Non-Q Design Analysis Cover Sheet

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10. Remarks

The following TBV/TBD are contained in the document: TBV-325, TBV-324, TBV-276, and TBV-333

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21 OCT 98**2. DESIGN ANALYSIS TITLE****Subsurface Construction and Development Analysis****3. DOCUMENT IDENTIFIER (Including Rev. No.)****BCA000000-01717-0200-00014, Rev. 01****4. Description of Revision****00 Initial Issue**

The following major changes were made between Rev. 00 and Rev. 01 of this analysis:

- 1) Section 7.1 describing the subsurface layout was replaced, reference is now made to the Subsurface Layout Configuration Analysis.
- 2) Section 7.2.9 TBM Advance Rates was completely revised.
- 3) Section 7.3.4 Drill-and-Blast Excavation was expanded and now includes a sequence for the excavation of turnouts.
- 4) Section 7.3.7 Performance Confirmation Drift Excavation was added.
- 5) Section 7.7.3 Finishing and Commissioning of Mains, Section 7.7.4 Ramp and Main Finishing and Commissioning, and Section 7.9.12 Emplacement Drift Finishing and Commissioning were added.
- 6) Section 7.14 Contract Structure, Section 7.15 Schedule Risks Versus Construction Scheme, Section 7.16 Impact of Utilities on the Start of Construction, and Section 7.17 Surface Facilities to Support Underground Work were added.
- 7) The Conclusions have been rewritten and expanded.

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1. PURPOSE

The purpose of this analysis is to identify appropriate construction methods and develop a feasible approach for construction and development of the repository subsurface facilities. The objective of this analysis is to support development of the subsurface repository layout for License Application (LA) design.

The scope of the analysis for construction and development of the subsurface Repository facilities covers:

- Excavation methods, including application of knowledge gained from construction of the Exploratory Studies Facility (ESF) .
- Muck removal from excavation headings to the surface. This task will examine ways of preventing interference with other subsurface construction activities.
- The logistics and equipment for the construction and development rail haulage systems.
- Impact of ground support installation on excavation and other construction activities.
- Examination of how drift mapping will be accomplished.
- Men and materials handling.
- Installation and removal of construction utilities and ventilation systems.
- Equipping and finishing of the emplacement drift mains and access ramps to fulfill waste emplacement operational needs.
- Emplacement drift and access mains and ramps commissioning prior to handover for emplacement operations.
- Examination of ways to structure the contracts for construction of the repository.
- Discussion of different construction schemes and how to minimize the schedule risks implicit in those schemes.
- Surface facilities needed for subsurface construction activities.

This analysis was performed as part of the scope of work described in Summary Account number 12472375M1, Subsurface Facilities.

2. QUALITY ASSURANCE

This analysis discusses a viable approach for the construction and development of a subsurface repository. Different methods for constructing the repository are discussed. The foregoing activities were evaluated in accordance with Quality Administrative Procedure QAP-2-0, *Conduct of Activities*, and it was determined that none of the activities will affect Q-List (Ref. 5.4) items or items that are subject to Quality Assurance Requirements and Description (QARD) requirements.

In compliance with NLP-3-18, this analysis is designated not quality affecting and QA Controls do not apply. The analysis was developed and checked in accordance with PRO-TS-004, Design Analysis Not Subject to QARD Requirements.

3. METHOD

This analysis was performed using the analytical approach. In this analysis different alternatives for equipment or construction methods are discussed. This discussion, in most cases, lead to a recommendation for a preferred construction method or piece of equipment. In some cases additional work must be accomplished in other analyses before a final solution can be made.

4. DESIGN INPUTS

4.1 DESIGN PARAMETERS

4.1.1 Unconfined Compressive Strength

The unconfined compressive strength of the Topopah Spring Welded Tuff (TSw2) formation is 155MPa $\pm$ 59MPa (TBV-324). (Ref. 5.12, Section 1.1322)

4.1.2 Tunnel Boring Machine (TBM) Advance Rates

The 7.62m diameter TBM will advance at a rate of 35m/day (TBV-325) and the 5.5m diameter TBM will advance at a rate of 30m/day (TBV-325). Considerable discussion has been made on TBM advance rates. These rates reflect the current thinking of the Design Consulting Board. (Ref. 5.5, pages 34 & 35)

4.1.3 TBM Advance Limits

The 7.62m diameter TBM advanced from Station 24+89 to 62+27 during the period 30 Oct 95 to 16 Aug 96. This is 201 working days. Stations were chosen as they were within the Topopah Spring welded tuff (TSw2) formation.(Attachment IX)

4.1.4 TBM Utilization

The information in Attachment X on TBM utilization is used in Section 7.2.9. The information is from an unpublished Construction Management Office study.

4.1.5 Electrical Transformer Capacity

The current capacity of the electrical transformer (and thus the system) is 10,000 kVA (Ref. 5.31). The transformer is expandable to 12,500 kVA with the addition of cooling fans or 16,000 kVA with the addition of fans, an oil circulating pump, and an additional oil reservoir

(CRWMS M&O verbal communication, J. Calle to N. Kramer, February, 1998).

4.1.6 Subsurface Fire and Subsurface Non-potable Water Systems Capacity

The current capacity of the subsurface fire and subsurface non-potable water systems is 600 gpm (Ref. 5.32, page 6).

4.1.7 Compressed Air System Capacity

The current capacity of the compressed air system is 4,095 cfm at 125 psia (CRWMS M&O. 1997. *Draft: Title III Evaluation Report for the Compressed Air System*. BA0000000-01717-5705-00006, Rev. 00. Las Vegas, Nevada: Author. MOL.19980310.0019, page 17).

4.1.8 Waste Water System Capacity

The current capacity of the waste water system is 665 gpm (Ref. 5.34, page 6).

4.1.9 Anticipated Demand for Electricity

The anticipated demand for electricity is 14,495 kVA in 2005 and 23,150 kVA in 2007 (Ref. 5.13, Pages B-2 & B-4).

4.1.10 Anticipated Demand for Water

The anticipated demand for water is 50 gpm in 2005 and 170 gpm in 2007. These are the maximum values the waste water system will be required to remove (Attachment XI).

4.1.11 Anticipated Demand for Compressed Air

The anticipated demand for compressed air is 4400 cfm in 2005 and 4730 cfm in 2007 (Attachment XI).

4.2 CRITERIA

Reference used: *Subsurface Ventilation System Description Document (Ventilation SDD)*- Ref. 5.9, *Ground Control System Description Document (Ground Control SDD)*- Ref. 5.10, *Subsurface Facility System Description Document (Subsurface Facility SDD)*- Ref. 5.11.

4.2.1 Separate Ventilation Systems

The system shall provide ventilation for the development and emplacement areas by two separate and independent systems. (Ventilation SDD, 1.2.1.7)

4.2.2 Maximum Grades

The system provides access main, ramp, emplacement drift, and turnout grades of 3% or less. (Subsurface Facility SDD 1.2.4.2)

4.2.3 Geologic Mapping

The system shall accommodate geologic mapping of 10 percent (minimum) of emplacement drifts, 100 percent of non-emplacement drift openings, and observation/recording of rock mass conditions during construction. (Ground Control SDD, 1.2.1.3)

4.2.4 OSHA Standard

The system shall comply with the applicable provisions of the Occupational Safety & Health Administration (OSHA). (Subsurface Facility SDD 1.2.6.1)

4.3 ASSUMPTIONS

The basis for CDA (Ref. 5.23) assumptions are included with the CDA.

4.3.1 Rail Transport

Rail transport will be used for subsurface transport of waste packages. This assumption has been withdrawn from the current version of Reference 5.23. However, the reason for its withdrawal is that it has been added to the baseline via drawings (Ref. 5.37 and Ref. 5.38). However, since the drawings are preliminary design, the assumption is still valid. (Ref. 5.23, CDA Key 010W) [Used in Sec. 7.5]

4.3.2 Primary Method of Excavation

The primary method of tunnel excavation will be tunnel boring machine. Other mechanical methods are the secondary method of drift excavation. (Ref. 5.23, CDA DCSS 005) [Used in Sec. 7.2.2]

4.3.3 Drilling & Blasting

Where it is impractical to use mechanical methods (for excavation), drill-and-blast may be used to a limited degree primarily in non-emplacement areas of the repository. (Ref. 5.23, CDA DCSS 005) [Used in Sec. 7.2.2 and 7.3.4]

4.3.4 Use of Rail for Transportation

Rail will be used for transporting underground supplies and personnel to the extent practical. (Ref. 5.23, CDA Key 030) [Used in Sec. 7.4]

4.3.5 Waste Package Placement

Waste packages will be placed center-in-drift, on supports, using gantry emplacement. (Ref. 5.23, CDA Key 066) [Used in Sec. 7.9]

4.3.6 North Ramp

The North Ramp will be used for waste transport. (Ref. 5.23, CDA Key 068) [Used in Sec. 7.5]

4.3.7 Not Used

4.3.8 Thickness of Shaft Lining

The thickness of the shaft lining will be 0.3m (Ref. 5.1, pg 83). This value is existing data and does not need to be confirmed. The lining thickness is a reasonable value and a reasonable value is all that is needed for this analysis. [Used in Section 7.3.5]

4.3.9 Repository Layout

The current subsurface repository layout has been baselined and contains the following features:(Ref. 5.2) [Used in Figure 7-1]

- Long parallel emplacement drifts with 28m center-to-center spacing (TBV-276)
- Only upper emplacement block (no lower emplacement block)
- In-drift waste package emplacement
- Central exhaust main below emplacement drifts
- Two (ventilation) shafts and two ramps
- One upper block perimeter drift
- Ventilation raises between Exhaust Main and Emplacement Drifts

4.3.10 Diesel Equipment Not Allowed

The use of diesel powered equipment will not be allowed in the subsurface repository under normal conditions.(Ref. 5.23, CDA DCSS 040) [Used in Sec. 7.11]

4.3.11 Not Used.

4.3.12 Material Handling Equipment

Repository material handling equipment: (Ref. 5.23, CDA DCSS 010) [Used in Sec. 7.4]

- Supplies: rail transport
- Excavated rock: conveyor belt, or conveyor belt variation when practical

4.3.13 Shaft Excavation Method

Shaft excavation method: Mechanical where practical (Ref. 5.23, CDA DCSS 014) [Used in Sec. 7.2.10 and 7.3.6]

4.3.14 Restriction on Organic Materials

Organic materials (e.g. epoxy resin, timber) are restricted for use as rock support and other postclosure permanent materials in all openings.

Concrete (subject to restrictions on chemical composition of cementitious materials) and steel are allowable preclosure construction materials in all openings. (Ref. 5.23, CDA DCSS 027) [Used in Sec. 7.6]

4.3.15 Access for Underground Construction

Underground construction will not use the North Portal for access once emplacement operations begin. (Ref. 5.23, CDA DCSS 032) [Used in Sec. 7.10.4 & 7.10.5]

4.3.16 Temporary Ground Support

Temporary ground support systems will be covered by a future analysis. For purposes of consistency it is assumed that temporary ground support systems designed for use in the ESF will also be used for repository construction. [Used in Sec. 7.6.1]

4.3.17 Permanent Ground Support - Emplacement & Non-Emplacement Drifts

Precast concrete will be used for ground support in emplacement drifts not requiring geologic mapping. Steel sets and lagging will be used in emplacement drifts requiring geologic mapping. Ground support for non-emplacement drifts will be either cast-in-place concrete or steel sets. (Ref. 5.15, pgs 137-138). [Used in Sec. 7.6]

4.3.18 Permanent Ground Support - Ramps and Mains

Permanent ground support systems for the Ramps and Mains will be evaluated by a future analysis. Since a cast-in-place concrete lining will probably bound the cost and schedule aspects of other systems being considered, it is assumed that a cast-in-place concrete lining will be installed as permanent ground support in all repository ramps, mains, shafts, and turnouts. [Used in Sec. 7.6.3 and 7.7]

4.3.19 Emplacement Drift Length

Emplacement drifts will be approximately 1000-1200m in length. This is determined from Reference 5.1, Table II-3. This information is existing data and does not need to be confirmed as it is used only to establish the order of magnitude for the length of emplacement drifts. [Used in Section 7.2.5]

4.3.20 Emplacement Drift Doors

Doors are required at entrances to emplacement drifts. (Ref. 5.23, CDA DCSS 036) [Used in Sec. 7.9]

4.3.21 Emplacement Drift Turnout Radius

The emplacement drift turnout radius will be 20m (Ref 5.1, pg 88). This information is existing data and does not need to be confirmed as it is only used to defend the selection of railcars for muck removal versus a conveyor belt. The minimum turning radius for a conveyor is 305m (Attachment II, pg II-5). [Used in Section 7.2.5 & 7.3.1]

4.3.22 Length of Bridge Carrier and Bridge Conveyor

Attachment VIII provides the pivot-to-pivot length of both pieces of equipment. The conveyor with extension is 40' and the carrier is 25' ($40'+25'=65'$ or about 20m) (Attachment VIII, pgs VIII-3 & VIII-5). This information is existing data and does not need to be confirmed. The information is provided to show capabilities of conveyor equipment available from manufactures, but not to select the equipment for construction, fabrication, or procurement. [Used in Section 7.2.5]

4.3.23 Early Construction Ventilation

Surface (air) intake through the North Ramp then through the East Main, the South Ramp and exhaust to surface. Temporary exhausting fans with barrier doors will be installed at the South Portal to supply air for the ventilation mode. (Ref. 5.25, Sec. 7.6) [Used in Sec. 7.11.1]

4.3.24 Development Ventilation

Surface (air) intake through the Development Shaft and split into the West Main and Exhaust Main (via South Ramp Extension), then through emplacement drift construction activities and exhaust through East Main, South Ramp and surface. The primary fan location is near the Development Shaft Collar pushing the air into the development subsurface activities. (Ref. 5.25, Sec. 7.7) [Used in Sec. 7.2.3, 7.11.2 and 7.11.3]

4.3.25 Emplacement Ventilation

Surface air will intake through the North Ramp and split into West and East Mains, then through the active or inactive emplacement drifts. The air will downcast through ventilation raises and into the Exhaust Main drift or Exhaust Main auxiliary ducts with optional HEPA filter system. Return air from (both) Exhaust Main and Exhaust Main auxiliary ducts are directed into the Emplacement Shaft and returns to the surface. The primary fan location is near the Emplacement Shaft collar exhausting the air from the subsurface activities. (Ref. 5.25, Sec. 7.8) [Used in Sec. 7.11.3]

4.3.26 Depth of Shafts

The emplacement shaft is 422m deep and the development shaft is 347m deep (Ref. 5.1, pg 80). These values are existing data and do not need to be confirmed as a reasonable value for the shaft depth is all that is needed for this analysis. [Used in Section 7.2.10]

4.3.27 Characteristics of the DOSCO TTM100

Reference 5.16 provides these characteristics for the DOSCO TTM100:

The TTM100 can cut rock with a compressive strength from 136 MPa to 331 MPa. The cutting rate at 156 MPa is listed as 17.5 m³/hour, but because of the variability of the TSw2 formation and to be conservative, a value of 15 m³/hour is used in this analysis. The cutting profile is 5.338m high by 6.676m wide using horizontal anchor cylinders or 4.5m high by 6.676m wide using the vertical anchor cylinders. Water usage is 39 gpm. This information is existing data and does not need to be confirmed. The information is provided to show the capabilities of equipment which is available from manufactures, not to select equipment for construction, fabrication, or procurement. (Ref. 5.16) [Used in Section 7.3.3]

4.3.28 Characteristics of the Atlas Copco ET 150

Attachment I provides these characteristics for the Atlas Copco ET 150:

The cutting profile is 4.8m by 6.1m. This information is existing data and does not need to be confirmed. The information is provided to show the capabilities of equipment which is available from manufactures, but not to select the equipment for construction, fabrication, or procurement. (Attachment I, pg I-1) [Used in Section 7.3.3]

4.3.29 Length of Performance Confirmation Drifts

Performance Confirmation (PC) Drifts will have the following lengths: PC Drift #1= 2000m, PC Drifts #2-5=1200m each, and PC Access Drift = 3550m. The distance between PC Drift #2 and #5 is 2100m. These lengths are existing data and do not have to be confirmed as the values are reasonable ones and reasonable numbers are all that is required for this analysis. Scaled from Reference 5.1, Page 59. [Used in Section 7.3.7, Attachment VII & 4.3.38]

4.3.30 Width of Conveyor Belt

The conveyor belt in the 7.62m diameter drift will be 36" (915mm) and a 24" (610mm) conveyor belt will be used in the PC Drifts (CRWMS M&O e-mail, M. Grigore to N. Kramer, MOL.19980826.0179, April 21, 1998). These dimensions are existing data and do not have to be confirmed. These values are reasonable ones and reasonable numbers are all that is required for this analysis. [Used in Section 7.3.7 & 7.4.1]

4.3.31 Dimensions for TBM Assembly/Disassembly Chambers and Emplacement Drift Turnouts

The TBM assembly/disassembly chambers will be 11.0m by 11.0m (Ref. 5.1, pg 85). The emplacement drift turnouts will be 8.0m wide and 7.0m high (Ref. 5.1, pg 87). These dimensions are existing data and do not have to be confirmed. These values are reasonable ones and reasonable numbers are all that is required for this analysis. [Used in Section 7.3.3]

4.3.32 Miscellaneous Rail Information

The construction rail gauge is 915mm and weighs 42 kg/m (Ref. 5.19). The muck cars will be 6m³ capacity granby type (Attachment IV, pg IV-1). Rolling stock dimensions will be: for railcars- 1.52m wide, 0.72m high, and 4.67m long; for 12-man capacity personnel cars- 1.47m wide, 2.44m high, and 5.64m long (Attachment V, pg V-1). The locomotive will be 915mm gauge, 1150mm wide, 1790mm high, 5640mm long, and its weigh is about 18 metric tons (Attachment III, pg III-1). This information is existing data and does not need to be confirmed. The information is provided to show the capabilities of equipment which is available from manufacturers, but not to select the equipment for construction, fabrication or procurement. [Used in Section 7.4.2 & Attachment VII]

4.3.33 Bendicar Information

The Bendicar shuttle car will be 17.68m long, 2.97m wide, 1.27m high, weigh 41.8 metric tons and have an electric cable reel capacity of 229m (Ref. 5.16). This information is existing data and does not need to be confirmed. The information is provided to show the capabilities of equipment which is available from manufacturers, but not to select the equipment for construction, fabrication or procurement. [Used in Section 7.4.3]

4.3.34 Concrete Lining

The concrete lining which will be placed over the drift invert will be 300mm thick (Ref. 5.1, page 64). The lining thickness is existing data and does not need to be confirmed. It is a reasonable value for lining thickness and a reasonable value is all that is needed for this analysis. [Used in Section 7.5]

4.3.35 Cycle Time for the TBM

A 30 minute cycle time is assumed for the TBM operations in emplacement drifts. This cycle is composed of 20 minutes for cutting and 10 minutes to regrip. These figures were developed from the 30m/day advance rate (4.1.2) for emplacement drifts and knowing that the precast segments will be 1.5 m wide (Ref. 5.22, pg. 16). As shown in Table 1, mining will account for about 40% of daily activities. Therefore:

$$(30\text{m/day}) / [40\% \times 24\text{hr/day}] = 3.1\text{m/hr}$$

$$3.1\text{m/hr} / 1.5 \text{ m} \approx 2 \text{ strokes/hr (or a 30 min cycle time)}$$

the split between cutting and regripping is based on (Ref. 5.30, pg. 160). The reference shows two ratios for the relationship between mining time/regripping and this analysis chose the ratio which was reflective of the initial excavation accomplished in the reference.

[Used in Section 7.5.5 and Attachment VII]

4.3.36 Excavated Dimensions of Openings

Excavated dimensions for the following subsurface openings:

Emplacement Drifts- 5.50m diameter, Access Drifts- 7.00m x 7.00m, Access Mains and Ramps 7.62m diameter, Performance Confirmation Drifts 5.5m diameter or 4.50m x 4.50m, Exhaust Main 7.62m diameter, Ventilation Shaft- 6.70m diameter, Ventilation Raises- 2.00m, and Turnouts 6.00m x 8.00m (TBV-333). These dimensions are the same as those used in Reference 5.1. [Used throughout]

4.3.37 Locomotive Speed

Page III-2 shows that the 18mt locomotive proposed for use in the repository can travel between 12 mph (19.3 kph) and 4.5 mph (7.2 kph). The speeds used in this analysis are less to account for starting, stopping, acceleration, and deceleration of the muck train. This analysis uses average trip speeds of 8 kph for an empty muck train and 5 kph for a full muck train. These values are conservative for this piece of equipment and would allow other types of locomotive to be substituted. This information is existing data and does not need to be confirmed. The information is provided to show the capabilities of equipment which is commercially available, but not to select the equipment for construction, fabrication, or procurement. [Used in Attachment VII]

4.3.38 Tramming Distances

A value of 200m was selected for the tramming distance from the entrance to PC Drift #1. This value was selected because the East Main Dump Station will be located near PC Drift #1 which the drift is being excavated. The exact distance to this dump station is not important for this analysis (although it could affect the total number of trains needed for this operation). A distance of 300m was selected for the return distance as the muck train must travel further on its return trip to the entrance to PC Drift #1. The train may have to switch to another track and then switch back to the single track going into PC Drift #1. In addition, the muck train begins its return trip on the far side of the dump station and so the train must pass the station to return to the PC Drift entrance.

These values are in contrast to the 2100m tramming distance used for the construction of PC Drift #2. The 2100m distance is the distance between the entrance to PC Drift #2 and the dump station at Drift #5 (4.3.29). The reason that the haul and return distances are the same is because the muck train will not switch tracks (as there is only one track in the PC Access Drift). The muck train will begin its return journey on the far side of the dump point but this short distance will not greatly affect the time the train takes to travel the 2100m return distance. These values are existing data and do not need to be confirmed. These values are provided to estimate the number of trains needed in a typical haulage situation but not to select the equipment for construction, fabrication, or procurement. [Used in Attachment VII]

4.3.39 Granby Style Muck Cars Dump Time

The time to dump one granby style muck car is 45 seconds (fax, S. Gorzalczynski to M. Grigore, MOL.19980826.0130), Feb. 20, 1998). This analysis will use 0.8 minutes (48 seconds) to dump a car to be conservative. This time is existing data and does not need to be confirmed. The time is used to estimate the number of trains needed in a typical haulage situation but not to select the equipment for construction, fabrication, or procurement. [Used in Attachment VII]

4.4 CODES AND STANDARDS

4.4.1 Code of Federal Regulations

29 CFR Part 1910, Occupational Safety and Health Standards, Revised as of 7/1/95. 240288.

29 CFR Part 1926, Safety and Health Regulations for Construction, Revised as of 7/1/95. 240289.

30 CFR Part 57, Safety and Health Standards - Underground Metal and Nonmetal Mines, Revised as of 7/1/95. 240290.

5. REFERENCES

- 5.1** Gorrell, C.R. 1997. *Repository Subsurface Layout Configuration Analysis*. BCA000000-01717-0200-00008, Rev. 00. Las Vegas, Nevada: CRWMS M&O. MOL.19971201.0879.
- 5.2** CRWMS M&O. 1997. *Subsurface Repository VA Design Layout Plan*. BCAA000000-01717-2700-81024, Rev. 00. Las Vegas, Nevada: Author. MOL.19980408.0609.
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** Engineering Change Request (ECR) E96-0057 written against this drawing does not affect the information used in this analysis. MOL.19960809.0036.

6. USE OF COMPUTER SOFTWARE

Lotus 1-2-3 R5 spreadsheets were used to summarize some data in the Attachments.

7. DESIGN ANALYSIS

7.0 INTRODUCTION

This section discusses activities for constructing the repository and includes excavation methods, ground support, equipment and material handling. Alternative methods and equipment are identified and the rationale for selection is provided. Equipment required to support the construction effort is described and equipment lists developed for major items. Utility systems including ventilation are described. Construction phases are developed to show the sequence of major activities. Particular attention is paid to potential interference between activities.

7.1 SUBSURFACE REPOSITORY CONFIGURATION

The repository configuration is covered in detail in the repository Subsurface Layout Configuration Analysis (Ref. 5.1) and it will not be reiterated in this analysis. Figure 7-1 shows the general layout of the repository.

7.2 ALTERNATIVE CONSTRUCTION METHOD EVALUATION

Alternative construction methods or equipment were identified and evaluated, including methods for excavating the North Ramp Extension, approaches for excavating emplacement drifts and shafts, emplacement drift haulage systems, haulage equipment, and underground concrete delivery system. Alternative Ground Support Systems and Ventilation Systems were not evaluated, because these systems are discussed in other analyses.

7.2.1 Excavation Methods - 7.62 m Main Drifts

The Exploratory Study Facilities (ESF) North Ramp, Main Drift and South Ramp were excavated at 7.62 m diameter by TBM (Ref. 5.6, page 22). Since these drifts will be integrated into the repository, the repository Mains will be excavated to the same 7.62 m (TBV-333) (4.3.36) diameter, and equipment for repository activities will be designed to fit within this opening. The repository main drifts will be excavated by a 7.62 m TBM (Ref. 5.1, pg 51) using one TBM (Ref. 5.3, Sheet A). However, two TBMs could be used and this analysis will discuss that possibility.

NOTES : (TBV-276)

1. SPACING OF EMPLACEMENT DRIFTS = 28
2. NUMBER OF EMPLACEMENT DRIFTS = 105
 NUMBER OF CONTINGENCY DRIFTS = 15

ALL DIMENSIONS ARE SHOWN IN METERS
 UNLESS OTHERWISE NOTED

THIS FIGURE FROM REFERENCE 5.1, PAGE 33 IS BASED ON
 EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY. (4.3.9)

FIGURE 7-1
 SUBSURFACE REPOSITORY LAYOUT
 FOR VA DESIGN

7.2.2 Excavation Method - North Ramp Extension

All of the main drifts, except the North Ramp Extension, are within the repository emplacement area and will be excavated by mechanical methods (4.3.2), mostly by TBM (4.3.2). The North Ramp Extension is located in a non-emplacement area and can be excavated by drill-and-blast methods (4.3.3). In an effort to shorten the schedule for 7.62 m TBM main drift excavation, alternative methods for excavating the North Ramp Extension including drill-and-blast and Roadheader were evaluated.

The North Ramp Extension lies parallel to the East Main North Extension and will connect the North Ramp with the North Main. Completion time is flexible because the drift is not required until waste emplacement operations are ready to begin. The North Ramp Extension will be 7.62 m by 7.62 m in a horseshoe (if done by a roadheader) or 7.62 m (TBV-333) (4.3.36) circular cross section (if done by other excavation methods) and 1491 m long (Ref. 5.1, pg 62) including two curves. The alternative excavation evaluation is presented below:

7.2.2.1 Roadheader

The size of the North Ramp Extension exceeds the drift profile excavation capabilities of the DOSCO Roadheader currently available. The roadheader would require four passes to excavate an opening of the specified size (7.3.3.3). Four passes will adversely impact roadheader advance rates and thus result in higher costs than if a TBM were used. Dust will be generated by the roadheader and this dust will be difficult to control.

7.2.2.2 Drill-and-Blast

Drill-and-blast excavation is an available method when mechanical excavation is impractical and the excavation is located in a non-emplacement area of the repository (4.3.3). Drill-and-blast is a standard method that could be used for excavating the North Ramp Extension, but for this particular application some potential problems may exist.

Drill-and-blast excavation can produce large amounts of airborne dust during blasting and mucking. The blast concussion can also damage ventilation control devices (e.g. brattices or ducting). Fumes will also be generated by the explosion. Blasting will also produce chunks of rock in the muck pile that are too large for the conveyor system to handle. However, a railcar could be parked near the excavation to handle oversize rocks which do not fit on the conveyor.

7.2.2.3 Alternative Excavation Evaluation

Neither the Roadheader nor drill-and-blast excavation appears to be an acceptable alternative to the TBM for excavating the North Ramp Extension. Both the Roadheader and drill-and-blast excavation methods will generate large quantities of dust that will be more difficult to confine and control than dust that is generated by the TBM. In addition, roadheader costs should be more than a TBM because of the length of time required to excavate the drift using multiple passes.

7.2.3 Excavation - Emplacement Drifts

Under normal conditions a single TBM (7.3.2) advancing at an average rate of 28m/day can meet the emplacement drift completion schedule (Ref. 5.3, pg 31 and Sheet AA). However, this analysis will use 30m/day (TBV-325)(4.1.2). The Performance Confirmation (P.C.) Drifts (7.3.7) must be available for service before or at the same time as the emplacement drifts (in order to perform their function of monitoring the emplacement drifts), therefore, another TBM is required for P.C. drift construction. The P.C. drift footage is considerably less than emplacement drift footage, so the P.C. drift TBM could be available to provide part time support for emplacement drift excavation, if required. Two alternatives are considered: 1) one 5.5m diameter TBM to construct emplacement drifts and one 5.5m diameter for PC drifts plus emplacement drifts and 2) two 5.5m diameter TBMs to excavate emplacement drifts plus one 5.5m diameter TBM for P.C. drifts, and will represent an upper bounding case. Two emplacement drift TBMs may be required by unforeseen circumstances or a more aggressive waste delivery schedule. The following evaluation describes the alternatives considered and the preferred operating method is recommended.

The TBM(s) will be assembled and launched to excavate the emplacement drift. After drift excavation is completed, the TBM will be recovered for relocation to the next emplacement drift. Several alternative methods for launching and recovering the TBM were evaluated. Alternatives that required the excavation of large assembly/disassembly chambers for gantry cranes or smooth flat floor surfaces for special air pallets or support rollers for moving the TBM were rejected as too time consuming and/or expensive. The method chosen was partial disassembly of the TBM within the far turnout, backing the TBM through the drift to the near turnout, followed by reassembly and launch in the next turnout in the construction sequence. The TBMs will excavate alternate drifts or alternate blocks of three or four drifts. Two alternative approaches of this method were considered - two TBMs excavating in the same direction or two TBMs excavating in opposite directions.

Same Direction - Two TBMs would excavate emplacement drifts commencing from the same main and progress through the emplacement block to breakthrough in the opposite main. The East Main to West Main alternative was chosen because the overall haul is shorter between the emplacement drifts and dump station and between the dump station and the surface. The trailing gear will be

removed and parked in an open drift and the TBM partially disassembled (7.3.2). The TBM will be backed through its respective emplacement drift to the East Main and relocated to another turnout. The muck will be transported to surface by a conveyor system that extends from the South Portal to the East Main. A rail system with side dump cars will be used to transport muck from each TBM to the conveyor system (Muck haulage alternatives are discussed in paragraph 7.2.5). This description also applies to the case of one TBM used to excavate emplacement drifts.

Opposite Directions - Two TBMs will concurrently excavate in opposite directions in parallel drifts from their respective launch main toward the opposite East or West Main. After breakthrough into the main the trailing gear will be removed and parked in an open drift and the TBM partially disassembled (7.3.2). The TBMs will be backed through their respective drifts to the near turnout and relocated to another turnout. The muck will be transported to surface by a conveyor system that extends from the South Portal to the East Main. A rail system with side dump cars will be used to transport muck from each TBM to the conveyor system. Muck from the TBM launched from the West Main will be hauled by railcars through a completed emplacement drift to the conveyor dump station in the East Main. This rail traffic will introduce dust into the fresh air stream that flows from the West Main through the emplacement drifts to the East Main (4.3.24). Also, exhaust air from the West Main emplacement drift will have to be captured in a duct or filtered to prevent contamination of the fresh air stream. (These would not be required in the same direction case starting at the East Main).

Although each alternative has advantages and disadvantages the deciding factors were ventilation and haulage distance. The two TBM's excavating in the same direction from the East Main to the West Main is the preferred approach because the haul distance is shorter, ventilation is better as less dust is introduced into the fresh air stream.

7.2.4 Excavation Muck Haulage (7.62 m Drifts) (TBV-333) (4.3.36)

Excavation muck will be produced by one or two TBMs. Two methods of hauling muck from the TBM to surface were considered - rail haulage and conveyor haulage. Based on the following comparison, the conveyor system was selected for muck haulage. An analysis should be performed to more fully develop the rail versus conveyor haulage alternatives, including a cost comparison study.

7.2.4.1 Rail Haulage

Rail haulage trains would transport muck from the TBM up the South Ramp to surface and return using the same portal. As haulage distances increase (e.g. during the TBMs Main Drift perimeter drive), additional haulage units would be added leading to increased rail traffic. Rail traffic through

the South Ramp is also likely to generate airborne dust that would be difficult to control. Rail haulage would also require more personnel than conveyor haulage.

7.2.4.2 Conveyor Haulage

The conveyor system will receive muck directly from the TBM and convey the muck up the South Ramp to surface. The conveyor system will be extended periodically to stay abreast of TBM advance, but distance increases between the TBM and surface will cause no other haulage impacts. The conveyor may generate some airborne dust, but it could be controlled by water sprays, dust hoods, and scrubbers.

7.2.5 Excavation Muck Haulage (5.5 m Drifts) (TBV-333) (4.3.36)

The emplacement drifts will be 5.5 m in diameter (TBV-333) (4.3.36) and approximately 1000-1200 m in length (4.3.19). A TBM will excavate the emplacement drifts from the East Main to the West Main. Three alternative methods, conveyors, rail haulage and shuttle trains were evaluated for providing muck haulage support to the TBM. The rail haulage alternative was selected.

7.2.5.1 Conveyor Haulage

The main haulage conveyor (7.4.1) (Flight No. 1A) will be located in the East Main along the right (east) rib (Ref. 5.1, pg 68). A feeder conveyor will be installed in the emplacement drift to provide muck haulage support to the 5.5 m TBM. The emplacement drift conveyor will cross the East Main and transfer onto conveyor flight 1A. A portion of the East Main crown may need to be excavated to provide clearance between the conveyor, vent ducts and rail traffic. The emplacement conveyor drive and belt storage unit will be located in the emplacement drift turnout. There is insufficient space between the track and the rib for the conveyor drive and belt storage unit, thus the turnout width will be increased. Conveyor intermediate structure will be continuously added as the TBM advances, and belting will be periodically added to the belt storage unit.

After completion of the emplacement drift all of the conveyor equipment must be removed before the TBM trailing gear can be backed up through the emplacement drift. The duration of the conveyor removal task would increase the time required to move the TBM and setup for the next drift.

Because of the need for additional excavation in the turnout and East Main and delays in relocating the TBM, this alternative is not recommended.

7.2.5.2 Rail Haulage

In this alternative the 5.5m diameter TBM would be supported by rail haulage. Trains will haul supplies, including invert segments, ground support, rail, and pipe to the TBM, and muck from the TBM to a conveyor dump station in the East Main for transfer onto the main conveyor. Supply and muck trains will operate on the construction track installed for the TBM trailing gear. Rail haulage trains will include a locomotive, supply cars, and side dump (Granby type) muck cars. Granby style railcars were chosen because the dump station can fit within the 7.62 m (TBV-333)(4.3.36) opening (bottom dump cars would require additional excavation).

To effectively handle the excavated muck and supplies at least two trains will be required for a single emplacement drift TBM. The TBM requires empty muck cars in order to excavate and in this case one train will unload in the main drift while the other is filled at the TBM. The empty train will then wait in the main drift until the full train exits the emplacement drift and heads for the dump station. An additional muck train to increase TBM productivity would require a movable track switching system, generally referred to as a California Switch, immediately behind the TBM. The California Switch allows trains to pass in the tunnel close to the TBM and increases railcar muck handling capacity in long tunnels where long delays would otherwise result in waiting for an empty muck train to return to the TBM. This switch should be used when the TBM must wait for muck cars, that is, experiences long delays.

Supply cars entering the emplacement drift with the empty muck cars will be pushed ahead of the muck cars and unloaded at the TBM and the empty supply cars will be taken out with the full muck train. The railcars will be selected so as to travel without impediment along the trailing gear deck track. The number of muck cars needed will depend on the TBM advance per stroke, drift diameter, and the capacity the muck cars, this is discussed further in Section 7.2.9. Railcar mucking with side dump (Granby Type) cars combined with the materials supply cars provides a proven method for muck removal and servicing the TBM. The muck trains can negotiate the 20 m (4.3.21) turnout radius and do not require additional excavation at the turnouts to operate as would a conveyor storage magazine. For these reasons muck removal by side dump (Granby Type) cars is recommended.

7.2.5.3 Shuttle Train

The shuttle train alternative would also use the construction rail system to haul the muck to the East Main dump station. The shuttle train is comprised of several rail mounted shuttle cars that are coupled together and drawn by a locomotive. Each shuttle car is equipped with a chain conveyor in its bed to provide self loading/unloading capability, and the discharge end of each car fits into the loading end of the car behind. Thus TBM muck will be transferred from car to car in succession

until the train is filled. Because shuttle train haulage will utilize the construction rail system, there will be no added capital cost for track. The shuttle cars are more expensive to purchase than the Granby cars and their mechanical complexity leads to higher maintenance costs. This alternative is not recommended.

7.2.6 Secondary Excavation Muck Haulage

Secondary excavation (7.3.3) will be performed by roadheaders and will include turnouts, assembly/disassembly chambers, TBM launch drifts, and shaft bottom access drifts. Conveyors (7.4.1) will be used to transport muck from underground to surface. The muck will be loaded onto the conveyor system by dump stations (7.4.1.2) that will receive the muck from side dump railcars (7.2.5.2, 7.4.2.2). This section will evaluate alternative methods for handling muck from secondary excavation. The alternative systems will be required to transport the muck from the roadheader to the nearest rail point and discharge the muck into a railcar. Three methods, Load-Haul-Dump units (LHDs), continuous haulage, and shuttlecars were identified and are evaluated below. Shuttlecars were selected as the best overall alternative .

7.2.6.1 LHD

The LHD will be a rubber tired, electrically powered unit (diesel not considered - 4.3.10) equipped with a large muck bucket on the front end. The LHD bucket will be loaded directly by the roadheader muck conveyor or the LHD will load the bucket from a pile on the floor and tram the muck to the rail muck cars. The muck bucket will be raised over the side of the railcar and dumped. The LHD requires considerable headroom for dumping; trolley lines and ventilation ducting will limit overhead clearance. A trailing cable will supply power to the LHD. The LHD is mechanically more complex than a shuttlecar and on an equivalent capacity basis more expensive to purchase. The mechanical complexity leads to higher maintenance costs. Because of higher purchase and operating costs and headroom requirements, the LHD is not recommended.

7.2.6.2 Continuous Haulage Equipment

Electrically powered, continuous haulage equipment similar to that used in coal mining will trail the roadheader and provide muck removal, on demand. Bridge carrier and bridge conveyor units could be added when needed and thus this system is very flexible. This system would be more expensive than either shuttlecars or LHDs. The number of transfer points along the conveyor would be higher and thus the possibility of dust generation would be more. Manufacturers literature (Attachment VIII) indicates that the bridge carrier and bridge conveyor combination would be about 20m long (4.3.22). This would require many units (and operators) when excavating shaft access or TBM assembly/disassembly drifts as these drifts are relatively long compared to the carrier/conveyor

combination. Due to the number of units required and possibility of dust generation the continuous haulage equipment is not recommended. However, this equipment could be acceptable if it is only used to excavate emplacement drift turnouts.

7.2.6.3 Shuttlecars

The shuttlecar will be a rubber tired, electrically powered unit (diesel and battery were not considered for reasons discussed in 7.2.7) equipped with a carrying hopper and loading/discharge mechanism. The shuttle car(s) will be loaded by the roadheader muck conveyor and will tram the muck to the rail muck cars. The shuttlecars will be equipped with an elevating discharge section that can extend over the side of the rail muck car. A trailing cable will supply power to the shuttlecar. The shuttlecars will provide intermittent muck haulage as only one shuttlecar will be able to fit into a roadheader excavation at a time. This may introduce unacceptable delays in the excavation cycle time for the roadheader. However, the shuttlecar can be sized to accept all material mined by the roadheader without repositioning the roadheader. The shuttlecar will then dump its load of muck while the roadheader moves and repositions itself. Space limitations would prevent having the roadheader, shuttlecar, rail muck car and TBM operations occurring in the same main at the same time. That is, only roadheader excavation or TBM operations could occur at any one time. If the roadheader excavates a short starter drift for itself and the shuttlecar, this should provide sufficient space that the roadheader and TBM support operations could occur concurrently in the same main.

Shuttlecars are recommended for most secondary excavation applications. Continuous haulage can be used in turnout excavation.

7.2.7 Rail Locomotives

Haulage tasks during repository construction will include: hauling supplies, materials, personnel and equipment between surface and underground; and hauling muck from the emplacement drifts and roadheader excavations to the conveyor dump stations. Some of the hauls will be through large 7.62m (TBV-333)(4.3.36) openings and other hauls will be through smaller 5.5m (TBV-333)(4.3.36) diameter openings. The hauls between surface and underground are relatively long with steep grades (steep for locomotives)(4.2.2), while the hauls within the repository horizon are relatively short with flat grades. Long hauls on steep upgrades are heavy power consumers, while short hauls on flat grades are moderate power consumers. The three power systems commonly used in underground rail locomotives - electric trolley, battery and diesel are discussed below:

7.2.7.1 Electric Trolley

The locomotive is powered by electric drive motors. The electrical energy is delivered to the

locomotive through a pickup arm that contacts a continuous conductor (trolley wire) that is installed along the track. In underground applications the conductor is usually installed above the center of the tracks in a shielded envelope. Advantages of this system include - (1) little additional ventilation is required for the electric motors, (2) adequate power is available for heavy duty haulage (3) units require no batteries or fuel tanks. Disadvantages include - (1) locomotives are restricted to locations with a trolley wire and grounding system.

7.2.7.2 Battery

The locomotive will be powered by electric drive motors. The electrical energy will be supplied by lead-acid storage batteries that are carried on-board. During usage the stored energy becomes depleted and the batteries must be replaced with a freshly charged set. Advantages of this system include - (1) little additional ventilation is required for the electric motors, (2) mobility not restricted by trolley wire. Disadvantages include - (1) heavy hauling rapidly consumes stored energy, (2) extra battery sets and charging stations are required, (3) batteries require a large space on the locomotive.

7.2.7.3 Combination Trolley/Battery

The locomotive will be powered by electric motors. The electrical energy will be supplied by either overhead trolley wire or lead-acid storage batteries. The combination locomotive offers several advantages for performing the varied haulage tasks that include - (1) little additional ventilation is required for the electric motors, (2) adequate power for long and/or steep grades, (3) mobility. The combination locomotive can use the trolley operating mode for long hauls in the Mains, and the battery mode for hauling from the emplacement drifts. This unit is the preferred alternative for development side operations.

The electric trolley is the preferred alternative for emplacement side operations because the rail system, once established, will not change.

7.2.7.4 Diesel

The locomotive will be powered by a diesel engine. Capacity of the on-board fuel tank will be adequate for a complete operating shift. Advantages of this system include - (1) adequate power for heavy duty haulage, (2) good mobility. Disadvantages include - (1) requires large quantities of ventilation, (2) fuel is combustible - a fire hazard. The introduction of diesel combustion products into the underground environment may be unacceptable as a waste isolation issue and diesel has been banned (4.3.10) from the repository in most cases. This alternative also imposes additional ventilation requirements and introduces a fire hazard - not recommended.

7.2.8 Concrete Delivery System

Large quantities of concrete will be placed underground to provide permanent ground support to large diameter excavated openings. The concrete will be batched at a plant and transported to the underground emplacement location. Two alternative methods for transporting the concrete from the batch plant to the underground construction site were evaluated. These were: overland transportation to a surface borehole or shaft and transfer to the underground by slickline; or loading into rail mixer cars for haulage by locomotive. Loading in rail mixer cars was selected as the best alternative.

7.2.8.1 Surface to Underground by Slickline

Concrete will be loaded into transit mixer trucks at a surface batch plant and transported overland to a slickline located in a borehole or in the Development and/or Emplacement Shaft. The concrete will be discharged into a concrete pump and fed into the slickline. At the underground horizon the concrete will discharge into a transit mixer unit for transportation to the construction site.

A slickline borehole to the underground would offer little advantage over using either or both of the shafts. Alternatively several boreholes at various locations would reduce underground haulage distances, but the added cost of the surface to underground borehole pathways created is unacceptable. The borehole alternative will also require the construction of access roads in rugged terrain. Because of the added costs and waste isolation concerns the borehole/slickline alternative is not recommended.

Slickline(s) could also be installed in either or both of the shafts for transferring concrete from surface to underground. Surface access roads to the shafts will be built during shaft construction and available for hauling concrete from the batch plant. This method will require mixer trucks and drivers for both surface and underground. A remixing station will be required at the shaft bottom. Close coordination of the surface and underground drivers will be required to avoid delays at either location. After usage the slickline will need to be cleaned by flushing with water. The introduction of additional water into the underground could be a problem. Because of the added surface haulage cost, potential coordination and water problems this alternative is not recommended.

7.2.8.2 Concrete Transportation by Rail Mixer Car

Concrete could be loaded into rail mixer cars at a surface batch plant and transported underground by locomotive. The locomotive operator can handle several mixer cars in the train. There will be no rehandling required between the batch plant and underground. This method offers lower labor costs, lower equipment costs and introduces little water underground. The concrete will need to be retarded to allow sufficient time for transportation and placement. As the retarders are usually

organic, this may introduce unwanted organic compounds into the repository. The surface plant can supply concrete for both the precast segment yard and underground operations.

A batch plant could also be placed on railcars and located underground near the point of concrete placement. This scheme will not require retarders as travel times will be greatly reduced. The close proximity of the batch plant to the placement activities reduces the risk of problems associated with the transportation system. Location of the batch plant underground will block off a section of the underground rail line and increase congestion around the area of the plant. The batch plant will create dust and introduce water into the repository making it a less attractive choice than a surface location.

7.2.9 TBM Advance Rates

Rates of advance for the 7.62m TBM excavating main drifts and the 5.5m TBM excavating emplacement drifts are 35m/day and 30m/day, respectively (TBV-325)(4.1.2). These rates are based on the industry experience rates in Reference 5.5, pages 34 & 35 and supported by historical information as discussed below.

7.2.9.1 Perimeter and Exhaust Mains - 7.62m Diameter TBM

Attachment IX is a listing of 7.62 m diameter TBM daily advance rates from Station 24+89m to Station 62+27m. The TBM excavated in this area from 30 Oct 95 to 16 Aug 96 and was the portion of the Exploratory Studies Facility (ESF) tunnel in which the TSw2 formation is located. The majority of the underground repository will be located in this formation and thus an examination of this data is prudent. The overall TBM advance rate for this section of the tunnel was:

$$(6228 - 2487) / 201 \text{ working days (4.1.3)} = 18.6 \text{ m/day}$$

This figure includes all delays for maintenance, breakdowns and ground support.

Attachment XI (4.1.4) is a listing of the TBM utilization for the period of time mentioned above. The attachment indicates the following percentages for actual utilization of the TBM as shown in Table 1:

Table 1
7.62 m Diameter TBM Utilization

Description	Percent of Time Actual (4.1.4)	Percent of Time Revised
Mining	19.86	40.4
Regrip	7.04	7.0
Shift Change	7.40	1.0
Daily Maintenance	2.53	2.5
Scheduled Maintenance	15.22	15.2
Unscheduled Maintenance	9.33	9.3
Unscheduled Maintenance Non-TBM	3.27	3.3
Conveyor Work	4.30	4.3
Ground Support	19.20	5.0
Engineering Laser	1.37	1.4
Other	5.24	5.4
Booster Drive	0.11	0.1
Cutter Change	2.74	2.7
Scientists	0.03	0.0
Lunch	2.36	2.4
Total	100.00	100.00

Industry experience suggests that the average TBM advance rate experienced by the ESF could be improved to 35 m/day (TBV-325) (4.1.2). This change could be accomplished by revising the ground support method and by requiring all shift changes be accomplished at the face. These changes could produce a new TBM utilization as shown in the "Revised" column of Table 1. This could produce a new advance rate of:

$$(40.4\%/19.86\%) * 18.6 \text{ m/day} = \underline{37.8} \text{ m/day advance rate}$$

This is slightly higher than the industry experience rate. The remainder of this analysis will use an

average advance rate of 35 m/day (TBV-325) (4.1.2) for the 7.62 m diameter TBM.

7.2.9.2. Emplacement Drifts - 5.5m Diameter TBM

A 5.5m diameter TBM was not used during the ESF and consequently does not have any data which can be analyzed in a fashion similar to the 7.62m diameter machine. A previous analysis (Ref. 5.3, Sheet AA) indicated an advance rate of 28 m/day for this smaller TBM. This analysis will use 30 m/day (TBV-325) (4.1.2).

7.2.10 Shaft Excavation

Repository shafts include an Emplacement Shaft which is 6.7m in diameter (4.3.36) and 422 m deep (4.3.26), and a Development Shaft which is 6.7m in diameter (4.3.36) and 347 m deep (4.3.26). Typical methods for excavating shafts include conventional sinking (i.e. Drill-and-blast), blind drilling, raise boring, and in-the-hole machine boring or reaming. Selection of a shaft excavation method depends on factors that include: shaft diameter, depth, geologic conditions and whether underground access to the shaft bottom is available.

Mechanical methods will be used for shaft excavation where practical (Assumption 4.3.13). Conventional sinking could be considered if this assumption is relaxed.

Raise boring or in-the-hole reaming require access to the shaft bottom for muck removal. Since access to the shaft bottom will be provided, raise boring and downhole reaming are acceptable construction methods. Blind drilling relies on fluid circulation to remove cuttings from the hole and carry them to surface. Liquids are probably an unacceptable fluid media because of possible contamination of the surrounding rock mass. Air can also be used as a fluid media for chip removal, but it is difficult to maintain adequate air velocities for chip removal across the bottom of the hole and controlling dust on surface can be a problem. Because of these blind drilling concerns, raise boring and downhole reaming were judged the best alternatives.

Raise boring is a two or more stage process that requires drilling a pilot hole from surface to connect with the underground shaft access drift. A reaming bit is then attached to the drill string through the underground access drift, and the pilot hole diameter enlarged by backreaming to surface. To enlarge the hole to the required 6.7 m diameter a 3rd excavation stage will be required. The 3rd stage would be excavated by a down hole vertical boring machine. The size of the hole excavated during the 2nd stage would be large enough to handle muck from the 3rd excavation stage.

7.3 EXCAVATION METHODS DESCRIPTION

Most of the excavation work described in Reference 5.1 is included under Mains, emplacement drifts, P.C. drifts and ventilation drifts (Primary Excavation). Secondary excavation work includes turnouts, TBM assembly/launch chambers, shafts, raises, and alcoves. Section 7.2 evaluated alternatives and selected preferred methods for excavating the several different types of openings. This section describes in more detail the various excavation methods that will be used to construct the subsurface openings.

7.3.1 Primary Excavations - 7.62m Diameter (TBV-333) (4.3.36)

Ramps, Access/Service Mains and the Exhaust Main will be 7.62m in diameter (TBV-333) (4.3.36). The primary excavation work for these mains will be performed by a 7.62m diameter TBM and includes - the South Ramp Extension, West Main, North Main, East Main - North Extension, North Ramp Extension, and the Exhaust Main.

The 7.62m TBM will be required to excavate horizontal curves of a minimum radius of 305 meters (4.3.21) (to facilitate the use of conveyors for muck removal), and excavate tunnel gradients up to $\pm 3\%$ (4.2.2) (the maximum grade for rail haulage). The production rate of the 7.62m TBM will be 35m per day (TBV-325) (4.1.2) @ 3 shifts/day. The material excavated will be mainly in the TSw2 formation which has unconfined compressive strength of 155 MPa $\pm$ 59 MPa (TBV-324) (4.1.1).

The 7.62m TBM will be comprised of a cutterhead, ground support installation system, propulsion systems, ventilation and dust control systems capable of handling siliceous dust, muck handling conveyor, operators console and trailing gear. The trailing gear attaches to the end of the machine and will include utilities and power control systems, and facilities for handling and loading muck cars. When an excavation task is completed the trailing gear will be detached to facilitate moving the machine between underground work places. The assembly and disassembly tasks will be performed in an enlarged chamber that will provide sufficient working space for access to the TBM and for a gantry crane. The specific sequence for TBM assembly and disassembly is explained on Figure 7-2.

The TBM will be designed for installing temporary ground support that includes rockbolts, rolled steel ribs and shotcrete and for placing invert segments. The machine will also be designed for mining through existing circular excavations up to 5.5 meters in diameter (cross block drifts).

7.3.2 Primary Excavations - 5.5m Diameter (TBV-333) (4.3.36)

Emplacement Drifts will be 5.5m in diameter (TBV-333) (4.3.36). The primary excavation work

1.0 PLACE CUTTERHEAD SEGMENTS IN THE FRONT OF THE CHAMBER

2.0 POSITION MAIN BEARING AND SEAL ASSEMBLY BEHIND CUTTERHEAD SEGMENTS

3.0 PLACE VERTICAL FRONT SUPPORT BEHIND MAIN BEARING AND SEAL ASSEMBLY

4.0 ASSEMBLE SIDE SUPPORTS TO VERTICAL FRONT SUPPORT. TEMPORARILY WELD TOGETHER. LIFT ASSEMBLED PIECES. PLACE DOLLY SYSTEM UNDER

5.0 PLACE CUTTERHEAD SUPPORT ON VERTICAL FRONT SUPPORT BEFORE RELEASING THE LOAD FROM CRANE. INSTALL & EXTEND WEDGES BETWEEN SIDE SUPPORT AND CUTTERHEAD SUPPORT

6.0 INSTALL FORWARD SECTION OF MAIN BEAM TO CUTTERHEAD SUPPORT. INSTALL DOLLY TO SUPPORT THE END OF MAIN BEAM

7.0 INSTALL MAIN BEARING AND SEAL ASSEMBLY IN CUTTERHEAD SUPPORT. MAIN DRIVES IN CUTTERHEAD SUPPORT, AND CUTTERHEAD SEGMENTS TO MAIN BEARING AND SEAL ASSEMBLY

8.0 INSTALL THE ROOF AND SIDE SHIELDS SUPPORT

9.0 INSTALL GRIPPERS TO GRIPPER CARRIER, THE THRUST CYLINDERS, AND THE TBM CONVEYOR

10.0 ASSEMBLED 7.62 m DIAMETER TBM IN POSITION ON LAUNCH RAILS

NOTE:
DISASSEMBLY WILL BE IN REVERSE ORDER OF ASSEMBLY

FIGURE 7-2
7.62 m DIA TBM ASSEMBLY
AND DISASSEMBLY DIAGRAM

includes emplacement drifts and performance confirmation drifts . The production rate of the 5.5 m TBM will be 30 m/day (TBV-325) (4.1.2) @ 3 shifts/day. The material excavated will be mainly in the TSw2 formation which has unconfined compressive strength of 155 MPa $\pm$ 59 MPa (TBV-324) (4.1.1).

The 5.5m TBM will be comprised of a cutterhead, ground support installation and propulsion systems, muck handling conveyor, ventilation and dust control systems capable of handling siliceous dust created during excavation, operators console and trailing gear. The trailing gear attaches to the end of the machine and will include utilities, power control systems, a muck loading system, and face ventilation equipment. When an excavation task is completed the trailing gear will be detached to facilitate moving the machine between underground work places. The 5.5m TBM will be designed for partial disassembly for recovery in a turnout located at the end of the emplacement drifts or within a blind heading (see Figure 7-3). As shown on the figure, dollies will transport the TBM within the repository. The figure also shows temporary blocking to raise the TBM to the emplacement drift elevation.

7.3.3 Secondary Excavation

Secondary excavation work in the repository will be mostly performed by mechanical methods (4.3.2). Excavation dust will be controlled by use of dust collectors, water, water with wetting agent, ventilation or other approved methods or devices. Mechanical excavation methods proven during ESF construction were the TBM and Roadheader. The TBM is not suitable for performing short length excavations of variable cross section so the Roadheader is discussed in this section. Secondary excavation work includes: TBM Assembly/Disassembly Chambers, TBM Launch Drifts, Shaft Bottom Access Drifts, Alcoves, Emplacement Drift Turnouts and other miscellaneous excavations.

7.3.3.1 Machine Description

A roadheader machine such as a DOSCO Model TTM 100 (See Reference 5.16) is being considered for performing most secondary excavation work . Unlike earlier generation roadheaders this machine is designed specifically for excavating hard rock such as the TSw2. The machine is crawler mounted, uses a milling type cutting head and includes horizontal and vertical hydraulic thrust cylinders that react against the ribs and/or roof to anchor the machine rigidly in place. The DOSCO roadheader is too large for some applications and an Atlas Copco Model ET 150 with improved cutter head is proposed (Attachment I) for these particular applications.

LAUNCH TURNOUT ELEVATION

LAUNCH TURNOUT SECTION

FIGURE 7-3
 5.5 m DIA TBM
 LAUNCH TURNOUT

7.3.3.2 Cutting Capability

The unconfined compressive strength (UCS) of the TSw2 formation is 155 MPa $\pm$ 59MPa. (4.1.1). The manufacturer's listed capability for the Dosco roadheader ranges from 136 MPa to 331 Mpa (4.3.27). The TSw2 appears to fall in the lower range of the manufacturer's listed UCS capabilities. Information on the ET 150 is not available.

7.3.3.3 Excavation Profile

The manufacturer's stated maximum profile cutting capability for the DOSCO TTM100 is 5.338m high by 6.676m wide using the horizontal anchor cylinders or 4.5m high by 6.676m wide using the vertical anchor cylinders (4.3.27). The actual construction profile requirements range from 7.0m high by 8.0m wide for emplacement drift turnouts for the 5.5m TBM to 11.0m high by 11.0m wide for the 7.62m TBM assembly chamber (4.3.31). To excavate the required profile a multi-pass process will be used. The initial pass will ramp-up to the required roof horizon and will be performed using the vertical anchor cylinders. A second horizontal pass will ramp-up to the roof horizon and using the vertical anchor cylinders will extend the room to the required width. The third and fourth passes will excavate the bench to the required room height without use of the anchor cylinders, which is a less efficient operation. The maximum cutting profile for the ET 150 is 4.8m by 6.1m (4.3.28). Multiple passes will be required by this machine to excavate an opening.

7.3.3.4 Production Rate

The manufacturer's performance data provides guidelines for estimating production rates for rock of comparable UCS to the TSw2 unit. The estimated excavation rate is 15 m³/operating hour (4.3.27). However, this rate has not been verified by operational experience. Although it is risky to base an excavation rate on equipment with limited use, the 15 m³/operating hour (4.3.27) will be adopted until more experience is gained with this type of equipment. No production information is available for the ET 150.

7.3.3.5 Dust Control

Dust generated by the roadheader will be controlled by water sprays, ventilation hood, fan and ducting, and shields that extend to the perimeter of the opening to confine and control dust.

7.3.3.6 Roof Bolting Equipment

Roof bolting equipment will follow the roadheader. The equipment will install the roof bolts as temporary ground support .

7.3.4 Drill-and-Blast Excavation

Drill-and-blast excavation is restricted to secondary excavation applications and to areas that are not part of the repository (4.3.2). Because of these restrictions and concerns, drill-and-blast excavation may be limited to deepening the shaft bottoms on the Development and Emplacement Shafts. Rock drilling dust will be controlled by dust collectors, water, water with wetting agent, ventilation or other approved methods or devices that are effective in controlling dust.

Drilling and blasting have limitations as will be discussed below but they have the large advantages of being flexible and not requiring much space to be accomplished. Table 2 lists the advantages and disadvantages of drilling and blasting.

Table 2
Drill-and-Blast Characteristics

Advantages	Disadvantages
<ul style="list-style-type: none">• Minimal Equipment (compared to other methods)• Flexible• Minimal space requirements• Highly skilled workers not needed• Can be done concurrently with TBM operations	<ul style="list-style-type: none">• Dust generation• Overbreak & thus weaken the rock• Fumes• Fly rock• Incomplete breakage

The disadvantages listed above can be overcome with the proper planning and procedures. For example, the effect of dust and fumes on the workers can be lessened by only shooting at the end of the last shift on Friday. The damage caused by fly rock can be reduced by using blasting mats. Blasting mats are composed of chains and old tires and are placed over the area to be shot after the explosives have been loaded. Overbreak can be reduced by drilling a series of holes around the perimeter of the excavation and presplitting the area to be excavated. Overbreak is caused by the propagation of cracks from explosions. These cracks tend to weaken the rock mass and provide pathways for water intrusion. Presplitting requires that perimeter holes be lightly loaded with explosive and be detonated first in the explosion sequence, causing cracks around the perimeter of the excavation and intercepting cracks created later in the explosion sequence. Incomplete breakage produces rocks too large to be handled by the conveyor system. These rocks could be segregated during mucking operations and hauled to the surface in railcars. Mucking can occur outside of the five regular working days as it will involve few people. This work could occur on the weekends and would allow the crew to repair any damage to the mains or ventilation ducting caused by the explosives.

DAY	SHIFT	ACTIVITY
-----	-------	----------

1	1	DRILL A
	2	DRILL A

2	1	DRILL B
	2	DRILL B

3	1	DRILL C
	2	DRILL C

4	1	DRILL D
	2	DRILL D

5	1	LOAD A + B + BLAST MATS
	2	LOAD C + D + BLAST MATS

SHOOT

6	1	MUCK D. REPAIR MAIN. ROOF BOLTS
	2	MUCK C. REPAIR MAIN. ROOF BOLTS

7	1	MUCK B. REPAIR MAIN. ROOF BOLTS
	2	MUCK A. REPAIR MAIN. ROOF BOLTS

FIGURE 7-4
DRILL-AND-BLAST SEQUENCE
WEEK 1

DAY	SHIFT	ACTIVITY
1	1	DRILL A
	2	DRILL A
2	1	DRILL B
	2	DRILL B
3	1	DRILL C
	2	DRILL C
4	1	DRILL D
	2	DRILL D
5	1	LOAD A + B + BLAST MATS
	2	LOAD C + D + BLAST MATS
SHOOT		
6	1	MUCK D. REPAIR MAIN. ROOF BOLTS
	2	MUCK C. REPAIR MAIN. ROOF BOLTS
7	1	MUCK B. REPAIR MAIN. ROOF BOLTS
	2	MUCK A. REPAIR MAIN. ROOF BOLTS

FIGURE 7-5
DRILL-AND-BLAST SEQUENCE
WEEK 2

DAY	SHIFT	ACTIVITY
-----	-------	----------

1	1	DRILL A
	2	DRILL A

2	1	DRILL B
	2	DRILL B

3	1	DRILL C
	2	DRILL C

4	1	DRILL D
	2	DRILL D

5	1	LOAD A + B + BLAST MATS
	2	LOAD C + D + BLAST MATS

SHOOT

6	1	MUCK D. REPAIR MAIN. ROOF BOLTS
	2	MUCK C. REPAIR MAIN. ROOF BOLTS

7	1	MUCK B. REPAIR MAIN. ROOF BOLTS
	2	MUCK A. REPAIR MAIN. ROOF BOLTS

ADDITIONAL BLASTING MAY BE DONE TO
SMOOTH THE STEP PATTERN SHOWN IN
B, C, & D.

FIGURE 7-6
DRILL-AND-BLAST SEQUENCE
WEEK 3

DAY	SHIFT	ACTIVITY
1	1	DRILL A
	2	DRILL A
2	1	DRILL B
	2	DRILL B
3	1	DRILL C
	2	DRILL C
4	1	DRILL D
	2	DRILL D
5	1	LOAD A + B + BLAST MATS
	2	LOAD C + D + BLAST MATS
SHOOT		
6	1	MUCK D, REPAIR MAIN, ROOF BOLTS
	2	MUCK C, REPAIR MAIN, ROOF BOLTS
7	1	MUCK B, REPAIR MAIN, ROOF BOLTS
	2	MUCK A, REPAIR MAIN, ROOF BOLTS

FIGURE 7-7
DRILL-AND-BLAST SEQUENCE
WEEK 4

DAY	SHIFT	ACTIVITY
-----	-------	----------

1	1	DRILL A
	2	DRILL A

2	1	DRILL B
	2	DRILL B

3	1	DRILL C
	2	DRILL C

4	1	DRILL D
	2	DRILL D

5	1	LOAD A + B + BLAST MATS
	2	LOAD C + D + BLAST MATS

SHOOT

6	1	MUCK D. REPAIR MAIN. ROOF BOLTS
	2	MUCK C. REPAIR MAIN. ROOF BOLTS

7	1	MUCK B. REPAIR MAIN. ROOF BOLTS
	2	MUCK A. REPAIR MAIN. ROOF BOLTS

FIGURE 7-8
DRILL-AND-BLAST SEQUENCE
WEEK 5

The ability to drill-and-blast concurrently with TBM operations provides an opportunity to shorten the overall schedule. If a short starter drift is constructed by drill-and-blast methods, this will provide sufficient space so that the roadheader could accomplish the remaining excavation and not block the main access for TBM operations. Figures 7-4 thru 7-8 show the sequence for this work.

7.3.5 Shaft Excavation

The Emplacement Shaft and the Development Shaft will be 6.1m finished inside diameter. Allowing for a 0.3m thick cast-in-place concrete lining (4.3.8), the excavated shaft(s) diameter will be bored to 6.7m (4.3.36). The shafts will be excavated (7.2.10) by a three stage process: (1) pilot hole drilled down; (2) upward backream and (3) downward ream (See Figure 7-9). All of the drilling will be performed from surface, and the underground shaft access drifts will be used for cuttings removal and installing the reaming bit. A raise drill system will be used for stages 1 and 2 and a vertical boring machine will be used for stage 3. Surface facilities will include a headframe, hoist house, and batch plant. Hoists will include a main hoist, men and material transfer hoist, and a service and emergency hoist. The concrete lining will be placed from the work deck.

7.3.5.1 Raise Drill System

The raise drill's main derrick frame will be mounted on a concrete pad on surface. The drive motor, gear box and drive will be mounted on a crosshead platform that travels up and down the main derrick frame.

The crosshead and the connected drill string will be raised and lowered by hydraulic cylinders. The raise drill will be used to drill a pilot hole from surface to the subsurface shaft access drift. The pilot hole will be continuously surveyed to ensure that required alignment tolerances are maintained. Alignment corrections will be made as required. The drill cuttings will be carried to the surface through the drill string by compressed air.

After the pilot hole has been completed and the pilot bit removed, a reaming bit will be brought underground and attached to the drill string. The raise drill will pullback on the drill string to maintain tension and apply a slow rotation to the reaming bit to cut the rock. The drill cuttings will fall down the shaft to the shaft access drift for removal by shuttle car to a conveyor and then to the surface. After the shaft has been backreamed by raise drill, the raise drill system will be removed.

7.3.5.2 Vertical Boring Machine

The vertical boring machine is essentially a TBM that has been modified to operate in a vertical position. The boring machine will be used to ream the backreamed hole to 6.7m diameter (4.3.36).

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

ALL DIMENSIONS ARE SHOWN IN MILLI-
 METERS UNLESS OTHERWISE NOTED

FIGURE 7-9
 SHAFT EXCAVATION SEQUENCE

The boring machine will be anchored in a vertical position by the gripper pads which bear against the shaft sidewalls. The cutterhead is thrust against the face (shaft bottom) and rotated to cut the rock. The cuttings will be directed to the borehole at the center of the face and fall by gravity to the shaft access drift for removal by shuttlecar to the nearby conveyor belt.

7.3.6 Ventilation Raises - Raise Boring

The Exhaust Main/Emplacement Level ventilation raises will be excavated by a rail-mounted raise drill machine (4.3.13)(See Figure 7-10). The raise drill machine will be transported to the emplacement drift and set-up at the drift mid-point. A vertical pilot hole will be drilled from the Emplacement Drift to the Exhaust Main below. The Exhaust Main will provide lower level access for attaching a reaming bit to the drill string and for mucking. The reaming bit will be pulled back to the Emplacement Drift to enlarge the pilot hole to 2.0m (4.3.36) and the raise will be lined with concrete. A similar sequence will be used to bore the raises between the Performance Confirmation Drifts and the East, West, and Exhaust Mains.

A portable muck chute will transfer cuttings from the raise to a muck car. The portable chute will be mounted on a gantry for movement between raises. The chute can be raised and lowered into position by lifting pistons. A flow regulating gate on the chute will permit muck cars to be changed without muck spillage. The muck will be transported by muck cars to the surface.

7.3.7 Performance Confirmation (PC) Drift Excavation

Figure 7-11 shows the location of the five performance confirmation (PC) drifts. These drifts will be excavated periodically over the course of development as discussed below.

Performance confirmation drift #1 will be excavated during the initial construction period (2005-2009). This 2000m (4.3.29) long drift will be constructed from the North Ramp using a 5.5m diameter TBM with muck removed by a 610mm (4.3.30) extendable belt conveyor. This 610mm conveyor will empty onto a 915mm (4.3.30) belt conveyor in the North Ramp for muck removal to the surface. After the conveyor and TBM have been removed, a roadheader will construct ten PC alcoves at the locations shown in Figure 7-11. Long hole drilling will be performed from these alcoves, and instruments will be inserted to monitor the temperature, rock deformation and/or radiation level around the emplacement drifts. The excavation for alcoves and long hole drilling for instrumentation will be the same for all other PC drifts. Page VII-1 contains an analysis of the number of trains required and muck tramming times.

FIGURE 7-10
 VENTILATION RAISE BORING

THIS FIGURE IS BASED ON DESIGN INFORMATION FROM THIS ANALYSIS

CROSS BLOCK DRIFT IS FROM REFERENCE 5.35. PAGE 10.

FIGURE 7-11
LAYOUT SHOWING PERFORMANCE
CONFIRMATION FACILITIES

The excavation of PC drifts # 2-5 will require the excavation of a long (3550m) (4.3.29) PC access drift. This access drift will be constructed using a TBM with a conveyor for muck haulage. The muck haulage conveyor is 610mm (4.3.30) wide and feeds from a conveyor magazine near the beginning of the access drift. This 610mm wide conveyor dumps onto the 915mm (4.3.30) conveyor in the South Ramp. Excavation of the PC access drift must proceed beyond the entrance to PC drift #2 to allow for the positioning of muck trains during future excavations. A roadheader will excavate turnouts to all PC drifts beginning with PC drift #2 after the TBM has stopped excavating the PC access drift. Muck from the roadheader will be transferred to a shuttle car and will then empty onto the conveyor for removal from the PC turnout. The conveyor will be removed, a section at a time, as the roadheader completes the remaining turnouts. A small roadheader (Attachment I) will be used to excavate the turnouts and alcoves. This roadheader is smaller than the one used for the access main turnouts as the PC drifts are 5.5m diameter (TBV-333)(4.3.36) versus 7.62m diameter (TBV-333) (4.3.36) for the East and West Mains. Even though the PC drift turnouts will not be needed for years, it is prudent to excavate them while the conveyor is present for muck removal in the PC access drift.

The conveyor will be completely removed from the PC access drift to allow access for the raise borer. Muck from the raise borer will empty onto the East Main conveyor belt (See Figure 7-11). The first raise to be excavated will be at PC drift #5. Excavation of the raise at PC drift #5 will facilitate the removal of muck from the TBM operation for PC drifts #2-5. This raise will connect the PC drift level to the conveyor belt in the East Main (Figure 7-12). PC drift raises #2, #3 & #4 will then be excavated after excavation of the raise at PC drift #5. After excavation of the raise for PC drift #2 the TBM will be repositioned to excavate PC drift #2. Both PC drift raises #3 & #4 will be excavated while the TBM is being set up at PC drift #2.

Performance confirmation drifts #s 2-5 will be constructed with a TBM and muck removal by rail haulage. Muck will be transported by a train and be dumped into PC drift raise #5. Muck trains will turn into PC drift #5 via a switch. This raise will be equipped with an unloading ramp to tip the muck cars into the raise. The raise will be equipped with a grizzly to catch oversize muck. At the bottom of the raise a chute with a muck gate will empty onto a vibrating feeder which will feed into a conveyor hopper above the east main conveyor belt. Excavation of PC drifts #s 2-5 will be similar and so only one excavation sequence will be described. Page X-2 is an analysis of the tramming times for muck haulage from PC drift #2 to the dump point at the entrance to PC drift #5. The excavation sequence for PC drift #2 will be as follows (See Figure 7-11):

- Train #1 loads at the TBM and leaves for the dump point when full.
- Train #2, which was sitting at the California switch on the TBMs trailing gear, moves into position to be loaded.

FIGURE 7-12
 PC ACCESS MAIN RAISE
 @ PC DRIFT #5

- As soon as Train #1 clears the entrance to the drift, Train #3 travels down the drift from its waiting place at the entrance to the drift and positions itself on the California switch behind the TBM.
- Train #1 proceeds down the PC access drift to the California switch near PC drift #4 and stops on the switch. Train #1 must wait for Train #4 to complete its dump cycle.
- Train #1 can proceed to the dump after Train #4 passes on its way to the entrance to PC drift #2.
- Train #1 goes to the raise near the entrance to PC drift #5, dumps its cars, and travels back to the California switch near PC drift #4 and waits for Train #2.
- Train #1 can proceed to PC drift #2 after Train #2 passes the California switch.

This sequence will insure that the TBM is not delayed and that the only delays are caused by trains waiting for each other.

Four trains are estimated to be needed for the excavation of PC drift #2. During the excavation of PC drift #s 3-5, the haul distance will be shorter, the number of trains can decrease and an intermediate California switch will not be needed near PC drift #4. Attachment VII has additional information on construction of PC drifts #1 and #2.

7.4 MUCK/MATERIAL HANDLING SYSTEMS

Excavated rock will be transported (from underground to surface) by conveyor belt (4.3.12). Excavated rock will be produced by TBMs, Roadheaders or by drill-and-blast. The rock from the 7.62m TBM will discharge directly onto a conveyor belt for transportation to surface. The rock from the 5.5m TBM will discharge into railcars for haulage to a conveyor dump station. The rock from the Roadheader will discharge into shuttlecars; the shuttlecars will transfer the muck into railcars for haulage to surface or from railcar to a conveyor dump station.

Underground supplies and personnel will be transported by rail (4.3.4, 4.3.12). The rail transportation system (7.5) will extend from surface down the North and South Ramps and into the Mains. Combination trolley/battery locomotives (7.2.7.3) will be used to haul several types of rolling stock for transporting personnel, equipment and supplies between surface and underground. The muck and material handling systems are discussed in the following subsections.

Attachment II presents vendor information on belt conveyors and related installations of the type

considered for this application.

7.4.1 Conveyor Layout

7.4.1.1 Conveyor Layout Using One 7.62m Diameter TBM

Conveyor flight no. 1 (See Figure 7-13) will be an extendible type conveyor with the capability to negotiate curves. The conveyor flight will include 915 mm (4.3.30) wide rubber covered fabric belting, troughing idlers, return idlers, support structure, terminal pulleys, belt storage magazine, belt tensioning unit and drive unit(s). The initial conveyor installation will extend from the surface through the South Portal to the South Ramp TBM assembly chamber. The #1 drive unit and belt storage magazine will be located on surface outside of the South Portal; the intermediate conveyor structure will be located along the lefthand rib of the South Ramp.

Conveyor flight no. 1 will provide muck handling support for TBM excavation of the Mains. Muck will discharge directly from the TBM onto the conveyor. As the TBM advances, belting and intermediate structure, and drive unit(s) will be added as required to extend the conveyor. Conveyor flight no. 1 will ultimately extend through the South Ramp Extension, West, North, and East Main North Extension Mains with an ultimate length of approximately 9700m.

After completion of the main drifts served by conveyor flight no.1, the conveyor will be removed to allow placement of a concrete lining in the South Ramp and the Mains. The conveyor will be reinstalled in a new configuration (1A) after the lining work is completed to support emplacement drift construction (See Figure 7-13). The conveyor will be installed along the right hand rib of the East Main. The drive unit for #1A, the belt storage and takeup units will be located near the south end of the East Main and the tail section and dump station will be located at the north end of the East Main. The conveyor will be shortened periodically to meet construction requirements. The conveyor will handle muck from the emplacement drifts delivered to the dump station by railcar.

Conveyor flight no. 2 (See Figure 7-13) will be an extendible type conveyor with the capability to negotiate curves. The conveyor flight will include 915 (4.3.30) mm wide rubber covered fabric belting, troughing idlers, return idlers, support structure, terminal pulleys, belt storage unit, belt tensioning unit and drive unit(s). The initial conveyor installation will extend from a conveyor transfer terminal located at the intersection of the South Ramp Extension and the Exhaust Main to the back of the TBM excavating the Exhaust Main. The #2 drive unit, the belt storage and takeup unit will be located in the Exhaust Main TBM Assembly chamber. Conveyor flight no. 2 will receive muck from the TBM transfer conveyor and transfer it onto conveyor flight no. 1 for transport to surface. As the TBM advances, belting, intermediate structure, and drive unit(s) will be added as required to extend the conveyor length. Conveyor flight no. 2 handles muck from the 7.62m

TBM. Conveyor flight no. 2 will be disassembled and removed from the repository at the completion of the Exhaust Main. Muck from ventilation raise excavation will be transported to the surface by muck car and will not require a conveyor for its transportation.

LEGEND:

— TBM ASSEMBLY/DISASSEMBLY CHAMBER

**FIGURE 7-13 GENERAL ARRANGEMENT
 CONSTRUCTION CONVEYOR & RAIL SYSTEM
 (ONE TBM)**

7.4.1.2 East Main Dump Station

The East Main Dump Station (See Figure 7-14) will allow railcars to discharge muck from the emplacement drift and other excavations onto conveyor flight no. 1A at a location near the north end of the East Main. The dump station will include a hopper, a chain conveyor, and a raised section of track adjacent to the dump hopper. The raised section will provide additional height to facilitate the discharge of muck from the railcars into the hopper. The locomotive operator will activate the hydraulic dumping system that will raise the side door of the railcars as they pass through and discharge the muck at the correct location. Electronic sensors will restrict the location where the car will dump. A chain conveyor will remove muck from the hopper at a controlled rate. The inclined chain conveyor will be aligned at an angle between the rail and conveyor centerlines in order to elevate the muck to a transfer chute located above the conveyor. A hood over the dump hopper will help control dust.

The East Main dump station will move periodically to ensure that haul distances do not become excessive for muck transportation and to ensure that the station does not become part of the emplacement side.

7.4.1.3 Conveyor Layout Using Two 7.62m Diameter TBMs (Method 1)

This section and the next discuss possible options which could be implemented if a faster repository completion time is desired.

Conveyor flight no. 3 will be similar to conveyor flight no. 1 (see Figure 7-15). It will extend from the surface through the South Portal to the South Ramp TBM assembly chamber. The conveyor will be extended as the South Ramp Extension and the West Main are excavated by the 7.62m diameter TBM #1.

Conveyor flight no. 4 will be similar to conveyor flight no. 1A. It will extend from the surface through the South Portal, along the East Main to the East Main North Extension TBM assembly chamber. The conveyor will be extended as the East Main North Extension, North Main, and the North part of the West Main are excavated by the 7.62m diameter TBM #2. Both TBMs will meet at Cross Block Drift #1 and be disassembled. Unlike conveyor flights 1 and 1A, flights 3 and 4 will exist in the south ramp at the same time.

After TBM #2 reaches Cross Block Drift 1, conveyor flight no. 4 will be partly disassembled. The conveyor flight will extend from the South Portal to the East Main Dump Station. TBM #2 will be moved to the North Ramp Extension assembly chamber. The North Ramp Extension will be excavated by TBM #2 and use railcars which dump at the East Main Dump Station. Turnouts for

DUMP HOPPER AND CHAIN CONVEYOR - PLAN

DUMP HOPPER AND CHAIN CONVEYOR - ELEVATION

LOCOMOTIVE AND MUCK TRAIN - ELEVATION

LOCOMOTIVE AND MUCK TRAIN - TYPICAL SECTION

FIGURE 7-14
 EAST MAIN
 RAILCAR DUMP STATION

LEGEND:

== TBM ASSEMBLY/DISASSEMBLY CHAMBER

FIGURE 7-15 GENERAL ARRANGEMENT
 CONSTRUCTION CONVEYOR & RAIL SYSTEM
 (TWO TBMS - METHOD 1)

the emplacement drifts will be constructed during this period. After sufficient turnouts have been constructed, a 5.5m diameter TBM will begin to excavate the emplacement drifts. Muck from these operations will be dumped in the East Main Dump Station by railcars.

After TBM #1 reaches Cross Block Drift #1, conveyor flight no. 3 will be shortened to the conveyor transfer station at the Exhaust Main. TBM #1 will be disassembled and reassembled in the Exhaust Main assembly station. Figure 15 shows the maximum extent of the conveyor system. This configuration will not all happen at the same time and the figure should only be used for conveyor locations.

Conveyor flight no. 5 will be extended as TBM #2 excavates the Exhaust Main.

7.4.1.4 Conveyor Layout Using Two 7.62m Diameter TBMs (Method 2)

Conveyor flight no. 3 will be similar to conveyor flight no. 1 (see Figure 7-16). It will extend from the surface through the South Portal to the South Ramp TBM assembly chamber. The conveyor will be extended as the South Ramp Extension, West Main, North Main, and North Ramp Extension are excavated by the 7.62m diameter TBM #1.

Conveyor flight no. 4 will be similar to conveyor flight no. 1A. It will extend from the surface through the South Portal, along the East Main to the East Main North Extension TBM assembly chamber. The conveyor will be extended as the East Main North Extension is excavated. The conveyor will follow TBM #2 as it excavates a 180° swing and decreases in elevation to align with the Exhaust Main. TBM #2 will then excavate the Exhaust Main.

The excavations of both TBMs will cross at the junction of the North Ramp Extension and East Main North Extension. This may require that TBM #2 be shut down until TBM #1 has started to excavate the North Ramp Extension. To minimize the shut down, a receiving chamber will be constructed in the North Ramp Extension for TBM #1. The excavation for TBM #1 should lead the excavation for TBM #2.

This excavation scheme changes the configuration of the repository slightly. This scheme will excavate slightly longer mains, but will require a fewer number of TBM assemblies and disassemblies. This scheme will also minimize roadheader excavations. For these reasons this scheme should be considered.

7.4.2 Locomotive Haulage

Rail will be used for transporting underground supplies and personnel to the extent practical (4.3.4)

LEGEND:

== TBM ASSEMBLY/DISASSEMBLY CHAMBER

**FIGURE 7-16 GENERAL ARRANGEMENT
CONSTRUCTION CONVEYOR & RAIL SYSTEM
(TWO TBMS - METHOD 2)**

over the rail transportation system (7.5). This section discusses the equipment (i.e. rolling stock) that will be used to perform this function. Trains will include a 915 mm gauge (4.3.32) trolley/battery powered locomotive and one or more railcars. A locomotive and Granby style railcars that will be used for muck haulage are shown at the dump station in Figure 7-14.

7.4.2.1 Locomotive

The locomotives will be combination units (7.2.4) that can operate in either a trolley or battery mode (trolley mode in the main drifts or battery mode in the emplacement drifts). The locomotives are 1150 mm wide by 1790 mm high by 5640 mm long and will weigh about 18 metric tons (4.3.32). (See Attachment III)

7.4.2.2 Railcars - Muck

Muck railcars will be used to haul muck from the cross block drifts, shafts, raises, and TBM assembly/disassembly chambers; and muck from the Turnouts and Emplacement drifts will be hauled to the East Main dump station. The muck railcar dumping method at the East Main dump station is described in subsection 7.4.1.2. The muck railcars will be Granby style cars with a capacity of 6 m³ (4.3.32). Each car will be supplied with a self contained hydraulic dump mechanism that includes a hydraulic cylinder, accumulator and pump. (See Attachment IV)

7.4.2.3 Railcars - Supplies

The railcars will be double bogie, flatcar models 1.52 m wide by 0.72 m high by 4.67 m long (4.3.32). (See Attachment V)

7.4.2.4 Railcars - Personnel

The railcars will be double bogie, 12-man capacity, 1.47 m wide by 2.44 m high by 5.64 m long (4.3.32). The railcars will be fitted with facing benches on each side of the car, overhead canopy and safety chains at each end. (See Attachment V)

7.4.2.5 Railcars - Open Frame

The open frame railcar will be used to transport long supplies i.e. rail, pipe and tube. The railcars will be double bogie, open frame models and approximately twice as long as the flatcar described in Section 7.4.2.3.

7.4.2.6 Railcars - Concrete Mixer

The concrete mixer railcars will be used to transport concrete from the batch plant to the underground construction site. Several models of mixer are available. The figure in Attachment VI shows a gauge of 750mm. An appropriate gauge will be chosen to fit the repository tracks.

7.4.3 Mobile Muck Hauling Equipment

Two types of mobile muck hauling equipment are proposed for use in the underground repository.

7.4.3.1 Shuttlecars

Shuttlecars will be used to haul muck produced by the roadheader (7.2.5). The shuttlecars, such as the DOSCO Bendicar (Reference 5.16), will be electrically powered, rubber-tired, articulated units that will be comprised of three or more linked modules - a power module at the feed end, one or more cargo modules in the middle and an elevating bed module at the discharge end. Each module will be supported by a single, driven axle. Muck will be conveyed through the shuttlecar by a continuous chain conveyor that travels across the beds of the modules. Each module will have a capacity of 12 m³ or a total of 36 m³ for a three-module shuttlecar. The three-module shuttlecar will be 17.68 m long by 2.97 m wide and 1.27 m high. The empty weight of the unit will be 41.8 metric tons and the electric cable reel capacity will be 229 m (4.3.33).

7.4.3.2 Continuous Haulage Equipment

Continuous haulage equipment (Attachment VIII) may replace shuttlecars in certain instances. The continuous haulage equipment will be tracked and consist of a bridge carrier and bridge conveyor units.

7.4.4 Haulage Interference

The conveyor and rail components of the haulage will be fixed after installation and will thus be difficult to move or to maneuver around. Therefore, it is imperative that their initial placement be well planned so that interference with the TBMs, mobile equipment, concreting operations, and with each other will be minimized. In addition the construction of the underground repository will rely heavily upon one portal (South) for access. This portal will have a conveyor, ventilation ducting as well as numerous locomotives hauling material underground. These restrictions could choke the smooth flow of men and supplies necessary for the efficient construction of the repository. A number of factors will aid in producing a smooth flow of items entering the repository, among them are:

-
- Proper integration of excavation and haulage equipment.
 - A control system which provides the status and location of all major equipment.
 - Work rules which regulate and control the transportation of men and materials. For example, outbound traffic (items leaving the repository) has the right-of-way.
 - A communications system which provides timely information to all key personnel.
 - A repository construction plan which provides spatial and temporal space between activities.

For example, Figure 7-17 provides a suggested layout for the intersection of the South Ramp Extension and the Exhaust Main. It shows an arrangement for facilitating muck removal and haulage. In this figure the Exhaust Main conveyor is lifted over the South Main tracks and dumps into a conveyor for removal to the surface. A hopper with dust cover controls the dust generated during the transfer.

Electronic instrumentation will allow each piece of equipment to be given its own transmitter which will continuously report its position to sensors throughout the repository. Computers will allow all key personnel to be connected through electronic mail both on the surface and at their workplace underground. For example, a detailed daily schedule could be transmitted to all supervisors so that they can properly utilize their crews.

7.5 RAIL SYSTEMS

Underground supplies and personnel will be transported by rail to the extent practical (4.3.4). The North Ramp and rail transportation will be used for subsurface transport of waste packages (4.3.1&4.3.6). Rail systems will support the construction, development and emplacement Phases over the life of the repository. Two separate rail systems will be used - the construction rail system (See Figures 7-14, 7-15 & 7-16) will support repository construction and development, and the emplacement rail system will support repository emplacement operations.

The construction rail system will include mainline track in the South Ramp and branch tracks in the East Main, North Ramp; the Exhaust Main; and the South Ramp Extension, West Main and North Main. The mainline and branch construction tracks will be supported by an invert segment and will include a double track of 42 kg/m rails anchored to steel ties on 915 mm gauge (4.3.32). Double tracks on the construction rail system will allow the muck haulage traffic to be separated from the supply haulage traffic in order to minimize delays. Switches will also allow the two center rails to be used for transporting the 5.5 m diameter TBM. A single track will be installed in the P.C. access drift and drifts to provide construction rail support.

The construction tracks are too light to support the heavy loads (waste package and transporter)

required for repository emplacement operations. Therefore, the construction rail system will be removed and replaced by a much heavier emplacement rail system. A 300 mm (4.3.34) concrete slab will be placed over the construction rail invert segments to form the base for installing the emplacement track. This task will be performed during the development phase in sections that cover the width of an emplacement panel. The emplacement rail system will include mainline track in the North Ramp and branch tracks in the East Main; the Exhaust Main; and the North Ramp Extension, North Main and West Main. A single track of heavy duty rail anchored on a wide gauge will be installed.

THIS FIGURE FROM REFERENCE 5.30, PAGE 43
IS BASED ON EXISTING DATA. AND IS PRESENTED
FOR REFERENCE ONLY.

FIGURE 7-17
CONVEYOR TRANSFER STATION

Figures 7-18 & 7-19 show schematics for rail traffic within the repository. During construction, as shown in Figure 7-18, insufficient drifts will be constructed to allow storage of materials in emplacement drifts. The materials will be stored on one of the tracks in the North Main, East Main North Extension or South Main. These materials will always be stored on railcars to permit their easy movement to the drift being excavated. Periodic cross overs from one rail set to another will allow materials to be segregated and spread out along the tracks. A locomotive will be dedicated to storage and will transport the materials to the drift undergoing excavation.

During development, as shown in Figure 7-19, emplacement drifts will be used for storage of materials. These materials will always be stored on railcars to permit their easy movement to the drift being excavated and to insure that loose materials do not block the previously constructed emplacement drifts.

Locomotives dedicated to storage will stay underground to transfer supplies. Other locomotives will be charged with transporting supplies from the surface to the underground storage areas. To optimize the number of train engines required, the replenishment of supplies could occur on the third or maintenance shift. Determination of the optimum number of locomotives is beyond the scope of this analysis.

Personnel will be transferred underground by using passenger cars similar to those in Attachment V. During shift change several trains will be dedicated to transferring personnel from the surface to the underground work areas. These trains could make periodic stops along the access mains to ensure that workers do not have to walk long distances to their work places. These trains will also pick up the workers coming off shift. During the work shift one train will be dedicated to transferring workers from one location to another underground location and from the underground to the surface. This train or "bus" could operate on a fixed time schedule to make the transfers more systematic.

7.5.1 Construction Rail System - Mainline

The mainline segment of the construction rail system will begin on surface and extend from the South Portal to the horizontal curve near the bottom of the South Ramp. The tracks will branch at the bottom of the South Ramp with the East Main branch turning to the north and the West Main branch continuing down the South Ramp Extension to the west.

7.5.2 Construction Rail System - East Main Branch

The East Main branch of the construction rail system will extend from the end of the mainline track through the East Main and North Ramp to the North Portal on surface. Switches will be installed

FIGURE 7-18
ANALYSIS OF RAIL TRAFFIC
YEAR = 2008

FIGURE 7-19
ANALYSIS OF RAIL TRAFFIC
YEAR = 2015

on the inside set of rails at each emplacement drift turnout after construction of the turnout.

7.5.3 Construction Rail System - West Main Branch

The West Main branch of the construction rail system will extend from the end of the mainline track through the South Ramp Extension, West Main and North Main to the East Main-North Extension intersection with the East Main. The West Main branch will support TBM excavation of the Mains. As the TBM advances through the South, West, North and East Main-North Extension Mains, invert segments and rail will be added to the tracks to stay abreast of the TBM advance. Switches will be installed for branch rail connections at the Exhaust Main and North Ramp Extension drifts and on the inside set of rails at each emplacement entry turnout. After the TBM is relocated from the East Main-North Extension, the West Main branch will be linked to the East Main branch in the East Main to form a loop.

7.5.4 Construction Rail System - Exhaust Main Branch

The Exhaust Main branch of the construction rail system will extend from the West Main branch in the South Ramp Extension through the Exhaust Main to the North Main where it will rejoin the West Main branch track. The Exhaust Main branch will support TBM excavation of the Exhaust Main drift. As the TBM advances through the Exhaust Main, invert segments and rail will be added to the tracks to stay abreast of the TBM advance.

7.5.5 Construction Rail System - Emplacement Drifts

A single track will be installed in each emplacement drift to support TBM excavation and construction. The track will branch from the inside track of the East Main or West Main branch and follow a left-hand horizontal curve radius until it meets the alignment of the emplacement drift. The track will be inclined through the turnout and assembly chamber section to compensate for a rise in elevation. Rail will be added to the emplacement drift rail system as the TBM advances.

Figures 7-20 to 7-22 detail the sequence to remove muck from behind the TBM excavating the emplacement drifts. The sequence is predicated upon a 30 minute cycle time for the TBM (4.3.35). This cycle time is composed of 20 minutes of cutting and 10 minutes for regripping. The TBM trailing gear will be designed to allow installation of a complete ring segment and to fill all eight 6 m³ (4.3.32) muck cars during the 20 minutes of cutting time. During the regripping time the TBM will be surveyed to ensure it is aligned correctly.

Figures 7-20 to 7-22 show the time which has elapsed between the activities. For example, at Step "C" the 20 minute cutting cycle has ended and Train "A" has been moved forward using

FIGURE 7-20
 SEQUENCE OF MUCK REMOVAL - I

FIGURE 7-21
 SEQUENCE OF MUCK REMOVAL - II

FIGURE 7-22
SEQUENCE OF MUCK REMOVAL - III

the car mover. Train "B" is backed into position by its locomotive. At Step "F" the second cutting cycle is nearly complete and the flatcars have been emptied of their precast ring segments. The flat cars are being moved forward with the help of one of the two car movers. Train "C" has arrived with empty muck cars and flatcars loaded with precast segments.

Supplies will be transported to the TBM via flat car. The two flat cars shown in the figures will contain one set of ring segments each. Space limitations will prevent other supplies being carried on these same flat cars and thus the TBM may have to interrupt its cycle to bring these supplies forward. For example, rails will need to be brought forward periodically to insure the TBM and trailing gear can advance. An alternate proposal is to store some of the supplies in the first few trailing gear segments so that they are readily available for use. For example, rail could be stored near the front of the trailing gear for use during the work shifts. These rail and other supplies could be replenished on the maintenance or third shift. Since the TBM excavation work is repetitious the list of supplies needed could be accurately determined. This supply scheme will minimize delays during the shifts devoted to excavation.

7.5.6 Construction Rail System - PC Drifts

PC Drift No. 1 - A single track will be installed in PC drift No. 1 to support TBM excavation and construction. The track will branch from the East Main branch in the North Ramp and follow the drift alignment.

PC Access Drift - A single track will be installed in the PC access drift to support TBM excavation and construction of PC Drift No's 2, 3, 4, and 5.

7.5.7 Emplacement Rail System - Mainline

The mainline segment of the emplacement rail system will begin on surface and extend from the North Portal to the horizontal curve near the bottom of the North Ramp. The tracks will branch at the North Ramp Extension turnout with the East Main branch turning to the south and the West Main branch continuing to the west along the North Ramp Extension.

7.5.8 Emplacement Rail System - East Main Branch

The East Main branch of the emplacement rail system will extend from the end of the mainline track through the curve to the East Main and end at the isolation barrier. From this point the track will extend to the south in the East Main and to the north in the East Main-North Extension. During the initial phases of emplacement operations the emplacement panels along the East Main-North Extension will be accessed through the North and West Main branches to allow the East Main

branch to remain accessible for construction. This will be accomplished by routing the emplacement traffic through the North Ramp Extension then south through the East Main North Extension. The connecting track between the East Main and the North ramp will be activated when emplacement panel development has progressed southward beyond that point.

The East Main branch will be used to transport waste packages from surface to the east entrance of the waste emplacement drifts. The East Main branch will contain switches located near the entrance of each waste emplacement drift turnout. The switches will connect the branch track to a rail spur that follows a lefthand circular curve through the turnout providing access to the transfer dock in each waste emplacement drift.

7.5.9 Emplacement Rail System - West Main Branch

The West Main branch of the emplacement rail system will extend from the end of the mainline track through the curve to the North Ramp Extension. From this point the track will extend to the west in the North Main and to the south in the West Main. The branch will end at the isolation barrier.

The West Main branch will be used to transport waste packages from surface to the west entrance of the waste emplacement drifts. The West Main branch will contain switches located near the entrance of each waste emplacement drift turnout. The switches will connect the branch track to a rail spur that follows a lefthand circular curve through the turnout providing access to the transfer dock in each waste emplacement drift.

7.5.10 Emplacement Rail System - Exhaust Main Branch

The Exhaust Main branch will be used to provide rail access for maintenance and operations purposes to the ventilation equipment and structures located near the Emplacement Exhaust Shaft and in the Exhaust Main. The Exhaust Main track will branch from the West Main branch track in the North Main and extend into the Exhaust main as far as the isolation barrier.

7.6 GROUND SUPPORT SYSTEMS

Underground openings will be constructed with suitable ground support. Organic materials (e.g. epoxy resin, timber) are restricted for use as rock support and other postclosure permanent materials in all openings (4.3.14). Concrete (subject to restrictions on chemical composition of cementitious materials) and steel are allowable preclosure construction materials in all openings (4.3.14). Ground support systems will be installed in excavated underground openings to enhance the structural stability. The selection of a ground support system will depend on several factors including the design documents, geologic mapping requirements, actual field ground conditions and worker safety.

A final ground support system has not been chosen so the following discussion will cover the most likely choices for ground support.

7.6.1 Temporary Ground Support - Repository Excavations

Temporary ground support systems used for repository construction will be the same designs used in the ESF (4.3.16).

7.6.1.1 Rock Bolts

Pattern rock bolting and accessories (if used) will be installed by a rock bolting machine in accordance with design documents to provide temporary ground support or for worker safety in repository excavations. Types of rock bolts and plates used to provide temporary ground support include Split Sets, Standard Swellex or Super Swellex (Ref. 5.17, page 918). Accessories include roof mats, welded wire fabric, rolled steel channels and interlocking mesh.

7.6.1.2 Rolled Steel Ribs

Rolled Steel Ribs with partial or full lagging will be installed in accordance with design documents to provide temporary ground support in 7.62 m repository excavations. Ribs will be either W6x20 or W8x30 structural steel and will extend in a partial circle from each edge of the invert segment. "C" Channel lagging, partial or full, will span the opening between ribs (Ref. 5.20, page 11 & Ref. 5.21).

7.6.1.3 Shotcrete

Shotcrete and reinforcement (if used) will be installed in accordance with design documents to provide temporary ground support or for worker safety.

7.6.2 Permanent Ground Support - Emplacement Drifts

A single ground support system will be used in emplacement drifts, unless geologic mapping requirements dictate otherwise. Precast concrete will be used for ground support in emplacement drifts not requiring geologic mapping. Steel sets and lagging will be used in emplacement drifts requiring geologic mapping. Ground support for non-emplacement drifts will be either cast-in-place concrete or steel sets (4.3.17).

7.6.2.1 Precast Concrete Segments

Precast concrete segments, if used, would extend above the invert segment (See section 7.5) to provide full circle support to the excavated opening. Each support set would include five 1.5 m wide segments. The precast concrete segments would be erected behind the TBM tail shield.

7.6.2.2 Cast-in-Place Concrete

A cast-in-place concrete ground support system, if used, would require two passes to complete. Temporary ground support (7.6.1) would be installed to support the ground during non-emplacement drift excavation. After excavation is completed and the TBM has been removed, the cast-in-place concrete lining would be placed through the length of the three non-emplacement drifts.

7.6.2.3 Rolled Steel Ribs w/Full Lagging

Rolled steel ribs, if used, would extend above the invert segment to provide intermittent full circle support to the excavated opening. Spaces between the ribs will be bridged by full steel lagging; lagging may be steel channel or panel. The steel rib segments and lagging would be installed behind the TBM tail shield.

7.6.3 Permanent Ground Support - Main Drifts/Shafts

A cast-in-place concrete lining was chosen as the basis for this analysis for installation in all repository development drifts and shafts to provide permanent support (4.3.18). Temporary ground support (7.6.1), if needed by ground conditions, would be installed to support the ground during excavation. Forms would be erected inside the temporary supports and concrete would be pumped behind the forms and vibrated to fill the voids. The concrete would be delivered from a batch plant by rail mixer car or possibly by means of a rail based batch plant underground. Lining thickness, concrete mix design and reinforcement would be in accordance with the design documents.

7.6.4 Ground Support Interference with Excavation

As shown in Attachment X, ground support used over 19% of the 7.62m diameter TBMs' utilization time during construction of the ESF. Ground support can therefore have a great effect on TBM excavation rates. Some form of ground support will be necessary during TBM operations for the construction of the repository. An ideal situation occurs when ground support is erected concurrently with TBM excavation or regripping activities. There is thus no lost time either for the TBM excavation or ground support installation.

7.6.5 Ground Support Interference with Other Activities

Depending upon the ground support system chosen, other repository activities may be impacted. For example, if temporary ground support is followed by a cast-in-place lining, installation of the lining could prevent movement through the section of the main which is being lined. This restriction could prevent the free movement of men and materials supporting other repository activities. A concrete bridge (Ref. 5.22, page 134) could allow rail and muck movement through the area being concreted.

Reference 5.22 pages 61-64, detailing the concrete lining sequence, is briefly reiterated below.

- Remove the conveyor, utilities and all other obstructions for the section of main to be concreted.
- Place the portable forms and connect them to the precast invert.
- Place the concrete and allow it to set.
- Advance the forms to a new location.
- Several sets of forms will be used to facilitate set-up, concrete placement, and movement of forms.
- Reinstall the utilities and conveyor (if needed).

It is desirable to perform these concreting operations at the end of TBM excavation so that the TBM conveyor does not have to be reinstalled and that the forming and placing of the concrete does not interfere with the muck hauling.

7.6.6 Geologic Mapping

Detailed geologic mapping of the mains employing cast-in-place lining can be accomplished between the TBM excavation and the installation of the lining. The temporary ground support will not block visual access to the sides of the main and there will be weeks or months to accomplish the mapping work while the TBM completes its work.

Detailed geologic mapping of emplacement drifts employing precast lining as the permanent ground support will be virtually impossible to accomplish. There will be insufficient time between excavation and precast liner placement. In addition the TBM tail shield will block visual access to

the top portion of the drift. These factors preclude visual mapping of the drift. Some form of mapping based on acoustical or other geophysical techniques is possible and these techniques are recommended for further study. It is also possible to temporarily support the emplacement drift and to use a cast-in-place lining technique. Decisions regarding mapping are outside the scope of this analysis although geologic mapping is required (4.2.3).

7.7 MAIN DRIFT CONSTRUCTION

Repository main drifts (See Figure 7-1) may be excavated by one 7.62m TBM. The drifts will be excavated in sequence beginning with the South Ramp Extension, West Main, North Main, East Main - North Extension, North Ramp Extension and Exhaust Main. If two TBMs are used this sequence could change as described in Sections 7.4.1.3 & 7.4.1.4. A cast-in-place concrete liner will be installed for ground support (4.3.18). The following description assumes one TBM will be used.

7.7.1 Drift Excavation

The 7.62m diameter TBM will be launched from the South Ramp Extension assembly chamber (Figure 7-13) to commence excavation (7.3.1) of the South Ramp Extension. Excavated muck will be removed by conveyor flight no. 1 (7.4.1.1), and supplies will be delivered over the West Main branch rail system (7.5.3). Fresh air will be provided by the ventilation system (7.11.1, 7.11.4). The ventilation, conveyor, utility and rail systems will be extended, and invert segments and temporary ground support will be installed to stay abreast of TBM advance. Cross sections of the main drifts during construction are shown in Figure 7-23. Conveyor flight no. 2 (7.4.1.1) and the Exhaust Main rail branch (7.5.4) will be installed to support excavation of the Exhaust Main.

7.7.2 Install Permanent Ground Support

After excavation of the main drifts is completed, the conveyor system, ventilation ducts and utilities will be removed and permanent ground support installed. The cast-in-place concrete lining was chosen for this analysis to provide permanent ground support (7.6.3). The final invert concrete will be placed later following removal of the construction rail. The sequence of concrete lining installation is staged to avoid excavation activities.

7.7.3 Finishing and Commissioning of Mains

An internal project agreement needs to be made as to what Development will accomplish during finishing and commissioning and what Emplacement will accomplish. Table 3 is a possible division between these two organizations (assuming concrete lining installed and construction rail removed).

FIGURE 7-23
DRIFT CROSS SECTIONS
REPOSITORY CONSTRUCTION PHASE

Table 3
Main Access Finishing and Commissioning

<i>Development Responsibility</i>	<i>Emplacement Responsibility</i>
<ul style="list-style-type: none">• Install emplacement rail including switches and rail in turnouts and check for operability• Install permanent air, fire water and waste water piping and check for operability• Install permanent electrical system including lighting and check for operability• Raise access main floor elevation by concrete placement• Install access main instrumentation and check for operability• Install new bulkhead between emplacement and development and check for operability	<ul style="list-style-type: none">• Connect main access systems to emplacement side• Test main access systems• Remove existing bulkhead between development and emplacement

7.7.4 Ramp and Main Finishing and Commissioning

All ramps and mains will be commissioned either during or after completion of development. The East, West, and Exhaust Mains will be commissioned piecemeal as they are turned over to Emplacement operations. Construction will be responsible for verifying that their work meets the specifications. In general the activities shown in Table 4 will take place during commissioning:

Table 4
Ramp & Main Finishing and Commissioning

<i>Development Responsibilities</i>	<i>Emplacement Responsibilities</i>
<ul style="list-style-type: none">• Install concrete lining for permanent ground support• Reinstall utilities after completion of lining• Install ventilation doors• Install & wire lighting system• Install & wire instrumentation• Install permanent rail for waste transport• Construct new isolation barriers in mains• Raise the ramp & main floor elevation	<ul style="list-style-type: none">• Connect ramp and main control & communication systems to control room• Test all waste handling systems• Connect utilities for newly commissioned panel to the existing Emplacement utility system• Connect ventilation tubes for new panel to existing Emplacement ventilation system

7.8 TURNOUT CONSTRUCTION

Turnouts (See Figure 7-24) will be constructed at each end of the emplacement drifts to provide space for the assembly/launch or disassembly of the 5.5 m TBM. The development cycle for turnouts will include three activities - (1) Drift excavation; (2) Install permanent ground support; (3) Install construction rail spur.

7.8.1 Drift Excavation

The turnouts will be excavated by roadheader (7.3.3) or by blasting and roadheader. The turnout location will be marked by a cut around the perimeter of the turnout opening. The cut will penetrate through the concrete lining to provide a smoother, more stable opening. As shown in Figure 7-24 the roadheader will require several passes to excavate the turnout. Permanent ground support and installation of rail track will be required as part of this operation. Two roadheaders will be used, one will operate in the East Main and another will operate in the West Main. Two roadheaders are required because of the long distance (>1000 m) between turnouts in the East and West Main (as shown in Figure 7-1). It is impractical to tram a roadheader between these locations. Temporary ground support using rockbolting equipment (7.6.1) will be installed as the roadheader advances.

The excavated muck will be hauled by shuttlecars (7.4.3.1) or by continuous haulage equipment (7.4.3.2). Two shuttlecars will be used to perform the mucking function for each roadheader. One unit will remain at the roadheader to receive and store the excavated muck; the second unit will receive stored muck from the first unit and transfer the muck into railcars for haulage to the East Main dump station (7.4.1.2). The railcars hauling muck from the West Main turnouts will travel through one of the open Emplacement Drifts to the East Main Dump Station. The primary ventilation system (7.11.3) will provide fresh air to the West and East Main. Turnouts will be ventilated during construction by a secondary ventilation system (7.11.4).

7.8.2 Install Permanent Ground Support

A cast-in-place concrete lining (7.6.3) was chosen as the basis of this analysis to be placed on the invert, wall and crown of the turnout. This lining provides a firm surface for the TBM during its setup and initial cut of the face.

7.8.3 Install Construction Rail Spur

A construction rail spur on a lefthand circular curve will be installed through the turnout to provide access to the emplacement entry. The rail spur will include one set of 42 kg/m rails on 915 mm gauge (4.3.32).

FIGURE 7-24
TURNOUT CONSTRUCTION

7.9 EMPLACEMENT DRIFT CONSTRUCTION

An Alternative Evaluation (7.2.3) was performed to determine the preferred approach for TBM Excavation of emplacement drifts. The evaluation concluded that one or two TBMs excavating from the East Main to the West Main was preferable because of better ventilation aspects and shorter haulage distances. A TBM will be mobilized in the first turnout drift at the north end of the East Main. Following TBM mobilization twelve separate activities will be performed to construct an Emplacement Drift including - (1) drift excavation, (2) raise excavation, (3) raise lining, (4) install gantry track, (5) remove construction utility systems, (6) remove construction rail, (7) construct transfer dock, (8) place waste package supports, (9) install radiation doors and shadow shields, (10) install gantry control and monitoring systems, (11) install gantry power systems and (12) commissioning. Each activity will be performed independently and in a fixed sequence or development cycle (although activities can overlap). The development cycle will be repeated for each emplacement drift. The development cycle for emplacement drift construction is described in more detail below:

7.9.1 Drift Excavation

A 5.5 m TBM will be assembled in a turnout drift and launched (See Figure 7-25) to begin excavation of the emplacement drift. The TBM will be raised to the proper elevation by using temporary timber or prefab ties. These ties will also support the rail spur from the East Main. The East Main rails will be raised to the proper elevation by a temporary concrete cap placed over the invert. Granby Style railcars (7.4.2.2) drawn by locomotive (7.4.2.1) will be used to haul muck to the East Main Dump Station (7.4.1.2). After the TBM has advanced sufficiently for the rail system to be extended into the tunnel, a sloped section of track supported on wooden blocking will be installed through the turnout to compensate for a rise in elevation between the invert in the East Main and the bottom of the bored section of 5.5 m tunnel (TBV-333) (4.3.36).

As the TBM advances invert segments and rail will continually be added to keep the rail system abreast of tunnel advance. Temporary or permanent ground support will be installed behind the TBM shield (7.6). The work areas will be ventilated by a secondary ventilation system (7.11.4) that delivers fresh air from the East Main into the working face.

After breakthrough into the West Main the TBM will rest on a concrete cradle and will be partially disassembled (See Figure 7-26), the ventilation duct removed and the TBM backed through the emplacement drift to the East Main for relocation to another emplacement drift. Figure 7-26 depicts the partial disassembly of the TBM and its component parts such as: main bearing, cutter head, thrust cylinders, and conveyor. As on the East Main, the rail will be raised to the correct elevation by using timber or precast ties.

EMPLACEMENT DRIFT ELEVATION

CONSTRUCTION RAIL DETAIL

KEY PLAN

NOTE: DIMENSIONS (TBV-333)
 (4.3.36)

FIGURE 7-25
 EMPLACEMENT DRIFT CONSTRUCTION
 ELEVATION AND DETAIL

5.5 m DIA TBM - BACKING MACHINE OUT OF THE EMPLACEMENT DRIFT, USING DOLLIES AND BACKING COMPONENTS OUT OF TUNNEL (RECOVERY PHASE)
 THE NUMBER OF COMPONENTS WILL PRECLUDE MOVING ALL OF THEM AT THE SAME TIME

5.5 m DIA TBM - RECOVERY IN THE WEST MAIN TURNOUT

FIGURE 7-26
 EMPLACEMENT DRIFT
 TBM RECOVERY

7.9.2 Ventilation Raise Excavation

The ventilation raise will be located at the mid-point of the emplacement drift and will connect the emplacement drift with the Exhaust Main below to provide a flow through ventilation circuit. The ventilation raise will be excavated by a raise drill machine (7.3.6) (See Figure 7-10) in two stages (1) Pilot hole drilled down; (2) upward backream.

During the reaming process the cuttings will fall through the raise and into a rail mounted, portable muck chute (See Figure 7-10) located in the Exhaust Main. The portable muck chute will be supported on a gantry frame that will travel on the two outside rails of the Exhaust Main (7.5.4). Clearance provided under and between the gantry frame will allow passage of a 6 m³ (4.3.32) railcar on the inside pair of rails. The muck chute will load the cuttings into side dump railcars for haulage to the East Main Dump Station or to the surface.

7.9.3 Ventilation Raise Lining

The ventilation raise will be lined with a cast-in-place concrete lining (See Figure 7-27). A steel plate collar will be installed at the bottom of the ventilation raise in the Exhaust Main and grouted in place. Centralizers will hold the steel collar in position during grouting. A grout line will allow introduction of grout behind the collar and a plug will prevent the grout from escaping. A cast-in-place concrete lining will be placed in lifts from the top of the grouted steel collar to the top of the raise using a collapsible form.

7.9.4 Install Gantry Track

Waste packages will be placed center-in-drift using gantry emplacement (4.3.5). Two sections of 44.64 kg/m rail will be installed (See Figures 7-28 & 7-29), one in the east and the other in the west.

7.9.5 Remove Construction Utility Systems

The construction utility systems will be removed from the emplacement drifts.

7.9.6 Remove Construction Rail

The construction rail system and construction utility systems will be removed from the emplacement drift.

NOTE: DIMENSIONS (TBV-333)
 (4.3.36)

FIGURE 7-27
 EMPLACEMENT DRIFT
 VENTILATION RAISE DETAILS

ALL DIMENSIONS ARE SHOWN IN MILLI-
 METERS UNLESS OTHERWISE NOTED

5.5 m DIAMETER EMPLACEMENT DRIFT
SECTION AT THE TRANSFER DOCK

NOTE: ISOLATION DOORS NOT SHOWN FOR CLARITY.

5.5 m DIAMETER EMPLACEMENT DRIFT
SECTION AT THE WASTE PACKAGE
SUPPORT LOCATION

NOTE: DIMENSIONS (TBV-333)
(4.3.36)

FIGURE 7-28
DRIFT CROSS SECTIONS

NOTE: DIMENSIONS (TBV-333)
 (4.3.36)

FIGURE 7-29
 EMPLACEMENT DRIFT ELEVATION

7.9.7 Construct Transfer Dock

A transfer dock (See Figures 7-28 & 7-29) will be constructed at both emplacement drift entrances. The dock will be comprised of a raised concrete block and a section of track of sufficient length to receive a waste package on a transport car. The elevation and gauge of the track will match the elevation and gauge of the rails in the waste transporter and will allow the waste package transport car to be moved onto the transfer dock. A safety bumper block will be installed at the end of the transfer track. A rigid chain guide will be used to pull the transport car out of the waste package transporter (not shown).

7.9.8 Place Waste Package Supports

Waste packages will be placed center-in-drift on supports (4.3.5). The steel waste package supports (See Figures 7-28 & 7-29) will be installed along the invert of the emplacement drift except for three short non-waste zones at the ends and center of the emplacement drift. The installation of waste package supports will be delayed until just prior to final commissioning when spacing requirements are better defined.

7.9.9 Radiation Doors/Shadow Shields

Doors are required at entrances to emplacement drifts (4.3.20). Doors will be installed at each end of the emplacement drift to provide radiation shielding and ventilation control (See Figure 7-29). The doors will close against the vertical plane between the turnout and bored section and will swing out into the turnout. Shadow shields (See Figure 7-29) will be installed at both ends of the emplacement drift behind the transfer dock bumper block to contain radiation shine within the emplacement drift.

7.9.10 Install Gantry Control and Monitoring

Electrical control systems (Not shown on figures) will be installed in the east and west half of the emplacement drift to control the operation of the gantry crane. Monitoring systems will also be installed to provide information on the gantry operation and other parameters within the emplacement drift. Wheel stops will be located near the ventilation raise to prevent gantry movement over the raise.

7.9.11 Install Gantry Power Systems

Open conductor bars (See Figure 7-29) will be installed along the Gantry Crane runway to supply power to the gantry collector.

7.9.12 Emplacement Drift Finishing and Commissioning

Each emplacement drift will be subjected to several inspections and operating tests to ensure that it is constructed in accordance with the design documents and meets system performance requirements. These activities will be performed within the panel area (7.10.4), and will include all panel emplacement drifts. Some activities (See Table 4) will be performed before the panel is isolated and some will be performed after isolation. After successfully passing the inspections and tests, the emplacement drifts will be commissioned for Emplacement Operations service.

An agreement needs to be made as to what Development will accomplish during finishing and commissioning and what Emplacement will accomplish. Table 5 is a possible division between these two organizations for emplacement drifts; assume that precast concrete lining has been installed by the excavation process. The constructor will be responsible for verifying the operation of all equipment they install.

Table 5
Emplacement Drift Finishing and Commissioning

<i>Development Responsibilities</i>	<i>Emplacement Responsibilities</i>
<ul style="list-style-type: none">• Install shadow shields• Install isolation doors & raise outlet• Install waste supports• Install & wire lighting system• Install & wire instrumentation• Install rail for gantries	<ul style="list-style-type: none">• Switch control & communication systems to control room• Test all waste handling systems• Install & move gantries

7.10 PHASED CONSTRUCTION APPROACH

Repository construction must be performed in phases. The repository construction plan includes many interrelated and complex tasks that will be performed during the construction and development of the repository. To understand how these tasks interrelate, the construction plan was decomposed into its major tasks, and these tasks were sorted according to the logical sequence in which the tasks would be performed. Tasks occurring within the same time periods were grouped into phases. This section will identify the major tasks and the sequence or phase when the task will be performed. The methods for accomplishing each task will be described and the required equipment, support facilities and utilities will be listed. The construction phase transitions to the development phase when emplacement operations begin, i.e. the development phase includes concurrent construction and emplacement activities. The five construction and development phases are described below. Only one construction scheme is described. Other construction schemes will have similar tasks grouped into different phases.

In this analysis the word "phase" has a similar meaning to the phases described in the *Mined Geologic Disposal System Requirements Document* (Ref. 5.37). Phases I-IV below coincide with the Construction Phase in Reference 5.37 and Phase V coincides with the Operations Phase in the same reference. In this analysis the Operations Phase is divided into development and emplacement portions.

7.10.1 Phase I Construction

Phase I Construction (See Figure 7-30) will be a start-up phase that will provide the support facilities for launching the TBMs. In general this phase will include the assembly and launch of the 7.62 m TBM in the South Ramp Extension; the assembly and launch of the 5.5 m TBM and completion of the three cross block emplacement drifts; and beginning of the Development Shaft excavation.

7.10.1.1 Turnout Construction

Three turnouts will be excavated (7.8.1) in the East Main to provide space for the assembly/launch of the 5.5 m TBM. The turnouts will be excavated by roadheader (7.3.3). The muck will be hauled to surface by railcars. The construction cycle for turnouts will include three activities - (1) Turnout excavation and installation of temporary ground support; (2) Placement of a cast-in-place concrete lining on the floor, wall and crown (3) Installation of a construction rail spur.

7.10.1.2 Cross Block Emplacement Drifts

Three 5.5 m (TBV-333) (4.3.36) Cross Block Emplacement Drifts will be excavated from the East Main to near the Solitario Canyon fault on the west side of the repository block. The drifts will be excavated sequentially south to north to ensure the fault is located for alignment of the West Main.

The 5.5 m TBM will be assembled in the turnout drift and launched. TBM muck will be hauled by railcars (7.4.2) to surface. As the TBM advances invert segments and rail will continually be added to keep the rail system abreast of the advance. Temporary ground support (7.6.1) will be installed behind the TBM shield to allow mapping of the exposed geology. The work areas will be ventilated by a secondary ventilation system (7.11.4) that induces fresh air to flow from the East Main into the working face. The fan will be moved-up and the vent duct extended to stay abreast of the TBM advance.

Drilling ahead of the TBM will establish the location of the Solitario Canyon fault. The TBM will be stopped prior to entering the fault zone. The alignment of the West Main will be established east of the fault. The cross block drifts must be excavated prior to the West Main so that the Main can be accurately located in relation to the fault.

FIGURE 7-30
PHASE I
SUBSURFACE CONSTRUCTION

After a cross block drift is excavated the TBM will be partially disassembled and backed through the drift to the East Main. The TBM will be relocated to the next turnout drift and the above process repeated until all three cross block emplacement drifts are completed.

7.10.1.3 South Ramp Extension TBM Assembly Chamber

A TBM assembly chamber and launch drift will be constructed for the 7.62 m diameter TBM in the South Ramp Extension. The chamber will be excavated by roadheader (7.3.3) and temporary ground support (7.6.1) will be installed as the roadheader advances. Muck will be loaded and hauled by appropriately designed shuttlecars (7.4.3) and transferred to Granby style railcars for haulage to surface. The work areas will be ventilated by a secondary ventilation system (7.11.4) that delivers fresh air from the South Ramp into the work area.

7.10.1.4 Main Drift Excavation

The 7.62 m TBM will be assembled in the South Ramp Extension Assembly Chamber and launched. The TBM will advance the face of the South Ramp Extension up to the Exhaust Main. The TBM may be stopped at this point if the information needed to determine the West Main alignment is not available. Once the TBM advances beyond the Exhaust Main, it will turn north and excavate the West Main advancing the face in a northerly direction.

7.10.1.5 Development Shaft Access Drift

An access drift will be excavated by roadheader from the West Main, just north of the South Ramp Extension curve, to the Development Shaft to provide early access to the shaft bottom. Two shuttlecar units (7.4.3) will be used to perform the mucking function. One unit will remain at the roadheader to receive and store the excavated muck; the second unit will receive stored muck from the first unit and transfer the muck to a nearby conveyor. Temporary ground support (7.6.1) will be installed as the roadheader advances. The work areas will be ventilated by a secondary ventilation system (7.11.4) that delivers fresh air from the West Main into the work area. The development shaft access drift will provide underground access to the bottom of the shaft during shaft construction.

7.10.1.6 Development Shaft

The Development Shaft (Figure 7-9) will be excavated in three stages: (1) pilot hole down, (2) backream up and (3) bore down (7.3.5). A pilot hole will be drilled from surface to the Development Shaft access drift. The access drift will provide underground access for attaching a reaming bit to the drill string. The reaming bit will be pulled to surface to enlarge the pilot hole. During the

reaming process cuttings will fall through the shaft to the access drift where the cuttings will be loaded into appropriately designed shuttlecars (7.4.3). The shuttlecars will transfer the cuttings to railcars for haulage to surface. A vertical boring machine will be used to enlarge the shaft to its final 6.7 m (TBV-333) (4.3.36) diameter. A shaft lining operation will follow the excavation and install a cast-in-place concrete lining. After the concrete lining is completed, the shaft bottom will be deepened by Drill-and-blast methods to provide a sump.

7.10.1.7 TBM Disassembly Chambers

TBM disassembly chambers will be constructed for the 7.62 m TBM in the East Main North Extension near its junction with the East Main and in the North Ramp Extension near its junction with the North Ramp.

The TBM disassembly chambers will be excavated by Roadheader (7.3.3). The excavated muck will be hauled by shuttlecars (7.4.3). Two shuttlecar units will be used to perform the mucking function. One unit will remain at the roadheader to receive and store the excavated muck; the second unit will receive stored muck from the first unit and transfer the muck into railcars for haulage to surface. The work areas will be ventilated by a secondary ventilation system (7.11.4) that delivers fresh air from the East Main into the working face. Temporary ground support (7.6.1) will be installed to support the excavated opening.

7.10.1.8 Muck Handling System

Conveyor flight no. 1 (7.4.1.1) will be installed to transport development muck from the 7.62 m TBM to surface. Conveyor Flight No. 1 will initially extend from surface through the South Ramp to a tail terminal located at the TBM. Railcars (7.4.2.2) will be used to haul muck produced by the roadheader and 5.5 m TBM from underground to the surface.

7.10.1.9 Construction Rail System

The mainline segment (7.5.1) and East Main branch (7.5.2) of the construction rail system will be installed in the South Ramp, East Main and North Ramp. The initial portion of double track for the West Main branch (7.5.3) will be installed in the South Ramp Extension.

7.10.1.10 Ventilation

At construction startup ventilation airflow will be established underground from the North Portal to the South Portal (7.11.1). A fan installation located at the North Portal will blow fresh air down the North Ramp, through the East Main, and up the South Ramp where the air will discharge through

the South Portal to atmosphere. Secondary ventilation systems (7.11.4) will draw fresh air from this source and deliver it to the working faces.

7.10.1.11 Logistical Support

The rail transportation system including locomotives (7.4.2.1) and railcars (7.4.2.3, 7.4.2.4, 7.4.2.5) will be used to provide logistical support for moving men, equipment and supplies between the underground and the South Portal on surface.

7.10.2 Phase II Construction

Phase II Construction (See Figure 7-31) will focus on completing excavation of the Mains, the North Ramp Extension, the TBM assembly and disassembly chambers for the Exhaust Main, and the Emplacement Shaft.

7.10.2.1 Main Drift Excavation

The TBM will complete excavation of the South Ramp Extension, followed by the West Main, North Main, and East Main North Extension in sequence. Following completion of the latter drift the TBM will be disassembled and backed through the East Main North Extension, North Main and relocated into the North Ramp Extension assembly chamber. The TBM will be re-assembled and launched to drive the North Ramp Extension drift. Muck from all Mains will be transported to surface by conveyor flight no. 1. The conveyor will be extended as required to stay abreast of the TBM (7.3.1) advance. Temporary ground support, invert segments, utilities and rail will also be installed as the TBM advances.

Ventilation airflow will be from the North Portal to the South Portal (7.11.1). Secondary ventilation systems (7.11.4) will draw fresh air from this source and deliver it to the working faces. Following the breakthrough of the West Main into the first cross block emplacement drift part of the airflow from the East Main will be diverted through the cross block drift to the West Main.

7.10.2.2 Exhaust Main TBM Disassembly Chamber

A section of the Exhaust Main will be excavated by roadheader (7.3.3) from the North Main to provide early access to the bottom of the Emplacement Shaft. The section will include a TBM disassembly chamber for the 7.62 m diameter TBM. The section excavated will extend, from the North Main along the Exhaust Main alignment until the face is beyond the location of the emplacement shaft access drift.

FIGURE 7-31
 PHASE II
 SUBSURFACE CONSTRUCTION

The chamber will be excavated by roadheader (7.3.3) and the excavated muck will be hauled by shuttlecars (7.4.3). Two shuttlecar units will be used to perform the mucking function. One unit will remain at the roadheader to receive and store the excavated muck; the second unit will receive stored muck from the first unit and transfer the muck into railcars for haulage to the surface. Temporary ground support will be installed as the roadheader advances. The work areas will be ventilated by a secondary ventilation system that delivers fresh air from the North Main into the work area (7.11.4).

7.10.2.3 Emplacement Shaft Access Drift

After excavating the section of the Exhaust Main the roadheader will turn west and excavate the access drift to the base of the Emplacement Shaft. Mucking, ground support and ventilation will be as described in 7.10.2.2. The Emplacement Shaft Access Drift will provide underground access to the bottom of the shaft during shaft construction.

7.10.2.4 North Ramp Extension Assembly Chamber

A TBM assembly chamber and launch drift will be constructed for the 7.62 m diameter TBM in the North Main. The chamber will be excavated by roadheader (7.3.3) and temporary ground support (7.6.1) will be installed as the roadheader advances. Muck will be loaded and hauled by shuttlecars (7.4.3) to railcars for transportation to surface. The chamber will be ventilated by a secondary ventilation system (7.11.4) that delivers fresh air from the North Main into the work area.

7.10.2.5 Emplacement Shaft

The Emplacement Shaft will be excavated (See Figure 7-9) in three stages: (1) pilot hole down, (2) backream up and (3) bore down. A pilot hole will be drilled from surface to intercept the emplacement access drift. The access drift will provide underground access for attaching a reaming bit to the drill string. The reaming bit will be pulled to surface to enlarge the pilot hole. During the reaming process cuttings will fall through the shaft to the access drift where the cuttings will be loaded into shuttlecars. The shuttlecars will transfer the cuttings into railcars for haulage to surface. A vertical boring machine will be used to enlarge the shaft to its final 6.7 m (TBV-333) (4.3.36) diameter. A shaft lining operation will follow behind the final excavation pass to install a cast-in-place concrete lining. After the concrete lining is completed, the shaft bottom will be deepened by drill-blast methods for a sump.

7.10.2.6 North Ramp Extension

The North Ramp Extension will be excavated to establish a connection between the North Ramp and

the North Main. The 7.62 m diameter TBM will be reassembled in the North Ramp Extension assembly chamber and launched. Muck will be transported to surface by conveyor flight no.1. The conveyor flight will be extended as required to stay abreast of TBM (7.3.1) advance. Temporary ground support, invert segments and rail will be installed as the TBM advances.

At the end of the North Ramp Extension the TBM will break into the previously excavated disassembly chamber. The TBM will be disassembled, and then transported through the East Main and South Ramp Extension to the TBM Assembly Chamber located at the south end of the Exhaust Main.

7.10.2.7 Exhaust Main Assembly Chamber

A TBM assembly chamber and launch drift will be constructed for the 7.62 m diameter TBM in the Exhaust Main. The chamber will be excavated by roadheader (7.3.3) and temporary ground support (7.6.1) will be installed as the roadheader advances. Muck will be loaded and hauled by shuttlecars (7.4.3) to Conveyor Flight No. 1. The work areas will be ventilated by a secondary ventilation system (7.11.4) that delivers fresh air from the South Ramp into the work area.

7.10.2.8 Construction Rail System

The West Main branch (7.5.3) will be extended and linked to the East Main branch (7.5.2). A rail spur will be extended from the West Main Branch into the North Ramp Extension to support TBM excavation.

7.10.2.9 Muck Handling System

Conveyor flight no. 1 (7.4.1.1) will be continuously extended in the Mains to stay abreast of TBM advance.

7.10.2.10 Cast-In-Place Concrete Lining

A wall and crown cast-in-place concrete lining will be placed in the North Portal, the North Ramp, the East Main, the East Main North Extension and the three cross block emplacement drifts. The placement of final invert concrete will be deferred until the Development phase.

7.10.3 Phase III Construction

During Phase III Construction (See Figure 7-32) the excavation of the access mains will be completed. Major activities will include: (1) The 7.62 m TBM will be relocated to the Exhaust

FIGURE 7-32
PHASE III
SUBSURFACE CONSTRUCTION

Main; (2) Exhaust Main excavation will be completed and the TBM disassembled and brought to surface; (3) A cast-in-place concrete lining will be placed in the unlined Mains; (4) Conveyor flights no. 1 and 2 will be removed.

7.10.3.1 Exhaust Main Excavation

The 7.62 m TBM will be assembled and launched to excavate the Exhaust Main. The muck handling system, rail system, ventilation system and other support systems will all be extended as required to support the TBM advance. The ventilation raises (7.9.2) that connect the Exhaust Main to the three overlying cross block drifts, will be excavated when the TBM trailing gear has cleared. The raises will provide fresh air to the Exhaust Main. Near the north end of the Exhaust Main the TBM will breakthrough into the TBM Disassembly Chamber. This will complete all excavation work by the 7.62 m TBM which will be disassembled and backed-up in sequence through the Exhaust Main, the South Ramp Extension and the South Ramp to surface.

7.10.3.2 Muck Handling System

Conveyor flight no. 2 (7.4.1.1) will be installed in the Exhaust Main to support TBM excavation of the Exhaust Main. The initial conveyor installation will extend from a conveyor transfer terminal located at the intersection of the South Ramp Extension and the Exhaust Main to the back of the TBM. The discharge pulley and transfer chute will be located above conveyor flight no. 1; the drive unit (#1), the takeup section and belt storage units will be installed in the TBM assembly chamber; the tail section will be located behind the TBM. Conveyor flights no. 1 and 2 will be removed after excavation of the Exhaust Main is completed. Removal of the conveyors will precede placement of the cast-in-place concrete liner.

7.10.3.3 Construction Rail System

The Exhaust Main branch (7.5.4) of the construction rail system will be installed in the Exhaust Main to support TBM excavation. Invert segments and rail will be added to extend the tracks as the TBM advances. After excavation is completed and the TBM is removed the Exhaust Main branch will be linked to the West Main branch in the North Main.

7.10.3.4 Cast-in-Place Concrete

A Cast-in-Place concrete lining (7.6.3) will be placed in the North Ramp Extension, the North Main, the West Main, the South Ramp Extension, and the Exhaust Main.

7.10.4 Phase IV Construction

Emplacement drift construction will be initiated during Phase IV (See Figure 7-33). The objective during this phase will be to complete a panel (Panel 1) of physically isolated emplacement drifts that are ready for commissioning (7.9.12). Phase IV Construction will include the construction of six and commissioning of five waste emplacement drifts (See Figure 7-34) and one P.C. Drift. The ventilation systems for the development and emplacement areas will be provided by two separate and independent systems that are physically separated in the underground (4.2.1). To provide radiological protection to repository construction workers, the subsurface repository will include isolation barriers and separate ventilation systems to isolate the two operations. The barriers will be constructed in the East and West Mains and in the Exhaust Main at Emplacement Drift No. 5. Since the barriers will be located on either side of the emplacement drift, drift number 5 will be captive within the barriers and temporarily unavailable for waste emplacement. When the barriers are moved to a new location, a new drift will become captive and drift number 5 will be released for emplacement. Panel 1 will include four drifts available for waste emplacement. Drift number 6 will serve as a ventilation pathway and a material stage area for future panel development. Major Phase IV construction activities are described below.

7.10.4.1 Muck Handling System

Conveyor Flight No. 1A (7.4.1.1) will be installed in the South Ramp and East Main to transport repository development muck to surface. The conveyor will be installed along the right hand rib in both drifts and will extend to the north end of the East Main. The East Main Dump Station (7.4.1.2) will be installed at the conveyor tail section. The dump station will receive muck from railcars and will feed the muck onto Conveyor 1A.

7.10.4.2 Turnout Construction

Turnouts will be excavated at each end of the emplacement drifts to provide space for the assembly/launch or disassembly of the 5.5 m TBM. The turnouts will be excavated by two roadheaders (7.8.1) - one operating in the East Main and one in the West Main. The roadheader in the East Main will be mobilized first to provide a completed turnout sooner for the TBM launches that will originate from the East Main. After the roadheader in the East Main is operating, the roadheader in the West Main will be mobilized. All turnouts in both mains will be excavated sequentially north to south. The development cycle for turnouts will include three active phases -(1) Turnout excavation and installation of temporary ground support; (2) Placement of a cast-in-place concrete lining in the floor, wall and crown (3) Installation of a construction rail spur.

FIGURE 7-33
PHASE IV
SUBSURFACE CONSTRUCTION

FIGURE 7-34
EMPLACEMENT DRIFT
CONSTRUCTION

7.10.4.3 Emplacement Drift Construction

After the fourth turnout in the East Main has been excavated, a 5.5 m TBM will be assembled in the first turnout and launched to excavate (7.9.1) the northernmost emplacement drift. After the breakthrough of the TBM into the West Main, the TBM will be disassembled and backed through the emplacement drift to the East Main (See Figure 7-26). The TBM will be relocated to the next turnout to repeat the excavation process.

7.10.4.4 Ventilation Raises

After the TBM has been removed from the emplacement drift, a rail-mounted raise drill machine will be transported into the emplacement drift and setup at the drift midpoint. A ventilation raise will be excavated (7.3.6) to connect the midpoint of each emplacement drift with the Exhaust Main located below (See Figure 7-10).

When excavation is completed the ventilation raises will be lined with a cast-in-place concrete liner from the bottom up. A steel collar will be anchored and grouted at the bottom of the raise (See Figure 7-27). The concrete lining will be placed in lifts starting from the steel collar.

7.10.4.5 Emplacement Ventilation Equipment

Ventilation ducts will be installed along the crown of the Exhaust Main to connect the Emplacement Exhaust Shaft with the emplacement drift ventilation raises. The ducts will be located on both sides of the emplacement drift ventilation raises. A bifurcated duct fitting will be attached to the ventilation raise steel collar and connected to each duct (See Figure 7-29). Exhaust fans and accessories will be installed at the collar of the Emplacement Shaft and banks of HEPA filters at the underground level.

7.10.4.6 Main Drift Construction

During Phase IV sections of the East and West Main that adjoin emplacement panel no. 1 will be modified as follows:

- a) The construction rail system will be removed from designated sections of the East and West Main and the Exhaust Main.
- b) A 300 mm (4.3.34) thickness of cast-in-place concrete will be placed over the existing precast concrete invert in the designated sections of the East and West Main and the Exhaust Main.

c) The East Main branch (7.5.8), the West Main branch (7.5.9) and the Exhaust Main branch (7.5.10) of the emplacement rail system will be extended up to the ventilation barrier between the development and construction sides of the repository. Rail switches and a short rail spur will be installed from the East and West Main branches into the emplacement drift turnouts.

d) Isolation barriers will be installed in the East and West Main and in the Exhaust Main to isolate the emplacement operations area from the development operations area. Because the section of straight tunnel between turnout curves is short (< 10 m) (Figure 7-24), the barriers will be installed on both sides (i.e. straddle) of emplacement drift number 5.

7.10.4.7 Commissioning

Certain commissioning activities will be performed before panel isolation and others will be performed after panel isolation (7.9.12). The emplacement drift, turnouts and ventilation raise will be inspected for conformance with the design before panel isolation. The inspections will include the physical facility, documentation, materials, equipment, tolerances, and workmanship. After panel isolation a series of tests will be performed to ensure that the emplacement transportation, emplacement and recovery systems meet performance requirements.

7.10.4.8 P.C. Drift Construction

An assembly chamber will be constructed on the north side of the North Ramp near the entrance to the North Ramp Extension. The chamber will be used for launching a 5.5 m TBM for the excavation of PC Drift No. 1. The drift will be aligned in a northwest direction and sloped on a positive gradient to climb above the emplacement horizon. The drift will curve to follow an alignment that is parallel to and above emplacement panel no. 1.

A rail spur from the construction rail system east main branch will be installed through the turnout and extended to follow the TBM. Muck will be hauled by railcars to surface. Ventilation raises will be excavated by raise drill to connect the PC drift to the East, West, and Exhaust Mains.

Alcoves will be constructed at intervals along the PC Drift to hold instrumentation which will monitor the repository.

7.10.5 Phase V Development

The second repository panel commissioned for emplacement will include 15 emplacement drifts. Phase V will be the final phase of repository development; all remaining emplacement panels will be constructed during this phase (See Figure 7-35). At the start of this phase an expanded sixteen

FIGURE 7-35
 PHASE V
 SUBSURFACE CONSTRUCTION

drift emplacement panel (Panel 2) will be constructed. Panel 2 will be a pattern for the construction of all subsequent emplacement panels. The construction activities and sequencing that are used to construct Panel 2 will be repetitive for all subsequent panels.

While Panel 2 is under construction, emplacement operations will begin in Panel 1.

The ventilation systems for development and emplacement areas will be provided by two separate and independent systems that are physically separated in the underground (4.2.1). Underground construction (i.e. development) will not use the North Portal for access once emplacement operations begin (4.3.15).

Section 7.9 discusses the activities that will be performed during the construction of an emplacement drift. Each of these activities will be performed within each drift in sequence. The number of emplacement drifts that are included within a panel is a compromise between a number of factors that include - relocating the ventilation barriers between the construction and emplacement operations, waste receipt schedules, equipment excavation rates and construction schedule. For purposes of this analysis it appears that about sixteen to twenty-one emplacement drifts per panel is a reasonable compromise that minimizes the number of ventilation barrier relocations, and is within the bounds of equipment capabilities and emplacement requirements. The following paragraph discusses the twenty drift emplacement panel.

As each group of emplacement drifts is completed and commissioned, isolation barriers will be installed in the East, West and Exhaust Mains at the panel boundary. The barriers will capture the end emplacement drift in the panel and make it temporarily unavailable for waste emplacement. When a new panel is created the barriers will be moved to a new location and the captive drift will be released to the new panel. The designated captive drift must be commissioned before it becomes a captive barrier. This pattern of releasing the captive drift and incorporating it into the new panel will recur with each new panel. Major Phase V construction activities are described below:

7.10.5.1 Muck Handling System

Conveyor flight no. 1A (7.4.1.1) in the South Ramp and East Main will be used to transport repository development muck to surface. The conveyor will be shortened and the East Main Dump Station (7.4.1.2) relocated for each new panel location. The dump station will receive muck from railcars and will feed the muck onto the conveyor.

7.10.5.2 Turnout Construction

Turnouts will be excavated at each end of the emplacement drifts to provide space for the assembly/launch or disassembly of the 5.5 m TBM. One roadheader in the East Main and one in the West Main will continue to excavate turnouts (7.8.1) at the beginning of Phase V. Work schedules may allow a cutback to a single roadheader at a later time. Turnouts in both mains will be excavated sequentially north to south. Turnout drift construction can be performed independently of emplacement drift excavation as long as turnout construction stays ahead of the emplacement drift excavation cycle.

The development cycle for turnouts will include three functions - (1) Turnout excavation and installation of temporary ground support; (2) Placement of a cast-in-place concrete lining in the floor, wall, and crown (3) Installation of a construction rail spur.

7.10.5.3 Emplacement Drift Construction

Emplacement drift construction (7.9) will continue with one or two TBMs (7.2.3) during Phase V. TBMs will be launched from the East Main and will excavate from east to west. After TBM breakthrough into the West Main, the TBM will be partially disassembled and backed through the emplacement drift to the East Main for relocation to another turnout to repeat the excavation process.

7.10.5.4 Ventilation Raises

After the TBM has been removed from the emplacement drift, a rail-mounted raise boring machine will be transported into the emplacement drift and set-up at the mid-point. A ventilation raise will be excavated (7.3.6) to connect the mid-point of each emplacement drift with the Exhaust Main located below.

When excavation is completed the ventilation raises will be lined with a cast-in-place concrete lining from the bottom up. A steel collar will be anchored and grouted at the bottom of the raise. The concrete lining will be placed in lifts starting from the steel collar (Figure 7-27).

7.10.5.5 Exhaust Main Equipment

Two parallel ventilation ducts will be installed along the crown of the Exhaust Main to connect the Emplacement Exhaust Shaft with the emplacement drift ventilation raises. The ducts will be located on both sides of the emplacement drift ventilation raises. A bifurcated duct fitting will be installed to connect the steel collar on the ventilation raise to each duct (Figure 7-29).

7.10.5.6 P.C. Drift Construction

A turnout and TBM assembly chamber will be constructed on the north side of the South Ramp near the curve to the East Main. The turnout will be used for launching a second 5.5 m TBM for the excavation of the PC Access Drift. The drift will be aligned in a northwest direction and sloped on a positive gradient to climb above the emplacement horizon. The drift will curve to follow an alignment that is parallel to and above the East Main.

Four PC Drifts will branch at intervals from the PC Access Drift (7.3.7) and cross over the emplacement horizon; their alignment will be parallel to the emplacement drifts. Ventilation raises will be excavated by raise drill to connect each PC drift to the East, West, and Exhaust Mains.

Alcoves will be constructed at intervals along the four PC Drifts to hold instrumentation which will monitor the repository.

7.10.5.7 Main Drift Construction

During Phase V sections of the East and West Main that are adjacent to the emplacement panels and the Exhaust Main will be modified as follows:

- a) The construction rail system will be removed from the designated sections of the East and West Main and the Exhaust Main.
- b) Cast-in-place concrete will be placed over the existing precast concrete invert in the designated sections of the East and West Main and the Exhaust Main following removal of the construction rail to raise the invert height to the required elevation.
- c) Isolation barriers will be installed in the East, West, and Exhaust Mains to isolate the emplacement operations area from the development operations area. Two barriers will be used in each Main to provide an airlock.
- d) The East Main branch (7.5.8), the West Main branch (7.5.9) and the Exhaust Main branch (7.5.10) of the emplacement rail system will be extended from the old isolation barrier in each Main to the new isolation barrier described in "c" above.

7.10.5.8 Commissioning

Certain commissioning activities will be performed before panel isolation and others will be performed after panel isolation. The emplacement drift, turnouts and ventilation raise will be

inspected for conformance with the design before panel isolation. The inspections will include the physical facility, documentation, materials, equipment, tolerances, and workmanship. After panel isolation a series of tests will be performed to ensure that the emplacement transportation, emplacement, and recovery systems meet performance requirements.

7.11 VENTILATION SYSTEM

This section describes the ventilation requirements for the phased construction approach described in Section 7.10. Other construction schemes have been considered in this report and their ventilation requirements will be described in other analyses.

7.11.1 Phase I & II Construction Ventilation

At construction startup ventilation airflow will be established underground from the North Portal to the South Portal. A fan installation located at the North Portal will blow fresh air down the North Ramp, through the East Main, and up the South Ramp where the exhaust air will discharge through the South Portal to atmosphere (4.3.23). Secondary ventilation systems will draw fresh air from this source and deliver it to the working faces.

Following the breakthrough of the West Main into the first cross block emplacement drift part of the airflow from the East Main will be diverted through the emplacement drift to the West Main. This flowthrough ventilation path will provide primary ventilation air to the West Main. When the West Main breaks into the second and third cross block emplacement drifts, these drifts will provide additional airflow pathways between the East Main and the West Main.

7.11.2 Phase III Construction Ventilation

Following completion of the Development Shaft, fans will be installed on the surface to force fresh air down the shaft and provide a pressurized fresh air intake source. The air will flow north through the West Main and Exhaust Main, east through the cross block drifts, south through the East Main, east through the South Ramp and will discharge through the South Portal to the atmosphere (4.3.24). Secondary ventilation systems will draw fresh air from the shaft and deliver it to the working faces. During excavation of the Exhaust Main the ventilation raises (7.9.2) that connect the Exhaust Main to the three overlying cross block drifts, will be excavated when the TBM trailing gear has cleared. The raises will provide a fresh air ventilation circuit through the Exhaust Main.

7.11.3 Phase IV & V Development/Emplacement Ventilation

7.11.3.1 Development Ventilation

The Development ventilation will force fresh air down the Development Shaft. The air will flow north through the West Main and Exhaust Main, east through the cross block drifts, south through the East Main, east through the South Ramp and will discharge through the South Portal to atmosphere (4.3.24). Secondary ventilation systems will draw fresh air from this source and deliver it to the working faces.

7.11.3.2 Emplacement Ventilation

The Emplacement Ventilation system will utilize exhaust fans on top of the Emplacement Shaft to draw fresh air through the North Portal. The air will flow down the North Ramp and split into East and West Main air streams. The air will flow into both ends of the emplacement drift toward the exhaust raise located at the midpoint. The air will downcast through the raise and into the Exhaust Main or Exhaust Main auxiliary ducts with the optional High Efficiency Particulate (HEPA) filter system. The air is drawn to the Emplacement Shaft where it will discharge to the atmosphere (4.3.25).

7.11.4 Secondary Ventilation

Secondary ventilation systems will be used to provide fresh air to the working face. Air will be drawn from the fresh air source into the heading by a secondary ventilation system. This consists of fan(s) located near the working face that draw air from the face area and discharge it into ducts, ducts that conduct the air to a downstream discharge point, and filtration unit(s) as required located outside of the immediate work area.

7.12 UTILITY INSTALLATION AND REMOVAL

A complete discussion of utility installation and removal is beyond the scope of this analysis. However, in all phases there will be air, water, and waste water lines plus power and communication cables in the Mains. The sizes of these lines will be determined by another analysis.

The construction and development systems are temporary in nature although portions of them may be used for more than 20 years or be incorporated into the permanent system. Prior to emplacing the cast-in-place concrete lining the construction or development utilities will need to be removed. The utilities will then need to be reinstalled and then again removed prior to installation of the permanent or emplacement utilities.

Another consideration is the requirement to keep the emplacement and development ventilation systems separate (4.2.1). This will necessitate having separate utility systems at the North and South portals. For example, an electrical substation will be required at both portals as there will be a physical break between the systems at the ventilation barriers in the Access Mains. As these barriers are advanced (North to South) the development utilities will be taken up and the emplacement utilities will be installed. The installation and removal of utilities should be well planned to reduce the potential that lack of utilities will hinder the construction effort.

7.13 CONSTRUCTION HEALTH AND SAFETY

Safety and Health protection systems shall be provided in underground spaces as required by 29 CFR 1910 (Occupational Safety and Health Standards) and 29 CFR 1926 (Safety and Health Regulations for Construction) to afford the greatest protection (4.2.4).

7.13.1 Underground Access Control

A system shall be provided to control (personnel) access to the underground as required by 29 CFR 1926.800(c)(4.2.4). A tag-in/tag-out system will be used to control access to the underground areas.

7.13.2 Ventilation Monitoring

Sufficient airflow will be maintained in the underground excavations including shafts and ramps to satisfy the quantity/quality/velocity criteria imposed by regulatory requirements. Performance of the ventilation system will be monitored by performing periodic dust and gas sampling.

7.13.3 Facilities and Systems

Underground facilities and systems will be constructed to afford the greatest protection and in accordance with the applicable health and safety requirements of 29 CFR 1910 and 29 CFR 1926 (4.2.4).

7.14 CONTRACT STRUCTURE

In this analysis the organizational structure shown in Figure 7-36 will be used. This type of structure provides an example of a typical organization for the management of large construction projects. This structure provides a framework for discussion for various aspects of the construction process. The first construction aspect to discuss is contract formation.

The main type of subsurface construction contracts are fixed price and cost plus (Ref. 5.18, page 58).

The fixed price contract is appropriate to use when the construction scope, quality and schedule are well defined. In tunnel contracting, the geological conditions should be well defined for this type of contract. Cost plus contracts are more appropriate for construction of unique one-of-a-kind items or scientific investigations. That is, the construction scope and schedule are not well defined or are impossible to define at the beginning of the project. In cost plus contracts, contractors are reimbursed for all their expenses plus a fee. The fee may be fixed or based upon a percentage of the total cost. The advantages and disadvantages of these types of contracts are listed in Table 6:

* POSSIBLE CONTRACTS INCLUDE:

1. Access Main Excavator
2. Emplacement Drift Excavator
3. Drift Commissioning Contractor
4. Electrical Contractor
5. Mechanical Contractor
6. Shaft Excavation Contractor
7. Construction Services Contractor
(ie ventilation, sanitary,
transportation or utilities)

FIGURE 7-36
ORGANIZATIONAL STRUCTURE

Table 6
Advantages and Disadvantages of Fixed Price and Cost Plus Contracts (Ref. 5.18, p. 58-68)

Fixed Price Contracts	
<i>Advantages</i>	<i>Disadvantages</i>
<ul style="list-style-type: none"> • Maximum price competition • Incentive for lowering costs • Reasonable assurance of cost control • Reduced contract formation time • Consistency with FAR, DEAR*, and industry practice • Conventional and relatively simple contractual instrument • Final cost more nearly predictable 	<ul style="list-style-type: none"> • Contractors may bid low to secure job - then attempt to make extensive claims for changed conditions • Potential overextension of contractor resources • Contractor motivated to provide minimum effort bidding • Detailed plans and specifications required before bidding • Probably greatest elapsed time for design and construction • Reduces flexibility to accommodate innovations in design and construction • Claim costs can increase total price substantially

*Federal Acquisition Regulations, Department of Energy Acquisition Regulations

Cost Plus Contracts	
<i>Advantages</i>	<i>Disadvantages</i>
<ul style="list-style-type: none"> • Encourages contractor ingenuity and innovation • Reduces potential for adversarial relationships • No incentive for contractor to cut corners • Generally deemed appropriate for projects without precedent in size, design, or site • Forces better consideration of contractor • Construction contract can be formed based on incomplete design 	<ul style="list-style-type: none"> • Substantial contract administration resources required • Evaluation and selection of contractors can be difficult • More difficult to control costs • Some procurement regulatory constraints (e.g., cost and pricing data qualification analysis) • Definition of cost elements may lead to disputes • Negotiation costs for contractors and repository construction manager • Lengthy negotiation time • Will require broader range of skills and experience in repository construction manager • Not traditional in tunneling industry

The unprecedented site investigation which is currently taking place will help to define the geologic formations which must be excavated to construct the repository - thus reducing the risk of unknown conditions. The design process will take five or more years prior to construction and thus the design should be nearly complete prior to the start of excavation. A process of pre-screening the bidders

for financial and technical strengths will help to reduce the risk that the bidders will submit poor or incomplete bids.

Since the scope and geology will be well defined for the repository, the preferred contracting method is fixed price. However, to be successful this recommendation needs to have other important areas defined and implemented.

An important area to be defined is risk. Particularly how will risk be allocated between the DOE, repository construction management and the construction contractor. The contractor should not be required to accept all risk as the contingencies allocated to cover all risks will greatly increase the bid price. The Department of Energy (DOE) could accept all risks associated with changed site conditions - that is, a comprehensive statement that geologic conditions will not be different than those stated in the site conditions report. In addition the DOE could accept all price increases due to inflation (i.e. wage increases). Since construction will take place over a number of years there will probably be inflationary increases. Because the DOE has covered these increases, the contractors will not have to include contingency amounts in their bids for these items. This should produce lower overall bids for the project.

Repository construction management needs to define a mechanism for resolving contractor questions and for settling disputes between all the parties in a timely fashion. A high level committee should be set up to handle questions or concerns from any party on the project. This committee should be composed of all parties and chaired by the repository Construction Manager. Participation in the committee by DOE is recommended. A Disputes Review Board (DRB) could be set up to handle disputes (Ref. 5.36, page 470). The Board may be composed of three members. One member is chosen by the contractor, one member is chosen by DOE and both these members choose a third member to act as chairman.

The number and type of contracts is expected to change as the project progresses. For example, during the Construction Period (2005-2009), shaft and access main construction contractors will be needed and they will become unnecessary during development (2010+). Some consideration needs to be given as to the relationship between the contractors and the scope of work which they will perform- that is how will the work be packaged.

During Construction it would be prudent to have the access main excavation contractor construct an initial group of emplacement drifts (perhaps six). This will reduce the possibility of interference between the TBMs constructing the main and the emplacement drifts. The access main contractor may also be responsible for:

-
- Finishing and commissioning the initial group of emplacement drifts
 - Cast-in-place concrete lining
 - Muck removal (conveyor operations)
 - Operation of the precast concrete plant
 - Construction utility installation

Shaft construction could also be included in this contract because of the close coordination necessary between shaft and access main construction. The remainder of the construction work could be distributed among one or more contractors.

During Development one contractor could be responsible for all functions. Since the vast majority of the Development work will be associated with driving the emplacement drifts and the remaining contract work is small in comparison - it would simplify the contracting procedure to award all work to one contractor. The work could be planned and scheduled in packages of 5-20 emplacement drifts. This allows flexibility for the DOE to set the pace of completion of the repository. Economic, budgetary or political pressures may require a faster or slower pace of construction.

The construction contracts will be packaged to attract large and medium-sized contractors. Goals for women-owned, minority or small business participation can be contained in the contract documents.

7.15 SCHEDULE RISKS VERSUS CONSTRUCTION SCHEME

This section will explore the schedule risks inherent in the choice of a particular construction scheme. The first major schedule choice for the underground portion of the repository is whether to use one or two TBMs. Using one TBM will produce a linear schedule which is vulnerable to stoppages or delay if problems are encountered. Using two TBMs reduces the risk that the entire project will be delayed because of the breakdown of one machine.

Using two 7.62m diameter TBMs is not necessarily desirable in all cases. In order for the repository to operate, both surface and subsurface facilities must be completed. With two TBMs it is possible to complete the underground portion of the project too far in advance of the surface work. Therefore, the subsurface portion of the repository would be idle until the surface facilities were completed. Using two TBMs will also cause a severe peak in the requirements for personnel and funding during the construction period. This is not necessarily desirable from a project management point of view.

The choice of secondary excavation (roadheader or Drill-and-blast) should also be of concern. Operational experience with the Dosco Roadheader has been limited and so actual production rates

may be quite different than those anticipated. Drilling and blasting can be accomplished in most excavation situations but it has limitations as discussed in Section 7.3.4. These limitations prevent the use of drilling and blasting for all secondary excavations.

There are three basic ways or methods to reduce the risk of failure in a construction scheme or schedule. Schedule failure is taken to mean that an activity takes longer than anticipated. The first method sets a low production rate - a rate which can usually be beaten by the construction crews. The second method involves creating an activity called "schedule contingency". This activity sets aside a block of time to be used in the event of delays or other unforeseen occurrence. The last method provides sufficient redundancy in personnel and equipment that no activity or combination of circumstances will delay the project.

On this project a combination of all three methods should be used. The TBM advance rate could be modified by allowances for assembly, disassembly, launching, and maintenance. The creation of a "schedule contingency" is usually reserved for high levels of management and an allowance has been made for this activity in the current schedule. A value of 6 months to a year for this activity is not unreasonable for a repository which is in essence a large tunneling project. Redundancy in personnel can be achieved by having more than one shift and keeping all shifts fully manned. Redundancy in equipment can be achieved by purchasing additional equipment as spares or making an arrangement with the TBM manufacture to keep a selected list of spare parts available within a short period of time.

7.16 IMPACT OF UTILITIES ON THE START OF CONSTRUCTION

Planning, designing, and building utility infrastructure generally takes long periods of time. The repository Manager must ensure that adequate utilities are available so that the proposed schedule is not impacted. Table 7 shows the current utility capacities of the Exploratory Studies Facilities (ESF) and future needs.

Table 7
Utilities - Current ESF Capacities and Future Needs

Utility	Current Capacity	Needed in 2005	Needed in 2007
Electrical	10,000 kVA ¹	14,495 kVA ⁵	23,150 kVA ⁵
Water	600 gpm ²	50 gpm ⁶	170 gpm ⁶
Air	4,095 cfm @ 125 psia ³	4,400 cfm ⁷	4,730 cfm ⁷
Waste Water	665 gpm ⁴	50 gpm ⁶	170 gpm ⁶

Notes: 1) 4.1.5 2) 4.1.6 3) 4.1.7 4) 4.1.8 5) 4.1.9 6) 4.1.10 7) 4.1.11

Table 12 illustrates that the present capacity for electrical power and air will be exceeded by construction demands for these utilities. The demand for air can be solved by the addition of a fourth air compressor to join the existing three. The shortfall in electrical power is not so easily solved because of the number of parties involved and the long lead time required.

The Department of Energy, Maintenance & Operating Contractor, Nevada Power, the Nevada Test Site, and possibly Valley Power will be involved in the discussion to supply power to the repository. The engineering studies which will form the basis of the discussions are scheduled to be performed in FY99 and will take one and a half years to be accomplished. Permitting and securing rights of way may take up to two years. Changes to the existing substation on the Nevada Test Site, necessary upgrading of the transmission lines, and installation of additional transmission lines from the substation to the repository may take two and a half years (CRWMS M&O e-mail, J. Hilton to J. Clark, MOL.19980825.0194, 06/11/98). When the time to accomplish the items mentioned above is considered it is possible that enough electrical power will not be available when required by the schedule.

7.17 SURFACE FACILITIES TO SUPPORT UNDERGROUND WORK

As shown in Figure 7-37, there will be an extensive facility at the South Portal to support the underground work. This facility will be designed to promote the efficient transportation of men and material through the portal to the repository.

The justification for the location and type of facilities at the South Portal will be performed in another analysis. A general description of these facilities is given below.

Rail transportation will be used extensively underground (4.3.4) and therefore surface facilities must be provided for support of this transportation method. Facilities such as rail shops, locomotive and railcar repair shop, and battery charging station are provided.

Precast segments will be used for the emplacement drifts (4.3.17) and therefore a precast yard for their production will be needed. This precast yard will include: segment storage area, batch plant, segment forming area, material storage areas, and a steam plant (for segment curing).

Utilities for the development side of the repository via the South Portal. These utilities and their surface facilities are:

- electrical power - electrical switchgear
- water service - water tanks
- air service - compressor
- waste water - water retention pond

Several other surface facilities are directly supportive of the underground workers. These facilities include restrooms, lunchroom, change house, lamp house, and office.

8. CONCLUSIONS

8.1 Excavation Methods Description

8.1.1 Primary Excavations - 7.62 m Diameter

Primary excavations (7.62 m diameter) include the South Ramp Extension, West Main, North Main, East Main North Extension, North Ramp Extension, and the Exhaust Main. These drifts will be excavated by a 7.62 m diameter TBM that will be comprised of a cutterhead, ground support and propulsion systems, ventilation and dust control systems, operators console and trailing gear. The TBM will be required to excavate horizontal curves of minimum 305 m radius to facilitate conveyor haulage, and tunnel gradients of up to approximately $\pm 3\%$ for rail haulage. The material excavated will primarily be the TSw2 formation which has an unconfined compressive strength of 155 Mpa $\pm$ 59 Mpa. The TBM will be designed for installing temporary ground support that includes rockbolts, rolled steel ribs and shotcrete, and must be capable of placing invert segments. The machine will also be designed for mining through existing circular excavations up to 5.5 m in diameter. The trailing gear containing utility and power systems will be detachable to facilitate moving the machine between underground work places. One or two TBMs can be used depending upon schedule requirements.

The proposed excavation rate for the 7.62 m diameter TBM is 35 m/day. The baseline schedule reflects this rate but includes adjustments for TBM assembly, disassembly, launching, and maintenance requirements.

8.1.2 Primary Excavations - 5.5 m Diameter

Primary excavations (5.5 m diameter) include all emplacement drifts and performance confirmation drifts. The drifts will be excavated by 5.5 m TBM(s) that will be comprised of a cutterhead, ground support and propulsion systems, ventilation and dust control systems, operators console and trailing gear. The TBM will be launched from 8 m wide by 7 m high turnouts. The TBM will be designed to load the muck into Granby style railcars. A segment erector located behind the TBM shield will be used for installing precast concrete segments or rolled steel ribs. The material excavated will be mainly in the TSw2 formation which has unconfined compressive strength of 155 Mpa $\pm$ 59 Mpa. When an emplacement drift excavation is completed, the trailing gear will be detached and the TBM partially disassembled and backed up through the emplacement drift to the East Main for re-launch.

The proposed excavation rate for the 5.5 m diameter TBM is 30 m/day. The baseline schedule reflects this rate but includes adjustments for TBM assembly, disassembly, launching, and maintenance requirements.

8.1.3 Secondary Excavations

Secondary excavations include the TBM Assembly/Disassembly Chambers, TBM Launch Drifts, shaft bottom access drifts, alcoves and emplacement drift turnouts. These drifts will be excavated by a Roadheader such as a DOSCO Model TTM100. The estimated excavation rate is 15 m³/operating hour.

8.1.4 Drill-and-Blast Excavation

Drill-and-blast excavation will be used to deepen the Emplacement and Development Shafts. Drilling and blasting can be used to excavate the initial portion of the emplacement drift turnouts.

8.1.5 Shaft Excavation

The Emplacement and Development Shafts will be 6.7 m in diameter. To excavate a shaft of this size by mechanical methods a three stage process will be used: (1) pilot hole drilled down; (2) upward backream and (3) downward bore. A raise drill machine will be used to perform stages 1 and 2, and a vertical boring machine will be used to perform stage 3.

8.1.6 Raise Boring - Ventilation Raises

The 2.0 m diameter ventilation raises that will connect the Emplacement Drifts with the Exhaust Main will be excavated by a raise drill from the emplacement drift in two stages: (1) pilot hole drilled down and (2) upward backream. A rail mounted raise drill machine operating from the emplacement drifts will be used to perform both stages. Muck will be removed through the Exhaust Main by railcars.

8.2 Muck/Material Handling Systems

8.2.1 Conveyor Belt/Dump Station

Conveyor belts will be used to transport muck from the underground to the surface. Conveyor flight no. 1 will be located in the South Ramp and will receive muck from

the 7.62 m TBM driving the Mains. Conveyor flight no. 2 will be located in the Exhaust Main and will transfer muck from the TBM driving the Exhaust Main onto conveyor flight no. 1 for transportation to surface. Conveyor flight no. 1A will be located in the South Ramp and will extend into the East Main to support emplacement drift construction.

A conveyor belt dump station located in the East Main will be used to load muck from Granby style railcars onto conveyor flight 1A. The dump station will include a hopper, a chain conveyor and a transfer chute. The hopper will receive muck discharged from railcars and the chain conveyor will withdraw muck from the hopper at a controlled rate and discharge it onto the conveyor belt. The conveyor belt dump station will be relocated as required to maintain short train hauls.

8.2.2 Locomotive Haulage

Locomotive haulage will be used for transporting excavated muck, people, equipment and supplies within the underground areas. The haulage locomotives will be combination trolley/battery units that will operate on 910 mm gauge tracks. Several types of rolling stock will be used for performing the various haulage functions. The muck haulage railcars will be hydraulic operated side dump models with a 6 m³ capacity. Flatbed models will be used for transporting supplies. A canopy equipped model with benches will be used for transporting people. Concrete mixer units will be used for transporting concrete between the batch plant and underground.

8.2.3 Shuttlecars

Shuttlecars will be used for hauling muck produced by the roadheader and shaft excavation machines. The shuttlecar will be an electrically powered, rubber-tired, articulated machine that is comprised of three or more linked modules including a power module at the feed end, one or more cargo modules in the middle and an elevating bed module at the discharge end. Each module has a capacity of 11 m³ or 34 m³ for a three module shuttlecar. The shuttlecar presented in this design analysis, Reference 5.16, could be modified to enable it to load the muck cars presented in Attachment IV.

8.2.4 Continuous Haulage Equipment

Continuous haulage equipment can replace shuttlecars in certain instances. The

continuous haulage equipment will be tracked and consist of a bridge carrier and bridge conveyor units.

8.3 Rail Systems

Rail Systems will support the construction, development and emplacement phases over the life of the repository. Two separate rail systems will be used - the construction rail system will support repository construction and development and the emplacement rail system will support repository emplacement operations. The construction rail system will include mainline track in the South Ramp and branch tracks in the East Main, Exhaust Main and West Main. Construction and emplacement rail systems will include tracks in each emplacement drift turnout and PC drift. The emplacement rail system will include mainline track in the North Ramp and branch tracks in the East Main, Exhaust Main and West Main. During the development phase, as repository emplacement panels are completed, sections of the construction rail system will be removed and replaced by the emplacement rail system.

8.3.1 Construction Rail System

The East Main branch will extend from the end of the South Ramp mainline track through the East Main and North Ramp to the North Portal on the surface. The West Main branch will extend from the end of the mainline track through the South Ramp Extension, West Main, and North Main to the East Main-North Extension intersection with the East Main. The construction rail system will include two parallel sets of 42 kg/m rail anchored to steel ties on 915 mm gauge. In the East and West Main branches switches and tracks will be installed into each emplacement drift turnout. In the North ramp a switch and track will be installed into no.1 PC drift; in the South Ramp a switch and track will be installed in the PC Main.

The West Main branch will support TBM excavation of the Mains. After the TBM is relocated from the East Main-North Extension, the West Main branch will be connected to the East Main branch to form a loop. The Exhaust Main branch will extend from the West Main branch in the South Ramp Extension through the Exhaust Main to the North Main where it will rejoin the West Main branch.

8.3.2 Emplacement Rail System

The East Main branch will extend from the end of the North Ramp mainline track through the curve into the East Main. From this point the track will extend to the south in the East Main and to the north in the East Main-North Extension. The West

Main branch will extend from the end of the mainline track through the curve to the North Ramp Extension. From this point the track will extend to the west in the North Main and to the south in the West Main. The construction tracks are too light to support the heavy loads required for repository emplacement operations. Therefore, the construction rail system will be removed and replaced by a much heavier emplacement rail system. During the initial phases of emplacement operations the emplacement panels along the East Main-North Extension will be accessed through the West Main branch. The connecting track between the East Main and the North Ramp will be activated when Panel 3 is commissioned.

The Exhaust Main Branch will provide rail access to the ventilation equipment and structures located near the Emplacement Exhaust Shaft and in the Exhaust Main.

8.4 Ground Support Systems

Temporary and permanent ground support systems will be used for repository construction. The selection of a ground support system will depend on several factors including the design documents, mapping requirements, actual ground conditions and worker safety. Permanent ground support will be installed in all openings. However, in some locations the initial support will be temporary and will be followed by permanent support.

8.4.1 Temporary Ground Support

Temporary ground support systems include pattern rock bolting, rolled steel ribs and lagging and shotcrete. Types of rock bolts and plates used to provide temporary ground support include Split Sets, Standard Swellex or Super Swellex. Accessories include roof mats, welded wire fabric, rolled steel channels and interlocking mesh. Rolled steel ribs include W6x20 or W8x30 that will extend in a partial circle from the edges of the invert segment in horizontal openings and full circle in shafts. "C" Channel lagging, partial or full, will span the opening between ribs. Temporary ground support will be installed in mains, drifts, and shafts.

8.4.2 Permanent Ground Support - Emplacement Drifts

Permanent ground support will be installed in the emplacement drifts. Types of ground support include precast concrete segments, rolled steel ribs with full lagging or cast-in-place concrete. Precast concrete segments or rolled steel ribs will be installed behind the TBM shield. The cast-in-place concrete lining will require two passes to install - temporary ground support will be installed on the TBM advance,

and the cast-in-place concrete lining will be placed when excavation is completed and the TBM support equipment has been removed.

8.4.3 Permanent Ground Support - Development Drifts/Shafts

A cast-in-place concrete lining was chosen as the basis of this analysis for installation in all repository development drifts and shafts to provide permanent support.

8.5 Repository Construction

Several sections of the analysis detail how portions of the repository could be constructed. This analysis describes one way in which the repository could be constructed but no recommendation is made as to exactly how the construction work should progress nor the order in which it should proceed. Construction is broken into phases to better observe the relationships between the tasks.

However, a recommendation is made regarding commissioning. There must be an agreement between the emplacement and development sides of the repository as to exactly what each side will accomplish in order to complete an emplacement drift or access main.

8.6 Ventilation System

Ventilation will be provided to all areas of the repository. The ventilation will be adequate for both personnel and equipment.

8.7 Utility Installation and Removal

Utilities will have to be installed and removed several times as the project progresses. The emplacement and development sides of the repository will have separate systems with different capacities and demands. The installation and removal of utilities will need to be planned so that it supports the construction work rather than hinders its completion.

8.8 Construction Health and Safety

Safety and health protection systems will be provided as required by regulation and in keeping with the best construction practices.

8.9 Contract Structure

Lump sum contracts are recommended for use in constructing the repository. The highly detailed geologic and engineering design information which will be available to potential contractors should reduce the construction risk for parties. Risk should be shared between all parties as this will reduce the overall cost of the repository. A high level committee should be formed to resolve construction questions and a Disputes Review Board should be formed to handle disputes which may occur. The use of one main contractor during construction and development is recommended.

8.10 Schedule Risk

Inherent in any construction scheme is the risk that the construction task will not be completed in the time allowed. In order to reduce this risk three strategies can be pursued; set a low production rate, include schedule contingency, and provide redundancy in personnel and equipment. This analysis recommends all three methods be used.

8.11 Utility Impacts on the Start of Construction

Insufficient supply is estimated to occur for the electrical power and air supply utilities. The shortfall in air supply could be corrected by the addition of an additional air compressor. The shortfall in electrical supply will be more complex to solve. The number of parties involved in the discussion and the long lead time required to actually provide power to the repository make this a potential problem for the repository construction team.

9. ATTACHMENTS

Attachment I (2 Pages):	ET 150 Roadheader
Attachment II (12 pages):	Belt Conveyors
Attachment III (2 pages):	Locomotive
Attachment IV (3 pages):	Muck Car
Attachment V (3 pages):	Personnel Railcar & Flatcar
Attachment VI (4 pages):	Concrete Mixer Car
Attachment VII (2 Pages):	PC Drift Trimming Times
Attachment VIII (5 pages):	Continuous Haulage Literature
Attachment IX (5 pages):	7.62m Diameter TBM Daily Advance Rates
Attachment X (3 pages):	TBM Utilization
Attachment XI (2 pages):	Estimate of Utility Demand

Attachment I - ET 150 Roadheader (Ref. 5.14)
(Used by permission of Atlas Copco, 1998)

AC-E Roadheader
Another Proof of our Modular
Design Technique

The ET 150: for small tunnels, though with an extended reach for extra height requirements

Technical Data AC-EICKHOFF Roadheaders		Machine Type	
		ET 150-Q	ET 150-L
Machine Dimensions:			
Machine length	mm	8.880	8.900
Platform height	mm	1.700	1.700
Machine height	mm	2.430	2.430
Machine width over crawler	mm	1.900	1.900
Width of loading apron	mm	2.100-3.200	2.100-3.200
Ground clearance	mm	175	175
Width of crawler plates	mm	450	450
Machine weight (approx.)	kg	31.000	32.000
Specific ground pressure (approx.)	N/cm ²	16,3	16,3
Application:			
Max. cutting height	mm	4.650	4.800
Max. cutting width	mm	5.850	5.900
Undercut	mm	175	200
Max. cross section from stationary pos.	m ²	24	25
Gradability, dip and rise/transverse	degree	18/18/5	18/18/5
Downfold/upfold radius	m	21/20	21/20
Electric:			
Cutter head power, cont. rating	kW	110	110
Total installed electr. power (approx.)	kW	190	190
Voltage rating	V/Hz	380, 500/50	380, 500/50
Hydraulic drive motor	kW	45	45
Conveyor drive motor	kW	30	30
Closed cooling system	kW	0,6	0,6
Cutter Head:			
Type		transverse	in-line
Diameter	mm	750	750/1000
Rotation speed	rpm	76	51
Cutting speed	m/s	3,0	2,0/2,7
General Data:			
Travelling speed	m/min	0 - 5	0 - 5
Traction force	kN	2 x 150	2 x 150
Conveyor throat	mm	640 x 400	640 x 400
Conveyor capacity	m ³ /h	300	300
Max. operating hydraulic pressure	MPa	14	14
Tank capacity	l	300	300

Options

- cutter heads of in-line or transverse type
- power controls: direct hydraulic, pilot hydraulic or electric
- remote control: umbilical or radio
- profile and directional control with monitor, microprocessor and scanner laser beams
- diagnostic monitor
- water-spray system externally or with pick-track spraying
- flame-proof electrics and hydraulics
- voltage and frequency as required
- closed or open cooling system
- hydraulic rotary or percussive drill/bolter on board
- discharge conveyors to adjust to transport requirements
- diesel hydraulic drive motor for crawler
- loading system of gathering arm or disc type
- support setting device for arches and frames on board
- dust collector
- dust extraction ducts

AC-Eickhoff reserves the right to alter specifications without prior notice.

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Attachment II - Belt Conveyors (Ref. 5.7 & 5.8)

(Used by permission of Continental Conveyor & Equipment Co., 1998 and Long-Airdox, 1998)

TBM Trailing Conveyor Provides Muck Haulage Advantages for 35' Diameter, 6.86 Mile Tunnel

Some information may be obliterated or obscured, but has no affect on the information or conclusions contained in this analysis.

Conveyor System Reduces Labor and Ventilation Costs

TBM Trailing Conveyor Provides Muck Haulage Advantages for 35' Diameter, 6.86 Mile Tunnel

The Continental conveyor system "trails," or moves continuously with the TBM, allowing uninterrupted muck haulage.

Chicago's \$3.7 billion tunnel and reservoir plan (TARP) is already a history-making operation. TARP is designed to control pollution and flooding in the Chicago area in a two phase program. It was begun in 1976 and will continue through the 1990's. Phase I is currently under construction 250-300 feet beneath the streets of Chicago. Tunnel boring

machines (TBMs) are creating 109 miles of tunnels that will have finished diameters ranging from 9 to 33 feet. These tunnels will collect and hold up to a billion gallons of stormwater and sewer overflow from a 375 square mile area, which will allow a controlled flow to be sent to sewage treatment systems for appropriate wastewater treatment.

TARP is the largest hard rock bore in history, and the cost effectiveness of methods used to haul the bored-out rock, or "muck," is a crucial factor in whether the 20 or so contracts for TARP tunnel construction will represent a profit or loss for the companies involved.

"It was no problem to install the conveyor while we were advancing around the curves," Tom Martin, Morrison-Knudsen, Project Manager.

Entire Conveyor System Supplied By Continental Conveyor

Morrison-Knudsen of Boise, Idaho, has been involved in four TARP contracts, one of which is the \$156 million 59th Street to Cernak Road section. It is a five year project to bore 6.86 miles of tunnel, most to a diameter of 35 feet 4 inches, and then finish the tunnel with concrete to a diameter of 33 feet. They are using a \$10 million Robbins hard rock TBM followed by a 36" trailing conveyor system that can move muck at 1200 tons an hour at a speed of 675 feet per minute. The total length of the horizontal conveyor will eventually be made up of three flights, with a belt take-up unit in each one, and a belt storage unit in the flight closest to the TBM. That allows the conveyor to continuously lengthen, following the advance of the TBM and continuously convey the muck as it is bored out of the rock. The entire horizontal conveyor system was supplied by Continental.

Having a dependable conveyor system is crucial when you have a multimillion dollar TBM depending on it to advance. With the tunnel roughly half complete, the Continental system has proved itself. Morrison-Knudsen Project Manager Tom Martin explains: "I think the Continental conveyor we are using is

a good system. It's an easy system to install. It can be advanced without delaying the mining, and that is extremely important. I think it is adaptable—we could take what we have now and add to it or subtract from it for other tunnels. That is very important.

"One of the major reasons that conveyors are cost effective is that it allows you to lower the cost of ventilation due to reduced or eliminated diesel exhaust. In the big tunnels we used the same locomotive we used in the smaller ones—little 8 ton locomotives. If we used muck cars, those wouldn't be big enough. We'd have to go to at least 20 ton diesels.

"Conveyors also save labor—it certainly saved some labor in our case. If we had to go back to conventional haulage, we would have to add about five to six people a shift; instead we needed only one.

"The muck is dolomitic limestone, about 170 pounds per cubic foot in situ, and about 85 pounds per cubic foot as transported on the belt. It is approximately 30 percent 3 inch minus chunks, 30 percent one inch minus chunks and about 40 percent real fine material, like sand. Generally, our rate of advance is about 94 feet a day.

"When we hit wet places, it doesn't really cause any problem. It just means that the TBM buckets

A Tunneling Professional's Perspective On Conveyors

Project manager Tom Martin has been in the tunneling business since 1964. Mr. Martin is a widely known and respected tunneling professional, and is frequently quoted in tunneling articles. He has witnessed the upsurge of conveyor usage in his career. "From my experience in tunneling in America, I know that conveyor usage has steadily increased. I remember one of the first tunnel conveyors I knew of in the early 1980's out in the test range in Nevada. It was very successful, so we felt the procedure was there, that it could work," recalls Mr. Martin. "Then I was operations manager over another job in Atlanta in 1983 called Entrenchment Creek and we used a conveyor system on that job even though it had two curves in it; a 3000 foot radius curve and a 1000 foot radius curve. We felt from watching that job that the number of people it took to maintain and run the conveyor system was significantly lower than the number of people it would have taken to run diesel equipment and the trains. I knew then that tunnel conveyors were going to catch on. I think if you have a good job and people come to see it, then the people start to duplicate it.

"Besides saving money, I think conveyor systems are safer. I would say that the potential for accidents with a conveyor system is less. Compared to people hooking and unhooking the trains, it's certainly safer than that.

"Conveyor technology is well understood. I think they are environmentally acceptable—they certainly don't pollute the tunnel. I think that's important. And you don't have to buy an entire system at once if you don't want to—you can get parts of it now and add to it later. Muck haulage using a conveyor makes sense and I think you're going to see more of it. In fact, I know of two tunnels that are currently getting underway, and both are going to use conveyors. Morrison-Knudsen has already used conveyors on five tunneling projects, with total mined footage exceeding twenty miles. That's a pretty good indication that the construction industry at least has recognized why mining operations have been doing it for years—that moving large amounts of materials can best be done with conveyors."

would pick it up and dump it on the conveyor, and we'd have wet material on the conveyor. It doesn't make too much difference. We had very little problem with belt cleaning with the Continental system. The TBM is not limited by the conveyor's capacity."

Not only did the conveyor system have wet material to contend with as it was continually being advanced, but it had to do so around curves. "It was no problem to install the conveyor while we were advancing around the curves," states Mr. Martin.

Maintenance and repair has also proved itself on the Continental system. Mr. Martin explains: "The drives are performing well, and we have only had a few idlers wear out; it didn't strike me as being excessive.

"For regular maintenance, it doesn't take any special skills or tools. Changing out an idler is easy, very easy. All you need is a spud wrench, which is a crescent wrench with a tail on it, like a rat tail. It doesn't take anything at all. They just unclamp the holders and lift it out and put another one in. I would estimate you only need a couple of man hours a shift to devote to inspection and maintenance."

The belt storage unit allows the conveyor to continuously lengthen, following the advance of the TBM.

Conveyor System Does Double Duty

Another reason Mr. Martin likes the conveyor system used in this contract is a special option that Continental designed into it: "We're planning to use the conveyor to bring in wet concrete to line the second half of the tunnel. We need the belt for the muck, so we can't use it for the concrete until we get to about the middle of the tunnel, then we'll switch over and try the conveyor for the last half," states Mr. Martin. "Being able to haul the wet concrete in with the same conveyor system adds another layer of cost effectiveness—that's why we are going to try it. And since concrete hauling was part of the original design, it only adds a few percent of extra cost to the system—less than five percent certainly."

After The Contract Is Complete, Continental Value Continues To Pay Dividends

One concern among leading tunneling contractors is the value they have left in a conveyor system after the job is finished. Recently a random survey of used mining equipment re-sellers was conducted, and they were asked the following question: "Which used conveyor

equipment brings the highest price?" In every response, Continental was ranked either first or second out of the eight leading conveyor manufacturers in North America. "I don't think there is any problem starting another job with a conveyor system that's been used on a previous one. We've got one conveyor system with part of it now on the third job," says Mr. Martin.

One reason Continental can provide such a valuable product to the tunneling industry is their 40 years of working with the mining industry, providing mine duty equipment and service. And since tunneling operations are extremely similar to mining operations, mining experience brings a big plus to a tunneling operation. Mr. Martin agrees: "I think there is technology and knowledge in the mining industry that could be helpful if transferred to the tunneling industry, such as conveyor haulage concepts. They've been using them in mining for years. We think there are technologies developed underground that would help other underground operations, like tunneling. I suspect there's all kinds of better equipment available from mining technology."

TARP service area, which serves Chicago and 15 suburbs.

CONTINENTAL CONVEYOR & EQUIPMENT COMPANY
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Some information may be obliterated or obscured, but has no affect on the information or conclusions contained in this analysis.

Attention tunneling contractors:

Your lowest cost and most reliable muck hauling option: Continental Conveyor and their complete range of conveyor system technology

Your single source for muck haulage from TBM to surface

Continental Conveyor has been manufacturing North America's heaviest duty and longest lasting conveyor equipment and conveyor systems for over 50 years. They have developed a solid reputation as the leading underground haulage experts.

You can rely on them to provide you with all the muck haulage equipment you need for your tunneling job, including a TBM trailing tail section, powerful drives, a heavy-duty conveyor that negotiates curves, belt storage units allowing the conveyor to extend with a TBM, booster drives that allow uninterrupted single flights that are miles in length, and the world's most efficient vertical haulage system.

Curving conveyors are standard equipment

Continental has proven curving conveyor technology that negotiates curves with a radius as tight as a 1000 feet (305 meters). The curving conveyor sections can be installed at rates matching the fastest advances and without stopping the belt or in any way interrupting muck flow. Adjustments to the belt position are simple and do not require any special tools or training.

The world's most efficient design for vertical haulage

Continental's High Angle Conveyor (HAC®) is proven the world over as the most efficient vertical haulage system. It uses the same standard conveyor components as the horizontal belt. The HAC sandwiches the muck between two conveyor belts that move the muck at the same rate as the horizontal belt. Single-run lifts beyond 1000 feet (305 meters) are possible with standard fabric belts and much higher single run lifts are possible with steel cord or aramid fiber belts.

Single flights that are miles in length

When appropriate, using a single long flight instead of several shorter flights is another haulage option Continental can offer you. By using their specially designed booster drives to help power a longer flight, Continental can create flights that are miles in length from TBM to the vertical haulage conveyor.

The ability to install longer sections has been important to contractors who have found that single flights eliminate both the spillage and extra belt wear that occur at transfer points.

Long-life, heavy-duty conveyor system can be re-used or sold

One concern among tunneling contractors is the value they have left in a conveyor system after the

job is finished. Recently, a random survey of used mining equipment re-sellers in North America was conducted. They were asked the following question: "Which used equipment brings the highest price?" In every response, Continental's equipment was ranked first or second out of the eight leading conveyor manufacturers in North America.

TBM trailing conveyor provides muck haulage advantages for 35 foot diameter (10.7 meter), 6.86 mile (11 kilo- meter) long tunnel

Continental has supplied a conveyor system to the tunneling contracting firm Morrison-Knudsen of Boise, Idaho, for their section of the \$3.7 billion tunnel and reservoir plan (TARP) project in Chicago, Illinois.

The project manager for Morrison-Knudsen, Mr. Tom Martin, comments on the Continental system: "I think the Continental conveyor we are using is a good system. It's an easy system to install. It can be advanced without delaying the mining, and that is extremely important. I think it is adaptable — we could take what we have now and add to it or subtract from it for other tunnels. That is very important."

Your one-source haulage solution

Continental Conveyor & Equipment Company is your most comprehensive source for muck haulage. Continental equipment can take the muck from the TBM and without interruption put it on a surface conveyor or truck. To accomplish this important task, Continental provides a selection of

proven tunneling equipment; but more importantly, Continental provides the *site-specific* engineering that makes the entire system operate smoothly and efficiently for the duration of your project. Continental is in the unique position to apply over *five decades* of underground conveying

experience to each tunneling project. One benefit of this experience is that Continental is equipped with dynamic and predictive analysis tools that can actually provide you a view of the operating parameters of your customized Continental conveyor system before it is installed.

Trailing tail section has ample room for idler installation

Ample room is provided in the Continental trailing tail section so that vital idler installation can progress efficiently. The tail section is specifically engineered to smooth the transition from TBM to horizontal conveyor. Of course, it can be provided (along with all other appropriate trailing gear) to meet the requirements of any TBM.

Heavy-duty conveyor components add value

Continental conveyor components are engineered to withstand the harsh demands of underground haulage applications. The bearing, seal and shaft arrangements in Continental idlers have consistently surpassed other manufacturer's designs in certified tests. Many of the strength and design advantages can be clearly seen by simply looking at Continental equipment next to other manufacturers'. The heavy-duty design of Continental equipment is also demonstrated in the marketplace for used conveyors — where Continental equipment has a consistently strong demand due to superior equipment quality and very low depreciation rate.

Curving sections that are easy on the belt

As you know, it is better to "train" a conveyor belt around curves than to force a belt into position. And that is why all Continental curving sections consist of individually adjustable troughing idlers. In this way, the proper belt position can be specifically engineered and adjusted to fit different curving sections properly. These idler positions are specified in the engineering phase to insure quick start-up and trouble-free operation.

Belt storage units proven in the toughest underground applications

Continental belt storage units are famous for their single carriage design which permits the use of automatic drop carriage assemblies, which have been proven in the toughest underground applications. Also, the stationary pulley section concept used on Continental systems eliminates fifteen moving parts commonly found on typical units — thus adding to inherent durability and reliability. The high performance Constant Tension Winch or standard winch units manufactured by Continental are

custom engineered to meet your particular requirements.

Fully-engineered booster drive systems

Booster drives can solve many tunneling problems; however, they are intolerant of "guess-work" or rough estimations. That's why Continental uses the industry's most sophisticated engineering techniques and dynamic analysis tools to avoid costly unscheduled downtime. Continental is one of the pioneers of booster drive technology and your system will benefit from application experience which has been consistently building since the early 1970's.

The vertical haulage leader

In the early 1980's Continental developed the high angle conveying system known today as the HAC. Experience has proven it to be ideally suited for the types of materials typically generated by TBM's, no matter what the water content. Also, the HAC's unique design employs standard conveyor components and belting, which makes the transfer from the horizontal conveyor simple and trouble-free, especially when compared to traditional vertical haulage methods that have been used in the past.

**CONTINENTAL CONVEYOR
& EQUIPMENT COMPANY**

P.O. Box 400 • Winfield, AL 35594 • 205/487-6492
FAX: 205/487-4233 • TELEX: 89769

A NESCO COMPANY

Ample room is provided in the Continental TBM trailing tail section, so that vital idler installation operation can progress efficiently.

Continental conveyor components are engineered to withstand the harsh demands of muck haulage applications.

The curving conveyor sections can be installed at rates matching the fastest advances and without stopping the belt or in any way interrupting muck flow.

Continental belt storage units use a single carriage design which permits the use of automatic drop carriage assemblies.

By using specially designed booster drives, Continental can create flights that are miles in length from TBM to the vertical haulage conveyor.

The HAC sandwiches the muck between two conveyor belts that move the muck at the same rate as the horizontal belt.

Some information may be obliterated or obscured, but has no affect on the information or conclusions contained in this analysis.

LONG-AIRDOX®

Belt Conveyor Systems: Belt Storage Units

Some information may be obliterated or obscured, but has no affect on the information or conclusions contained in this analysis.

BELT STORAGE UNITS—APPLICATIONS

Make Your Longwalls More Productive

Long-Airbox "stage loading" systems are materially assisting longwall operators in achieving record production figures. This All American conceived and manufactured system consists of three separate, yet complementary, units: a chain-type transfer conveyor (or stage loader), a crawler-mounted tailpiece and a belt storage & take-up section. Designed to handle longwall output up to 20 tons per minute. (or more, if required), the system is ruggedly constructed for continuous operation without excessive downtime. All units of the system work in concert with each other to move the coal outby from the longwall face in one continuous motion without the necessity of shutting the longwall down, *even to move the belt.*

The belt storage sections automatically store excess belt as the crawler-mounted tailpiece retreats and pay out the belting, as required, if advancing. Three basic design concepts and configurations are available with storage capacities ranging from 300 feet to 500 feet (91.44 m to 152.4 m) of belt. Units have been designed and built to accommodate single ply woven carcass belting, as well as multi-ply belting. Located immediately behind the conveyor drive section, these storage units also provide hydraulic belt tensioning for good conveyor operation.

Long-Airbox Storage sections can be an integral part of the complete Long-Airbox stage loading system, or can be intermixed with other manufacturer's stage loading equipment to help keep the coal flowing from the face.

TYPICAL LONGWALL FACE

Illustrated is the Long-Airbox Transfer Conveyor (or Stage Loader) flexibly attached to the discharge end of the Armored Face Conveyor. The Stage Loader is connected to a dolly on the Long-Airbox Crawler-Mounted Tailpiece. When the face conveyor moves, the Stage Loader and dolly move with it . . . advancing or retreating without stopping the flow of coal. These units can be moved while the coal continues to flow from the face. The Long-Airbox Belt Storage Unit (not illustrated) automatically stores excess belt as the Crawler-Mounted Tailpiece retreats, and pays out the belt if advancing.

The Long-Airbox Super HD 500 Storage Section is illustrated installed immediately behind the belt conveyor drive section, indicating its relationship to the crawler-mounted tailpiece and the chain-type transfer conveyor (or stage loader) in a longwall application.

For complete information on Longwall Stage Loading Equipment, request Bulletin No. 900 from your local Long-Airbox representative, or write Long-Airbox Company, P.O. Box 331, Oak Hill, WV 25901.

Some information may be obliterated or obscured, but has no effect on the information or conclusions contained in this analysis.

BELT STORAGE UNITS

Super Heavy Duty Belt Storage Unit Dimensions and Specifications

		SUPER HEAVY DUTY	
		300	400
Length	Closed Position (Each Half)	25'-0" (7.62 m)	28'-6" (8.69 m)
	Closed Position (Assembled)	50'-0" (15.24 m)	57'-0" (17.37 m)
	Fully Extended	76'-10" (23.42 m)	90'-10" (27.69 m)
Width	36" (91.44 cm) Belt	—	—
	42" (1.07 m) Belt	—	—
	48" (1.22 m) Belt	8'-7 $\frac{3}{4}$ " (2.64 m)	8'-7 $\frac{3}{4}$ " (2.64 m)
Overall Height (Max.)		4'-6" (1.37 m)	4'-6" (1.37 m)
Belt	Width	48" (1.22 m)	48" (1.22 m)
	Ply	Multiple	Multiple
		300' (91.44 m)	400' (121.92 m)
Cluster	Pulley Dia.	16" (40.64 cm)	16" (40.64 cm)
	Bearing Dia.	2 $\frac{1}{8}$ " (7.46 cm)	2 $\frac{1}{8}$ " (7.46 cm)
Type Mount		Skid	Skid
Take-Up Cylinders		4'-6" x 60" (15.24 cm x 1.52 m)	4'-6" x 60" (15.24 cm x 1.52 m)
Power Pack	Motor HP	20	20
	Voltage	460, 575 or 950	460, 575 or 950
	Hydraulic Pressure (Nom.)	1500 PSI (105.47 kg/cm ²)	1500 PSI (105.47 kg/cm ²)
	Tank Capacity	80 Gal. (302.8 Liters)	80 Gal. (302.8 Liters)

BELT STORAGE UNITS

Super Heavy Duty 500 Belt Storage Unit Dimensions and Specifications

HYDRAULIC POWER PACK AND WINCH:

This unit includes the complete hydraulic equipment for operating the take up. These hydraulics include the (a) 5 foot (1.52 m) stroke belt tensioning cylinder, two 25 foot (7.62 m) high pressure hoses for cylinder; (b) 20,000 pound (9072 kg) pull at 40 FPM hydraulic winch with drum clutch, drum brake, and 330 feet (100.58 m) of 5/8 inch (1.59 cm) diameter wire rope; (c) winch motor; (d) pressure switch; (e) accumulator; (f) hydraulic controls; and (g) power take off suitable for use with "Hy-Winder" belt handling station. It is furnished complete with 20 HP electrical equipment. Provision is made for either jacking down or bolting to mine floor.

Optionally available, at extra cost, is a wide flange beam mounting package to replace the customer-furnished rails. This package permits positive hold-down of the pulley clusters during operation.

		SUPER 500 HD	SPECIAL SUPER 500 HD T.M.W.
Length	Closed Position (Each Half)	—	—
	Closed Position (Assembled)	—	—
	Fully Extended	124' (37.80 m)	124' (37.80 m)
Width	36" (91.44 cm) Belt	—	—
	42" (1.07 m) Belt	7'-6 1/2" (2.30 m)	7'-6 1/2" (2.30 m)
	48" (1.22 m) Belt	7'-6 1/2" (2.30 m)	7'-6 1/2" (2.30 m)
Overall Height (Max.)		49 1/4" (1.25 m)	49 1/4" (1.25 m)
Belt	Width	42"-48" (1.07 m—1.22 m)	42"-48" (1.07 m—1.22 m)
	Ply	Multiple	Multiple
	Take-Up Capacity	500' (152.4 m)	500' (152.4 m)
Cluster	Pulley Dia.	16" (40.64 cm)	16" (40.64 cm)
	Bearing Dia.	3 1/8" (10.0 cm)	3 1/8" (10.0 cm)
Type Mount		Rail	Rail
Rail Size		60 lbs. (27.22 kg)	60 lbs. (27.22 kg)
Take-Up Cylinders		1-5" x 60" (12.7 cm x 1.52 m)	1-5" x 60" (12.7 cm x 1.52 m)
Power Pack	Motor HP	20	20
	Voltage	460, 575 or 950	460, 575, or 950
	Hydraulic Pressure (Nom.)	1500 PSI (105.47 kg/cm ²)	1500 PSI (105.47 kg/cm ²)
	Tank Capacity	43 Gal. (162.8 Liters)	80 Gal. (302.8 Liters)
	Winch Pull (Max.)	*40,000 lbs. (18144 kg)	*60,000 lbs. (27216 kg)

*Using 2:1 sheave

Attachment III -Locomotive (Ref. 5.27)
 (Used by permission of Goodman Equipment Corp., 1998)

goodman

20 TON OPERATING WEIGHT BATTERY POWERED LOCOMOTIVE

Spec. No: 20T-188-750-100B

Standard Equipment

Number of Motors	Two
Horsepower Each Motor	60
Operating Voltage	220 volts D.C.
Control System	Full magnetic
Dynamic Braking	Included
Wheels	36" (914 mm) diameter
Brakes	Air, spring set
Axle Journal Bearings	Self aligning, tapered roller
Axle Box	Pedestal type
Warning Signal	Air horn and manual gong
Headlights	Two
Battery Box	Two, lift off type
Sanders	Air operated
Battery Condition Gauge	Electronic LED type
Minimum Turning Radius	60' (18 m)
Track Gauge	750 mm
Minimum Ground Clearance	3.50" (90 mm)

Standard Options

☐ Electronic thyristor control	☐ Automatic battery charger
☐ Automatic couplers, Willison or as specified	☐ Fire extinguisher
	☐ Lifting jack

Operating Characteristics:

For a 20 Ton Battery Locomotive
 equipped with two Type 188 motors
 on a 220 volt battery system,
 36 inch diameter wheels,
 14:81 gear ratio.

Specifications 188 Motor

Horsepower (one hour - 75° C)	60 (45 kw)
Voltage	250
Enclosure	Standard
Continuous current, amperes	87
RPM	400
Speed - 7500 lbs. (33,500 Nts) DBP	7 mph (11 kph)
Motor shell	Solid cast steel
Type of gear case	Sheet and cast steel
Diameter of wheels	36" (914 mm)
Gear Ratio	14:81
Pitch of gearing	3
Face of gearing	3.5" (89 mm)
Minimum gauge	24" (610 mm)
Commutator diameter	16.5" (419 mm)
Commutator face	3.09" (79 mm)
Number of brush holders (radially adjustable)	2
Brushes per holder	2
Size of brush (thickness & width)	1" x 1.25" (25mm x 32mm)
Armature core diameter	18.84" (479 mm)
Armature bearings	Ball
Main poles	4
Interpoles	4
Type of insulation:	
Field coils	Class H
Armature coils	Class H
Weight of Motor	2,575 lbs. (1168 kg)
Weight of Armature	760 lbs. (354 kg)

Battery Boxes and Batteries

BATTERIES

	NO. OF TRAYS	NO. OF CELLS	AH*	KWHR*	APPROX. WEIGHT WET (LBS.)
Maximum	2	110	1,105	236	20,000

* Based on a 6 hour discharge basis.
 Other battery capacities are available. Consult factory.

goodman

GOODMAN EQUIPMENT CORPORATION
 5430 West 70th Place, Bedford Park, IL 60638 USA
 Phone (708) 496-1188 • Fax (708) 496-3939
 Telex 6871228

wabi

Attachment IV -Muck Car (Ref. 5.28)
 (Used by permission of Wabi Iron & Steel Corp., 1998)

MINE CAR DIMENSIONS

GRANBY TYPE MUCK CARS

OPTION NO.	CAPACITY RANGE FT ³	A OVERALL LENGTH	B BOX LENGTH	C WHEEL BASE	D RAIL TO HITCH CENTERLINE	E RAIL TO TOP OF DUMP BOX	F MINIMUM TRACK GUAGE	G OVERALL CAR WIDTH (NOT INCLUDING DD OR EE)	AA MAXIMUM DUMP HEIGHT	BB MAXIMUM DUMP WIDTH FROM CENTERLINE	CC HITCH CENTERLINE TO BOX EDGE (DUMP POS.)	DD DUMP WHEEL OVERHANG (DUMP RAMP TYPE)
1	60-80	9'6"	7'4"	3'	12"	4'4"	24"	4'2"	5'6"	3'3"	1'10"	6"
2	80-120	11'2"	8'4"	3'6"	14"	5'	24"	4'5"	6'4"	3'8"	2'	6"
3	120-160	12'8"	9'	4'6"	14"	5'6"	30"	4'10"	7'10"	4'	2'3"	7"
4	160-200	13'8"	9'6"	5'4"	14"	5'10"	30"	5'2"	8'4"	4'8"	2'6"	8"
5	200-250	14'6"	10'8"	6'	16"	6'2"	30"	5'5"	8'5"	5'4"	2'10"	10"
6	250-350	15'8"	12'4"	7'	16"	7'6"	36"	6'5"	9'4"	5'9"	3'2"	15"

GRANBY CAR DUMPING ARRANGEMENTS

wabi

CHEVRON TYPE SUSPENSION SYSTEM

FEATURES:

- CHEVRON TYPE SUSPENSION SYSTEM ALLOWS WHEEL AND AXLE ASSEMBLY 3-AXIS MOVEMENT
- NEGOTIATION OF VERY TIGHT TRACK RADII POSSIBLE WITH LARGER WHEEL BASE CARS (ESPECIALLY ON SWITCHES)
- SUPERIOR TRACKING ABILITY EVEN ON POORLY ALIGNED RAIL SYSTEMS
- WHEEL FLANGE BREAKAGE GREATLY REDUCED

GRANBY STYLE MINE CAR

WADI

AUTOMATIC CAR COUPLERS

Attachment V -Personnel Railcar & Flatcar (Ref. 5.28)
(Used by permission of Wabi Iron & Steel Corp., 1998)

Wabi

IRON & STEEL CORP.

330 Broadwood Ave.
New Liskeard, Ontario, P0J 1P0

Fax Cover Sheet

DATE: May 7, 1997

TO: Mike Gregore **PHONE:** (702) 295-4465
MORRISON KNUDSEN CO. INC. **FAX:** (702) 295-5198

FROM: Stan Gorzalczynski **PHONE:** (705) 647-4383
FAX: (705) 647-6954

RE: Personnel / Materials Handling Cars - Rail Haulage

Message

The attached sketches outline the overall configuration of the rail cars that we have discussed in previous conversations. The 'lettered' dimensions correspond to the following values :

1. Double Bogie Personnel Car - 12 Man Capacity

A = 4'-10"
B = 36"
C = 8'-0"
D = 18'-6"

2. Double Bogie Flat Car

B = 36"
E = 15'-4"
F = 5'-0"
G = 2'-4 1/2"

wabi

DOUBLE BOGIE PERSONNEL CAR

wabi

DOUBLE BOGIE FLAT CAR

Beton-Nachmischer

Remixers
Remescladores
Malaxeurs à Béton
Rimescolatore di calcestruzzo per galleria
KBM 4/1000

europa-
bewährt

service-
proved
in Europe

éprouvé
en Europe

una affer-
mazione
Europea

acreditadas
en Europa

wirtschaftlich	robust	zuverlässig
economic	robust	reliable
economique	robuste	sur
economico	robusto	di sicura efficienza
económicas	robustas	seguras

MÜHLHAUSER

Title: Subsurface Construction and Development Analysis
Document Identifier: BC A000000-01717-0200-00014 Rev. 01
Attachment VI -Concrete Mixer Car (Ref. 5.29)
(Used by permission of Karl-H. Mühlhauser GmbH & Co., 1998)

TECHNISCHE DATEN

TECHNICAL DATA
DONNÉES TECHNIQUES
DATI TECNICI
DATOS TÉCNICOS

TROMMELINHALT: 4,8/4 m³	DRUM CAPACITY: 4,8/4 m³	CAPACITÉ: 4,8/4 m³	CONTENUTO DEL CASSONE: 4,8/4 m³	CAPACIDAD DE LA CAJA: 4,8/4 m³
ANTRIEB: stufenlos elektro-hydraulisch E.-Motor, 24 KW	DRIVE: infinitely variable electro-hydraulic electric motor, 24 KW	COMMANDE: progression continue électrohydraulique moteur électrique, 24 KW	AZIONAMENTO: con progressione continua elettroidraulico elettromotore, 24 KW	ACCIONAMIENTO: con progression continua electrohidraulico motor eléctrico, 24 KW
LAUFZEUG: Kegellager-Losradsätze 350/400 mm () 100/130 mm 110 Vierkant Spurweite 750 mm je Achse 4fach abge- federt	RUNNING GEAR: taper roller loose wheel sets 350/400 mm () 100/130 mm 110 square gauge 750 mm each axle fourfold suspended	TRAIN DE ROULEMENT: Train de roues à Piliers côniques 350/400 mm () 100/130 mm Carré de 110 Ecartement de voie: 750 mm chaque axe suspendu sur 4 ressorts	CARELLO DI CORSA: Ruota su cuscinetto () mm, 350/400 100/130 mm Quadrangolare 110 Scartamento: 750 mm 4 ammortizzatori per ogni assale	RODAMEN: Rodámenes de ruedas exteriores con cojinetes cónicos 350/400 mm () 100/130 mm eje, cuadrado de 110 ancho de vía 750 mm cada eje amortiguado 4 veces
KUPPLUNG: Spezial-Teleskopkupplung schwenkbar	COUPLING: telescopic special coupling swivable	ATTELAGE: attelage télescopique spécial	ACCOPIAMENTO: agganciamento speciale telescopico orientabile	ENGANCHE: enganche especial telescopico oscilante
SONDERAUSFÜHRUNG: Adapter	SPECIAL DESIGN Adapter	EXECUTION SPECIALE: Adaptateur	ESECUZIONE SPECIALE: Adattore	EJECUCION ESPECIAL: Adaptador
Gesamtgewicht: 3850 kg	Total weight: 3850 kgs.	Poids total: 3850 kilos	Peso totale: 3850 Kg.	Peso total: 3850 kgs

MÜHLHAUSER

D-6120 MICHELSTADT/OPW.
Fernsprecher 06061/674-676
Fernschreiber 4191623
Telefax 06061-5626

Technische Änderungen vorbehalten
Subject to engineering changes
Sauf modifications techniques
Salvo modificaciones técnicas
Salvo modificaciones técnicas

Some information may be obliterated or obscured, but has no affect
on the information or conclusions contained in this analysis.

DN. 31 10 85

The most important technical data

Type	Capacity of drum m ³	Drive	Length mm	Width mm	Height mm	Gauge mm	Turning Circle Ø	Total Weight KN
BM 1/950	1,1/1,4	Electric motor, 5,5 kw alternative : Pneumatic motor	3370	866	1243	600		15,60
KBM 2/100	2,0/2,4	Pneumatic motor, 7 kw at 6 bar	4435	950	1400	950		22,00
KBM 4/400	4,2/5,0	24 kw, electro-hydrostatic	3680	1540	1870	600/750/900		32,50
KBM 4/500	4,2/5,0	Central drive with cardan shaft	3700	1540	1880	600/750/900		34,20
KBM 4/700	4,7/5,2	motor turnable or electro-hydrostatic	3700	1540	2100	600 to 1435		43,00
KBM 4/1000	4/4,8	24 kw, electro-hydrostatic	4240	1400	1720	750		38,50
KBM 4/2000	4/4,8	24 kw, electro-hydrostatic	4965	1300	1650	750		42,00
KBM 5/100	4,3/5,1	15 kw, electro-hydrostatic	7300	1050	1610	600 to 750		52,00
BM 5/1000	4,3/5,1	Pneumatic motor, 16 kw at 6 bar alternative: diesel motor with hydrostatic	7350	1050	1575	600/750		49,00
KBM 6/100	6,1/7,6	Pneumatic motor, 24 kw at 6 bar	5450	1540	1895	600/750/900		55,00
KBM 6/350	6,1/7,6	24 kw, electro-hydrostatic	5450	1540	1895	600/750/900		55,00

The most important technical data

Type	Capacity of drum m ³	Drive	Length mm	Width mm	Height mm	Gauge mm	Turning Circle Ø	Total Weight KN
KBM 6/500	6,1/7,6	24 kw, electro-mechanic	5030	1540	2240	914		70,00
KBM 6/600	6,1/7,6	Pneumatic motor, 26 kw at 6 bar	5380	1540	2240	1067		67,00
KBM 7/100	7/8,4	34 kw, electro-hydrostatic	7655	1300	1825	750		62,00
KBM 9/100	9,1/11,4	37 kw, electro-hydrostatic	7000	1600	2110	750/900/1000		75,00
PK 1000	1,5	6 kw, diesel-motor with hydrostatic	5500	1700	1950		5100	50,00
PK 4000	3,4	17 kw, diesel-motor with hydrostatic	6700	1800	2500		7100	93,00
PK 6000	5,2	30 kw, diesel-motor with hydrostatic	8400	2000	2800		8700	150,00
PK 8000	6,8	50 kw, diesel-motor with hydrostatic	8250	2350	3000		9100	188,00

DNr. 39-03-86

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Technische Änderungen vorbehalten
Subject to engineering changes
Sauf modifications techniques
Salvo modificazioni tecnici
Salvo innovaciones técnicas

Attachment VII - PC Drift Tramming Times

PERFORMANCE CONFIRMATION DRIFT #1 EXCAVATION AND MUCK HAULAGE

TRAMMING DISTANCE	200m	400m	600m	800m	1000m	1200m	1400m	1600m	1800m	2000m
1 TIME TO LOAD 8 CARS										
2 TIME TO TRAM TO N. MAIN (FULL)	(7) 2.4	4.8	7.2	9.6	12	14.4	16.8	19.2	21.6	24
3 TIME TO TRAM TO DUMP STATION (FULL) (4.3.39)	(8) 2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
4 TIME TO TRAM TO DUMP STATION	(9) 6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
5 TIME TO TRAM TO ENTRANCE TO EMPLACEMENT DRIFT (300m) (EMPTY) (4.3.39)	(10) 2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
6 TIME TO TRAM TO TBM (EMPTY)	(11) 1.5	3	4.5	6	7.5	9	10.5	12	13.5	15
TOTAL ROUND TRIP TIME (min)	35	38.9	42.8	46.7	50.6	54.5	58.4	62.3	66.2	70.1

***** TIME TO SURVEY AND REGrip = 10 min
 IF 2+6 > 10 min THEN A CALIFORNIA SWITCH IS NEEDED @ TBM SO THAT EXCAVATION IS NOT DELAYED

ADD ITEMS 2+6

THEREFORE CALIFORNIA SWITCH IN NEEDED AFTER 500m

***** TIME FOR ONE TBM CYCLE = 20 + 10 = 30 min

IF 2+6 > 30 min THEN AN ADDITIONAL CALIFORNIA SWITCH IS NEEDED IN PC DRIFT #1 SO THAT EXCAVATION IS NOT DELAYED

ADD ITEMS 2+6

THEREFORE AN ADDITIONAL CALIFORNIA SWITCH IN NEEDED AFTER 1400m

***** TIME FOR ONE TBM CYCLE = 20 + 10 = 30 min

NUMBER OF MUCK TRAINS NEEDED

ROUND TRIP/30 min
 ROUND UP FOR NUMBER OF TRAINS
 ADJUST CALIF SWITCHES MUST BE FULL

	200m	400m	600m	800m	1000m	1200m	1400m	1600m	1800m	2000m
	1.17	1.30	1.43	1.56	1.69	1.82	1.95	2.08	2.21	2.34
	2	2	2	2	2	2	2	2	3	3
	2	2	3	3	3	3	3	3	4	4

NOTES:

- 1) TBM CUTS 1.5m PER STROKE IN A 5.5m DIAMETER PERIMETER DRIFT (4.3.39)
- 1a) VOLUME OF MUCK PRODUCED = 48 CUBIC METERS (INCLUDING SWELLING)
- 1b) TIME FOR ONE STROKE = 20 min (4.3.39)
- 2) TBM NEEDS 10 min TO SURVEY AND REGrip (4.3.39)
- 3) MUCK TRAIN IS COMPOSED OF 8 CARS OF 8 CUBIC METER CAPACITY (4.3.32)
- 3a) EACH CAR REQUIRES 0.8 min TO DUMP OR 6.4 min PER TRAIN (4.3.29)
- 4) FULLY LOADED TRAINS TRAVEL @ 5 km/hr (4.3.37)
- 5) EMPTY TRAINS TRAVEL @ 8 km/hr (4.3.37)
- 6) DELAY TIME IS NOT CONSIDERED IN THIS ESTIMATE

FILE=NEKPCMK

PERFORMANCE CONFIRMATION DRIFT #2 EXCAVATION AND MUCK HAULAGE

	(4.3.29)					
TRAMMING DISTANCE	200m	400m	600m	800m	1000m	1200m
1 TIME TO LOAD 8 CARS	20	20	20	20	20	20
2 TIME TO TRAM TO PC ACCESS DRIFT (FULL)	(7) 2.4	4.8	7.2	9.6	12	14.4
3 TIME TO TRAM TO DUMP STATION AT PC DRIFT #5 (2100m) (FULL) (4.3.38)	(8) 25.2	25.2	25.2	25.2	25.2	25.2
4 TIME TO DUMP @ DUMP STATION	(9) 6.4	6.4	6.4	6.4	6.4	6.4
5 TIME TO TRAM TO ENTRANCE TO EMPLACEMENT DRIFT #2 (EMPTY)	(10) 15.8	15.8	15.8	15.8	15.8	15.8
6 TIME TO TRAM TO TBM (EMPTY)	(11) 1.5	3	4.5	6	7.5	9
TOTAL ROUND TRIP TIME (min)	71.3	75.2	79.1	83	86.9	90.8
***** TIME TO SURVEY AND REGRIIP = 10 min						
IF 2+6 > 10 min THEN A CALIFORNIA SWITCH IS NEEDED @ TBM SO THAT EXCAVATION IS NOT DELAYED						
ADD ITEMS 2+6	3.9	7.8	11.7	15.6	19.5	23.4
THEREFORE CALIFORNIA SWITCH IS NEEDED AFTER 500m TRAVEL						
***** TIME FOR ONE TBM CYCLE = 20+10 = 30 min						
IF 3+5 > 30 min THEN AN ADDITIONAL CALIFORNIA SWITCH IS NEEDED IN THE PC ACCESS DRIFT						
ADD ITEMS 3+5	41	41	41	41	41	41
THEREFORE AN ADDITIONAL CALIFORNIA SWITCH IS NEEDED IN THE PC ACCESS DRIFT SO MUCK TRAINS CAN BYPASS EACH OTHER						
***** TIME FOR ONE TBM CYCLE = 20+10 = 30 min						
IF 2+6 > 30 MIN THEN AN ADDITIONAL CALIFORNIA SWITCH IS NEEDED IN PC DRIFT #2 SO THAT EXCAVATION IS NOT DELAYED						
ADD ITEMS 2+6	3.9	7.8	11.7	15.6	19.5	23.4
THEREFORE AN ADDITIONAL CALIFORNIA SWITCH IS NOT NEEDED IN THE PC DRIFT						
***** TIME FOR ONE TBM CYCLE = 20+10 = 30 min						
NUMBER OF MUCK TRAINS NEEDED						
ROUND TRIP/30 min	2.38	2.51	2.64	2.77	2.90	3.03
ROUND UP FOR NUMBER OF TRAINS	3	3	3	3	3	4
ADJUST CALIF SWITCHES MUST BE FULL	4	4	4	4	4	4

NOTES

- 1) TBM CUTS 1.5m PER STROKE IN A 5.5m DIAMETER PERIMETER DRIFT (4.3.35)
- 1a) VOLUME OF MUCK PRODUCED = 48 CUBIC METERS (INCLUDING SWELLING)
- 1b) TIME FOR ONE STROKE = 20 min (4.3.35)
- 2) TBM NEEDS 10 min TO SURVEY AND REGRIIP (4.3.35)
- 3) MUCK TRAIN IS COMPOSED OF 8 CARS OF 6 CUBIC METER CAPACITY (4.3.32)
- 3a) EACH CAR REQUIRES 0.8 min TO DUMP OR 6.4 min PER TRAIN (4.3.39)
- 4) FULLY LOADED TRAINS TRAVEL @ 5 km/hr (4.3.37)
- 5) EMPTY TRAINS TRAVEL @ 8 km/hr (4.3.37)
- 6) DELAY TIME IS NOT CONSIDERED IN THIS ESTIMATE

FILE=NEKPC2MK

- 7) [200m/5000m/hr] x [60 min/hr] = 2.4 min ; [400m/5000m/hr] x [60min/hr] = 4.8 min ...
- 8) [2100m/5000m/hr] x [60 min/hr] = 25.2 min
- 9) 8 cars x 0.8 min/car = 6.4 min
- 10) [2100m/8000m/hr] x [60 min/hr] = 15.8 min
- 11) [200m/8000m/hr] x [60 min/hr] = 1.5 min ; [400m/8000m/hr] x [60 min/hr] = 3.0 min ...

Attachment VIII -Continuous Haulage Literature (Ref. 5.8)
(Used by permission of Long-Airbox Co., 1998)

FULL DIMENSION[®]

CONTINUOUS

HAULAGE

PB 36C Chain Piggyback® Bridge Conveyor

Features

For Full Dimension® Continuous Haulage Systems

The Long-Airbox PB 36C chain-type Piggyback is a heavy-duty bridge conveyor with peak capacities of 30 TPM for high production sections. It is designed to work with other components of the Full Dimension Continuous Haulage System in seam heights as low as 48". With attached Systems, the first or inby "Pig" attaches to a yoke on the discharge boom of the continuous miner. For the detached System, the Pig bridges two MBCs (Mobile Bridge Carriers) to quickly and efficiently transport the mined material from the face. The discharge end of the Piggyback is connected to a traveling "dolly" on the MBC cascading the mined material through the System. The outby Pig is attached to a dolly on the RFM (Rigid Frame Modular) Tailpiece. Nominally a 40-foot conveyor (pivot to pivot), the Piggyback features a 10-foot, bolt-on intermediate section which can be eliminated to "tailor" the System to specific mining projections, if required. An adjustable, bolt-on yoke plate, at both the receiving and discharge ends, permits "custom-fitting" of the System to various seam heights and to accommodate individual mine conditions. Sideboards can be added for increased capacity, where conditions allow.

- Rigid frame, steel-channel construction for strength and durability
- 2-Strand, heavy-duty conveyor chain of forged steel with bolt-on flights spaced on 18" centers. 58,000 lb. rating per strand
- 1/4" x 3" wear bars for longer conveyor life
- Heavy-duty grease take-up with Caterpillar seal arrangements on shafts (Manual shim locks are optional)
- Drive shafts are splined through reducers for maximum performance and maintenance
- Conveyor drive sprockets are 10-tooth solid steel. Split sprockets available for easy field replacement
- Tailshaft, with Caterpillar seals, can be greased or oil-filled and sealed for life
- Yoke plates, at both discharge and receiving ends, are adjustable from 40" to 48" to accommodate mine conditions
- 3" diameter, heavy-duty connector pins for attaching to MBC
- Cable handling equipment designed to carry all trailing cable. (With attached System, the Pig also handles the miner cable and hose)
- USBM permissible-type electrical equipment
- Heavy-duty hopper skirting

(NOTE: Only complete Systems bear permissibility plates)

PB 36C Chain-Type Piggyback® Bridge Carrier Specifications

PB 36C

GENERAL SPECIFICATIONS

Overall Length	
(w/10'0" Intermediate Section)	43'0"
(w/10'0" Intermediate Section)	33'0"
Overall Width at Motors (Max.)	69-7/8"
Overall Height (Receiving End)	40" to 43"
Length, Pivot to Pivot (Actual Reach In Mine)	
(w/10'0" Intermediate Section)	40'0"
(w/10'0" Intermediate Section)	30'0"
Swing (Each Side of Center Line)	90°
Weight (Approximate)	11,000 lbs.

CONVEYOR SPECIFICATIONS

Conveyor Width	36"
Conveyor Depth	11 7/14"
Flight Spacing	18"
Chain Speed	300 FPM
Capacity (Continuous - w/11" Depth)	20 TPM
(Continuous - w/14" Depth)	27 TPM
(Peak - w/11" Depth)	25 TPM
(Peak - w/14" Depth)	30 TPM
Conveyor Chain Take-Up (Adjustable)	GREASE

TECHNICAL SPECIFICATIONS

Number of Motors	2
Motor Horsepower (Each)	20-HP
Voltage	460, 550 or 960 VAC

Some information may be obliterated or obscured, but has no affect on the information or conclusions contained in this analysis.

LONG-AIRDOX COMPANY

227 WEST MAPLE AVENUE OAK HILL, WV 25901 304/469-3301

MBC 36C Chain Mobile Bridge Carrier

Features

The Long-Airdox Mobile Bridge Carrier (MBC) is the "heart" of the Full Dimension Continuous Haulage System. It provides the means to articulate the System around corners and move in concert with the continuous miner. It is a crawler-mounted chain conveyor unit designed to work effectively in seam heights of 45" and above. It is also the support unit for the Piggyback® Bridge Conveyors. The 36" conveyor width enables this unit to convey mined material to 30 TPM. For greater reliability, particularly in mines with bad bottom, the MBC 36C is equipped with internal drive crawler assemblies. These assemblies provide maximum power for better tram speeds and maneuverability. The crawlers are equipped with 14" track shoes for easy mobility and to minimize ground pressure.

This MBC is equipped with a swing-out floating operator's cab which swings 25° (21"). The compartment is adjustable, vertically, from 4" to 10". The cab includes an MSHA-approved canopy to comply with regulations. Swiveled, adjustable controls provide easy access to the cab.

The discharge end of the Pig is connected to a traveling dolly, on the MBC, with 5 feet of travel. This enables the operator to move more effectively when advancing or retreating.

- Rigid frame construction of 1-1/2" T-1 steel plate for strength
- Conveyor booms are hinged and independently articulated, in vertical plane, for maximum flexibility in rolling seams
- 10-tooth solid steel sprocket on drive shaft. Split sprockets available for easy field replacement
- Output shaft on internal drive; idler shaft in crawler and conveyor tail return shaft are equipped with Caterpillar seals—can be greased or oil-filled and sealed for life
- Conveyor motor connected to headshaft through Long-Airdox right-angle, gear and pinion-type reducer
- Conveyor drive has fluid-drive transmission between motor and reducer for soft start and additional overload protection
- 2-Strand, heavy-duty chain with bolted, forged steel flights on 18" centers. 58,000 lb. rating per strand
- Jalloxy 360AR coal lines with 1/4" x 3" wear bars. Astralloy wear bars optional
- Centralized greasing
- Dry chemical fire suppression system
- Yoke plates, at both the discharge and receiving ends, are adjustable for various seam heights
- USBM permissible electrical equipment

For Full Dimension®
Continuous Haulage Systems

(NOTE: Only complete Systems bear permissibility plates)

MBC 36C Chain-Type Mobile Bridge Carrier Specifications

MBC 36C		MBC 36C	
GENERAL SPECIFICATIONS		CRAWLER SPECIFICATIONS	
Overall Length	277"	Crawler Length (Center to Center)	60"
Overall Width	97"	Crawler Width	14"
Overall Height (Max. at Midpoint)	40"	Tram Drive (No. Motors/HP)	1-75 HP
Stack-Up Height (Over Bridges)		Tram Speed	65 FPM
Receiving End (w/Sideboards)	40"	Ground Pressure	15 PSI
Discharge End (w/Sideboards)	43"	(w/Two Bridges)	20 PSI
Length, Mine Reach (Pivot to Pivot)	250"	Crawler Take-Up Adjustment (w/Manual Shim Locks)	GREASE
Dolly Travel	51"		
Weight, Empty (Approximate)	30,000 lbs.		
(w/Two Bridges Attached)	41,000 lbs.		
Ground Clearance	10"		
Oil Tank Capacity	90 Gallon		
Hydraulic Pressure	3,500 PSI		
Voltage	960 VAC		
CONVEYOR SPECIFICATIONS		SURGE HOPPER	
Conveyor Width	36"	Overall Length	10'6"
Conveyor Depth	11"	Overall Width	90"
Conveyor Drive (No. Motors/HP)	2-20 HP	Depth	11"
(With Fluid Drive Transmission)		Capacity (Standard)	27 TPM
Chain Speed	300 FPM	(Peak)	30 TPM
Flight Spacing	18"		
Capacity (Continuous)	27 TPM		
(Peak)	30 TPM		
Conveyor Chain Take-Up (Adjustable, Spring Tension)	GREASE		

Some information may be obliterated or obscured, but has no affect on the information or conclusions contained in this analysis.

LONG-AIRDOX COMPANY

227 WEST MAPLE AVENUE

OAK HILL, WV 25901

304/469-3301

Attachment IX -7.62m Diameter TBM Daily Advance Rates

(CRWMS M&O interoffice correspondence, no author, MOL.19980825.0205, August 25, 1998)

The TBM advance rates were obtained from the daily advance rates published in the "ESF Construction Progress Summary". This information was published via interoffice e-mail during the period 1994-97. The information presented in this Attachment is a subset of the entire set of data. This Attachment includes data between 10/30/95 (Station 24+89) and 08/16/96 (Station 62+27). This data shows the TBM advance rates while in the Tsw2 formation. The TBM was utilized five days per week and only potential work days were counted (weekends and holidays excluded). Days where maintenance was performed were counted as work days.

Attachment X shows similar information but is summarized on a weekly basis. There is a difference between the total progress shown in Attachments IX and X. Attachment IX shows a total length of 3,738 meters and Attachment X shows a length of 3,699 meters. For this analysis the value of 3,738 m was used. Conclusions reached in this analysis would not have been affected by using the shorter length.

Day	Progress (meters)	Station at End of the Day
1	27.6	2516.9
2	21.7	2538.6
3	32.4	2571
4	29.9	2600.9
5	29.2	2630.1
6	24.6	2654.7
7	31	2685.7
8	30.5	2716.2
9	13.8	2730
10	25.1	2755.1
11	35.4	2790.5
12	27.3	2817.8
13	28.5	2846.3
14	30.5	2876.8
15	30.1	2906.9
16	36.7	2943.6
17	13.2	2956.8
18	28.2	2985
19	46.4	3031.4
20	48.4	3079.8
21	37.4	3117.2
22	57.7	3174.9
23	0	3174.9
24	0	3174.9
25	0	3174.9
26	0	3174.9
27	0	3174.9
28	9.5	3184.4
29	41.4	3225.8
30	44	3269.8
31	43.9	3313.7
32	31.1	3344.8
33	33.6	3378.4
34	11.2	3389.6
35	27.1	3416.7
36	33.9	3450.6
37	18.5	3469.1
38	35.5	3504.6
39	15	3519.6
40	6.5	3526.1
41	27.1	3553.2
42	36.1	3589.3
43	12.3	3601.6
44	43	3644.6
45	29.6	3674.2
46	54.3	3728.5
47	37.5	3766
48	30	3796
49	30.3	3826.3
50	15.2	3841.5
51	38.4	3879.9
52	14.5	3894.4
53	0	3894.4
54	0	3894.4
55	0	3894.4

Day	Progress (meters)	Station at End of the Day
56	0	3894.4
57	0	3894.4
58	39.9	3934.3
59	27.5	3961.8
60	19.4	3981.2
61	35.8	4017
62	28.6	4045.6
63	12.4	4058
64	10	4068
65	17.8	4085.8
66	11.2	4097
67	38.1	4135.1
68	9.2	4144.3
69	14.9	4159.2
70	10.1	4169.3
71	21	4190.3
72	37.2	4227.5
73	7.6	4235.1
74	8.6	4243.7
75	0	4243.7
76	7.3	4251
77	34.9	4285.9
78	10.7	4296.6
79	16.5	4313.1
80	9	4322.1
81	31.3	4353.4
82	18	4371.4
83	15.7	4387.1
84	16.2	4403.3
85	13.8	4417.1
86	15.1	4432.2
87	4.5	4436.7
88	17.6	4454.3
89	11.1	4465.4
90	15	4480.4
91	24.7	4505.1
92	19.2	4524.3
93	15.6	4539.9
94	19.8	4559.7
95	15.9	4575.6
96	18.4	4594
97	29	4623
98	0	4623
99	0	4623
100	7.3	4630.3
101	17.6	4647.9
102	12.7	4660.6
103	8	4668.6
104	15.9	4684.5
105	20.3	4704.8
106	23.4	4728.2
107	29.5	4757.7
108	28.9	4786.6
109	19.7	4806.3
110	12.1	4818.4

Day	Progress (meters)	Station at End of the Day
111	23.3	4841.7
112	24.6	4866.3
113	0	4866.3
114	0	4866.3
115	0	4866.3
116	0	4866.3
117	0	4866.3
118	0	4866.3
119	6.9	4873.2
120	19.1	4892.3
121	21.6	4913.9
122	38.3	4952.2
123	24.2	4976.4
124	31.2	5007.6
125	36	5043.6
126	27.4	5071
127	39.7	5110.7
128	28.6	5139.3
129	23.6	5162.9
130	43.5	5206.4
131	31.8	5238.2
132	32.6	5270.8
133	0	5270.8
134	12.3	5283.1
135	21.6	5304.7
136	7.6	5312.3
137	45.9	5358.2
138	19.6	5377.8
139	10.4	5388.2
140	29.4	5417.6
141	9.2	5426.8
142	31.2	5458
143	17	5475
144	0	5475
145	29.7	5504.7
146	22.2	5526.9
147	29.4	5556.3
148	16.1	5572.4
149	12.9	5585.3
150	13.1	5598.4
151	12.6	5611
152	8.5	5619.5
153	11.1	5630.6
154	11.2	5641.8
155	16.9	5658.7
156	3.2	5661.9
157	16	5677.9
158	15.8	5693.7
159	8.8	5702.5
160	15.1	5717.6
161	23	5740.6
162	18.1	5758.7
163	26.4	5785.1
164	30.5	5815.6
165	18.2	5833.8

Day	Progress (meters)	Station at End of the Day
166	20.5	5854.3
167	20.7	5875
168	8.1	5883.1
169	14.8	5897.9
170	23.9	5921.8
171	24.3	5946.1
172	15.2	5961.3
173	0	5961.3
174	0	5961.3
175	0	5961.3
176	16.3	5977.6
177	20.7	5998.3
178	25.3	6023.6
179	3.4	6027
180	5.1	6032.1
181	3.5	6035.6
182	3.6	6039.2
183	7.1	6046.3
184	6	6052.3
185	5.1	6057.4
186	0	6057.4
187	10.9	6068.3
188	22.7	6091
189	13.3	6104.3
190	9.6	6113.9
191	6.1	6120
192	9.6	6129.6
193	12	6141.6
194	12.4	6154
195	12.9	6166.9
196	19.1	6186
197	6.6	6192.6
198	16.3	6208.9
199	8.7	6217.6
200	5.6	6223.2
201	3.7	6226.9
Total (m)	3737.6	18.59502 m/day Average

Attachment X -TBM Utilization

(CRWMS M&O interoffice correspondence, no author, MOL.19980825.0206, August 25, 1998)

TBMUTIL1.WK4

TBM UTILIZATION BY WEEK ENDING

(THE FIGURES SHOWN BELOW ARE BASED ON A 24 HR DAY)

DESCRIPTION	11/03	11/10	11/17	11/24	12/01	12/08	12/15	12/22	12/29	01/05	01/12	01/19	01/26	02/02	02/09	02/16
Mining	28.6%	28.2%	28.8%	33.4%	31.0%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%
Regrind	19.4%	17.4%	20.5%	12.0%	20.5%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%
Shift Change	3.3%	3.1%	3.1%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Daily Maintenance	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%
Scheduled Maintenance	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Unscheduled Maintenance TBM	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%
Unscheduled Maintenance NonTBM	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Conveyor Work	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%
Ground Support	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Engineering Labor	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%
Other	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%
Booster Drive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cutter Change	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electrical Problems	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scientists	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Waiting on Muck Train	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lunch	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Availability	73.2%	70.2%	70.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%
Utilization	26.8%	29.8%	29.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%
Progress (in Feet)	140.80	99.90	140.80	80.00	218.30	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80
Penetration Rate (in Feet Per Hour)	481.32	337.67	481.32	262.40	718.02	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32
Availability = 100% (Scheduled TBM Maint. and Unsched. TBM Maint.)	15.92	14.11	15.92	11.56	19.57	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92
Utilization = Mining Time for the TBM, expressed as a percent of the total available time.	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

THIS IS THE INPUT SECTION

WEEKLY TOTAL MINUTES

DESCRIPTION	11/03	11/10	11/17	11/24	12/01	12/08	12/15	12/22	12/29	01/05	01/12	01/19	01/26	02/02	02/09	02/16
Mining	28.6%	28.2%	28.8%	33.4%	31.0%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%
Regrind	19.4%	17.4%	20.5%	12.0%	20.5%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%
Shift Change	3.3%	3.1%	3.1%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Daily Maintenance	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%	16.2%
Scheduled Maintenance	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Unscheduled Maintenance TBM	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%
Unscheduled Maintenance NonTBM	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Conveyor Work	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%	10.8%
Ground Support	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Engineering Labor	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%
Other	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%
Booster Drive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cutter Change	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electrical Problems	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scientists	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Waiting on Muck Train	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lunch	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Availability	73.2%	70.2%	70.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%	73.2%
Utilization	26.8%	29.8%	29.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%	26.8%
Progress (in Feet)	140.80	99.90	140.80	80.00	218.30	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80	140.80
Penetration Rate (in Feet Per Hour)	481.32	337.67	481.32	262.40	718.02	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32	481.32
Availability = 100% (Scheduled TBM Maint. and Unsched. TBM Maint.)	15.92	14.11	15.92	11.56	19.57	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92
Utilization = Mining Time for the TBM, expressed as a percent of the total available time.	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

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TBMUTL1.WK4

TBM UTILIZATION BY WEEK ENDING
(THE FIGURES SHOWN BELOW ARE BASED ON A 24 HO

DESCRIPTION	02/25	03/03	03/10	03/17	03/24	03/31	04/08	04/15	04/22	04/29	05/05	05/12	05/19	05/26	06/02	06/09
Mining	16.04%	20.83%	13.83%	17.01%	18.31%	8.81%	24.57%	17.31%	0.00%	24.93%	32.88%	28.26%	23.49%	22.18%	25.64%	0.00%
Regrip	4.88%	8.28%	8.11%	8.03%	7.96%	4.78%	7.88%	8.88%	0.00%	8.53%	8.71%	4.18%	8.85%	4.22%	5.71%	7.18%
Shift Change	2.34%	4.17%	3.81%	3.82%	6.93%	5.97%	4.88%	8.42%	3.13%	4.17%	3.78%	4.51%	8.83%	19.43%	14.48%	19.13%
Daily Maintenance	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scheduled Maintenance	2.87%	13.57%	10.90%	21.92%	9.43%	35.06%	8.53%	30.46%	96.88%	25.85%	10.78%	29.86%	9.80%	8.99%	15.76%	2.28%
Unscheduled Maintenance TBM	17.80%	7.32%	8.04%	10.38%	3.88%	8.65%	6.08%	3.87%	0.00%	6.87%	12.67%	5.44%	11.31%	18.89%	12.47%	3.61%
Unscheduled Maintenance NonTBM	25.00%	0.00%	0.00%	0.00%	18.78%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Conveyor Work	2.80%	3.79%	10.38%	3.24%	0.00%	1.48%	7.23%	0.00%	0.00%	2.29%	5.10%	8.28%	3.79%	1.78%	3.13%	3.34%
Ground Support	18.49%	38.21%	39.87%	36.84%	24.81%	30.22%	22.32%	25.85%	0.00%	18.08%	8.99%	5.38%	14.88%	2.98%	4.85%	48.85%
Engineering Laser	1.94%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.23%	0.00%
Other	3.39%	8.83%	1.28%	2.40%	11.84%	2.89%	10.29%	4.88%	0.00%	4.28%	12.24%	10.24%	9.88%	9.40%	8.87%	3.97%
Booster Drive	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cutter Change	5.18%	0.00%	4.18%	1.67%	0.00%	2.13%	3.54%	2.32%	0.00%	3.46%	6.01%	1.72%	13.10%	6.72%	2.88%	7.47%
Electrical Problems	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scientists	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Waiting on Muck Train	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lunch	0.00%	0.00%	0.00%	0.00%	0.00%	3.33%	8.07%	3.78%	0.00%	3.78%	4.14%	4.18%	2.92%	5.42%	5.42%	7.15%
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Availability	79.83%	79.11%	81.06%	87.71%	86.89%	59.29%	85.39%	65.88%	3.13%	67.49%	78.85%	64.71%	79.10%	72.13%	71.78%	84.11%
Utilization	16.04%	20.83%	13.83%	17.01%	18.31%	8.81%	24.57%	17.31%	0.00%	24.93%	32.88%	28.26%	23.49%	22.18%	25.64%	0.00%
Progress (in Meters)	52.90	98.50	67.20	85.80	83.10	45.70	118.00	79.70	0.00	118.20	182.80	131.50	107.00	97.20	97.40	58.30
Progress (in Feet)	173.51	298.84	220.42	280.77	272.57	149.90	387.04	261.42	0.00	381.46	633.98	431.32	350.98	318.82	319.47	191.22
Penetration Rate (in FEET PER HOUR)	11.27	11.87	13.48	13.75	12.41	13.00	13.13	12.59	ERR	12.08	13.62	12.72	12.45	11.98	12.98	ERR

Availability = 100% - (Scheduled TBM Maint., Daily TBM Maint.,
Utilization = Mining Time for the TBM, expressed as a percent

THIS IS THE INPUT SECTION
WEEKLY TOTAL MINUTES

DESCRIPTION	02/25	03/03	03/10	03/17	03/24	03/31	04/08	04/15	04/22	04/29	05/05	05/12	05/19	05/26	06/02	06/09
Mining	924	1,500	981	1,225	1,318	692	1,765	1,248		1,795	2,353	2,035	1,691	1,597	1,477	458
Regrip	280	380	594	890	573	344	654	472		470	411	301	378	304	329	488
Shift Change	138	300	260	276	434	385	337	390	228	300	273	326	420	1,399	833	1,216
Daily Maintenance	148	877	785	1,578	678	2,524	814	2,193	8,978	1,861	778	2,148	891	647	907	145
Scheduled Maintenance	1,014	827	679	747	279	407	438	264		480	908	392	814	1,280	718	230
Unscheduled Maintenance TBM	1,440				1,360											
Unscheduled Maintenance NonTBM	150	273	740	233		105	520			168	387	451	273	129	180	213
Conveyor Work	1,068	2,823	2,878	2,199	1,725	2,176	1,807	1,847		1,302	603	387	1,070	213	383	2,920
Ground Support	112														71	
Engineering Laser	195	280	92	173	838	184	741	350		308	881	737	710	877	384	293
Other	297	140	301	120		183	255	167		249	433	124	843	484	188	478
Booster Drive																
Cutter Change																
Electrical Problems																
Scientists																
Waiting on Muck Train																
Lunch	8,780	7,200	7,300	7,200	7,500	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	6,760	6,368

Availability Minutes	4,598.00	5,898.00	5,838.00	4,875.00	5,242.00	4,288.00	5,148.00	4,743.00	225.00	4,259.00	5,518.00	4,858.00	5,895.00	5,193.00	4,138.00	5,993.00
Utilization Minutes	924.00	1,500.00	981.00	1,225.00	1,318.00	692.00	1,769.00	1,248.00	0.00	1,795.00	2,353.00	2,035.00	1,691.00	1,597.00	1,477.00	0.00
Progress (in Meters)	62.90	98.50	67.20	85.80	83.10	45.70	118.00	79.70	0.00	118.20	182.80	131.50	107.00	97.20	97.40	58.30
Progress (in Feet)	173.51	298.84	220.42	280.77	272.57	149.90	387.04	261.42	0.00	381.46	633.98	431.32	350.98	318.82	319.47	191.22
Penetration Rate (in FEET PER MINUTE)	0.19	0.20	0.22	0.23	0.21	0.22	0.22	0.21	ERR	0.20	0.23	0.21	0.21	0.20	0.22	ERR

TBMUTIL1.WK4

TBM UTILIZATION BY WEEK ENDING

(THE FIGURES SHOWN BELOW ARE BASED ON A 24 HR)

DESCRIPTION	06/16	06/23	06/30	07/07	07/14	07/21	07/28	08/04	08/11	TOTAL
Mining	12.13%	17.71%	16.33%	20.21%	6.92%	12.61%	4.72%	11.93%	12.42%	19.88%
Regrip	0.68%	0.22%	4.97%	6.67%	6.97%	7.49%	3.13%	11.06%	10.88%	7.04%
Shift Change	17.11%	19.46%	18.87%	20.81%	18.89%	14.21%	14.49%	9.13%	4.19%	7.40%
Daily Maintenance	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.83%
Scheduled Maintenance	7.18%	4.00%	4.03%	7.31%	49.21%	10.84%	1.85%	1.94%	1.31%	16.22%
Unscheduled Maintenance TBM	12.13%	3.89%	9.44%	7.06%	3.61%	4.64%	23.93%	11.44%	6.18%	9.33%
Unscheduled Maintenance NonTBM	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.27%
Conveyor Work	2.66%	11.21%	6.11%	4.88%	4.64%	0.00%	0.00%	6.64%	6.64%	4.30%
Ground Support	25.83%	20.00%	19.39%	14.24%	1.82%	22.16%	39.39%	32.10%	39.17%	19.20%
Engineering Laser	2.76%	0.28%	0.00%	3.40%	1.86%	2.16%	0.28%	4.18%	0.96%	1.37%
Other	2.47%	0.08%	0.90%	6.86%	1.36%	10.31%	4.28%	2.84%	1.32%	6.24%
Booster Drive	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%
Cutter Change	2.32%	3.04%	6.32%	1.11%	0.00%	10.39%	4.28%	4.03%	2.42%	2.74%
Electrical Problems	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scientists	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%
Waiting on Muck Train	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lunch	8.94%	6.08%	6.83%	6.65%	6.36%	6.35%	3.96%	6.16%	4.16%	2.36%
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Availability	80.72%	82.15%	86.83%	85.83%	46.89%	84.72%	74.51%	86.61%	90.54%	72.93%
Utilization	12.13%	17.71%	19.33%	20.21%	6.92%	12.61%	4.72%	11.93%	12.42%	19.88%
Progress (in Meters)	83.20	91.40	98.60	83.00	32.90	58.00	21.80	62.60	66.00	3,696.50
Progress (in Feet)	207.30	299.79	321.44	208.64	107.91	190.24	71.60	205.33	216.48	12,131.88
Penetration Rate (in FEET PER HOUR)	14.26	14.11	13.88	14.20	13.00	12.67	12.62	14.48	14.63	0.00

Availability = 100% (Scheduled TBM Maint., Daily TBM Maint.,

Utilization = Mining Time for the TBM, expressed as a percent

THIS IS THE INPUT SECTION
WEEKLY TOTAL MINUTES

DESCRIPTION	06/16	06/23	06/30	07/07	07/14	07/21	07/28	08/04	08/11	TOTAL
Mining	873	1,275	1,392	873	498	908	340	852	894	85,038
Regrip	618	664	358	392	430	636	225	792	783	19,500
Shift Change	1,232	1,401	1,344	886	1,343	1,023	1,043	657	302	20,518
Daily Maintenance										6,998
Scheduled Maintenance	618	268	290	316	3,843	768	119	140	94	42,172
Unscheduled Maintenance TBM	873	277	680	305	274	334	1,716	824	897	25,891
Unscheduled Maintenance NonTBM										9,063
Conveyor Work	184	612	440	216	291			479	879	11,901
Ground Support	1,860	1,440	1,396	616	131	1,898	2,836	2,311	2,748	83,202
Engineering Laser	200	20		147	134	167	20	302	645	3,800
Other	178	368	497	240	88	742	308	183	85	14,607
Booster Drive										300
Cutter Change	167	219	393	48		748	308	290	174	7,802
Electrical Problems										0
Scientists										87
Waiting on Muck Train										0
Lunch	600	438	420	293	458	385	285	371	299	6,549
	7,200	7,200	7,200	4,320	7,200	7,200	7,200	7,200	7,200	277,088
Availability Minutes	6,312.00	6,335.00	6,230.00	3,899.00	3,383.00	6,100.00	8,365.00	6,238.00	6,819.00	202,047
Utilization Minutes	873.00	1,275.00	1,392.00	873.00	498.00	908.00	340.00	852.00	894.00	85,038
Progress (in Meters)	83.20	91.40	98.60	83.00	32.90	58.00	21.80	62.60	66.00	3,699
Progress (in Feet)	207.30	299.79	321.44	208.64	107.91	190.24	71.60	205.33	216.48	12,131
Penetration Rate (in FEET PER MINUTE)	0.24	0.24	0.23	0.24	0.22	0.21	0.21	0.24	0.24	0.22

Attachment XI - Estimate of Utility Demand

The following estimate for water demand is based on information from Brian Newman (Kewitt) on the ESF water usage (e-mail, B. Newman to N. Kramer, MOL.19980825.0193, 01/23/98).

Initial

	GPM	
TBM #1 7.62m	20	Same as ESF
Conveyor #1 water sprays	10	Allow ½ ESF rate to start
TBM #2 5.5m	15	75% of 7.62m rate
	S/T 45	
Leakage allow @10%	5	
Total	50	

Mid-Construction

	GPM	
TBM#1 7.62m	20	
Conveyor #1 water sprays	20	
TBM #2 5.5m	15	
Conveyor #1A water sprays	10	Shorter conveyor than #1
Roadheader #1	40	
Roadheader #2	40	
	S/T 155	
Leakage allow @10%	15	
Total	170	

Since the repository will be fairly dry, the waste water return will be the same as that for the water usage- 50 gpm and 170 gpm.

This estimate is based on existing data and does not need to be confirmed. The numbers are approximate and used only to determine if there is an imbalance between the capacity of the existing water system and the projected need.

The following estimate for air demand is based on standard air usage rates.

Initial

	Free Air Required (CFM) @100% usage
TBM #1 Air Tools (allow)	200
Rock Bolters 2ea @ 150	300
TBM #2 Air Tools (allow)	200
Rock Bolters 2ea @ 150	300
Scientific Investigations	<u>3000</u> *
	S/T 4000
Leakage @10% (allow)	<u>400</u>
Total	4400

Mid-Construction

	Free Air Required (CFM) @100% usage
TBM #1 (as above)	500
TBM #2 (as above)	500
Scientific Investigations	3000 *
Roadheader #1 Rock Bolter	150
Roadheader #2 Rock Bolter	<u>150</u>
	S/T 4300
Leakage @10% (allow)	<u>430</u>
Total	4730

This estimate is based on existing data and does not need to be confirmed. The numbers are approximate and used only to determine if there is an imbalance between the capacity of the existing air system and the projected need.

*CRWMS M&O. 1997. *Draft: Title III Evaluation Report for the Compressed Air System.*
BA0000000-01717-5705-00006, Rev. 00. Las Vegas, Nevada: Author. MOL.19980310.0019.