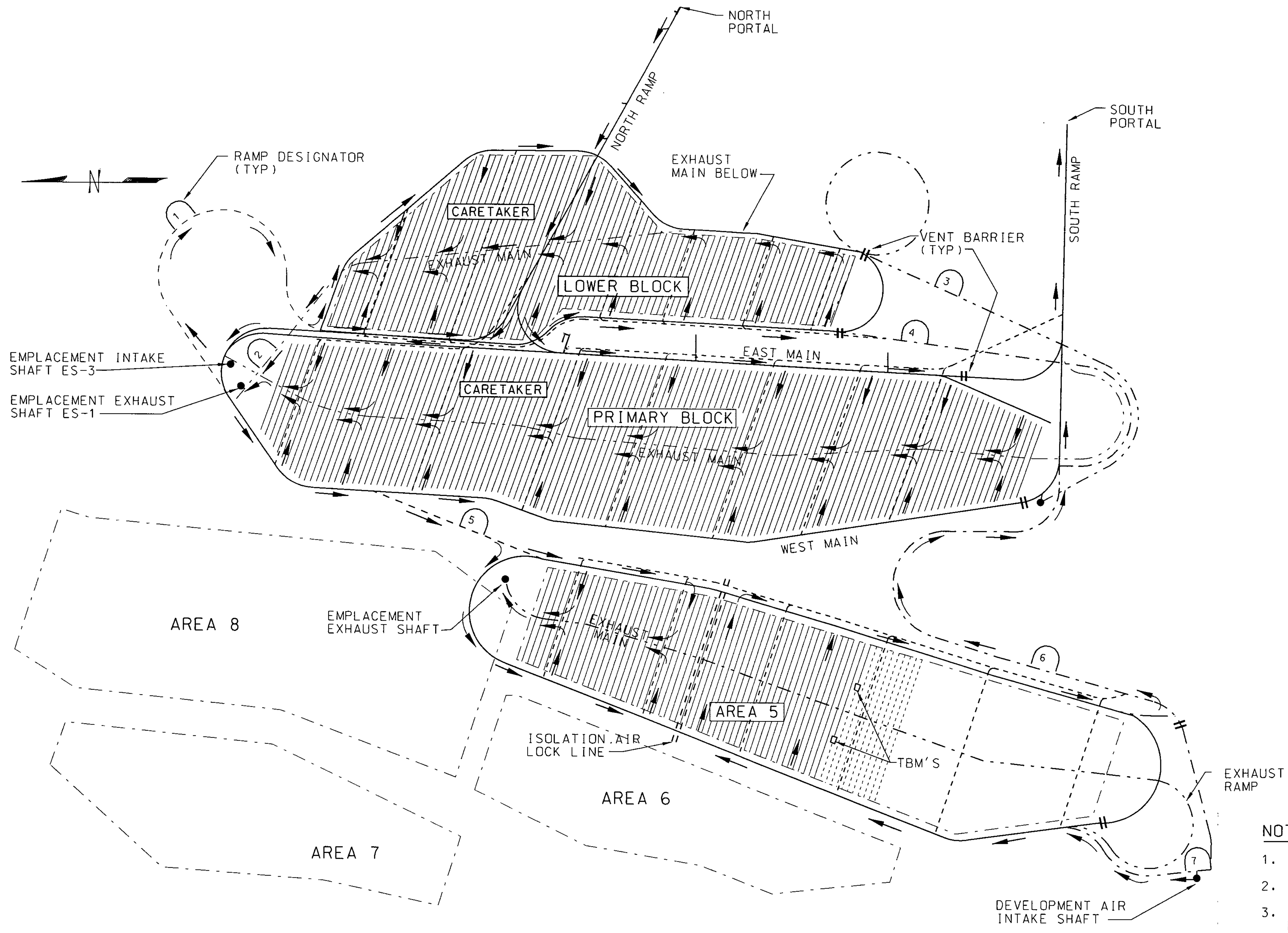

NOTES:

1. PRIMARY BLOCK: EMPLACED.
2. LOWER BLOCK: EMPLACED.
3. AREA 5 SIMULTANEOUS DEVELOPMENT AND EMPLACEMENT.

FIGURE 4.3.5-5
INTERMEDIATE MODULE 1 & 2b CASE
VENTILATION FLOW PATH

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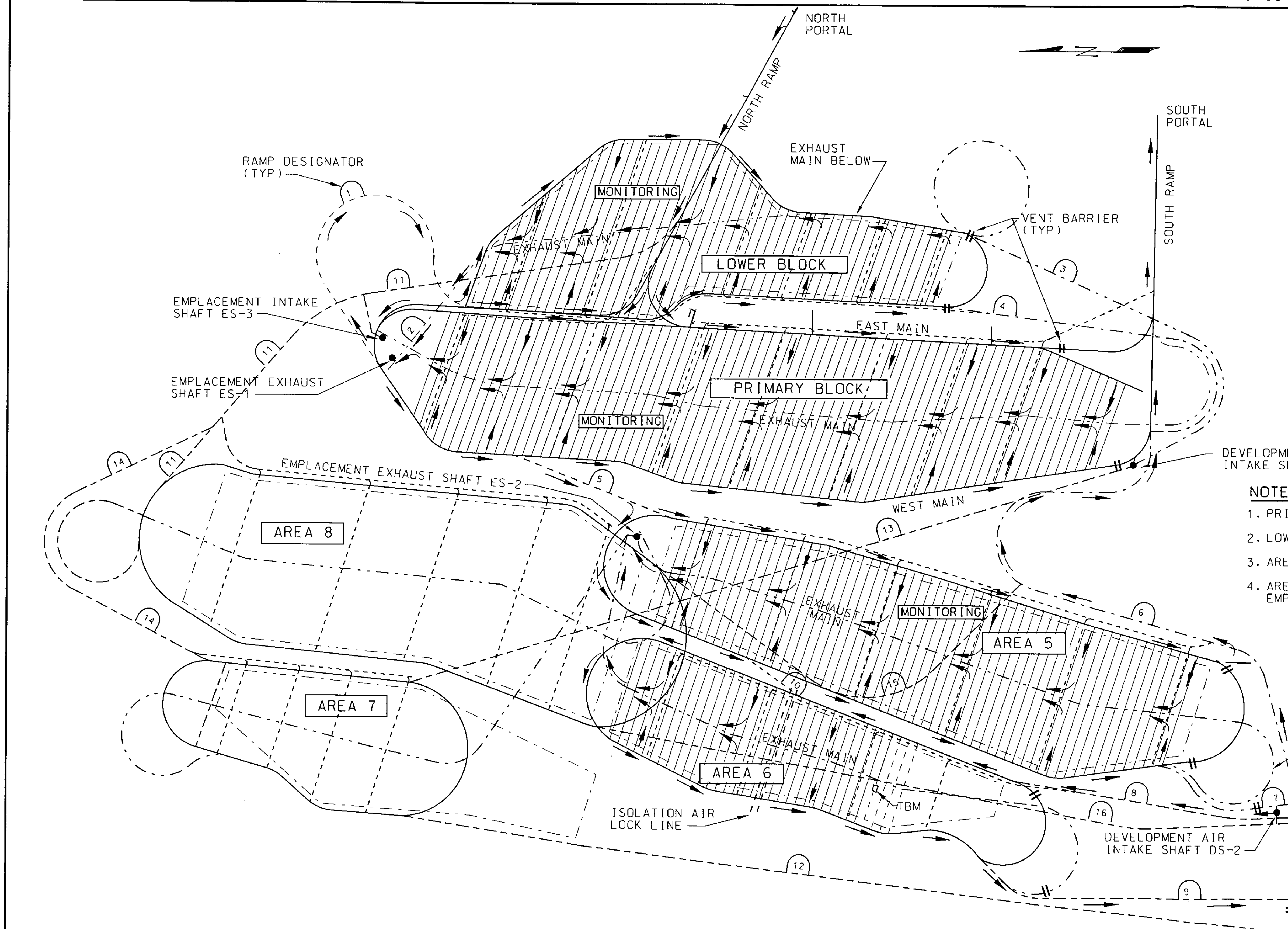

NOTES:

1. PRIMARY BLOCK: MONITORING.
2. LOWER BLOCK: MONITORING.
3. AREA 5: MONITORING.
4. AREA 6: SIMULTANEOUS DEVELOPMENT AND EMPLACEMENT.

FIGURE 4.3.5-6
LOW THERMAL MODULE 1 & 2b CASE
VENTILATION FLOW PATH

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During the development of Area 8, the main airflow will be directed to travel from the Development Shaft DS-2 to Ramp #16, through Ramp #16, the A8 South and A8 West Mains, and made available for excavation of emplacement drifts (see Figure 4.3.5-7). Exhaust air is ducted around the eastside of Area 8 and into Ramp #15 to the extended South Ramp.

During the waste emplacement for Area 7, the intake air will travel through the Emplacement Intake Shaft ES-3 through a connector to Ramp #11, up Ramp # 11 to split into Ramp #14 then again splitting into the A7 East and A7 West Mains of Area 7 (see Figure 4.3.5-8). Fresh air is drawn into the emplacement drifts where it is regulated to pass into the exhaust raises. Exhaust ventilation ducts in the A7 Exhaust Main through the A7 Exhaust Ramp to the Shaft ES-2 HEPA filter Facility.

During the waste emplacement for Area 8 (see Figure 4.3.3-8), the intake air will travel through the Shaft ES-3, as in Area 7, through Ramp # 11 past the Ramp #14 split then to the A8 North Main. Air is then divided between the A8 East and A8 West Mains (see Figure 4.3.5-8). Exhaust air flows through the A8 Exhaust Main, A8 Exhaust Ramp to the HEPA filter Facility at Exhaust Shaft ES-2.

After completion of waste emplacement air supplies for the Monitoring Phase operations are as follows:

Area	Main Intake	Main Exhaust
Primary Block	Shaft ES-3	Shaft ES-1
Lower Block	North Ramp	Shaft ES-1
AREA 5	Shaft DS-1	Shaft ES-1
AREA 6	Shaft DS-2 & S. Ramp	Shaft ES-2
AREA 7	Shaft DS-2 & S. Ramp	Shaft ES-2
AREA 8	Shaft DS-2 & S. Ramp	Shaft ES-2

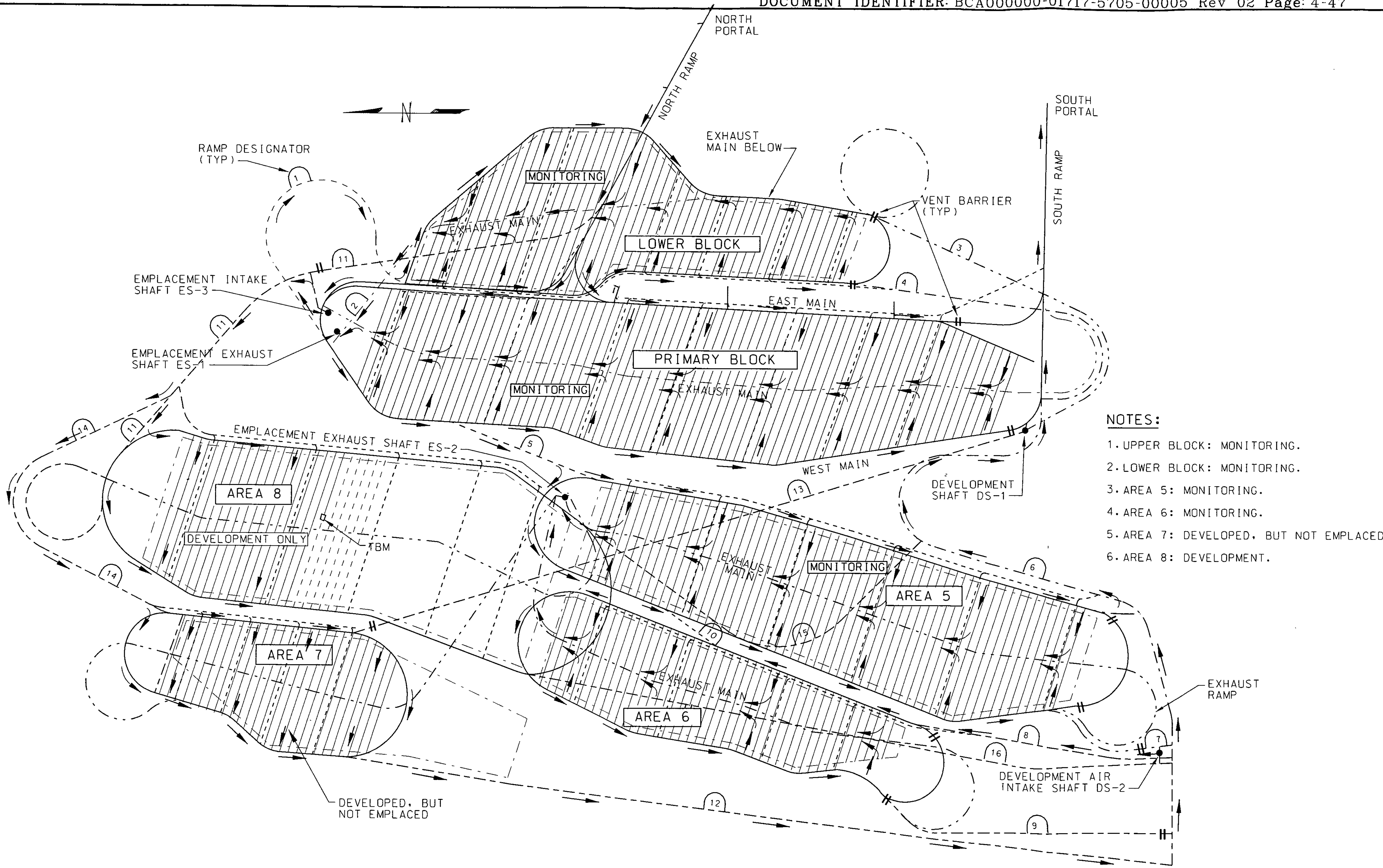

FIGURE 4.3.5-7
LOW THERMAL MODULE 1 & 2b CASES
VENTILATION FLOW PATH

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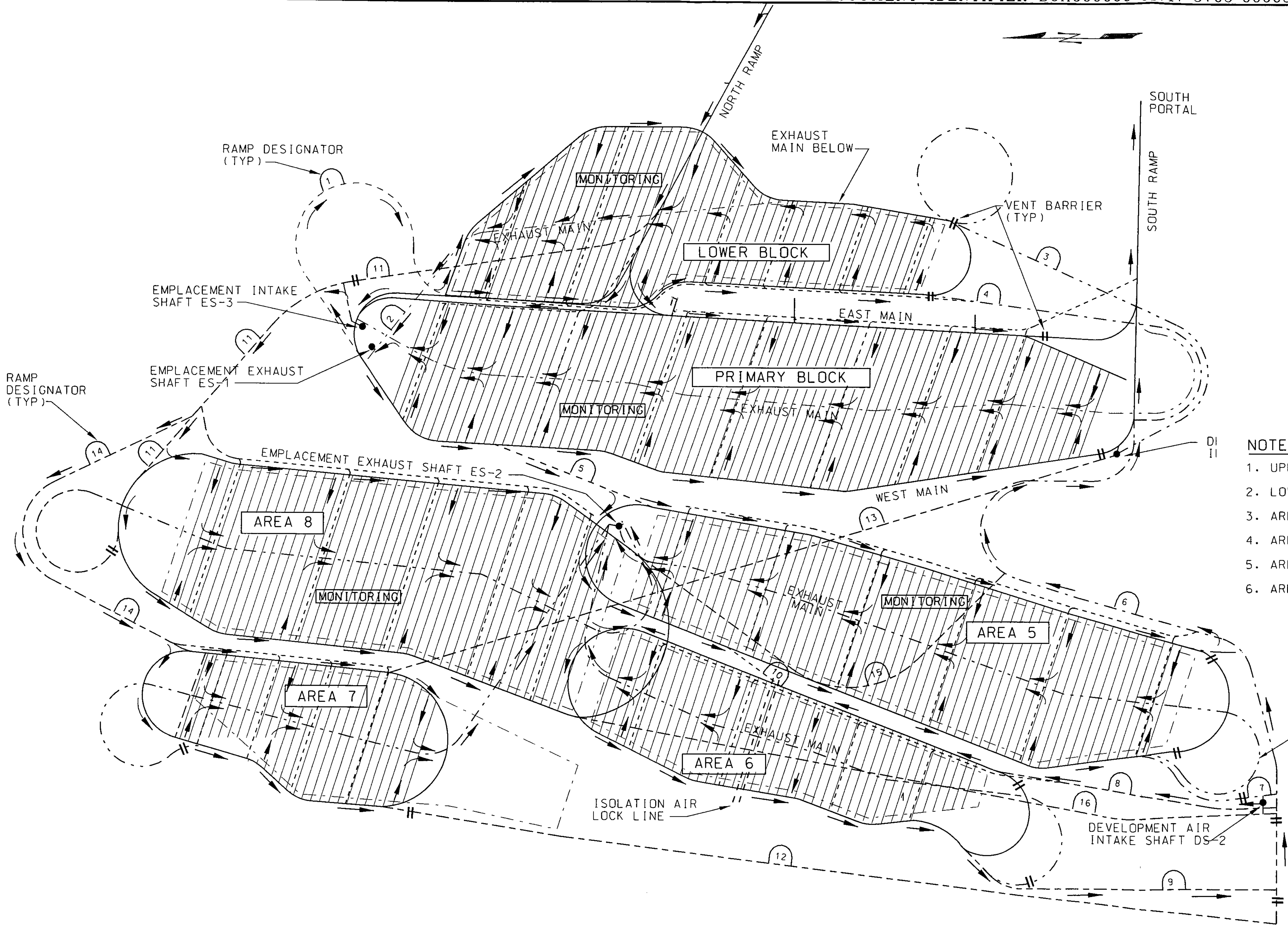

NOTES:
1. UPPER BLOCK: MONITORING.
2. LOWER BLOCK: MONITORING.
3. AREA 5: MONITORING.
4. AREA 6: MONITORING.
5. AREA 7: EMPLACEMENT.
6. AREA 8: MONITORING

FIGURE 4.3.5-8
LOW THERMAL MODULE CASES
VENTILATION FLOW PATH (AREAS 5,6,7,8)

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4.3.6 UNDERGROUND SHIELDING EQUIPMENT/SYSTEMS

The shielding will be designed with the goal of limiting the annual dose in intermittently occupied areas (< 40 hours per week) to less than 1 rem/year. This shielding design goal is factored into the ALARA goal of 500 mrem/year which also considers occupancy time, distance, facilities, access control, and frequency of exposure (see Section 4.4.6) (CRWMS M&O 1998b., Key 089). Individual waste packages are not considered to provide shielding for personnel protection. Shielding for protection of personnel will be provided by the subsurface transporter within the surface and subsurface facilities (Figure 4.3.2.8-2). Shadow shields and the shielded subsurface transporter are anticipated for the subsurface repository as shown in Figure 4.3.2.8-1..

In order to protect workers from radiation, human entry will not be allowed in emplacement drifts containing one or more waste packages. The waste emplacement/retrieval equipment may use robotics and/or remote control features to perform operations and monitoring within the emplacement drifts. Under off-normal conditions, human entry could be considered while using a qualified form of worker protection. Emergency procedures and rescue equipment will be in place prior to any waste handling operations underground.

4.4 SUBSURFACE CONCEPT OF OPERATIONS

The following concept of operations for the subsurface repository is based on the current level of design as described in the documents referenced in this section.

4.4.1 WASTE RECEIPT EFFECTS ON SUBSURFACE OPERATIONS

Subsurface functions for waste package (WP) emplacement begins with the receipt of waste packages at the waste handling building, continues through transport of the waste packages to the emplacement drifts and end when the waste packages are placed on pedestals in the emplacement drifts. For all cases, emplacement begins in year 2010.

The current waste package emplacement schedule assumes that waste arriving at MGDS is emplaced within the same year it is received. For this subsurface engineering file, there is no planned retention of waste at the surface to optimize the subsurface emplacement operation. Emplacement however will be managed so thermal loads are not exceeded. The schedule ramps up from approximately 38 SNF waste packages in the first year increasing annually until the sixth year when HLW shipments begin. An average of 500 total waste packages would be expected each year for 15 years, then tapering off to approximately 312 packages in the 24th year of emplacement operations for the base case inventory.

4.4.2 SEPARATION OF EMPLACEMENT AND DEVELOPMENT OPERATIONS

Separation of emplacement and development operations is planned. This concept ensures that ventilation systems cannot intermix and that personnel cannot cross over except under extreme emergency circumstances. As described in the analysis: *Subsurface Ventilation Isolation Barriers*, (CRWMS M&O 1997ab) development activities are allowed the freedom to excavate and construct under standard industrial practices without accidental exposure to radiation hazards. Similarly, this allows the emplacement operations to be conducted free of development interferences. Figure 4.4.2-1 illustrates the separation between operations and initial development. The same concept is used throughout. For ventilation details see Section 4.3.5.

The barrier that separates the emplacement and development area is illustrated in Figure 4.4.2-2. The barriers are arranged in air locks so that in emergency conditions, equipment can pass through the barrier without air leakage. Personnel doors will also be provided. The barriers will be constructed of steel panels, which connect to steel frames. The primary support members will be spaced to permit removal of specific panels for the passage of equipment or personnel. Bolted connections will be used so that the barriers can be dismantled and moved as required. As emplacement panels are completed, the barriers are moved so that waste can be emplaced in the completed drifts and development can continue on the development side of the barrier.

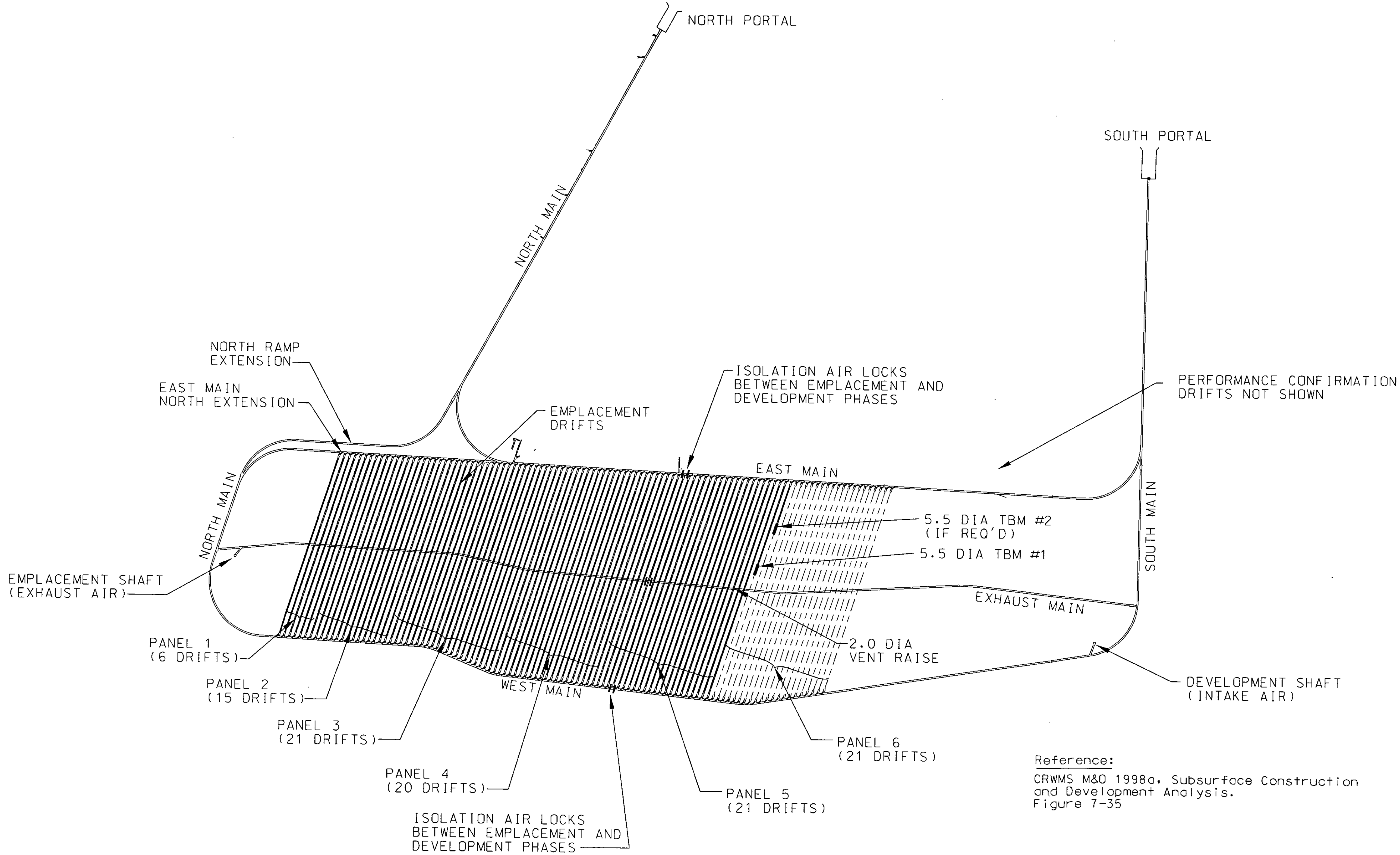
4.4.3 DEVELOPMENT APPROACH

The general approach to development is to complete the first emplacement panel shown in Figure 4.4.2-1 by year-2010 when emplacement of waste packages is scheduled to begin. See Section 3.3 for a comparison of layouts. Subsequent development is scheduled so that the waste can be emplaced as it is received. The approach is described in the *Subsurface Construction and Development Analysis* (CRWMS M&O 1998a).

In the Base Case High Thermal Load, one 7.62 m diameter TBM is used to develop the perimeter drifts, two 5.5 m diameter TBMs are used to develop the emplacement drifts and performance confirmation drifts. Two road headers develop TBM launch chambers, recovery chambers and other minor openings. The operation of the road headers is intermittent. At any point in time, the maximum number of TBMs operating is three and the maximum number of road headers operating is two.

In all other cases, two 7.62-diameter TBMs are required in the Engineering and Construction Phase. The rest of the excavation fleet is the same - two 5.5 m diameter TBMs and two road headers. At any point in time, the maximum number of TBMs operating is four and the maximum number of road headers is two.

After emplacement begins, development continues at a rate that allows waste to be emplaced as it is received and packaged.



Reference:
CRWMS M&O 1998a. Subsurface Construction and Development Analysis. Figure 7-35

FIGURE 4.4.2-1
TYPICAL CONCURRENT SUBSURFACE DEVELOPMENT & EMPLACEMENT

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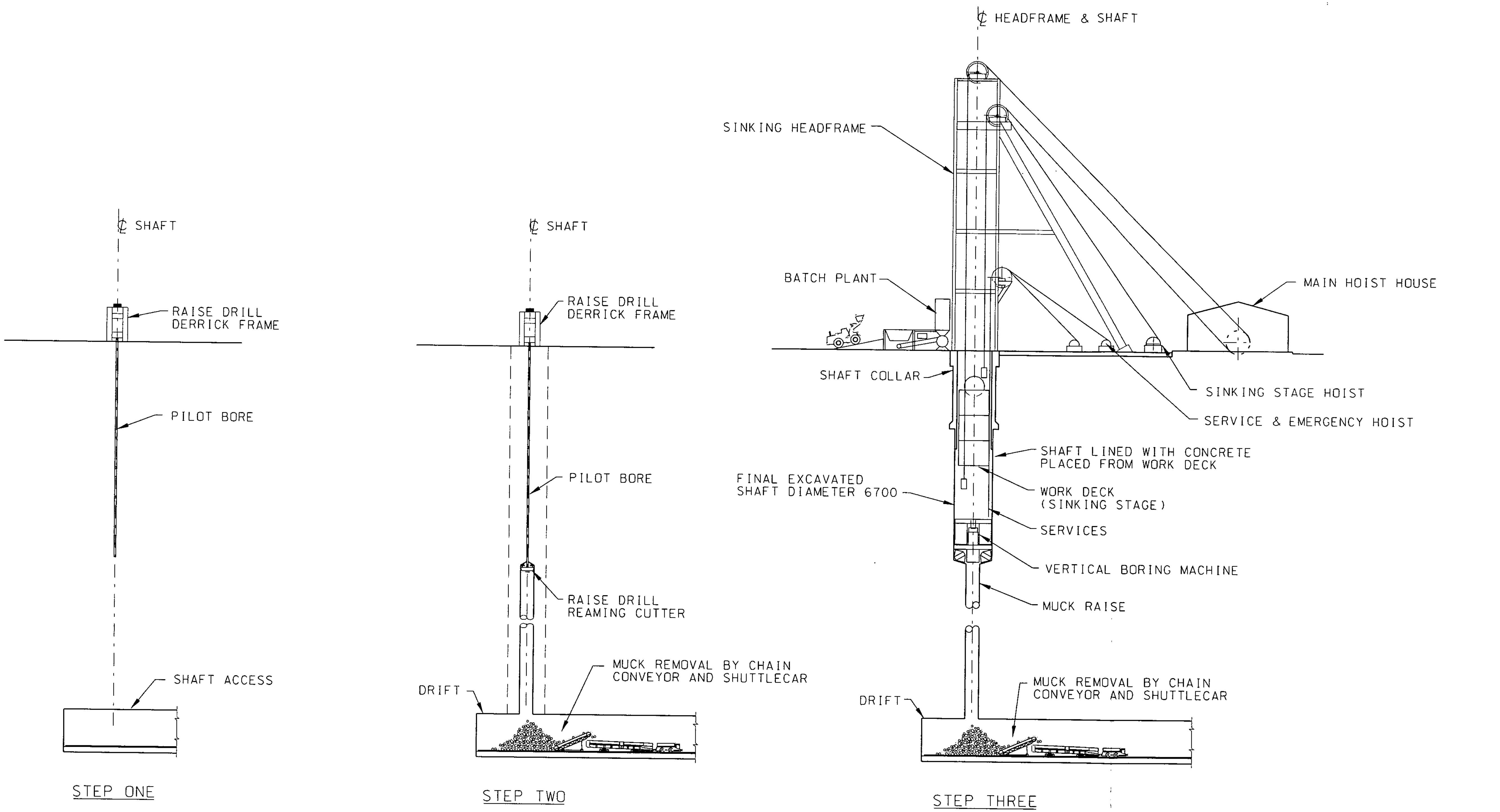

COMPONENTS OF VERTICAL BORING MACHINE
SHAFT CONSTRUCTION SYSTEM OF A 6700 mm DIAMETER SHAFT

Reference:
CRWMS M&O 1998 a. Subsurface Construction and Development Analysis. Figure 7-9

FIGURE 4.4.3-1
SHAFT EXCAVATION SEQUENCE

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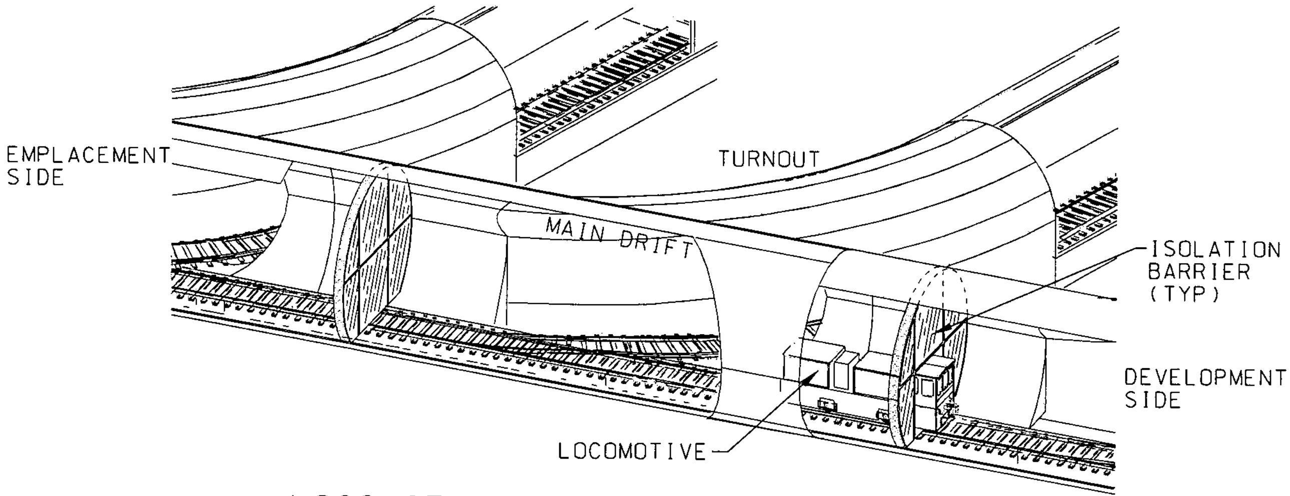
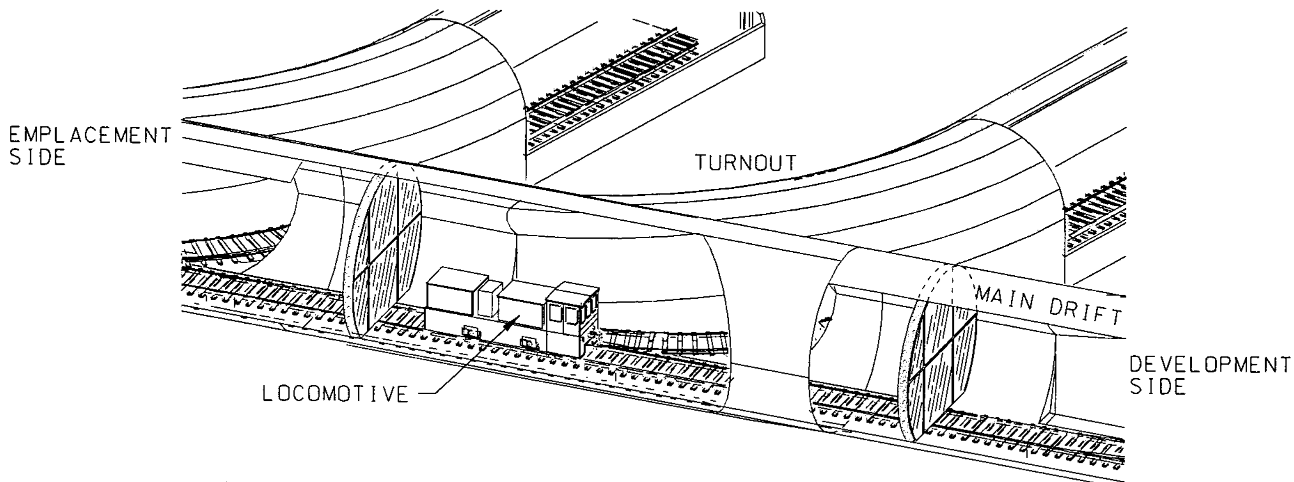
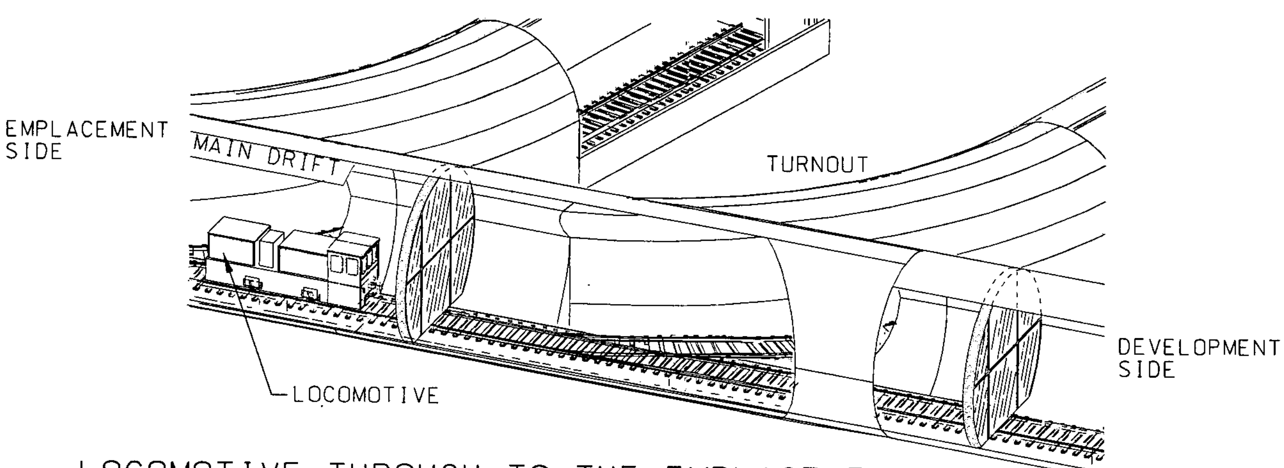


LOCOMOTIVE ENTERING ISOLATION AREA



DEVELOPMENT SIDE PANEL RE-INSTALLED



LOCOMOTIVE THROUGH TO THE EMPLACEMENT SIDE

Reference:
CRWMS M&O 1997 ab. Subsurface Ventilation Isolation Barriers. Figure 7.1-1

FIGURE 4.4.2-2
PASSAGE OF LOCOMOTIVE DURING OFF-NORMAL CONDITIONS

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Ramps and mains are constructed for ventilation, equipment passage, personnel access, and materials handling. Two 6.1-meter diameter ventilation shafts will also be constructed. One shaft will be located at the north end of the repository block to serve as the emplacement exhaust shaft. The other shaft will be located at the south end of the block and serve as the development intake. The shafts will be excavated using mechanical means as shown in Figure 4.4.3-1.

The North Ramp will initially support repository construction activities such as concrete lining of mains. With commissioning of the initial panel of emplacement drifts, it will serve solely for waste disposal/retrieval functions. It will be the waste transportation access and ventilation intake from surface to the emplacement side of the active repository area.

The South Ramp will provide access for construction and development activities until the conclusion of the Emplacement Operations Phase. The South Ramp's predominant role will be access to the repository for conveying mined rock from the excavation operations to the surface disposal operation. During the Monitor Phase, it will serve maintenance activities related to the remaining development-side of the repository. During the Closure Phase, it will serve as the access opening to bring fill materials into the performance confirmation drifts and those openings not included in the GROA. In all of these operating phases, it will be the primary ventilation air exhaust to the surface.

Construction of service accesses, excavation, finishing, and commissioning of the emplacement related facilities must be closely tied to emplacement panel development, and sequencing. These and the following operations must be coordinated accordingly:

- Cast-in-place concrete lining of access and exhaust mains
- Emplacement Drift Turnouts including lining and fixtures and isolation doors
- Emplacement Drift TBM Launch Chambers and disassembly Chambers
- Ventilation raises accessing the Exhaust Main.

Specific openings and facilities that also influence the sequence include the following:

- Development Emplacement Shaft/Exhaust Main Connector,
- Shaft/South Ramp Extension Connector (CRWMS, 1997h, fig. 7-33 (pg. 92 of 109))

The above openings will be excavated using road headers or other mechanical miners. Drill-blast practices may also be used to excavate incidental openings of such shape, size, or location not practical using mechanical means. Excavated rock will be removed from the TBMs using railcars loaded near the advancing face. Loaded rail cars will discharge at a Railcar Dump Station. The conveyor system will then move the excavated rock through the South Ramp to the surface stockpile.

4.4.4 OPERATIONS OF SUBSURFACE UTILITIES

4.4.4.1 Electricity

For subsurface operations it is assumed that the operating contractor installs and supplies electrical services. Backup generation would be available for limited emergency operation at both the North and South Portals.

4.4.4.2 Communications

A specialty contractor will install and maintain communication services. Subcontractors employ personnel who are permanently assigned to a single contract such as the repository. To accommodate the remote monitoring and control of the waste disposal processes, specialized data highways may be installed.

4.4.4.3 Process Water

Process water is used for mixing concrete in developing the subsurface. It is also used for dust control during excavation and muck handling in development of the repository.

Fixed process water lines will be provided only in the development and construction areas. Process water, if needed in the GROA during waste handling operations, will be delivered in tank cars for the specific purpose then removed. This approach fulfills the process water need of the development phase, yet avoids the accidental release of large amounts of water into the waste handling areas.

4.4.4.4 Compressed Air

Compressed air will be used in the GROA to open and close isolation and ventilation doors, to activate rail switches, operate ventilation regulators and possibly other emplacement operating activities. During the construction phase and development operations, compressed air will operate drills for ground control installation, grouting, operating rail switches, doors and other equipment and facilities. Compressors located at the South Portal area will supply this air.

At the North portal, an independent compressor will supply air specifically for the waste emplacement operations. Individual activities requiring compressed air include: throwing track switches, opening and closing isolation doors, and supplying maintenance activities.

4.4.5 MANAGING RADIATION EFFECTS

Conclusions of the *MGDS Subsurface Radiation Shielding Design Analysis* (CRWMS M&O 1997m, pg. 102-104 of 105), are based on waste packages containing 21 pressurized water reactors (PWR) fuel assemblies with characteristics of 4.2% initial enrichment, 48.1 GWd/MTU burn up, and 10 years decay since reactor discharge (design basis fuel). Compared with the average commercial spent nuclear fuel ,as described as Key 004 of the "Controlled Design Assumptions Document" (CRWMS M&O 1998b.), these assumptions, are conservative.

For the WP transport and emplacement, the analysis concluded that:

- Preliminary designs indicate that a composite shield consisting of stainless steel, carbon steel and borated polyethylene would result in a transporter surface dose rate of approximately 33 mrem/hr, which meets the criterion of 50 mrem/hr (CRWMS M&O 1997m, pg.84 of 105).

- Both scattered neutrons and photons are included as contributors to the transporter external dose rate, and may contribute 10 to 15% of the overall dose rate, depending upon specifics of the transporter surroundings. In addition, a secondary gamma source, arising from neutron reactions, contributes about 20% of the total dose external to the transporter. These factors have been included in the calculated transporter surface rate..

- Because the transporter external dose rate may exceed the limit of 2.5 mrem/hr that is the limit for normally occupied areas. Therefore, the vicinity of the transporter, when loaded, will be controlled as an "intermittently occupied area" with radiation protection measures to maintain occupational exposure as low as reasonably achievable (ALARA). This means that that people would not be able to work near the transporter for 40 hrs per week (or 2000 hr/yr).

- The emplaced waste packages, each containing 21 PWR fuel assemblies, give a maximum in-drift radiation field of about 40 rem/hr for the design basis fuel, which is prohibitive for human entry to emplacement drifts. Without any additional shielding (meaning no shadow shield or credit for the drift isolation doors), the radiation field in the main drift is about 64 mrem/hr, exceeding the limit of 2.5 mrem/hr required for normal occupational access (40 hr/wk or 2,000 hr/yr.).

- Use of a concrete shadow shield installed between the last emplaced waste package and drift entrance door is effective in reducing the radiation field to 0.8 mrem/hr (for design basis fuel) at the nearest edge of the main drift when the drift isolation door is closed. Since this dose rate is less than the 2.5 mrem/hr limit, the main drift can be classified as a normally occupied area for 40 hr/wk (or 2,000 hr/yr.) occupational access. However, when the door is opened, the main-drift radiation field increases to 3.5 mrem/hr (for design basis fuel) requiring some administrative control to ensure that personnel radiation exposures are maintained ALARA.

- The subsurface central monitoring and control facility is being evaluated but it will contain radiation detection monitors (CRWMS M&O 1998b., Sec. 4.2.5.4). Specific monitors may be located at each emplacement drift entrance. These would continually send radiation data to the central control facility on the surface. This equipment can be situated to provide real-time information from strategic locations during the emplacement/retrieval operations. Many of these locations could not be occupied by personnel.

- Radiation protection personnel have not been described in the conceptual works, but they will be directed by future operations documents.

For details of analyses and calculation, see Appendix G.

4.4.6 ESTIMATED RADIATION EXPOSURE FOR SUBSURFACE REPOSITORY

The objective of this section is to estimate what the annual radiation exposure would be for personnel working in the subsurface repository and to summarize the total annual radiation dose for all personnel working in the emplacement side of the repository.

4.4.6.1 Potential Exposure Activities

The following assumed crew assignments are used throughout this radiation exposure estimate:

Portal Support - The crew works on the surface and provides logistical support to the underground operating crews. It includes batch plant and crushing/screening operations required to produce fill material during the closure phase.

Control and Monitoring Maintenance - The crew maintains the monitoring and instrumentation systems in the subsurface repository.

Utilities Maintenance - The crew operates and maintains the utility systems in the subsurface repository emplacement side during emplacement, caretaker, closure, retrieval, (if waste packages are retrieved) and for backfill (if emplacement drifts are backfilled). Utility systems include the following: Compressed air, water supply/fire water, waste water system, power supply and lights, general housekeeping and sanitation.

Facilities Maintenance - The crew performs the maintenance on surface for all underground related surface facilities including the change house, shop, warehouse, office, yards, and utilities.

Transport and Emplacement - The crew operates the trains that haul waste packages from the waste handling building to the emplacement drifts.

Shadow Shield Installation - The crew installs shadow shields in the emplacement drifts during the emplacement operation after the last waste package is emplaced. This is assumed as a bounding design as opposed to having the shadow shield emplaced before any waste packages are moved into the emplacement drifts. The crew will not normally enter the emplacement drift or the turnout area. The operation will be entirely remotely controlled.

Main Ventilation Fan Maintenance - The crew maintains fan installations on surface.

Commissioning - The crew does the final preparation of emplacement drifts for waste package emplacement. No waste packages are present in the area where they work.

Retrieve Waste Packages - The crew that would retrieve waste packages. It is the same as the transport and emplacement crew.

Retrieve Shadow Shields - The crew that removes the shadow shields prior to retrieval. The crew will not normally enter the emplacement drift or the turnout area. The operation will be entirely remotely controlled.

Closure Filling Access Mains -The crews that install backfill in the main drifts during closure. The crew does not work in the emplacement drifts or turnouts.

Salvaging of Materials from Access Mains -The crew that prepares the access mains for fill during closure operations.

Plug and Seal Access Mains - The crew that installs the final plugs and seals in the main drifts during closure.

4.4.6.2 Potential Exposure Locations

The following are assumptions describing the areas of the repository used when defining the Radiation Exposure Table and the length of time that the crews would spend in the various areas.

Main Drifts - The main drifts are those that intersect emplacement drifts such as the East and West Access Mains.

Turnouts -The curved portion of the emplacement drift between the Access Main drift rib and the emplacement drift door.

Exhaust Main Drift - The main exhaust drift for the emplacement areas. It is connected to the emplacement drifts by a vertical opening called a raise.

Locomotive Cab Coupled WP Transporter - The occupied cab of either locomotive moving the waste package transporter.

4.4.6.3 Potential Exposure Rates

Average Radiation Dose Rates - Calculated average radiation exposure rates have been used wherever such values have been explicitly calculated and documented. Otherwise, the calculation of the average radiation dose rate is based on a factor of 5 which has been estimated as the ratio of radiation fields from Design Basis Fuel [Maximum Radiation Rate] to average the fuel (CRWMS-M&O 1997m. Section 8.5). In all instances, the radiation rates are reported as being related to waste-imposed radiation only.

The radiation dose rate is 1.0 mrem/hr maximum for the transport locomotive cab attached to a transporter containing a waste package loaded with Design Basis Fuel (See CRWMS M&O 1998c) and no shielding on the cab window. The average radiation exposure rate is 1/5 of this value or 0.2 mrem/hr. At the worker location between the transporter and locomotive the maximum exposure rate is 20 mrem/hr, based on an estimate from the transporter end surface value of 38.5 mrem/hr given in CRWMS-M&O 1997m, Section 7.5.4. The average radiation exposure rate is 1/5 of this value or 4.0 mrem/hr.

The radiation exposure rate in the Exhaust Main is 1.0 mrem/hr assuming that the limiting waste packages are in the emplacement drift on both sides of the raise. This also assumes no shielding effects caused by the ventilation system. The average radiation exposure rate in the exhaust main is 1/5 of this value or 0.2 mrem/hr.

The Design Basis Fuel (DBF) for PWR fuel was used as the source term in the *MGDS Subsurface Radiation Shielding Analysis,* (CRWMS M&O 1997m, p. 12 of 105) for the determination of maximum radiation exposure rates (see Section 4.4.5).

The DBF parameters bound 97.85% of all PWR fuel which is expected to be the most limiting of the PWR, BWR, and DHLW types of radiation sources to be included in repository waste packages.

Limiting Waste Package Radiation Source Term - The radiation source term used in the determination of the Maximum Radiation Exposure Rates in CRWMS-M&O 1997m (Section 4.2) are based on the most limiting configuration with each waste package containing 21 DBF assemblies.

Considerable effort has been made in the design of the repository to maintain personnel nuclear radiation exposure to as low as possible. However, no formal analysis has been performed, at this time, on operations or processes that will result in as low as reasonably achievable (ALARA) radiation exposures in accordance with the *Mined Geologic Disposal System ALARA Design Program* (CRWMS M&O 1995e). Design modifications will be the subject of future analysis and design refinements.

4.4.6.4 Estimated Radiation Exposure Rates

The radiation exposure rates have been detailed in Appendix G for selected locations and design conditions. The maximum radiation exposure rates determined are based on the limiting radiation source term as noted in the first column of Table 4.4.6-1. The maximum exposure rates are not, however, expected to be representative of the worker annual averages that will be experienced by the personnel work force in the repository. Rather, they would be expected to be exposed to the average annual radiation exposure rate. Documented values for the average radiation exposure rates have been used wherever possible. Otherwise, they have been calculated from the ratio of radiation fields from Design Basis Fuel [Maximum Radiation Exposure Rate] to average fuel which has been estimated to be a value of 5. The calculated Average Exposure Rates are identified in the second column of numbers in Tables 4.4.6-1 and 4.4.6-1a. Because the low thermal loading of 25 MTU/acre requires a different spacing of waste packages than do the High and Intermediate Thermal Cases the Table 4.4.6-1a is added.

Table 4.4.6-1. Estimated Exposure Rates for Selected Locations and Conditions (High and Intermediate Thermal Load Cases Only)

Subsurface Location and Condition	Maximum (mrem/hr)	Average (mrem/hr)
1. Main Drift -- at elevation of worker in Main Drift -- limiting waste package last in emplacement drift -- shadow shield in place:		
- Isolation door open	3.53	0.56
- Isolation door closed	0.80	0.16
2. Transporter at the surface -- limiting waste package in transporter:		
- Side surface	33.0	7.64
- End surface	38.5	7.58
3. Turnouts -- at location of isolation door -- limiting waste package last in drift:		
- Isolation door open	84.3	13.7
- Isolation door closed	24.0	5.06
4. Main Drift during retrieval (emplacement in reverse order) -- limiting waste package last in drift::		
a. Initial condition	<1.0	<0.2
b. Preparation for retrieval -- isolation door open -- shadow shield removed	60	12
c. WP on gantry in emplacement drift	100	20
d. WP on reusable rail car -- transporter at isolation door	30	6
e. WP in transporter adjacent to open isolation door	6	1.2
f. WP loaded in transporter in transit through Main Drift	40	8
g. Removal of gantry from emplacement drift	20	4
h. Completion of retrieval -- shadow shield installed -- isolation doors closed	<1.0	<0.2
5. Locomotive Cab Position -- limiting waste package in transporter -- no shielding assumed in cab window	1	0.2
6. Between locomotive and transporter -- limiting waste package in transporter -- worker dose	20	4.0
7. Exhaust Main -- located at bottom of raise -- limiting waste package in emplacement drift on either side of raise	2	0.2
See Appendix G for details of radiation analyses		

Table 4.4.6-1a. Estimated Exposure Rates for Selected Locations and Conditions
(Low Thermal Load Cases Only with 38-meter Drift Spacing and 35 to 38-meter WP Spacing)

Subsurface Location and Condition	**Maximum (mrem/hr)**	**Average (mrem/hr)**
1. Main Drift -- at elevation of worker in Main Drift -- limiting waste package last in emplacement drift -- shadow shield in place:		
- Isolation door open:	2.0	0.40
- Isolation door closed	0.50	0.10
2. Transporter at the surface -- limiting waste package in transporter:		
- Side surface	33.0	7.64
- End surface	38.5	7.58
3. Turnouts -- at location of isolation door -- limiting waste package last in drift:		
- Isolation door open	23.0	4.6
- Isolation door closed	7.0	1.4
4. Main Drift during retrieval (emplacement in reverse order) -- limiting waste package last in drift::		
a. Initial condition	<1.0	<0.2
b. Preparation for retrieval -- isolation door open -- shadow shield removed	60	12
c. WP on gantry in emplacement drift	100	20
d. WP on reusable rail car -- transporter at isolation door	30	6
e. WP in transporter adjacent to open isolation door	6	1.2
f. WP loaded in transporter in transit through Main Drift	40	8
g. Removal of gantry from emplacement drift	20	4
h. Completion of retrieval -- shadow shield installed -- isolation doors closed	<1.0	<0.2
5. Locomotive Cab Position -- limiting waste package in transporter -- no shielding assumed in cab window	1	0.2
6. Between locomotive and transporter -- limiting waste package in transporter -- worker dose	20	4.0
7. Exhaust Main -- located at bottom of raise -- limiting waste package in emplacement drift on either side of raise	1	0.2
See Appendix G for details of radiation analyses		

4.4.6.5 Radiation Exposure for Personnel

The radiation exposure rates listed in Table 4.4.6-1 do not imply that workers will actually be exposed to those levels under normal operating conditions. The values in the table are of interest because they point out areas that should not be normal workplaces. The design of the repository should not require maintenance or operating personnel to spend any significant amount time working in some of the areas and under some of the conditions identified. For example, a repository design that required a worker to spend 2,000 hours/year (250 days/year x 8 hours/day) in the main drift, directly in line with the emplacement drift and with the isolation door open would be unacceptable. Likewise, a maintenance procedure that required personnel under normal conditions to work on the waste package transporter with the waste package onboard would also be unacceptable. Measures would normally be taken to limit exposures as explained below:

- Main drifts

  Under normal conditions, the isolation doors would be closed unless waste packages are being placed in or being removed from emplacement drifts. Personnel traveling in the main drift would be exposed to an average of 0.16 mrem/hr (High and Intermediate Thermal Cases) or 0.10 mrem/hr (Low Thermal Cases) with the isolation doors closed. If a door were to be open, personnel would not be allowed to travel past the turnout to the open emplacement drifts. Similarly, personnel would not be allowed in the main drifts or ramps while the waste package transporter passes.

  During the emplacement operations, personnel would occupy the main drifts but from inside the cab of one of the two locomotives. There is no reason for the operators to park in line with the emplacement drifts and subject themselves to conditions created by an open isolation door.

- Transporter

  Under normal conditions, the crew operating the emplacement locomotives that move the WP Transporter would be positioned in the cabs of the locomotives. Their exposure would average 0.2 mrem/hour as shown in item 5 of Tables 4.4.6-1 and 4.4.6-1a.

  Under normal conditions, maintenance crews would not work on the waste package transporter with a waste package onboard. However, this addendum assumes that emergency repairs could be needed. Approximately 1% of the time maintenance crews' time could be allocated to the WP Transporter with a waste package onboard. When personnel do maintenance work on the transporter their exposure is assumed to be 4.0 mrem/hr. An operator manually uncoupling a loaded WP Transporter from an emplacement locomotive is not discussed in Sections 4.4.6.1 and 4.4.6.2

- Turnout

The design of the emplacement cycle and the emplacement equipment will not require personnel to work in turnout areas. The emplacement crew need not enter the turnout during the emplacement cycle and, therefore, they would not be exposed to the conditions described in item 3 of Tables 4.4.6-1 and 4.4.6-1a.

Maintenance crews such as the Controls and Monitoring Maintenance Crew would not normally work in the turnouts because most maintainable equipment would be located in the main drifts or performance confirmation drifts. However, this addendum assumes that 1% of the time conditions may exist that require maintenance of controls and monitoring equipment in the area.

The Utilities Maintenance crew could be required to maintain track or other utilities in the turnout area. This system is highly reliable and the assumption is that the crew would spend no more that 1% of its time in the turnouts. When personnel work in the turnouts, the radiation exposure assumed is 1.4 mrem/hr (Low Thermal Case) and 5.06 mrem/hr (High & Intermediate Cases).

- Main Drift During Retrieval

The exposures listed in Table 4.4.6-1, Item 4 would apply to a person standing directly in line with an emplacement drift during the retrieval process. These exposures emphasize the reason for remote operation of equipment during both retrieval and emplacement. As in the emplacement operation, the radiation exposure assumed for the personnel in the main drift is 0.10 mrem/hr (Low Thermal Cases) and 0.16 mrem/hr (High & Intermediate Thermal Cases).

- Locomotive Cab Position

The locomotive cab position is a normal work location for the locomotive operator and the brakeman. The waste package is only onboard the waste package transporter during the trip from the waste handling building to the emplacement drift. During the return trip, exposures are less because the WP is not onboard. The assumed exposure when a waste package is onboard is 0.2 mrem/hr.

- Between Locomotive and Transporter

  This is a transient location for the brakeman when he uncouples the waste package transporter from the locomotive during the emplacement cycle. The assumed exposure for the brakeman as he uncouples the waste package transporter with a waste package onboard is 4.0 mrem/hr. When he does the same procedure in the main drift with no waste package onboard, the assumed exposure is 0.10 mrem/hour (Low Cases) and 0.16 mrem/hr (High & Intermediate Thermal Cases). When the uncoupling is done on surface with no waste package onboard, the assumed exposure above background is 0.0 mrem/hour.

- Exhaust Main

  Maintainable equipment in the main exhaust drift would not be located directly below the raise. Therefore, the Controls and Monitoring Maintenance Crew and the Utility Maintenance crew would not normally work in that location. However, the addendum assumes that 1% of the time abnormal conditions may exist that require these crews to work near the bottom of the raise. When personnel work in the exhaust main, the assumed exposure at the bottom of the raise is 0.2 mrem/hr in the three thermal loading cases.

  Areas will exist in the repository where personnel will not work under normal conditions. Repository work practices and systems will be defined so personnel do not work in these areas. Acceptable levels of radiation exposure will, therefore, be maintained for the personnel working in the subsurface repository.

4.4.7 REMOTE SYSTEMS AND CONTROL OPERATION

Because of the elevated radiation exposure potentials related to nuclear waste handling, most operations and manipulations must be done by remote or automated systems. The following mobile equipment must have remote control capability:

- Transport Locomotive
- WP Transporter
- Emplacement Gantry
- Remote inspection systems
- Multi-purpose vehicle (for off-normal recovery operations)
- Load-haul-dump (for off-normal recovery operations)

Specific stationary equipment will also need remote control operability:

- Emplacement Drift Isolation Doors
- Rails Switches
- Thermal and radiation monitoring instruments
- Camera systems
- Air monitoring instruments.

Mobile emplacement equipment control systems use solid state technology to operate the machine. Manually operated equipment will also be monitored. Commands from joysticks, levers and push buttons, made by an operator in an isolated cab, are fed into a solid state system where they are processed. Interlocks must be satisfied. Outputs from all achieve the desired control action. The addition of remote control capability only slightly complicates the equipment design.

4.4.7.1 Transport Locomotive

Two transport locomotives will be used to provide the tractive power necessary to move the WP Transporter and the gantry carrier. One will be coupled to each end of the WP Transporter mechanically, electrically and pneumatically. When tramming the WP Transporter, each will be specified to be capable of moving and stopping the three part unit train loaded without assistance from the other locomotive. Each locomotive will also be fully capable of performing all waste handling operations as either the Primary or the Secondary Locomotive. The Primary Locomotive is attached to the non-door end of the W.P. Transporter and need not be decoupled under normal operation. The Secondary Locomotive is decoupled at each end of the transport cycle to allow the W.P. Transporter to be opened loaded or off-loaded.

The locomotives will be commercially available mining locomotives equipped with the conventional manual and wireless control systems. On-board operators will manually control the locomotives from the lead locomotive cab when transporting the WP Transporter between the Waste Handling Building and the subsurface emplacement drift turnout.

Along with the manual controls, the locomotives will be provided with commercially available equipment that provides fail-safe wireless remote control and operation. Use of redundant backup systems will ensure high system reliability. When the locomotives are operated manually, supervisory operators located at the remote command center will continuously monitor the locomotives to ensure that they are proceeding properly and safely. When in position to begin waste package off-loading, the on-board operators will leave the Primary Locomotive cab and full remote control will be transferred to the command center.

4.4.7.2 WP Transporter

The WP Transporter will be used to provide shielded transportation of waste packages from the surface facilities to the entrance of emplacement drifts. It will have no tractive power and must be pulled or pushed by the transport locomotives. Because of the high radiation levels associated with waste packages, waste loading and unloading operations will be done remotely.

The shielding door of the transporter must be remotely opened and closed when the waste package is installed and again when it is unloaded at the emplacement site. Each transporter's shielding door will be equipped with an actuator to provide the power necessary to open and close. Limit switches will be provided to gage and monitor door positions during all phases of the emplacement process. The Primary transport locomotive's onboard PLC will provide the logic of operation and communicate with the transporter's PLC control and sensors.

The loading/unloading mechanism must be controlled remotely as the waste packages will be exposed during this operation causing radiation dose to be greater than allowable for personnel exposure. The reversible motor which loads and unloads waste packages can be controlled remotely by an initiating command from the remote control station. Sensors will track loading/unloading progress and limit switches will send stop signals to the controlling system when the loading/unloading operation has reached the waste packages predetermined position and to prevent over-travel of the assembly. On-board cameras will record and communicate the loading and off-loading operations to the command center.

Sensors installed within the WP Transporter will monitor the environmental conditions while the waste package is in transit. These sensors may monitor temperature, radiation, gas accumulation, and any other environmental factor that may give early warning of an abnormality so that appropriate activities can be implemented. As the WP Transporter will be coupled to at least one locomotive whenever handling waste, these monitoring signals will, also, be transmitted to the locomotive PLC.

The WP Transporter's control and monitoring systems as well as the power source for the loading/unloading operations must be hard wired to one or both of the transporter locomotives. Electrical couplers must be designed to facilitate this coupling/decoupling operation easily and reliably. The waste handling personnel can manually make and break the couplings as those operations only take place when the WP Transporter is fully closed. Automating this coupling/decoupling process would be even better as a method of reducing exposure and opportunity for human error.

4.4.7.3 Gantries

Gantries will be used to lift the waste packages from the WP Transporter's reusable rail car, transport them into the emplacement drift and set them onto a supporting device at a predetermined location. The emplacement gantry is designed to operate inside the high-temperature, high-radiation environment of the emplacement drifts. The gantries will be similar, from a control standpoint, to the transport locomotive. However, it has no accommodation for onboard personnel or manual operation. Should the automated system fail or should an unanticipated event happen, the waste handlers in the remote control station can override the automated controls to complete the operation. The gantry will have directional control (forward/reverse), speed control, braking, and precise positioning. As a gantry, the mechanism must be able to position itself precisely over a waste package and activate its rigid lifting frame. Gantries will be electrically powered with direct current supplied by conductor bars. Control and communication signals may also be conducted along with the power. Each gantry will be equipped with a PLC to provide automated control of the waste package handling and tramming. Limit switches and sensors will provide input to the PLC data processing. Programmed logic decisions will be fed to the operating motors for contacting the waste package, lifting it, moving it, stopping at the designated emplacement location, lowering the waste package to the emplacement pedestal, disengaging from the waste package and returning to the starting position. For recovering a designated waste package, the automated system will be capable of approximate reverse operations. The gantry will be equipped with a system of video equipment, which will provide waste handling personnel oversight of the emplacement and retrieval operations.

The document entitled *Waste Package Retrieval Equipment* (CRWMS M&O 1997n, pg. 45-48 of 118) describes how a loaded gantry could be recovered if there were a failure of the normal systems (abnormal condition).

4.4.7.4 Communications Backbone

The communications backbone of the subsurface repository will consist of a network of digitally based PLCs and other equipment that controls and monitors the waste emplacement/retrieval operations. A network of PLCs will control rail switches and isolation doors. These will be based on a multiple-redundant fiber-optic system connected to the surface-based Operations Control Center and to the subsurface movable remote control stations. Other facilities and equipment will be installed to control the emplacement gantry, the WP Transporters, and the transport locomotives. All of this control equipment will need to communicate with the master control center that will provide necessary integrated services for the emplacement process. This main control system will also store the massive amount of information generated during each waste package's emplacement.

Although the radiation levels inside the emplacement drift will be too high to permit unrestricted human entry, from a remote control system standpoint, nuclear radiation will be quite tolerable. Equipment can be designed for the radiological conditions so that there are not high failure rates. The nuclear industry has developed remote control systems that operate in higher radiation environments than those expected in the emplacement drifts of the repository.

4.4.8 THE EMPLACEMENT AND RETRIEVAL PROCESSES

Fundamentally, waste package emplacement or retrieval are similar. To ensure safe and dependable recovery of all emplaced waste packages, the subsurface waste handling processes are reversible. Waste retrieval, however, will only occur upon direction.

4.4.8.1 Waste Package Emplacement

Waste package emplacements begin at the waste handling building carrier bay, where the WPs are loaded into the shielded WP transporters. The design and procedures also allow remote control of the transport locomotives with operators positioned in either the underground remote control stations or the surface-based Master Control Center. The WPs will be emplaced in a horizontal mode, in the center of the drift on pedestals using a gantry. Figure 4.4.8.1 - 1 (*Reference Subsurface Construction and Development Schedule Analysis* CRWMS M&O 1997g, Attachment III) shows how emplacement progresses in the base case high thermal load. The same systematic approach is used in low thermal load and expanded inventory cases.

Emplacement/retrieval processes meet the goal of ALARA regarding radiation exposure by using, as primary tools, remotely operated and automated equipment. Figure 4.4.8.1 - 2 illustrates the emplacement process.

4.4.8.2 Waste Package Retrieval

Retrieval means the act of intentionally removing radioactive waste from the underground location at which the waste had been previously emplaced for disposal (Sec. 8.1, 10 CFR 60.2).

Retrieval would occur only as a result of a policy decision by the Department of Energy to recover resources or the Nuclear Regulatory Commission to protect public health and safety or the environment. Other movements or recovery of waste could occur as part of normal repository operation and as performance assessment, but are not considered to be retrieval operations.

The retrieval process is described in *Waste Package Retrieval Equipment* (CRWMS M&O 1997n, pg. 19 of 118). Because retrieval is the reverse of emplacement and the same equipment is used, Figure 4.4.8.1 - 2 , with its continuations, illustrates the retrieval process if the steps are taken in reverse. The retrieval of waste packages is discussed in detail in *Waste Package Retrieval Equipment* (CRWMS 1997n, pg. 19-31 of 118). Retrieval under abnormal conditions is included in that document.

4.4.9 MAINTENANCE

Maintenance is defined for the subsurface facilities in two general categories. General maintenance is fundamentally industrial standard practice maintenance. It covers all facilities and equipment except the emplacement drifts and area. The emplacement drifts are a special consideration because of the radiation exposure potential.

4.4.9.1 General Maintenance Approach

The Operating Contractor should assign detailed maintenance to the organization most closely involved with the facility or system. Long range accountability is maintained through the operating contractor's records management system.

The construction subcontractors have maintenance responsibility for their individual projects until acceptance and turnover has occurred for their units and the operating contractor has taken possession for the DOE. The operating contractor, from that point on, assumes maintenance responsibility for the remaining life of the MGDS. Divisions of maintenance responsibilities within the operating contractor's organization are discussed below.

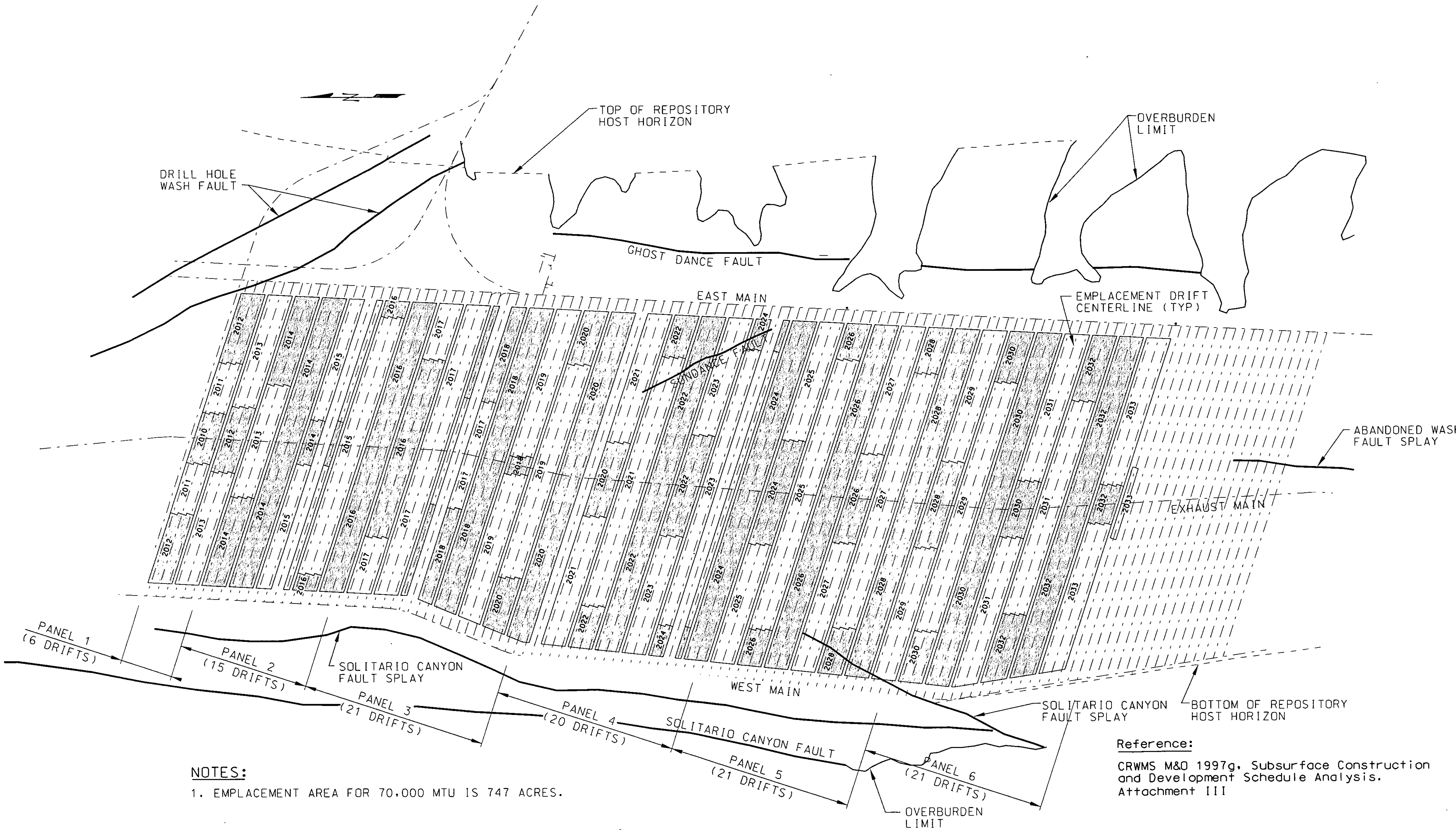
4.4.9.2 Maintenance of Waste Emplacement Drifts

Maintenance of the drifts means that the track, drift linings and mechanical systems would be kept in good condition. During the construction and development phases the construction and/or development opening maintenance crew would maintain facilities.

Following acceptance and turn over of each specific emplacement drift, any maintenance of the pre-cast concrete lining that must be performed in the empty emplacement drifts will be performed by the same crew that maintains the openings in the service mains.

After waste package emplacement has commenced, no maintenance activities will be performed because of the heat and radiation generated by the emplaced waste. Should an off-normal event occur, which damages a portion of an emplacement drift's functional opening, then appropriate actions must take place. In general this means making temporary repairs, removing waste packages and then making final repairs. If repairs are successful, then waste could be re-emplaced using normal emplacement equipment and procedures. Actions are described in the *Waste Package Retrieval Equipment* Document (CRWMS M&O 1997n).

Should the license to close the repository require that all emplacement drifts to be backfilled for permanent waste disposal, then certain alterations might be engineered into the emplacement drifts to accommodate efficient placing of the backfill material. Maintenance activities and responsibilities will be addressed at that time.



NOTES:

1. EMPLACEMENT AREA FOR 70,000 MTU IS 747 ACRES.

Reference:

CRWMS M&O 1997g, Subsurface Construction and Development Schedule Analysis. Attachment III

FIGURE 4.4.8.1-1
EMPLACEMENT PLAN FOR 70,000 MTU OF WASTE

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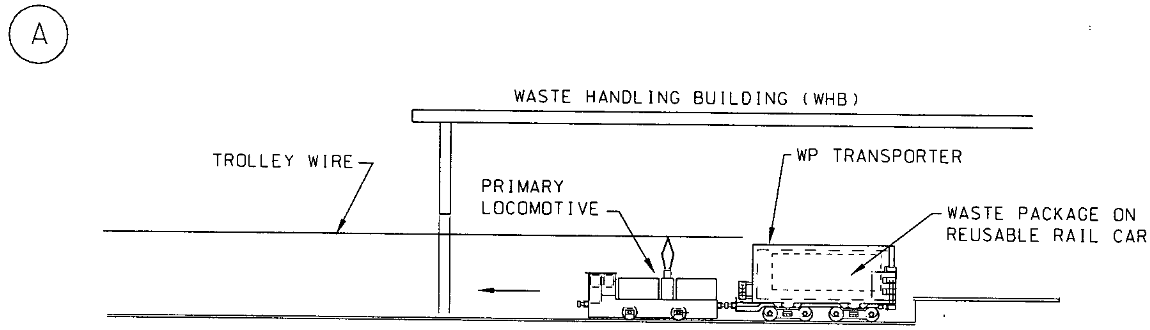
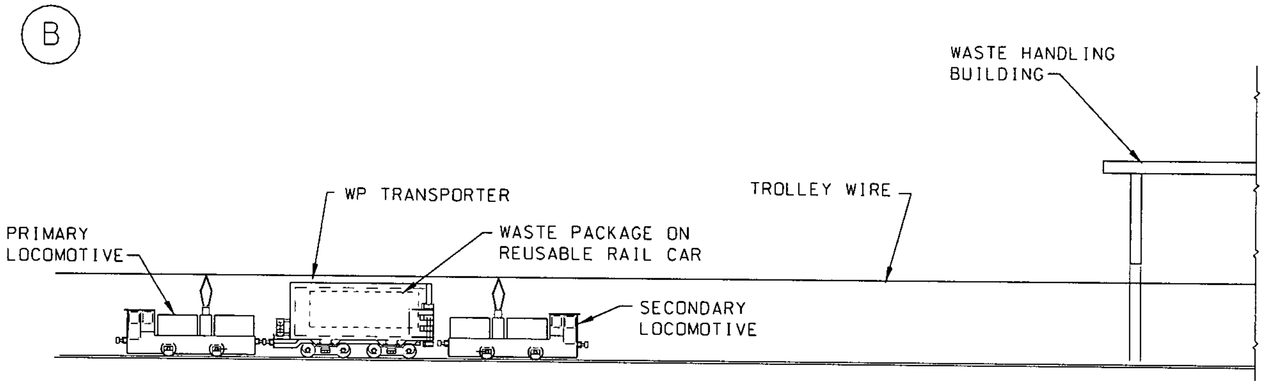
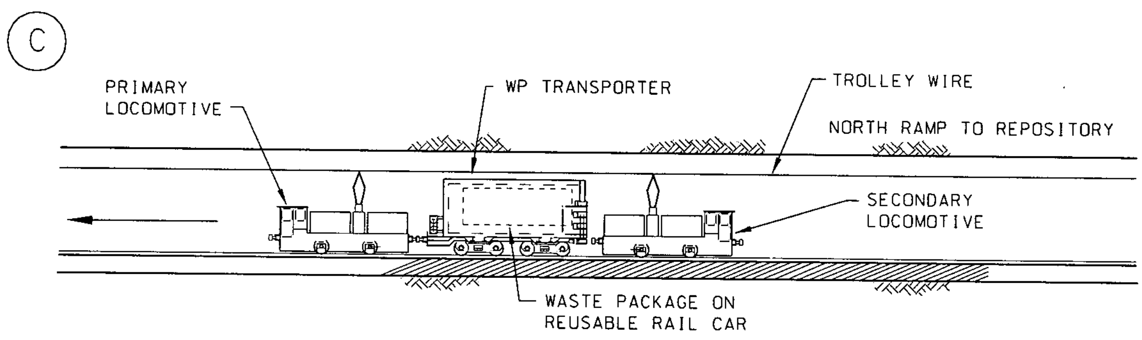


TRANSPORT LOCOMOTIVE AND WP TRANSPORTER WITH WASTE PACKAGE MOVE OUT OF THE WHB



SECONDARY TRANSPORT LOCOMOTIVE COUPLES TO END OF WP TRANSPORTER

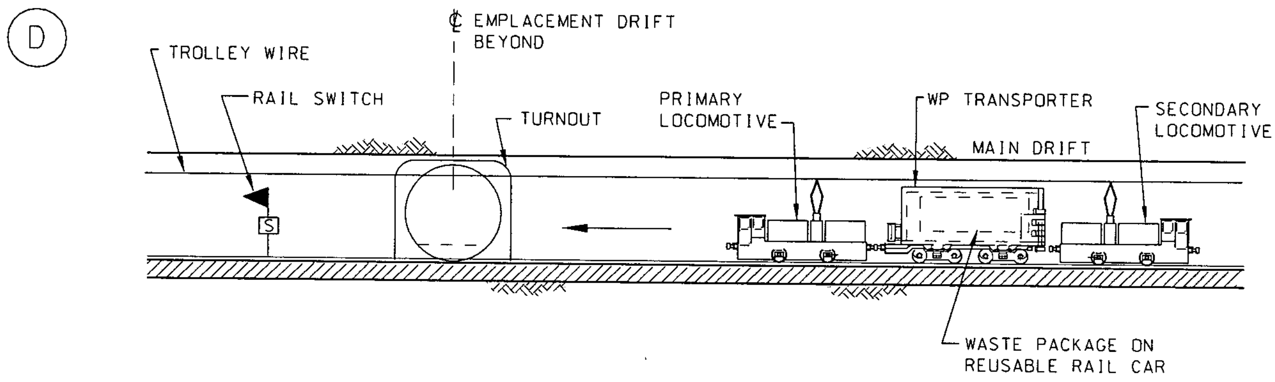


WASTE PACKAGE IS TRANSPORTED DOWN THE NORTH RAMP TO THE REPOSITORY

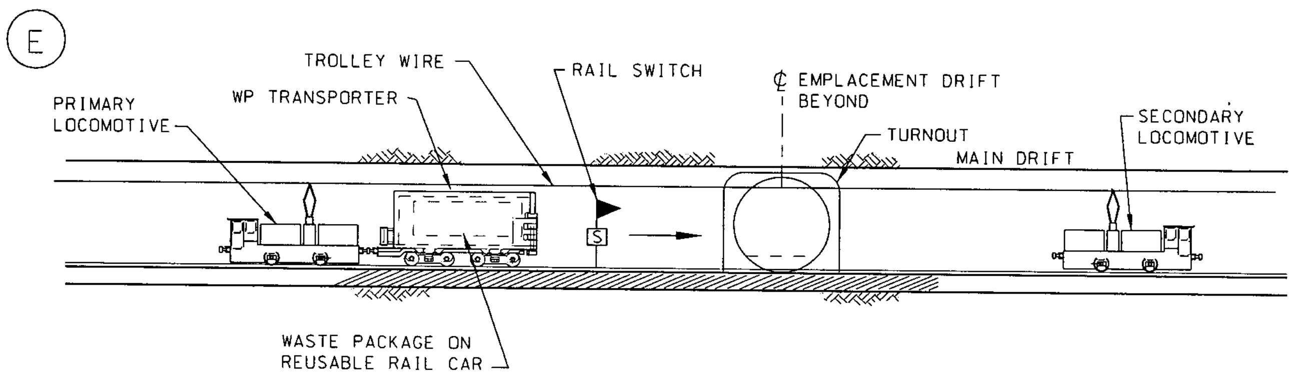
Reference:

CRWMS M&O 1997 w. Evaluation of Waste Package Transport and Emplacement Equipment. Figure 6

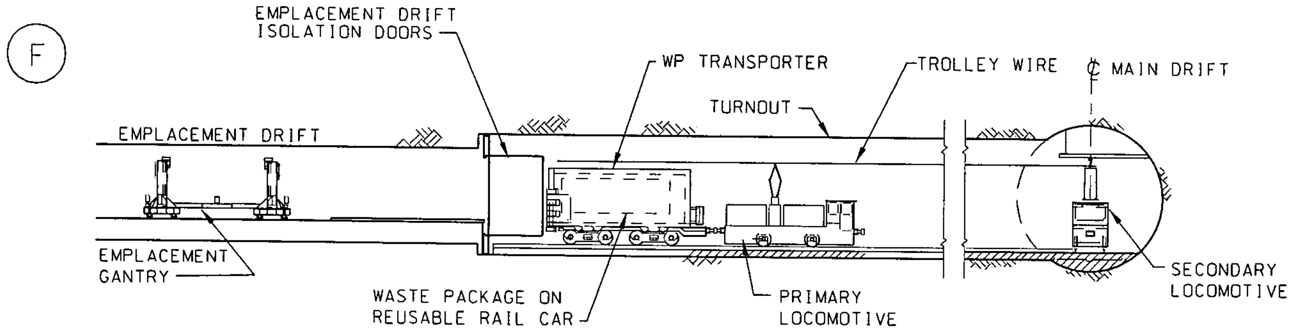
FIGURE 4.4.8.1-2
WASTE PACKAGE EMPLACEMENT IN-DRIFT,



TRANSPORT LOCOMOTIVES AND WP TRANSPORTER
MOVE FROM NORTH RAMP TO EAST MAIN DRIFT



SECONDARY LOCOMOTIVE DECOUPLES AHEAD OF DRIFT ENTRANCE POSITION.
SWITCH IS THROWN, PRIMARY TRANSPORT LOCOMOTIVE AND
WP TRANSPORTER MOVE FROM MAIN DRIFT INTO TURNOUT



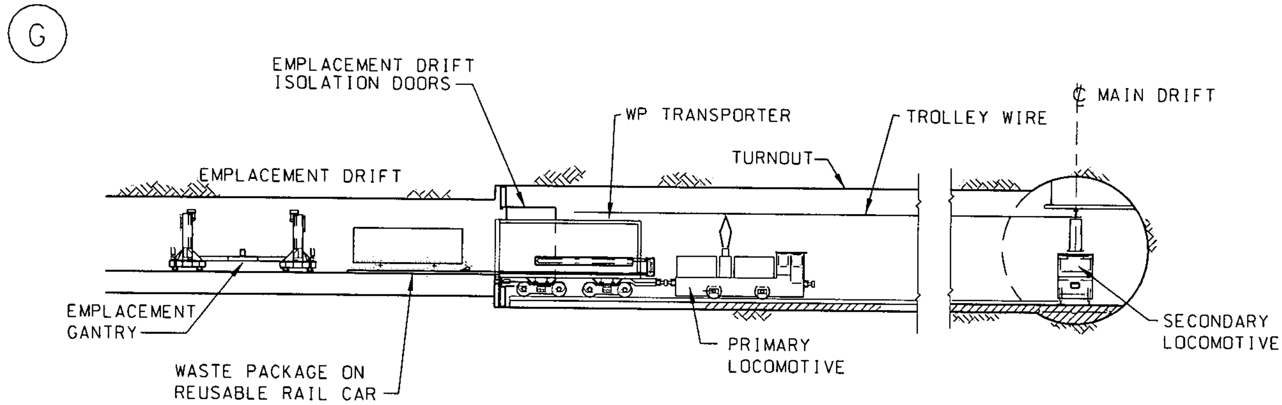
PERSONNEL EVACUATE IMMEDIATE AREA

TRANSPORT LOCOMOTIVE AND WP TRANSPORTER MOVE THRU
TURNOUT AND STOP SHORT OF EMPLACEMENT DRIFT ENTRANCE. WP
TRANSPORTER DOORS AND EMPLACEMENT DRIFT DOORS OPEN

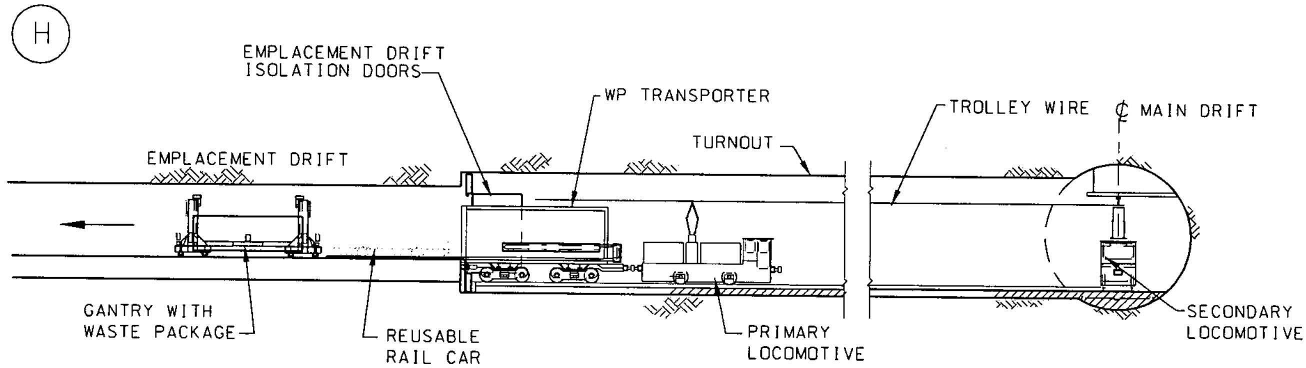
Reference:

CRWMS M&O 1997 w. Evaluation of Waste Package Transport and Emplacement Equipment. Figure 6

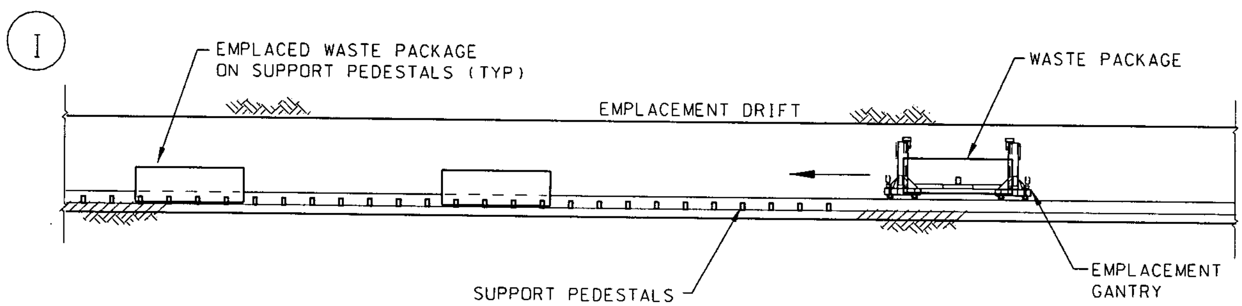
FIGURE 4.4.8.1-2 (cont)
WASTE PACKAGE EMPLACEMENT IN-DRIFT



WP TRANSPORTER DOCKS AT EMPLACEMENT DRIFT AND INTERNAL LOADING MECHANISM MOVES REUSABLE RAIL CAR WITH WP INTO DRIFT



GANTRY MOVES OVER WASTE PACKAGE ON REUSABLE RAIL CAR, PICKS UP WP AND MOVES TOWARD EMPLACEMENT

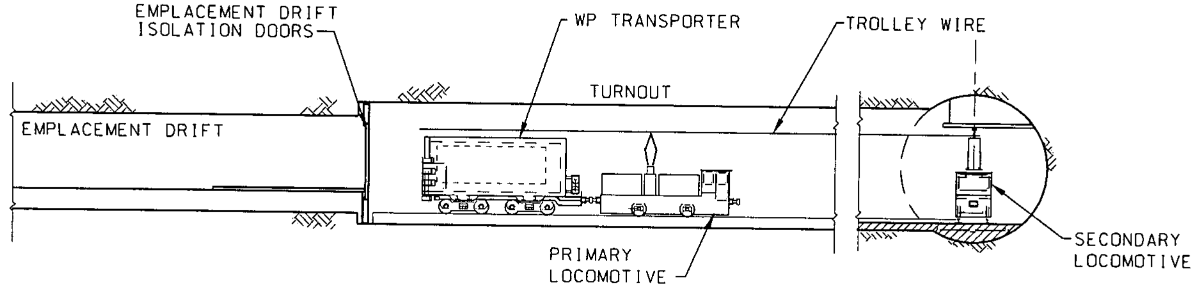


GANTRY WITH WASTE PACKAGE MOVES TO, AND PLACES WP ONTO, SUPPORT PEDESTALS AT EMPLACEMENT LOCATION IN DRIFT

Reference:
CRWMS M&O 1997 w. Evaluation of Waste Package Transport and Emplacement Equipment. Figure 6

FIGURE 4.4.8.1-2 (cont)
WASTE PACKAGE EMPLACEMENT IN-DRIFT

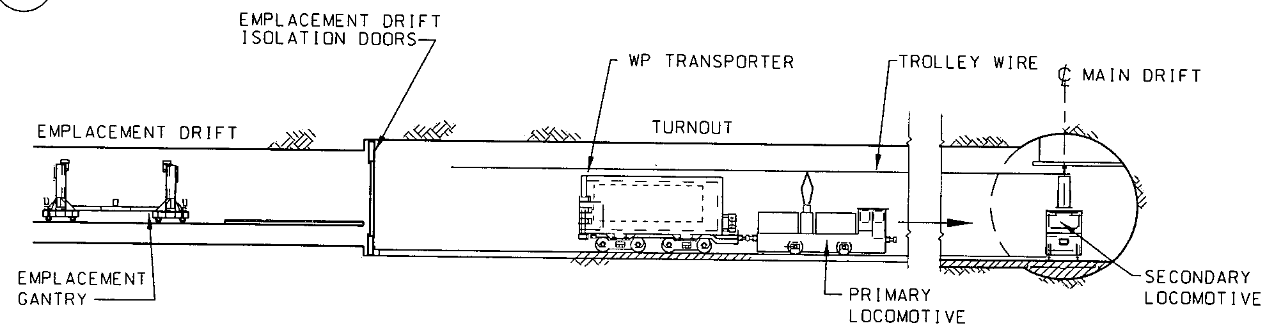
(J)



REUSABLE RAIL CAR RETRACTS INTO WP TRANSPORTER. LOCOMOTIVE AND EMPTY WP TRANSPORTER MOVE AWAY FROM DOCK. DRIFT ISOLATION DOORS AND WP TRANSPORTER DOORS CLOSE

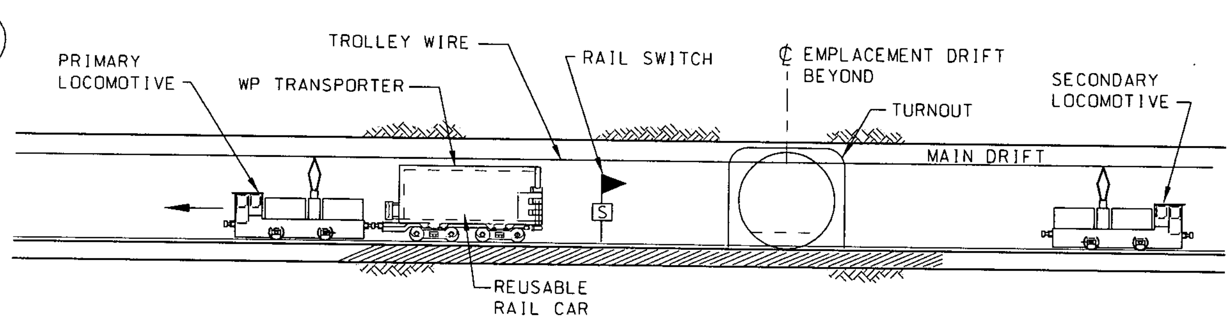
PERSONNEL MAY RETURN TO AREA

(K)



EMPTY GANTRY RETURNS TO DRIFT ENTRANCE AREA FOR NEXT WP DELIVERY. LOCOMOTIVE AND WP TRANSPORTER MOVE VIA TURNOUT TO MAIN DRIFT

(L)



TRANSPORT LOCOMOTIVE AND WP TRANSPORTER MOVE PAST RAIL SWITCH IN MAIN DRIFT AND SWITCH IS THROWN

Reference:

CRWMS M&O 1997 w. Evaluation of Waste Package Transport and Emplacement Equipment. Figure 6

FIGURE 4.4.8.1-2 (cont) WASTE PACKAGE EMPLACEMENT IN-DRIFT

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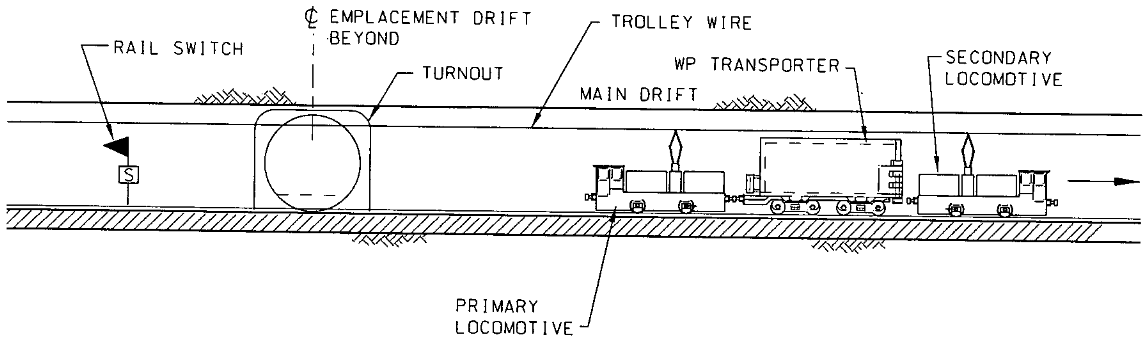

SECONDARY LOCOMOTIVE COUPLES TO REAR OF WP TRANSPORTER. TRANSPORT LOCOMOTIVES AND WP TRANSPORTER MOVE THRU MAIN DRIFT INTO NORTH RAMP

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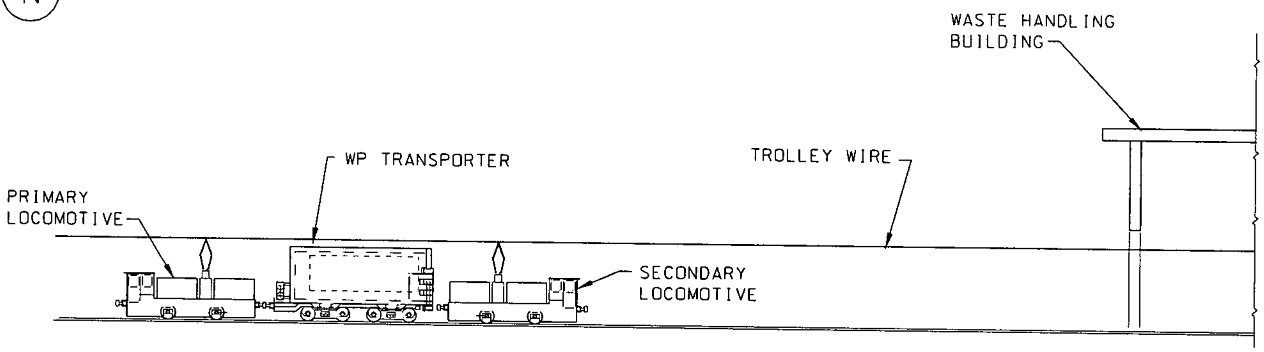

TRANSPORT LOCOMOTIVES MOVE WP TRANSPORTER BACK TO THE SURFACE FACILITY

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Reference:

CRWMS M&O 1997 w. Evaluation of Waste Package Transport and Emplacement Equipment. Figure 6

FIGURE 4.4.8.1-2 (cont)
WASTE PACKAGE EMPLACEMENT IN-DRIFT

4.4.10 CLOSURE OPERATIONS

Closure will begin when the NRC amends the license to authorize permanent closure of the repository. Subsurface Closure and Decommissioning will include removal of underground equipment and underground related equipment located on surface; backfilling all drifts and tunnels not containing waste packages; sealing of shafts, ramps and boreholes; and establishing institutional barriers.

During the transition from the Monitor Phase to the Closure/Decommissioning Phase, the repository must be converted from the emplacement mode of operation to the closure-fill mode of operation. This will allow the various construction activities required for Closure and decommissioning to be performed. To accomplish this change, the underground isolation doors barriers and air locks will be reconfigured. Ventilation pipe, rail, power cables and other utility systems will be removed/salvaged from the underground access openings prior to backfilling. The current plan, subject to verification, is to fill applicable openings with crushed and sized tuff from the mined rock stockpile.

The closure fill preparation plant will be located on surface near the tuff stockpile. The plant will process the tuff rock into a sized product that will be used to fill the underground access openings. The tuff rock will be reclaimed from the surface stockpile using a wheel loader and trucks will haul it the process plant. The trucks will dump into a surge hopper that discharges onto a screen deck that will separate the product and feed a cone crusher. Crushed rock will be screened and washed to remove deleterious fines, vegetation, and other unwanted material. A single wash facility may have a capacity of 100 short tons per hour.

The screen and crusher will process the material in a closed circuit to produce a graded product of specified top size. The fill product will discharge onto a conveyor that feeds onto a radial stacker.

Fill material will be hauled from surface to the underground access drifts by rail. It will be placed in the underground openings by one or more pneumatic closure fill setups (Figure 4.4.9-1). A pneumatic setup will include an air compressor or blower; a stower; a hydraulic drive unit; an electrical power feeder and switchgear; a material receiving hopper; and, a swiveling discharge nozzle. The stower is the central component consisting of a large rotary air lock that introduces coarse material into a fast moving, low-pressure airstream. Elongated plates attached to a central shaft, which turns within a curved, tight fitting case, form eight compartments. The bottom of the stower is vertically elongated forming an enclosure through which compressed air flows. Fill material is dumped into the top of the stower and is carried into the base compartment. Once suspended, the material is conveyed in the compressed air stream to the point of discharge (the nozzle). Upon exiting the nozzle, the material velocity rapidly decreases causing the material to fall to the ground or onto previously placed closure fill. The fill material builds up until the opening is nearly filled. The method of filling will be designed to meet performance confirmation requirements.

See Appendix H for estimations of time periods necessary to close the subsurface repository. The following periods are summarized below:

Base Cases at 70,000 MTU Total Waste:

• Base Case High Thermal Loading	5 years
• Base Case Intermediate Thermal Loading	6 years
• Base Case Low Thermal Loading	15 years

Extended Inventory at 105,414 MTU Spent Nuclear Fuel:

• Modules 1 & 2b High Thermal Loading	13 years
• Modules 1 & 2b Intermediate Thermal Loading	17 years
• Modules 1 & 2b Low Thermal Loading	27 years

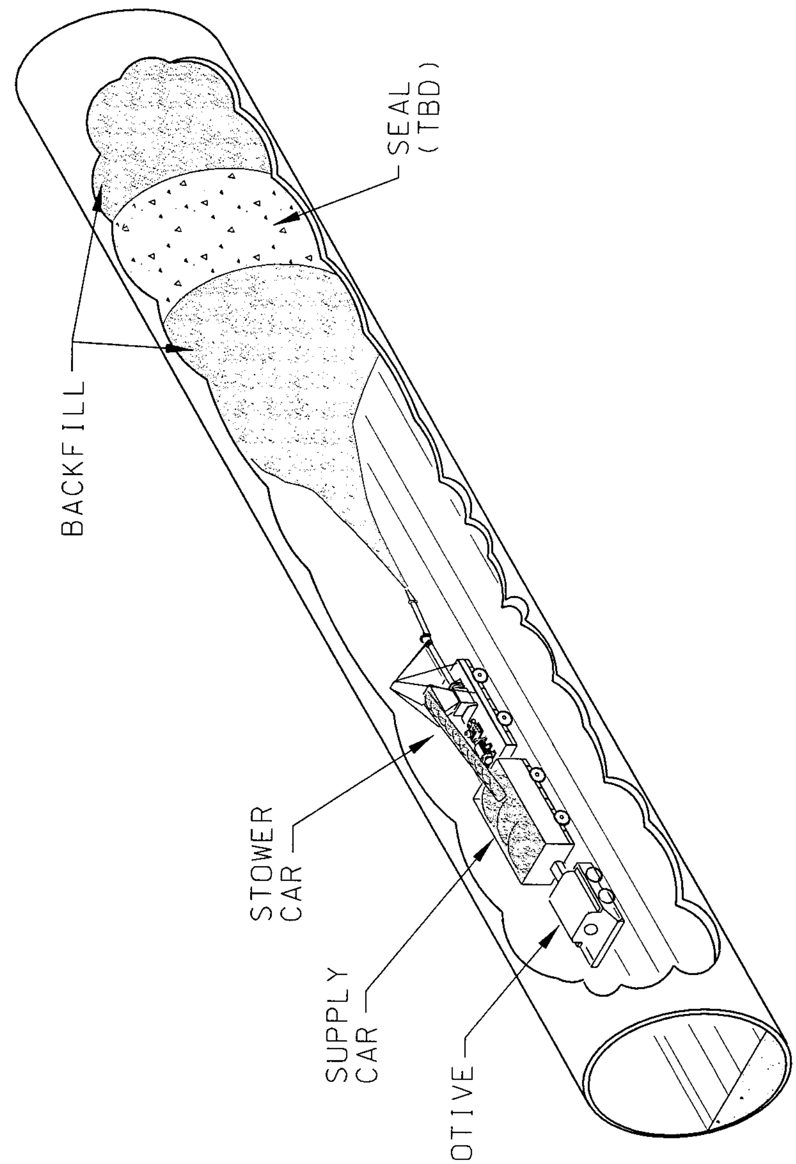
The crushing/screening plant, loading and haulage equipment, surface stockpile, rail haulage system, rolling stock and backfill placement system will be maintained when the equipment is not scheduled to operate, by a maintenance crew that works night shift and Saturday.

Dust generation will be minimized by removal of fines during surface processing and through the use of curtain partitions that would still the air velocity in the vicinity of the filling operations. Supplemental sprays may be used. If required, wet or dry air scrubbers would be used in the same manner as described for the ventilation of road headers.

During the closure and decommissioning phase all shafts, ramps and boreholes will be sealed. The concrete batch plant will prepare concrete for sealing the shafts, ramps and boreholes. For purposes of the study it is assumed that seals will be constructed as scheduled and that the concrete batch plant will operate 10 shifts to produce the concrete for each seal.

The utility systems including - ventilation, compressed air, water supply, fire system, waste water, power supply, lighting and sanitation /housekeeping systems will be maintained by a dedicated maintenance crew. The crew will normally work day shift, but will schedule repairs that require system shutdowns on weekends.

Subsurface related the facility maintenance crew would maintain facilities on surface (including a change house, shop, warehouse, office, yards and utilities). For purposes of this engineering file it is assumed that the surface facilities will not be impacted by the various areal mass loading cases.



NOTE:
VENTILATION NOT SHOWN. SEE VENTILATION
FIGURES IN SECTION 4.3.1.

Reference:
CRWMS 1996d, Mined Geological Disposal System
(MGDS), Advanced Conceptual Design Report (ACD),
Figure 9.4.3-1

FIGURE 4.4.9-1

PNEUMATIC BACKFILL SET-UP

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A crew will be provided on surface to support underground construction and maintenance activities. For purposes of this engineering file it is assumed that the surface support services staff will not be impacted by the various areal mass loading cases and the staffing will be the same for all cases.

During the Closure and Decommissioning Phase, the emplaced waste, engineered barriers and natural barriers will be monitored on a continuous basis.

A dedicated crew will be provided to maintain the development ventilation system. The system will include the main fan on surface, vent tube and in-line fans, and mobile scrubber units. For purposes of this engineering file it is assumed that the staff will not be impacted by the various areal mass loading cases.

If the emplacement drifts are to be backfilled, the same surface facility would be required. However, a different method is required for placing the fill in emplacement drifts containing waste packages. The method is described in *Backfill Strategy and Preliminary Design Analysis* (CRWMS 1997p, pg.31-32 of 64). If a decision is made to backfill emplacement drifts, then the fill material assumed is crushed tuff.

4.4.11 IN-SITU MONITORING SYSTEMS DURING ALL OPERATING PHASES

The performance confirmation system, as described in Section 4.3.2.6, will be used to monitor the subsurface repository during all phases. The *Performance Confirmation Data Acquisition System* analysis (CRWMS M&O 1997b) provides background information.

4.4.12 SUBSURFACE UTILITIES AND SERVICES

It is assumed that the operating subcontractor will install and operate the utility systems, supplying any subcontractors with utility services during the construction phase—continuing to operate throughout the life if the repository.

4.4.12.1 Contamination Control Systems

Dust control systems

The document: *Overall Development and emplacement Ventilation Systems* (CRWMS M&O 1997l) identifies sources of dust and the dust control philosophy used in the design and operation of the subsurface repository. The VA design does not consider regular use of diesel powered equipment, because of the adequate capabilities of electric equipment and concerns for organic contaminants and their effects on long-term waste isolation. Diesel may, however, be used by emergency equipment which deals with abnormal subsurface events.

Mechanical tunnel excavation creates airborne dust comprising a range of particle sizes, but dust particles smaller than 10 microns have little weight and inertia compared with surface area; therefore, remain suspended in dry air for long periods. Dust derived from welded tuff is largely composed of silica-based minerals of which Cristobalite averages 18 to 28% of the in-place rock. The crushing action of the TBM cutter disks is the major source of air-borne rock dust. Because Crystobalite is the most hazardous of the silica minerals, emphysis is placed on its Threshold Limit Values (TLV) and contained quantities for engineering the dust control systems. Crystalline quartz is also hazardous to health but with a less restrictive TLV than the other forms of silica. By containing the Crystobilite in its conservative range of volume, the other minerals contained in the rock will be captured at levels below their TLVs. The International Agency has classified silica including Cristobalite as a Class 1 (known) carcinogen for Research on Carcinogens (IARC). Breathing such dust is hazardous to health. (CRWMS M&O 1997l).

Normal underground mechanical excavation produces dust when the rock is broken loose from the face. Dust is also generated when the broken rock is transferred to rail cars or conveyors, or in other similar operations wherein rock falls from one elevation to another through the airstream. Dust concentration in the air can increase when exhaust air is allowed to re-circulate within the ventilation system or when airflow velocity in the drifts is high enough to entrain dust previously deposited on the floor and walls of the tunnel.

In order to ensure that workers are not exposed to dust concentrations in excess of the threshold limit value (TLV) as defined by American Conference of Government Industrial Hygienists (ACGIH), engineering controls are employed. As TBMs or road headers are breaking the rock from the face, water is used to wet both the face and the broken rock to prevent dust from becoming airborne. Wet or dry dust scrubbers with mechanical fans are used to capture dust that is not suppressed by the water sprays. To prevent re-circulation, fresh and exhaust air are separated. The preferred system for TBM ventilation is one which delivers fresh air to the TBM face through a duct hung in the tunnel. Air pressure in the duct is higher than in the drift so that the airflow is always from the duct containing the fresh air into the drift. Therefore, exhaust air cannot be re-circulated into the fresh air stream. Return air from the TBM face goes through scrubbers before it is returned for drift ventilation. The air in the drift is reprocessed for dust removal as required as it travels back and joins the primary airstream.

Systems that ventilate TBMs and roadheaders consist of ventilation ducts hung in the drifts, fans and wet or dry scrubbers. Air flow volumes and the fan/scrubber capacities vary. Figures 4.4.12.1-1 and 4.4.12.1-2 show the systems.

Dust control at locations where the broken rock falls through the air as it is transferred to rail cars or conveyors are also controlled by wetting the rock with water and/or by installing dust collection hoods.

The water will suppress the dust so that it does not become airborne. The dust collection hoods exhausting into local dust collectors capture dust not suppressed by the water sprays.

Finally, the repository ventilation system is designed for controlled air velocity in the drifts so that dust is not re-entrained.

If the engineering controls combined with administrative controls, fail to maintain dust concentrations below the required threshold limit value, then personnel would be required to wear respirators until adequate engineering controls could be established

Radiological leakage

Under normal conditions, there is no source of radiological leakage in the subsurface repository because all radiological material is contained in the waste packages. Leakage consisting of noble gasses and respirable particulates could occur if a waste package were breached. If a waste package breaches, there are two major concerns. One is protection of the public. The other is projection of the workers in the subsurface repository.

To protect the public, if there is a release, air that is used to ventilate the emplacement drifts (with emplaced waste) is passed through high efficiency particulate air filters (if required) before it is discharged from the ventilation shafts. Under normal conditions, exhaust air would not be filtered. The HEPA filters are designed to remove radioactive particulates. The noble gasses, which are not a threat, would pass through the deployed filters.

Workers in the development areas of the repository would be protected because the ventilation system is designed to control the direction of air leakage through bulkheads separating the development and emplacement operations. Lower air pressure on the emplacement side would draw airflow from the development area into the emplacement area. Therefore, contaminated dust from the emplacement side would not enter the development areas.

A breached waste package, in a filled emplacement drift, would be detected by an exhaust-air monitor specific to that emplacement drift. The individual breached waste package would then be identified by an inspection gantry specially installed in the designated drift. The inspection gantry is operated remotely. It would locate the damaged waste package and provide an overall assessment. This would be used in selecting the appropriate actions for removal.

The analysis, *Waste Package Retrieval Equipment* (CRWMS M&O 1997n, Section 7.1) describes a strategy to protect workers on the emplacement side of the repository. The initial response to an accident would include evacuation of the repository. Subsequently, bulkheads with HEPA filters would be constructed both upwind and downwind of the breached waste package to prevent the spread of contamination as the damaged waste package was recovered. Equipment used to recover the waste

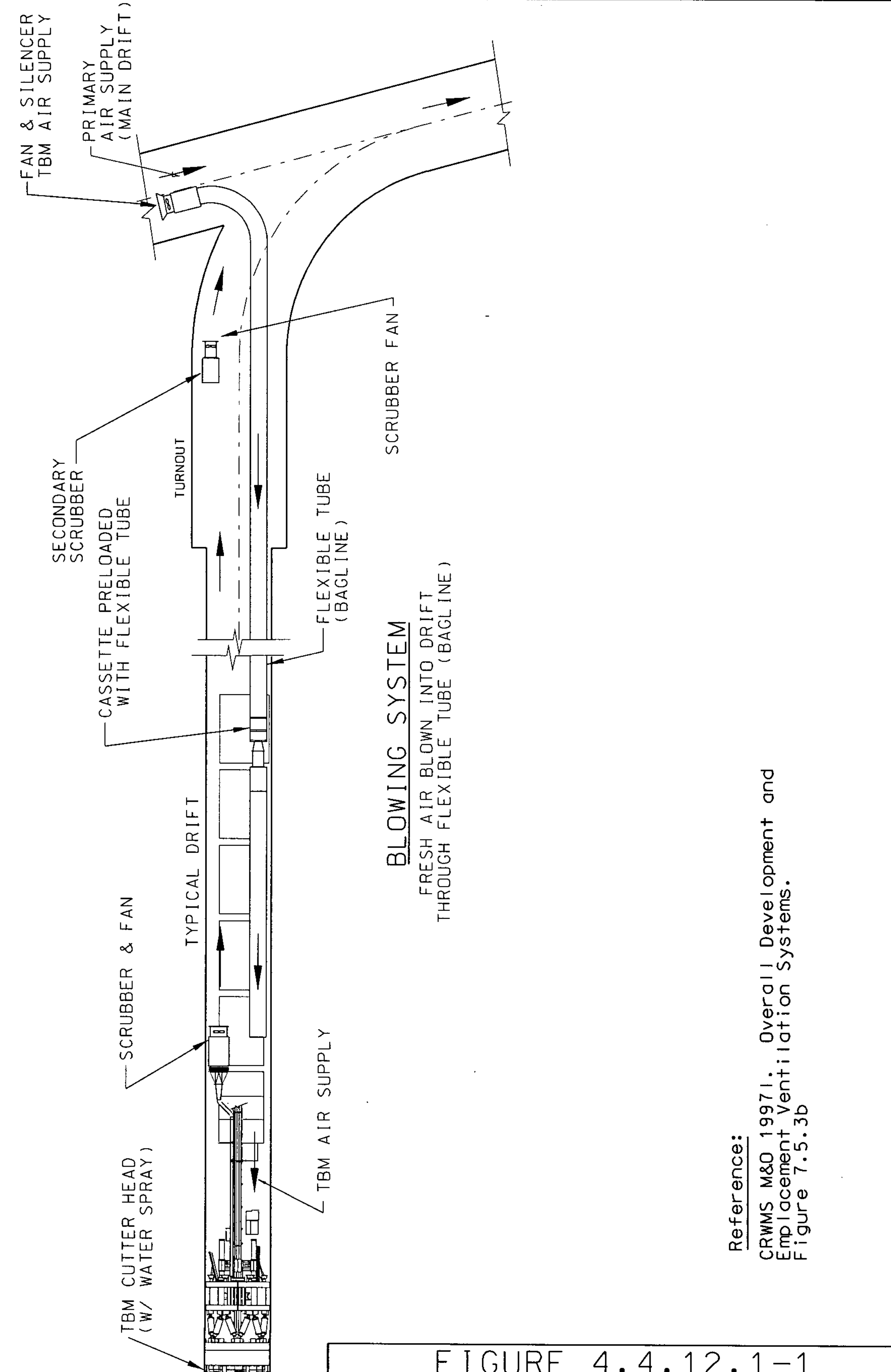
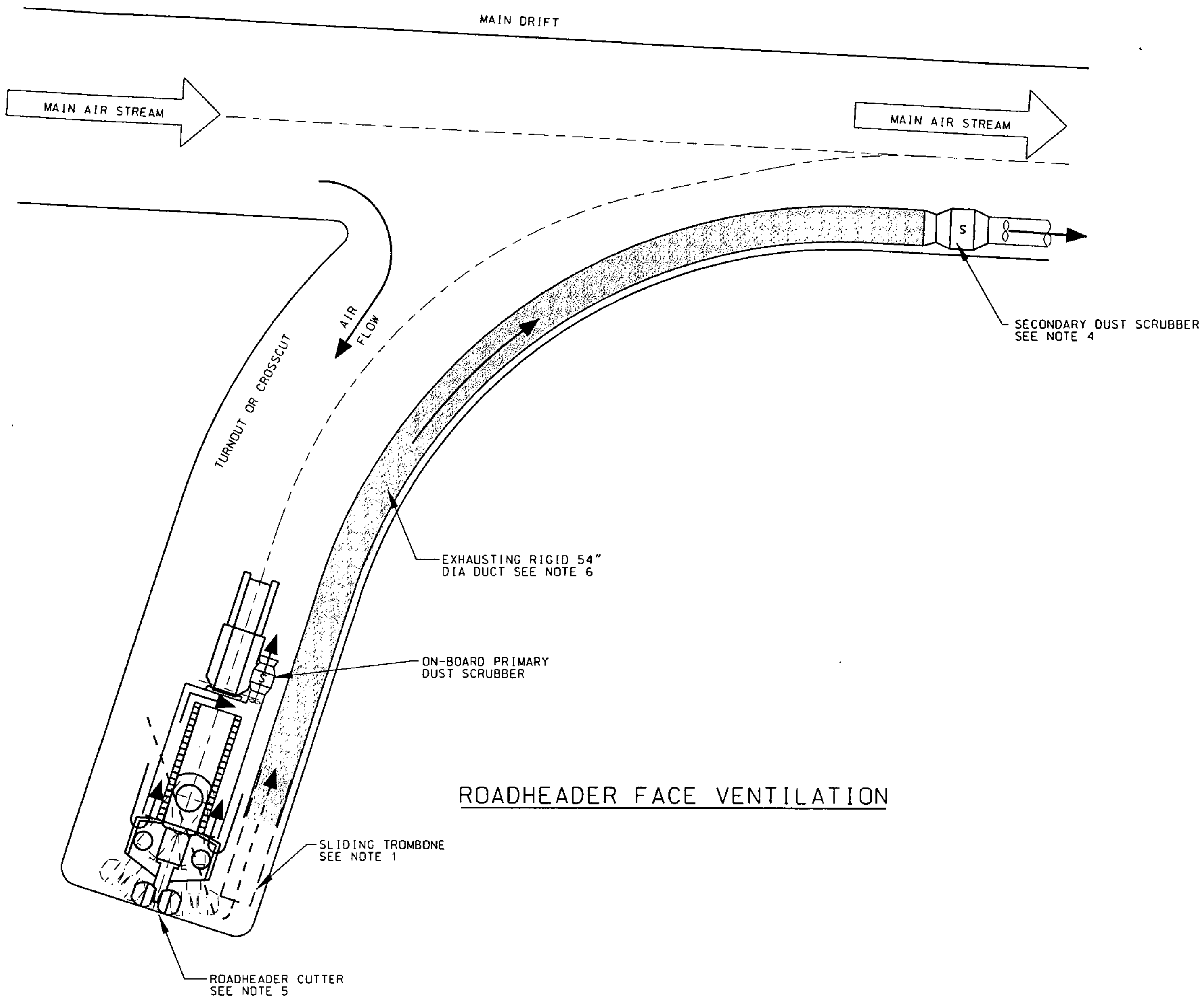
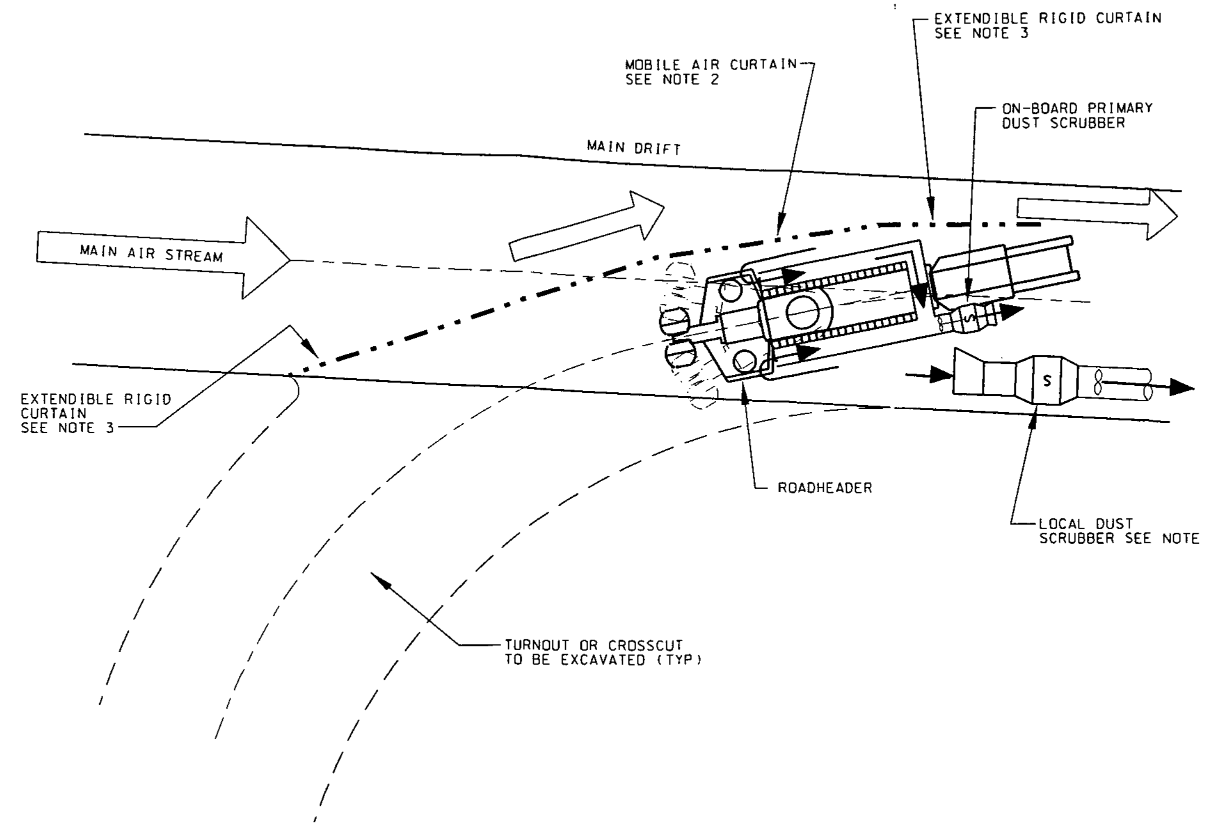


FIGURE 4.4.12.1-1
TBM FACE VENTILATION
BAGLINE SYSTEM



ROADHEADER FACE VENTILATION



ROADHEADER INITIAL CUTTING AND DUST CONTROL BYPASS - ALONG MAINS (TYP)

SEE NOTE 7

NOTES:

1. SLIDING TROMBONE EXTENDS AS CLOSE AS FEASIBLE TO THE FACE. DUST BACKFLOW FROM ROADHEADER CUTTING HEAD WILL EXHAUST INTO DUCT AND INTO DUST SCRUBBER WITHOUT PASSING THROUGH PERSONNEL BREATHING AREA NEAR FACE.
2. MOBILE AIR CURTAIN MOUNTED ON FLAT CAR TO MOVE IN POSITION NOT TO DISTURB ROADHEADER ACTIVITY.
3. RIGID CURTAIN WALL WITH EXTENDIBLE HEIGHT AND LENGTH TO FIT NEEDS OF BLOCKING HIGH VELOCITY AIR INTO ROADHEADER ACTIVITY. CURTAIN HAS GRIPPERS TO STABILIZE POSITION.
4. LOCAL DUST SCRUBBER INSTALLED ALONG DRIFT AS NEEDED.
5. ROADHEADER CUTTING WITH WATER SPRAY ARRANGEMENT WILL BE INCLUDED IN ROADHEADER SPECIFICATION.
6. AIR QUANTITY DELIVERY INSIDE DUCT IS DESIGNED TO PRODUCE NOMINAL 0.6 m/s (118 fpm) OF AIR VELOCITY ALONG DRIFT.
7. ROTATE IMAGE AS NEEDED FOR SPECIFIC ROADHEADER FACE VENTILATION ARRANGEMENT.

Reference:

CRWMS M&O 1997i. Overall Development and Emplacement Ventilation Systems. Figure 7.5.5

FIGURE 4.4.12.1-2
ROADHEADER FACE VENTILATION

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package would be controlled from a remote, safe location to prevent exposure of the workers to contamination. Administrative controls would also be used to limit worker exposure.

Potential Radon

Naturally occurring radon gas is often found in igneous rocks therefore tests are being conducted as part of site characterization; however data from these tests and monitoring efforts are not yet available for inclusion in this engineering file. The EIS contractor requested that the "Engineering File – Subsurface Repository Rev. 01" contain some estimates of locations and staff-hours related to the South Portal area. Table 4.4.12.3-1 below contains estimated data based on Figure 4.3.2.1-1.

Table 4.4.12-1 South Portal Area Location and Personnel Estimate

Work Location	Dist. From So. Portal (ft)	Approx. Bear.	# Staff	Occupied Hr/day	Staff/hr
Locomotive & Railcar Repair Shop	500	S. 10° E.	5	16	80
Covered & uncovered Storage Area	500	S. 45° E.	2	8	16
Security Post	100	N.35° E.	1	24	24
Dispatcher house	180	N.30 ° E.	1	24	24
Lunchroom	200	N.40° E.	30	3	90
Subsurface Office & Change Room	250	N.45° E.	5	16	80
Parking Lot	700	N.50° E.	100	1.5	150
Precast Segment Fabrication	1,200	N.10° E.	5	16	90

4.4.12.2 Site-Generated Waste

Unless an off-normal event should cause a release of radioactive particles that contaminate a large area or cause the HEPA filters to be contaminated, there would be no subsurface site-generated nuclear waste.

5 DESCRIPTION OF CASES

This section describes the areas of impact significant to evaluation of subsurface repository cases defined in Section 3. These impacts are detailed in the environmental data listed in Section 6 and then analyzed in Section 7. As noted in all sections of this subsurface engineering file, the Viability Assessment (VA) concepts and criteria are the Base Case. The cases are described in Table 3.1-1.

5.1 HIGH THERMAL CASES

Thermal loading is a primary repository design criterion because it affects the subsurface areal extent of waste disposal and the heat distribution into that geologic disposal area. Development of the emplacement area for each thermal loading alternative is modified by the magnitude of the areal change for each alternative. The High thermal loading cases involve the least subsurface areal development for disposal. This is true for not only the Base (VA) waste-receipt assumption, but for each of the extended waste inventory modules.

5.1.1 BASE HIGH THERMAL CASE

This Base High Thermal case would dispose of the 70,000 MTU of heavy metal described in the VA analyses and their references. All impacts created by alternatives, options or modifications are compared to this case. Emplacement drift spacing is set at 28 meters in the high cases centerline-to-centerline and waste package spacing along the emplacement drift is adjusted to create a thermal loading of 85 MTU/acre. See Figure 3.3-1 for layout illustration.

Retrieval of all waste creates an additional operation to this case thereby extending the life-cycle of the repository for a period that approximates the emplacement operating phase. Retrieval Operation is contingent on a directive from the NRC. Should that directive be given then the MGDS goes into the "Retrieval Phase" and its configuration of facilities. For purposes of the EF, this occurs at the completion of waste emplacement. Environmental data is addressed in Section 6 for the Retrieval Operation.

Currently, backfilling of waste emplaced in the repository drifts is not required. Should this modification be added, it would cause retrieval of waste to be more difficult—not impossible. Backfilling is considered, for this engineering file, to terminate the Monitor Phase. Maintenance activities are included in the backfilling operations. As an operation, it would be conducted just prior to initiation of the Closure & Decommissioning Phase. Details related to backfilling operations and environmental data are addressed in Appendix I of this engineering file.

5.1.2 MODULE 1 & 2B HIGH THERMAL CASES

This extended waste inventory high thermal case would dispose of approximately 105,414 MTU of CSNF heavy metal described in Section 3.3 and its references. It creates excavation impacts in the Primary

Block when compared to this "Base Case High Thermal Load." The extended waste package inventory creates the need for additional emplacement drifts (see Figure 3.3-4). This in-turn requires that the exhaust and perimeter mains be extended in the Primary Block and partial development of the Lower Block.

Emplacement of the Modules 1 & 2b nuclear waste inventories is accommodated, by extending the Emplacement Phase. Section 6.2.3 reflects this extension in its tables. Because of the extension to the Emplacement Phase, the Caretaker Phase is shortened proportionally. Like the Base Case, retrieval of all waste creates an additional operation thereby extending the life cycle of the repository. The Modules 1 and 2b operations would lengthen the retrieval because of the extended inventory of waste packages emplaced. The environmental data for the Retrieval Period are noted in Sections 6.1.5 and 6.2.5. As in the Base Cases, backfilling emplaced waste is not required.

5.2 INTERMEDIATE THERMAL LOAD CASES

The intermediate thermal load (60 MTU/acre) requires, approximately 42%, more subsurface area than does the Base High Thermal Case.

5.2.1 INTERMEDIATE BASE CASE

To achieve the reduction of a thermal load on the subsurface repository, the spacing of emplacement drifts is increased from 28 to 40 meters centerline-to-centerline. The spacing of waste packages is held to be approximately the same. While more area is required, the number and length of emplacement drifts do not increase significantly. Because the distance between emplacement drifts is increased and a few more emplacement drifts are added, the perimeter access mains and the Exhaust Main are increased in length. See Figure 3.3-2 for illustration.

For the base inventory case this expansion of repository disposal area is accommodated in the Primary Block by developing more area to the north of the Base Case layout and by using more of the southern portion of the block. Use of the southern portion of the block causes the need for an extension to the East Main. The Exhaust Main must, also, go to a lower elevation using a circular ramp at the southern end of the repository extending its length on both ends. This lower elevation, also, accommodates emplacement drifts at the southern end of the Primary Block.

To accomplish waste receipt in year 2010 and to maintain development operations ahead of the waste receipt schedule, analysis showed that one 7.62-meter TBM was insufficient. The increased requirements in length for the perimeter and exhaust mains would delay the start of emplacement drift development if the same construction approach and sequence as the VA Base Case were used. An alternative approach using two 7.62-meter TBMs is proposed. They would initiate excavation at opposite ends of the Primary Block for this intermediate case.

Like the High Base Case, retrieval of all waste creates an additional operation to this intermediate case thereby extending the life cycle. The environmental data for retrieval are noted in Section 6.1.5 and 6.2.5. Also, like the high thermal loading case, backfilling is considered to terminate the Monitoring Phase. As an operation, it would be conducted just prior to initiation of the Closure & Decommissioning Phase. Because emplacement drift length would not be significantly different in the intermediate case compared to the high thermal loading case, environmental data will be substantially the same (See Appendix I for details on emplacement drift backfill).

5.2.2 INTERMEDIATE MODULE 1 & 2B CASES

As in the Intermediate Base Case, the reduction of a thermal load on the subsurface repository area is accomplished by increasing the spacing of emplacement drifts from 28 to 40 meters centerline-to-centerline. The spacing of waste packages is held to be approximately the same. This expansion of repository disposal area is partially accommodated in the Primary Block as in the Intermediate Base Case. Additional, for the expanded inventory cases, all of the Lower Block and most of Area 5 must be developed.

To accomplish waste receipt in year 2010 and to maintain development operations ahead of the waste receipt schedule, two 7.62-meter TBMs are needed. Additional resources would be consumed in constructing the Intermediate Modules 1& 2b Case mains, ramps, shafts and emplacement drifts (see Section 6.2.1 and 6.2.2). Duration of the Monitor Phase would be shortened by the extended years of emplacement operations. Closure would involve an extended length of time needed to place fill material in the additional ramps and longer access mains. Retrieval of all waste in the Intermediate Modules 1 and 2b Cases would follow the same logic as described for the High Module Cases.

Backfilling of emplacement drifts in the Intermediate Modules 1& 2b Cases involves the Lower Block and Area 5 as well as the Primary Block, but the impacts are fundamentally the same (See Appendix I).

5.3 LOW THERMAL LOAD CASES

For the Rev 00 of the *Engineering File – Subsurface Repository* as it was issued in December 1997, the "Low" Thermal Cases assumed 36 MTU/acre as the areal mass density. After this version was accepted, the "Low" cases were re-defined with an areal mass density of 25 MTU/acre. To accommodate this change, Addendum E was prepared and issued in March of 1998. Addendum E contained the same data tables as the engineering file, but with a fourth column listing the 25 MTU/acre quantities. This revision of the Engineering File incorporates the 25 MTU/case as the Low case and discards the data for the original "Low" case of 36 MTU/acre.

Unlike the high and intermediate thermal loading cases achieving the reduction of thermal loading on the subsurface repository area, spacing of emplacement drifts and spacing of CSNF waste packages are modified. The aggregate length of emplacement drifts increases significantly. Because of the approximate 240% increase in subsurface areas required for low thermal density emplacements (when compared with the high cases) two to five additional blocks of suitable ground are added as discussed in Section 3.2.

The general assumption in the revised Low Thermal cases (25 MTU/acre) is that the waste packages should be placed in an approximately square pattern to distribute the thermal load evenly. To accomplish this, the emplacement drift spacing and the spacing of the waste packages in the emplacement drifts should be approximately equal. As detailed in Appendix F, the low thermal emplacement drift spacing becomes 38 meters centerline-to-centerline and approximately 35 meters between spent fuel waste packages along the emplacement drift centerlines.

5.3.1 LOW BASE CASE

The Low Base Case must include the expanded Primary Blocks, the Lower Block and Area 5 as shown in Figure 3.3-3. Like the Intermediate Base Case, the perimeter mains and the Exhaust Main in the Primary Block, are increased in length over the high thermal loading case. Significant increases in excavations are needed to access the two added emplacement areas.

Access mains, ramps and exhaust mains must be added and extended to accommodate the spacing and the greater number of emplacement drifts created by the "square pattern." Consequently, the period of excavation for ramps and mains is increased for several years beyond the completion dates identified for the other two thermal loading cases. This extension in 7.62-meter diameter TBM excavations has a significant impact as shown in the environmental data in Section 6. Like the high and intermediate thermal base cases, retrieval of all waste creates an additional operation to this low thermal case thereby extending the life-cycle of the repository.

5.3.2 LOW MODULES 1 & 2B

This Low Thermal extended inventory case would dispose of approximately 105,000 MTU of heavy metal. Major excavation impacts occur in the Primary Block, Lower Block, and Areas 5, 6, 7, and 8. This extended waste package inventory layout is illustrated in Figure 3.3-6. Excavated volumes are listed in Sections 6.2.1 and 6.2.2.

Extending the Emplacement Phase of operation accommodates emplacement of either of the Module 1 or Module 2b nuclear waste inventories. Section 6.2.3 reflects this extension in its tables. Because of the extension in time to the Emplacement Phase, the Monitor Phase is shortened proportionally. Retrieval of all waste in the Low Module 1 or 2b Cases would follow the basis described for the High and Intermediate extended inventory cases.

Emplacement of 105,414 MTU at an AML of 25 MTU/acre requires approximately 4,216 acres devoted to emplacement. This does not include areas which would not contain waste packages such as areas near faults that cross the emplacement blocks, main drifts, turnouts and drifts which are left empty for ventilation. The emplacement blocks described in the Rev 00 of the Engineering File contain only approximately 3,621 acres of usable emplacement area; therefore reexamination of the geologic model was needed to identify additional blocks suitable for emplacement. See Appendix F for details of the expanded layouts.

6 ENVIRONMENTAL DATA

Information in this section is derived from design documents and VA design analyses where possible. Where data included in Section Six is not currently available, estimations were developed based on cost estimates and other sources. These estimates are considered to be "backup material" and are contained in the "Records Package" for this engineering file (see reference CRWMS M&O 1999). For the thermal loading alternatives and the extended inventory cases, figures, estimations, assumptions, and calculations were made as appropriate. Assumptions are noted in Section 2. Section 6.1 relates to the "Base Case" "VA" waste inventory of 70,000 metric tons of heavy metals. Section 6.2 relates to the extended inventory cases designated as "Module 1" and "Module 2b." The primary divisions are by program phase as described in Section 1.5. In addition to those phases, is the optional operating phase of waste retrieval. The option of emplacement drift backfill is addressed in Appendix I.

6.1. DATA RELATED TO THE BASE CASE (VA) WASTE INVENTORY

Only data related to the 70,000 metric ton cases are addressed in the following subsections.

6.1.1 CONSTRUCTION PHASE

As described in Section 1.5, this phase only applies to activities that prepare the subsurface repository for initial waste disposal operations. For all the alternatives, construction phase excavation occurs only in the Primary Block. Development of the emplacement areas continues into the "Operations Phase" and may assigned to the expansion areas applicable to the thermal load case.

6.1.1.1 Staffing

Subsurface staffing Table 6.1.1.1-1 includes all workers regardless of whether their normal location of employment is underground or on surface. No distinction is made between construction contractor, operating contractor, subcontractor classification, or owner representative. The only distinction is made between craft and managerial. Approximate years of Construction Phase activity: 2004 to 2009.

Table 6.1.1.1-1. Construction Phase Staffing

Personnel	**Subject**	Base Case Personnel 5 years	Intermediate Thermal Case 5 years	Low Thermal Case 5 years
Managerial:	Peak number of workers:	131	131	131
	Average number of workers:	121	121	121
Craft:	Peak number of workers:	602	602	602
	Average number of workers:	459	491	491
Total	Peak number of workers:	712	712	712
Personnel:	Average number of workers:	580	612	612

Notes:

3) Staffing initiates preparation for construction in year 2004, but occupation of the site does not begin until actual construction starts in January, 2005, therefore averages do not include these early hires.

4) Variation in staffing between the Base High Thermal Case and the Intermediate and Low Thermal Cases is caused by the need for operating two 7.62-meter TBMs for a portion of the time in those lower two cases. The Base High Case can be ready for waste using a single TBM.

6.1.1.2 Resources Consumed

The process of construction consumes resources in producing the needed structure or facility. These resources are listed in Table 6.1.1.2-1 regardless of their end product.

Quantities listed below are summarized from several conceptual cost estimating calculations. The total electrical power includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment (trolley locomotives, road headers, perimeter and emplacement drift TBMs, etc.). Of the total power expended during the Construction phase, approximately 57% is used for two to four TBMs to drive access and emplacement drifts, 34% for primary stationary equipment, and 9% for numerous mobile and stationary equipment distributed throughout the underground repository.

Fuel and lubricants are expended in both surface (activities associated with underground) and underground operations. Fuels including diesel and gasoline are expended by surface equipment only. This equipment includes earth moving, transport, and personnel vehicles. Lubricants are used in both surface and underground equipment. Of the lubricants, grease is considered consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Table 6.1.1.6-1.

Table 6.1.1.2-1. Resources Consumed during Construction (total phase)

	THERMAL LOADING CASE		
ITEM	High Thermal	Intermediate	Low Thermal
Aggregate (mt)	218,000	274,000	281,000
Cement (mt)	86,000	109,000	112,000
Chemicals			
Concrete Additive (mt)	2,000	3,000	3,000
Electrical Power			
Total ('000) (mwh)	167.2	217.3	231.0
Peak (kw)	21,700	21,700	21,700
Fuel, Lubricants			
Diesel ('000 liters)	1,800	1,800	2,800
Gasoline ('000 liters)	≤100	≤100	≤100
Oil ('000 liters)	3,000	7,300	7,800
Grease ('000 kgs)	100	300	300
Sand (mt)	169,000	213,000	218,000
Steel			
Cutters (mt)	19	32	34
Drill Bits & Steel (mt)	1	1	1
Water (million liters)			
Potable	107.6	113.5	113.5
Concrete Additive	235.9	296.8	297.1
Process (Dust Suppress.)	323.2	393.9	398.5
Total (million liters)	666.7	804.2	809.1
Peak Use (liters/hr)	22,200	26,750	26,900

Units:
hr hour; mwh megawatt hours; kw kilowatts
kg kilograms; mt metric tons

Notes:

1) Resources consumed in producing concrete (aggregates, cement, chemical additives, sand and some of the water) increase with the increase in underground excavations for a phase or period. Because the Intermediate and Low Cases require greater lengths of access mains than does the Base Case High thermal load, resources consumed can be

expected to increase. Possible concrete additives include, but are not limited to: Silica Fume, a water-reducing admixture and a plasticizer.

2) Electrical power consumed increases with the equipment requirements for the phase or operating period. To excavate the additional lengths of access mains needed for the Intermediate and Low Cases, when compared with the Base Case High, a second 7.62-meter TBM is added to the excavation operations. This equipment and its support equipment produce the increased power consumption.

3) Diesel and gasoline consumption are related to surface operations. Diesel is used primarily on the mined rock stockpile. Gasoline consumption is unaffected by subsurface excavation operations.

4) All oil and grease listed is for lubricating the surface and underground equipment. The second 7.62-meter TBM applied to the Intermediate and Low Cases causes an increase in lubricants.

5) All steel listed is used for cutters, drill bits, etc. These are consumed in excavation. The increase noted in the Intermediate and Low Cases relates to the need for two 7.62-meter TBMs rather than only one in the Base High Case.

6) Water consumed for dust suppression increases with the need for two 7.62-meter TBMs in the Intermediate and Low Cases.

6.1.1.3 Materials Installed

Materials that become a permanent component of the facilities are listed in Table 6.1.1.3-1. Some of these materials may contain resources consumed as noted in Section 6.1.1.2.

Table 6.1.1.3-1. Material Installed during Construction (total phase)

	Thermal Loading Case		
Item	High Thermal	Intermediate	Low Thermal
Concrete (m^3)			
Concrete Materials	17,900	34,900	36,500
Invert	17,500	17,000	17,000
Pre-cast Liner	180,500	220,100	222,200
Grout	1,100	1,000	1,000
Total (m^3)	217,000	273,000	276,700
Copper (mt)	100	100	100
Steel (mt)			
Fibers	7,600	9,800	9,800
Lagging	2,600	2,600	2,600
Piping	4,800	5,200	5,200
Rock Bolts	300	300	300
Sets	2,200	2,200	2,200
Track & Accessories	9,400	11,600	11,600
Trolley Accessories	<100	<100	<100
Vent Ducting	10,800	19,100	19,100
Vent Raise Structure	<100	<100	<100
Welded Wire	200	200	200
Total (mt)	38,100	51,000	51,000

Units
m^3 - cubic meter   mt - metric ton

Notes:

1) All concrete items listed in the table are related to permanent underground facilities. Principal of these are the pre-cast emplacement drift liner segments, the emplacement drift pre-cast invert segments, and the main and ramp cast-in-place lining. The increase in concrete items for the Intermediate and Low thermal Cases when

compared with the Base High Case relates to the increased need of access and exhaust main lengths (See Table 6.1.1.4-1).

2) The copper and steel items listed in the table are considered to be permanently installed. The increases in quantities for the Intermediate and Low Cases are related to the increased length of access and exhaust main lengths.

6.1.1.4 Underground Openings Excavated

The Viability Assessment analyses used to form the "Base Case" provided a layout that includes the excavation units noted in the following condensed table:

Table 6.1.1.4-1. Base Case Thermal Load Alternatives (5 years)

	High Base Thermal Load		**Medium Thermal Load**		**Low Thermal Load**	
Description	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)
Main Drifts & Ramps - 7.62 m Dia. [1]	15,007	685,000	19,706	900,000	19,706	900,000
Main Drifts - Other Misc. Excavations	1,792	85,000	1,792	85,000	1,792	85,000
P.C. Launch drift	3,480	159,000	5,180	237,000	5,180	237,000
PC Drifts	1,963	47,000	1,941	46,000	1,941	46,000
Alcoves	0	0	0	0	0	0
Vent raises	NA	1,000	300	1,000	300	1,000
Other Misc.	338	19,000	338	19,000	338	19,000
(Cross block Drifts)	3,090	73,000	7,427	176,000	7,427	176,000
Misc. Ventilation	234	14,000	259	15,000	259	15,000
Shafts (6.7 m Diameter)						
Development Intake (DS1)	234	14,000	384	19,000	384	19,000
Emplacement Exhaust (ES1)	420	15,000	562	25,000	562	25,000
Emplacement Intake (ES3)					0	0
Shaft Connector Drifts			130	6,000	130	6,000
Emplacement Drifts	14,000	341,000	11,911	283,000	11,911	283,000
Turnouts, raises	1,040	75,000	1,007	50,000	1,007	50,000
Totals		1,528,000		1,862,000		1,862,000

Notes:

1) Main Drifts and Ramps do not include lengths and volumes excavated as ESF openings, i.e. North and South Ramps and the Tsw2 Main (Repository East Main).

2) Total volumes of excavation for this Construction Phase reflect only those subsurface units completed near the end of Year-2009. Excavations initiated after January 1, 2010 are incorporated into the emplacement as development (Sec. 6.1.2).

3) The increase in lengths and volumes in going from the High Base Case to the Intermediate and Low Cases relate to the need for increased emplacement area as the thermal loading is reduced. For the Construction Phase all excavations are confined to the Primary Block.

6.1.1.5 Rock Stockpiled at Surface

While the mined-rock stockpile facility is located at the surface (South Portal Area), it is totally subsurface related. Table 6.1.1.5-1 provides status at the completion of the Construction Phase.

Table 6.1.1.5-1. Construction Phase Stockpile Activity (5 years)

Stockpile Activity	High Base Case m^3	Intermediate Case m^3	Low Thermal Case m^3
Mined rock existing in stockpile	0	0	0
Mined rock placed into stockpile	2,037,000	2,483,000	2,483,000
Rock removed from stockpile	0	0	0
Rock in stockpile at end of phase	2,037,000	2,483,000	2,483,000

Notes:

1) All rock placed on the surface stockpile corresponds to the subsurface excavation during the Construction Phase.

2) All rock volumes expressed in the following table are loose. Data is based on mined volumes expanded by dividing the excavated volume by 0.75. This swell factor of approximately 33% is derived from ESF site experience.

6.1.1.6 Waste Generated

Production of waste products depend on the type of activity. Data shown in Table 6.1.1.6-1 reflects only subsurface construction activities.

Table 6.1.1.6-1. Construction Phase Wastes

Waste Material	High Base Case 5 years	Intermediate Case 5 years	Low Thermal Case 5 years
Hydrocarbons (lubricants & fluids) (total for phase) liters	3,028,000	7,300,000	7,800,000
Solid wastes (landfill) m^3/year	1,000	1,000	1,000
Solid wastes (recyclable) m^3/year	2,000	2,000	2,000
Sanitary waste liters/year	27,440,000	28,960,000	28,960,000
Low-level nuclear waste m^3/year	0	0	0
RCRA waste m^3/year	0	0	0

Notes:

1) Hydrocarbon waste, from equipment maintenance both underground and from the South Portal area, will go off the site to be recycled or otherwise treated for disposal.

2) Solid wastes are common garbage materials suitable for an off-site landfill or recycling.

3) Sanitary waste flow from shower and toilet facilities and will be treated and disposed through unspecified facilities on site. Sanitary waste is estimated at 50 gallons/person per day (see assumptions in Sec. 2.2).

4) Low-level nuclear waste is listed in the table. No nuclear waste is conceivable during the Construction Phase.

5) RCRA waste is listed in the table, but none is produced by normal subsurface operations.

6.1.1.7 Emissions and Effluents

Table 6.1.1.7-1 lists emissions and effluents in units per year.

Table 6.1.1.7-1. Construction Phase Emissions and Effluents (5 years of production)

Material	Base Case	Intermediate Case	Low Thermal Case
Diesel Exhaust (surface area) cubic meters/year	83,800,000	83,800,000	83,800,000
Dust (controlled to be less than) short tons/year	250	250	250
Water (assumed to be discharged in surface lagoon) liters/year	8,400,000	10,200,000	10,400,000

Notes:

1) Maintenance of the surface mined rock stock pile is a daily activity with the same equipment. Therefore the emission is the same regardless of thermal loading. Total diesel emissions are estimated on an assumed value of 2.96 billion cubic feet per year (see Appendix B).

2) Dust is maintained below 250 tons per year regardless of thermal load (see Appendix B).

3) Process water is used in the subsurface to control dust. Part of this is in excess of that amount absorbed or evaporated by an estimated 13%. This is considered to be pumped to surface and discharged into a surface lagoon near the South Portal area.

4) Diesel exhausts at the South Portal operations area result from construction equipment. The equipment fleet remains constant for all thermal loads and waste inventories.

6.1.1.8 Equipment

Consumables used by this equipment are listed in Section 6.1.1.2 as resources consumed.

Table 6.1.1.8-1. Equipment Acquired during Construction

Unit	Number	Unit	Number
Concrete Handling		Shaft Equipment	
•Concrete Batch Plant	1	•Headframe	2
•Concrete Pump (elec.)	1	•Headhouse	2
•Grout Mixer & Pump	1	•Hoist (elec.)	2
•Invert Paver (elec.)	1	•Ladder (373 m/each)	2
•Mixer Truck (diesel)	3		
Excavation & Support		Surface Mobil	
• Air Track Drill (elec.)	1	• Loader (diesel)	2
• TBM (5.5 m)(elec.)	1	• Pickup Truck	1
• TBM (7.62 m)(elec.)		• Flatbed Truck	1
• o High Thermal	1	• Forklift (4 t)(gas)	1
• o Inter. & Low Thermal	2	• Forklift (6-7½ t)(gas)	1
• Roadheader (elec.)	1	• Grader (Cat)(diesel)	1
• Roadheader (elec.)	2	•Hydraulic Crane (diesel)	1
• Raise Drill (elec.)	1	• Hyd Crane (diesel)	1
• Raise Miner (elec.)	1	• Loader (diesel)	1
• Drill Jumbo (elec.)	2	• Scraper (diesel)	1
• Ring Turner	1	• Tractor (diesel)	1
• Mesh Roller	1	• Transport Trailer (L.B.)	1
• Vibrator/Compactor	2	• Water Truck (diesel)	1
		• Water Wagon (diesel)	1
Rubber-Tired Haulage		Water Handling	
• Scooptram (diesel)	1	•Cent. Pump (elec.)	3
• Scooptram (electric)	2		

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Unit	Number	Unit	Number
Material Handling		Miscellaneous	
•Belt Conveyor (elec.)		• Air Hoist (5 t)	1
• ○ High	3900 m	•Generator (20-50 kw)	1
• ○ Intermediate	7871 m	•Light Plant	1
• ○ Low	7871 m	•Welder (300 amp-diesel)	1
•Muck Dump (elec.)	1	•Welder (300 amp-elect)	2
•Rad. Stacker (elec.)	1	•Work Platform	1
		•Platform Lift (Elec.)	3
		•Compressor (Elec.)	1
		•Compressor (Elec.)	2
Rail Haulage		Ventilation Equipment	
•Agitator Car	6	• Filter Fan (Electric)	4
•Flat Car (10 t)	12	• HEPA Filter (Main)	4
•Man Car	6	• HEPA Filter (Mobile)	2
•Man Trip (battery)	2	• Isolation Barrier	10
•Muck Car (13 m^3)	20	• Emplace Fan (2500 cfm)	1
•Segment Car	10	• Develop Fan (1750 cfm)	1
•Vacuum Car	1	• 150 hp Vent Fan (Electric.)	6
•Locomotive (Diesel)		• 250 hp Vent Fan (Electric)	
• ○ High & Intermediate	2	○ High & Intermediate	2
• ○ Low	3	○ Low	4
•Locomotive (Diesel)	1	• Mobile Scrubber (Elect.)	3
•Locomotive (Batt-10 ton)	1	• Mobile Scrubber (Elect.)	3
•Locomotive (Trly-25 ton)	4		

Unit	High Thermal Load	Intermediate	Low Thermal Load
Electrical Systems			
• Primary Equipment			
• ○ 15 KV Pwr Center	2	2	2
• ○ 12.5 KV/480V PC	16	20	20
• ○ 480/20V PC	16	20	20
• Power Cables			
• ○ 15 KV 500 MCM	8,704 m	9,451 m	9,451 m
• ○ 15 KV #4/0	18,086 m	21,836 m	21,836 m
• ○ 600 V # 8 AWG	9,043 m	10,918 m	10,918 m
• ○ #4/0 Bare Copper	9,043 m	10,918 m	10,918 m
• Lighting			
○ Wall Fixtures	590	712	712
○ Emergency Light	196	237	237
<u>Units</u> cfm cubic feet per minute cy cubic yards ft feet	gpm gallon per minute hp - hoursepower k thousand gal gallon	m meter t short ton	

Notes:

1) Electrical systems increase with the lengths of excavation; therefore, the Intermediate and Low thermal cases show greater numbers than does the High Case.

6.1.2 DEVELOPMENT OF EMPLACEMENT AREAS

6.1.2.1 Staffing

Subsurface staffing includes all subsurface related workers regardless of whether their normal location of employment is underground or on surface. No distinction is made between operating contractor and subcontractor classification. The only distinction is made between craft and managerial. Construction activities occurring after the start of the Emplacement Phase are included in this category beginning in year 2010. Staffing involved with waste emplacement operations is addressed in Section 6.1.3.

Table 6.1.2.1-1. Development of Emplacement Areas Period Staffing

Personnel	**Subject**	High Base Case 22 years	Intermediate Case 22 years	Low Thermal Case 22 years
Managerial:	Peak number of workers:	105	105	105
	Average number of workers:	76	76	76
Craft:	Peak number of workers:	361	361	361
	Average number of workers:	283	283	297
Total	Peak number of workers:	466	466	466
Personnel:	Average number of workers:	359	359	373

Notes:

1) Staffing in the Low thermal case reflects the need for development of internal ramps, a shaft, mains, and exhaust mains in both the Lower Block and Area 5.

6.1.2.2 Resources Consumed

Development operations utility systems are not currently engineered. Quantities listed below are summarized from several conceptual cost estimating calculations. The total electrical power shown in the table below includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment (trolley locomotives, emplacement drift TBM's, etc.). Of the total power expended during the Development phase, approximately 39% is used for TBM's to drive emplacement drifts, 38% for primary stationary equipment, and 23% for numerous mobile and stationary equipment distributed throughout the underground repository.

Fuel and Lubricants are consumed in both surface (activities associated with underground) and underground operations. Fuels including diesel and gasoline are consumed by surface equipment only. This equipment includes earth moving, transport, and personnel vehicles. Lubricants are used in both surface and underground equipment. Grease is the only lubricant considered to be consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Table 6.1.2.6-1.

Table 6.1.2.2-1. Resources Consumed during Development

	Thermal Loading Case		
Item	High Thermal 22 years	Intermediate 22 years	Low Thermal 22 years
Aggregate (mt)	421,000	479,000	1,661,000
Cement (mt)	167,000	190,000	659,000
Chemicals			
•Conc. Additive (mt)	4,000	4,800	16,700
Electrical Power			
•Total ('000)(mwh)	653.4	885.5	2,212.0
• Peak (kw)	19,405	19,405	19,405
Fuel, Lubricants			
•Diesel ('000 liters)	7,200	7,200	61,000
•Gasoline ('000 liters)	100	100	200
•Oil ('000 liters)	11,200	12,900	22,000
•Grease ('000 kgs)	400	500	1,000
Sand (mt)	326,000	371,000	1,288,000
Steel			
•Cutters (mt)	51	60	142
•Drill Bits & Steel (mt)	2	3	4
Water (million liters)			
•Potable	460.0	460.0	480.2
•Concrete Additive	617.2	704.1	2,636.6
•Dust Suppression	1,341.0	1615.9	5,498.4
• Total (million liters)	2,418.2	2,780.0	8,615.2
•Peak Use (liters/hr)	19,000	22,000	73,000

Units:

hr	hour	mkwh	megailowatt hours
kg	kilograms	mt	metric tons
kw	kilowatts	'000	one thousand

Notes:

1) Quantities listed in the table relate only to the development operations (starting January 2010) during the Emplacement Phase. Waste emplacement operations quantities are addressed in Section 6.1.3.

2) The significant increase in materials consumed noted in the Low Thermal Case result from the development of the Lower Block and Area 5.

6.1.2.3 Materials Installed

Materials installed relate to opening lining, inverts, trolleys, etc. Table 6.1.2.3-1 lists these materials under appropriate units.

Table 6.1.2.3-1. Materials Installed During Development

	Thermal Loading Case		
Item	High thermal 22 years	Intermediate 22 years	Low Thermal 22 years
Concrete (m^3)			
•Concrete Materials	70,700	106,300	595,600
•Invert	1,700	7,500	31,800
•Pre-cast Liner	337,500	354,600	1,002,600
•Grout	9,100	9,600	27,200
Total (m^3)	419,000	478,000	1,657,200
Copper (mt)	100	100	900
Steel (mt)			
•Fibers	3,900	4,900	34,100
•Lagging	300	1,100	19,800
•Piping	1,000	1,900	22,200
•Rock Bolts	200	400	3,000
•Sets	200	1,000	14,000
•Track & Accessories	42,200	47,200	186,600
•Trolley Accessories	<100	<100	200
•Vent Ducting	41,400	81,400	330,000
•Vent Raise Structure	300	300	300
•Welded Wire	100	200	400
Total (mt)	89,700	138,500	610,800
Units m^3 - cubic meter, mt - metric ton			

Notes:

1) The significant increase in installed materials in the Low Thermal Case directly relates to the development of the Lower Block. The relatively smaller increases in the Intermediate Case relate to the modified layout.

6.1.2.4 Underground Openings Excavated

Table 6.1.2.4-1. Development Excavation for the Three Thermal Cases

	High Base Thermal Load (22 years)		Intermediate (22 years)		Low Thermal Load (22 years)	
Description	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)
Main Drifts & Ramps 7.62m	0	0	0	0	46,044	2,103,000
Main Drifts - Other Misc. Excavations	0	0	0	0	1,467	170,000
P.C. Drifts - Launch Main	0	0	0	0	7,321	429,000
Chambers, vent raises, alcoves & Misc	0	0	0	0	6,806	139,000
PC Drifts	4,978	118,000	6,046	144,000	16,739	398,000
Vent/Exploration 5.5 m	0	0	2,870	46,000	11,643	292,000
Misc. Ventilation		42,000	127	1,000	481	31,000
Other Alcoves			298	21,000	2,175	87,000
Shafts (6.7 m Dia.)						
Development Intake (DS1)	0	0	0	0	0	0
Development Intake (DS2)	0	0	0	0	611	22,000
Emplacement Intake (ES3)	0	0	0	0	490	17,000
Emplace. Exhaust (ES1)	0	0	0	0	0	0
Emplace. Exhaust (ES2)	0	0	0	0	490	17,000
Shaft Connector Drifts	0	0	0	0	400	20,000
Emplacement Drifts	100,580	2,381,000	101,715	2,722,000	275,143	6,538,000
Turnouts, raises	6,900	313,000	10,084	505,000	25,454	1,455,000
Totals		2,854,000		3,439,000		11,701,000

Notes:

1) Main accesses and ramps three additional shafts are only excavated in the Low Thermal Case because the required emplacement area requires the use of the Lower Block and Area 5. To allow sufficient emplacement side ventilation air in the Low

Thermal Case, an Emplacement Intake Shaft (ES-3) is included in the development operations.

2) To provide performance confirmation access to the Lower and Area 5, additional excavation is included in the Low Thermal Case.

6.1.2.5 Rock Stockpiled at Surface

All rock volumes expressed in the following table are loose. Data is based on mined volumes expanded dividing the excavated volume by 0.75. This recognizes 33% voids in the broken rock.

Table 6.1.2.5-1. Development of Emplacement Areas Period Stockpile Activity

Stockpile Status	Base Case 22 years	Intermediate Case 22 years	Low Thermal Case 22 years
Mined rock existing in stockpile (loose cubic meters)	2,037,000	2,483,000	2,483,000
Mined rock placed into stockpile (loose cubic meters)	3,805,000	4,585,000	15,601,000
Rock removed from stockpile (loose cubic meters)	0	0	0
Rock in stockpile at end of phase (loose cubic meters)	5,842,000	7,068,000	18,084,000

6.1.2.6 Wastes Generated

Table 6.1.2.6 –1 shows waste products from the continuing emplacement area development through its estimated period of activity.

Table 6.1.2.6-1. Development of Emplacement Areas Period Waste

Waste Material	Base Case 22 years	Intermediate Case 22 years	Low Thermal Case 22 years
Hydrocarbons (lubricants & fluids) (total for period) (liters)	11,204,000	12,900,000	34,840,000
Solid wastes (landfill) (m^3/year)	500	500	1,400
Solid wastes (recyclable) (m^3/year)	1,400	1,400	3,500
Sanitary waste (liters/year)	16,985,000	16,985,000	17,648,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

6.1.2.7 Emissions and Effluents

Table 6.1.2.7-1. Development of Emplacement Area Period Emissions and Effluents

Material	Base Case 22 years	Intermediate Case 22 years	Low Thermal Case 22 years
Diesel Exhaust (surface area) (cubic meters/year)	83,800,000	83,800,000	83,800,000
Dust (controlled to be less than) (short tons/year)	250	250	250
Water (assumed to be discharged) (liters/year)	7,900,000	9,500,000	32,500,000

6.1.2.8 Equipment

Table 6.1.2.8-1. Equipment Acquired during Development (22 years)

Unit	Number	Unit	Number
Concrete Handling	High/Int/Low	Surface Mobil	High/Int/Low
Concrete Batch Plant	1/1/2	Bobcat Loader	3/3/4
Concrete Pump (elec.)	1/1/2	Drill Jumbo	4/4/4
Grout Mixer & Pump	1/1/2	Pickup Truck (3/4 t)	4/4/6
Mixer Truck	3/3/5	Flatbed Truck (10 t)	4/4/6
		Forklift (4 t) & (6-7½ t)	3/3/3
		Grader (Cat 12G)	1/1/2
		Hydraulic Crane (15 t)	3/3/3
		L.B. Transport	1/1/1
		Loader & Scraper (34cy-twin)	1/1/2
Excavation & Support	High/Int/Low	Material Handling	High/Int/Low
TBM (5.5 m) (elect.)	2/2/2	Muck Dump	2/2/2
TBM (7.62m) (elect.)	0/0/1	Radial Stacker (60hp)	3/3/3
Ring Turner	1/2/2		
Mesh Roller	5/5/7	Water Handling	
Vibrating Compactor	4/6/6	Cent. Pump (500 gpm)	9/9/9
Rail Haulage	High/Int/Low	Ventilation Equipment	High/Int/Low
Agitator Car	3/4/4	Devel. Fan (2,000 hp)	2/4/6
Man Trip (bat)	6/6/6	Isolation Barrier	194/all
Locomotive (Diesel)	4/4/6	Filter Fan (1000 hp)	8/10/15
Locomotive (Batt-10t)	3/4/6	150 hp Vent Fan	30/36/36
Locomotive (Trly-25t)	16/22/24	40 cfm Mble Scrubber	12/12/14
Locomotive (30t)	1/2/3	100 cfm Mble Scrubber	12/12/14

Unit	Number	Unit	Number
Rubber-Tired Haulage	High/Int/Low	Miscellaneous	High/Int/Low
Scooptram (2 cy-elect)	1/2/2	Welder (300 amp-diesel)	1/1/1
Scooptram (6cy-elect)	4/6/8	Welder (300 amp-elect)	2/2/2
		Platform Lift (Elect)	6/6/8
		Compressor (1500 cfm)	½/2/3
		Compressor (3000 cfm)	2/2/4

Units
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

	Thermal Loading Case		
Unit	High	Intermediate	Low Thermal Load
Electrical Systems			
Primary Equipment			
• 15 KV Pwr Center	2	2	2
• 12.5 KV/480V PC	27	38	89
• 480/20V PC	27	38	89
Power Cables			
• 15 KV 500 MCM	8,316 m	15,276 m	46,200 m
• 15 KV #4/0	29,786 m	41,802 m	111,100 m
• 600 V # 8 AWG	14,893 m	20,901 m	55,600 m
• #4/0 Bare Copper	14,893 m	20,901 m	55,600 m
Lighting			
• Wall Fixtures	971	1,363	3,121
• Emergency Light	323	454	1,040

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6.1.3 EMPLACEMENT OPERATIONS

6.1.3.1 Staffing

Personnel listed are part of the waste package emplacement activities. The approximate years of Base (VA) Emplacement Operating Phase activity are 2010 to 2033. The emplacement activities are driven by the waste receipt schedule and thermal loading has little effect on the emplacement operations. No staffing differentials are noted between thermal loading cases.

Table 6.1.3.1-1. Emplacement Phase Staffing

Personnel	Subject	Base Case 24 years	Intermediate Case 24 years	Low Thermal Case 24 years
Managerial:	Peak number of workers:	16	16	16
	Average number of workers:	16	16	16
Craft:	Peak number of workers:	74	74	74
	Average number of workers:	74	74	74
Total	Peak number of workers:	90	90	90
Personnel:	Average number of workers:	90	90	90

Notes:

All Base (VA) cases of waste inventory use essentially the same methods and operating concept for emplacement, therefore staffing is similar.

6.1.3.2 Resources Consumed

Quantities listed in Table 6.1.3.2-1 are summarized from cost estimating calculations. The total electrical power shown in the table below includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment (trolley locomotives, waste transporters, and service units). Of the total power expended during the Emplacement phase, approximately 81% is for primary stationary equipment and 19% for numerous mobile and stationary equipment distributed throughout the underground repository. Fuels are not expended for Emplacement Phase activities. Lubricants are used in underground equipment only. Grease is the only lubricant considered consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Table 6.1.3.6-1.

Table 6.1.3.2-1. Resources Consumed during Emplacement

	Thermal Loading Case		
Item	Base High Case 24 years	Intermediate Case 24 years	Low Thermal Case 24 years
Aggregate (mt)	<1,000	1,000	2,000
Cement (mt)	400	600	600
Chemicals			
•Concrete Additives (mt)	≤ 1	≤ 1	≤ 1
Electrical Power			
•Total ('000)(mwh)	460.0	460.0	497.1
•Peak (kw)	7,734	7,734	7,734
Fuel, Lubricants			
•Diesel ('000 liters)	500	500	500
•Oil ('000 liters)	2,900	3,000	3,000
•Grease ('000 kgs)	100	100	100
Sand (mt)	900	1,100	1,200
Water (million liters)			
•Potable	68.4	68.4	68.4
•Concrete Additive	1.6	1.8	2.4
Total	70.0	70.2	70.8
•Peak Use (liters /hr)	1,500	1,500	1,600

Units

hr	hour	mwh	megawatt hours
kg	kilograms	mt	metric tons
kw	kilowatts	'000	one thousand

NOTES:

1) Concrete materials allocated for the emplacement operations tables are for fabrication of the "shadow" shields installed as part of the emplacement operations. See Section 6.1.3.3-1 below.

6.1.3.3 Materials Installed

Table 6.1.3.3-1. Materials Installed during Emplacement

	Thermal Loading Case		
Item	High Base Case 24 years	Intermediate Case 24 years	Low Thermal Case 24 years
Concrete • Shadow Shields (m^3)	1,000	1,000	2,000

Units
m^3 - cubic meter

Notes:

1) All construction/development activities related to emplacement operations are addressed in the Construction Phase (Sec. 6.1.1) and development operations (Sec. 6.1.2). The shadow shields noted above are fabricated outside the emplacement operating area, but installed as part of the emplacement operation.

6.1.3.4 Underground Openings Excavated

No underground openings will be excavated by the waste package emplacement operations. See Section 6.1.2.4 for development operations during the Emplacement Phase time period.

6.1.3.5 Rock Stockpiled at Surface

No rock stockpile activities will be performed by the waste package emplacement operations. See Section 6.1.2.5 for stockpile activities during the Emplacement Phase time period

Table 6.1.3.5-1. Emplacement Phase Stockpile Activity (24 years)

Stockpile Status	**High Base Case m^3**	**Intermediate Case m^3**	**Low Thermal Case m^3**
Mined rock existing in stockpile	5,842,000	7,068,000	18,084,000
Mined rock placed into stockpile	0	0	0
Rock removed from stockpile	0	0	0
Rock in stockpile at end of phase	5,842,000	7,068,000	18,084,000

6.1.3.6 Waste Generated

Table 6.1.3.6-1. Emplacement Phase

Waste Material	Base Case 24 years	Intermediate Case m³ 24 years	Low Thermal Case m³ 24 years
Hydrocarbons (lubricants.& fluids) (total for phase) liters	2,900,000	3,000,000	3,000,000
Solid wastes (landfill) m^3/year	184	184	184
Solid wastes (recyclable) m^3/year	462	462	462
Sanitary waste liters/year	4,258,000	4,258,000	4,258,000
Low-level nuclear waste m^3/year	0	0	0
RCRA waste m^3/year	0	0	0

6.1.3.7 Emissions and Effluents

No emissions or effluents are allocated to waste emplacement operations. Emplacement operations take place underground with electric powered equipment. Diesel allocated to these operations is only incidental.

6.1.3.8 Equipment

Table 6.1.3.8-1. Equipment Acquired during Emplacement for all Cases (24 years)

Unit	Number	Unit	Number
Rail Haulage		Ventilation Equipment	
•Flat Car (10 t)	2	•Emplacement. Fan	2
•Gantry (Empl)	3	•Filter Fan	6
•Gantry Transport Car	2	•HEPA (Main)	4
•Inspection Gantry	2	•HEPA (Mobile)	2
•Locomotive (Empl)	4		
•Locomotive (Trly-25t)	2		
•Man Trip (bat)	6		
•Transport (Empl)	3		
•Vacuum Car	1		
Miscellaneous		Water Handling	
•Platform Lift (Elect)	6	•Cent. Pump (500 gpm)	6

Units: cfm = cubic feet per minute, cy = cubic yards, ft = feet; gal = gallon, gpm = gallon per minute, hp = horsepower; k = thousand, m = meter, t = short ton

6.1.4 MONITORING PHASE

The nature of the period of repository operation, between the emplacement of the final waste package and the initiation of the Closure Phase, was modified in 1998. In previous work this was known as the "Caretaker" Phase. With the VA, this became known as the "Monitoring" Phase. Since Rev 00 of the Subsurface Engineering File was issued in December of 1997, alternative periods for the Monitoring Phase have been recommended for EIS evaluation. These periods are 100 and 300 years starting at the emplacement of the first waste package in 2010. An Addendum B was issued in January 1998 addressing the 100-year alternative derived data which was included in the 25 MTU/acre work. Each of the three periods: 50, 100 and 300 are herein addressed. The changes to the engineering file created by the Addendum B are new to this Rev 01.

6.1.4.1 Staffing

All staffing in the Monitor Phase in considered to be employed by the operating contractor. These data are derived from the VA cost estimate and are new to this Rev 01. The Monitor Phase staffing is assumed to begin in year 2034 and end in each of the following years: 2059, 2109, and 2309 for the VA inventory cases.

Table 6.1.4.1-1. Monitor Phase Staffing

Personnel	**Subject**	Base Case 26, 76 & 276 years	Intermediate Thermal Case 26, 76 & 276 years	Low Thermal Case 26, 76 & 276 years
Managerial:	Peak number of workers:	13	13	13
	Average number of workers:	13	13	13
Craft:	Peak number of workers:	69	69	76
	Average number of workers:	69	69	76
Total	Peak number of workers:	82	82	89
Personnel:	Average number of workers:	82	82	89

6.1.4.2 Resources Consumed

Caretaker utility systems are not currently engineered. Quantities listed below are summarized from several conceptual cost estimating calculations. The total electrical power shown in the table below includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment (service units). Of the total power expended during the Emplacement phase, approximately 81% for primary stationary equipment and 19% for numerous mobile and stationary equipment distributed throughout the underground repository.

Fuel is expended for surface material handling and general service equipment only. Lubricants are used in both surface and underground equipment. Of the lubricants, grease is considered consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Tables 6.1.4.6-1a-c.

Table 6.1.4.2-1a. Resources Consumed during Monitor (26 years)

	Thermal Loading Case		
Item	High Base Case (26 years)	Intermediate Case (26 years)	Low Thermal Case (26 years)
Electrical Power			
•Total ('000)(mwh)	676.6	810.8	1,213.2
•Peak (kw)	7,734	7,734	7,734
Fuel, Lubricants			
•Diesel ('000 liters)	800	800	800
•Oil ('000 liters)	3,100	4,200	4,200
•Grease ('000 kgs)	100	200	200
Water			
•Potable (million liters)	40.9	40.9	44.4
•Total (million liters)	40.9	40.9	44.4
•Peak Use (liters/hr)	2,300	2,700	2,700

Notes
kg kilograms mwh megawatt hours
kw kilowatts '000 one thousand

Table 6.1.4.2-1b. Resources Consumed during Monitor (76 years)

	Thermal Loading Case		
Item	High Base Case (76 years)	Intermediate Case (76 years)	Low Thermal Case (76 years)
Electrical Power			
•Total ('000) (mwh)	1,975.7	2,367.5	3,542.5
•Peak (kw)	7,734	7,734	7,734
Fuel, Lubricants			
•Diesel ('000 liters)	2,300	2,300	2,300
•Oil ('000 liters)	9,052	12,300	12,300
•Grease ('000 kgs)	300	600	600
Water			
•Potable (million liters)	119.5	119.5	129.7
•Total (million liters)	119.5	119.5	129.7
•Peak Use (liters/hr)	2,300	2,700	2,700
Notes kg kilograms mwh megawatt hours kw kilowatts '000 one thousand			

Notes:

1) Factor used for resources consumed assumed = 76/26 years = 2.92

Table 6.1.4.2-1c. Resources Consumed during Monitor (276 years)

	Thermal Loading Case		
Item	High Base Case (276 years)	Intermediate Case (276 years)	Low Thermal Case (276 years)
Electrical Power			
•Total ('000)(mwh)	7,172	8,594.5	12,859.9
•Peak (kw)	7,734	7,734	7,734
Fuel, Lubricants			
•Diesel ('000 liters)	8,480	8,480	8,480
•Oil ('000 liters)	32,860	44,520	44,520
•Grease ('000 kgs)	1,060	2,120	2,120
Water			
•Potable (million liters)	433.9	433.9	471.1
•Total (million liters)	433.9	433.9	471.1
•Peak Use (liters/hr)	2,300	2,700	2,700
Notes kg kilograms mwh megawatt hours kw kilowatts '000 one thousand			

Notes:

1) Factor used for resources consumed assumed = 276/26 years = 10.6

6.1.4.3 Materials Installed

No planned installation of materials is defined for the Monitoring Phase.

6.1.4.4 Underground Openings Excavated

No underground excavations are planned as part of monitoring operations.

6.1.4.5 Rock Stockpiled at Surface

No storage or recovery of mined rock is planned for the Monitor Phase.

Table 6.1.4.5-1. Monitor Phase Stockpile Activity (26, 76 & 276 years)

Stockpile Status	Base High Case m^3	Intermediate Case m^3	Low Thermal Case m^3
Mined rock existing in stockpile	5,842,000	7,068,000	18,084,000
Mined rock placed into stockpile	0	0	0
Rock removed from stockpile	0	0	0
Rock in stockpile at end of phase.	5,842,000	7,068,000	18,084,000

6.1.4.6 Wastes Generated

Table 6.1.4.6-1a. Monitoring Phase (26 years)

Waste Material	Base Case (26 years)	Intermediate Case m^3 (26 years)	Low Thermal Case m^3 (26 years)
Hydrocarbons (lubricants & fluids) (total for phase) (liters)	3,100,000	4,200,000	4,200,000
Solid wastes (landfill) (m^3/year)	200	200	200
Solid wastes (recyclable) (m^3/year)	400	400	400
Sanitary waste (liters/year)	3,880,000	3,880,000	4,211,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

Table 6.1.4.6-1b. Monitoring Phase (76 years)

Waste Material	Base Case (76 years)	Intermediate Case m^3 (76 years)	Low Thermal Case m^3 (76 years)
Hydrocarbons (lubricants & fluids) (total for phase) (liters)	9,052,000	12,264,000	12,264,000
Solid wastes (landfill) (m^3/year)	200	200	200
Solid wastes (recyclable) (m^3/year)	400	400	400
Sanitary waste (liters/year)	3,880,000	3,880,000	4,210,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

Notes:

1) Factor used for resources consumed assumed = 76/26 years = 2.92

Table 6.1.4.6-1c. Monitoring Phase (276 years)

Waste Material	Base Case (276 years)	Intermediate Case m^3 (276 years)	Low Thermal Case m^3 (276 years)
Hydrocarbons (lubricants & fluids) (total for phase) liters	32,860,000	44,520,000	44,520,000
Solid wastes (landfill) m^3/year	200	200	200
Solid wastes (recyclable) m^3/year	400	400	400
Sanitary waste liters/year	3,880,000	3,880,000	4,210,000
Low-level nuclear waste m^3/year	0	0	0
RCRA waste m^3/year	0	0	0

Notes:

1) Factor used for resources consumed assumed = 276/26 years = 10.6

6.1.4.7 Emissions and Effluents

Table 6.1.4.7-1. Monitor Phase Emissions and Effluents (26, 76 & 276 years)

Material	Base Case	Intermediate Case	Low Thermal Case
Diesel Exhaust (surface area) cubic meters/year	400,000	400,000	400,000
Dust (controlled to be less than) short tons/year	250	250	250
Water (assumed to be discharged) liters/year	not determined	not determined	not determined

6.1.4.8 Equipment

Table 6.1.4.8-1a. Equipment Acquired during Monitor Period (26 years)

Unit	**Number**	**Unit**	**Number**
Rail Haulage		Surface Mobil	
•Flat Car (10 t)	6	•Flatbed Truck (10 t)	2
•Gantry Transport Car	2	•Forklift (4 t)	1
•Inspection Gantry	2	•Grader (Cat 12G)	1
•Locomotive (Trly-25t)		•Hydraulic Crane (15 t)	1
• ○ High	1	•Transport Trailer (L.B.)	1
• ○ Intermediate & Low	4	•Water Truck (3,300 gal)	1
•Man Trip (bat)	4		
•Vacuum Car	1		

Unit	Number	Unit	Number
Miscellaneous		Ventilation Equipment	
•Compressor (1,500 cfm)	2	•Develop. Fan (2,000 hp)	2
•Platform Lift (Elect)	10	•Emplace Fan (2,000 hp)	2
		•Filter Fan	8
		•Mobile Scrubber	10
		•Mobile Scrubber	10
Water Handling			
•Cent. Pump (500 gpm)	6		

Note
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

Table 6.1.4.8-1b. Equipment Acquired during Monitor Period (76 years)

Unit	Number	Unit	Number
Rail Haulage		Surface Mobil	
•Flat Car (10 t)	18	•Flatbed Truck (10 t)	6
•Gantry Transport Car	6	•Forklift (4 t)	3
•Inspection Gantry	6	•Grader (Cat 12G)	3
•Locomotive (Trly-25t)		•Hydraulic Crane (15 t)	3
• ○ High	3	•Transport Trailer (L.B.)	3
• ○ Intermediate & Low	12	•Water Truck (3,300 gal)	3
•Man Trip (bat)	12		
•Vacuum Car	3		
Miscellaneous		Ventilation Equipment	
•Compressor (1,500 cfm)	6	•Devel. Fan (2,000 hp)	6
•Platform Lift (Elect)	30	•Empl. Fan (2,000 hp)	6
		•Filter Fan	24
		•Moble Scrubber	30
		•Moble Scrubber	30
Water Handling			
•Cent. Pump (500 gpm)	18		

Note
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

Note:

1) Assume that equipment must be replaced three times the 26-year case.

Table 6.1.4.8-1c. Equipment Acquired during Monitor Period (276 years)

Unit	Number	Unit	Number
Rail Haulage		Surface Mobil	
•Flat Car (10 t)	60	•Flatbed Truck (10 t)	20
•Gantry Transport Car	20	•Forklift (4 t)	10
•Inspection Gantry	20	•Grader (Cat 12G)	10
•Locomotive (Trly-25t)		•Hydraulic Crane (15 t)	10
• ○ High	10	•Transport Trailer (L.B.)	10
• ○ Intermediate & Low	40	•Water Truck (3,300 gal)	10
•Man Trip (bat)	40		
•Vacuum Car	10		
Miscellaneous		Ventilation Equipment	
•Compressor (1,500 cfm)	20	•Develop Fan (2,000 hp)	20
•Platform Lift (Elect)	100	•Emplace Fan (2,000 hp)	20
		•Filter Fan	80
		•Mobile Scrubber	100
		•Mobile Scrubber	100
Water Handling			
•Cent. Pump (500 gpm)	60		

Note
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

Note:

1) Assume that equipment must be replaced 10 times the 26-year case.

6.1.5 WASTE RETRIEVAL

The period of time required to retrieve all waste packages is restricted by the surface waste handling operations capabilities to process the retrieved waste packages and ship them to their new destination. At the rate of four waste packages processed per working day, it is assumed, based on the Surface Facilities processing capacity (CRWMS M&O 1998e, p. I-5). The surface facility would process the entire base-case inventory in 10 years; therefore, the subsurface retrieval operations must accommodate that rate. The subsurface data is based on a retrieval operating period of 11 years to account for preparations and other contingencies.

6.1.5.1 Staffing

Staffing in the retrieval operation is considered to employ both the operating contractor and subcontractors.

Table 6.1.5.1-1. Retrieval Operations Staffing

Personnel	Subject	Base Case Personnel 11 years	Intermediate Thermal Case 11 years	Low Thermal Case 11 years
Managerial:	Peak number of workers:	16	16	16
	Average number of workers:	16	16	16
Craft:	Peak number of workers:	74	74	76
	Average number of workers:	74	74	76
Total	Peak number of workers:	90	90	92
Personnel:	Average number of workers:	90	90	92

Notes:

1) For this engineering file, it is assumed that waste retrieval begins immediately following emplacement of the final waste package.

2) Because retrieval removes all waste packages, there is no Monitor Phase. Closure operations begin with completion of retrieval.

6.1.5.2 Resources Consumed

The total electrical power shown in the table below includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment. The total power is not differentiated during the Waste Retrieval Phase.

Fuel is expended for surface service equipment only during the Waste Retrieval Phase. Lubricants are used in surface and underground equipment. Of the lubricants, grease is considered consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Table 6.1.5.6-1.

Table 6.1.5.2-1. Resources Consumed during Waste Retrieval (11 years)

	Thermal Loading Case		
Item	High	Intermediate	Low
Electrical Power			
•Total ('000)(mwh)	270.8	330.9	521.2
•Peak (kw)	7,734	7,734	7,734
Fuel, Lubricants			
•Diesel ('000 liters)	300	300	300
•Oil ('000 liters)	2,200	2,200	2,300
•Grease ('000 kgs)	100	100	100
Water			
•Potable (million liters)	65	65	66
•Total (million liters)	65	65	66
•Peak Use (liters/hr)	2,100	2,100	2,100

Notes
kg kilograms mwh megawatt hours
kw kilowatts '000 one thousand

6.1.5.3 Materials Installed

No materials are planned to be installed underground during the operation of waste package retrieval.

6.1.5.4 Underground Openings Excavated

No underground openings are planned for excavation during waste retrieval operations.

6.1.5.5 Rock Stockpiled at Surface

No storage or recovery of mined rock from the stockpile will be done during the waste retrieval operations.

Table 6.1.5.5-1. Retrieval Operations Stockpile Activity (11 years)

Stockpile Status	Base Case m^3	Intermediate Case m^3	Low Thermal Case m^3
Mined rock existing in stockpile	5,842,000	7,068,000	18,084,000
Mined rock placed into stockpile	0	0	0
Rock removed from stockpile	0	0	0
Rock in stockpile at end of phase	5,842,000	7,068,000	18,084,000

6.1.5.6 Waste Generated

Table 6.1.5.6-1. Waste Retrieval Phase

Waste Material	Base Case 11 years	Intermediate Case m^3 11 years	Low Thermal Case m^3 11 years
Hydrocarbons (lubricants. & fluids) (total for phase) (liters)	2,300,000	2,300,000	2,300,000
Solid wastes (landfill) (m^3/year)	300	300	300
Solid wastes (recyclable) (m^3/year)	800	800	800
Sanitary waste (liters/year)	4,258,000	4,258,000	4,352,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

6.1.5.7 Emissions and Effluents

Table 6.1.5.7-1. Retrieval Operations Emissions and Effluents (11 years)

Material	Base Case	Intermediate Case	Low Thermal Case
Diesel Exhaust (surface area) (cubic meters/year)	400,000	400,000	400,000
Dust (controlled to be less than) (short tons/year)	250	250	250
Water (assumed to be discharged) (liters/year)	No process water used	No process water used	No process water used

6.1.5.8 Equipment

Table 6.1.5.8-1. Equipment Acquired during Waste Retrieval (11 years)

Unit	Number	Unit	Number
Rail Haulage		Surface Equipment	
•Flat Car (10 t)	2	•Flatbed Truck (10t)	1
•Gantry (Empl)	3	•L.B. Transport	1
•Gantry Transport Car	1	•Water Truck (3,300 gal)	1
•Locomotive (Empl)	4	•Hydraulic Crane (15t)	1
•Locomotive (Trly-25t)	2	•Forklift (4t)	1
•Man Trip (bat)	4	•Grader (Cat 12G)	1
•Transport (Empl)	3		
•Vacuum Car	1		
Miscellaneous		Water Handling	
•Platform Lift (Elect)	2	•Cent. Pump (500 gpm)	3
•Compressor (1,500 cfm)	2		
Ventilation Equipment		Rubber-Tired Haulage	
•Develop. Fan (2,000 hp)	1	•Scooptram (2cy-elect)	1
•Emplace Fan (2,000 hp)	1		
•Filter Fan	4		
•40k cfm Mobile Scrubber	4		
•100k cfm Mobile Scrubber	4		
Note cfm cubic feet per minute cy cubic yards	ft feet gal gallon gpm gallon per minute		hp horsepower k thousand m meter t short ton

6.1.6 CLOSURE AND DECOMMISSIONING

6.1.6.1 Staffing

Staffing in the Closure and Decommissioning Phase is considered to be employed by both the operating contractor and subcontractors. The Closure Phase staffing is assumed to begin in year 2060 and is estimated to continue for five, eight or 15 years dependent on the thermal-load layout. The Base Case High Thermal Load in this Rev 01 of the Engineering File has been re-analyzed and reduced in period to closely coincide with the surface estimation of six years for closure. The other cases have also been revised using the same operational logic as the base case.

Table 6.1.6.1-1. Closure & Decommissioning Phase Staffing

Personnel	**Subject**	High Base Case 5 years	Intermediate Thermal Case 6 years	Low thermal Case 15 years
Managerial:	Peak number of workers:	45	45	45
	Average number of workers:	44	44	44
Craft:	Peak number of workers:	256	256	256
	Average number of workers:	218	218	218
Total	Peak number of workers:	301	301	301
Personnel:	Average number of workers:	263	263	263

6.1.6.2 Resources Consumed

The total electrical power shown in the table below includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment (service units). Of the total power expended during the Closure Phase, approximately 81% for primary stationary equipment and 19% for numerous mobile and stationary equipment distributed throughout the underground repository.

Fuel is not expended for Emplacement Phase activities. Lubricants are used in surface and underground equipment. Of the lubricants, grease is considered consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Table 6.1.6.6-1.

Table 6.1.6.2-1. Resources Consumed during Closure

Item	Thermal Loading Case		
	High Base Case 5 years	Intermediate Case 6 years	Low Thermal Case 15 years
Aggregate (mt)	1,900	2,100	4,400
Cement (mt)	800	800	1,800
Chemicals			
•Concrete Additive (mt)	≤ one mt	≤ one mt	≤ one mt
Electrical Power			
•Total ('000) (mwh)	236.5	357.2	554.5
•Peak (kw)	7,734	7,734	7,734
Fuel, Lubricants			
•Diesel ('000 liters)	1,500	3,700	7,600
•Oil ('000 liters)	1,600	3,700	5,400
•Grease ('000 kgs)	100	100	200
Sand (mt)	1,500	1,600	3,400
Steel			
•Crusher Liner (mt)	11	15	48
•Screen (mt)	1	1	3
Water			
•Potable (million liters)	55.0	66.0	165.0
•Concrete Additive	4	4	8
•Dust Suppression	249.7	328.1	795.9
• Total (million liters)	308.7	402.2	968.9
•Peak Use (liters/hr)	8,200	6,900	13,000

Units

hr	hour	mwh	megawatt hours
kg	kilograms	mt	metric tons
kw	kilowatts	'000	one thousand

6.1.6.3 Materials Installed

Materials installed as permanent features of the subsurface repository relate to closing and sealing the ramps, shafts and mains to prevent human intrusion and release of radionuclides to the accessible environment.

Table 6.1.6.3-1. Materials Installed during Closure

	Thermal Loading Case		
Item	High Base Case 5 years	Intermediate Case 6 years	Low Thermal Case 15 years
Concrete •Ready Mix (m^3)	2,000	2,000	4,000
Crushed Rock (m^3)	1,241,000	1,632,000	3,958,000
Steel •Rebar (mt)	700	900	1,900
Units m^3 cubic meter			

Notes:

1) Concrete used in closure seal construction is a relatively small amount, therefore it is assumed to come from off-site pre-mixed sources. Resources listed in Table 6.1.6.2-1 are included in this concrete.

2) All crushed rock used in closure operations comes from the surface mined rock stockpile as noted in Table 6.1.6.5-1.

3) Underground openings designated to receive closure backfill placement are listed at summary level in Appendix H.

6.1.6.4 Underground Openings Excavated

Small excavations may be made at the locations of seals. These will immediately be filled by seal structures. No volume is noted for these excavations.

6.1.6.5 Rock Stockpiled at Surface

Rock recovered from the surface mined stockpile will be used as backfill material for shafts ramps and mains. Mined rock in the stockpile at the end of closure will be re-contoured and covered by topsoil.

Table 6.1.6.5-1 Closure & Decommissioning Phase Stockpile Activity

Stockpile Status	Base Case m^3 5 years	Intermediate Case m^3 6 years	Low Thermal Case m^3 15 years
Mined rock existing in stockpile	5,842,000	7,068,000	18,084,000
Mined rock placed into stockpile	0	0	0
Rock removed from stockpile	1,242,000	1,632,000	3,958,000
Rock in stockpile at end of phase	4,600,000	5,436,000	14,126,000

6.1.6.6 Wastes Generated

Table 6.1.6.6-1 Closure & Decommissioning Phase

Waste Material	High Base Case m^3 5 years	Intermediate Case m^3 6 years	Low Thermal Case m^3 15 years
Hydrocarbons. (lubes & fluids) (Total for phase) (liters)	1,600,000	3,700,000	5,400,000
Solid waste (landfill) (m^3/year)	334	340	451
Solid waste (recyclable) (m^3/year)	833	848	1,127
Sanitary waste (liters/year)	12,443000	12,443,000	12,443,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

6.1.6.7 Emissions and Effluents

Table 6.1.6.7-1 Closure & Decommissioning Emissions and Effluents

Material	High Base Case (5 years)	Intermediate Case (6 years)	Low Thermal Case (15 years)
Diesel Exhaust (surface area) (cubic meters/year)	83,800,000	83,800,000	83,800,000
Dust (controlled to be less than)(short tons/year)	250	250	250
Water (assumed to be discharged) (liters/year)	7,000,000	7,000,000	7,000,000

6.1.6.8 Equipment

Table 6.1.6.8-1. Equipment Acquired during Closure (for 5, 6, or 15 years)

Unit	Number	Unit	Number
Concrete Handling		Miscellaneous	
•Concrete Batch Plant	0	•Platform Lift (Elect)	2
•Concrete Pump (25 cy)	1	•Compressor (diesel)	1
•Concrete Pump (60 cy)	1	•Compressor (3000 cfm)	1
•Transit Mixer	1		
Material Handling	High/Int./Low	Rail Haulage	High/Int./Low
•Backfill Placer	2/2/3	•Agitator Car	4/4/4
•Conveyor (40')	3/3/7	•Flat Car (10 t)	12/12/14
•Cone Crusher	1/1/3	•Man Trip (bat)	2/2/3
•Radial Stacker (25 hp)	1/1/3	•Muck Car (13 m^3)	2/2/2
•Scalping Screen	1/1/3	•Shuttle car (14 cy)	12/16/21
•Surge Bin (Portable)	2/3/5	•Vacuum Car	1/1/1
		•Locomotive (Diesel-25 t)	3/3/3
		•Locomotive (Trly-25t)	4/6/8
Ventilation Equipment	High/Int./Low	Surface Mobil	High/Int./Low
•Develop Fan (1750hp)	2/2/2	• End Dump Truck	2/2/5
•Filter Fan (1000hp)	2/2/2	• Flatbed Truck (10 t)	1/1/1
•Emplace Fan (2500hp)	1/1/1	• Forklift (4 t)	2/2/2
•250 hp Vent Fan	16/16/22	• Grader (Cat 12G)	1/1/1
•40 cfm Mobile Scrubber	4/4/4	• Hydraulic Crane (15 t)	2/2/2
•100 cfm Mobile Scrubber	4/4/4	• Loader (Cat 966)	2/3/5
		• Scraper (Cat 623B)	1/1/1
		• Tractor (Cat D8)	1/1/1
		• Transport Trailer (L.B.)	1/1/1
		• Water Truck (3300 gal)	1/1/3
		Water Handling	
		•Cent. Pump (500 gpm)	3

Units
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
m meter
t short ton

6.1.7 SUBSURFACE AREAL LAND USAGE

The three thermal loading cases are calculated on emplacement area defined in acres. Therefore, the subsurface areal land usage in each alternative is roughly inversely proportional to the thermal density expressed in MTU/acre. The following table lists the areas:

Table 6.1.7-1. Subsurface Areal Land Usage

Areal Land Usage	High Base Case (acres)	Intermediate Base Case (acres)	Low Base Case (acres)
Emplacement Area Needed	740	1,050	2,520

The Land used by the surface stockpile is shown in Figure 6.1.7-1 for the High and Intermediate thermal load cases. Figure 6.1.7-2 applies to the Low thermal load case only. Because of the increased excavation needed for the Low Cases, an area much larger than can be fit into the South Portal area must be used.

AREA NUMBERS	TOTAL STORAGE CAPACITIES m^3	AREA (ACRES)	STORAGE REQUIRED m^3	MTU/ACRE	DRIFT SPACING C/C
1 THRU 11	7,110,097	290	6,953,000	60	40 m
1 THRU 10	6,137,289	252	5,842,000	85	28 m

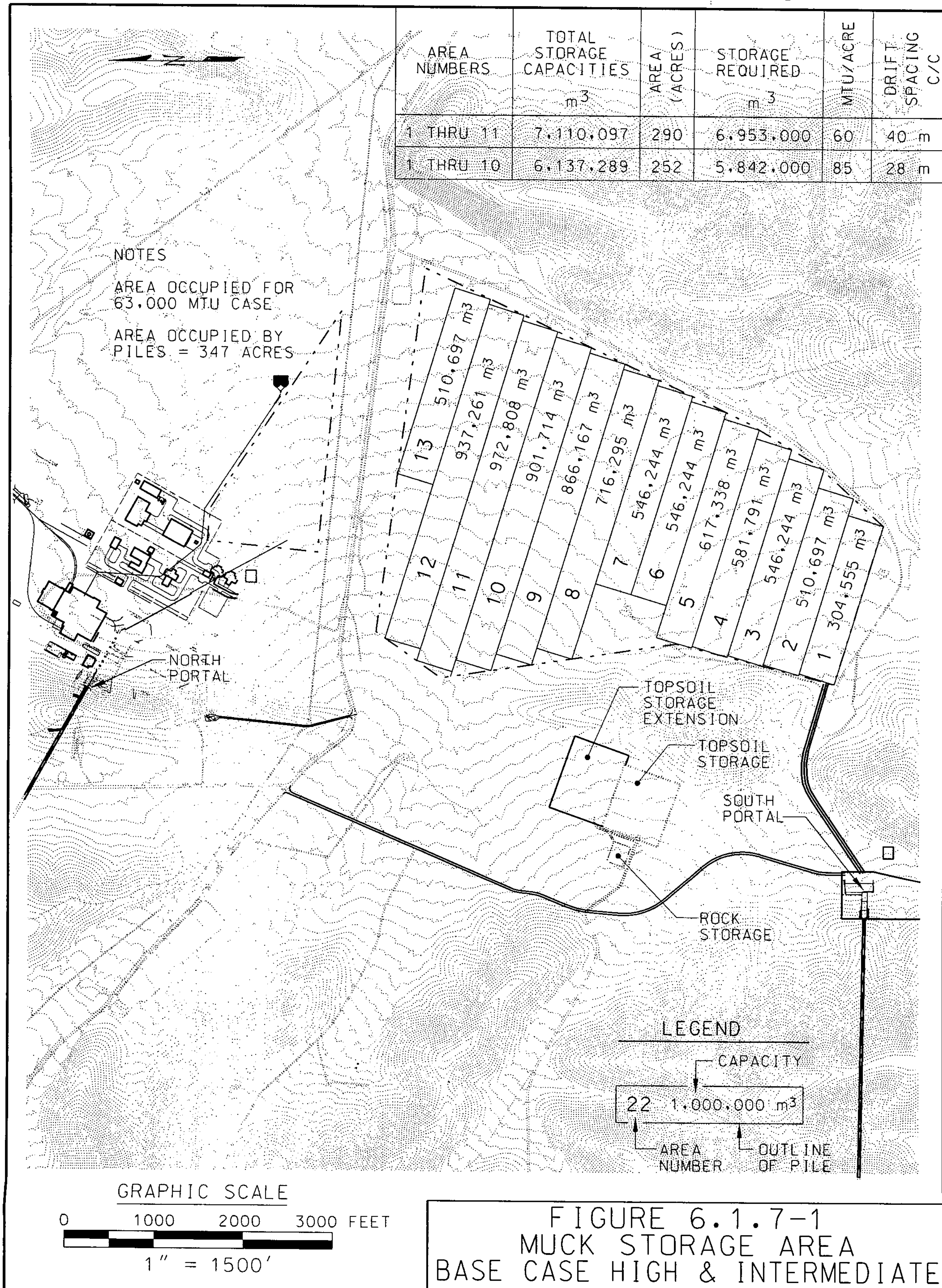

FIGURE 6.1.7-1
MUCK STORAGE AREA
BASE CASE HIGH & INTERMEDIATE

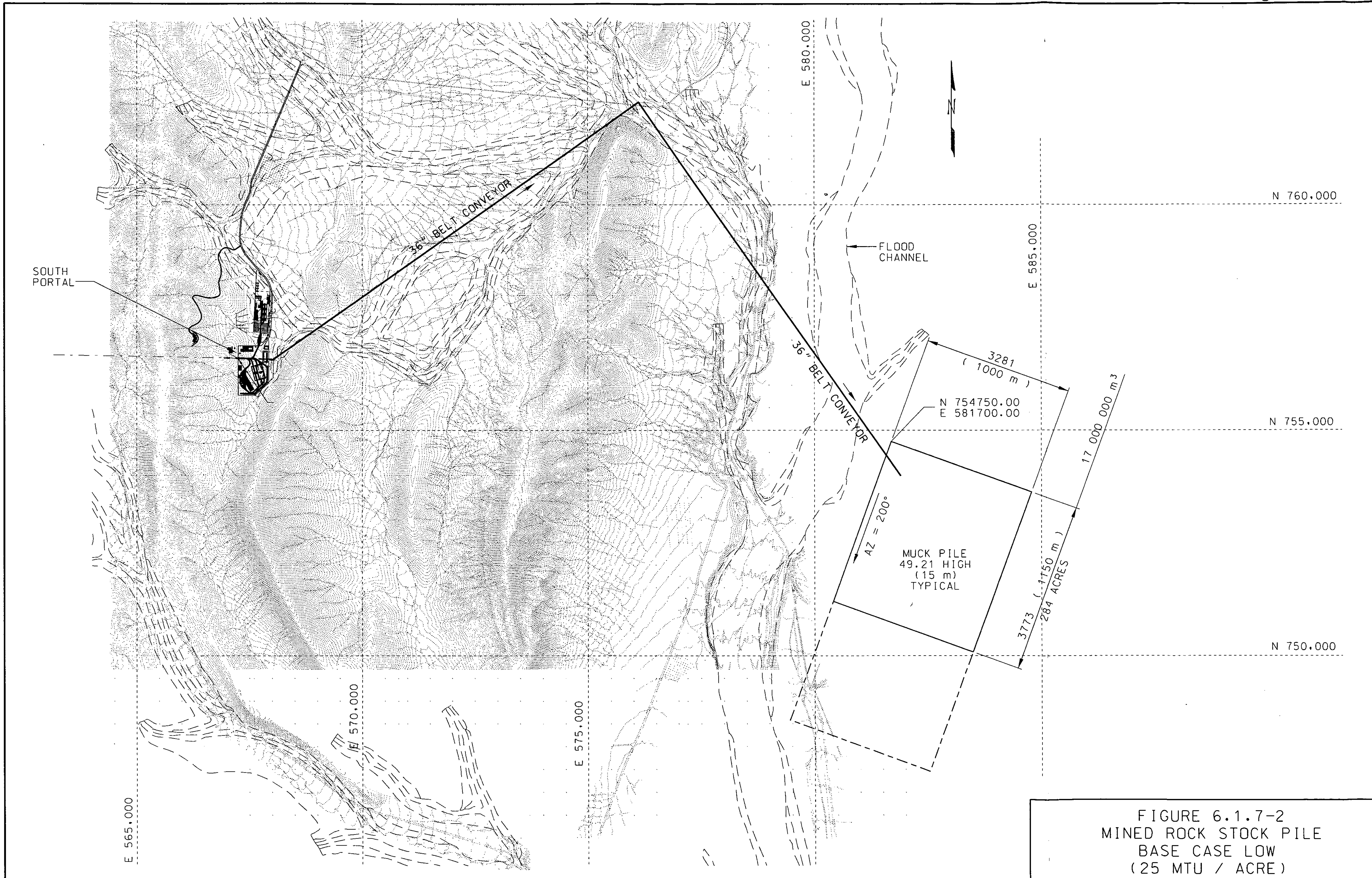

FIGURE 6.1.7-2
MINED ROCK STOCK PILE
BASE CASE LOW
(25 MTU / ACRE)

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6.2. DATA RELATED TO EXTENDED WASTE INVENTORY MODULES 1 AND 2B

As described in Section 3, Table 3.1-1, Modules 1&2b address disposal of 105,414 MTU of commercial spent nuclear fuel. Also, waste packages will be assembled to contain High Level Waste and Defense Spent Nuclear Fuel. Section 3. Table 3.1-1 lists a combined total of 17,435 waste packages to emplace. For the subsurface designs and operations, Module 1 and Module 2b are nearly identical, therefore they are considered the same in analyzing environmental data as addressed in the section.

This section follows the same overall organization and logic as Section 6.1. Descriptive material only addresses variations applicable to the subject module. The following levels of division address data important to environmental analyses. Each division is repeated for each operating phase even when inapplicable.

6.2.1 CONSTRUCTION PHASE

When comparing these extended inventory modules against the Base Cases, the only significant variation occurs in the High Base Case. The High Base Case does not require the access and exhaust mains to be as long (see Sec. 4.3). All Module 1 & 2b Cases require the extended Primary Block layout and two 7.62-meter TBMs.

6.2.1.1 Staffing

Subsurface staffing includes all workers regardless of whether their normal location of employment is underground or on surface. No distinction is made between operating contractor and subcontractor classification. The only distinction is made between craft and managerial. The approximate years of Construction Phase activity are 2004 to 2009.

Table 6.2.1.1-1. Construction Phase Staffing for Modules 1&2b

Personnel	Subject	High Thermal Case 5 years	Intermediate Case 5 years	Low Thermal Case 5 years
Managerial:	Peak number of workers:	131	131	131
	Average number of workers:	121	121	121
Craft:	Peak number of workers:	602	602	602
	Average number of workers:	491	491	491
Total	Peak number of workers:	712	712	712
Personnel:	Average number of workers:	612	612	612

Note:

1) Staffing for Modules 1&2b for the Construction Phase is similar to the Base Case inventory intermediate and low thermal loading.

6.2.1.2 Resources Consumed

Resources are consumed in producing the needed structure or facility. These resources are listed in the following table regardless of their end product.

Table 6.2.1.2-1. Resources Consumed during Construction

	Thermal Loading Case (Modules 1&2b)		
Item	High Case 5 years	Intermediate Case 5 years	Low Case 5 years
Aggregate (mt)	286,000	286,000	286,000
Cement (mt)	113,000	113,000	113,000
Chemicals			
•Concrete Additive (mt)	3,000	3,000	3,000
Electrical Power			
•Total ('000)(mwh)	231.8	231.8	231.8
•Peak (kw)	22,000	22,000	22,000
Fuel, Lubricants			
•Diesel ('000 liters)	13,400	13,400	13,400
•Gasoline ('000 liters)	100	100	100
•Oil ('000 liters)	8,000	8,000	8,000
•Grease ('000 kgs)	300	300	300
Sand (mt)	221,000	221,000	221,000
Steel			
•Cutters (mt)	33	33	33
•Drill Bits & Steel (mt)	3	3	3
Water			
•Potable (million liters)	113.5	113.5	113.5
•Concrete Additive	235.9	235.9	235.9
•Dust Suppression	323.2	323.2	323.2
Total (million liters)	672.6	672.6	672.6
•Peak Use (liters/hr)	22,600	22,600	22,600

Units
hr = hour mwh = megawatt hours
kg = kilograms mt = metric tons
kw = kilowatts '000 = one thousand

Notes:

3) No significant difference in resources consumed for the three cases, in the Construction Phase, because a similar overall subsurface layout applies.

6.2.1.3 Materials Installed

Materials that become a permanent component to the facility are listed in the following table. Some of these materials may contain resources consumed as noted in Section 6.2.1.2.

Table 6.2.1.3-1. Materials Installed during Construction

	Thermal Loading Case (Modules 1&2b)		
Item	High Case 5 years	Intermediate Case 5 years	Low Case 5 years
Concrete (m^3)			
•Concrete Materials	48,200	48,200	48,200
•Invert	19,400	19,400	19,400
•Pre-cast Liner	216,400	216,400	216,400
•Grout	1,000	1,000	1,000
Total (m^3)	285,000	285,000	285,000
Copper (mt)	100	100	100
Steel (mt)			
•Fibers	9,500	9,900	9,500
•Lagging	9,800	9,800	9,800
•Piping	5,500	5,500	5,500
•Rock Bolts	900	900	900
•Sets	4,900	4,900	4,900
•Track & Accessories	18,100	18,100	18,100
•Trolley Accessories	<100	<100	<100
•Vent Ducting	111,000	111,000	111,000
•Vent Raise Structure	<100	<100	<100
•Welded Wire	200	200	200
Total (mt)	160,100	160,100	160,100
Units: m^3 - cubic meter mt - metric ton			

6.2.1.4 Underground Openings Excavated

The extended waste inventory modules cause the subsurface repository areas to be expanded. Excavation during the Construction Phase is limited to the Primary Block. Excavation to accommodate the extended inventories is addressed in the development operations (Section 6.2.2) of the Emplacement Phase.

Table 6.2.1.4-1. Construction Phase Openings Excavation (Modules 1&2b)

	High Base Thermal (5 years)		Intermediate Thermal Load (5 years)		Low Thermal Load (5 years)	
Description	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)
Main Drifts and Ramps - 7.62 m Diameter	19,706	900,000	19,706	900,000	19,706	900,000
Main Drifts - Other Misc. Excavations	1,792	85,000	1,792	85,000	1,792	85,000
PC Access/Launch Drifts	5,180	237,000	5,180	237,000	5,180	237,000
PC Drifts	1,941	46,000	1,941	46,000	1,941	46,000
Vent raises, alcoves & Misc.	638	20,000	638	20,000	638	20,000
Crossblock/Vent. - 5.5 m diameter	7,427	91,000	7,427	91,000	7,427	91,000
Misc. Ventilation	259	14,000	259	14,000	259	14,000
Shafts (6.7 m Diameter)	--	--	--	--	--	--
Development Intake (DS1)	384	19,000	384	19,000	384	19,000
Emplacement Exhaust (ES1)	562	25,000	562	25,000	562	25,000
Shaft Connector Drifts	130	6,000	130	6,000	130	6,000
Emplacement Drifts	11,911	283,000	11,911	283,000	11,911	283,000
Turnouts, raises	1,007	50,000	1,007	50,000	1,007	50,000
Misc. Alcoves						
Totals		1,776,000		1,776,000		1,776,000

Notes:

1) "Main Drifts and Ramps" does not include lengths and volumes excavated as ESF openings.

2) These excavated volumes reflect only development of the Primary Block to be ready for initial emplacement January 2010.

3) Small changes in excavated volumes reflect differences in CD excavations.

6.2.1.5 Rock Stockpiled at Surface

Table 6.2.1.5-1. Construction Phase Stockpile Activity (Modules 1&2b)(5 years)

Stockpile Status	High Case (m^3)	Intermediate Case (m^3)	Low Case (m^3)
Mined rock existing in stockpile	0	0	0
Mined rock placed into stockpile	2,368,000	2,368,000	2,368,000
Rock removed from stockpile	0	0	0
Rock in stockpile at end of phase	2,368,000	2,368,000	2,368,000

6.2.1.6 Waste Generated

Table 6.2.1.6-1. Construction Phase Wastes (Modules 1&2b)(5 years)

Waste Material	High Case	Intermediate Case	Low Case
Hydrocarbons (lubricants & fluids) (total for phase) (liters)	8,000,000	8,200,000	8,000,000
Solid wastes (landfill) (m^3/year)	1,000	1,000	1,000
Solid wastes (recyclable) (m^3/year)	2,000	2,000	2,000
Sanitary waste (liters/year)	28,955,000	28,955,000	28,955,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

Notes:

1) Hydrocarbon wastes, from underground and South Portal equipment maintenance will go off the site to be recycled or treated for disposal.

2) Solid wastes are common garbage materials suitable for an off-site landfill or recycling.

3) Sanitary wastes flow from shower and toilet facilities and will be treated and disposed though an unspecified on site facilities.

6.2.1.7 Emissions and Effluents

Table 6.2.1.7-1. Construction Emissions and Effluents (Modules 1&2b)(5 years)

Material	High Case	Intermediate Case	Low Thermal Case
Diesel Exhaust (surface area) (cubic meters/year)	83,800,000	83,800,000	83,800,000
Dust (controlled to be less than)(short tons/year)	250	250	250
Water (assumed to be discharged) (liters/year)	8,403,000	8,403,000	8,403,000

6.2.1.8 Equipment

The following equipment is listed for information. Consumables applied to this equipment may be listed in Section 6.2.1.2 as resources consumed.

Table 6.2.1.8-1. Equipment Acquired during Construction (Modules 1&2b)(5 years)

Unit	**Number**	**Unit**	**Number**
Concrete Handling		Shaft Equipment	
• Concrete Batch Plant	1	•Head frame	2
• Concrete Pump (25 cy)	1	•Head house	2
• Grout Mixer & Pump	1	•Hoist	2
• Invert Paver	1	•Ladder (373 m/each)	2
• Mixer Truck	3		
Excavation & Support		Surface Mobil	
• Air Track Drill	1	• Bobcat Loader	2
• TBM (5.5 m)	2	• Pickup Truck (3/4 t)	2
• TBM (7.62 m)	2	• Flatbed Truck (10 t)	2
• Roadheader (48.5 t)	1	• Forklift (4 t)	1
• Roadheader (150 t)	2	• Forklift (6-7½ t)	1
• Raise Drill (8' dia.)	1	• Grader (Cat 12G)	1
• Raise Miner	1	• Hydraulic Crane (15 t)	1
• Drill Jumbo (2 boom)	2	• Hydraulic Crane (25-49 t)	1
• Ring Turner	1	• Loader	1
• Mesh Roller	1	• Scraper	2
• Vibratory Compactor	2	• Tractor	1
		• Transport Trailer	1
		• Water Truck & Wagon (7000 gal)	1

Unit	Number	Unit	Number
Rubber-Tired Haulage		Water Handling	
• Scooptram (diesel)	1	•Cent. Pump	3
Material Handling		Miscellaneous	
• Belt Conveyor		• Air Hoist (5 t)	1
○ High	8920 m	•Generator (20-50 kw)	1
○ Intermediate	8920 m	•Light Plant	1
○ Low	8920 m	•Welder (diesel)	1
•Muck Dump	2	•Welder (electric)	2
•Radial Stacker (60 hp)	1	•Work Platform	1
		•Platform Lift (Elect)	3
		•Compressor (1500 cfm)	1
		•Compressor (3000 cfm)	2
Rail Haulage		Ventilation Equipment	
•Agitator Car	6	•Filter Fan	4
•Flat Car (10 t)	12	•HEPA Filter (Main)	4
•Man Car	6	•HEPA Filter (Mobile)	2
•Man Trip (bat)	2	•Isolation Barrier	10
•Muck Car (13 m^3)	20	•Main Exhaust Fan	2
•Segment Car	10	•Main Intake Fan	2
•Vacuum Car	1	•150 hp Vent Fan	6
•Locomotive (Diesel-25 t)	3	•250 hp Vent Fan	2
•Locomotive (Diesel-30 t)	1	•40 cfm Mobile Scrubber	3
•Locomotive (Batt-10t)	1	•100 cfm Mobile Scrubber	3
•Locomotive (Trly-25t)	6		

Units

cfm	cubic feet per minute	ft	feet	hp	horsepower
cy	cubic yards	gal	gallon	k	thousand
		gpm	gallon per minute	m	meter
				t	short ton

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	Thermal Loading Cases (Modules 1&2b)(5 years)		
Unit	High Case	Intermediate Case	Low Case
Electrical Systems			
•Primary Equipment			
o 15 kv Pwr Center	2	2	2
o 12.5 KV/480V PC	16	20	20
o 480/20V PC	16	20	20
•Power Cables			
o 15 KV 500 MCM	16,150 m	9,451 m	9,451 m
o 15 KV #4/0	32,300 m	21,836 m	20,236 m
o 600 V # 8 AWG	16,855 m	10,918 m	10,918 m
o #4/0 Bare Copper	16,855 m	10,918 m	10,918 m
•Lighting			
o Wall Fixtures	590	712	712
o Emergency Light	196	237	237

6.2.2 DEVELOPMENT OF EMPLACEMENT AREAS

6.2.2.1 Staffing

Subsurface staffing includes all subsurface related workers regardless of whether their normal location of employment is underground or on the surface. No distinction is made between operating contractor and subcontractor classification. The only distinction is made between craft and managerial. Construction activities occurring after the start of the Emplacement Phase are included in this category beginning in year 2010.

Table 6.2.2.1-1. Development Period Staffing (Modules 1&2b)

Personnel	**Subject**	High Case 36 years	Intermediate Case 36 years	Low Case 36 years
Managerial	Peak number of workers:	105	105	105
	Average number of workers:	68	68	76
Craft:	Peak number of workers:	403	403	403
	Average number of workers:	253	265	288
Total	Peak number of workers:	484	484	484
Personnel:	Average number of workers:	320	333	362

Notes:

1) The duration of the operations of development are linked to providing commissioned emplacement drift panels in time for actual waste emplacement. In all three thermal cases, this duration time is based on emplacement drift excavation as the critical path. Even though the Low Thermal Case requires approximately 2.5 times more emplacement drift length than the other two cases, excavation must be completed in the estimated 36 years.

2) Staffing differences between the High and the Intermediate Cases reflect the extended requirements for 7.62-meter TBM excavations to provide access and ventilation openings. The staffing increase noted in the Low Thermal Case relates to the need for multiple 5.5-meter TBMs excavating the increased length of emplacement drifts.

6.2.2.2 Resources Consumed

Table 6.2.2.2-1. Resources Consumed During Development

	Thermal Loading Case (Modules 1&2b)		
Item	High Case 36 years	Intermediate Case 36 years	Low Thermal Case 36 years
Aggregate (mt)	870,000	1,135,000	3,183,000
Cement (mt)	345,000	451,000	1,278,000
Chemicals			
•Concrete Additive (mt)	9,000	11,000	32,000
Electrical Power			
•Total ('000)(mwh)	1,379.3	1,731.6	6,139.0
•Peak (kw)	19,000	19,000	19,000
Fuel, Lubricants			
•Diesel ('000 liters)	19,800	36,700	98,000
•Gasoline ('000 liters)	200	300	500
•Oil ('000 liters)	24,700	33,000	72,000
•Grease ('000 kgs)	1,000	1,300	2,800
Sand (mt)	674,000	879,000	2,465,000
Steel			
•Cutters (mt)	100	143	391
•Drill Bits & Steel (mt)	7	12	17
Water			
• Potable (million liters)	734.1	790.0	829.2
•Concrete Additive	1,031.6	1,340.2	3,811.0
•Dust Suppression	2,234.0	2,309.7	7,321.3
• Total (million liters)	3,999.7	4,439.9	11,961.5
•Peak Use (liters/hr)	19,000	24,000	65,000

Units

hr	hour	mwh	megawatt hours
kg	kilograms	mt	metric tons

Notes:

1) The increase in resources consumed reflects the significant increase in layout excavation in going from High to Low areal densities.

6.2.2.3 Materials Installed

Table 6.2.2.3-1. Materials Installed During Development

	Thermal Loading Case (Modules 1&2b)		
Item	High Case 36 years	Intermediate Case 36 years	Low Case 36 years
Concrete (m^3)			
•Concrete Materials	261,300	501,900	1,491,500
•Invert	14,300	34,300	86,100
•Pre-cast Liner	576,700	576,900	1,554,000
•Grout	15,700	15,700	41,900
	868,000	1,128,800	3,173,600
Copper (mt)	300	300	1,600
Steel (mt)			
•Fibers	11,800	21,600	72,200
•Lagging	8,200	19,400	83,600
•Piping	4,100	6,900	42,000
•Rock Bolts	1,100	2,200	6,000
•Sets	3,900	9,300	38,700
•Track & Accessories	82,000	101,100	390,100
•Trolley Accessories	<100	<100	200
•Vent Ducting	114,000	136,800	540,800
•Vent Raise Structure	500	600	700
•Welded Wire	300	600	1,600
Total (mt)	226,000	298,000	1,175,900
Units m^3 - cubic meter mt - metric ton			

Notes:

1) Materials installed relate directly to underground opening length. Therefore large material increases are observed by reducing the thermal densities.

6.2.2.4 Underground Openings Excavated for Modules 1&2b

Table 6.2.2.4-1. Development Excavation for the Three Thermal Cases

	High Base Thermal (36 years)		Intermediate Thermal Load (36 years)		Low Thermal Load (36 years)	
Description	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)	Length (m)	Volume (m^3)
Main Drifts – 7.62 m Dia. [1]	21,539	983,000	21,539	983,000	120,424	5,499,000
Main Drifts – Other Misc. Excavations	910	77,000	910	77,000	3,841	231,000
PC Access/Launch Drifts	3,690	168,000	3,690	168,000	15,664	715,000
PC Drifts	10,973	261,000	10,973	261,000	30,008	713,000
Vent raises, alcoves & Misc.	5,602	118,000	5,602	118,000	12,968	274,000
Cross Block Vent/Exploration - 5.5 m dia..	2,848	171,000	2,848	171,000	18,760	489,000
Misc. Ventilation	259	16,000	259	16,000	1,059	64,000
Shafts (6.7 m Dia..)	--	--	--	--	--	--
Development Intake (DS-1)	0	0	0	0	0	0
Development Intake (DS-2)	0	0	0	0	611	22,000
Emplacement Intake (ES-3)	0	0	0	0	490	17,000
Emplacement. Exhaust (ES-2)	0	0	0	0	490	17,000
Shaft Connector Drifts	270	14,000	270	14,000	400	20,000
Emplacement Drifts	179,131	4,256,000	177,539	4,218,000	466,700	11,078,000
Turnouts, raises	10,374	506,000	12,984	768,000	44,737	2,405,000
Other Alcoves	912	20,000	912	20,000	2,736	60,000
Totals		6,590,000		6,814,000		21,604,000

Notes:

1) The large variations in excavated volumes reflect the subsurface layouts for each case.

6.2.2.5 Rock Stockpiled at Surface

All rock volumes expressed in the following table are loose. Data is based on mined volumes expanded by dividing the excavated volume by 0.75 (33% swell).

Table 6.2.2.5-1. Development Period Stockpile Activity (Modules 1&2b)

Stockpile Status	High Case (m^3) 36 years	Intermediate Case (m^3) 36 years	Low Case (m^3) 36 years
Mined rock existing in stockpile	2,368,000	2,368,000	2,368,000
Mined rock placed into stockpile	8,787,000	9,085,000	28,797,000
Rock removed from stockpile	0	0	0
Rock in stockpile at end of phase	11,155,000	11,453,000	31,165,000

6.2.2.6 Waste Generated

Table 6.2.2.6-1. Development Period Wastes (Modules 1&2b)

Waste Material	High Case 36 years	Intermediate 36 years	Low Case 36 years
Hydrocarbons (lubricants. & fluids) (totals for period) (liters)	24,700,000	33,000,000	83,600,000
Solid wastes (landfill) (m^3/year)	500	500	1,400
Solid wastes (recyclable) (m^3/year)	1,400	1,400	3,500
Sanitary waste (liters/year)	15,178,000	15,755,000	17,221,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

6.2.2.7 Emissions and Effluents

Table 6.2.2.7-1. Development Period Emissions and Effluents (Modules 1&2b)

Material	High Case 36 years	Intermediate Case 36 years	Low Case 36 years
Diesel Exhaust (surface area) (cubic meters/year)	83,800,000	83,800,000	162,170,000
Dust (controlled to be less than) (short tons/year)	250	250	250
Water (assumed to be discharged) (liters/year)	8,067,000	8,341,000	26,438,000

6.2.2.8 Equipment for Modules 1&2b

Table 6.2.2.8-1. Equipment Acquired for High/Intermediate/ Low Cases

Unit	Number	Unit	Number
Concrete Handling	High/Int/Low	Shaft Equipment(1)(3)	High/Int/Low
• Concrete Batch Plant	1/3/5	•Headframe	1/1/3
•Concrete Pump (25 cy)	2/2/5	•Headhouse	1/1/3
•Grout Mixer & Pump	2/2/6	•Hoist (elect)	1/1/3
•Invert Paver	0/0/4	•Ladder (373m /each)	1/1/3
•Mixer Truck	6/8/23		
Rail Haulage	High/Int/Low	Surface Mobil	High/Int/Low
•Agitator Car	6/6/13	• Bobcat Loader	12/12/31
•Man Car	6/6/17	• Pickup Truck	6/9/8
•Man Trip (bat)	8/8/17	• Flatbed Truck	2/9/9
•Muck Car	20/20/55	• Forklift (4 t)	9/8/9
•Segment Car	10/10/25	• Forklift	9/9/9
•Loco. (Diesel-25 t)	12/13/28	•Grader	½/1/1
•Locomotive (Batt-10t)	3/3/8	•Tractor	1/5/8
•Locomotive (Trly-25t)	16/18/45	•Hydraulic Crane	7/9/10
Material Handling		• L.B. Transport	5/4/5
• Muck Dump	4/5/9	•Loader	2/1/6
•Radial Stacker (60hp)	5/4/10	•Scraper	2/6/9
		•Water Truck	3/3/3
		• Water Wagon	2/6/10
Excavation & Support	High/Int/Low	Water Handling	High/Int/Low
• Air Track Drill	1/1/3	•Centrifugal Pump	3/6/6
• TBM (5.5 m)	0/1/3		
• TBM (7.62 m)(2)	0/1/2		
• Drill Jumbo	4/10/26		
• Raise Miner	1/0/1		
• Raise Drill	1/0/1		
• Ring Turner	2/2/6		
• Mesh Roller	9/8/12		
• Vibrating Compactor	2/2/8		

Unit	Number	Unit	Number
Miscellaneous	High/Int/Low	Ventilation Equipment	High/Int/Lo w
•Air Hoist	1/3/8	•Develop Fan	2/4/4
•Welder (300 amp-diesel)	1/2/2	•Filter Fan	4/9/9
•Welder (300 amp-elect)	2/4/4	•HEPA Filter (Main)	4/4/4
•Platform Lift (Elect)	11/15/33	•HEPA Filter (Mobile)	2/2/2
•Compressor (1500 cfm)	1/2/2	•Develop Fan	4/8/15
•Compressor (3000 cfm)	2/4/4	•Isolation Barrier	365/365/37 5
•Light Plant	1/1/1	•150 hp Vent Fan	6/36/74
•Work Platform	1/1/3	•250 hp Vent Fan	2/2/6
		•40 cfm Scrubber	3/17/35
		•100 cfm Scrubber	3/17/35
Rubber-Tired Haulage	H/I/L		
• Scooptram (6cy-elect)	8/10/10		

Units

cfm	cubic feet per minute	gal	gallon	k	thousand
cy	cubic yards	gpm	gallon per minute	m	meter
ft	feet	hp	horsepower	t	short ton

Notes:

1) Equipment purchases/replacements are made for thermal cases as indicated by High/Intermediate/Low.

2) The 7.62 m TBMs will need replacement for the Intermediate and Low Thermal Cases due to the extensive amount of excavation of Mains and Ramps.

3) The Intermediate Thermal Case requires an additional Emplacement Intake Shaft. The Low Thermal Case requires three additional shafts.

	Thermal Loading Case (Modules 1&2b)		
Unit	High Case 36 years	Intermediate 36 years	Low Case 36 years
Electrical Systems			
•Primary Equipment			
o 15 KV Pwr Center	2	2	2
o 12.5 KV/480V PC	27	38	89
o 480/20V PC	27	38	89
•Power Cables			
o 15 KV 500 MCM	25,712 m	15,276 m	54,000 m
o 15 KV #4/0	51,424 m	41,802 m	130,000 m
o 600 V # 8 AWG	36,739 m	20,901 m	65,000 m
o #4/0 Bare Copper	36,739 m	20,901 m	65,000 m
•Lighting			
o Wall Fixtures	971	1,363	4,200
o Emergency Light	323	454	1,400

6.2.3 EMPLACEMENT OPERATIONS

While the variation in thermal loading, cause significantly different subsurface layouts, the waste emplacement operations are fundamentally the same. Therefore, little difference is apparent between Modules and between thermal loading cases.

6.2.3.1 Staffing

Personnel listed in this operation are only attached to the subsurface leg of the waste package emplacement activities. The approximate number of years of Emplacement Operating Phase activity is 2010 to 2047.

Table 6.2.3.1-1. Emplacement Phase Staffing (Modules 1&2b)

Personnel	**Subject**	High Case 38 years	Intermediate 38 years	Low Case 38 years
Managerial:	Peak number of workers:	16	16	20
	Average number of workers:	16	16	17
Craft:	Peak number of workers:	74	74	90
	Average number of workers:	74	74	79
Total	Peak number of workers:	90	90	110
Personnel:	Average number of workers:	90	90	96

Note:

1) Emplacement operations are similar in the three thermal loading cases, however the extended operating distances are reflected in the three staffing levels.

2) The extended inventories of Modules 1 and 2b are accommodated in the extended years of operation--38 years vs. 24 years.

3) For Module 2b only two craft workers could be added to reflect the additional waste packages emplaced compared with Module 1.

6.2.3.2 Resources Consumed

Table 6.2.3.2-1. Resources Consumed During Emplacement

	Thermal Loading Case		
Item	High Modules 1&2b Case 38 years	Intermediate Case 38 years	Low Modules 1&2b Case 38 years
Aggregate (mt)	2,000	3,000	7,000
Cement (mt)	800	900	3,000
Chemicals			
•Concrete Additives (mt)	<100	<100	100
Electrical Power			
•Total ('000) (mwh)	770.3	842.3	1057.9
•Peak (kw)	8,000	8,000	8,000
Fuel, Lubricants			
•Diesel ('000 liters)	800	800	900
•Oil ('000 liters)	5,200	5,300	6,400
•Grease ('000 kgs)	200	200	300
Sand (mt)	1,600	1,800	2,000
Water			
•Potable (million liters)	108.3	108.3	115.5
•Concrete Additive	2.4	2.7	6.5
•Dust Suppression	0	0	0
• TOTALS:	110.7	111.0	122.0
• Peak Use (liters/hr)	1,800	1,800	2,000

Units

hr	*hour*	*mwh*	*megawatt hours*
kg	*kilograms*	*mt*	*metric tons*
kw	*kilowatts*	*'000*	*one thousand*

6.2.3.3 Materials Installed

Table 6.2.3.3-1. Materials Installed during Emplacement

	Thermal Loading Case (Modules 1&2b)		
Item	High Case 38 years	Intermediate Case 38 years	Low Case 38 years
Concrete •Shadow Shields (m^3)	2,000	2,300	5,400
Units m^3 - cubic meter			

6.2.3.4 Underground Openings Excavated

No underground openings will be excavated by the waste package emplacement operations. See Section 6.2.2.4 for development operations during the Emplacement Phase time period.

6.2.3.5 Rock Stockpiled at Surface

No rock stockpile activities will be performed by the waste package emplacement operations. See Section 6.2.2.5 for stockpile activities during the Emplacement Phase time period

6.2.3.6 Waste Generated

Table 6.2.3.6-1. Emplacement Operations (Modules 1&2b)

Waste Material	High Case 38 years	Intermediate Case 38 years	Low Case 38 years
Hydrocarbons (lubricants & fluids) (total for operation)(liters)	5,200,000	5,300,000	6,400,000
Solid wastes (landfill) (m^3/year)	184	184	184
Solid wastes (recyclable) (m^3/year)	462	462	462
Sanitary waste (liters/year)	4,258,000	4,258,000	4,542,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

6.2.3.7 Emissions and Effluents

No emissions or effluents are allocated to waste emplacement operations. Development operations addressed in Section 6.2.2 cover these areas and are included in that section. Emplacement operations take place using underground electrical powered equipment. Diesel allocated to these operations is only incidental.

6.2.3.8 Equipment

Table 6.2.3.8-1. Equipment Acquired during Emplacement (38 years all cases)

Unit	Number	Unit	Number
Rubber-Tired Haulage		Water Handling	
•Scooptram (2 cy-elect)	1	•Cent. Pump	3
Rail Haulage	High/Int/Low	Ventilation Equipment	High/Int/Low
•Flat Car (10 t)	16/16/16	•Emplace Fan	8/6/10
•Gantry (Empl)	4/4/4	•Filter Fan	6/6/9
•Gantry Transport Car	2/2/2	•	
• Inspection Gantry	2/2/2		
•Locomotive (Empl)	8/9/10		
• Locomotive (Trly-25t)	20/22/23		
•Man Trip (bat)	8/8/8		
•Transport (Empl)	4/4/5		
•Vacuum Car	3/3/3		
Miscellaneous	H/I/L		
• Platform Lift (Elect)	11/13/15		

<u>Note</u>

cfm	cubic feet per minute	gal	gallon	m	meter
cy	cubic yards	gpm	gallon per minute	t	short ton
ft	feet	hp	horsepower		
		k	thousand		

6.2.4 MONITORING PHASE

As discussed in Section 6.1.4 of this engineering file, the nature of the period of repository operation between the emplacement of the final waste package and the initiation of the Closure Phase was modified in 1998. In addition, WP retrieval maintenance periods of 100 and 300 are addressed.

6.2.4.1 Staffing

All staffing in the Monitor Phase in considered to be employed by the operating contractor. The Monitor Phase staffing is assumed to begin in year: 2048 and end in one of the following years: 2059, 2109 or 2309 as do the VA cases. The extended Emplacement Phases (38 years) for the three thermal loading cases addressing the extended waste inventory modules result in Monitor Phase duration of 12, 62 and 262 years.

Table 6.2.4.1-1. Monitor Phase Staffing (Modules 1&2b)

Personnel	**Subject**	High Case 12, 62 & 262 years	Intermediate Case 12, 62 & 262 years	Low Case 12, 62 & 262 years
Managerial:	Peak number of workers:	13	13	26
	Average number of workers:	13	13	26
Craft:	Peak number of workers:	69	76	96
	Average number of workers:	69	76	96
Total	Peak number of workers:	82	89	122
Personnel:	Average number of workers:	82	89	122

Note:

1) Staffing increases over the Base Case reflect greater area to maintain.

6.2.4.2 Resources Consumed

Table 6.2.4.2-1a. Resources Consumed during Monitor Phase (12 years)

	Thermal Loading Case (Modules 1&2b)		
Item	High Case	Intermediate Case	Low Case
Electrical Power			
•Total ('000) (mwh)	510.8	592.6	848.5
•Peak (kw)	8,000	8,000	8,000
Fuel, Lubricants			
•Diesel ('000 liters)	400	400	400
•Oil ('000 liters)	1,900	1,900	1,900
•Grease ('000 kgs)	100	100	100
Water			
•Potable (million liters)	18.9	20.5	28.1
Totals	18.9	20.5	28.1
•Peak (liters/hour)	2,750	2,750	2,750

Units:
kg kilograms mwh megawatt hours kw kilowatts

Table 6.2.4.2-1b. Resources Consumed during Monitor Phase (62 years)

	Thermal Loading Case (Modules 1&2b)		
Item	High Case	Intermediate Case	Low Case
Electrical Power			
•Total ('000)(mwh)	2,641	3,064	6,237.2
•Peak (kw)	8,000	8,000	8,000
Fuel, Lubricants			
•Diesel ('000 liters)	2,100	2,100	2,100
•Oil ('000 liters)	9,800	9,800	9,800
•Grease ('000 kgs)	500	500	500
Water			
•Potable (million liters)	97.5	105.8	145.0
• Totals	97.5	105.8	145.0
•Peak (liters/hour)	2,750	2,750	2,750

Units:
kg kilograms mwh megawatt hours kw kilowatts

Note:

1) Because the Monitor Phase is extended to 62 years in this option, a factor for resources consumed is assumed. 62/12 years = 5.17

Table 6.2.4.2-1c. Resources Consumed during Monitor Phase (262 years)

	Thermal Loading Case (Modules 1&2b)		
Item	**High Case**	**Intermediate Case**	**Low Case**
Electrical Power			
•Total ('000)(mwh)	11,135	12,919	18,497
•Peak (kw)	8,000	8,000	8,000
Fuel, Lubricants			
•Diesel ('000 liters)	8,720	8,720	8,720
•Oil ('000 liters)	41,420	41,420	41,420
•Grease ('000 kgs)	2,180	2,180	2,180
Water			
•Potable (million liters)	412.0	447.2	612.8
• Totals	412.0	447.2	612.8
•Peak (liters/hour)	2,750	2,750	2,750
Units: kg kilograms mwh megawatt hours kw kilowatts '000 one thousand			

Note:

1) Because the Monitor Phase is extended to 262 years in this option, a factor for resources consumed is assumed. 262/12 years = 21.8

6.2.4.3 Materials Installed

No planned installation of material are defined for the Monitor Phase.

6.2.4.4 Underground Openings Excavated

No underground excavations are planned as part of monitoring operations.

6.2.4.5 Rock Stockpiled at Surface

No storage or recovery of mined rock is planned for the monitoring operations.

Table 6.2.4.5-1. Monitor Phase Stockpile Activity (12, 62 & 262 year cases)

Stockpile Status	High Case (m^3)	Intermediate Case (m^3)	Low Case (m^3)
Mined rock existing in stockpile	11,155,000	11,453,000	31,173,000
Mined rock placed into stockpile	0	0	0
Rock removed from stockpile	0	0	0
Remaining rock in stockpile	11,155,000	11,453,000	31,173,000

6.2.4.6 Waste Generated

Table 6.2.4.6-1a. Monitoring Phase (Modules 1&2b)(12 years)

Waste Material	High Modules 1&2b Case	Intermediate Case	Low Modules 1&2b Case
Hydrocarbons (lubricants & fluids) (totals for phase) (liters)	1,900,000	1,900,000	1,900,000
Solid wastes (landfill) (m^3/year)	200	200	200
Solid wastes (recyclable) (m^3/year)	400	400	400
Sanitary waste (liters/year)	3,880,000	4,211,000	5,772,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

Table 6.2.4.6-1b. Monitoring Phase (Modules 1&2b)(62 years)

Waste Material	High Modules 1&2b Case	Intermediate Case	Low Modules 1&2b Case
Hydrocarbons (lubricants & fluids) (totals for phase) (liters)	9,800,000	9,800,000	9,800,000
Solid wastes (landfill) (m^3/year)	200	200	200
Solid wastes (recyclable) (m^3/year)	400	400	400
Sanitary waste (liters/year)	3,880,000	4,211,000	5,772,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

Note:

1) Because the Monitor Phase is extended to 62 years in this option, a factor for wastes generated is assumed. 62/12 years = 5.17

Table 6.2.4.6-1c. Monitoring Phase (Modules 1&2b)(262 years)

Waste Material	High Case	Intermediate Case	Low Case
Hydrocarbons (lubricants & fluids) (totals for phase) (liters)	41,420,000	41,420,000	41,420,000
Solid wastes (landfill) (m^3/year)	200	200	200
Solid wastes (recyclable) (m^3/year)	400	400	400
Sanitary waste (liters/year)	3,880,000	4,211,000	5,772,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

Note:

1) Because the Monitor Phase is extended to 262 years in this option, a factor for wastes generated is assumed. 262/12 years = 21.8.

6.2.4.7 Emissions and Effluents

Table 6.2.4.7-1. Monitor Phase Emissions and Effluents (12, 62 & 262 years)

Material	High Thermal Case	Intermediate Case	Low Thermal Case
Diesel Exhaust (surface area) cubic meters/year	400,000	400,000	400,000
Dust (controlled to be less than) short tons/year	250	250	250
Water (assumed to be discharged) liters/year	not determined	not determined	not determined

6.2.4.8 Equipment

Table 6.2.4.8-1a. Equipment Acquired during Monitor Phase (12 years all cases)

Unit	Number	Unit	Number
Rail Haulage	High/Int/Low	Surface Mobil	High/Int/Low
•Flat Car (10 t)	6/6/6	•Flatbed Truck	1/2/2
•Gantry Transport Car	1/0/2	•Forklift	1/1/1
•Inspection Gantry	2/2/2	•Grader	1/1/1
•Locomotive (Trly-25t)	4/2/2	•Hydraulic Crane	1/1/1
•Man Trip (bat)	4/4/4	•Water Truck	1/1/1
Miscellaneous	High/Int/Low	Ventilation Equipment	High/Int/Low
•Compressor	2	•Develop. Fan	4/2/4
•Platform Lift (Elect)	5	•Emplace. Fan	0/2/4
		•Filter Fan	2/4/8
		•Mobile Scrubber	5/5/4
		•Mobile Scrubber	5/5/4
Water Handling			
•Centrifugal. Pump	6		

Units
cfm cubic feet per minute
cy cubic yards
gal gallon
gpm gallon per minute
k thousand
L.B. lowboy
m meter
t short ton

Table 6.2.4.8-1b. Equipment Acquired during Monitor Phase (62 years all cases)

Unit	Number	Unit	Number
Rail Haulage	High/Int/Low	Surface Mobil	High/Int/Low
•Flat Car	12/12/12	•Flatbed Truck	6/6/6
•Gantry Transport Car	2/4/4	•Forklift	3/3/3
•Inspection Gantry	2/4/4	•Grader	3/3/3
•Locomotive	4/4/4	•Hydraulic Crane	3/3/3
•Man Trip (battery)	4/6/8	•Water Truck	3/3/3
Miscellaneous	High/Int/Low	Ventilation Equipment	High/Int/Low
•Compressor	4/4/6	•Develop Fan	4/6/8
•Platform Lift (Elect)	5/5/10	•Emplace Fan	2/6/8
		•Filter Fan	6/8/16
		•Mobile Scrubber	10/10/10
		•Mobile Scrubber	10/10/10
Water Handling			
•Cent. Pump	10/10/12		

Units
cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

Table 6.2.4.8-1c. Equipment Acquired during Monitor Phase (262 years all cases)

Unit	Number	Unit	Number
Rail Haulage	H/I/L	Surface Mobil	H/I/L
•Flat Car	60	•Flatbed Truck	40
•Gantry Transport Car	20	•Forklift	20
•Inspection Gantry	40	•Grader	20
•Locomotive	20	•Hydraulic Crane	20
•Man Trip (battery)	60	•Water Truck	20
Miscellaneous		Ventilation Equipment	H/I/L
•Compressor	40	•Develop. Fan	80
•Platform Lift (Elect)	90	•Emplace Fan	60
		•Filter Fan	60
		•Mobile Scrubber	80
		•Mobile Scrubber	80
Water Handling			
•Centrifugal. Pump	120		

Units
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

6.2.5 WASTE RETRIEVAL

For the extended inventory cases, it is assumed that the approximate rate of retrieval is four waste packages per working day through the waste handling building. At this rate, working 255 days per year, 20 years will accommodate the extended waste inventories of 17,000 to 21,000 waste packages including preparations.

6.2.5.1 Staffing

Staffing in the retrieval operation is considered to employ both the operating contractor and subcontractors.

Table 6.2.5.1-1. Retrieval Operations Staffing (Modules 1&2b)

Personnel	**Subject**	High Case 20 years	Intermediate Case 20 years	Low Case 20 years
Managerial:	Peak number of workers:	16	16	20
	Average number of workers:	16	16	17
Craft:	Peak number of workers:	74	74	90
	Average number of workers:	74	74	79
Total	Peak number of workers:	90	90	110
Personnel:	Average number of workers:	90	90	96

Notes:

1) For this engineering file, it is assumed that waste retrieval begins with emplacement of the final waste package.

2) Because no waste will remain after retrieval, no Caretaker Phase will occur. Closure will begin with completion of waste retrieval.

6.2.5.2 Resources Consumed

Table 6.2.5.2-1. Resources Consumed during Waste Retrieval (20 years)

	Thermal Loading Case		
Item	High Case	Intermediate Case	Low Case
Electrical Power			
•Total ('000)(mwh)	847.3	977.5	1,391.0
• Peak (kw)	8,000	8,000	8,000
Fuel, Lubricants			
•Diesel ('000 liters)	600	600	600
•Oil ('000 liters)	4,400	4,400	4,600
•Grease ('000 kgs)	200	200	200
Water			
•Potable (million liters)	118.2	118.2	126.1
Totals	118.2	118.2	126.1
•Peaks (liters/year)	1,000	1,000	1,000

Units
kg kilograms mwh megawatt hours
kw kilowatts

6.2.5.3 Materials Installed

No materials are planned to be installed underground during waste retrieval.

6.2.5.4 Underground Openings Excavated

No underground openings are planned for excavation during waste retrieval operations.

6.2.5.5 Rock Stockpiled at Surface

No storage or recovery of mined rock from the stockpile will be done as part of the waste retrieval operations. See table 6.2.2.5-1 for stockpile status.

6.2.5.6 Waste Generated

Table 6.2.5.6-1. Waste Retrieval Phase (Modules 1&2b)

Waste Material	High Case 20 years	Intermediate Case 20 years	Low Case 20 years
Hydrocarbons (lubrication & fluids) (totals for operation) (liters)	4,400,000	4,400,000	4,600,000
Solid wastes (landfill) (m^3/year)	300	300	300
Solid wastes (recyclable) (m^3/year)	800	800	800
Sanitary waste (liters/year)	4,258,000	4,258,000	4,542,000
Low-level nuclear waste (m^3/year)	0	0	0
RCRA waste (m^3/year)	0	0	0

Notes:

1) Waste generated during waste retrieval are related to personnel and maintaining the waste handling equipment.

6.2.5.7 Emissions and Effluents

Table 6.2.5.7-1. Retrieval Operations Emissions and Effluents (20 years)

Material	Base Case	Intermediate Case	Low Thermal Case
Diesel Exhaust (surface area) (cubic meters/year)	400,000	400,000	400,000
Dust (controlled to be less than) (short tons/year)	250	250	250
Water (assumed to be discharged) (liters/year)	No process water used	No process water used	No process water used

6.2.5.8 Equipment

Table 6.2.5.8-1. Equipment Acquired during Waste Retrieval (20 years all cases)

Unit	Number	Unit	Number
Rail Haulage	H/I/L	Surface Equipment	H/I/L
•Flat Car (10 t)	2/2/2	•Flatbed Truck	1/1/2
•Gantry	4/4/4	•L.B. Transport	1/1/1
•Gantry Transport Car	1/1/1	•Water Truck	1/1/1
•Locomotive	8/8/10	•Hydraulic Crane	2/2/2
•Locomotive	2/3/2	•Forklift	1/1/1
•Man Trip (battery)	0/4/4	•Grader	1/1/1
•Transport	4/4/5		
•Vacuum Car	1/1/1		
Miscellaneous	H/I/L	Water Handling	
•Platform Lift (Elect)	6/8/8	•Cent. Pump	3
•Compressor	2/2/2		
Ventilation Equipment	H/I/L	Rubber-Tired Haulage	
•Devel. Fan (2,000 hp)	2/2/8	•Scooptram	1
•Empl. Fan (2,000 hp)	2/2/6		
•Filter Fan	6/4/12		
•40k cfm Scrubber	4/4/4		
•100k cfm Scrubber	4/4/4		

Units
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

6.2.6 CLOSURE AND DECOMMISSIONING

6.2.6.1 Staffing

Staffing in the Closure and Decommissioning Phase is considered to be employed by both the operating contractor and subcontractors. The Closure Phase staffing is assumed to begin in year 2060 and end in year 2070 and 2086 for the extended inventory cases.

Table 6.2.6.1-1. Closure & Decommissioning Phase Staffing (Modules 1&2b)

Personnel	**Subject**	High Case 13 years	Intermediate Case 17 years	Low Case 27 years
Managerial:	Peak number of workers:	45	45	45
	Average number of workers:	44	44	44
Craft:	Peak number of workers:	256	256	256
	Average number of workers:	218	218	218
Total	Peak number of workers:	301	301	301
Personnel:	Average number of workers:	263	263	263

6.2.6.2 Resources Consumed

Table 6.2.6.2-1. Resources Consumed during Closure

	Thermal Loading Case (Modules 1&2b)		
Item	High Case 13 years	Intermediate Case 17 years	Low Cases 27 years
Aggregate (mt)	3,000	5,000	8,000
Cement (mt)	1,200	1,800	3,200
Chemicals			
•Concrete Additive (mt)	<100	<100	100
Electrical Power			
•Total ('000)(mwh)	466.7	612.7	1,741.5
•Peak (kw)	8,000	8,000	8,000
Fuel, Lubricants			
•Diesel ('000 liters)	6,200	8,500	16,800
•Oil ('000 liters)	4,500	6,000	12,800
•Grease ('000 kgs)	200	200	500
Sand (mt)	2,400	3,600	6,200
Steel			
•Crusher Liner (mt)	37	56	141
•Screen (mt)	2	4	10
Water			
•Potable (million liters)	121.0	121.0	297.0
•Concrete Additive	4.0	6.7	10.7
•Dust Suppression	281.0	293.7	771.5
Totals	406.0	421.4	1,079.2
•Peak Use (liters/hr)	5,000	5,800	10,500

Units

hr	hour	mwh	megawatt hours
kg	kilograms	mt	metric tons
kw	kilowatts		

6.2.6.3 Materials Installed

Materials installed as permanent features of the subsurface repository relate to closing and sealing the ramps, shafts and mains to prevent human intrusion and release of radio nuclides to the accessible environment.

Table 6.2.6.3-1. Materials Installed during Closure

	Thermal Loading Case (Modules 1&2b)		
Item	High Case 13 years	Intermediate Case 17 years	Low Case 27 years
Concrete •Ready Mix (m^3)	3,000	5,000	8,000
Crushed Rock (m^3)	2,745,000	2,869,000	7,537,000
Steel •Rebar (mt)	1,400	2,000	3,500
Units m^3 cubic meter			

Note:

1) Crushed rock is the fill material assumed to be placed in the designated underground openings and does not include rejected material returned to the surface stockpile.

6.2.6.4 Underground Openings Excavated

Small excavations may be made at the locations of seals. These will be used by seal structures. No volume is noted for these excavations.

6.2.6.5 Rock Stockpiled at Surface

Rock recovered from the surface mined-rock stockpile will be used as backfill material for shafts, ramps, and mains. Mined rock remaining in the stockpile at the end of closure will be re-contoured and covered by topsoil.

Table 6.2.6.5. Closure & Decommissioning Phase Stockpile Activity

Stockpile Status	High Thermal Case (m^3) (13 years)	Intermediate Thermal (m^3) (17years)	Low Thermal Case (m^3) (27 years)
Mined rock existing in stockpile	11,155,000	11,453,000	31,173,000
Mined rock placed into stockpile	0	0	0
Rock removed from stockpile	2,745,000	2,869,000	7,537,000
Rock in stockpile at end of phase	8,410,000	8,584,000	23,636,000

6.2.6.6 Wastes Generated

Table 6.2.6.6-1. Closure & Decommissioning Phase (Modules 1&2b)

Waste Material		High Case 13 years	Intermediate Case 17 years	Low Case 27 years
Hydocarbons. (lubes. & fluids) (total for phase)	liters	4,500,000	6,000,000	12,800,000
Solid wastes (landfill)	m^3/year	334	340	451
Solid wastes (recyclable)	m^3/year	833	848	1,127
Sanitary waste	liters/year	12,443,000	12,443,000	12,443,000
Low-level nuclear waste	m^3/year	0	0	0
RCRA waste	m^3/year	0	0	0

6.2.6.7 Emissions and Effluent

Table 6.2.6.7-1. Closure & Decommissioning Emissions and Effluents

Material	High Case 13 years	Intermediate Case 17 years	Low Case 27 years
Diesel Exhaust (surface area) (cubic meters/year)	83,800,000	83,800,000	140,784,000
Dust (controlled to be less than) (short tons/year)	250	250	250
Water (assumed to be discharged) (liters/year)	2,435,000	3,064,000	5,606,000

Notes:

1) Surface activities related to recovering and processing stockpiled welded tuff will cause diesel and dust emissions.

2) Water discharges from closure operations have not been identified.

6.2.6.8 Equipment

For the closure case related to the low thermal case, roughly twice the time is needed to fill the extensive mains and ramps, consequently more equipment will be used and then replaced than the other two cases. Two tables are used for the cases.

Table 6.2.6.8-1a. Equipment -- High and Intermediate Closure (13 & 17 years)

Unit	Number	Unit	Number
Concrete Handling	High/Int/Low	Miscellaneous	High/Int/Low
•Concrete Batch Plant	1	•Platform Lift (Elect)	4/9
•Concrete Pump (25 cy)	1	•Compressor (diesel)	1
•Concrete Pump (60 cy)	1	•Compressor (elect.)	2
•Transit Mixer	2		
Material Handling	High/Int/Low	Ventilation Equipment	High/Int/Low
•Backfill Placer	4/5	•Develop Fan	4/8
•Conveyor (40')	9/10	•Filter Fan	2/4
•Cone Crusher	2/3	•Emplace Fan	2
•Radial Stacker (25 hp)	2/3	•150 hp Vent Fan	2
•Scalping Screen	4	•250 hp Vent Fan	16/24
•Surge Bin (Portable)	14/18	•Mobile Scrubber	4
		•Mobile Scrubber	4
Rail Haulage	High/Int/Low	Surface Mobil	High/Int/Low
•Agitator Car	4	•End Dump Truck	4
•Flat Car (10 t)	12	•Flatbed Truck	1/2
•Man Car	2	•Forklift	3
•Man Trip (bat)	2	•Grader	1
•Muck Car (13 m^3)	2	•Hydraulic Crane	2/3
•Shuttle car (14 cy)	9	•Loader	6/10
•Vacuum Car	1	•Scraper	2
•Loco. (Diesel)	4	•Tractor	1
•Locomotive (trolley)	6/12	•Transport Trailer	1/2
		• Water Truck	4/6
		Water Handling	
		•Cent. Pump	3

Units:

cfm	cubic feet per minute	gal	gallon	k	thousand
cy	cubic yards	gpm	gallon per minute	m	meter
ft	feet	hp	horsepower	t	short ton

Table 6.2.7.8-1b. Equipment Acquired during Low Thermal Closure (27 years)

Unit	Number	Unit	Number
Concrete Handling	High/Int/Low	Miscellaneous	High/Int/Low
•Concrete Batch Plant	1	•Platform Lift (Elect)	14
•Concrete Pump	2	•Compressors (diesel)	2
•Concrete Pump	2	•Compressor (Elect.)	3
•Transit Mixer	4		
Material Handling		Ventilation Equipment	
•Backfill Placer	8	•Develop Fan	8
•Conveyor	12	•Filter Fan	6
•Cone Crusher	4	•Emplace Fan	8
•Radial Stacker	3	•150 hp Vent Fan	2
•Scalping Screen	4	• 250 hp Vent Fan	32
•Surge Bin (Portable)	18	•Mobile Scrubber	8
		•Mobile Scrubber	8
Rail Haulage		Surface Mobil	
•Agitator Car	4	•End Dump Truck	6
•Flat Car	24	•Flatbed Truck	2
•Man Car	2	•Forklift	4
•Man Trip (battery)	2	•Grader	2
•Muck Car	2	•Hydraulic Crane	4
•Shuttle car	13	• Loader	12
•Vacuum Car	2	•Scraper	2
•Locomotive (Diesel)	5	•Tractor	2
•Locomotive (trolley)	16	•Transport Trailer	2
		•Water Truck	8
		Water Handling	
		•Cent. Pump	4

Units:

cfm	cubic feet per minute	gal	gallon	k	thousand
Cy	cubic yards	gpm	gallon per minute	m	meter
ft	feet	hp	horsepower	t	short ton

6.2.7 SUBSURFACE AREAL LAND USAGE

Because the three thermal loading cases are calculated on emplacement area defined in acres the subsurface areal land usage in each alternative is roughly inversely proportional to the thermal density expressed in MTHM/acre. The following table lists the areas:

Table 6.2.7 –1. Subsurface Areal Land Use

Areal Land Usage	High Modules 1&2b Case	Intermediate Case	Low Modules 1&2b Case
Emplacement Area Needed (acres)	1,240	1750	4,200

The amount of area used by the surface stockpile for the High and Intermediate cases are shown on Figure 6.2.7-1. The Low thermal case, because of the more extensive excavation, requires a greater surface area. This expanded surface case is illustrated in Figure 6.2.7-2.

AREA NUMBERS	TOTAL STORAGE CAPACITIES m3	AREA (ACRES)	STORAGE REQUIRED m3	MTU/ACRE	DRIFT SPACING C/C
1 THRU 13	13,000,000	347	11,453,000	60	40 m
1 THRU 12	11,525,000	290	11,155,000	85	28 m

NOTES

AREA OCCUPIED FOR 105,000 MTU CASES

AREA OCCUPIED BY PILES = 485 ACRES

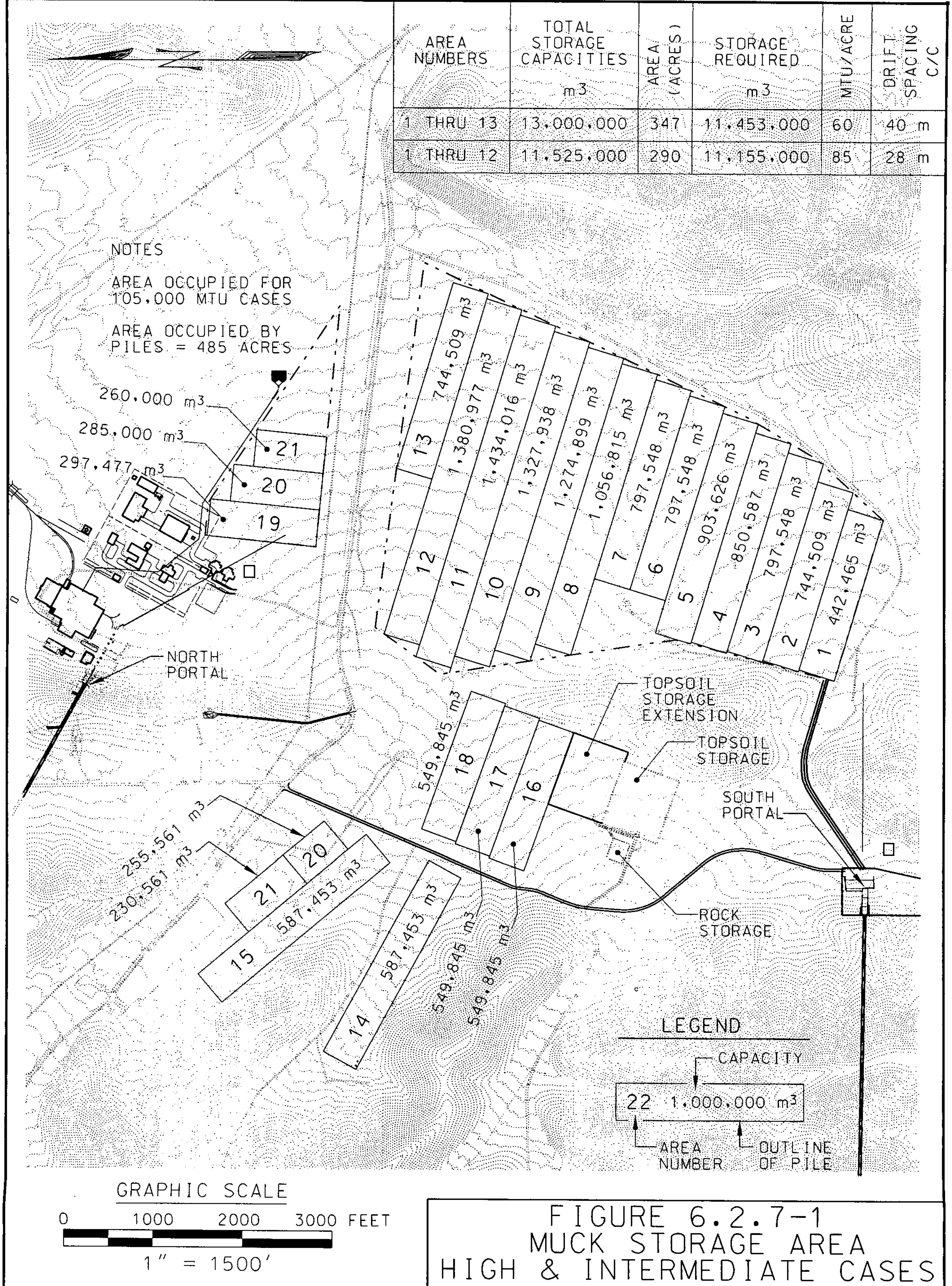

FIGURE 6.2.7-1
MUCK STORAGE AREA
HIGH & INTERMEDIATE CASES

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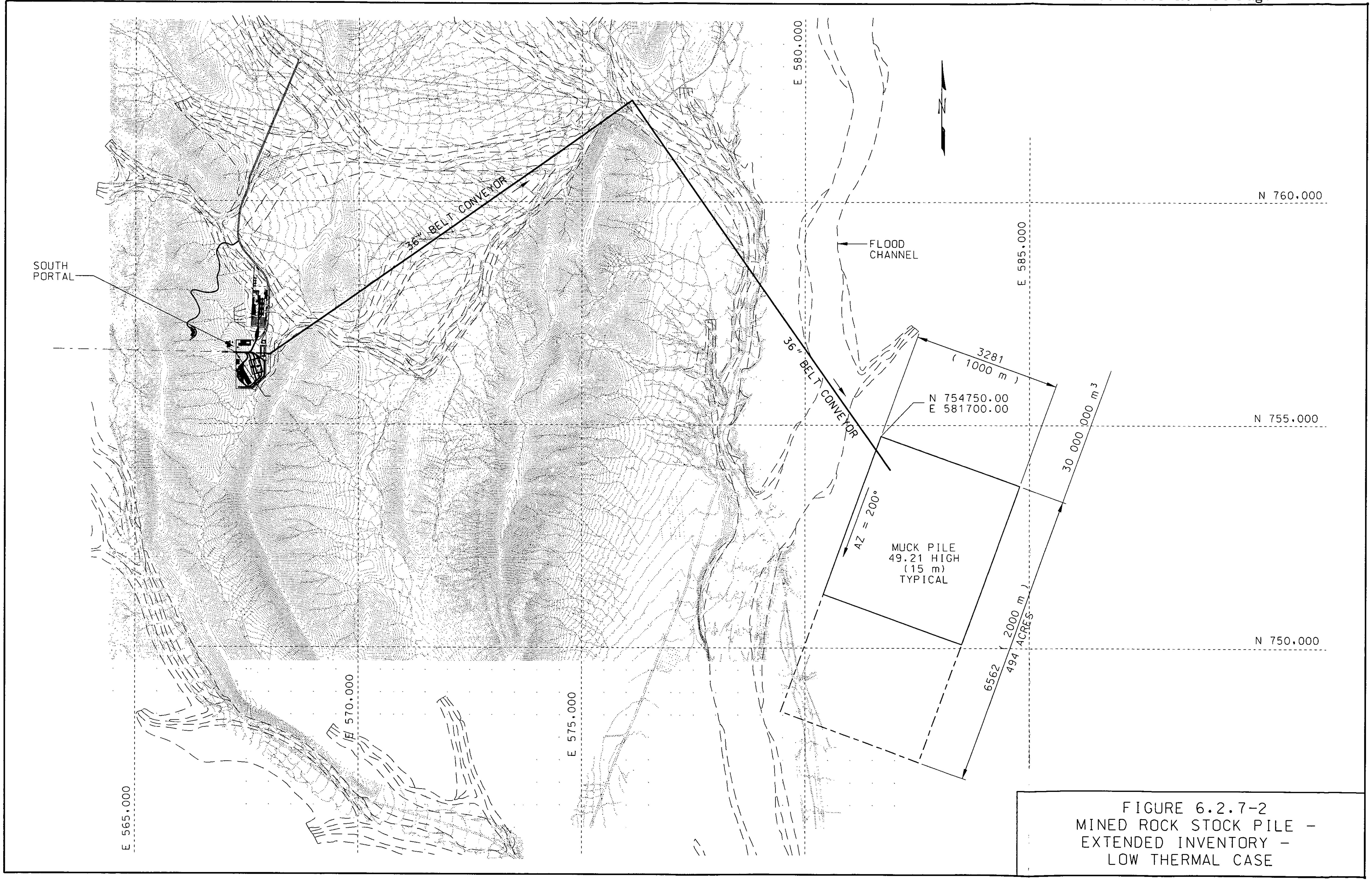

FIGURE 6.2.7-2
MINED ROCK STOCK PILE -
EXTENDED INVENTORY -
LOW THERMAL CASE

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7 ALTERNATIVE CASE ANALYSES

7.1 BASE (VA) WASTE INVENTORY CASES

This subsection is limited to comparing effects of design and operating alternatives based on the current limit of 70,000 metric tons of heavy metals as discussed in Section 3.1. The Base Case thermal loadings are "High" (85 MTHM/acre), "Low" (25 MTHM/acre) and "Intermediate" (60 MTU/acre). See Table 3.1-1.

Staffing levels in the three cases are estimated to be consistent during the Construction Phase. In the Low Case, the staffing level for extending access to the Lower Block continues into the Development Period.

Because of the increased subsurface excavations to access the greater underground emplacement areas and the extended periods of development activities, resources will be consumed in greater amounts corresponding to reduction of the thermal load.

Materials installed increases proportionally with the increase in access and exhaust main aggregate lengths for the Intermediate Case; and mains, shafts and ramps for the Low Case. The Intermediate Case requires increasing the aggregate length of the access mains only. The Low Case requires, not only adding to access mains aggregate length, but deepening both shafts and four additional interior ramps.

Because of the additional underground excavation needed for the Intermediate and Low Cases, additional mined rock will be stored in the surface stockpile.

Because of the increased excavation and construction involved with both the Low and Intermediate Cases, increased wastes will be produced in approximate proportion to the increased construction and development activities.

The increased periods of construction and development caused by the Low and Intermediate, Cases will cause total increases in subsurface related emissions and effluents however, annual production of emissions and effluents remain approximately the same.

The major increase in equipment procurement results from the need for a second 7.62-m TBM in both the Intermediate and Low cases.

Because the areal mass density definition uses subsurface acres as a divisor, reduction of the thermal density causes proportional increases in the area required for a fixed amount of nuclear waste.

The three thermal loading cases use the same waste handling concepts of operation. Maintaining identical waste receipt schedules will cause no significant effect on the emplacement operations for the three cases.

7.1.1 EFFECTS OF RETRIEVING ALL WASTE PACKAGES

Retrieving all waste packages from the subsurface is treated as an operation imposed on a filled repository. Retrieval of waste is based upon removing approximately 1000 WP per year as reported in the *Repository Surface Design Engineering Files report,* P. I-5 (CRWMS M&O 1998e)

Following retrieval of all waste packages, the result is an empty repository. All thermal density cases have this same result, but the Low Case would result in a much larger affected area than would the Base or Intermediate Cases. In all cases, the assumed approach is that the emplacement drifts would not be backfilled (see Sec. 2.2) even if made empty by retrieval. Administrative controls could be used to prevent entry into the empty emplacement drifts until closure. During closure, seals and backfill placed in the main drifts, ramps and shafts would prevent entry into the emplacement areas.

7.1.2 EFFECTS OF BACKFILLING ALL EMPLACEMENT DRIFTS

Should backfilling be mandated, the assumption made in this engineering file, is that all emplacement drifts would be filled. This means that the start of retrieval operations terminates the Monitoring Phase. Backfilling becomes an operating phase between Monitoring and the Closure Phase with its unique design features, facilities, equipment, etc. Because the aggregate length of emplacement drifts will be similar in the three thermal density cases, the length of time for backfilling them should be similar. With this same approach, the following items would be similar for the these cases: staffing, resources consumed, wastes generated, emissions and effluents, and equipment procured.

7.2 EXTENDED INVENTORY MODULES 1 AND 2B

The extended inventory modules 1 and 2B are described in Table 3.1-1. The following discussion is limited to comparing effects of designing and operating the repository for accepting the extended waste inventory alternatives and comparing them to the Base Cases addressed in Section 7.1.

Staffing levels in the three thermal cases are similar within the Construction Phase years. Staffing is also similar to the Base Intermediate and Low Cases.

Because of the increased volume of subsurface excavation, the extended periods of development activities and the extended Emplacement, resources will be consumed at overall larger amounts than in the Base Waste Inventory Cases.

Materials installed are increased approximately in proportion to the increase in access excavation aggregate length for each case when compared with the corresponding thermal Base Case. The Intermediate Case requires an increase in the aggregate length of the access mains, exhaust mains and requires four interior ramps. The Low Module 1 & 2b Cases require, not only more access mains, exhaust mains and interior ramps, but three additional shafts.

All Module 1 and 2b Cases produce more mined rock for the surface stockpile than do the Base Cases. Additionally, underground excavation needed for the Intermediate and Low Cases compared with the High Case produce proportional increases of mined rock to be stored.

Because of the increased development operations when compared with the Base Cases, increased wastes will be produced in approximate proportion to the increased activities. The increased periods of development and emplacement operations caused by the extended Modules 1 and 2b waste inventories also create proportionally greater emissions and effluents. Increased emissions and effluents will result approximately proportional to increased excavations of the Intermediate and Low Cases.

The extended waste inventories cause proportional increases in equipment procurement. Because of the greatly increased need for access ramps and mains in the Low case, more conveyor and ventilating equipment must also be procured. Some equipment will operate over such a long period of time that it will need replacement.

Increasing the civilian spent nuclear fuel inventory from 63,000 to 105,414 metric tons causes proportional increases in subsurface area used for waste emplacement. Because the thermal loading definitions use subsurface acreage as a divisor, reduction of the thermal density causes proportional increases in the area required for a fixed amount of nuclear waste.

The increases in waste inventories cause proportional increases in the duration Emplacement. The three thermal loading cases for Modules 1 and 2b use the same waste handling concepts of operation. Module 2b involves emplacing approximately 4,000 more WPs than Module 1. The increase can be accommodated within the design of Module 1. The additional WPs will be treated in a manner similar to the high-level waste packages and be placed between spent fuel waste packages. The additional waste inventory addressed in Module 2b will have insignificant thermal output. Consequently, they add no impact to the total thermal load to require additional emplacement drifts.

7.2.1 EFFECTS OF RETRIEVING ALL WASTE PACKAGES

Retrieving all waste packages from the subsurface is treated as an operation imposed on a filled repository. To analyze the effects of this, retrieval operations are treated as being superimposed on the Module 1 & 2b thermal loading cases.

Retrieval of all waste is estimated to require approximately 10 years to plan and 19 years for actual waste package retrieval.

7.2.2 EFFECTS OF BACKFILLING ALL EMPLACEMENT DRIFTS

Should backfilling be mandated, the assumption made in this engineering file is that all emplacement drifts would be involved.

Backfilling becomes an operating phase between the Monitor and the Closure Phases with unique design features, facilities, equipment, etc. Because the aggregate length of emplacement drifts will be similar in the three thermal density cases, the length of time for backfilling them should be similar. But, because of the increase in waste packages emplaced in the Module 1 and 2b Cases, backfilling those added emplacement drifts will increase the backfilling operation proportionally.

The backfilling method for emplacement drifts is described in the *Backfill Strategy and Preliminary Design Analysis* (CRWMS 1997p). A conveying system rather than pneumatic backfill placement is used.

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9 ACRONYMS AND ABBREVIATIONS

ACD	Advanced Conceptual Design
ALARA	As Low As Reasonably Achievable
AML	Areal Mass Loading
BWR	Boiling Water Reactor (also used to refer to CSNF assembly type)
CDA	Controlled Design Assumptions
CDR	Conceptual Design Report
CFR	Code of Federal Regulations
CRD	CRWMS Requirements Document
CRWMS	Civilian Radioactive Waste Management System
CSNF	Commercial Spent Nuclear Fuel
DBE	Design Basis Event
DC	Disposal Container
DHLW	Defense High Level Waste
DI	Document Identifier
DISPC	Disposable Canister
DPC	Dual Purpose Canister
DRD	Design Requirements Document
DSNF	DOE owned Spent Nuclear Fuel
EB	Engineered Barrier
EBDRD	Engineered Barrier Design Requirements Document
EEA	Emplacement Entry Area
EED	Equivalent Energy Density
EF	Engineering files
EIS	Environmental Impact Statement
ESF	Exploratory Studies Facility
FR	Federal Register
FY	Fiscal Year
GROA	Geologic Repository Operations Area
GTCC	Greater-Than-Class-C (waste)
HEPA	High-Efficiency Particulate Air
HLW	High Level radioactive Waste
HVAC	Heating, Ventilation, and Air Conditioning
LA	License Application
LLW	Low-Level Waste
LWT	Legal-Weight Truck
M&O	Management and Operating Contractor
MGDS	Mined Geologic Disposal System
MGDS-RD	MGDS Requirements Document
MOX	Mixed Oxide nuclear Fuel
MPC	Multi-purpose Canister
MSHA	Federal Mine Safety and Health Administration
MTHM	Metric Tonnes Initial Heavy Metal
MTU	Metric Tons of Initial Uranium
NEPA	National Environmental Policy Act
NOSHA	Nevada Occupational Safety and Health Administration

NOI	Notice of Intent
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act
OSHA	Federal Occupational Safety and Health Administration
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor (also used to refer to CSNF assembly types)
QA	Quality Assurance
RCA	Radiological Controlled Area
RCRA	Resource Conservation and Recovery Act of 1976, as amended
RDRD	Repository Design Requirements Document
RIB	Reference Information Base
RW	Radioactive Waste
SAR	Safety Analysis Report
SCP	Site Characterization Plan
SNF	Spent Nuclear Fuel
SPAR	Special/Performance Assessment Required
SS	Subsurface
SSC	Structures, Systems, and Components
TBD	To Be Determined
TBM	Tunnel Boring Machine
TBR	To Be Resolved
TBV	To Be Verified
TC	Transportation Cask
TSLCC	Total System Life Cycle Cost
TSPA	Total-System Performance Assessment
UCF	Uncanistered Fuel, or "bare" fuel (used for CSNF assemblies)
VA	Viability Assessment
WA	Waste Acceptance
WHB	Waste Handling Building
WP	Waste Package
YMP	Yucca Mountain Site Characterization Project
YMSCO	Yucca Mountain Site Characterization Office

A. APPENDIX -- SUBSURFACE DECISION ROAD MAP

This appendix describes major decisions related to the subsurface designs and operating concepts under current consideration.

A.1 SELECTION OF GEOLOGIC HOST HORIZON

The National Academy of Science (NAS) recommended nuclear waste disposal in a geologic medium and that tuff should be one of the rock types investigated. Before 1981, initial siting activities were performed by the "Nevada Nuclear Waste Storage Investigations" project (NNWSI) predecessor to YMP - Site Characterization Project. These focused on characterizing geologic units below the water table. Geologic units identified included: devitrified portions of the Bullfrog and Tram members of the Crater Flat Tuff.

In 1982, evaluation of the four potential repository units placed them in the descending order of preference as follows: 1) Topopah Spring welded tuff, 2) Calico Hills Formation, non-welded tuff, 3) Bullfrog member of the Crater Flat tuff, and 4) Tram member of the Crater Flat. The first two are in the unsaturated hydrologic zones and the second two are in the saturated zone below the water table.

[NAS 1995][DOE 1992]

In 1994 a design analysis titled *Definition of Repository Block Limits* (CRWMS M&O 1994b) was developed. This analysis used available geologic data and empirical techniques to define the potential repository limits. Lateral limits are defined by fault projections and the 200-meter minimum overburden requirement. Upper limits on the potential repository horizon include: the 200-meter overburden requirement, a standoff of 5 meters below the base zone of >10% lithophysal cavities, and a thermal goal related to surface temperature rise and surface uplift. Lower limits address excavation stability, thermal goals, and possible perched ground water. The analysis concluded that the TSw3 unit between the Calico Hills (CHn1) and TSw2 should be avoided due to its brittle nature. A 5-meter standoff between the potential repository floor and the top of TSw3 should be maintained. The thermal goal was yet to be determined in 1994 for the TSw3 but the 5-meter standoff may be satisfied by the excavation stability standoff as noted above. Perched water could occur at the top of TSw3.

In 1995 a report titled *Definition of The Potential Repository Block* (CRWMS M&O 1995c) was issued. It defined the available repository volume with 200-meter overburden standoff from surface topography, a 5-meter standoff below the bottom of TSw1 thermal-mechanical unit, a 5-meter standoff above the top of the TSw3 unit, the top of the groundwater table, and 60-meter standoffs from major faults with the exception of the west side of the Ghost Dance, where the standoff is 120 meters.

The ACD, which was issued in 1996, further defined the repository horizon criteria. These criterion include a 200-meter overburden standoff, a 5-meter standoff below the top of the repository horizon, 30-meter standoff above the bottom of the host horizon as a thermal related goal, repository horizon at least 100 m above the top of groundwater table, and 60-meter standoff from Type I (major) faults (120 meters standoff on the west side of the Ghost Dance Fault).

In April 1997, a more definitive description of the repository block limits was detailed in the design analysis entitled *Determination of Available Volume for Repository Siting* (CRWMS M&O 1997s). This analysis used new and updated data to refine the available block definition presented in the earlier *Definition of the Potential Repository Block* (CRWMS M&O 1995c). The analysis utilized a computer model developed in the LYNX software to define the spatial limits based on the following criteria and limiting factors:

- 200-m overburden surface
- 5-m standoff below the top of the Repository Host Horizon
- 10-m standoff above bottom of the Repository Host Horizon
- 100-m above the top of the groundwater table
- Type I faults

The 200-m overburden limit is a stated criterion for design (YMP 1993).

The Repository Host Horizon (RHH) was first defined in this document to represent the potentially suitable geologic horizon for repository siting. The RHH includes the lower part of the upper lithophysal zone, middle non-lithophysal zone, lower lithophysal zone, and lower non-lithophysal zone. The equivalent thermal-mechanical units included are the lower part of the TSw1 and the TSw2. The top of the RHH is identified by a significant, but gradational change in the character of the lithphysae and matrix rock from many small lithphysae in a fractured matrix above the contact to few large lithphysae in a solid matrix below the contact. The 5-m and 10-m standoff from the top and bottom contact, respectively, were assumptions.

The 100-m standoff above the top of the groundwater table was an assumption.

For the analysis, all major faults were assumed to be Type I. These included the following:

- Solitario Canyon Fault and associated splays,
- Ghost Dance Fault,
- Abandoned Wash Fault and associated splay,
- Dune Wash Fault,
- Pagany Wash Fault,
- Bow Ridge Fault,

- Imbricate faults.

Acceptable geology models for the expansion area west of Solitario Canyon Fault have not been developed in detail. With the data limited to two boreholes and surface mapping only, model development can only be preliminary in nature and potentially subject to error. In order to identify potential expansion blocks west of Solitario Canyon fault for EIS planning purposes, the available data were evaluated and a LYNX computer model was developed. This model was based on the following data and assumptions:

- Topography

Topographic coverage for the expansion area was developed previously for the LYNX modeling of the upper and lower repository block areas. The 200-meter overburden limit surface was also previously prepared for the area.

- Structural contours

Recent surface mapping identified the surface units in the area around Boomerang Point and part of Jet Ridge. A structural contour map was developed for the contact between two Tiva Canyon units to establish the structural trend for the surfaces. West Ridge and the remainder of Jet Ridge, surface mapping was used to establish the structural trend. It was assumed that the same general trends continued at depth.

- Outcrops

Lines of the outcrop for the top of TSw1 were obtained for the western edge of West Ridge, Jet Ridge, and Boomerang Point. These were used to help control the structures.

- Borehole logs

Two boreholes have been drilled in the expansion area, WT-7 and H-6. Cutting logs and geophysical logs from these boreholes were used to identify the unit contacts at depth.

- Faults

Where fault dips were identified on the mapping, they were used to construct the fault models. Where they were not identified, normal faults were assumed to have an 80° dip and strike-slip of 90°. Offsets were estimated from the apparent offset shown on the geologic maps.

The LYNX computer model of the geology was used to identify suitable expansion areas for repository placement by cutting the volume model with a plane coinciding with the slope of the repository block. Five areas were identified including the Lower Block, Areas 5, 6, 7, and 8 for a total additional area of about 2375 acres. These areas are at various elevations, but all slope to the south.

[CRWMS M&O 1997s]

A.2 DEFINING REPOSITORY PRIMARY AREA

Pre-conceptual repository designs developed in 1983 used a subsurface repository footprint based on the topography and limited subsurface fault data. This work assumed a thermal load of 50 kW/acre, two possible emplacement modes and a single exploratory shaft with little exploratory drifting.

[SNL, 1984a]

A.3 INITIAL CONCEPTUAL DESIGNS OF SUBSURFACE REPOSITORY

Sandia National Labs (SNL) continued the pre-conceptual repository design effort and defined a primary area for subsurface development the addressed the following three possible waste emplacement modes:

- Self shielding waste package place on the emplacement drift floor,
- vertical borehole emplacements in the emplacement drift floor,
- horizontal long borehole emplacements in the emplacement drift wall.

This study also assumed areal thermal loading of 50 kW/acre, one exploration shaft and limited exploration drifting.

[SNL 1986a & SNL 1987a]

In 1987 SNL developed a conceptual design to be used in the "Site Characterization Plan" (SCP-CD). It used a preliminary subsurface repository area similar to that defined in the 1984 study, but redesigned the layout into the "pork chop shaped" footprint used in various later studies. This conceptual design included the following features:

- A calculated areal thermal load of 57 kW/acre based on the desire to maintain access drift walls below 50 degrees C with ventilation,
- addressed both vertical and horizontal long borehole emplacement modes for the small waste packages,
- used TBMs for main and perimeter ventilation drifts and drill-blast methods for emplacement drifts,
- used rubber tired, diesel powered, emplacement vehicles,
- planned two exploratory shafts and an exploratory facility limited in areal extent, but with defined test rooms and facilities.

This SCP-Conceptual Design became the reference design and was sufficiently detailed to provide a basis for a Total System Life-Cycle Cost (TSLCC).

[SNL 1987b]

A.4 REPOSITORY SITE CHARACTERIZATION -- EXPLORATION

In 1991, the "ESF Alternatives Study" was concluded. It took a systematic approach to comparing 34 alternative ESF and repository designs addressing multiple criteria and goals including: long-term performance, construct ability, safety, cost, license ability, and others. By using multi-attribute decision analysis procedures, it selected the current approach replacing the SCP-CD concept of two exploratory shafts with repository-like TBM ramps.

Other features include the following:

- Site characterization was integrated with conceptual repository layouts to reduce the number of openings connecting the subsurface with the surface from six to four.
- The ESF ramps allowed the use of TBMs for exploratory purposes and then for repository development thereby minimizing the need for drill-blast excavation.
- This alternative explored the approximate middle of the SCP-CD repository pork chop shaped block as the TSw2 Main Drift. That main was then proposed to become a repository service main.
- The South Ramp developed in this alternative would explore the overlying geologic units at a different location than the North Ramp and then become the future repository's muck haulage ramp.
- Exploration drifts could be excavated off the TSw2 Main to cut critical fault areas at several locations within the primary area.
- The potential for exploring the Calico Hills Formation below the Topopah Spring for characterization purposes was considered.

Title II design work on the Exploratory Shaft Facility (ESF) was discontinued with this "ESF Alternatives Study" and the meaning of "ESF" was altered to "Exploratory Studies Facility" thereafter.

[SNL 1991]

A.5 INTEGRATION OF ESF AND REPOSITORY OPENINGS

In 1993, work on ESF design concepts was incorporated into the existing ESF Title I design and it become the reference repository layout. In doing so, it moved the testing facilities to the northeast part of the footprint and reduced the gradient of the North Ramp.

Also, in 1993 the "Repository Subsurface Layout Options and ESF Interface" (CRWMS M&O 1993b) provided information on changes to the SCP conceptual design report and the ESF Title I Design with its modifications. Features of this document include the following:

- A large multi-barrier waste package,
- large diameter TBM bored service mains and perimeter ventilation drifts,
- smaller diameter TBM mined emplacement drifts as opposed to large-cross-section, rectangular, drill-blasted emplacement drifts supporting borehole emplacement modes,
- ESF Title I portal location and azimuth for the North Ramp,
- avoided faults in the primary area,
- created flat/horizontal gradients in the emplacement drifts,
- assumed "In-Drift-On-Rail" emplacement of large waste packages,
- reduced the number of service mains and secondary access drifts,
- conventional rail transport was proposed for both emplacement and development operations,
- used the primary repository area and determined the maximum thermal loading to support 68,200 kW output at the time of emplacement,
- defined a common drainage point for all main drifts.

A.6 DEFINITION OF REPOSITORY BLOCK LIMITS

In 1994 a design analysis was developed and titled "Definition of Repository Block Limits" (CRWMS M&O 1994b). This analysis used available geologic data and empirical techniques to define the following potential repository limits:

- Lateral limits are defined by fault projections and the 200-meter minimum overburden requirement.
- Upper limits on the potential repository horizon include: the 200-meter overburden requirement, a standoff of 5 meters below the base zone of >10% lithophysal cavities, and a thermal goal related to surface temperature rise and surface uplift.
- Lower limits address excavation stability, thermal goals, and possible perched ground water. The analysis concluded that the TSw3 unit between the Calico Hills (CHn1) and TSw2 should be avoided due to its brittle nature. A 5-meter standoff between the potential repository floor and the top of TSw3 should be maintained. The thermal goal was yet to be determined in 1994 for the TSw3 but it may be satisfied by the excavation stability standoff as noted above. Perched water could occur at the top of TSw3.

In 1995 a report titled "Definition of The potential Repository Block" (CRWMS M&O 1995c) was issued. It defined the available repository volume with the following:

- 200-meter overburden standoff from surface topography,
- 5-meter standoff below the bottom of the TSw1 thermal- mechanical unit,
- 5-meter standoff above the top of the TSw3 unit,
- the top of the groundwater table,
- 60-meter standoffs from major faults except the West side of the Ghost Dance, which was defined as 120 meters.

The "Advanced Conceptual Design" (ACD) (CRWMS M&O 1996d) report was issued in 1996. It further defined criteria and limits as noted in the following sections:

1) Potential repository areas were limited by the following:

   a) 200-meter overburden standoff from surface topography,

   b) 5-meter standoff below the top of the repository horizon,

   c) 30-meter standoff above the bottom of the host horizon as a thermal related goal,

   d) top of the groundwater table,

   e) 60-meter standoff from Type I (major) faults (120 meters the West side of the Ghost Dance Fault).

2) Thermal loading used "Controlled Design Assumptions" (CDA) Key Assumption 019 - "Subsurface and waste package designs will be based on a reference thermal load of 80 - 100 MTU per acre. The reference thermal load is 83 MTU/acre" (See Sec. 1.6.7). This thermal criterion will accomplish the following:

   a) Keep emplacement drift wall temperature < 200 degrees C,

   b) limit TSw3 to < 115 degrees C,

   c) limit ground surface temperature change to <2 degrees C.

3) Strategy of thermal loading allows variation in placement and thermal management.

4) Waste package spacing is developed based on 83 MTU/acre.

5) Emplacement mode selected is "In-Drift" to accommodate the large waste package in a TBM mined opening.

6) Two concepts of in-drift studied: Center-In-Drift (5.0 m) and Off-Center-In-Drift (5.5 m).

7) Repository layouts evolved from earlier work as follows:

a) Starting with the reference repository layout,

b) modifying with the Interim layout concept - 1994,

c) using 24 MTU/acre layouts for expansion areas,

d) ACD subsurface layout 1996.

8) ACD excavated openings include:

a) 9-meter diameter TBM Launch Mains,

b) 7.62-meter diameter TBM Service Mains,

c) 5.0-meter diameter TBM Emplacement Drifts,

d) various non-TBM excavations.

9) Two levels of repository blocks separated by the Ghost Dance Fault -- connected by internal ramps and shafts.

10) Center-upper-block Exhaust Ventilation Drift within the emplacement horizon,

11) Emplacement drifts on 22.5-meter centers bored from east to west starting in the Launch Main and recovering in the West Main for return to the East Main by rail. These emplacement drifts would use:

a) Pre-cast concrete invert segments to follow the TBM using rails to service the TBM operation,

b) ground support to be installed specific to ground conditions,

c) emplacement rails set after ground support using steel ties on crushed tuff fill,

d) shielded closure doors,

e) added radiation protection from a car mounted shadow shield.

12) Divided ventilation systems whereby emplacement operations and development operations are isolated by movable bulkheads.

13) Emplacement side ventilation intakes air through the North Ramp and exhausts through the Emplacement Exhaust Shaft. Fans at surface draw air through the shaft and emplacement side segment of the Exhaust Main. The Exhaust Main collects air from all emplacement drifts receiving waste and smaller amounts from those already filled. A HEPA filter facility at the shaft collar is activated only in the event of a radio nuclide release. Should that happen, dampers will divert the contaminated air at reduced volume through the HEPA filters.

14) The development side intakes air through the South Ramp and exhausts through the Development Shaft. Fans located at the South Ramp Portal force air down the ramp through an airlock and into the East and West Mains. Exhaust air from mining is conducted through tubes to the development shaft where it joins air that has passed through the emplacement drifts under construction and into the development segment of the Exhaust Main. The differential underground air pressure would always be maintained so that leakage would be from development to emplacement.

15) Emplacement operations use rail transport of waste packages from the WHB to the emplacement drift using a standard gauge. Waste packages move into the emplacement drift on a narrow gauge rail car where it remains for disposal.

16) No human entry is allowed in the emplacement drifts after the first waste is emplaced in that drift.

17) The repository operating facilities are located at the North Portal.

18) Development operating facilities would be located at the South Portal.

19) Development of emplacement drifts would proceed in blocks of 12 emplacement drifts starting in the northern part of the repository block and progressing in a southerly direction.

20) Mined rock (muck) removal would use a combination of conveyors, railcars, and rubber tired load-haul-dump (LHD) vehicles.

21) Mined rock would be stockpiled on the surface accessible to the South Portal.

22) Emplacement operations would be conducted from both East and West Mains.

23) Waste packages would be transported in a shielded transporter trammed from the surface WHB by a trolley locomotive.

24) A waste package would be placed horizontally on a narrow gauge rail car in the waste handling building. An internal mechanism (in the waste package transporter) would pull the narrow gage rail car and WP into the transporter. A transport locomotive would move the waste package transporter from the waste handling building to the emplacement drift. At the emplacement drift, the internal mechanism would push the narrow gage rail car and waste package out of the transporter and onto a dock. A small, battery powered locomotive would push the rail car and WP to its specified location within the emplacement drift.

25) Shielding doors of concrete and steel would provide both isolation and radiation protection at the emplacement drift entries.

26) Emplacement operations would be conducted under remote control with the operator's position removed from the active emplacement area.

27) Subsurface communications and control systems would be integrated but redundant.

Many of the above ACD features continue into the current (1997) subsurface repository concepts.

A study completed in 1997 presents a more definitive description of the repository host horizon (CRWMS M&O 1997s) than presented in the ACD and identifies the volume within which the repository could be sited based on limiting criteria and assumptions.

A.7 ANALYSES OF THERMAL LOAD

The thermal load effects conditions underground as well as on surface. The impact of thermal loading on the surface is discussed in the Environmental Baseline File: Biological Resources, Preliminary Working Draft which is in preparation for the Environment Impact Statement.

Thermal loading is a major repository design criterion. It helps to define the amount of nuclear waste in its various forms that may be disposed of within a defined subsurface area. There are several ways to define thermal loading as noted below. Each has its own advantages and disadvantages.

- Areal Power Density (APD), or Areal Heat Load (AHL) refers to the average initial rate of heat generation by waste packages at the time of emplacement within a unit area. Units are in kilowatts per acre kW/acre.

- Areal Mass Loading (AML), expressed as mass of uranium and/or its equivalent divided by the area attributed to that mass, MTU/acre, or MTHM/acre (metric tons of heavy metal).

- Equivalent Energy Density (EED), refers to the total potential thermal energy produced by waste packages over a given length of time, within a unit area occupied by the waste packages, measured in gigajoules/square meter (gJ/m^2).

The pre-conceptual repository designs of 1983 and 1984 assumed an Areal Power Density of 50 kW/acre estimated to maintain thermal perturbations to the surface directly above the repository well below those specified by EPA regulations.

The SCP-CD in 1988 (SNL 1987b) used an Areal Power Density of 57 kW/acre. This was considered to be an efficient use of available area yet provided acceptable operating conditions for emplacement, caretaker and retrieval operations. Waste packages in this conceptual design were to be placed in boreholes in either the floor or the drift walls.

A systems engineering study performed in 1994 (CRWMS M&O 1994d) reevaluated thermal goals focused on protection of engineered and natural barriers. It narrowed the range of thermal loading to an areal mass loading of 100 MTU/acre as an upper limit.

A *Thermal Loading Strategy* (CRWMS M&O 1995d) concluded with a programmatic decision to focus current design activities on a reference design thermal load that will permit emplacement of at least the statutory maximum within the primary repository area and will produce dry conditions around the waste packages. The current working hypothesis is that an areal mass loading of 80 - 100 MTU/acre will satisfy both criteria. As a working hypothesis, the strategy will maintain prudent levels of flexibility by including alternative areal mass loadings through design options and variations in operational parameters. This thermal loading range was included in the CDA (CRWMS M&O 1996b) as Key 019.

The fiscal year 1995 *Thermal Loading Study FY 1995* (CRWMS M&O 1996a) recommended focusing thermal test planning on identifying parameters that may affect waste isolation as a function of thermal loading and prioritizing recommendations based on potential impacts to performance. It also made preliminary evaluations of selected thermal management issues including: non-uniform AML loading, ventilation and others.

The *Thermal Study for FY 1996* (CRWMS M&O 1996c) was performed to provide recommendations for MGDS requirements affected by thermal loading that will provide sufficient definition to facilitate development of design concepts and support life-cycle cost estimates. This study also provides a rationale for limiting thermal loading in the primary area to no more than 90 MTU/acre and suggests that once thermal measurements are available, some alternative loadings and thermal issues be reevaluated for license application submittal. It summarized its recommendations as follows:

- Delete the requirement stated in the *Controlled Design Assumptions* (CDA) limiting the TSw3 to less than 115 degrees C.
- Delete the CDA-assumed requirement limiting the CHn maximum temperature to less than 115 degrees C.
- Establish a not-to-exceed temperature of 90 degrees C for the zeolitized tuff in the Calico Hills Formation. This temperature limit would be based on the average depth of the top of the zeolitized unit beneath the given potential emplacement area.
- Retain the not-to-exceed emplacement drift wall temperature of 200 degrees C.
- Retain the not-to-exceed cladding temperature of 350 degrees C.

For the Advance Conceptual Design the reference thermal load used was 80 - 100 MTU per acre. This thermal loading had to meet the following criteria: keep emplacement drift wall temperature less than 200°C, limit TSw3 to less than 115°C, and limit ground surface temperature change to less than two degrees C. This strategy of thermal loading allows variation in placement and thermal management.

The VA design analyses used an AML of 85 MTU/acre; slightly reducing the needed repository area while still meeting all thermal goals.

A.8 WASTE PACKAGE EMPLACEMENT

Pre-conceptual repository designs in 1983 proposed two waste emplacement modes. In both these cases, spent nuclear fuel and high-level waste were packaged in relatively small disposal containers which could be handled by rubber tired emplacement equipment. The packaged waste was to be placed into holes bored either horizontally or vertically from the emplacement drifts. These two modes required heavily shielded transporters and emplacement devices, because the container provided little radiation protection. Emplacement boreholes could be left cased, partially cased or un-cased. Emplacement borehole collars required shielding closures that would mate to the emplacement vehicle to limit operator exposure.

SNL issued a study (SNL 1985) that compared three alternative emplacement modes. Borehole emplacement modes were again described and the "Self Shielding Waste Package" was analyzed. This self shielding emplacement mode placed very large waste packages on the emplacement drift floor, as they were considered to be too large for borehole emplacements. They were specified to have sufficient shielding so as to be safe for direct handling. This shielding would also serve as an engineered barrier to provide extended waste isolation. Part of this study's purpose was to compare total system costs of the three emplacement modes. The self shielding case was found to be very costly compared with the borehole methods. The Horizontal Long Borehole mode was determined to be least costly.

The repository conceptual design developed in 1987, and made the basis for the SCP-CD published in 1988, used both the horizontal long-borehole and the vertical borehole emplacement methods. While the horizontal long-borehole mode was favored because it was the least costly, the vertical mode was used as the basis for the Total System Life Cycle Cost (TSLCC) developed in 1989.

In 1993 the M&O issued a report titled: *Alternatives for Waste Package Emplacement, Retrieval, and Backfill Emplacement* (CRWMS M&O 1993c) as introductory work to the ACD. The SCP-CD emplacement modes: Vertical and Horizontal Long Borehole, were briefly readdressed as was the Self Shielding Waste Package in-drift mode. Because of the need to expand TBM excavation to all possible underground excavation, a concept for vertical borehole emplacement drift development was included. Large multi-barrier and multipurpose canister waste packages had been proposed as changes to the SCP-CD conceptual designs. Several variations on in-drift emplacements were suggested including: "Centerline Emplacement" on a pedestal and on rail cars, "Side-Cast Emplacement" on a pedestal, "Combined Vertical and Alcove," "Alcove," and "Invert Vault."

Later in 1993, the *Repository Subsurface Layout Options and ESF Interface* (CRWMS M&O 1993b) report was accepted to record modifications evolved from combining SCP-CD and ESF Title I Design changes. Emplacement mode features described in this report include: large multi-barrier waste packages; TBM mined emplacement drifts; essentially flat/horizontal emplacement drifts; "In-Drift-On-Rail" emplacement for the large waste packages, and the use of conventional rail transport for both emplacement and development operations.

Early in 1996, the ACD analyzed two emplacement modes only for the MPC type waste packages. These "In-Drift" concepts were "Center-In-Drift" using a 5.0 meter diameter emplacement drift and Off-Center-In-Drift using a 5.5 meter drift. Other emplacement features include the following:

- Emplacement operations would be conducted from both East and West Mains.
- Waste packages would be transported in a shielded transporter trammed from the surface WHB by a trolley locomotive.
- A waste package would be placed horizontally on a narrow gauge rail car in the waste handling building. An internal mechanism (in the waste package transporter) would pull the narrow gage rail car and WP into the transporter. A transport locomotive would move the waste package transporter from the waste handling building to the emplacement drift. At the emplacement drift, the internal mechanism would push the narrow gage rail car and waste package out of the transporter and onto a dock. A small, battery powered locomotive would push the rail car and WP to its specified location within the emplacement drift.
- Isolation (Shielding) doors of steel, mounted in concrete walls would provide both isolation and radiation protection at the emplacement drift entries.
- Emplacement operations would be conducted under remote control with operators' position removed from the active emplacement area.
- Subsurface communications and control systems would be integrated but redundant.

Viability Assessment studies show that high-level waste packages can be placed between SNF packages without significantly adding to the overall thermal load on the emplacement drift segment. This may require less overall tunnel excavation than the ACD layout.

A.9 WASTE PACKAGE CONCEPTUAL DESIGN INFLUENCES ON EMPLACEMENT

Early studies reported by SNL assumed waste packages that were pre-conceptual in design including *A Comparative Study of Radioactive Waste Emplacement Configurations* (SNL 1985). It analyzed three emplacement modes: Vertical Borehole, Horizontal Long Borehole and Self Shielded In-Drift. The self-shielded waste package was described as consisting of cylindrical, self-shielded canisters placed on the emplacement drift floor at 9-m intervals. The subsurface layout for the self-shielded case was similar to the vertical borehole mode. Despite the elimination of the need for thousands of boreholes, the self-shielded alternative was excessive in cost. A Sandia study titled: *Disposal of Radioactive Waste Packages in Vertical Boreholes* (SNL1987a) contained a description of the waste packages that might be emplaced in vertical boreholes.

This waste package would have a pentle on the neck to permit attachment of a grapple during emplacement and retrieval operations. A similar waste package to be used in long horizontal boreholes is described in another SNL study titled "An Assessment of The Feasibility of Disposing of Nuclear Waste in a Horizontal Configuration" 1986.

Prior to the amendment to the Nuclear Waste Policy Act (NWPAA), waste emplacement modes were intended to be similar in the nine mined geological disposal systems being considered in six states at that time. Borehole emplacement was the standard and waste packages were described which fit that emplacement mode. (See Section 8.1 for references.)

The SCP-CD continued the two borehole emplacement modes, while the conceptual waste package designs went from generic to conceptual.

Early in 1994 the spent nuclear fuel waste handling and disposal design basis was formally changed from the original smaller (SCP-CDR) un-canistered waste package design concept by adoption of the larger Multi-Purpose Canister (MPC) based concept. In the MPC concept, the waste was placed in a canister that could be used both during transport to the repository as well as for emplacement in the repository. This fundamental change in design basis had the effect of focusing ACD activities and emplacement mode options. Advanced conceptual design studies that followed, including the ACD Report in 1996, addressed in-drift waste package emplacement. Borehole emplacement is no longer considered to be an option because of MPC size, weight, and thermal output.

Current VA design analyses, also, assume large waste packages similar to those described in the ACD report.

A.10 REPOSITORY LAYOUT APPROACHES

The pre-conceptual repository designs starting in 1983 used a footprint outlined by major faults and the 200-meter minimum overburden requirement. Layouts of subsurface development openings were oriented to accommodate the strike of the prevalent faults and the general dip of the welded tuff units. The number of emplacement drifts depended on the emplacement mode. For vertical borehole emplacement, drift spacing was 100 feet while horizontal long borehole emplacement drift spacing was 1,360 feet between center lines. The assumed areal thermal density for these layouts was 50 kW/acre.

SNL continued the pre-conceptual repository design effort and defined a primary area for subsurface development that addressed the following three possible waste emplacement modes: self shielding waste packages placed on the emplacement drift floor, vertical borehole emplacements in the emplacement drift floor, and horizontal long borehole emplacement in the emplacement drift wall. This study also assumed areal thermal loading of 50 kW/acre, one exploration shaft and limited exploration drifting.

In 1987 SNL completed a conceptual design to be used as the basis for site characterization. It used a preliminary subsurface repository area similar to that defined in the 1984 study, but redesigned the layout into a footprint used in various later studies. This SCP-Conceptual Design became the reference design and was sufficient detailed to form the basis for a Total System Life-Cycle Cost (TSLCC). This conceptual design:

- Used a calculated areal thermal load of 57 kW/acre based on the desire to maintain access drift walls below 50°C

- Addressed both vertical and horizontal long borehole emplacement modes for the small waste packages

- Used TBMs for main and perimeter ventilation drifts. Used drill-blast methods for emplacement drifts

- Used rubber tired emplacement vehicles

- Planned two exploratory shafts and an exploratory facility limited in areal extent, but with defined test rooms and facilities.

In 1991, the *ESF Alternatives Study* (SNL 1991) was concluded. It took a systematic approach to compare 34 alternative ESF and repository designs addressing multiple criteria and goals including: long-term performance, construct ability, safety, cost, ability to license, and others. By using multi-attribute decision analysis procedures, it selected the current approach replacing the SCP-CD concept of two exploratory shafts with TBM excavated ramps. Title II design work on the Exploratory Shaft Facility (ESF) was discontinued with this *ESF Alternatives Study* and the title of *ESF* was altered to "Exploratory Studies Facility" thereafter. Features of this design effort are as follows:

- Site characterization was integrated with conceptual repository layouts to reduce the number of openings connecting the subsurface with the surface from six to four.

- The ESF ramps allowed the use of TBMs for exploratory purposes and then for repository development thereby minimizing the need for drill-and-blast excavation.

- This alternative explored the approximate middle of the SCP-CD repository block as the TSw2 Main Drift. That main was then proposed to become a repository service main.

- The South Ramp developed in this alternative would explore the overlying geologic units at a different location than the North Ramp and then become the future repositories "Tuff Ramp" (muck haulage).

- Exploration drifts could be excavated off the TSw2 Main to cut critical fault areas at several locations within the primary area.

- The potential for exploring the Calico Hills Formation below the Topopah Spring for characterization purposes was considered.

In 1993 the *Repository Subsurface Layout Options and ESF Interface* (CRWMS M&O 1993b) provided information on changes to the SCP conceptual design report and the ESF Title I Design with its modifications. Features of this document include the following:

- A large multi-barrier waste package

- Large diameter TBM bored service mains and perimeter ventilation drifts

- Smaller diameter TBM mined emplacement drifts (as opposed to large-cross-section rectangular drill-blasted emplacement drifts supporting borehole emplacement modes)
- ESF Title I portal location and azimuth for the North Ramp
- Avoided faults in the primary area, created flat/horizontal gradients in the emplacement drifts
- Assumed "In-Drift-On-Rail" emplacement of large waste packages
- Reduced the number of service mains and secondary access drifts
- Conventional rail transport was proposed for both emplacement and development operations
- Used the primary repository area and determined the maximum thermal loading to support 68,200 kW output at the time of emplacement
- Defined a common drainage point for all main drifts.

In March 1996 the ACD was issued. Its major features are noted below:

- Waste package spacing is developed based on 83 MTU/acre.
- Emplacement mode selected is "In-Drift" to accommodate the large waste package in a small diameter TBM mined opening.
- Two concepts of in-drift were studied: Center-In-Drift (5.0 m) and Off-Center-In-Drift (5.5m). Both used rail car emplacement modes.
- ACD-excavated openings include the following: 9-meter diameter TBM Launch Mains, 7.62-meter diameter TBM Service Mains, 5.0-meter diameter TBM Emplacement Drifts, and various non-TBM excavations.
- Two levels of repository blocks were laid out; separated by the Ghost Dance Fault and connected by internal ramps and shafts.
- Introduced center-upper-block Exhaust Ventilation Drift within the emplacement horizon
- Emplacement drifts were spaced on 22.5-meter centers bored from east to west starting in the Launch Main with TBM recovery in the West Main for return to the East Main by rail.
- Continued the divided ventilation systems whereby emplacement operations and development operations are isolated by movable bulkheads.

- Placed the repository operating facilities at the North Portal.
- Development operating facilities would be located at the South Portal.

Design activities in support of VA have made recommendations as follows:

- Increase spacing between center lines of emplacement drifts from 22.5 meters to 28 meters, reducing the total number of emplacement drifts for a constant thermal loading.
- The composite reduction in emplacement area needed for 70,000 MTU allows for emplacement of the total within the Primary (Upper) Block.
- Reexamination of the northern part of the Primary Repository Block allowed for the emplacement area to be moved northward leaving the southern part available for possible expansion.
- The nine-meter diameter TBM Launch Main was removed from the layout after modifying development operational procedures for the emplacement drift TBMs.
- The Exhaust Main was moved from the waste emplacement horizon to 10 meters below the bottom of the emplacement drift inverts.
- Space was not allocated to DHLW/DOE-SNF. Instead it is assumed to be placed between large CNF packages.

A.11 SUBSURFACE CONSTRUCTION AND DEVELOPMENT

Subsurface excavation methods have gone through an evolutionary process. Pre-conceptual designs done in 1983 and 1984 proposed drill-and-blast methods exclusively. Tunnel boring equipment was considered to lack flexibility in opening cross section, application, layouts, and emplacement mode designs. Cost of equipment was also of concern. Road headers capable of mining the very hard welded tuff were viewed as unavailable.

Conceptual designs supporting the SCP (SNL 1987b) proposed using TBMs for excavation of the ramps, access mains and perimeter ventilation drifts. Drill-blast methods were retained for the emplacement drifts because of the rectangular cross sections specified for both borehole waste package emplacement concepts. Difficulty in the launch-recovery-move process for boring the many emplacement drifts was also considered a limiting factor.

In reviewing the SCP-Conceptual Design Report in 1989, concern was expressed that blasting as a means of repository development could cause excessive wall rock fracturing thereby reducing the host rock's long-term performance for retarding radionuclides. In response to this concern and others, an extensive study was initiated. This *ESF Alternatives Study* (SNL, 1991) looked at 34 integrated ESF and repository layouts. Maximization of the application of mechanized mining methods was a determining factor in rating the alternatives.

The *Repository Subsurface Layout Options and ESF Interface* (CRWMS M&O 1993b) introduced TBM-mined small diameter emplacement drifts as well as the larger diameter TBM mined service mains into the repository concepts. The circular cross sections for emplacement drifts also accommodated the in-drift emplacement mode adopted by this document.

The ACD continued the use of TBMs as the major mining tool. It also specified mechanically mining emplacement drift turnouts, the Exhaust Main and other special-purpose openings using road headers. Drill-blast excavation was considered for only small individual openings. Other ACD defined construction and development systems, equipment and facilities are noted as:

- Emplacement operations uses rail transport of waste packages from the WHB to the emplacement drift using a wide gauge. Waste packages move into the emplacement drift on a narrow gauge rail car where they remain for disposal.
- Development of emplacement drifts would proceed in blocks of 12 emplacement drifts starting in the northern part of the repository block and progressing in a southerly direction.
- Mined rock (muck) removal would use a combination of conveyors, rail cars, and rubber tired load-haul-dump (LHD) vehicles.
- Mined rock would be stockpiled on the surface accessible to the South Portal.

Because of the conceptual state of all the repository designs through ACD (CRWMS M&O 1996d), the details of subsurface utilities have not been defined. The assumption has been that utilities would be supplied as needed. Because of specified equipment, electrical power and compressed air, would be supplied to both sides of the subsurface repository area. Services, likewise, have not been defined in detail.

The SCP Conceptual Design addresses ground-water control as follows: "Inflow of ground water is not anticipated in significant quantities; however, the drifts are designed so that any water, whether from ground water or from operations within the underground facilities, would be diverted away from the waste emplacement locations. All areas would drain in the direction of a sump located in the bottom of the emplacement area exhaust shaft, the lowest point in the underground facility. From this location, the water would be pumped to the surface through the emplacement area exhaust shaft. Backup pumps would be available to ensure adequate pumping capacity."

The ACD Report addresses water control in Section 8.3.4 Drainage Control as follows: "The low point for the upper block lies along the North Ramp Extension at the north end of the repository block. The low point for the block is the emplacement exhaust shaft. Water entering the repository will have a tendency to drain to these points."…. "However, ESF experience suggests that very little water flow occurs from excavation operations and that the dry ventilation air will quickly remove any accumulations of water."

Pre-conceptual repository designs used drill-blast as the major excavation tool. Equipment energy would consequently reflect this method in consumption of large amounts of diesel, compressed air and electricity.

The SCP-Conceptual Design still used drill-blast for emplacement drift excavation, but used TBM for main drifts. Conveyors became the favored muck haulage equipment; therefore, electricity became more dominant over diesel. Compressed air remained important as a source of blast-hole drilling energy.

The ACD proposes nearly all mining to be mechanized by using TBM for emplacement drift excavation and road headers for turnouts and other openings. Nearly all muck haulage would be by conveyor. Consequently, electricity would be by far the dominant energy source. Some compressed air would still be used, but little if any diesel fuel.

The potential VA design layout described in Section 4.3.1 allows minimization of road header excavation. This is accomplished by the elimination of the mid-block excavation seen in ACD and the emplacement drift cross cuts between the East Main and the eliminated TBM Launch Main. A VA modification to development operating procedures specifies the emplacement drift TBMs be reversible. This allows backing the TBMs to the East Main after each drift's excavation, then re-launching in the next turnout.

Analyses being conducted for input to VA are considering the placing of precast concrete lining behind the TBMs' excavation section.

A.12 SUBSURFACE VENTILATION

Pre-conceptual subsurface repository designs addressed the requirement and the need to separate the emplacement ventilation air and the development ventilation system. Emplacement ventilation serves to provide breathing air for personnel and equipment. It may also be used to remove heat from emplacement drifts if required. Should a release of radioactive particles occur within the operating phases of the repository, that contamination will be confined to the emplacement side. Development side ventilation systems serve functions unique to excavation and construction as well as providing breathing air. Some of these function areas follow removing dust created by mining; cooling mining equipment; providing combustion air to diesel powered equipment.

The SCP-Conceptual Design provided concepts for ventilating systems based on separation of emplacement and development areas. The Emplacement side would intake fresh air through the Waste Handling Ramp (North), pass the air through the emplacement access drifts and exhaust through a vertical shaft. Fans located at the emplacement exhaust shaft collar would draw the exhaust air thereby creating a negative pressure with respect to atmospheric. Should a release of nuclear particles be detected, then the exhaust air would be routed through HEPA filters also located at the shaft collar. The Development side would have surface fans forcing fresh air down a vertical shaft, circulating it though the underground development workings, then exhausting through the Tuff Ramp. This system would produce a positive air pressure with respect to atmospheric. Bulkheads would be designed to maintain the pressure differential underground between the two areas.

Subsurface MGDS layouts modified in the "ESF Alternative Study" (SNL 1991) and the *Repository Subsurface Layout Options and ESF Interface* (CRWMS M&O 1993b) maintained the SCP-CD basic ventilation concepts.

The ACD proposed major changes to the SCP-CD concepts including:

- A ventilation exhaust main constructed down the approximate center of the upper repository block to provide better control on ventilation of the in-drift emplacement mode.
- The development area ventilation system would be reversed in ventilation flow by in taking air through the Tuff Ramp (South) and exhausting through the vertical Development Shaft. This would allow personnel to travel through the Tuff Ramp in fresh air.
- The pressure differential between emplacement and development sides would be maintained by using movable bulkheads (air locks) and by installing fans at the Tuff Ramp collar and again using an airlock bulkhead.

Building on the ACD, VA analyses have proposed several significant changes:

- The mid-block Exhaust Main has been moved from the emplacement horizon to a parallel alignment 10 meters below the emplacement drift inverts. Vertically bored raises will connect the midpoints of each emplacement drift with the sub-level Exhaust Main.
- To better manage dust and other hazards, the South Ramp (Tuff) has been changed to the development-side exhaust route to surface. The vertical development shaft will be the fresh air intake.
- The emplacement area ventilation system has been refined to more effectively contain potential radionuclide releases. Steel ducts will collect small volumes of air from each filled emplacement drift, direct it through monitoring devices, and direct it to the Exhaust Shaft or to underground HEPA filters if radionuclides are detected.

A.13 EMPLACEMENT OPERATIONS AND APPROACHES

Pre-conceptual repository designs (1983) considered two emplacement modes each capable of isolating the relatively small waste packages. These modes were the following: "Horizontal Long Borehole" and "Vertical Borehole."

In 1984, SNL reported on studying three emplacement alternatives. Along with the two modes described above, an in-drift emplacement mode of "self shielding" waste packages was added.

In the SCP conceptual design (1987) the shelf shielding case was abandoned and the two borehole modes were considered.

The *Repository Subsurface Layout Options and ESF Interface* (CRWMS M&O 1993b) proposed the use of "in-drift on-rail" emplacement of the very large MPC-type waste packages.

Also, in 1993, the *Alternatives for Waste Package Emplacement, Retrieval, and Backfill Emplacement* (CRWMS M&O 1993c) studied the SCP-CD borehole emplacement modes, variations on both of those modes for MPC waste packages, several alcove emplacement modes, variations on in-drift emplacements, mined alcoves off the emplacement drift, and invert vaults.

Study of emplacement modes continued into 1994 with the *Repository Emplacement and Backfill Concepts and Operations Report* (CRWMS M&O 1994c). This report analyzed the following modes: center-in-drift, off-center-in-drift, in-sub-drift, in-short-perpendicular-alcove, in-short-parallel-alcove, and in-short-angled-alcove.

The *Initial Summary Report for Repository/Waste Package Advanced Conceptual Design* (CRWMS M&O 1994a) also discusses and compares the six general emplacement modes listed above, but then describes In-Drift approaches using rail car placement pedestal supports.

The *Emplacement Mode Evaluation Report* (CRWMS M&O 1995a) analyzed multiple attributes and recognized the six general emplacement modes. It also evaluated the "Rail-based" and "Pedestal-based "center In-Drift emplacement modes.

Waste package emplacements were narrowed down by the ACD to "Center-In-Drift" and "Off-Center-In-Drift" options. Both of these were based on rail cars supporting the waste packages in final disposal.

Taking the ACD emplacement concepts, the VA design analyses revised the "center in-drift, on-rail car" waste package emplacement mode to use pedestals to support the packages and self-propelled gantries to carry them to their emplacement position. The potential need for a larger equipment operating envelope causes the bored diameter of the opening to be increased to 5.5 meters in diameter.

A.14 WASTE PACKAGE RETRIEVAL OPERATIONS AND APPROACHES

The NWPA states that any repository shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in the repository for any reason pertaining to the public health and safety, the environment, or for the purpose of recovery of the economic valuable contents of the spent fuel. The Nuclear Regulatory Commission's regulation 10 CFR 60 further states this position as "To satisfy this objective, the GROA shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission."

Studies, reports and analyses prior to the ACD used the 50-year design requirement. In preparation for ACD the DOE directed that the 50-year requirement is extended to 100 years.

Key Assumption 016 was placed in the *Controlled Design Assumptions Document* (CRWMS M&O 1996f) to establish this position. The ACD (1996b), therefore is based on a 100-year retrievability period.

A retrievability strategy report has been completed (CRWMS M&O 1997j) and describes a strategy of waste package retrieval.

A.15 AUTOMATION, REMOTE CONTROLS AND MANUAL MANIPULATION FUNCTIONS

Pre-conceptual repository designs did not address automation nor remote controls. Waste packages were relatively small, were unshielded and required relatively complex mechanical methods for emplacements. While the waste handlers could not directly handle the packages, they could manually control the manipulation of the emplacement operations.

The SCP-Conceptual Design Report provided detailed description of the subsurface waste handling operations. The waste transport and emplacement/retrieval equipment maintained continual shielding during the emplacement processes for both vertical borehole and horizontal long borehole modes. The operators manually manipulated the processes from within equipment cabs.

With the program shift to MPCs and other large waste packages, borehole emplacement was shown to be impractical leading the subsequent studies and reports to focus on in-drift emplacements. In preparation for the ACD, the *Controlled Design Assumptions Document* (CRWMS M&O 1996f) adopted Key 013 which states that no human entry will be allowed in emplacement drifts containing waste packages. Key 013 establishes the need to investigate practical uses of robotics and remote operating systems for subsurface activities and pre-closure drift activities.

The ACD (CRWMS M&O 1996d) addressed the use of "Remote Handling Systems for Waste Package Emplacement" in Section 8.6.5. It lists the following remotely controlled equipment: Transport locomotive, transfer locomotive, emplacement locomotive, waste package transporter, emplacement locomotive carrier, actuated devises, and instrumentation and monitoring equipment. This same general section also discusses "Remote Systems Design Issues."

A VA design analysis entitled, *Subsurface Waste Package Handling - Remote Control and Data Communications Analysis* (CRWMS M&O 1997e) was completed in February 1997. Its purpose is to provide guidance in answering questions related to issues such as methods of control, types of inputs/outputs, estimates of overall control system complexity, remote handling system normal and off-normal events, and analyses of various mobile/remote communication technologies, i.e., radio, laser, optical, tether, or other technologies.

A.16 CONTROL AND COMMUNICATION SYSTEMS

Prior to the ACD effort, little was done to define control and communication systems. The ACD Report briefly describes the "Control System Architecture" as follows: "Critical emplacement operations can be remotely monitored, supervised, and controlled by human operators located at a central operator control station. This can be accomplished via a local area network and fiber optic backbone connected to a subsurface network of computer workstations, programmable logic controllers, and wireless radio frequency (RF), communications links to mobile equipment." Subsurface repository control systems include the following: A bridge/router interacting with surface systems, an in-situ camera network also interfacing with the surface located video display terminals, computer workstations, subsurface fiber optic communications backbone, leaky feeder co-ax communication system, distributed antenna system, programmable logic controllers, and control computers. It was recognized, in the ACD report that: remote handling of the waste packages can be accomplished by utilizing technology that is currently available, and that redundancy will be a key attribute of the remote handling control system.

[CRWMS M&O, 1996d]

This area of VA design is addressed by the *Subsurface Waste Package Handling - Remote Control and Data Communication Analysis* (CRWMS 1997e) described above in Section 4.3.2.10. Its purpose is to address methods of control, types of in-puts/out-puts, estimates of overall control system complexity, remote handling system normal and off-normal events, and analyses of various communications technologies.

A.17 PERFORMANCE CONFIRMATION

Section 9.3, Performance Confirmation, of the ACD Report states the following: "Performance confirmation is a program of baseline data acquisition and ongoing monitoring that ensure assumptions made during the repository licensing process are correct and confirms that the repository system is functioning, and will continue to function, as it was presented at the time of licensing."

Under Section 9.3.3, General Descriptions, the ACD Report states the following: "...there has been essentially no design effort expended on performance confirmation, and no description of the performance confirmation program available. The extent of the program, the types of data to be collected, and the collection interval needed remain largely unknown . . . "

"The program may or may not involve the periodic recovery of emplaced waste packages for inspection and/or testing. If all emplacement drifts required continuous monitoring, the operational impacts would be severe. However, if only selected drifts are continuously monitored, or if all drifts are monitored intermittently by mobile data acquisition units, the impacts to repository operations would be lessened . . . "

In summary, Section 9.3.4, the ACD Report continues: "As requirements are defined for the performance confirmation program, the questions of areal coverage, monitored parameters, and frequency/method of measurement will be better defined."

Monitoring of emplaced waste has been recognized as necessary, but has received little detailed consideration. Remote monitoring would occur during the emplacement/retrieval phase, the caretaker phase and the closure operations phase. Remote monitoring would be designed and operated to detect waste package failure and radio nuclide release. Waste package and near-field performance including ground support systems could be monitored and confirmed. Emplacement side ventilation air would be sampled at defined points to provide early detection of airborne radioactive particles. HEPA filters at the collar of the Emplacement-Exhaust Shaft could be activated on a signal from these sampling monitors.

Studies originating after issuance of the ACD Report addressing remote monitoring have been issued as VA design analyses in 1997. These are analysis titled: *Performance Confirmation Data Acquisition Systems* (CRWMS M&O, 1997b) and a design analysis titled: *Subsurface Repository Performance Confirmation Facilities* (CRWMS M&O, 1997c).

The first analysis concludes the following: Five key, primary designs for acquiring and processing repository performance confirmation data include: designs for exhaust air monitoring instrumentation and data acquisition; monitoring of emplacement drifts using permanently installed in-situ instrumentation; a remotely controlled inspection system; borehole instrumentation; and a design concept for a subsurface data acquisition network.

The second describes an overall system for obtaining performance confirmation parameters. It also identifies eight methodologies for that purpose.

A.18 RADIATION CONTROL AND PROTECTION

Pre-conceptual designs assumed the use of small waste packages with relatively thin container walls. These would be transported and emplaced in boreholes using adequately shielded equipment. Once in place, the boreholes would be plugged and sealed to prevent radiation from reaching the working environment.

The SCP-Conceptual Design was similar to the pre-conceptual approaches. Isolation of the radioactive waste from human contact was the principal control and protection method.

The ACD was based on the large MPC waste package. This waste package influenced concepts toward in-drift emplacements with its potential for human exposure. The commitment, also, to maintain radiation exposure from nuclear waste "As Low As Reasonably Achievable" (ALARA) caused modifications to the radiation control and protection systems. Isolation of personnel from waste is the major means of protection. This is achieved administratively by disallowing entry by all personnel to the emplacement drifts once emplacements begin. This isolation is made possible by the use of remote and automated waste handling equipment and systems. To further separate personnel from waste package radiation, "shadow shields" or plugs are placed in filled emplacement drifts between the last waste package and the isolation (shielding) door. The Isolation Doors specified for each emplacement drift can only be opened by remote control from the surface stationed operators. While these are large waste packages, they will be transported in shielded WP Transporters. By operating as prescribed, no personnel will physically be able to approach emplaced waste, but could work around the transporter if needed because of an abnormal event.

Preliminary Viability Assessment design work includes an analysis (CRWMS M&O 1997k) to identify the types of instrumentation, the appropriate ranges and set points needed, and the overall functional response characteristics of the repository to respond to normal and abnormal radiation conditions.

The project has also looked at Design Basis Accidents (DBA) and their prevention and mitigation; and, the use of secondary measures of radiation control such as shadow shields, isolation doors and treatment of the exhaust air with HEPA filters.

A.19 SUBSURFACE MOBILE EQUIPMENT ENERGY SOURCES

Pre-conceptual repository designs used drill-blast as the major excavation tool. Equipment energy would consequently reflect this method in consumption of large amounts of diesel, compressed air and electricity.

The SCP-Conceptual Design still used drill-blast for emplacement drift excavation, but used TBM for main drifts. Conveyors became the favored muck haulage equipment; therefore, electricity became more dominant over diesel. Compressed air remained important as a source of blast-hole drilling energy.

The ACD proposes nearly all mining to be mechanized by using TBM for emplacement drift excavation and road headers for turnouts and other openings. Nearly all muck haulage would be by conveyor. Consequently, electricity would be by far the dominant energy source. Some compressed air would still be used, but little if any diesel fuel.

VA design analyses use the same basic excavating methods and other subsurface energy requirements as described in the ACD.

B. APPENDIX -- EMISSIONS

During the repository operations, especially during construction/development activities, dust will be produced in various underground locations. Some airborne dust will be carried to the surface atmosphere by the exhaust air flows of the ventilation system. The main objective of the exhaust dust control is to ensure that the dust emission is within the acceptable levels so that the exhaust air will not become a major pollutant source. In 40 CFR 51.166 (1)(I)(b), the "major pollutant source" defined by the US Environmental Protection Agency (EPA) is "any stationary source which emits, or has the potential to emit 250 tons per year or more of any air pollutants.

(All dust emissions from subsurface operations are included in this 250 ton limit.)

The amount of dust emitted into the surface atmosphere is primarily dependent upon the quantity of airborne dust generated and the efficiency of dust collection systems. In an analysis of the ESF dust emission, evaluations were performed to determine the rates of dust generation from the underground operations, general range of ratio between airborne dust and excavated rock mass, and the efficiencies of most dust connection systems or units (CRWMS M&O 1994e).

The analysis concluded that the emission of dust from the underground construction is not anticipated to be a major source of pollutants (dust emission rate < 250 ton/yr) to the ambient air, with dust collection efficiencies of 63.5 percent for single ventilation duct operations, and 81.7 percent for two ducts that can potentially support simultaneous operation of two TBMs. These demanded dust collection efficiencies are achievable through current available dust control technology.

B.1 DIESEL EMISSION IN THE PORTAL MUCK PILE AREA

The general information used to estimate the amount of emission from diesel equipment based on the an earlier diesel emission analysis (CRWMS M&O 1993e):

- Literature review indicated that the general range of the brake specific fuel consumption (BSFC) rate is 0.19 to 0.5 lb./Bhp/hr, for most diesel engines under normal operating conditions.

- The stoichiometric Fuel/Air (F/A) ratio for typical diesel fuels is 0.067 (for perfect combustion). However, perfect combustion never exists. A review of a wide range of diesel equipment operations found that F/A ratios are approximately 0.033 - 0.050 for engines operating at maximum speed and brake horsepower, and about 0.01 at engine idle.

- Based on the above information, the volume of exhaust gas were estimated to be in the range of 225 - 338 ft^3 /lb of diesel fuel.

- The quantity of total diesel gases discharged from engines during a full-shift, is also dependent upon the engines shift loading factors (SLF). Based on data from previous studies, the analysis considered that the average SLF will be about 20 - 40%.

- The concentration of products in exhaust (CPE) are found to be:
  - CO 0.0114 - 0.2500%
  - HC 0.0030 - 0.0500%
  - NO 0.0225 - 0.1000%
  - NO_2 0.0008 - 0.0084%
  - CO_2 0.0300 - 11.800%
  - SO_2 0.0080 - 0.0098%
  - DPM 40.000 - 118.00 mg/m^3
  - (Particles)

Using the high rate of fuel consumption of 0.5 lb/Bhp/hr, exhaust rate is calculated to 112.5 to 169 ft^3/lb/Bhp/hr (or 151 to 227 ft^3/kW/hr).

To estimate the total emission rate of diesel exhaust in the muck pile area, the following equipment are assumed to be adequate for the construction or development operations:

Equipment	**Bhp (kW)**	**Quantity**
3/4-Ton Pickup	150 (112)	1
10-Ton Flatbed Truck	500 (373)	1
3300-Gal Water Truck	600 (447)	1
7000-Gal Water Truck	1000 (746)	1
8-Cy Transit Mix Truck	300 (224)	3
15-Ton Hyd. Crane	600 (447)	1
25~49-Ton Hyd. Crane	900 (671)	1
4-Ton Fork Lift	400 (298)	1
6~7.5-Ton Fork Lift	550 (410)	1
Bobcat Loader	500 (373)	2

CAT 966 3Cy Loader	300 (149)	1
CAT D8 Dozer	600 (447)	1
TOTAL	7500 (5593)	

When all the equipment is in operation, the total diesel emission rate in the muck pile area would be about 843,750 to 1,267,500 ft^3/hr. If these diesel equipment are operating at average SLF of 20 to 40% for two shifts per day, the total annual exhaust would be 9.86×10^8 to 2.96×10^9 ft^3/yr.

(For use in Section 6 tables, the above units convert to 83,800,000 cubic meters per year.)

The pollutants in the diesel emission will be at the following rates:

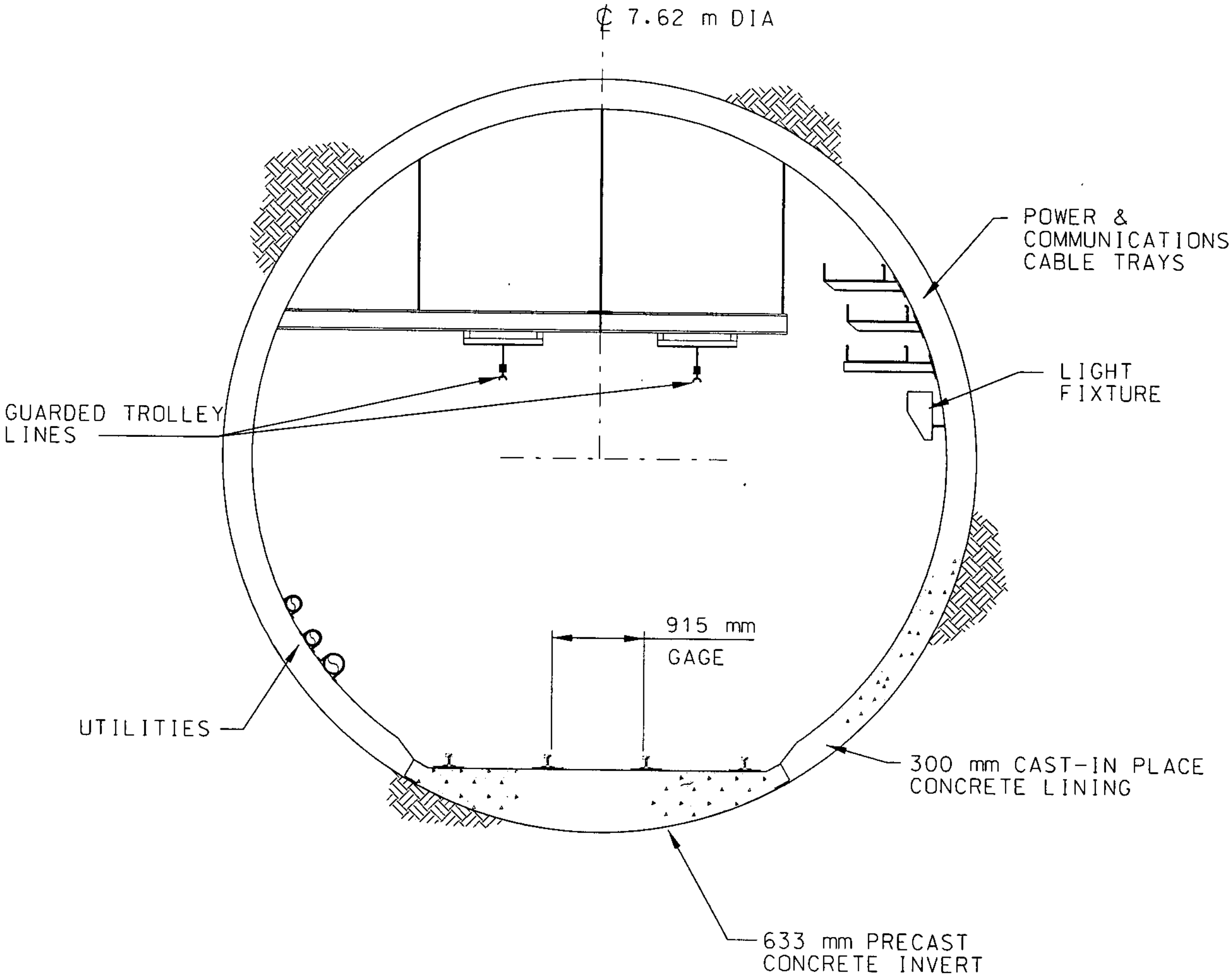
- CO 112,404 - 7,400,000 (ft^3/yr)
- HC 29,580 - 1,480,000 (ft^3/yr)
- NO 221,850 - 2,960,000 (ft^3/yr)
- NO_2 7,888 - 248,640 (ft^3/yr)
- CO_2 295,800 - 349,280,000 (ft^3/yr)
- SO_2 78,880 - 290,080 (ft^3/yr)
- DPM 149 - 1,322 (kg/yr)
- (Particles)

C. APPENDIX (NOT USED)

(This Appendix designation is not used in this revision of the Engineering File Subsurface Repository.)

D. APPENDIX -- SUBSURFACE DESIGN DETAILS

Cross sections of the major underground openings in construction/development mode are shown in Figures D-1 through D-6. All of the figures in this appendix of the engineering file were presented in Section 4 of Rev 00. They are typical arrangements and reflect the present design that may change. The figures show utility systems consisting of lights, utility pipes (compressed air - 150 mm diameter, process water - 100 mm diameter, waste water - 100 mm diameter), ventilation duct and cable trays for communications and electrical power. Figures D-7 through D-9 show the emplacement mode configuration of the drifts. The ground support is assumed to be a pre-cast or cast-in-place concrete liner. Pre-cast concrete lining means that concrete segments are formed on surface and installed immediately behind the TBM as excavation proceeds. Cast-in-place concrete means that forms are placed in the tunnels and concrete is pumped between the forms and the tunnel wall. The invert is the floor of the tunnel that forms a roadway and supports the tracks. Figure D-10 shows the vertical relationship between emplacement drifts, main drifts and the exhaust main. Shadow shields which help control radiation in the turnouts and main drifts are also shown.



Reference:

CRWMS M&O 1997h. Repository Subsurface Layout Configuration Analysis. Figure 7-12

FIGURE D-1
TYP SECTION OF NORTH RAMP
CONSTRUCTION MODE

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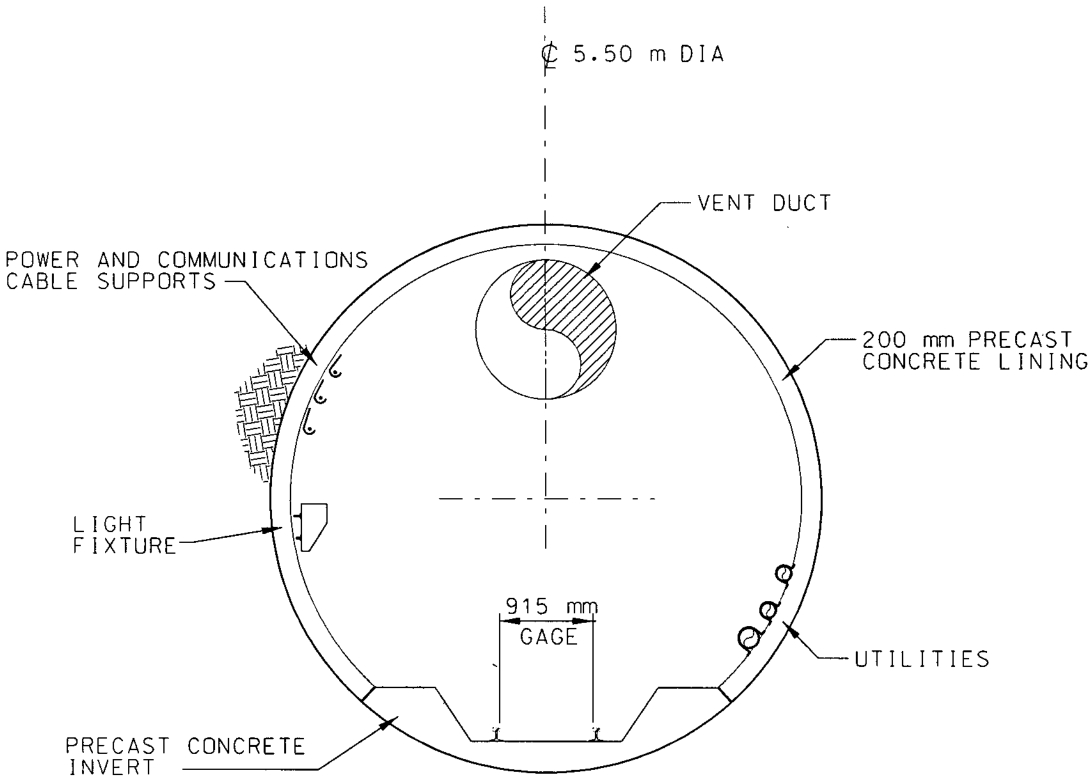

Reference:

CRWMS M&O 1997h. Repository Subsurface Layout Configuration Analysis. Figure 7-19

FIGURE D-2
TYP SECTION OF EMPL DRIFTS
CONST/DEVELOPMENT MODES

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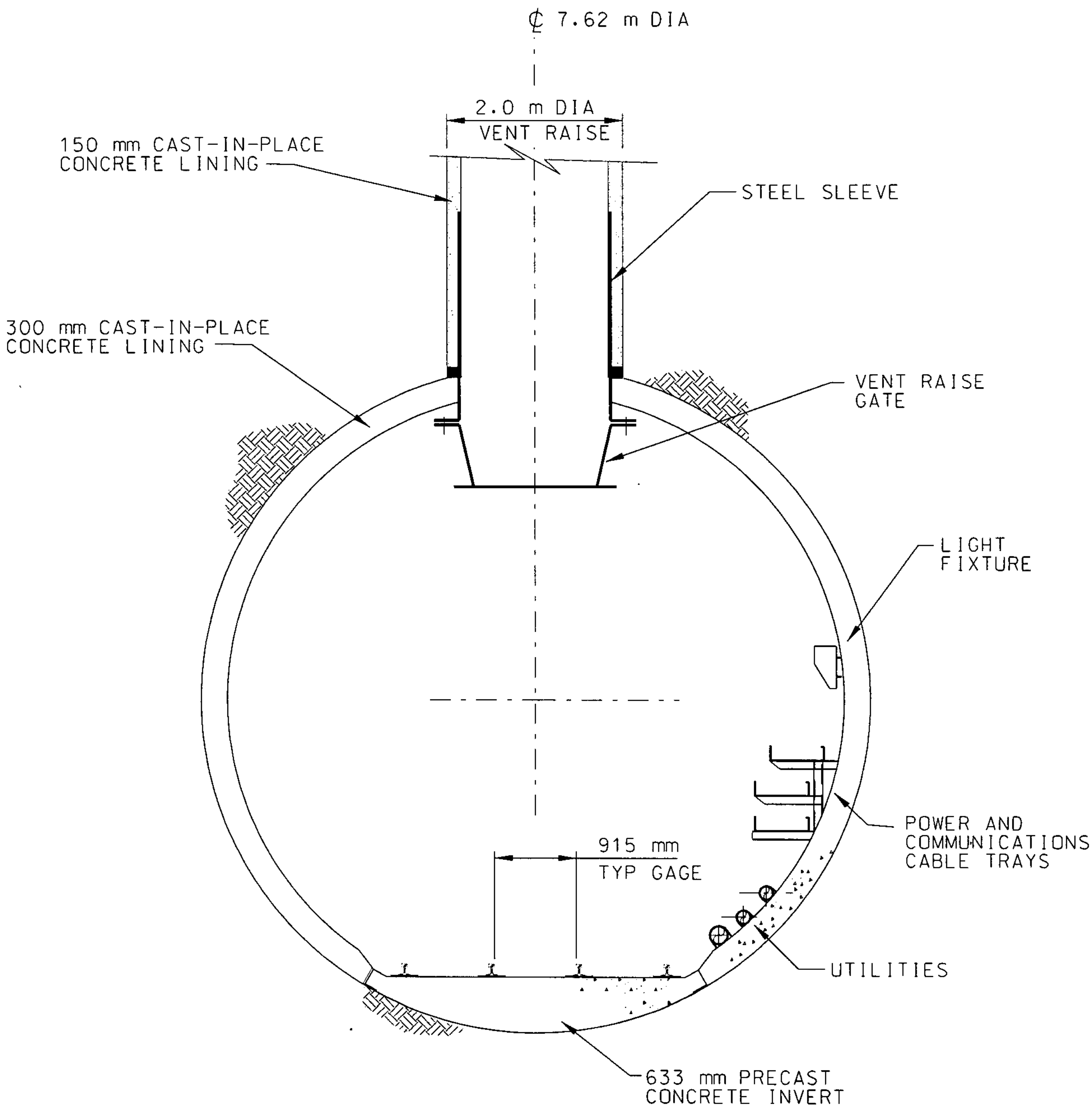

Reference:

CRWMS M&O 1997h, Repository Subsurface Layout Configuration Analysis. Figure 7-16

FIGURE D-3
TYP SECTION/EXHAUST MAIN
DEVELOPMENT MODE

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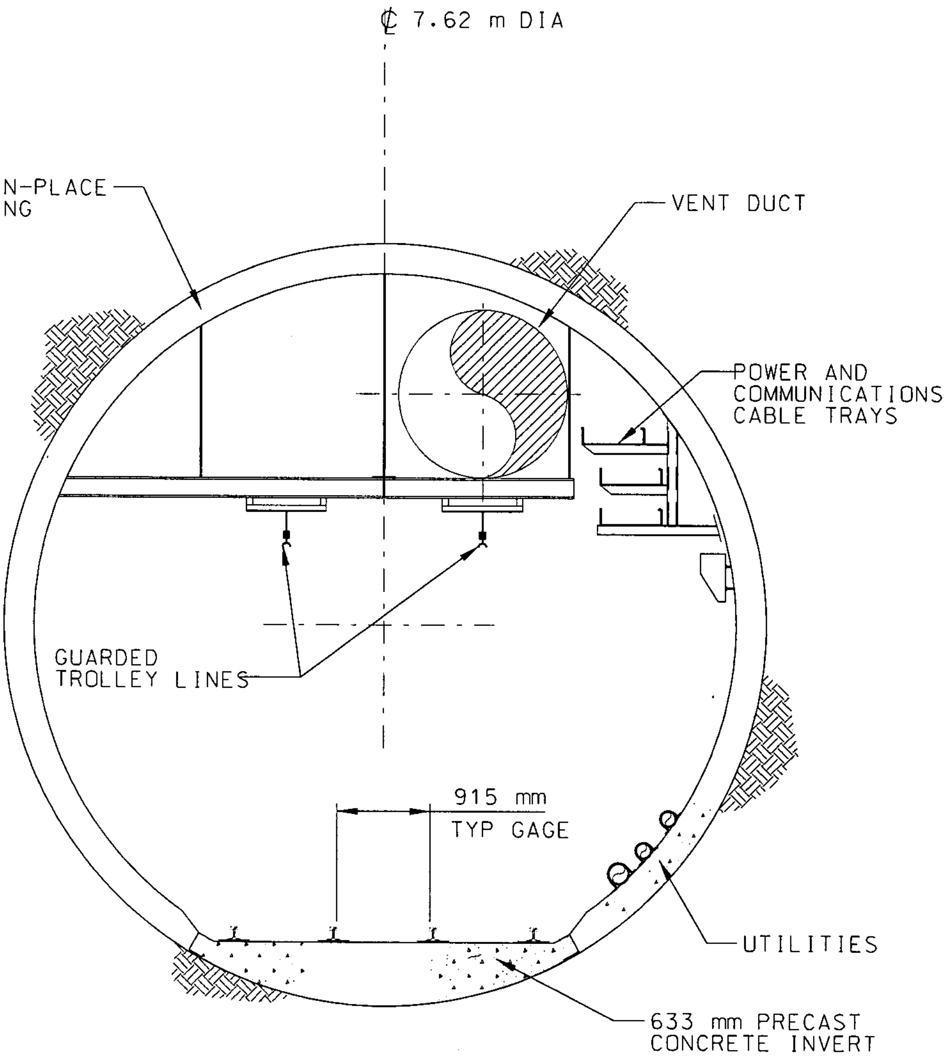

Reference:

CRWMS M&O 1997h, Repository Subsurface Layout Configuration Analysis. Figure 7-15

FIGURE D-4
TYP SECTION OF WEST MAIN DEVELOPMENT MODE

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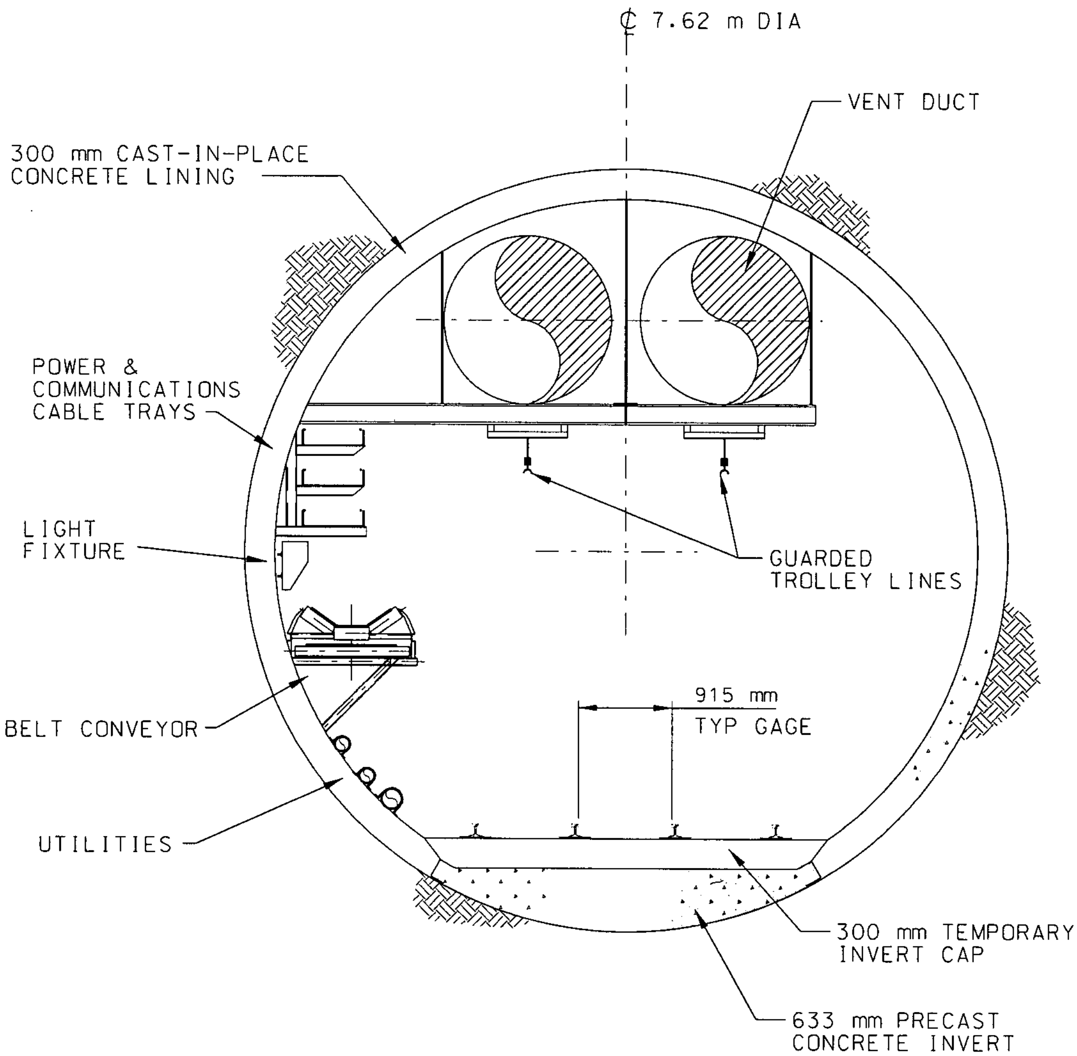

Reference:
CRWMS M&O 1997h, Repository Subsurface Layout Configuration Analysis, Figure 7-14

FIGURE D-5
TYP SECTION OF EAST MAIN
CONST/DEVELOPMENT MODES

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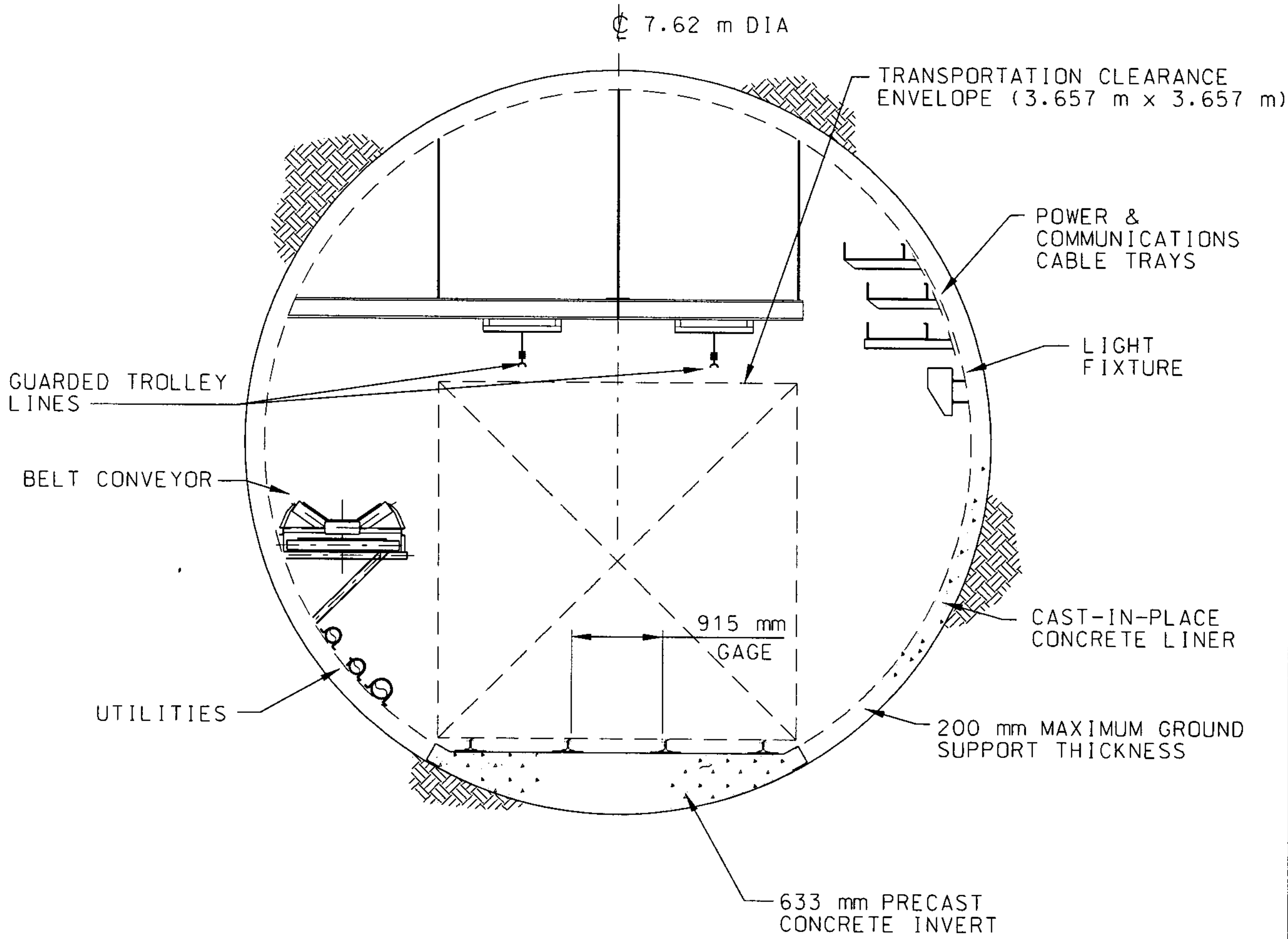

Reference:

CRWMS M&O 1997h, Repository Subsurface Layout Configuration Analysis, Figure 7-13

FIGURE D-6
TYP SECTION OF SOUTH RAMP
CONST/DEVELOPMENT MODES

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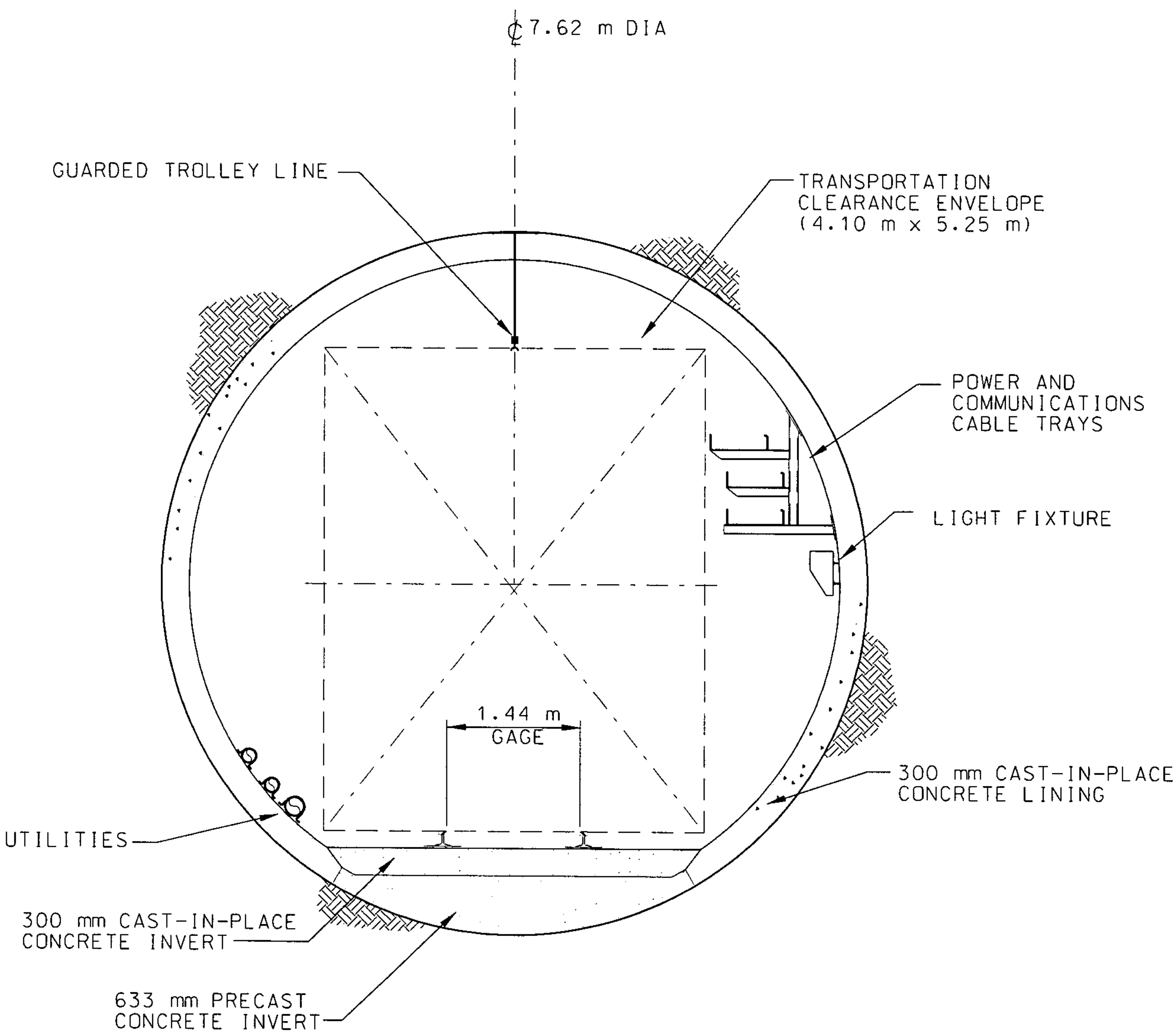
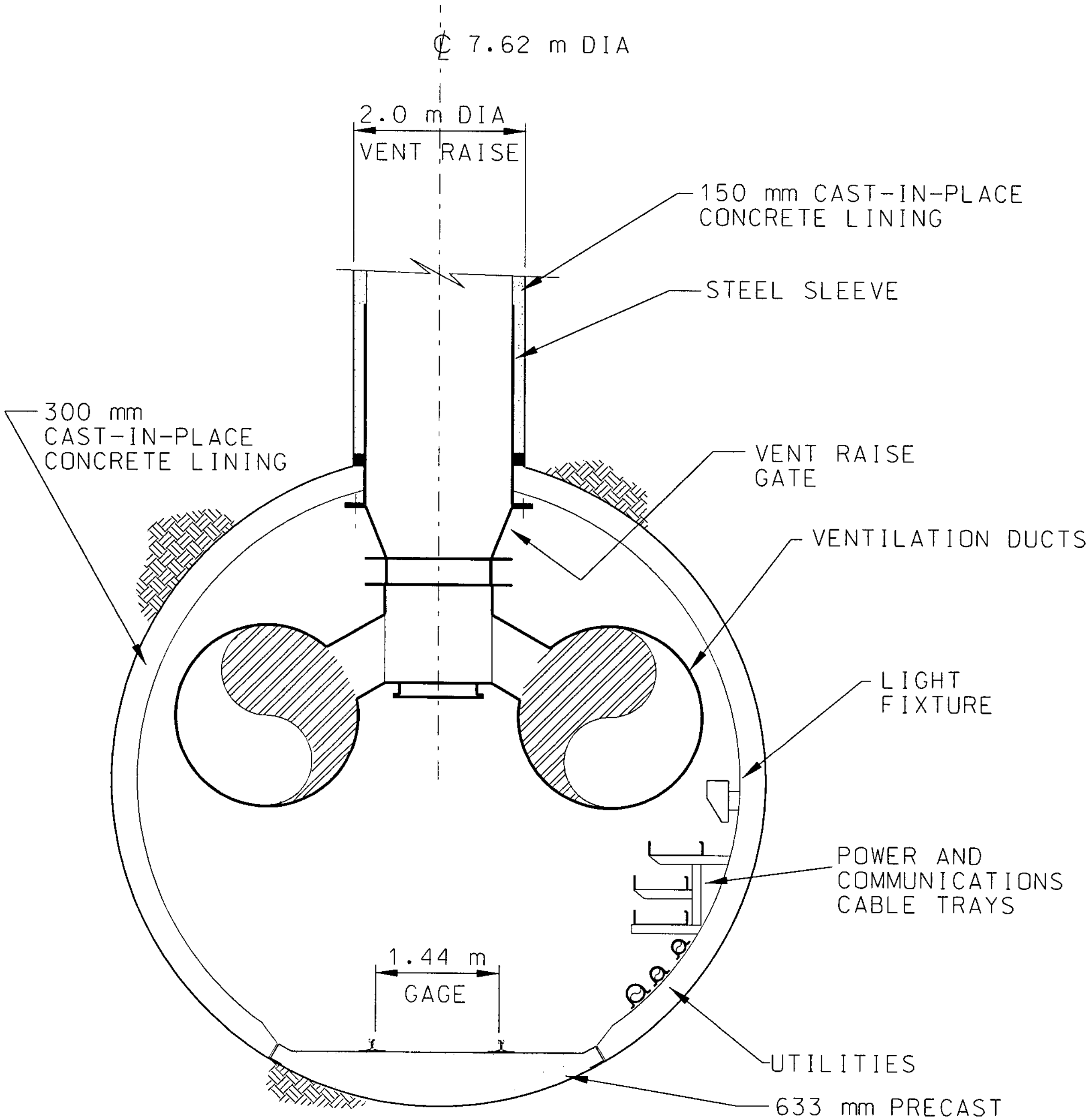


Reference:

CRWMS M&O 1997h, Repository Subsurface Layout Configuration Analysis. Figure 7-17

FIGURE D-7
SECTION OF RAMPS AND MAINS
EMPLACEMENT MODE



Reference:
CRWMS M&O 1997h. Repository Subsurface Layout Configuration Analysis. Figure 7-18

FIGURE D-8
SECTION OF EXHAUST MAIN
EMPLACEMENT MODE

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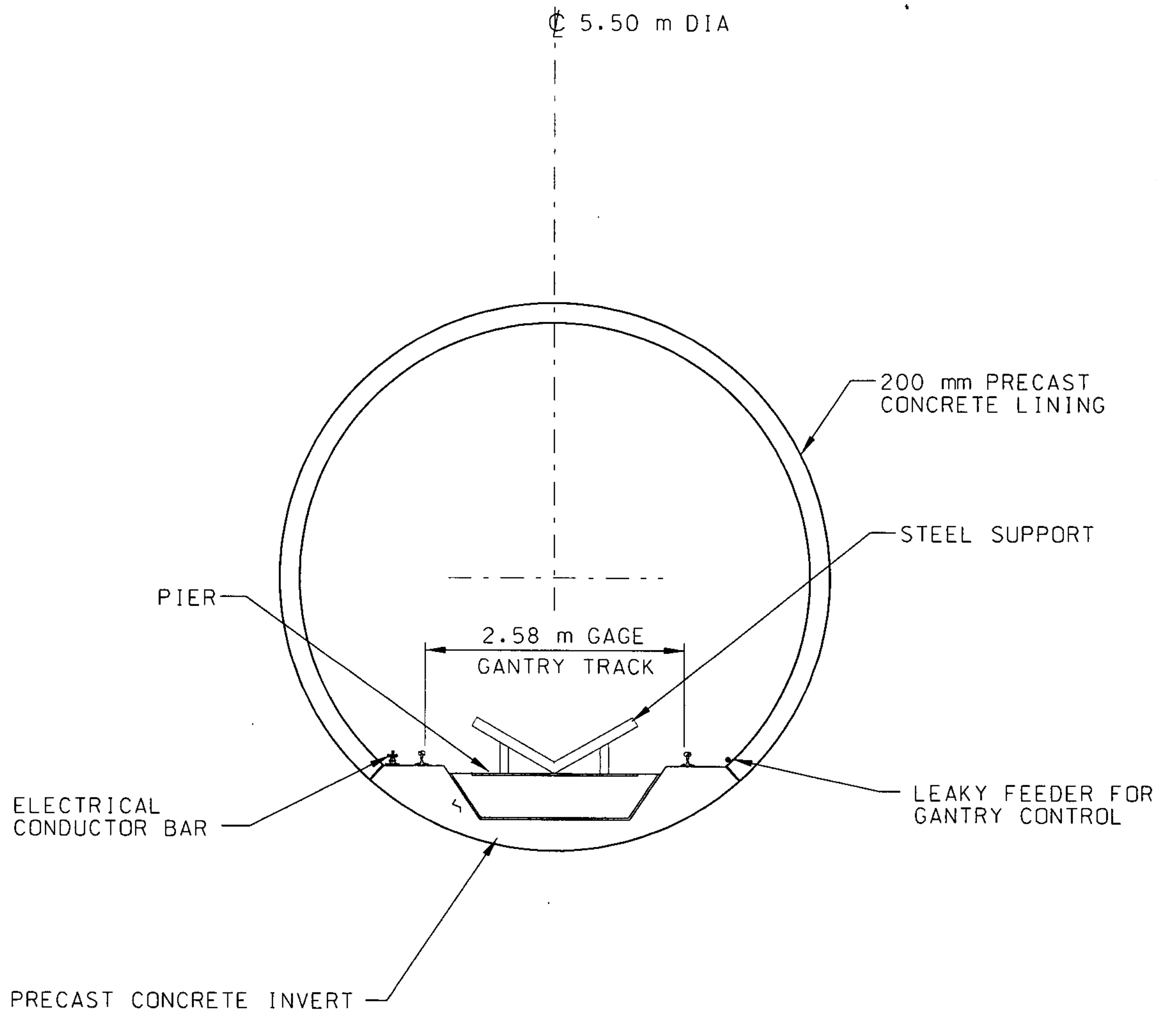
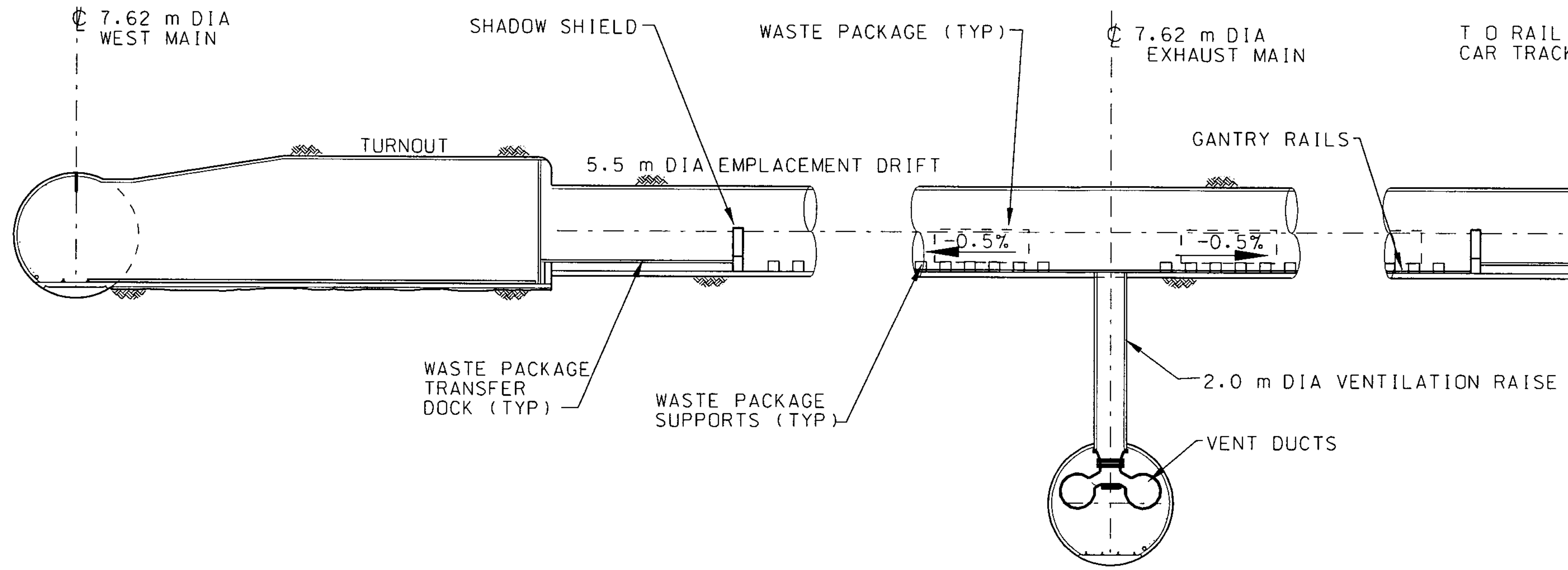
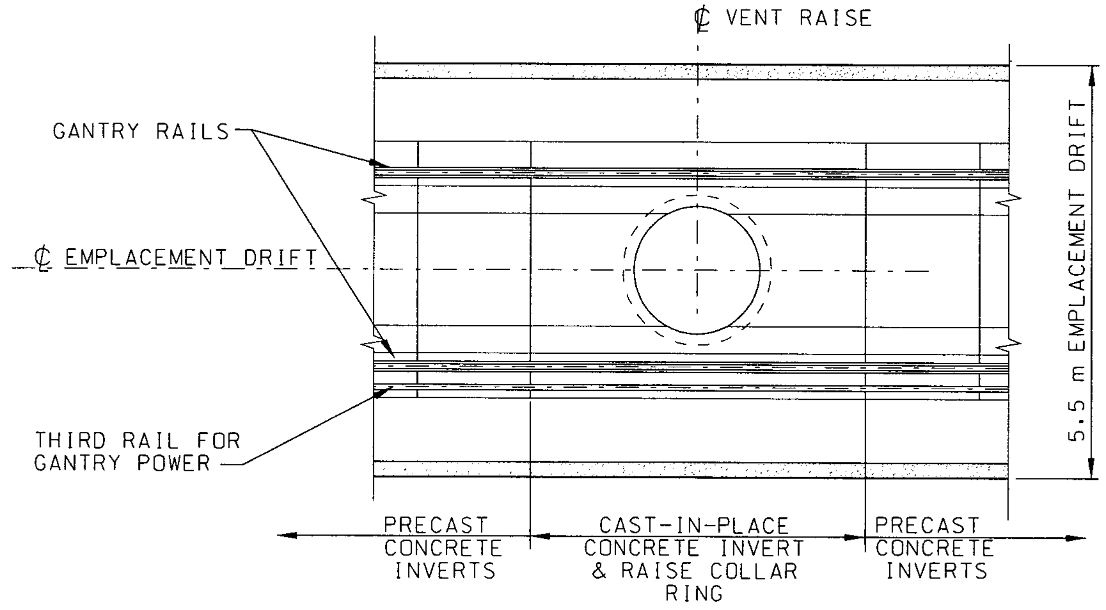


Reference:

CRWMS M&O 1997h. Repository Subsurface Layout Configuration Analysis. Figure 7-20

FIGURE D-9
SECTION OF EMPL DRIFTS
EMPLACEMENT MODE





PLAN AT VENTILATION RAISE

Reference:
CRWMS M&O 1997i, Subsurface Construction and Development Analysis.
Figure 7-18

FIGURE D-10
EMPLACEMENT DRIFT ELEVATION

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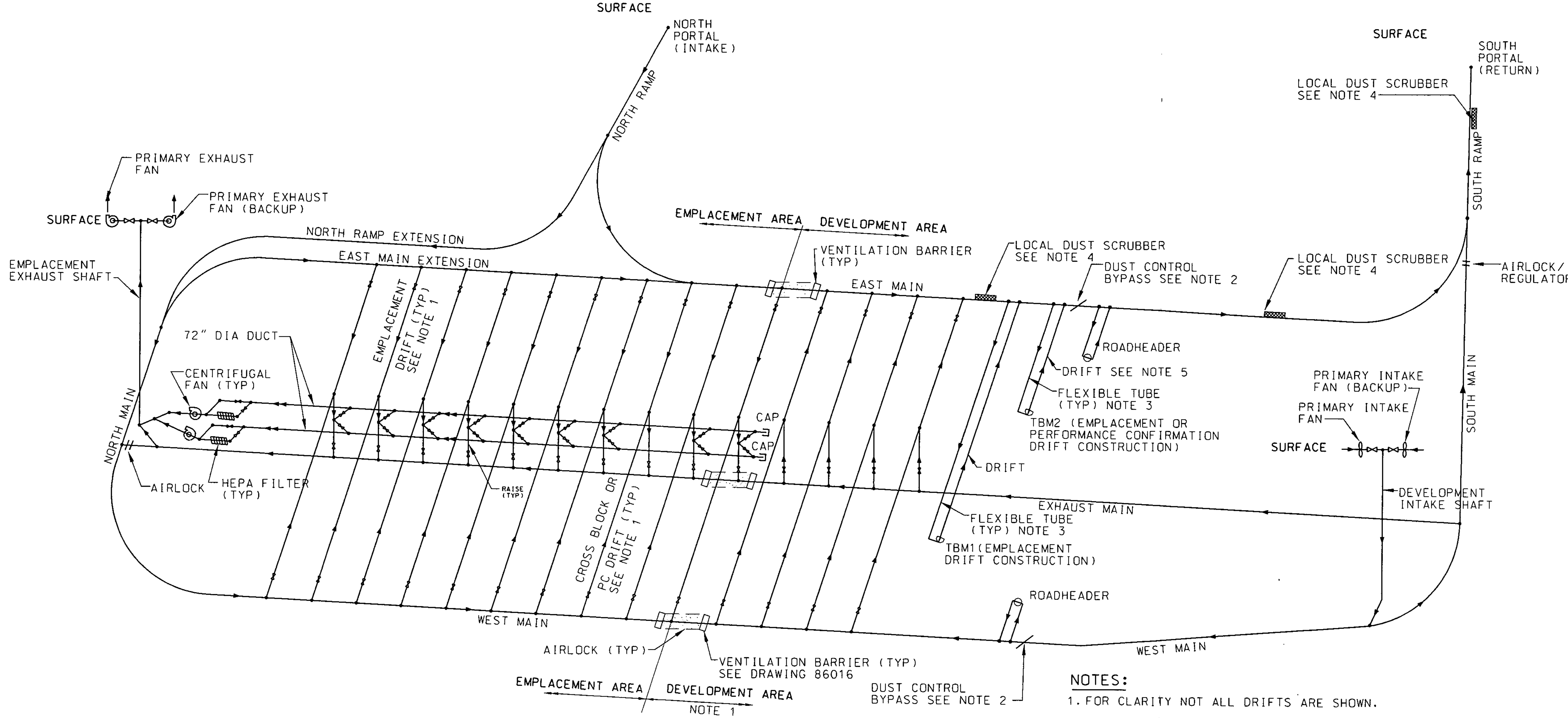
E. APPENDIX -- VENTILATION CONTROLS

Addendum A to Rev 00 of the "Repository Subsurface – Engineering File developed the following information on Ventilation controls:

- The ventilation system is illustrated in Figure E-1. This schematic shows concurrent development of emplacement drift panels and emplacement of waste packages in the commissioned emplacement panels. The two are isolated by isolation airlocks.
- Figures E-2 and E-3 illustrate the possible arrangements of drift instrumentation at the emplacement drift ventilation raise.



NOTES:

1. FOR CLARITY NOT ALL DRIFTS ARE SHOWN.
2. MOBILE DUST CONTROL BYPASS INSTALLED ALONG MAINS TO BYPASS HIGH VELOCITY AIR FROM INITIAL CUTTING OF ROADHEADERS.
3. FLEXIBLE TUBE FROM TBM CASSETTE DISPENSER IS INSTALLED BEHIND THE ADVANCING TBM. FLEXIBLE TUBE WILL BE REMOVED AS SOON AS FLOW-THROUGH VENTILATION IS ESTABLISHED.
4. MOBILE LOCAL DUST SCRUBBERS INSTALLED ALONG DRIFTS AS NEEDED.
5. DRIFT AIRFLOW PATHWAY:
   A) EMPLACEMENT DRIFT TO EAST MAIN AND SOUTH RAMP
   B) PERFORMANCE CONFIRMATION DRIFT TO PERFORMANCE CONFIRMATION MAIN AND SOUTH RAMP. SEE DRAWING 86021.

LEGEND

- AIRFLOW DIRECTION
- 72" INSIDE DIA INSULATED DUCT
- AIRFLOW CONTROL (VALVE OR DOOR)
- VENTILATION BARRIER

REFERENCE:

OVERALL DEVELOPMENT AND EMPLACEMENT VENTILATION SYSTEM, CRWMS 1997 I, BCA000000-01717-0200-00015, REV 00.

FIGURE E-1
SUBSURFACE VENTILATION SCHEMATIC

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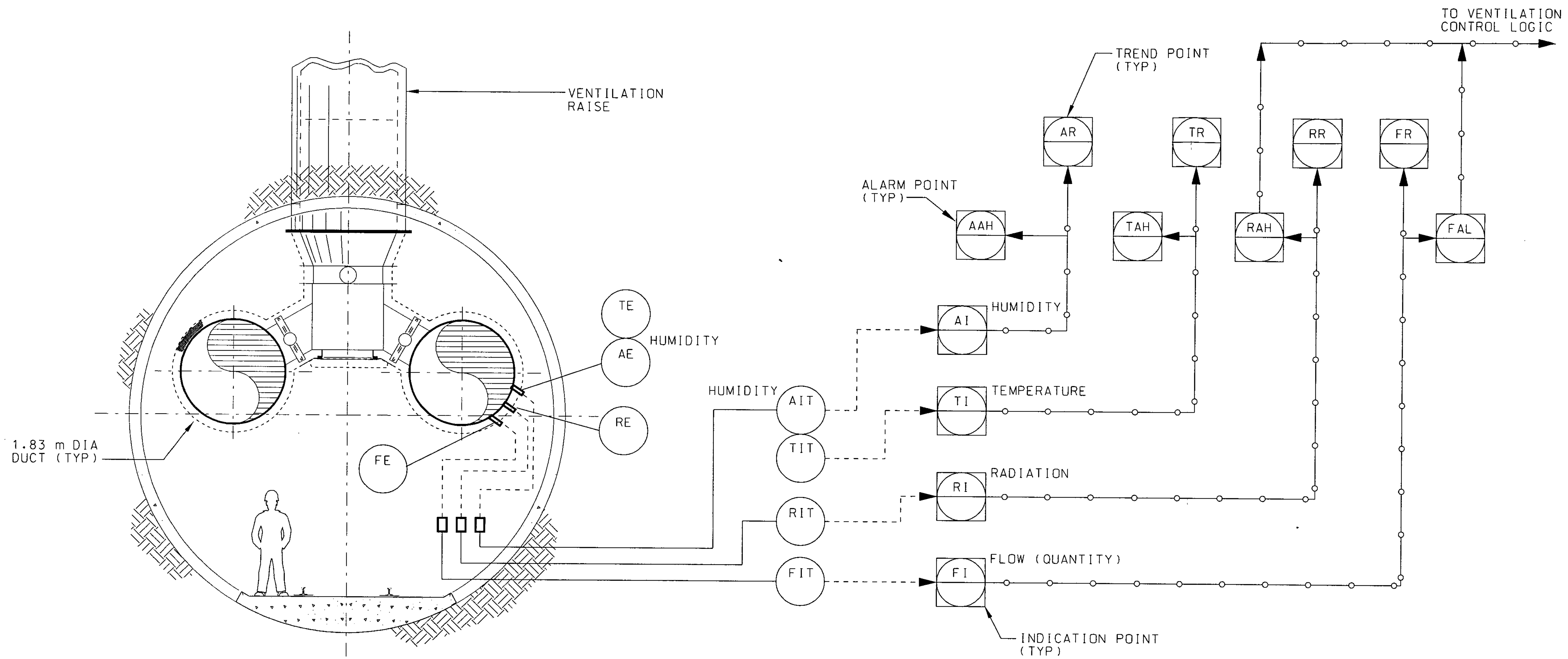
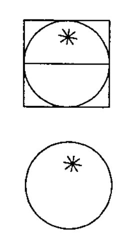


LEGEND:

INSTRUMENT ABBREVIATIONS:

AAH	ANALYZER ALARM HIGH
AE	ANALYZER SENSOR
AI	ANALYZER INDICATOR
AIT	ANALYZER INDICATING TRANSMITTER
AR	ANALYZER RECORDER
RAH	RADIATION ALARM HIGH
RE	RADIATION SENSOR
RI	RADIATION INDICATOR
RIT	RADIATION INDICATING TRANSMITTER
RR	RADIATION RECORDER
TAH	TEMPERATURE ALARM HIGH
TE	TEMPERATURE SENSOR
TI	TEMPERATURE INDICATOR
TIT	TEMPERATURE INDICATING TRANSMITTER
TR	TEMPERATURE RECORDER
FAL	FLOW ALARM LOW
FE	FLOW SENSOR
FI	FLOW INDICATOR
FIT	FLOW INDICATIONG TRANSMITTER
FR	FLOW RECORDER



* INSTRUMENT ABBREVIATION

SHARED DISPLAY MONITORING OR CONTROL POINT ON THE INSTRUMENTATION DATA HIGHWAY AND AT THE SUBSURFACE OPERATION'S CONTROL CENTER LOCATED ON THE SURFACE.

FIELD MOUNTED INSTRUMENT

---------- ELECTRIC SIGNAL

—o——o— SYSTEM LINK (SOFTWARE)

INSTRUMENTATION SHOWN IS TYPICAL FOR EACH DUCT

REFERENCE:

Emplacement Drift Air Control System, CRWMS 1997K, BCAD00000-01717-0200-00005 REV 00

FIGURE E-2
POSSIBLE ARRANGEMENT OF DRIFT INSTRUMENTATION NEAR 1st EMPLACEMENT RAISE

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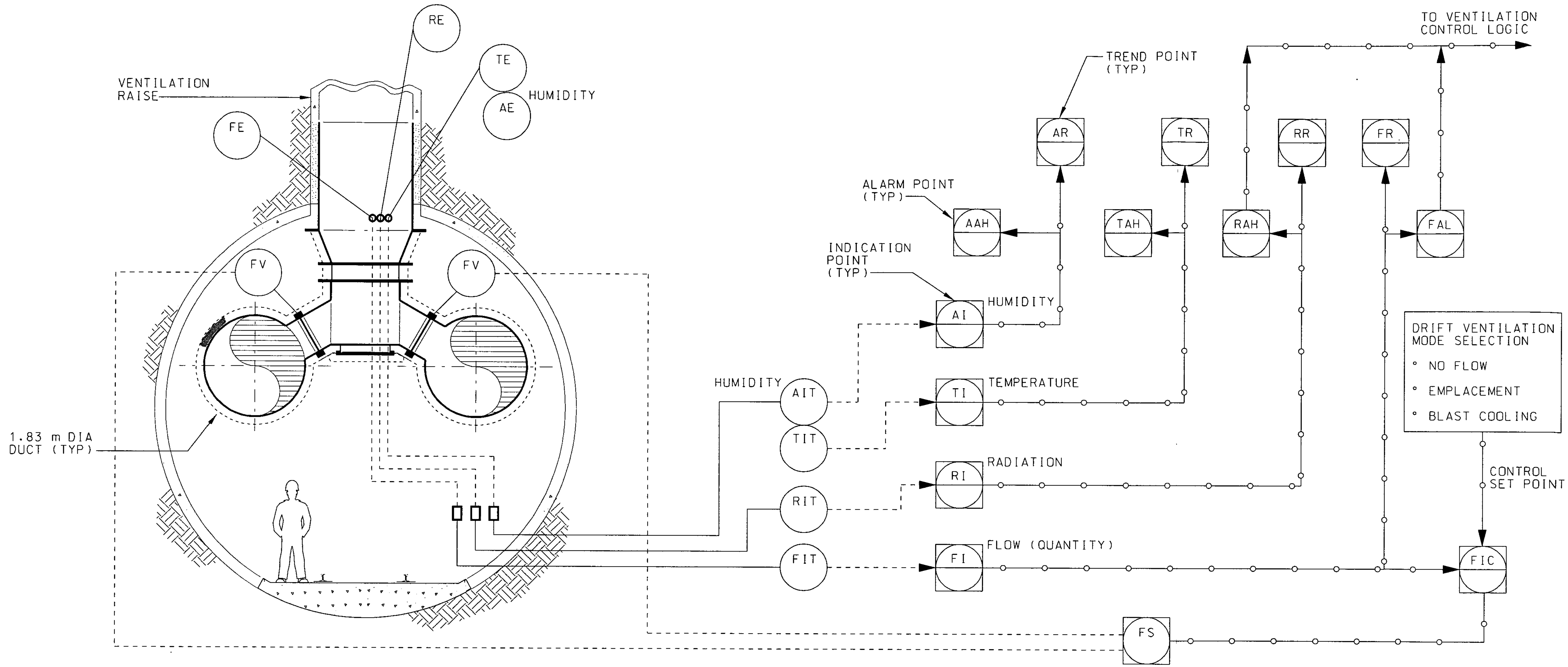

LEGEND:

AAH	ANALYZER ALARM HIGH
AE	ANALYZER SENSOR
AI	ANALYZER INDICATOR
AIT	ANALYZER INDICATING TRANSMITTER
AR	ANALYZER RECORDER
RAH	RADIATION ALARM HIGH
RE	RADIATION SENSOR
RI	RADIATION INDICATOR
RIT	RADIATION INDICATING TRANSMITTER
RR	RADIATION RECORDER
TAH	TEMPERATURE ALARM HIGH
TE	TEMPERATURE SENSOR
TI	TEMPERATURE INDICATOR
TIT	TEMPERATURE INDICATING TRANSMITTER
TR	TEMPERATURE RECORDER
FAL	FLOW ALARM LOW
FE	FLOW SENSOR
FI	FLOW INDICATOR
FIC	FLOW INDICATING CONTROLLER
FIT	FLOW INDICATING TRANSMITTER
FR	FLOW RECORDER
FS	FLOW SWITCH
FV	FLOW VALVE

* INSTRUMENT ABBREVIATION

SHARED DISPLAY MONITORING OR CONTROL POINT ON THE INSTRUMENTATION DATA HIGHWAY AND AT THE SUBSURFACE OPERATION'S CONTROL CENTER LOCATED ON THE SURFACE.

FIELD MOUNTED INSTRUMENT

--------- ELECTRIC SIGNAL

—o—o— SYSTEM LINK (SOFTWARE)

INSTRUMENTATION SHOWN IS TYPICAL FOR EACH RAISE

REFERENCE:

Emplacement Drift Air Control System, CRWMS 1997K, BCAD00000-01717-0200-00005 REV 00

FIGURE E-3
POSSIBLE ARRANGEMENT OF DRIFT INSTRUMENTATION AT EMPLACEMENT RAISE

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F. APPENDIX -- EXPANDED SUBSURFACE LAYOUTS

F.1 OBJECTIVE AND SCOPE

The objective of this Appendix (condensed from Addendum E) is to provide background information to the Engineering File – Subsurface Repository (Rev 01) supporting the Repository Environmental Impact Statement. The scope is to describe emplacement of 105,000 metric tons of uranium (MTU) and Base Case (70,000 MTU) (63,000 MTU CSNF). Both waste inventories are applied to an "areal mass loading" (AML) of 25 MTU per acre. This AML would be achieved by adjusting both the waste package spacing in the emplacement drifts and the emplacement drift spacing

F.2 TECHNICAL APPROACH

Emplacement of 105,414 MTU at an AML of 25 MTU/acre requires approximately 4217 acres (105,414/25) devoted to emplacement. This does not include areas which would not contain waste packages such as areas near faults that cross the emplacement blocks, main drifts, turnouts and drifts which are left empty for ventilation. The emplacement blocks described in the Engineering File contain only approximately 3,621 acres of usable emplacement area; therefore, to accommodate the emplacement area first step reexamined the geologic model to identify additional blocks suitable for emplacement. The second step determined the emplacement drift spacing and the length of emplacement drift required based on the emplacement drift spacing.

In order to determine the layout required for emplacement, the emplacement blocks are drawn with appropriate offsets for main drifts, turnouts, and faults. The emplacement drifts are located in the blocks and scaled to determine the amount of drifting that would actually be used for emplacement. The amount of drifting is used to calculate the amount of rock that would be excavated and stockpiled on surface.

When the emplacement blocks are defined, access drifting is plotted. Lengths and volumes for all excavations required are then determined.

Separate calculations, for the 25 MTU/acre cases, are made to determine ventilation requirements based on the number of emplacement drifts containing waste packages and excavation equipment in operation. Since the ventilation system and excavation equipment comprise most of the power that is required, these calculation are used to approximate the amount of power required to operate the extensive underground openings developed for the 25 MTU/acre subsurface repository.

The environmental data which include staffing, resources consumed, materials installed, wastes generated, emissions and effluents and equipment are factored from the 105,000 MTU, 36 MTU/acre case. This "Low Thermal" case is used as a basis because the layout is similar to the layout required for the 105,414 MTU, 25 MTU/acre case.

F.3 EMPLACEMENT DRIFT AND WASTE PACKAGE SPACING - 105,414 MTU

The general assumption in this addendum is that the waste packages should be placed in an approximately square pattern so that the thermal load is distributed evenly. To accomplish this, the emplacement drift spacing and the spacing of the waste packages in the emplacement drifts should be approximately equal.

Basing the emplacement drift spacing on the waste package containing the most MTHM, means that the drift spacing is approximately equal to or greater than the spacing of the waste packages in the emplacement drifts.

F.4 EMPLACEMENT AREA - 105,414 MTU, 25 MTU/ACRE CASE

To address the area required by the 25 MTU/acre areal mass loading (4,217 Acres), the LYNX model was reexamined. The parameters used are identified in Section 3.2.

For additional emplacement areas, geologic sections were prepared using the LYNX model, at various elevations and a sloping plane, corresponding to the level of the emplacement blocks. The slope of the Primary emplacement block was defined with a plane having an azimuth of 108 degrees and a dip of lower elevation. For the expansion areas west of Solitario Canyon, the same defining plane was 0.8 degrees to the north. The lower block was defined with this same plane, only adjusted to the used only the dip was changed to 0.8 degrees to the south. The south-dipping plane is more compatible with the attitude of the Repository Host Horizon in this area. The resulting emplacement areas are described in Table F.7.2-1 and represent the maximum available area.

Table F.7.2- 1. Expansion Area Nomenclature and Areas

Previous Block Name	Change Description	Gross Area (Acres)	New Block Name (Figure 3.2-1
Upper Block	Expanded north & south between 1036 and 1112 m elev.	1421	Upper Block
Lower Block	Expanded north & east	763	Lower Block
Area 1a & 1b	Lowered elevation of Area 1a and combined with Area 1b	1041	Area 5
Area 2	Raised elevation 15 m	541	Area 6
Area 3	Raised elevation 12 m	566	Area 7
Area 8	Raised elevation 2 m & extended south	1060	Area 8
	TOTAL GROSS ACRES	5392	

Figure F.7.2-1 shows the emplacement blocks with the emplacement drifts shown on 38 m center lines and offsets for turnouts, faults and (in the case of the Upper Block), an area in the north end of the block which is narrow and conflicts with shaft locations. In total, the expanded area contains approximately 4,700 acres of usable area.

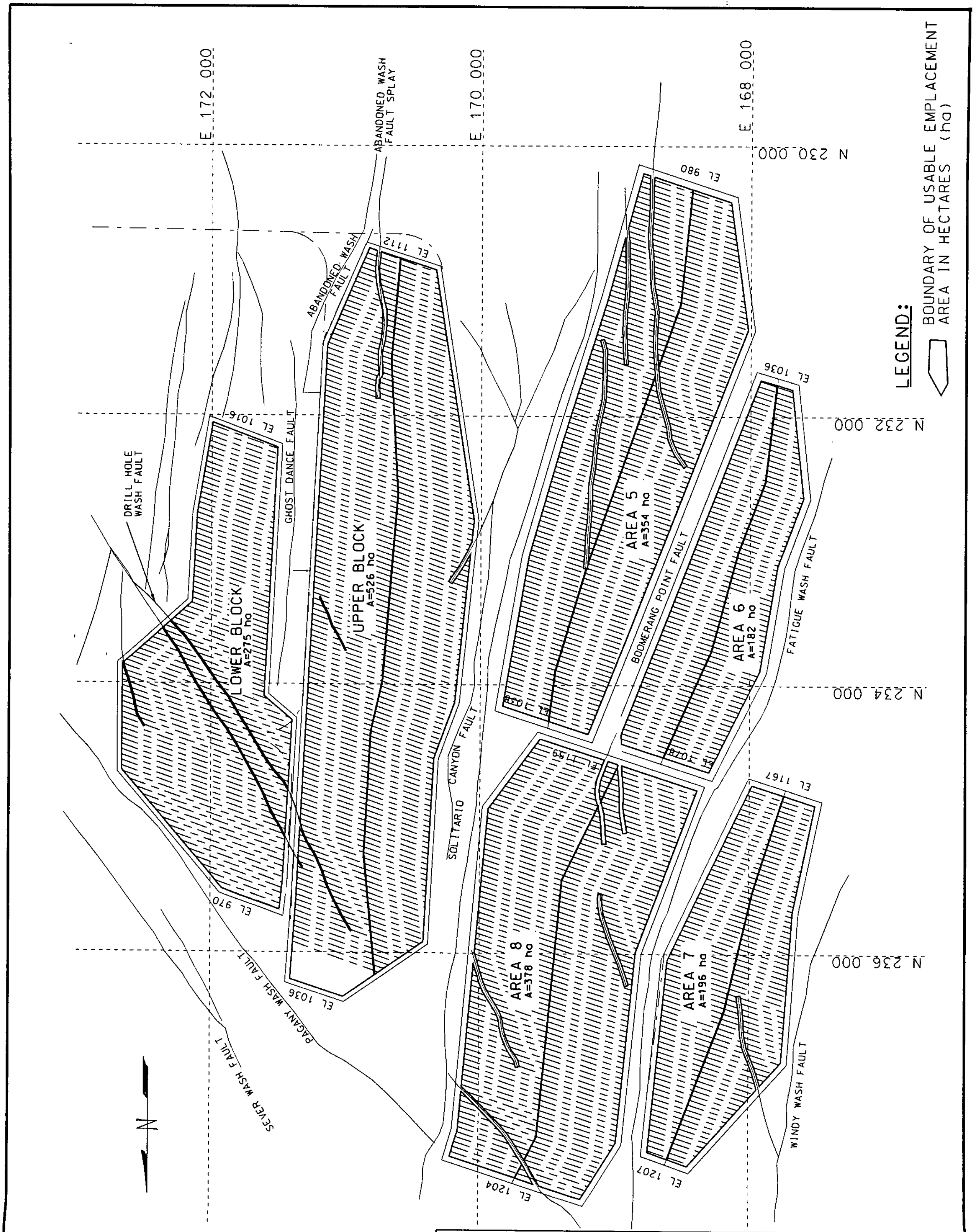

FIGURE F-7.2-1
25 MTU/ACRE - 38 m DRIFT SPACING
WASTE EMPLACEMENT AREA

G. APPENDIX -- RADIATION EXPOSURE

This appendix includes the tables created to estimate radiation exposures to personnel working in and around the emplacement side of the repository and its operations.

Table G - 1 illustrates the time (stated as a percentage of a shift comprised of 8 hours) that those crews (exclusive of personnel that operate the emplacement locomotives) would spend in various areas of the repository. The crews that work on surface spend 100% of their time in areas not exposed to waste package radiation. Maintenance crews spend most of their time in the main drifts with short excursions into the turnout areas and/or into the area near the bottom of the vent raise in the main exhaust drifts.

Table G - 2 shows the estimated radiation exposure for personnel working in the various areas of the repository (High and Intermediate Cases only). Table G-2a applies to the Low Thermal Loading Cases only. The exposure rates in these tables are expressed in mrem/hour, mrem/shift and in mrem/person/year. To make the conversion to mrem/shift, multiply the Radiation Exposure in mrem/hour times 8 hours/shift. To convert from mrem/shift to mrem/person/year, multiply the value for mrem/shift time 250 shifts per year.

Tables G–3 and G-3a shows the estimated radiation dose for craft personnel working in the emplacement side of the subsurface repository. The exposures are calculated by multiplying the percentage of time that personnel will be in a particular area (Table G - 1) by the radiation exposure - average waste package- mrem/person/year in Tables G –2 or G-2a. For example, for Controls and Monitoring Maintenance personnel working in the main drifts, multiply 73.0% times 320 mrem/person/year for an approximate annual dose of 234 mrem. To calculate the total annual exposure for a crew, add the individual location doses.

Tables G – 4 and G-4a show the annual dose for the personnel that operate the emplacement locomotives. The cycle times in this table are based on unpublished, preliminary travel and operating times. They also indicate that it could take one shift to emplace two waste packages. Based on the *Controlled Design Assumptions Document* (CRWMS M&O 1996b) Key 003, Table 3-9, in most years, there are about 500 waste packages to emplace. That means that one shift operation at two waste packages per shift is adequate. The expected time to perform an activity is shown in the "Hours Doing Activity" column.

The exposure in mrem/hour for the particular activity is shown in the Exposure During Activity column. To calculate the dose per day, multiply the hours for the activity times the exposure. To convert the daily exposure to an Annual dose, multiply the dose per day by 250 days per year. Total exposures are shown in the rows at the bottom of the table. Since there are two cycles per shift, the values are 2 times the values for one cycle.

Tables G–5 and G-5a show the distribution of personnel for the Emplacement Side of the repository for the Base Cases of (63,000 MTU of CSNF) under respective thermal loads. Tables G-6 and G-6a show the resulting radiation exposure estimates for the Base –Case thermal loadings. Tables G-7 and G-7a show the distribution of Emplacement-Side personnel for the Extended Inventory Cases (105,414 MTU CSNF). Tables G-8 and G-8a show the resulting radiation exposure estimates for the

Extended Inventory Cases. Only personnel working on the emplacement side of the repository are listed. Engineering and Construction Phase personnel and development personnel are excluded. Personnel work Monday through Friday. Overtime personnel are those that would be scheduled for weekends. The table shows that maintenance crews exist during all phases of the repository. Crews such as the Transport and Emplacement crew only exist in the Emplacement Phase.

Table G - 1 – Craft Distribution of Time in Various Areas

Emplacement Side of the Repository

FOR ALL WASTE PACKAGE INVENTORIES AND AREAL MASS LOADINGS							
LOCATION							
CREW	%OF TIME IN MAIN DRIFTS	%OF TIME IN MAIN TURNOUTS	%OF TIME IN MAIN EXHAUST	%OF TIME LOCOMOTIVE CAB	%OF TIME BETWEEN LOCOMOTIVE & WP TRANSPORT	%OF TIME NOT EXPOSED TO WP RADIATION	TOTAL (% OF TIME)
PORTAL SUPPORT CREW	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
CONTROLS & MONITORING MAINTENANCE	73.0%	1.0%	1.0%	0.0%	0.0%	25.0%	100.0%
UTILITY MAINTENANCE	73.0%	1.0%	1.0%	0.0%	0.0%	25.0%	100.0%
FACILITY MAINTENANCE	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
TRANSPORT & EMPLACE							
Operations Shifter	73.0%	1.0%	0.0%	0.0%	1.0%	25.0%	100.0%
Operator 6 (loci operator.)	73.0%	1.0%	0.0%	0.0%	1.0%	25.0%	100.0%
Operator 4 (brakeman)	73.0%	1.0%	0.0%	0.0%	1.0%	25.0%	100.0%
H.D. Repairman	73.0%	1.0%	0.0%	0.0%	1.0%	25.0%	100.0%
Electrician	73.0%	1.0%	0.0%	0.0%	1.0%	25.0%	100.0%
SHADOW SHIELD INSTALL	73.0%	1.0%	0.0%	0.0%	1.0%	25.0%	100.0%
MAIN VENT FAN MAINTAIN	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
COMMISSIONING	75.0%	0.0%	0.0%	0.0%	0.0%	25.0%	100.0%
BACKFILL ACCESS MAINS	75.0%	0.0%	0.0%	0.0%	0.0%	25.0%	100.0%
CLEANOUT ACCESS MAINS	75.0%	0.0%	0.0%	0.0%	0.0%	25.0%	100.0%
PLUG & SEAL ACCESS MAINS	75.0%	0.0%	0.0%	0.0%	0.0%	25.0%	100.0%

Table G – 2 -- Estimated Radiation Exposure

Various Areas of The Emplacement Side of The Repository

FOR ALL WASTE PACKAGE INVENTORIES, HIGH AND INTERMEDIATE AREAL MASS LOADINGS						
	LOCATION					
Area of the Repository => / **EXPOSURE DESCRIPTION**	EXPOSURE MAIN DRIFT	EXPOSURE TURNOUT	EXPOSURE MAIN EXHST. DRIFT	EXPOSURE LOCI CAB	EXPOSURE BTW'N LOCI & WP TRANSPORT	EXPOSURE NOT EXPOSED TO WP
Radiation Exposure - Average Waste Package - mrem/hour	0.16	5.06	0.40	0.20	4.00	0.00
Hours per shift	8.00	8.00	8.00	8.00	8.00	8.00
Rad. Exposure - Average Waste Package - mrem/shift	1.28	40.48	3.20	1.60	32.00	0.00
Rad. Exposure - Average Waste Package - mrem/Person @ 250 shifts/year	320.00	10,120.00	800.00	400.00	8,000.00	0.00

Note:

1) No individual would receive those doses because no individual would occupy any of the areas 100% of the time.

Table G – 2a -- Estimated Radiation Exposure (Low Thermal Case)

Various Areas of The Emplacement Side of The Repository

FOR ALL WASTE PACKAGE INVENTORIES, LOW (25 MTU/acre) AREAL MASS LOADING ONLY						
	LOCATION					
Area of the Repository => / **EXPOSURE DESCRIPTION**	EXPOSURE MAIN DRIFT	EXPOSURE TURNOUT	EXPOSURE MAIN EXHST. DRIFT	EXPOSURE LOCI CAB	EXPOSURE BTW'N LOCI & WP TRANSPORT	EXPOSURE NOT EXPOSED TO WP
Radiation Exposure - Average Waste Package - mrem/hour	0.10	1.40	0.20	0.20	4.00	0.00
Hours per shift	8.00	8.00	8.00	8.00	8.00	8.00
Rad. Exposure - Average Waste Package - mrem/shift	0.80	11.20	1.60	1.60	32.00	0.00
Rad. Exposure - Average Waste Package - mrem/Person @ 250 shifts/year	200.00	2,800.00	400.00	400.00	8,000.00	0.00

Note:

1) No individual would receive those doses because no individual would occupy any of the areas 100% of the time.

Table G – 3 -- Estimated Radiation Dose for Personnel Working in Various Areas

Emplacement Side of The Repository

FOR ALL WASTE PACKAGE INVENTORIES, HIGH AND INTERMEDIATE MASS LOADINGS

CREW	ANNUAL DOSE MAIN DRIFTS	ANNUAL DOSE TURNOUTS	ANNUAL DOSE MAIN EXHAUST	ANNUAL DOSE LOCI CAB	ESTIMATED EXPOSURE BTW'N LOCI & WP TRANSPORT	NO RADIATION FROM WP	TOTAL YEAR DOSE
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
				(see note 1)	(see note 1)		
PORTAL SUPPORT CREW	0	0	0	0	0	0	0
CONTROLS AND MONITORING MAINTENANCE	234	101	8	0	0	0	343
UTILITY MAINTENANCE	234	101	8	0	0	0	343
FACILITY MAINTENANCE	0	0	0	0	0	0	0
TRANSPORT & EMPLACEMENT (SEE NOTE 1)	0	0	0	0	0	0	0
OPERATIONS SHIFTER	234	101	0	0	80	0	415
OPERATOR 6 (LOCI OPERATOR)	234	101	0	0	80	0	415
OPERATOR 4 (BRAKEMAN)	234	101	0	0	80	0	415
H.D. REPAIRMAN	234	101	0	0	80	0	415
ELECTRICIAN	234	101	0	0	80	0	415
SHADOW SHIELD INSTALLATION	234	101	0	0	80	0	415
MAIN VENT FAN MAINTENANCE	0	0	0	0	0	0	0
COMMISSIONING	240	0	0	0	0	0	240
BACKFILL ACCESS MAINS	240	0	0	0	0	0	240
CLEANOUT ACCESS MAINS	240	0	0	0	0	0	240
PLUG & SEAL ACCESS MAINS	240	0	0	0	0	0	240

NOTE 1:

Part of the transport and emplacement crew is dedicated to maintenance of emplacement equipment. These personnel do not run the locomotive or couple and uncouple the waste package transporter from the locomotive. The radiation exposures for the people that operate the locomotive and couple and uncouple the transporter from the locomotive is shown on Table G - 4.

Table G – 3a -- Estimated Radiation Dose (Low Thermal)

Personnel Working in Various Areas of The Emplacement Side of The Repository

FOR ALL WASTE PACKAGE INVENTORIES, LOW (25 MTU/acre) AREAL MASS LOADING

CREW	ANNUAL DOSE MAIN DRIFTS	ANNUAL DOSE TURNOUTS	ANNUAL DOSE MAIN EXHAUST	ANNUAL DOSE LOCI CAB	ESTIMATED EXPOSURE BTW'N LOCI & WP TRANSPORT	NO RADIATION FROM WP	TOTAL YEAR DOSE
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
				(see note 1)	(see note 1)		
PORTAL SUPPORT CREW	0	0	0	0	0	0	0
CONTROLS AND MONITORING MAINTENANCE	146	28	4	0	0	0	178
UTILITY MAINTENANCE	146	28	4	0	0	0	178
FACILITY MAINTENANCE	0	0	0	0	0	0	0
TRANSPORT & EMPLACEMENT (SEE NOTE 1)	0	0	0	0	0	0	0
OPERATIONS SHIFTER	146	28	0	0	80	0	254
OPERATOR 6 (LOCI OPERATOR)	146	28	0	0	80	0	254
OPERATOR 4 (BRAKEMAN)	146	28	0	0	80	0	254
H.D. REPAIRMAN	146	28	0	0	80	0	254
ELECTRICIAN	146	28	0	0	80	0	254
SHADOW SHIELD INSTALLATION	146	28	0	0	80	0	254
MAIN VENT FAN MAINTENANCE	0	0	0	0	0	0	0
COMMISSIONING	150	0	0	0	0	0	150
BACKFILL ACCESS MAINS	150	0	0	0	0	0	150
CLEANOUT ACCESS MAINS	150	0	0	0	0	0	150
PLUG & SEAL ACCESS MAINS	150	0	0	0	0	0	150

NOTE 1:

Part of the transport and emplacement crew is dedicated to maintenance of emplacement equipment. These personnel do not run the locomotive or couple and uncouple the waste package transporter from the locomotive. The radiation exposures for the people that operate the locomotive and couple and uncouple the transporter from the locomotive is shown on Table G – 4a.

Table G – 4 -- Estimated Radiation Exposure and Annual Dose for Transport & Emplacement

Personnel Who Operate the Locomotives and Couple and Uncouple The Waste Package Transporter

For all waste inventories, High and Intermediate Thermal Loads

DESCRIPTION OF ACTIVITIES IN A SHIFT	HOURS OING ACTIVITY (HRS)	EXPOSURE DURING ACTIVITY (mrem/hr)	DOSE PER DAY (mrem)	ANNUAL DOSE (mrem)	PERSONNEL LOCATION DESCRIPTION
DETAIL FOR OPERATOR LOCI OPERATOR - ONE PERSON					
LOAD TRANSPORTER AT WHB & MOVE AWAY	0.38	0.2	0.08	19.17	LOCI CAB - SURFACE
COUPLE TO 2ND LOCOMOTIVE - WP ON BOARD	0.05	0.2	0.01	2.50	LOCI CAB - SURFACE
TRAVEL TO EMPLACEMENT DRIFT - WP ON BOARD	1.15	0.2	0.23	57.50	LOCI CAB - SUBSURFACE
UNCOUPLE TRANSPORTER FROM 2ND LOCOMOTIVE	0.05	0.2	0.01	2.50	LOCI CAB - MAIN DRIFT
POSITION TRANSPORTER AT DOCK	0.18	0.16	0.03	7.33	LOCI CAB - MAIN DRIFT
REMOVE WP FROM TRANSPORTER	0.22	0.16	0.03	8.67	LOCI CAB - MAIN DRIFT
MOVE TRANSPORTER OUT OF TURNOUT	0.20	0.16	0.03	8.00	LOCI CAB - MAIN DRIFT
COUPLE LOCI TO WP TRANSPORTER - NO WP ON BOARD	0.05	0.16	0.01	2.00	LOCI CAB - MAIN DRIFT
RETURN TO WHB - NO WP ON BOARD	1.15	0	0.00	0.00	LOCI CAB - SUBSURFACE
UNCOUPLE TRANSPORTER - NO WP ONBOARD	0.05	0	0.00	0.00	LOCI CAB - SURFACE
INSPECT AND POSITION AT WHB - NO WP ONBOARD	0.33	0	0.00	0.00	LOCI CAB - SURFACE
REPOSITION AT THE WASTE HANDLING BUILDING	0.18	0	0.00	0.00	VARIOUS - BACKGROUND
TOTALS FOR ONE CYCLE	4.00	N/A	0.43	107.67	

Table G – 4 (continued) – Estimated Radiation Exposure and Annual Dose for Transport & Emplacement Personnel Who Operate the Locomotives and Couple and Uncouple The Waste Package Transporter

For all waste inventories, High and Intermediate Thermal Loads

DESCRIPTION OF ACTIVITIES IN A SHIFT	HOURS DOING ACTIVITY	EXPOSURE DURING ACTIVITY	DOSE PER DAY	ANNUAL DOSE	PERSONNEL LOCATION DESCRIPTION
DETAIL FOR BRAKEMAN - ONE PERSON					
LOAD TRANSPORTER AT WHB & MOVE AWAY	0.38	0.20	0.08	19.17	LOCI CAB - SURFACE
COUPLE TO 2ND LOCOMOTIVE - WP ON BOARD	0.05	4.00	0.20	50.00	BETWEEN LOCI CAB & TRANSPORTER - SURFACE
TRAVEL TO EMPLACEMENT DRIFT - WP ON BOARD	1.15	0.20	0.23	57.50	LOCI CAB - SUBSURFACE
UNCOUPLE TRANSPORTER FROM 2ND LOCOMOTIVE	0.05	4.00	0.20	50.00	BETWEEN LOCOMOTIVE & TRANSPORTER
POSITION TRANSPORTER AT DOCK	0.18	0.16	0.03	7.33	LOCI CAB IN MAIN DRIFT
REMOVE WP FROM TRANSPORTER	0.22	0.16	0.03	8.67	LOCI CAB IN MAIN DRIFT
MOVE TRANSPORTER OUT OF TURNOUT	0.20	0.16	0.03	8.00	LOCI CAB IN MAIN DRIFT
COUPLE LOCI TO WP TRANSPORTER - NO WP ON BOARD	0.05	0.16	0.01	2.00	LOCI CAB IN MAIN DRIFT
RETURN TO WHB - NO WP ON BOARD	1.15	0.00	0.00	0.00	LOCI CAB IN MAIN DRIFT
UNCOUPLE TRANSPORTER - NO WP ONBOARD	0.05	0.00	0.00	0.00	BETWEEN LOCOMOTIVE & TRANSPORTER
INSPECT AND POSITION AT WHB - NO WP ONBOARD	0.33	0.00	0.00	0.00	LOCI CAB
REPOSITION AT THE WASTE HANDLING BUILDING	0.18	0.00	0.00	0.00	BETWEEN LOCOMOTIVE & TRANSPORTER
TOTALS FOR ONE CYCLE	4.00	N/A	0.81	202.67	
TOTAL SHIFT CONSISTING OF 2 CYCLES					
LOCOMOTIVE OPERATOR	8.00	N/A	0.86	215.33	
BRAKEMAN	8.00		1.62	405.33	

Table G – 4 a -- Estimated Radiation Exposure and Annual Dose for Transport & Emplacement (Low Thermal Case)

Personnel Who Operate the Locomotives and Couple and Uncouple The Waste Package Transporter

For all waste inventories, Low (25 MTU/acre) Thermal Load Only

DESCRIPTION OF ACTIVITIES IN A SHIFT	HOURS OING ACTIVITY (HRS)	EXPOSURE DURING ACTIVITY (mrem/hr)	DOSE PER DAY (mrem)	ANNUAL DOSE (mrem)	PERSONNEL LOCATION DESCRIPTION
DETAIL FOR OPERATOR LOCI OPERATOR - ONE PERSON					
LOAD TRANSPORTER AT WHB & MOVE AWAY	0.38	0.2	0.08	19.17	LOCI CAB - SURFACE
COUPLE TO 2ND LOCOMOTIVE - WP ON BOARD	0.05	0.2	0.01	2.50	LOCI CAB - SURFACE
TRAVEL TO EMPLACEMENT DRIFT - WP ON BOARD	1.15	0.2	0.23	57.50	LOCI CAB - SUBSURFACE
UNCOUPLE TRANSPORTER FROM 2ND LOCOMOTIVE	0.05	0.2	0.01	2.50	LOCI CAB - MAIN DRIFT
POSITION TRANSPORTER AT DOCK	0.18	0.30	0.06	13.75	LOCI CAB - MAIN DRIFT (two sources 0.10 + 0.20)
REMOVE WP FROM TRANSPORTER	0.22	010	0.02	5.42	LOCI CAB - MAIN DRIFT
MOVE TRANSPORTER OUT OF TURNOUT	0.20	0.10	0.02	5.00	LOCI CAB - MAIN DRIFT
COUPLE LOCI TO WP TRANSPORTER - NO WP ON BOARD	0.05	0.10	0.01	1.25	LOCI CAB - MAIN DRIFT
RETURN TO WHB - NO WP ON BOARD	1.15	0.10	0.12	28.75	LOCI CAB - SUBSURFACE
UNCOUPLE TRANSPORTER - NO WP ONBOARD	0.05	0.00	0.00	0.00	LOCI CAB - SURFACE
INSPECT AND POSITION AT WHB - NO WP ONBOARD	0.33	0.00	0.00	0.00	LOCI CAB - SURFACE
REPOSITION AT THE WASTE HANDLING BUILDING	0.18	0.00	0.00	0.00	VARIOUS - BACKGROUND
TOTALS FOR ONE CYCLE	4.00	N/A	0.92	230.83	

Table G – 4 a (continued) – Estimated Radiation Exposure and Annual Dose for Transport & Emplacement Personnel Who Operate the Locomotives and Couple and Uncouple The Waste Package Transporter

For all waste inventories, Low (25 MTU/acre) Thermal Load Only

DESCRIPTION OF ACTIVITIES IN A SHIFT	HOURS DOING ACTIVITY	EXPOSURE DURING ACTIVITY	DOSE PER DAY	ANNUAL DOSE	PERSONNEL LOCATION DESCRIPTION
DETAIL FOR BRAKEMAN - ONE PERSON					
LOAD TRANSPORTER AT WHB & MOVE AWAY	0.38	0.20	0.08	19.17	LOCI CAB - SURFACE
COUPLE TO 2ND LOCOMOTIVE - WP ON BOARD	0.05	4.00	0.20	50.00	BETWEEN LOCI CAB & TRANSPORTER - SURFACE
TRAVEL TO EMPLACEMENT DRIFT - WP ON BOARD	1.15	0.20	0.23	57.50	LOCI CAB - SUBSURFACE
UNCOUPLE TRANSPORTER FROM 2ND LOCOMOTIVE	0.05	4.00	0.20	50.00	BETWEEN LOCOMOTIVE & TRANSPORTER
POSITION TRANSPORTER AT DOCK	0.18	0.30	0.06	13.75	LOCI CAB IN MAIN DRIFT
REMOVE WP FROM TRANSPORTER	0.22	0.10	0.02	5.42	LOCI CAB IN MAIN DRIFT
MOVE TRANSPORTER OUT OF TURNOUT	0.20	0.10	0.20	5.00	LOCI CAB IN MAIN DRIFT
COUPLE LOCI TO WP TRANSPORTER - NO WP ON BOARD	0.05	0.10	0.01	1.25	LOCI CAB IN MAIN DRIFT
RETURN TO WHB - NO WP ON BOARD	1.15	0.10	0.12	28.75	LOCI CAB IN MAIN DRIFT
UNCOUPLE TRANSPORTER - NO WP ONBOARD	0.05	0.00	0.00	0.00	BETWEEN LOCOMOTIVE & TRANSPORTER
INSPECT AND POSITION AT WHB - NO WP ONBOARD	0.33	0.00	0.00	0.00	LOCI CAB
REPOSITION AT THE WASTE HANDLING BUILDING	0.18	0.00	0.00	0.00	BETWEEN LOCOMOTIVE & TRANSPORTER
TOTALS FOR ONE CYCLE	4.00	N/A	0.92	230.83	
TOTAL SHIFT CONSISTING OF 2 CYCLES					
LOCOMOTIVE OPERATOR	8.00	N/A	1.09	271.67	
BRAKEMAN	8.00		1.85	461.67	

Table G - 5 -- Total Craft Manpower Distribution – Emplacement Side of Subsurface Repository

BASE CASE, 85 MTU/ACRE										
	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL 2005 - 2068	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE ^2060 - 2068	TOTAL # 2005 - 2068
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
TUNNEL SHIFTER	0.00	0.50	1.38	2.29	4.17	0.00	0.10	0.28	0.15	0.53
BULL GANG	0.00	0.99	2.77	6.10	9.86	0.00	0.20	0.55	0.31	1.06
CARPENTER	0.00	0.50	1.38	0.76	2.64	0.00	0.10	0.28	0.15	0.53
OPERATOR 6	0.00	0.50	1.38	14.31	16.19	0.00	0.10	0.00	0.15	0.25
COMPRESSOR OPERATOR	0.00	0.50	1.38	2.29	4.17	0.00	0.00	0.28	0.31	0.58
WHSE CLERK	0.00	0.99	2.77	4.58	8.33	0.00	0.20	0.55	0.00	0.75
H.D. REPAIRMAN	0.00	0.50	1.38	6.10	7.98	0.00	0.10	0.28	0.00	0.38
H.D. REPAIRMAN	0.00	0.00	0.00	3.28	3.28	0.00	0.50	1.38	0.00	1.88
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	0.00	1.00	1.38	0.75	3.13	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	2.00	2.77	1.50	6.27	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	1.00	1.38	0.75	3.13	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.08	0.14	0.06	0.28	0.00	0.00	0.00	0.00	0.00
UTILITY MAINTENANCE										
OPERATING FORMAN	0.00	1.00	1.11	0.61	2.72	0.00	0.20	0.28	0.12	0.60
H.D. REPAIRMAN	0.00	2.00	2.21	1.22	5.43	0.00	0.40	0.55	0.24	1.20
ELECTRICIAN FORMAN	0.00	1.00	1.11	0.61	2.72	0.00	0.20	0.28	0.12	0.60
ELECTRICIAN	0.00	2.00	2.21	1.22	5.43	0.00	0.40	0.55	0.24	1.20
BULLGANG	0.00	4.00	2.21	2.44	8.65	0.00	0.40	0.55	0.24	1.20
LOCI OPERATOR	0.00	2.00	2.21	1.22	5.43	0.00	0.20	0.28	0.12	0.60
BRAKEMAN	0.00	0.50	0.55	0.31	1.36	0.00	0.20	0.28	0.12	0.60
H.D. REPAIRMAN A	0.00	0.00	0.89	0.35	1.24	0.00	0.75	0.00	0.00	0.75

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103 **Table G - 5 (Continued)**

BASE CASE, 85 MTU/ACRE	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL 2005 - 2064	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL # 2005 - 2064
PERSONNEL DESCRIPTION – STRAIGHT TIME						OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	0.00	0.10	0.28	0.15	0.53	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.25	0.55	0.31	1.11	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN FORMAN	0.00	0.15	0.28	0.15	0.58	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.22	0.55	0.31	1.08	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.50	1.11	0.61	2.21	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.20	0.55	0.31	1.06	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.05	0.14	0.08	0.26	0.00	0.00	0.00	0.00	0.00
GRADER OPERATOR	0.00	0.50	1.38	0.76	2.64	0.00	0.00	0.00	0.00	0.00
H.D. DRIVER	0.00	0.50	1.38	0.76	2.64	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	1.49	4.15	2.29	7.93	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.99	2.77	1.53	5.28	0.00	0.00	0.00	0.00	0.00
COMMON LABORER	0.00	0.99	2.77	1.53	5.28	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.20	0.55	0	0.75	0.00	0.00	0.00	0.31	0.31
H.D. REPAIRMAN	0.00	0.05	0	0	0.05	0.00	0.00	0.00	0.12	0.12
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00

Table G - 5 (Continued)

BASE CASE, 85 MTU/ACRE	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL 2005 - 2064	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL # 2005 - 2064
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	0.00	1.50	4.15	1.97	7.62	0.00	0.28	0.00	0.10	0.38
OPERATOR 5	0.00	0.00	0.96	0.42	1.38	0.00	0.43	0.00	0.12	0.54
H.D. REPAIRMAN	0.00	5.00	10.66	8.15	23.80	0.00	0.20	0.00	0.03	0.23
ELECTRICIAN	0.00	5.00	8.19	7.51	20.70	0.00	0.20	0.00	0.03	0.23
COMMISSIONING										
OPERATOR 4	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 3	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
HD REPAIRMAN	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0	0
LOADER OPERATOR	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0	0
LOCI OPERATOR	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0	0
BRAKEMAN	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0	0
OPERATOR 6	0.00	0.00	0.00	2.29	2.29	0.00	0.00	0.00	0	0
BULL GANG	0.00	0.00	0.00	6.07	6.07	0.00	0.00	0.00	0	0
OPERATOR FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.081	0.081
H.D. WELDER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.153	0.153
ELECT. FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.076	0.076
ELECTRICIAN	0.00	0.00	0.00	0.76	0.76	0.00	0.00	0.00	0.153	0.153
LOCI OPERATOR	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.081	0.081
BRAKEMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.081	0.081
BULL GANG	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.083	0.083

Table G - 5 (Continued)

BASE CASE, 85 MTU/ACRE	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL 2005 - 2064	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL # 2005 - 2064
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.04	0.04
ELECTRICIAN	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
OPERATING SHIFTER	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.01	0.01
ELECT. FORMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
TOTAL PEOPLE	0.00	49.06	71.07	111.17	231.29	0.00	5.15	6.37	3.76	15.28

Table G - 5 a -- Total Craft Manpower Distribution – Emplacement Side of Repository (Intermediate Thermal Case)

BASE CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD										
	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	0.00	0.50	1.38	2.29	4.17	0.00	0.10	0.28	0.15	0.53
BULL GANG	0.00	0.99	2.77	6.10	9.86	0.00	0.20	0.55	0.31	1.06
CARPENTER	0.00	0.50	1.38	0.76	2.64	0.00	0.10	0.28	0.15	0.53
OPERATOR 6	0.00	0.50	1.38	14.31	16.19	0.00	0.10	0.00	0.15	0.25
COMPRESSOR OPERATOR	0.00	0.50	1.38	2.29	4.17	0.00	0.00	0.28	0.31	0.58
WHSE CLERK	0.00	0.99	2.77	4.58	8.33	0.00	0.20	0.55	0.00	0.75
H.D. REPAIRMAN	0.00	0.50	1.38	6.10	7.98	0.00	0.10	0.28	0.00	0.38
H.D. REPAIRMAN	0.00	0.00	0.00	3.28	3.28	0.00	0.50	1.38	0.00	1.88
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	0.00	1.00	1.38	0.75	3.13	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	2.60	2.77	1.50	6.27	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	1.00	1.38	0.75	3.13	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.08	0.14	0.06	0.28	0.00	0.00	0.00	0.00	0.00
UTILITY MAINTENANCE										
OPERATING FORMAN	0.00	1.00	1.11	0.61	2.72	0.00	0.20	0.28	0.12	0.60
H.D. REPAIRMAN	0.00	2.00	2.21	1.22	5.43	0.00	0.40	0.55	0.24	1.20
ELECTRICIAN FORMAN	0.00	1.00	1.11	0.61	2.72	0.00	0.20	0.28	0.12	0.60
ELECTRICIAN	0.00	2.00	2.21	1.22	5.43	0.00	0.40	0.55	0.24	1.20
BULLGANG	0.00	4.00	2.21	2.44	8.65	0.00	0.40	0.5	0.24	1.20
LOCI OPERATOR	0.00	2.00	2.21	1.22	5.43	0.00	0.20	0.28	0.12	0.60
BRAKEMAN	0.00	0.50	0.55	0.31	1.36	0.00	0.20	0.28	0.12	0.60
H.D. REPAIRMAN A	0.00	0.00	0.89	0.35	1.24	0.00	0.75	0.00	0.00	0.75

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Table G – 5a (Continued)

BASE CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE ^2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION – STRAIGHT TIME						OVERTIME PERSONNEL				
OPERATION SHIFTER	0.00	0.10	0.28	0.15	0.53	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.25	0.55	0.31	1.11	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN FORMAN	0.00	0.15	0.28	0.15	0.58	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.22	0.55	0.31	1.08	0.00	0.10	0.10	0.00	0.20
BULL GANG	0.00	0.50	1.11	0.61	2.21	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.20	0.55	0.31	1.06	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.05	0.14	0.08	0.26	0.00	0.00	0.00	0.00	0.00
GRADER OPERATOR	0.00	0.50	1.38	0.76	2.64	0.00	0.00	0.00	0.00	0.00
H.D. DRIVER	0.00	0.50	1.38	0.76	2.64	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	1.49	4.15	2.29	7.93	0.00	0.00	0.00	0.00	0.80
OFFICE CLEANER	0.00	0.99	2.77	1.53	5.28	0.00	0.00	0.00	0.00	0.00
COMMON LABORER	0.00	0.99	2.77	1.53	5.28	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.20	0.55	0.00	0.75	0.00	0.00	0.00	0.31	0.31
H.D. REPAIRMAN	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.12	0.12
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00

Table G – 5a (Continued)

BASE CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL 2005 - 2068	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL # 2005 - 2068
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	0.00	1.50	4.15	1.97	7.62	0.00	0.28	0.00	0.10	0.38
OPERATOR 5	0.00	0.00	0.96	0.42	1.38	0.00	0.43	0.00	0.12	0.54
H.D. REPAIRMAN	0.00	5.00	10.66	8.15	23.80	0.00	0.20	0.00	0.03	0.23
ELECTRICIAN	0.00	5.00	8.19	7.51	20.70	0.00	0.20	0.00	0.03	0.23
COMMISSIONING										
OPERATOR 4	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 3	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
HD REPAIRMAN	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	0.00	0.00	0.00	1.52	2.74	0.00	0.00	0.00	0.00	0.00
LOADER OPERATOR	0.00	0.00	0.00	1.52	2.74	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	4.57	8.23	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	4.57	8.23	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	2.29	3.35	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	6.07	10.98	0.00	0.00	0.00	0.00	0.00
OPERATOR FORMAN	0.00	0.00	0.00	0.38	0.69	0.00	0.00	0.00	0.08	0.08
H.D. WELDER	0.00	0.00	0.00	1.52	2.74	0.00	0.00	0.00	0.15	0.15
ELECT. FORMAN	0.00	0.00	0.00	0.38	0.69	0.00	0.00	0.00	0.08	0.08
ELECTRICIAN	0.00	0.00	0.00	0.76	1.37	0.00	0.00	0.00	0.15	0.15
LOCI OPERATOR	0.00	0.00	0.00	0.38	0.69	0.00	0.00	0.00	0.08	0.08
BRAKEMAN	0.00	0.00	0.00	0.38	0.69	0.00	0.00	0.00	0.08	0.08
BULL GANG	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08

Table G – 5a (Continued)

BASE CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.04	0.04
ELECTRICIAN	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
OPERATING SHIFTER	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.01	0.01
ELECT. FORMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
TOTAL PEOPLE	0.00	49.06	71.07	111.17	231.29	0.00	5.15	6.37	3.76	15.28

Table G - 5 b -- Total Craft Manpower Distribution – Emplacement Side of Repository (Low Thermal Case)

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	0.00	0.50	1.51	2.29	4.29	0.00	0.10	0.30	0.15	0.55
BULL GANG	0.00	0.99	3.02	6.10	10.11	0.00	0.20	0.60	0.31	1.11
CARPENTER	0.00	0.50	1.51	0.76	2.77	0.00	0.10	0.30	0.15	0.55
OPERATOR 6	0.00	0.50	1.51	14.31	16.32	0.00	0.10	0.00	0.15	0.25
COMPRESSOR OPERATOR	0.00	0.50	1.51	2.29	4.29	0.00	0.00	0.20	0.31	0.61
WHSE CLERK	0.00	0.99	3.02	4.58	8.58	0.00	0.20	0.60	0.00	0.80
H.D. REPAIRMAN	0.00	0.50	1.51	6.10	8.10	0.00	0.10	0.30	0.00	0.40
H.D. REPAIRMAN	0.00	0.00	0.00	3.28	3.28	0.00	0.50	1.51	0.00	2.00
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	0.00	1.00	1.51	0.75	3.26	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	2.00	3.02	1.50	6.52	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	1.00	1.51	0.75	3.26	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.08	0.15	0.06	0.29	0.00	0.00	0.00	0.00	0.00
UTILITY MAINTENANCE										
OPERATING FORMAN	0.00	1.00	1.21	0.61	2.82	0.00	0.20	0.30	0.12	0.65
H.D. REPAIRMAN	0.00	2.00	2.41	1.22	5.63	0.00	0.40	0.60	0.24	1.25
ELECTRICIAN FORMAN	0.00	1.00	1.21	0.61	2.82	0.00	0.20	0.30	0.12	0.62
ELECTRICIAN	0.00	2.00	2.41	1.22	5.63	0.00	0.40	0.60	0.24	1.25
BULLGANG	0.00	4.00	2.41	2.44	8.85	0.00	0.40	0.60	0.24	1.25
LOCI OPERATOR	0.00	2.00	2.41	1.22	5.63	0.00	0.20	0.30	0.12	0.62
BRAKEMAN	0.00	0.50	0.60	0.31	1.41	0.00	0.20	0.30	0.12	0.62
H.D. REPAIRMAN A	0.00	0.00	0.97	0.35	1.32	0.00	0.75	0.00	0.00	0.75

Table G – 5b (Continued)

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE ^2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION – STRAIGHT TIME						OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	0.00	0.10	0.30	0.15	0.55	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.25	0.60	0.31	1.16	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN FORMAN	0.00	0.15	0.30	0.15	0.60	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.22	0.60	0.31	1.13	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.50	1.21	0.61	2.31	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.20	0.60	0.31	1.11	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.05	0.15	0.08	0.28	0.00	0.00	0.00	0.00	0.00
GRADER OPERATOR	0.00	0.50	1.51	0.76	2.77	0.00	0.00	0.00	0.00	0.00
H.D. DRIVER	0.00	0.50	1.51	0.76	2.77	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	1.49	4.53	2.29	8.30	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.99	3.02	1.53	5.53	0.00	0.00	0.00	0.00	0.00
COMMON LABORER	0.00	0.99	3.02	1.53	5.53	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.20	0.60	0.00	0.80	0.00	0.00	0.00	0.31	0.31
H.D. REPAIRMAN	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.12	0.12
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00

Table G – 5b (Continued)

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL 2005 - 2068	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL # 2005 - 2068
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	0.00	1.50	4.53	1.97	8.00	0.00	0.28	0.00	0.10	0.38
OPERATOR 5	0.00	0.00	1.04	0.42	1.47	0.00	0.43	0.00	0.12	0.54
H.D. REPAIRMAN	0.00	5.00	11.62	8.15	24.76	0.00	0.20	0.00	0.03	0.23
ELECTRICIAN	0.00	5.00	8.93	7.51	21.44	0.00	0.20	0.00	0.03	0.23
COMMISSIONING										
OPERATOR 4	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 3	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
HD REPAIRMAN	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	0.00	0.00	0.00	1.52	6.00	0.00	0.00	0.00	0.00	0.00
LOADER OPERATOR	0.00	0.00	0.00	1.52	6.00	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	4.57	10.00	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	4.57	10.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	2.29	6.00	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	6.07	12.00	0.00	0.00	0.00	0.00	0.00
OPERATOR FORMAN	0.00	0.00	0.00	0.38	1.00	0.00	0.00	0.00	0.08	0.08
H.D. WELDER	0.00	0.00	0.00	1.52	3.00	0.00	0.00	0.00	0.15	0.15
ELECT. FORMAN	0.00	0.00	0.00	0.38	2.00	0.00	0.00	0.00	0.08	0.08
ELECTRICIAN	0.00	0.00	0.00	0.76	4.00	0.00	0.00	0.00	0.15	0.15
LOCI OPERATOR	0.00	0.00	0.00	0.38	2.00	0.00	0.00	0.00	0.08	0.08
BRAKEMAN	0.00	0.00	0.00	0.38	2.00	0.00	0.00	0.00	0.08	0.08
BULL GANG	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08

Table G – 5b (Continued)

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.04	0.04
ELECTRICIAN	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATING SHIFTER	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.03	0.03
ELECT. FORMAN	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.01	0.01
LOCI OPERATOR	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
TOTAL PEOPLE	0.00	49.06	77.46	111.17	237.69	0.00	5.15	6.94	3.76	15.85

Table G - 6 -- Total Average Annual Collective Radiation Dose

BASE CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	-	0	0	0		-	0	0	0	
BULL GANG	-	0	0	0		-	0	0	0	
CARPENTER	-	0	0	0		-	0	0	0	
OPERATOR 6	-	0	0	0		-	0	-	0	
COMPRESSOR OPERATOR	-	0	0	0		-	-	0	0	
WHSE CLERK	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	-	-	0		-	0	0	-	
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	-	343	474	257		-	-	-	-	
ELECTRICIAN	-	686	949	514		-	-	-	-	
LOCI OPERATOR	-	343	474	257		-	-	-	-	
H.D. REPAIRMAN	-	27	47	21		-	-	-	-	

Table G - 6 (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
UTILITY MAINTENANCE										
OPERATING FORMAN	-	343	380	209		-	69	95	42	
H.D. REPAIRMAN	-	686	759	418		-	137	190	84	
ELECTRICIAN FORMAN	-	343	380	209		-	69	95	42	
ELECTRICIAN	-	686	759	418		-	137	190	84	
BULLGANG	-	1,371	759	836		-	137	190	84	
LOCI OPERATOR	-	686	759	418		-	69	95	42	
BRAKEMAN	-	171	190	105		-	69	95	42	
H.D. REPAIRMAN A	-	-	304	121		-	258	-	-	

Table G - 6 (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN FORMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN	-	0	0	0		-	-	-	-	
BULL GANG	-	0	0	0		-	-	-	-	
LOCI OPERATOR	-	0	0	0		-	-	-	-	
BRAKEMAN	-	0	0	0		-	-	-	-	
GRADER OPERATOR	-	0	0	0		-	-	-	-	
H.D. DRIVER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
COMMON LABORER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	-	415	-	-		-	-	-	-	
OPERATOR 6	-	415	-	-		-	-	-	-	
OPERATOR 4	-	830	-	-		-	-	-	-	
H.D. REPAIRMAN	-	415	-	-		-	-	-	-	
ELECTRICIAN	-	415	-	-		-	-	-	-	
I::										

Table G - 6 (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	-	7	-	-		-	-	-	-	
OPERATOR 6	-	12	-	-		-	-	-	-	
OPERATOR 4	-	25	-	-		-	-	-	-	
H.D. REPAIRMAN	-	7	-	-		-	-	-	-	
ELECTRICIAN	-	7	-	-		-	-	-	-	
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	-	0	0	0		-	0	-		0
OPERATOR 5	-	0	0	0		-	0	-		0
H.D. REPAIRMAN	-	0	0	0		-	0	-		0
ELECTRICIAN	-	0	0	0		-	0	-		0
COMMISSIONING										
OPERATOR 4	-	240	-	-		-	-	-		-
OPERATOR 3	-	240	-	-		-	-	-		-
HD REPAIRMAN	-	480	-	-		-	-	-		-
ELECTRICIAN	-	-	-	-		-	-	-		-
H.D. REPAIRMAN	-	48	-	-		-	-	-		-

Table G - 6 (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	-	-	-	366		-	-	-	-	
LOADER OPERATOR	-	-	-	366		-	-	-	-	
LOCI OPERATOR	-	-	-	1,097		-	-	-	-	
BRAKEMAN	-	-	-	1,097		-	-	-	-	
OPERATOR 6	-	-	-	550		-	-	-	-	
BULL GANG	-	-	-	1,458		-	-	-	-	
OPERATOR FORMAN	-	-	-	92		-	-	-	19	
H.D. WELDER	-	-	-	366		-	-	-	37	
ELECT. FORMAN	-	-	-	92		-	-	-	18	
ELECTRICIAN	-	-	-	183		-	-	-	37	
LOCI OPERATOR	-	-	-	92		-	-	-	19	
BRAKEMAN	-	-	-	92		-	-	-	19	
BULL GANG	-	-	-	92		-	-	-	20	
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	195		-	-	-	-	
TUNNEL MINER	-	-	-	548		-	-	-	-	
BULL GANG	-	-	-	548		-	-	-	-	
LOCI OPERATOR	-	-	-	195		-	-	-	-	
BRAKEMAN	-	-	-	195		-	-	-	-	
H.D. REPAIRMAN	-	-	-	137		-	-	-	9	
ELECTRICIAN	-	-	-	46		-	-	-	-	

Table G - 6 (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	16		-	-	-	-	
TUNNEL MINER	-	-	-	47		-	-	-	-	
BULL GANG	-	-	-	47		-	-	-	-	
OPERATOR 6	-	-	-	68		-	-	-	-	
LOCI OPERATOR	-	-	-	31		-	-	-	-	
BRAKEMAN	-	-	-	31		-	-	-	-	
OPERATING SHIFTER	-	-	-	2		-	-	-	1	
H.D. REPAIRMAN	-	-	-	14		-	-	-	3	
ELECT. FORMAN	-	-	-	2		-	-	-	1	
ELECTRICIAN	-	-	-	4		-	-	-	-	
LOCI OPERATOR	-	-	-	2		-	-	-	-	
BRAKEMAN	-	-	-	2		-	-	-	-	
TOTAL	-	9,238	6,234	11,850		-	943	949	602	

Table G – 6a -- Total Average Annual Collective Radiation Dose (Intermediate Thermal Case)

BASE CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	-	0	0	0		-	0	0	0	
BULL GANG	-	0	0	0		-	0	0	0	
CARPENTER	-	0	0	0		-	0	0	0	
OPERATOR 6	-	0	0	0		-	0	-	0	
COMPRESSOR OPERATOR	-	0	0	0		-	-	0	0	
WHSE CLERK	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	-	-	0		-	0	0	-	
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	-	343	857	405		-	17	69	-	
ELECTRICIAN	-	891	2,948	1,053		-	17	69	-	
LOCI OPERATOR	-	343	1,028	405		-	17	69	-	
H.D. REPAIRMAN	-	27	1,399	32		-	17	69	-	
TOTAL		1,604	6,232	1,895			68	276		

Table G – 6a (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
UTILITY MAINTENANCE										
OPERATING FORMAN	-	343	380	209		-	69	69	81	
H.D. REPAIRMAN	-	857	759	418		-	137	137	162	
ELECTRICIAN FORMAN	-	343	380	209		-	69	69	81	
ELECTRICIAN	-	771	759	418		-	137	137	162	
BULLGANG	-	1,714	759	836		-	137	137	162	
LOCI OPERATOR	-	686	759	418		-	69	69	81	
BRAKEMAN	-	171	190	105		-	69	69	81	
H.D. REPAIRMAN A	-	-	304	121		-	257	257	304	
TOTALS		4,885	4,290	2,734			944	944	1,114	

Table G – 6a (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN FORMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN	-	0	0	0		-	-	-	-	
BULL GANG	-	0	0	0		-	-	-	-	
LOCI OPERATOR	-	0	0	0		-	-	-	-	
BRAKEMAN	-	0	0	0		-	-	-	-	
GRADER OPERATOR	-	0	0	0		-	-	-	-	
H.D. DRIVER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
COMMON LABORER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	-	415	-	-		-	-	-	-	
OPERATOR 6	-	415	-	-		-	-	-	-	
OPERATOR 4	-	830	-	-		-	-	-	-	
H.D. REPAIRMAN	-	415	-	-		-	-	-	-	
ELECTRICIAN	-	415	-	-		-	-	-	-	
TOTALS::		2,090								

Table G – 6a (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	-	8	-	-		-	-	-	-	
OPERATOR 6	-	8	-	-		-	-	-	-	
OPERATOR 4	-	16	-	-		-	-	-	-	
H.D. REPAIRMAN	-	8	-	-		-	-	-	-	
ELECTRICIAN	-	8	-	-		-	-	-	-	
TOTAL		48								
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	-	0	0	0		-	0	-	0	
OPERATOR 5	-	0	0	0		-	0	-	0	
H.D. REPAIRMAN	-	0	0	0		-	0	-	0	
ELECTRICIAN	-	0	0	0		-	0	-	0	
COMMISSIONING										
OPERATOR 4	-	240	-	-		-	-	-	-	
OPERATOR 3	-	240	-	-		-	-	-	-	
HD REPAIRMAN	-	480	-	-		-	-	-	-	
ELECTRICIAN	-	480	-	-		-	-	-	-	
H.D. REPAIRMAN	-	48	-	-		-	-	-	-	
TOTAL		1,488								

Table G – 6a (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 – 2009	EMPLACMENT man-mrem 2010 – 2033	CARETAKER man-mrem 2034 – 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	-	-	-	659		-	-	-	-	
LOADER OPERATOR	-	-	-	659		-	-	-	-	
LOCI OPERATOR	-	-	-	1,976		-	-	-	-	
BRAKEMAN	-	-	-	1,976		-	-	-	-	
OPERATOR 6	-	-	-	805		-	-	-		
BULL GANG	-	-	-	2,634		-	-	-	-	
OPERATOR FORMAN	-	-	-	165		-	-	-	33	
H.D. WELDER	-	-	-	659		-	-	-	66	
ELECT. FORMAN	-	-	-	165		-	-	-	33	
ELECTRICIAN	-	-	-	329		-	-	-	66	
LOCI OPERATOR	-	-	-	165		-	-	-	33	
BRAKEMAN	-	-	-	165		-	-	-	33	
BULL GANG	-	-	-	165		-	-	-	33	
TOTAL				10,522					297	
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	329		-	-	-	-	
TUNNEL MINER	-	-	-	988		-	-	-	-	
BULL GANG	-	-	-	988		-	-	-	-	
LOCI OPERATOR	-	-	-	329		-	-	-	-	
BRAKEMAN	-	-	-	329		-	-	-	-	
H.D. REPAIRMAN	-	-	-	247		-	-	-	16	
ELECTRICIAN	-	-	-	82		-	-	-	-	
TOTAL				3,292						

Table G – 6a(Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2010	EMPLACMENT man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068		CONSTRUCT man-mrem 2005 - 2010	E MPLACE man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	13		-	-	-	-	
TUNNEL MINER	-	-	-	39		-	-	-	-	
BULL GANG	-	-	-	39		-	-	-	-	
OPERATOR 6	-	-	-	50		-	-	-	-	
LOCI OPERATOR	-	-	-	26		-	-	-	-	
BRAKEMAN	-	-	-	26		-	-	-	-	
OPERATING SHIFTER	-	-	-	2		-	-	-	0	
H.D. REPAIRMAN	-	-	-	11		-	-	-	2	
ELECT. FORMAN	-	-	-	1		-	-	-	0	
ELECTRICIAN	-	-	-	3		-	-	-	-	
LOCI OPERATOR	-	-	-	1		-	-	-	-	
BRAKEMAN	-	-	-	1		-	-	-	-	
				212					2	
TOTAL	-	10,098	15,409	26,767		-	1,011	1,217	1,430	

Table G – 6b -- Total Average Annual Collective Radiation Dose (Low Thermal Case)

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	-	99	396	2,772		-	13	50	0	
BULL GANG	-	125	500	3,750		-	25	100	0	
CARPENTER	-	63	250	1,000		-	0	0	0	
OPERATOR 6	-	63	250	30,000		-	13	50	0	
COMPRESSOR OPERATOR	-	63	250	1,750		-	13	50	0	
WHSE CLERK	-	125	500	2,250		-	25	100	-	
H.D. REPAIRMAN	-	63	250	1,750		-	13	50	-	
TOTALS		599	2,396	43,272			102	400		
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	-	241	601	481		-	-	-	-	
ELECTRICIAN	-	722	2,068	1,203		-	-	-	-	
LOCI OPERATOR	-	241	962	722		-	-	-	-	
H.D. REPAIRMAN	-	139	741	241		-	-	-	-	
TOTALS		1,342	4,372	2,646						

Table G – 6b (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
UTILITY MAINTENANCE										
OPERATING FORMAN	-	241	471	722		-	48	48	48	
H.D. REPAIRMAN	-	722	1,082	1,924		-	96	96	96	
ELECTRICIAN FORMAN	-	241	471	722		-	48	48	48	
ELECTRICIAN	-	661	810	2,165		-	96	96	96	
BULLGANG	-	1,443	2,241	3,608		-	96	96	96	
LOCI OPERATOR	-	601	904	1,443		-	48	48	48	
BRAKEMAN	-	241	255	481		-	48	48	48	
H.D. REPAIRMAN A	-	301	382	481		-	0	0	0	
TOTALS		4,451	6,616	11,546			481	481	481	

Table G – 6b (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	-	50	50	250		-	-	-	-	
H.D. REPAIRMAN	-	125	125	250		-	-	-	-	
ELECTRICIAN FORMAN	-	50	50	250		-	-	-	-	
ELECTRICIAN	-	238	113	250		-	-	-	-	
BULL GANG	-	250	250	500		-	-	-	-	
LOCI OPERATOR	-	225	100	250		-	-	-	-	
BRAKEMAN	-	150	25	125		-	-	-	-	
GRADER OPERATOR	-	143	250	125		-	-	-	-	
H.D. DRIVER	-	17	250	250		-	-	-	-	
OFFICE CLEANER	-	50	750	250		-	-	100	100	
OFFICE CLEANER	-	33	500	250		-	-	-	-	
COMMON LABORER	-	33	500	250		-	-	-	-	
OFFICE CLEANER	-	25	25	250		-	-	-	0	
H.D. REPAIRMAN	-	25	25	250		-	-	-	0	
TOTALS		1,413	3,013	3,500				100	100	
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	-	321	-	-		-	-	-	-	
OPERATOR 6	-	0	-	-		-	-	-	-	
OPERATOR 4	-	641	-	-		-	-	-	-	
H.D. REPAIRMAN	-	317	-	-		-	-	-	-	
ELECTRICIAN	-	317	-	-		-	-	-	-	
ITOTALS::		1,595								

Table G – 6b (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	-	6	-	-		-	-	-	-	
OPERATOR 6	-	6	-	-		-	-	-	-	
OPERATOR 4	-	12	-	-		-	-	-	-	
H.D. REPAIRMAN	-	6	-	-		-	-	-	-	
ELECTRICIAN	-	6	-	-		-	-	-	-	
TOTAL		35								
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	113	375	750	1,000		24	78	79	32	
OPERATOR 5	0	0	173	250		28	94	94	38	
H.D. REPAIRMAN	375	1,250	2,525	3,000		15	50	50	20	
ELECTRICIAN	375	1,250	2,275	3,750		15	50	50	20	
TOTALS	863	2,875	5,723	6,000		82	271	273	109	
COMMISSIONING										
OPERATOR 4	-	213	-	-		-	-	-	-	
OPERATOR 3	-	213	-	-		-	-	-	-	
HD REPAIRMAN	-	425	-	-		-	-	-	-	
ELECTRICIAN	-	425	-	-		-	-	-	-	
H.D. REPAIRMAN	-	43	-	-		-	-	-	-	
TOTALS		1,318								

176 **Table G – 6a (Continued) – Total Average Annual Collective Radiation Dose**

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BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 – 2009	EMPLACMENT man-mrem 2010 – 2033	CARETAKER man-mrem 2034 – 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	EMPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	-	-	-	1,275		-	-	-	-	
LOADER OPERATOR	-	-	-	1,275		-	-	-	-	
LOCI OPERATOR	-	-	-	2,125		-	-	-	-	
BRAKEMAN	-	-	-	2,125		-	-	-	-	
OPERATOR 6	-	-	-	1,275		-	-	-	-	
BULL GANG	-	-	-	2,550		-	-	-	29	
OPERATOR FORMAN	-	-	-	213		-	-	-	29	
H.D. WELDER	-	-	-	638		-	-	-	58	
ELECT. FORMAN	-	-	-	425		-	-	-	29	
ELECTRICIAN	-	-	-	850		-	-	-	58	
LOCI OPERATOR	-	-	-	425		-	-	-	29	
BRAKEMAN	-	-	-	425		-	-	-	29	
BULL GANG	-	-	-	213		-	-	-	0	
TOTAL				13,813					262	
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	425		-	-	-	-	
TUNNEL MINER	-	-	-	1,063		-	-	-	-	
BULL GANG	-	-	-	1,063		-	-	-	-	
LOCI OPERATOR	-	-	-	425		-	-	-	-	
BRAKEMAN	-	-	-	319		-	-	-	-	
H.D. REPAIRMAN	-	-	-	319		-	-	-	15	
ELECTRICIAN	-	-	-	213		-	-	-	-	
TOTALS				3,825					15	

Table G – 6b (Continued) – Total Average Annual Collective Radiation Dose

BASE CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2010	EMPLACMENT man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068		CONSTRUCT man-mrem 2005 - 2010	E MPLACE man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	213		-	-	-	-	
TUNNEL MINER	-	-	-	213		-	-	-	-	
BULL GANG	-	-	-	213		-	-	-	-	
OPERATOR 6	-	-	-	213		-	-	-	-	
LOCI OPERATOR	-	-	-	213		-	-	-	-	
BRAKEMAN	-	-	-	213		-	-	-	-	
OPERATING SHIFTER	-	-	-	106		-	-	-	1	
H.D. REPAIRMAN	-	-	-	213		-	-	-	3	
ELECT. FORMAN	-	-	-	106		-	-	-	0	
ELECTRICIAN	-	-	-	106		-	-	-	1	
LOCI OPERATOR	-	-	-	106		-	-	-	-	
BRAKEMAN	-	-	-	106		-	-	-	-	
TOTALS				2,019						
TOTAL	863	13,626	22,122	88,618		82	952	1,254	873	

Table G - 7 -- Total Craft Manpower Distribution – Emplacement Side of Repository (Extended Inventory)

EXTENDED INVENTORY (105,414 MTU) CASE, 85 MTU/ACRE										
	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL 2005 - 2068	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE ^2060 - 2068	TOTAL # 2005 - 2068
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	0.00	0.50	1.38	2.29	4.17	0.00	0.10	0.28	0.15	0.53
BULL GANG	0.00	0.99	2.77	6.10	9.86	0.00	0.20	0.55	0.31	1.06
CARPENTER	0.00	0.50	1.38	0.76	2.64	0.00	0.10	0.28	0.15	0.53
OPERATOR 6	0.00	0.50	1.38	14.31	16.19	0.00	0.10	0.00	0.15	0.25
COMPRESSOR OPERATOR	0.00	0.50	1.38	2.29	4.17	0.00	0.00	0.28	0.31	0.58
WHSE CLERK	0.00	0.99	2.77	4.58	8.33	0.00	0.20	0.55	0.00	0.75
H.D. REPAIRMAN	0.00	0.50	1.38	6.10	7.98	0.00	0.10	0.28	0.00	0.38
H.D. REPAIRMAN	0.00	0.00	0.00	3.28	3.28	0.00	0.50	1.38	0.00	1.88
TOTALS	0.00	4.48	12.44	39.71	56.62	0.00	1.30	3.60	1.07	5.96
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	0.00	1.00	1.38	0.75	3.13	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	2.00	2.77	1.50	6.27	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	1.00	1.38	0.75	3.13	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.08	0.14	0.06	0.28	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	4.08	5.67	3.06	12.81	0.00	0.00	0.00	0.00	0.00
UTILITY MAINTENANCE										
OPERATING FORMAN	0.00	1.00	1.11	0.61	2.72	0.00	0.20	0.28	0.12	0.60
H.D. REPAIRMAN	0.00	2.00	2.21	1.22	5.43	0.00	0.40	0.55	0.24	1.20
ELECTRICIAN FORMAN	0.00	1.00	1.11	0.61	2.72	0.00	0.20	0.28	0.16	0.60
ELECTRICIAN	0.00	2.00	2.21	1.22	5.43	0.00	0.40	0.55	0.24	1.20
BULLGANG	0.00	4.00	2.21	2.44	8.65	0.00	0.40	0.55	0.24	1.20
LOCI OPERATOR	0.00	2.00	2.21	1.22	5.43	0.00	0.20	0.28	0.12	0.60
BRAKEMAN	0.00	0.50	0.55	0.31	1.36	0.00	0.20	0.28	0.12	0.60
H.D. REPAIRMAN A	0.00	0.00	0.89	0.35	1.24	0.00	0.75	0.00	0.00	0.75
TOTALS	0.00	12.50	12.50	7.98	32.98	0.00	2.75	2.77	1.24	6.75

Table G - 7 (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, 85 MTU/ACRE	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL 2005 - 2064	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL # 2005 - 2064
PERSONNEL DESCRIPTION – STRAIGHT TIME						OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	0.00	0.10	0.28	0.15	0.53	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.25	0.55	0.31	1.11	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN FORMAN	0.00	0.15	0.28	0.15	0.58	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.22	0.55	0.31	1.08	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.50	1.11	0.61	2.21	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.20	0.55	0.31	1.06	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.05	0.14	0.08	0.26	0.00	0.00	0.00	0.00	0.00
GRADER OPERATOR	0.00	0.05	1.38	0.76	2.64	0.00	0.00	0.00	0.00	0.00
H.D. DRIVER	0.00	0.05	1.38	0.76	2.64	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	1.49	4.15	2.29	7.93	0.00	0.0 0	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.99	2.77	1.53	5.28	0.00	0.00	0.00	0.00	0.00
COMMON LABORER	0.00	0.99	2.77	1.53	5.28	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.20	0.55	0.00	0.75	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.31	0.31
TOTALS	0.00	5.29	17.01	8.79	31.40	0.00	0.00	0.00	0.12	0.12
PERSONNEL DESCRIPTION – STRAIGHT TIME						OVERTIME PERSONNEL				
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	6.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00

Table G - 7 (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, 85 MTU/ACRE	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL 2005 - 2064	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL # 2005 - 2064
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	0.00	1.50	4.15	1.97	7.62	0.00	0.28	0.00	0.10	0.38
OPERATOR 5	0.00	0.00	0.96	0.42	1.38	0.00	0.43	0.00	0.12	0.54
H.D. REPAIRMAN	0.00	5.00	10.66	8.15	23.80	0.00	0.20	0.00	0.03	0.23
ELECTRICIAN	0.00	5.00	10.66	8.15	20.70	0.00	0.20	0.00	0.03	0.23
TOTALS	0.00	11.50	26.43	18.69	53.50	0.00	1.11	0.00	0.28	1.38
COMMISSIONING										
OPERATOR 4	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 3	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
HD REPAIRMAN	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	4.20	0.00	0.00	4.20	0.00	0.00	0.00	0.00	0.00

Table G - 7 (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, 85 MTU/ACRE	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL 2005 - 2064	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL # 2005 - 2064
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
LOADER OPERATOR	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	2.29	2.29	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	6.07	6.07	0.00	0.00	0.00	0.00	0.00
OPERATOR FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
H.D. WELDER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.15	0.15
ELECT. FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
ELECTRICIAN	0.00	0.00	0.00	0.76	0.76	0.00	0.00	0.00	0.15	0.15
LOCI OPERATOR	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
BRAKEMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
BULL GANG	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
TOTALS	0.00	0.00	0.00	26.24	26.24	0.00	0.00	0.00	0.70	0.70
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.04	0.04
ELECTRICIAN	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.00	0.00	7.75	7.75	0.00	0.00	0.00	0.04	0.04

Table G - 7 (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, 85 MTU/ACRE	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL 2005 - 2064	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2064	TOTAL # 2005 - 2064
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
OPERATING SHIFTER	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.01	0.01
ELECT. FORMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.00	0.00	1.13	1.13	0.00	0.00	0.00	0.00	0.00
TOTAL PEOPLE	0.00	49.06	71.07	111.17	231.29	0.00	5.15	6.37	3.76	15.28

Table G - 7 a -- Total Craft Manpower Distribution – Emplacement Side of Repository (Intermediate Thermal Case)

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD										
	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	0.00	0.50	1.51	2.29	4.30	0.00	0.10	0.30	0.15	0.55
BULL GANG	0.00	0.99	3.02	6.10	10.11	0.00	0.20	0.60	0.31	1.11
CARPENTER	0.00	0.50	1.51	0.76	2.77	0.00	0.10	0.30	0.15	0.55
OPERATOR 6	0.00	0.50	1.51	14.31	16.32	0.00	0.10	0.00	0.15	0.25
COMPRESSOR OPERATOR	0.00	0.50	1.51	2.29	4.30	0.00	0.00	0.30	0.31	0.61
WHSE CLERK	0.00	0.99	3.02	4.58	8.59	0.00	0.20	0.60	0.00	0.80
H.D. REPAIRMAN	0.00	0.50	1.51	6.10	8.11	0.00	0.10	0.30	0.00	0.40
H.D. REPAIRMAN	0.00	0.00	0.00	3.28	3.28	0.00	0.50	1.51	0.00	2.00
TOTALS	0.00	4.48	13.59	39.71	57.78	0.00	1.30	3.91	1.07	6.27
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	0.00	1.00	1.51	0.75	3.26	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	2.00	3.02	1.50	6.52	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	1.00	1.51	0.75	3.26	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.08	0.15	0.06	0.29	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	4.08	6.19	3.06	13.33	0.00	0.00	0.00	0.00	0.00
UTILITY MAINTENANCE										
OPERATING FORMAN	0.00	1.00	1.21	0.61	2.82	0.00	0.20	0.30	0.12	0.62
H.D. REPAIRMAN	0.00	2.00	2.41	1.22	5.63	0.00	0.40	0.60	0.24	1.24
ELECTRICIAN FORMAN	0.00	1.00	1.21	0.61	2.82	0.00	0.20	0.30	0.12	0.62
ELECTRICIAN	0.00	2.00	2.41	1.22	5.63	0.00	0.40	0.60	0.24	1.24
BULLGANG	0.00	4.00	2.41	2.44	8.85	0.00	0.40	0.60	0.24	1.24
LOCI OPERATOR	0.00	2.00	2.41	1.22	5.63	0.00	0.20	0.30	0.12	0.62
BRAKEMAN	0.00	0.50	0.60	0.31	1.41	0.00	0.20	0.30	0.12	0.62
H.D. REPAIRMAN A	0.00	0.00	0.97	0.35	1.32	0.00	0.75	0.00	0.00	0.75
TOTALS	0.00	12.50	13.63	7.98	34.11	0.00	2.75	3.00	1.20	6.95

Table G – 7a Continued

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE ^2060 - 2065	TOTAL # 2005 - 2065
FACILITY MAINTENANCE										
PERSONNEL DESCRIPTION – STRAIGHT TIME						OVERTIME PERSONNEL				
OPERATION SHIFTER	0.00	0.10	0.30	0.15	0.55	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.25	0.60	0.31	1.16	0.00	0.09	0.10	0.00	0.00
ELECTRICIAN FORMAN	0.00	0.15	0.30	0.15	0.60	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.22	0.60	0.31	1.13	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.50	1.21	0.61	2.32	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.20	0.60	0.31	1.11	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.05	0.15	0.08	0.28	0.00	0.00	0.00	0.00	0.00
GRADER OPERATOR	0.00	0.50	1.51	0.76	2.77	0.00	0.00	0.00	0.00	0.00
H.D. DRIVER	0.00	0.50	1.51	0.76	2.77	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	1.49	4.53	2.29	8.31	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.99	3.02	1.53	5.54	0.00	0.00	0.00	0.00	0.00
COMMON LABORER	0.00	0.99	3.02	1.53	5.54	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.20	0.60	0.00	0.80	0.00	0.00	0.00	0.31	0.31
H.D. REPAIRMAN	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.12	0.12
TOTALS	0.00	6.19	17.95	8.79	32.93	0.00	0.00	0.00	0.4.3	0.4.3
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	6.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00

Table G – 7a (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL 2005 - 2068	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL # 2005 - 2068
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	0.00	1.50	4.53	1.97	8.00	0.00	0.28	0.00	0.10	0.38
OPERATOR 5	0.00	0.00	1.04	0.42	1.47	0.00	0.43	0.00	0.12	0.55
H.D. REPAIRMAN	0.00	5.00	11.62	8.15	24.76	0.00	0.20	0.00	0.03	0.23
ELECTRICIAN	0.00	5.00	8.93	7.51	21.44	0.00	0.20	0.00	0.03	0.23
TOTALS	0.00	11.50	26.12	18.05	55.67	0.00	1.11	0.00	0.28	1.39
COMMISSIONING										
OPERATOR 4	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 3	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
HD REPAIRMAN	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	4.20	0.00	0.00	4.20	0.00	0.00	0.00	0.00	0.00
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
LOADER OPERATOR	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	2.29	2.29	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	6.07	6.07	0.00	0.00	0.00	0.00	0.00
OPERATOR FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
H.D. WELDER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.15	0.15
ELECT. FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
ELECTRICIAN	0.00	0.00	0.00	0.76	0.76	0.00	0.00	0.00	0.15	0.15
LOCI OPERATOR	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
BRAKEMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
BULL GANG	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
TOTALS	0.00	0.00	0.00	24.72	24.72	0.00	0.00	0.00	0.70	0.70

Table G – 7a (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.04	0.04
ELECTRICIAN	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.00	0.00	7.75	7.75	0.00	0.00	0.00	0.04	0.04
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
OPERATING SHIFTER	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.01	0.01
ELECT. FORMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.00	0.00	1.13	1.13	0.00	0.00	0.00	0.01	0.01
TOTAL PEOPLE	0.00	49.06	77.46	111.17	237.69	0.00	5.15	6.94	3.76	15.85

Table G - 7b -- Total Craft Manpower Distribution – Emplacement Side of Repository (Low Thermal Case)

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL [1]				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	0.00	0.53	2.06	2.29	4.88	0.00	0.10	0.41	0.15	0.66
BULL GANG	0.00	1.06	4.12	6.10	11.28	0.00	0.20	0.82	0.31	1.33
CARPENTER	0.00	0.53	2.06	0.76	3.36	0.00	0.10	0.41	0.15	0.66
OPERATOR 6	0.00	0.53	2.06	14.31	16.90	0.00	0.10	0.00	0.15	0.25
COMPRESSOR OPERATOR	0.00	0.53	2.06	2.29	4.88	0.00	0.00	0.41	0.31	0.72
WHSE CLERK	0.00	1.06	4.12	4.58	9.76	0.00	0.20	0.82	0.00	1.02
H.D. REPAIRMAN	0.00	0.53	2.06	6.10	8.69	0.00	0.10	0.41	0.00	0.51
H.D. REPAIRMAN	0.00	0.00	0.00	3.28	3.28	0.00	0.50	2.06	0.00	2.56
TOTALS	0.00	4.77	18.54	39.71	63.03	0.00	1.30	5.34	1.07	7.71
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	0.00	1.07	2.06	0.75	3.88	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	2.14	4.12	1.50	7.76	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	1.07	2.06	0.75	3.88	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.09	0.21	0.06	0.35	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	4.37	8.45	3.06	15.87	0.00	0.00	0.00	0.00	0.00
UTILITY MAINTENANCE										
OPERATING FORMAN	0.00	1.07	1.65	0.61	3.33	0.00	0.20	0.41	0.12	0.73
H.D. REPAIRMAN	0.00	2.14	3.30	1.22	6.66	0.00	0.40	0.82	0.24	1.47
ELECTRICIAN FORMAN	0.00	1.07	1.65	0.61	3.33	0.00	0.20	0.41	0.12	0.73
ELECTRICIAN	0.00	2.14	3.30	1.22	6.66	0.00	0.40	0.82	0.24	1.47
BULLGANG	0.00	4.28	3.30	2.44	10.02	0.00	0.40	0.82	0.24	1.47
LOCI OPERATOR	0.00	2.14	3.30	1.22	6.66	0.00	0.20	0.41	0.12	0.73
BRAKEMAN	0.00	0.54	0.82	0.31	1.66	0.00	0.20	0.41	0.12	0.73
H.D. REPAIRMAN A	0.00	0.00	1.32	0.35	1.67	0.00	0.75	0.00	0.00	0.75
TOTALS	0.00	13.38	18.64	7.98	39.99	0.00	2.75	4.10	1.20	8.06

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Table G – 7b (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE ^2060 - 2065	TOTAL # 2005 - 2065
FACILITY MAINTENANCE										
PERSONNEL DESCRIPTION – STRAIGHT TIME						OVERTIME PERSONNEL				
OPERATION SHIFTER	0.00	0.11	0.41	0.15	0.67	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.27	0.82	0.31	1.40	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN FORMAN	0.00	0.16	0.41	0.15	0.72	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.24	0.82	0.31	1.37	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.53	1.65	0.61	2.79	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.21	0.82	0.31	1.34	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.05	0.21	0.08	0.34	0.00	0.00	0.00	0.00	0.00
GRADER OPERATOR	0.00	0.53	2.06	0.76	3.35	0.00	0.00	0.00	0.00	0.00
H.D. DRIVER	0.00	0.53	2.06	0.76	3.35	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	1.59	6.19	2.29	10.07	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	1.06	4.12	1.53	6.71	0.00	0.00	0.00	0.00	0.00
COMMON LABORER	0.00	1.06	4.12	1.53	6.71	0.00	0.00	0.00	0.00	0.00
OFFICE CLEANER	0.00	0.21	0.82	0.00	1.03	0.00	0.00	0.00	0.31	0.31
H.D. REPAIRMAN	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.12	0.12
TOTALS	0.00	6.59	24.51	8.79	39.90	0.00	0.00	0.00	0.43	0.43
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	0.00	1.07	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	1.07	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	1.07	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	6.21	0.00	0.00	6.21	0.00	0.00	0.00	0.00	0.00
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
OPERATOR 4	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00

Table G – 7b (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL 2005 - 2068	CONSTRUCT 2005 - 2010	EMPLACE 2010 - 2034	CARETAKER 2034 - 2060	CLOSURE 2060 - 2068	TOTAL # 2005 - 2068
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	0.00	1.61	6.19	1.97	9.76	0.00	0.28	0.00	0.10	0.38
OPERATOR 5	0.00	0.00	1.42	0.42	1.85	0.00	0.43	0.00	0.12	0.54
H.D. REPAIRMAN	0.00	5.35	15.88	8.15	29.38	0.00	0.20	0.00	0.03	0.23
ELECTRICIAN	0.00	5.35	12.21	7.51	25.06	0.00	0.20	0.00	0.03	0.23
TOTAL	0.00	11.50	22.89	29.00	63.39	0.00	1.11	0.00	0.28	1.38
COMMISSIONING										
OPERATOR 4	0.00	1.07	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00
OPERATOR 3	0.00	1.07	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00
HD REPAIRMAN	0.00	2.14	0.00	0.00	2.14	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.21	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	4.49	0.00	0.00	4.49	0.00	0.00	0.00	0.00	0.00
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
LOADER OPERATOR	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	4.57	4.57	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	2.29	2.29	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	6.07	6.07	0.00	0.00	0.00	0.00	0.00
OPERATOR FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
H.D. WELDER	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.15	0.15
ELECT. FORMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
ELECTRICIAN	0.00	0.00	0.00	0.76	0.76	0.00	0.00	0.00	0.15	0.15
LOCI OPERATOR	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
BRAKEMAN	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
BULL GANG	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.08	0.08
TOTALS	0.00	0.00	0.00	24.34	24.34	0.00	0.00	0.00	0.70	0.70

Table G – 7b (Continued)

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL 2005 - 2065	CONSTRUCT 2005 - 2009	EMPLACE 2010 - 2033	CARETAKER 2034 - 2059	CLOSURE 2060 - 2065	TOTAL # 2005 - 2065
PERSONNEL DESCRIPTION - STRAIGHT TIME						OVERTIME PERSONNEL				
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.04	0.04
ELECTRICIAN	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.00	0.00	7.75	7.75	0.00	0.00	0.00	0.04	0.04
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
TUNNEL MINER	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
BULL GANG	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
OPERATOR 6	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00
OPERATING SHIFTER	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
H.D. REPAIRMAN	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.01	0.01
ELECT. FORMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
ELECTRICIAN	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
LOCI OPERATOR	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
BRAKEMAN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
TOTALS	0.00	0.00	0.00	1.13	1.13	0.00	0.00	0.00	0.01	0.01
TOTAL PEOPLE	0.00	52.28	105.89	111.17	269.34	0.00	5.15	9.49	3.76	18.40

Table G - 8 -- Total Annual Average Collective Radiation Dose (Extended Inventory)

EXTENDED INVENTORY (105,414 MTU) CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	-	0	0	0		-	0	0	0	
BULL GANG	-	0	0	0		-	0	0	0	
CARPENTER	-	0	0	0		-	0	0	0	
OPERATOR 6	-	0	0	0		-	0	-	0	
COMPRESSOR OPERATOR	-	0	0	0		-	-	0	0	
WHSE CLERK	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	-	-	0		-	0	0	-	
TOTALS	0	0	0	0		0	0	0	0	
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	-	1,806	4,415	1,878		-	-	2,709	-	
ELECTRICIAN	-	1,806	15,532	4,883		-	-	-	-	
LOCI OPERATOR	-	1,806	7,224	1,878		-	-	-	-	
H.D. REPAIRMAN	-	1,806	5,562	150		-	-	-	-	
TOTALS		7,224	32,833	8,790				2,709		

Table G - 8 (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
UTILITY MAINTENANCE										
OPERATING FORMAN	-	372	729	298		-	74	74	60	
H.D. REPAIRMAN	-	930	1,793	744		-	149	149	119	
ELECTRICIAN FORMAN	-	372	729	298		-	74	74	60	
ELECTRICIAN	-	837	1,254	670		-	149	149	119	
BULLGANG	-	1,860	1,860	1,488		-	149	149	119	
LOCI OPERATOR	-	744	1,399	595		-	74	74	60	
BRAKEMAN	-	186	394	149		-	74	74	60	
H.D. REPAIRMAN A	-	0	0	0		-	0	0	0	
TOTALS		5,301	8,158	4,241		0	744	744	595	

Table G - 8 (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	EMPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN FORMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN	-	0	0	0		-	-	-	-	
BULL GANG	-	0	0	0		-	-	-	-	
LOCI OPERATOR	-	0	0	0		-	-	-	-	
BRAKEMAN	-	0	0	0		-	-	-	-	
GRADER OPERATOR	-	0	0	0		-	-	-	-	
H.D. DRIVER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
COMMON LABORER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	-	1,996	-	-		-	-	-	-	
OPERATOR 6	-	1,996	-	-		-	-	-	-	
OPERATOR 4	-	5,988	-	-		-	-	-	-	
H.D. REPAIRMAN	-	1,996	-	-		-	-	-	-	
ELECTRICIAN	-	1,996	-	-		-	-	-	-	
TOTALS!::		13,972								

Table G - 8 (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	-	40	-	-		-	-	-	-	
OPERATOR 6	-	40	-	-		-	-	-	-	
OPERATOR 4	-	80	-	-		-	-	-	-	
H.D. REPAIRMAN	-	40	-	-		-	-	-	-	
ELECTRICIAN	-	40	-	-		-	-	-	-	
TOTALS		240								
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	-	0	0	0		-	0	-	0	
OPERATOR 5	-	0	0	0		-	0	-	0	
H.D. REPAIRMAN	-	0	0	0		-	0	-	0	
ELECTRICIAN	-	0	0	0		-	0	-	0	
COMMISSIONING										
OPERATOR 4	-	240	-	-		-	-	-	-	
OPERATOR 3	-	240	-	-		-	-	-	-	
HD REPAIRMAN	-	480	-	-		-	-	-	-	
ELECTRICIAN	-	480	-	-		-	-	-	-	
H.D. REPAIRMAN		480								
TOTALS		1,920								

Table G – 8 (Continued) – Total Annual Average Collective Radiation

EXTENDED INVENTORY (105,414 MTU) CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	-	-	-	500		-	-	-	-	
LOADER OPERATOR	-	-	-	500		-	-	-	-	
LOCI OPERATOR	-	-	-	1,500		-	-	-	-	
BRAKEMAN	-	-	-	1,500		-	-	-	-	
OPERATOR 6	-	-	-	500		-	-	-	-	
BULL GANG	-	-	-	1,999		-	-	-	-	
OPERATOR FORMAN	-	-	-	125		-	-	-	25	
H.D. WELDER	-	-	-	500		-	-	-	50	
ELECT. FORMAN	-	-	-	125		-	-	-	25	
ELECTRICIAN	-	-	-	250		-	-	-	50	
LOCI OPERATOR	-	-	-	125		-	-	-	25	
BRAKEMAN	-	-	-	125		-	-	-	25	
BULL GANG	-	-	-	125		-	-	-	25	
TOTALS	0	0	0	7,873					225	
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	250		-	-	-	-	
TUNNEL MINER	-	-	-	750		-	-	-	-	
BULL GANG	-	-	-	750		-	-	-	-	
LOCI OPERATOR	-	-	-	250		-	-	-	-	
BRAKEMAN	-	-	-	250		-	-	-	-	
H.D. REPAIRMAN	-	-	-	187		-	-	-	12	
ELECTRICIAN	-	-	-	62		-	-	-	-	
TOTALS				2,500					12	

227 **Table G - 8 (Continued) – Total Annual Average Collective Radiation Dose**

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EXTENDED INVENTORY (105,414 MTU) CASE, HIGH (85 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2064	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	16		-	-	-	-	
TUNNEL MINER	-	-	-	48		-	-	-	-	
BULL GANG	-	-	-	48		-	-	-	-	
OPERATOR 6	-	-	-	164		-	-	-	-	
LOCI OPERATOR	-	-	-	32		-	-	-	-	
BRAKEMAN	-	-	-	32		-	-	-	-	
OPERATING SHIFTER	-	-	-	2		-	-	-		
H.D. REPAIRMAN	-	-	-	14		-	-	-	3	
ELECT. FORMAN	-	-	-	2		-	-	-	0	
ELECTRICIAN	-	-	-	4		-	-	-	1	
LOCI OPERATOR	-	-	-	2		-	-	-	-	
BRAKEMAN	-	-	-	2		-	-	-	-	
TOTALS				365						
TOTAL	-	28,657	40,991	23,768		-	744	3,453	837	

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Table G – 8a -- Total Annual Average Collective Radiation Dose (Intermediate Thermal Case)

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	-	0	0	0		-	0	0	0	
BULL GANG	-	0	0	0		-	0	0	0	
CARPENTER	-	0	0	0		-	0	0	0	
OPERATOR 6	-	0	0	0		-	0	-	0	
COMPRESSOR OPERATOR	-	0	0	0		-	-	0	0	
WHSE CLERK	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	-	-	0		-	0	0	-	
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	-	1,806	3,612	1,426		-	-	-	-	
ELECTRICIAN	-	4,696	16,435	3,707		-	-	-	-	
LOCI OPERATOR	-	1,806	7,224	1,426		-	-	-	-	
H.D. REPAIRMAN	-	144	5,562	114		-	-	-	-	
TOTALS		8,452	32,833	6,673						

Table G – 8a (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
UTILITY MAINTENANCE										
OPERATING FORMAN	-	372	670	294		-	74	134	59	
H.D. REPAIRMAN	-	930	1,674	294		-	149	268	117	
ELECTRICIAN FORMAN	-	372	670	294		-	74	134	59	
ELECTRICIAN	-	837	1,135	661		-	149	268	117	
BULLGANG	-	1,860	3,348	1,468		-	149	268	117	
LOCI OPERATOR	-	744	1,339	587		-	74	134	59	
BRAKEMAN	-	186	335	147		-	74	134	59	
H.D. REPAIRMAN A	-	-	193	0		-	279	279	220	
TOTALS		5,301	9,364	3,745			1,023	1,618	808	

Table G – 8a (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN FORMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN	-	0	0	0		-	-	-	-	
BULL GANG	-	0	0	0		-	-	-	-	
LOCI OPERATOR	-	0	0	0		-	-	-	-	
BRAKEMAN	-	0	0	0		-	-	-	-	
GRADER OPERATOR	-	0	0	0		-	-	-	-	
H.D. DRIVER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
COMMON LABORER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	-	1,996	-	-		-	-	-	-	
OPERATOR 6	-	1,996	-	-		-	-	-	-	
OPERATOR 4	-	5,988	-	-		-	-	-	-	
H.D. REPAIRMAN	-	3,992	-	-		-	-	-	-	
ELECTRICIAN	-	3,992	-	-		-	-	-	-	
TOTALS		12,964								

Table G – 8a (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	EMPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	-	46	-	-		-	-	-	-	
OPERATOR 6	-	46	-	-		-	-	-	-	
OPERATOR 4	-	92	-	-		-	-	-	-	
H.D. REPAIRMAN	-	46	-	-		-	-	-	-	
ELECTRICIAN	-	46	-	-		-	-	-	-	
TOTALS		275								
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	-	0	0	0		-	0	-	0	
OPERATOR 5	-	0	0	0		-	0	-	0	
H.D. REPAIRMAN	-	0	0	0		-	0	-	0	
ELECTRICIAN	-	0	0	0		-	0	-	0	
COMMISSIONING										
OPERATOR 4	-	240	-	-		-	-	-	-	
OPERATOR 3	-	240	-	-		-	-	-	-	
HD REPAIRMAN	-	480	-	-		-	-	-	-	
ELECTRICIAN	-	480	-	-		-	-	-	-	
H.D. REPAIRMAN	-	48	-	-		-	-	-	-	
TOTALS		1,488								

Table G – 8a (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 – 2009	EMPLACMENT man-mrem 2010 – 2033	CARETAKER man-mrem 2034 – 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	-	-	-	601		-	-	-	-	
LOADER OPERATOR	-	-	-	601		-	-	-	-	
LOCI OPERATOR	-	-	-	1,803		-	-	-	-	
BRAKEMAN	-	-	-	1,803		-	-	-	-	
OPERATOR 6	-	-	-	766		-	-	-	-	
BULL GANG	-	-	-	2,403		-	-	-	-	
OPERATOR FORMAN	-	-	-	150		-	-	-	30	
H.D. WELDER	-	-	-	601		-	-	-	60	
ELECT. FORMAN	-	-	-	150		-	-	-	30	
ELECTRICIAN	-	-	-	300		-	-	-	60	
LOCI OPERATOR	-	-	-	150		-	-	-	30	
BRAKEMAN	-	-	-	150		-	-	-	30	
BULL GANG	-	-	-	150		-	-	-	30	
TOTALS				9,648					270	
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	300		-	-	-	-	
TUNNEL MINER	-	-	-	901		-	-	-	-	
BULL GANG	-	-	-	901		-	-	-	-	
LOCI OPERATOR	-	-	-	300		-	-	-	-	
BRAKEMAN	-	-	-	300		-	-	-	-	
H.D. REPAIRMAN	-	-	-	225		-	-	-	15	
ELECTRICIAN	-	-	-	75		-	-	-	-	
TOTALS				3,004					15	

Table G – 8a (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, INTERMEDIATE (60 MTU/ACRE)										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2010	EMPLACMENT man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068		CONSTRUCT man-mrem 2005 - 2010	E MPLACE man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	19		-	-	-	-	
TUNNEL MINER	-	-	-	56		-	-	-	-	
BULL GANG	-	-	-	56		-	-	-	-	
OPERATOR 6	-	-	-	9		-	-	-	-	
LOCI OPERATOR	-	-	-	37		-	-	-	-	
BRAKEMAN	-	-	-	37		-	-	-	-	
OPERATING SHIFTER	-	-	-	2		-	-	-		
H.D. REPAIRMAN	-	-	-	17		-	-	-	3	
ELECT. FORMAN	-	-	-	2		-	-	-	1	
ELECTRICIAN	-	-	-	5		-	-	-	1	
LOCI OPERATOR	-	-	-	2		-	-	-	-	
BRAKEMAN	-	-	-	2		-	-	-	-	
TOTALS				244					5	
TOTAL		33,480	42,196	23,755			1,023	1,618	1,099	

Table G – 8b -- Total Annual Average Collective Radiation Dose (Low Thermal Case)

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PORTAL SUPPORT CREW										
TUNNEL SHIFTER	-	0	0	0		-	0	0	0	
BULL GANG	-	0	0	0		-	0	0	0	
CARPENTER	-	0	0	0		-	0	0	0	
OPERATOR 6	-	0	0	0		-	0	-	0	
COMPRESSOR OPERATOR	-	0	0	0		-	-	0	0	
WHSE CLERK	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	0	0	0		-	0	0	-	
H.D. REPAIRMAN	-	-	-	0		-	0	0	-	
CONTROLS AND MONITORING MAINTENANCE										
ELECTRICAL FORMAN	-	178	445	356		-	-	-	-	
ELECTRICIAN	-	463	1,531	1,780		-	-	-	-	
LOCI OPERATOR	-	178	712	356		-	-	-	-	
H.D. REPAIRMAN	-	14	548	356		-	-	-	-	
TOTALS		833	3,236	2,848						

Table G – 8b (Continued) -- Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
UTILITY MAINTENANCE										
OPERATING FORMAN	-	178	349	356		-	36	36	36	
H.D. REPAIRMAN	-	445	858	890		-	71	71	71	
ELECTRICIAN FORMAN	-	178	349	356		-	36	36	36	
ELECTRICIAN	-	401	600	712		-	71	71	71	
BULLGANG	-	890	1,659	1,780		-	71	71	71	
LOCI OPERATOR	-	356	669	534		-	36	36	36	
BRAKEMAN	-	89	189	178		-	36	36	36	
H.D. REPAIRMAN A	-	-	93	0		-	134	134	134	
TOTALS		2,537	4,765	4,806			490	490	490	

Table G – 8b (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
FACILITY MAINTENANCE										
OPERATION SHIFTER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN FORMAN	-	0	0	0		-	-	-	-	
ELECTRICIAN	-	0	0	0		-	-	-	-	
BULL GANG	-	0	0	0		-	-	-	-	
LOCI OPERATOR	-	0	0	0		-	-	-	-	
BRAKEMAN	-	0	0	0		-	-	-	-	
GRADER OPERATOR	-	0	0	0		-	-	-	-	
H.D. DRIVER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
COMMON LABORER	-	0	0	0		-	-	-	-	
OFFICE CLEANER	-	0	0	0		-	-	-	-	
H.D. REPAIRMAN	-	0	0	0		-	-	-	-	
TRANSPORT & EMPLACEMENT										
OPERATIONS SHIFTER	-	254	-	-		-	-	-	-	
OPERATOR 6	-	254	-	-		-	-	-	-	
OPERATOR 4	-	762	-	-		-	-	-	-	
H.D. REPAIRMAN	-	508	-	-		-	-	-	-	
ELECTRICIAN	-	508	-	-		-	-	-	-	
TOTALS		2,286								

Table G – 8b (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2009	EMPLACMENT man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
SHADOW SHIELD INSTALLATION										
OPERATION SHIFTER	-	6	-	-		-	-	-	-	
OPERATOR 6	-	6	-	-		-	-	-	-	
OPERATOR 4	-	12	-	-		-	-	-	-	
H.D. REPAIRMAN	-	6	-	-		-	-	-	-	
ELECTRICIAN	-	6	-	-		-	-	-	-	
TOTALS		36								
MAIN VENT FAN MAINTENANCE										
OPERATOR 5	-	0	0	0		-	0	-	0	
OPERATOR 5	-	0	0	0		-	0	-	0	
H.D. REPAIRMAN	-	0	0	0		-	0	-	0	
ELECTRICIAN	-	0	0	0		-	0	-	0	
COMMISSIONING										
OPERATOR 4	-	150	-	-		-	-	-	-	
OPERATOR 3	-	150	-	-		-	-	-	-	
HD REPAIRMAN	-	300	-	-		-	-	-	-	
ELECTRICIAN	-	300	-	-		-	-	-	-	
H.D. REPAIRMAN	-	30	-	-		-	-	-	-	
TOTALS		930								

Table G – 8a (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 – 2009	EMPLACMENT man-mrem 2010 – 2033	CARETAKER man-mrem 2034 – 2059	CLOSURE man-mrem 2060 - 2065		CONSTRUCT man-mrem 2005 - 2009	E MPLACE man-mrem 2010 - 2033	CARETAKER man-mrem 2034 - 2059	CLOSURE man-mrem 2060 - 2065	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
BACKFILL ACCESS MAINS										
OPERATOR SHIFTER	-	-	-	600		-	-	-	-	
LOADER OPERATOR	-	-	-	900		-	-	-	-	
LOCI OPERATOR	-	-	-	2,250		-	-	-	-	
BRAKEMAN	-	-	-	2,250		-	-	-	-	
OPERATOR 6	-	-	-	600		-	-	-	-	
BULL GANG	-	-	-	2,400		-	-	-	-	
OPERATOR FORMAN	-	-	-	300		-	-	-	24	
H.D. WELDER	-	-	-	750		-	-	-	49	
ELECT. FORMAN	-	-	-	300		-	-	-	24	
ELECTRICIAN	-	-	-	300		-	-	-	49	
LOCI OPERATOR	-	-	-	150		-	-	-	24	
BRAKEMAN	-	-	-	150		-	-	-	24	
BULL GANG	-	-	-	150		-	-	-	24	
TOTALS				11,100					218	
CLEANOUT ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	750		-	-	-	-	
TUNNEL MINER	-	-	-	1,200		-	-	-	-	
BULL GANG	-	-	-	1,200		-	-	-	-	
LOCI OPERATOR	-	-	-	300		-	-	-	-	
BRAKEMAN	-	-	-	300		-	-	-	-	
H.D. REPAIRMAN	-	-	-	300		-	-	-	12	
ELECTRICIAN	-	-	-	300		-	-	-	-	
TOTALS				4,350					12	

Table G – 8b (Continued) – Total Annual Average Collective Radiation Dose

EXTENDED INVENTORY (105,414 MTU) CASE, LOW (25 MTU/ACRE) THERMAL LOAD										
OPERATING PHASE UNITS INTERVAL	CONSTRUCTION man-mrem 2005 - 2010	EMPLACMENT man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068		CONSTRUCT man-mrem 2005 - 2010	E MPLACE man-mrem 2010 - 2034	CARETAKER man-mrem 2034 - 2060	CLOSURE man-mrem 2060 - 2068	
PERSONNEL DESCRIPTION	STRAIGHT TIME PERSONNEL					OVERTIME PERSONNEL				
PLUG & SEAL ACCESS MAINS										
TUNNEL SHIFTER	-	-	-	150		-	-	-	-	
TUNNEL MINER	-	-	-	150		-	-	-	-	
BULL GANG	-	-	-	150		-	-	-	-	
OPERATOR 6	-	-	-	150		-	-	-	-	
LOCI OPERATOR	-	-	-	150		-	-	-	-	
BRAKEMAN	-	-	-	150		-	-	-	-	
OPERATING SHIFTER	-	-	-	150		-	-	-	0	
H.D. REPAIRMAN	-	-	-	150		-	-	-	3	
ELECT. FORMAN	-	-	-	150		-	-	-	0	
ELECTRICIAN	-	-	-	150		-	-	-	1	
LOCI OPERATOR	-	-	-	150		-	-	-	-	
BRAKEMAN	-	-	-	150		-	-	-	-	
TOTALS				1,800					4	
TOTAL	-	6,621	8,001	24,904		-	490	490	726	

H. APPENDIX -- CLOSURE PERIOD ESTIMATIONS

Table H- 1. Summary of Subsurface Repository Closure Periods as Estimated

Bases of estimates included as backup material in the CRWMS records package.

Base Cases at 70,000 MTU Total Waste:

• Base Case High Thermal Loading	4.5 years
• Base Case Intermediate Thermal Loading	6 years
• Base Case Low Thermal Loading	14 years

Extended Inventory at 105,000 MTU Spent Nuclear Fuel:

• Modules 1 & 2b High Thermal Loading	12 years
• Modules 1 & 2b Intermediate Thermal Loading	15 years
• Modules 1 & 2b Low Thermal Loading	24 years

I. APPENDIX -- BACKFILL OF EMPLACEMENT DRIFTS

Backfilling of the emplacement drifts is not planned in the VA but is maintained as an option. Estimations for the values shown in the following tables are contained as backup material in the CRWMS record package.

I.1 STAFFING

Staffing in the backfilling operation is considered to employ both the operating contractor and subcontractors. The backfilling is assumed to begin in year 2060 and end in year 2068 for the VA inventory case for both High and Intermediate Loading. The Low Thermal Case requires approximately 2.5 times as emplacement drift length, therefore the assumption was made to extend backfill operations proportionally to 30 years.

Table I.1-1. Backfilling of Emplacement Area, Staffing

Personnel	Subject	High Base Case (8 years)	Intermediate Thermal Case (8 years)	Low Thermal Case (20 years)
Managerial:	Peak number of workers:	30	30	30
	Average number of workers:	30	30	30
Craft:	Peak number of workers:	173	182	182
	Average number of workers:	173	182	182
Total	Peak number of workers:	203	212	212
Personnel:	Average number of workers:	203	212	212

I.2 RESOURCES CONSUMED

The total electrical power shown in the table below includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment. The total power is not differentiated during the Backfill phase.

Fuel is expended for surface service equipment only during the Backfill phase. Lubricants are used in surface and underground equipment. Of the lubricants, grease is considered consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Table I.6-1.

Table I.2-1. Resources Consumed during Backfilling

Item	Thermal Loading Case		
	High Base Case 8 years	Intermediate Case 8 years	Low Thermal Case 20 years
Electrical Power			
Total ('000)(mwh)	272.0	317.3	680.0
Peak (kw)	7,734	7,734	7,734
Fuel, Lubricants			
Diesel ('000 liters)	2,500	2,700	6,250
Oil ('000 liters)	3,000	3,200	7,500
Grease ('000 kgs)	100	100	300
Steel			
Crusher (mt)	16	17	40
Screen (mt)	1	1	1
Water (million liters)			
Potable	55.0	57.0	137.5
Dust Suppression	253.2	275.2	633.0
Totals	308.2	332.2	870.5
Peak Use (liters/hr)	6,400	6,900	6,900
Units kg kilograms mt metric ton kw kilowatts kwh kilowatt hours			

I.3 MATERIALS INSTALLED

Materials installed by the backfill operation are estimated and listed in the following table.

Table I.3-1. Backfilling Operating Period, Materials Installed

Material	High Base Case m^3 (8 years)	Intermediate Case m^3 (8 years)	Low Thermal Case m^3 (20 years)
Mined rock reclaimed from surface stockpile	2,300,000	2,500,000	6,867,000
Total Materials	2,300,000	2,500,000	6,867,000

I.4 UNDERGROUND OPENINGS EXCAVATED

No underground openings are planned for excavation by the emplacement drift backfill operations.

I.5 ROCK STOCKPILED AT SURFACE

To backfill the emplacement drifts, mined rock is assumed to be recovered from the surface stockpile. All rock volumes expressed in the following table are loose.

Table I.5-1. Backfilling Emplacement Area Operation

Stockpile Status	Base Case m³ (8 years)	Intermediate Case m³ (8 years)	Low Thermal Case m³ (20 years)
Mined rock existing in stockpile	5,842,000	7,068,000	18,084,000
Mined rock placed into stockpile	0	0	0
Rock removed from stockpile	2,300,000	2,300,000	6,867,000
Rock in stockpile at end of phase	3,542,000	4,768,000	11,217,000

I.6 WASTES GENERATED

Table I.6-1. Emplacement Area Backfill Operations

Waste Material	Base Case m³ 8 years	Intermediate Case m³ 8 years	Low Thermal Case m³ 20 years
Hydrocarbons (lubricants & fluids) (total for period) liters	3,000,000	3,200,000	7,500,000
Solid wastes (landfill) m³/year	334	334	334
Solid wastes (recyclable) m³/year	833	833	833
Sanitary waste liters/year	9,604,000	10,030,000	10,030,000
Low-level nuclear waste m³/year	0	0	0
RCRA waste m³/year	0	0	0

I.7 EMISSIONS AND EFFLUENTS

Table I.7-1. Backfilling of Emplacement Area Emissions and Effluents

Material	Base Case (8 years)	Intermediate Case (8 years)	Low Thermal Case (20 years)
Diesel Exhaust (surface area) cubic meters/year	83,800,000	83,800,000	83,800,000
Dust (controlled to be less than) short tons/year	250	250	250
Water (assumed to be discharged) liters/year	not determined	not determined	not determined

I.8 EQUIPMENT

Table I.8-1. Equipment Acquired during Backfill High and Intermediate Cases (8 years)

Unit	Number	Unit	Number
Rail Haulage		Surface Mobil	
Flat Car (10 t)	2	End Dump Truck	2
Man Trip (battery)	2	Flatbed Truck	1
Shuttle car	28	Forklift	1
Vacuum Car	1	Grader	1
Locomotive (Diesel)	2	Hydraulic Crane	1
Locomotive (Trolley)	2	Loader	1
Locomotive (Trolley)	5	Transport Trailer	1
		Water Truck	1
Miscellaneous		Water Handling	
Platform Lift (Elect.)	2	Cent. Pump	3
Compressor	2		
Ventilation Equipment		Material Handling	
Develop Fan	1	Cone Crusher	1
Emplace Fan	1	Conveyor	5
Filter Fan	4	Backfill Placer	2
Mobile Scrubber	4	Rad. Stacker	1
Mobile Scrubber	4	Scalping Screen	1
		Surge Bin	1

Table I.8-2. Equipment Acquired during Backfill Low Thermal Case (20 years)

Unit	Number	Unit	Number
Rail Haulage		Surface Mobil	
Flat Car (10 t)	4	End Dump Truck	6
Man Trip (battery)	4	Flatbed Truck	3
Shuttle car	25	Forklift	3
Vacuum Car	3	Grader	2
Locomotive (Diesel)	4	Hydraulic Crane	2
Locomotive (Trolley)	4	Loader	3
Locomotive (Trolley)	8	Transport Trailer	2
		Water Truck	3
Miscellaneous		Water Handling	
Platform Lift (Elect.)	4	Cent. Pump	6
Compressor	4		
Ventilation Equipment		Material Handling	
Develop Fan	3	Cone Crusher	2
Emplace Fan	3	Conveyor	10
Filter Fan	6	Backfill Placer	5
Mobile Scrubber	10	Rad. Stacker	1
Mobile Scrubber	10	Scalping Screen	3
		Surge Bin	1

Note: cfm cubic feet per minute; cy cubic yards; ft feet; gal gallon; gpm gallon per minute; hp horsepower; k thousand; m meter; t short ton

Note:

1) The above equipment items were increased from those estimated for a 8-year operating life to a 20-year life.

I.9 NOT USED

I.10 BACKFILLING OF MODULES 1 & 2B EMPLACEMENT DRIFTS

The following sections and tables reflect only backfilling of the extended inventory cases referred to as Modules 1 & 2b.

I.11 STAFFING

Staffing in the backfilling operation is considered to employ both the operating contractor and subcontractors. The backfilling is assumed to begin in year 2060 and end in year 2072 for the extended inventory High and Intermediate Cases. The Low Thermal Case is assumed to take 2.5 times longer to backfill the greater lengths of emplacement drifts; therefore, approximately 30 years. Completion for the Low Case would then be 2090.

Table I.11-1. Backfilling of Emplacement Area, Staffing (Modules 1&2b)

Personnel	Subject	High ThermalCase (12 years)	Intermediate Thermal Case (12 years)	Low Thermal Case (30 years)
Managerial:	Peak number of workers:	40	40	40
	Average number of workers:	40	40	40
Craft:	Peak number of workers:	185	185	195
	Average number of workers:	185	185	195
Total Personnel:	Peak number of workers:	225	225	235
	Average number of workers:	225	225	235

I.12 RESOURCES CONSUMED

The total electrical power shown in the table below includes power for stationary equipment (fans, compressors, pumps, etc.) and mobile equipment. The total power is not differentiated during the Backfill phase.

Fuel is expended for surface service equipment only during the Backfill phase. Lubricants are used in surface and underground equipment. Of the lubricants, grease is considered consumed by the equipment while lubricating oil is recaptured and disposed with other hydrocarbons (oil, hydraulic fluid, and solvents) as shown in Table I.16-1.

Table I.12-1. Resources Consumed during Backfilling

Item	Thermal Loading Cases (Modules 1&2b)		
	High Thermal Case 12 years	Intermediate Case 12 years	Low Thermal Case 30 years
Electrical Power			
Total ('000)(mwh)	610.2	686.4	1,525.0
Peak (kw)	8,000	8,000	8,000
Fuel, Lubricants			
Diesel ('000 liters)	4,000	4,000	9,000
Oil ('000 liters)	4,900	4,900	11,000
Grease ('000 kgs)	200	200	450
Steel			
Crusher (mt)	26	26	61
Screen (mt)	2	2	5
Water (million liters)			
Potable	91.4	91.4	228.4
Dust Suppression	379.8	379.8	949.5
Totals	471.2	471.2	1,177.5
Peak Use (liters/hr)	6,500	6,500	13,200

Units
kg kilograms mt metric ton
kw kilowatts
kwh kilowatt hours

I.13 MATERIALS INSTALLED

Materials installed by the backfill operation are estimated and listed in the following table.

Table I.13-1. Backfilling Operating Period, Materials Installed

Material	High Thermal Case (12 years)	Intermediate Case (12 years)	Low Thermal Case (30 years)
Mined rock reclaimed from surface stockpile in cubic meters	4,152,000	4,116,000	10,380,000
Total Materials (cubic meters)	4,152,000	4,116,000	10,380,000

I.14 UNDERGROUND OPENINGS EXCAVATED

No underground openings are planned for excavation by the emplacement drift backfill operations.

I.15 ROCK STOCKPILED AT SURFACE

To backfill the emplacement drifts, mined rock is assumed to be recovered from the surface stockpile. All rock volumes expressed in the following table are loose.

Table I.15-1. Backfilling Emplacement Area Operation (Modules 1&2b)

Stockpile Status	High Thermal Case (12 years)	Intermediate Case (12 years)	Low Thermal Case (30 years)
Mined rock existing in stockpile in cubic meters	11,155,000	11,453,000	31,173,000
Mined rock placed into stockpile in cubic meters	0	0	0
Rock removed from stockpile in cubic meters	4,152,000	4,116,000	10,380,000
Rock in stockpile at end of phase in cubic meters	7,003,000	7,337,000	20,793,000

I.16 WASTES GENERATED

Table I.16-1. Emplacement Area Backfill Operations (Modules 1&2b)

Waste Material	High Thermal Case (12 years_	Intermediate Thermal Case (12 years)	Low Thermal Case (30 years)
Hydrocarbons (lubricants & fluids) (total for period) liters	4,900,000	4,900,000	12,250,000
Solid wastes (landfill) cubic meters/year	334	334	334
Solid wastes (recyclable) cubic meters/year	833	833	833
Sanitary waste liters/year	10,645,000	10,645,000	12,065,000
Low-level nuclear waste cubic meters/year	0	0	0
RCRA waste cubic meters/year	0	0	0

I.17 EMISSIONS AND EFFLUENTS

Table I.17-1. Backfilling of Emplacement Area Emissions and Effluents (Modules 1&2b)

Material	High Thermal Case (12 years)	Intermediate Case (12 years)	Low Thermal Case (30 years)
Diesel Exhaust (surface area) cubic meters/year	83,800,000	83,800,000	83,800,000
Dust (controlled to be less than) short tons/year	250	250	250
Water (assumed to be discharged) liters/year	not determined	not determined	not determined

I.18 EQUIPMENT

Table I.18-1. Equipment Acquired during Backfill High and Intermediate Cases for Modules 1&2b (12 years)

Unit	Number	Unit	Number
Rail Haulage		Surface Mobil	
Flat Car (10 t)	2	End Dump Truck	3
Man Trip (battery)	2	Flatbed Truck	1
Shuttle car	28	Forklift	3
Vacuum Car	1	Grader	1
Locomotive (Diesel)	3	Hydraulic Crane	2
Locomotive (Trolley)	3	Loader	2
Locomotive (Trolley)	8	Scraper	1
		Tractor	1
		Transport Trailer	1
		Water Truck	3
Miscellaneous		Water Handling	
Platform Lift (Elect.)	4	Cent. Pump	3
Compressor	2		
Ventilation Equipment		Material Handling	
Develop Fan	2	Cone Crusher	2
Emplace Fan	2	Conveyor	8
Filter Fan	4	Backfill Placer	5
Mobile Scrubber	4	Rad. Stacker	2
Mobile Scrubber	4	Scalping Screen	2
		Surge Bin	4

Table I.18-2. Equipment Acquired during Backfill Low Thermal Case for Modules 1&2b (30 years)

Unit	Number	Unit	Number
Rail Haulage		Surface Mobil	
Flat Car (10 t)	4	End Dump Truck	8
Man Trip (battery)	4	Flatbed Truck	3
Shuttle car	60	Forklift	7
Vacuum Car	3	Grader	2
Locomotive (Diesel)	8	Hydraulic Crane	5
Locomotive (Trolley)	8	Loader	5
Locomotive (Trolley)	16	Transport Trailer	2
		Water Truck	4
Miscellaneous		Water Handling	
Platform Lift (Elect.)	8	Cent. Pump	7
Compressor	6		
Ventilation Equipment		Material Handling	
Develop Fan	5	Cone Crusher	3
Emplace Fan	5	Conveyor	14
Filter Fan	10	Backfill Placer	10
Mobile Scrubber	10	Rad. Stacker	2
Mobile Scrubber	10	Scalping Screen	5
		Surge Bin	4

Note
cfm cubic feet per minute
cy cubic yards
ft feet
gal gallon
gpm gallon per minute
hp horsepower
k thousand
m meter
t short ton

Note:

1) The above equipment items were increased from those estimated for a 12-year operating life to a 30-year life.