Non-Q Design Analysis Cover Sheet

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<p>1. The following individuals contributed to this analysis:</p> <ul style="list-style-type: none"> A. Romeo Jurani: Responsible for all ventilation system calculations and ventilation system figures. B. Jeff Steinhoff: Responsible for all dust control related sections and figures. C. Richard Logan: Responsible for all fire hazard related sections. D. Robert Vance: Responsible for all monitoring and control systems related sections and figures. E. Christine Gorrell: Responsible for overall preparation of the analysis and remaining sections. <p>2. This analysis contains the following TBV/TBD:</p> <p>TBV-356, Section 4.3.12</p> <p>3. This analysis was started and substantial work was done under NAP-MG-013 Rev. 0. This procedure was superseded by PRO-TS-004 Rev. 0, effective July 10, 1998. The analysis was in the last step of the checking process at the time (Final Check, Section 5.3) and was completed using NAP-MG-013.</p>			

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1. PURPOSE

The purpose of this analysis is to determine ventilation needs during construction and development of the subsurface repository and develop systems to satisfy those needs. For this analysis, construction is defined as pre-emplacement excavation and development is excavation that takes place simultaneously with emplacement. The three options presented in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5) for development ventilation will be applied to construction ventilation in this analysis as well as adding new and updated ventilation factors to each option for both construction and development.

The objective of this analysis is to develop a preferred ventilation system to support License Application Design. The scope of this analysis includes:

- Description of ventilation conditions;
- Ventilation factors (fire hazards, dust control, construction logistics, and monitoring and control systems);
- Local ventilation alternatives;
- Global ventilation options; and
- Evaluation of options.

2. QUALITY ASSURANCE

Quality assurance controls for this analysis are documented in accordance with NLP-3-18, *Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents*. This design analysis activity has been evaluated (Reference 5.10) in accordance with QAP-2-0, *Conduct of Activities*, and has been determined that it is not subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) (Reference 5.1); therefore, QA controls are not applicable to this analysis. QAP-2-3, *Classification of Permanent Items*, is not applicable to this procedure as construction ventilation equipment are not permanent items.

3. METHOD

The ventilation methods used during development were described in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5). These methods are from an analysis supporting the Viability Assessment design and are, therefore, to be verified (TBV). In this analysis, the methods are applied to ventilation conditions that would likely be encountered when the construction plan to be used for License Application is determined.

The conditions that would likely be encountered are developed by using the construction phases described in the *Subsurface Construction and Development Analysis* (Reference 5.13) and considered bounding conditions for drift length for ducting, equipment operation, and the impact of freeing large areas of the repository for installation of a cast-in-place concrete lining. The conditions that are described preserve the time phased construction sequence for construction as established in the phases described in the *Subsurface Construction and Development Analysis* (Reference 5.13).

In order to apply the methods to expected conditions, the ventilation system was considered in two parts. One part is local ventilation and the other is global ventilation. Local ventilation means providing ventilation from the main drift through the working drift to the working face. For example, the ventilation system between a TBM excavating an emplacement drift and the intersection of the emplacement drift and the main drift is termed a local system. The other ventilation system is termed global ventilation which is the ventilation provided in the main drifts. An example of the global ventilation would be the system between the emplacement drift/main drift intersection and the surface. For purposes of this analysis, the working drift begins at the intersection of the main drift and the drift where excavation is taking place and contains the working face. The working face is where a mechanical excavator is operating at the excavation face of a working drift which is a dead-end heading. A dead-end heading is defined as having the only escape route through the drift behind the excavation.

Three options for global ventilation are considered as follows: Ducted Intake/Ducted Exhaust (Option A); Flow-Through (Option B); and Ducted Exhaust (Option C). Global ventilation systems are discussed in Section 7.4. The alternatives for local ventilation are: Intake through a duct, exhaust through the drift (Alternative 1); intake through the drift and exhaust through a duct (Alternative 2); and intake through a duct and exhaust through a duct (Alternative 3). Local ventilation systems are described in Section 7.3 and discussed as part of the global ventilation systems in Section 7.4.

The global ventilation options are combined with compatible local ventilation alternatives to describe overall ventilation systems. These systems are ranked according to their effectiveness in controlling health and safety conditions (fire hazards, dust control and air quality, and noise), their effectiveness in controlling airflow, system reliability, system monitoring, construction logistics, and cost.

Finally, figures are developed which show the three ventilation options applied to the conditions expected in the License Application layout. For each option and condition, the figures show air volumes, duct sizes, pressures, drift size information, fan horsepower, and instrumentation for measuring airflow and air quality.

4. DESIGN INPUTS

4.1 DESIGN PARAMETERS

- 4.1.1 The mean dry bulk density of the TSw2 unit is 2.219 g/cm^3 which equates to 2.219 mt/m^3 (Reference 5.18).
- 4.1.2 The ventilation supplies $36.5 \text{ m}^3/\text{s}$ (77,300 cfm) to the 7.62 m TBM and $16.3 \text{ m}^3/\text{s}$ (34,500 cfm) to each 5.5 m TBM (Reference 5.5, Table 7.4.2). The ventilation also supplies $34.3 \text{ m}^3/\text{s}$ (72,700 cfm) to each roadheader for Conditions 1 through 3 (Reference 5.5, Table 7.4.2) and $34.22 \text{ m}^3/\text{s}$ (72,500 cfm) for Condition 4 (Reference 5.5, Attachment IV). The roadheader value for Condition 4 varies slightly because of rounding for ease in calculations used by the referenced document. [TBV]
- 4.1.3 The production rate of a roadheader is $15 \text{ m}^3/\text{hr}$ (Reference 5.13, Section 7.3.3.4). [TBV]
- 4.1.4 Parameters used in the ventilation system calculations are summarized in Sections II.1 (general inputs for all three options), II.2 (Option A), II.3 (Option B), and II.4 (Option C) in Attachment II. These parameters include: airflow quantities, drift diameters, lengths of drift (duct), and friction factors. [TBV]

4.2 CRITERIA

The design criteria that specifically apply to this analysis were developed based on requirements from the *Subsurface Ventilation System Description Document* (SDD) (Reference 5.2). Specific SDD requirements are cited as reference for each criteria.

- 4.2.1 The system shall provide a minimum quantity of fresh air (surface ambient) to accommodate a maximum of 305 persons on the development side. (SDD 1.2.1.1 as it applies to construction and development ventilation)
- 4.2.2 The system shall provide ventilation for the development and emplacement areas by two separate and independent systems. (SDD 1.2.1.7)
- 4.2.3 The system shall be capable of monitoring the following system parameters and providing instrument readings to the Subsurface Safety & Monitoring System.
- Airflow rate (or velocity) in development areas and in ventilation ducts.
 - Air pressure differential at air locks and ventilation fans
 - Air temperature in development areas and ventilation ducts
 - Relative humidity of airflow in main intake and exhaust airflows.
 - Concentration of non-radioactive particulates in all underground working locations and in the main intake and exhaust airflows.
 - Concentration of carbon monoxide (CO) in the main intake and exhaust airflows and in all underground working areas.
- (SDD 1.2.1.8 and 1.2.4.1 as they apply to construction and development ventilation)

- 4.2.4 The system shall provide operational equipment status for the following identified items:
- Valves (Dampers) – Open/Close position
 - Air locks – Open/Close position
 - Fans – revolutions per minute (RPM), voltage, current, On-Off (SDD 1.2.5.5 as it applies to construction and development ventilation)
- 4.2.5 The system shall provide a minimum quantity of 200 cfm/min (5.7 m³/min) per person working underground. (29 CFR 1926.800(k)(2))
- 4.2.6 The system shall locate air intakes a sufficient distance away from air exhaust openings to preclude exhaust-to-intake airflow. (SDD 1.2.2.2.1)
- 4.2.7 The system shall comply with the applicable provisions of 29 CFR 1910, Occupational Safety and Health Standards. (SDD 1.2.6.1)
- 4.2.8 The system shall comply with the applicable provisions of 29 CFR 1926, Safety and Health Regulations for Construction. (SDD 1.2.6.2)

4.3 ASSUMPTIONS

The assumptions and justification for the assumptions used in this analysis are listed below. Most of the assumptions are cited from the *Controlled Design Assumptions Document* (CDA) (Reference 5.3) and are so referenced. The rationale for the CDA assumptions can be found in the CDA. All CDA assumptions will require substantiation as discussed in Section 1.6 of the CDA. Other assumptions used in this analysis are listed with their own rationale and justifications.

- 4.3.1 The primary method of tunnel excavation will be mechanical. (Reference 5.3, Key 027)

This assumption is used in Section 7.2.2. [TBV]

- 4.3.2 General fan selection for all options:

Based on air quantity and calculated total pressure losses of the airway, an axial fan with a matching air quantity and potential maximum pressure performance (with at least 70% fan efficiency) is selected from the fan curves in Joy Catalogs J-670 and J-610 (Reference 5.17). The duty pressure performance of each fan is distributed in equal space over the entire length of the duct system. Horsepower requirements are determined with the equation/formula given in the calculations. Surface primary fans are based on the one developed in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Section 7.11.2.1).

This assumption is used in Attachment II. [TBV]

- 4.3.3 The threshold limit value (TLV) for respirable dust is 0.15 mg/m³ (Reference 5.6, Section 7.6). As stated in the referenced document, the TLV calculation meets

the limits for crystalline silica as required by 29 CFR 1926.55(a) and 29 CFR 1910 Subpart Z (Criteria 4.3.8 and 4.3.7).

This number is used as an upper limit for dust concentration when comparing various ventilation systems. During any one shift, the concentration of respirable dust breathed by a worker would be determined by the National Institute of Occupational Safety and Health (NIOSH) Analytical Method 7500. The actual TLV would be determined by laboratory analysis of the sample taken and may be more or less than 0.15 mg/m^3 .

This assumption is used in Sections 7.2.2, 7.2.2.1, and 7.2.2.2. [TBV]

- 4.3.4** The concentration of dust in fresh air is assumed to be 0.05 mg/m^3 . Fresh air as it is used in this analysis is air that enters a particular ventilation system. The fresh air may come from outside the repository for global ventilation or from a point in the main drift for local ventilation. For example, the fresh air for alcove excavation at the Exploratory Studies Facility (ESF) came from a point in the tunnel. As a dust concentration for fresh air from surface, the number is conservative. As seen in the *Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January Through December 1996* (Reference 5.14, Table 9), the highest 24-hour average during the years 1989 through 1995 exceeded 0.05 mg/m^3 only in year 1990. A general representative number for fresh air at a particular point in the tunnel is not available. A concentration of 0.05 mg/m^3 is considered representative.

This number is existing data. It is used in comparing ventilation options and not for designing the final ventilation system. Therefore, it does not need verification. This assumption is used in Section 7.2.2.2.

- 4.3.5** Based on uses in hard rock metal mines, the amount of leakage in the duct portions of a ventilation system can vary from 15% for good ventilation practices to 25% for average ventilation practices (Reference 5.9, Page 529). In March 1997, measurements for leakage were taken at the ESF (Centers for Disease Control and Prevention Letter, F. Kissell to C. Parker, April 8, 1997, MOL.19971210.0149). The measurements identified 32% leakage (recirculation) in the system. The system performance was below average because the leakage was greater than 25%.

When the measurements were taken at the ESF, the ventilation duct was about 7,000 meters long. The actual recirculation was about 5% per 1,000 meters ($32/7 = 4.57$). Leakages of about 4% per 1,000 meters ($25/7 = 3.57$) from an average system and about 2% per 1,000 meters ($15/7 = 2.14$) from a good system would be expected. Achieving a system with 2% leakage per 1,000 meters may be very difficult in a construction situation.

These are existing data. These numbers are used to compare what the concentration of dust would be in the drifts for various ventilation conditions and for the ventilation options for those conditions. Since we are comparing options and not designing the final ventilation system, the numbers do not need to be

verified. However, additional measurements are being taken during the construction of the Enhanced Characterization of the Repository Block (ECRB) drift at the ESF that may be available to support future ventilation work. This assumption is used in Section 7.2.2.7.

4.3.6 Scrubber efficiency and the amount of dust generated by TBMs:

Measurements were taken in April 1997 to determine the efficiency of the dry scrubber on the tunnel boring machine (TBM) at the ESF (CRWMS M&O interoffice correspondence, C.W. Parker to R.R. Dresel, LV.MOSH.CWP.5/97-071, May 7, 1997, MOL.19971029.0588). Tables 2 and 3 of that document contain the quantity of dust in the vent stream both before and after the scrubber. This analysis assumes that the concentration of dust in the exhaust stream in pounds/hour is typical for a TBM with a single scrubber. The results used in the assumption are from Test D, EHS-002, EHS-004 and TBM-002. Although other measurements were taken, they are not used because the referenced document recommends that they not be used.

The backup for some of the data in Tables 2 and 3 is also contained in the referenced document and is identified as TBM Test D. TBM Test D contains the airflow rate for the scrubber. There is no backup for EHS-002, EHS-004, and TBM-002. Since these tests were done on the same scrubber as TBM Test D, the same airflow rate is assumed. The post scrubber airflow was 1,316.56 m³/min or 21.94 m³/s.

Test Scrubber	Post-Scrubber Concentration (lbs/hr)	Efficiency
Test D	1.29	88.25%
Test D (worst case)	2.67	92.39%
Test EHS-002	18.64	80.75%
Test EHS-004	1.88	24.50%
TBM -002	1.47	92.18%

This assumption is used in Section 7.2.2.1.

4.3.7 Properly designed water sprays on the head of the TBM could reduce dust concentrations by 60% (Reference 5.12, Page 1700). The number is used to show how the post scrubber concentrations in Assumption 4.3.6 could be reduced if similar results were achieved for TBM excavation in the repository. For conservatism, it is assumed that the same would apply to a roadheader operation.

The number is existing data. The number is used for comparison of options and is not used to design the final ventilation system; therefore, it does not need to be verified. This assumption is used in Sections 7.2.2.1 and 7.2.2.2.

4.3.8 Dust generated by a roadheaders:

The *Underground Mining Methods Handbook* (Reference 5.12, Page 1688) indicates that approximately 50,000 mg of respirable dust is generated per tonne of hard rock cut. The number is very generic and no information is given concerning the type of hard rock being cut or other details.

The number is used to make an order of magnitude estimate of the amount of scrubbing that would be required during roadheader operation. The estimate is used for comparison of options and not used for final design of the ventilation system; therefore, it does not need to be verified. This assumption is used in Section 7.2.2.2.

4.3.9 Drift excavation methods:

- Primary: tunnel boring machine (TBM)
- Secondary: other mechanical methods, and drill-and-blast where mechanical methods are impractical.

(Reference 5.3, DCSS 005)

This assumption is used in Section 7.2.2. [TBV]

4.3.10 Shaft excavation method: Mechanical where practical. (Reference 5.3, DCSS 014)

This assumption is used in Section 7.2.2. [TBV]

4.3.11 For Option A, the air exhausted in the duct from the working face is equal to the amount of air that the scrubber at the working face can accommodate and is as follows:

- 7.62 m TBM -- $16.52 \text{ m}^3/\text{s}$ (35,000 cfm) (This number is based on experience in the ESF and a Lotus Note is found in Attachment I for justification. The Lotus Note states that the maximum is $16.99 \text{ m}^3/\text{s}$ (36,000 cfm); but for conservatism and ease in calculations, this analysis rounds down to $16.52 \text{ m}^3/\text{s}$ (35,000 cfm)).
- 5.5 m TBM -- $12.04 \text{ m}^3/\text{s}$ (25,500 cfm) (Reference 5.5, Attachment IV)
- Roadheader (Conditions 1 through 3) -- $12.89 \text{ m}^3/\text{s}$ (27,300 cfm) (Reference 5.5, Table 7.4.2; $100,000 \text{ cfm} - 72,700 \text{ cfm} = 27,300 \text{ cfm}$)
- Roadheader (Condition 4) -- $12.98 \text{ m}^3/\text{s}$ (27,500 cfm) (Reference 5.5, Attachment IV). The roadheader value for Condition 4 varies slightly because of rounding for ease in calculations used by the referenced document.

This assumption is used in Attachment II. [TBV]

4.3.12 Mobile equipment used in the repository is assumed to be battery-operated. No diesel will be used because the organic particulates may interfere with waste isolation. However, if this assessment is changed by Performance Assessment, the use of diesel equipment may be considered.

This assumption is used in Section 7.2.1.1.1. [TBV-356]

4.4 CODES AND STANDARDS

29 CFR 1926. Labor: Occupational Safety and Health Administration, Department of Labor. 1997.

5. REFERENCES

- 5.1 DOE 1998. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev 8. Washington, D.C.: U.S. Department of Energy.
MOL.19980601.0022.
(Note: The accession number shown is for only those portions pertaining to Revision 8 of the QARD. However, there are several additional accession numbers for other portions pertaining to other revisions of the QARD that are still incorporated in the document and are still valid. These other accession numbers are too numerous to list and can be found in the Record Information System.)
- 5.2 CRWMS M&O 1998. *Subsurface Ventilation System Description Document*. BCA000000-01717-1705-00016 REV 00, ICN 1. Las Vegas, Nevada: Author.
MOL.19980604.0151 (REV 00, ICN 1) and MOL.19980511.0220 (REV 00, ICN 0).
(Note: The two accession numbers shown contain the entire information needed to retrieve the SDD version used.)
- 5.3 CRWMS M&O 1998. *Controlled Design Assumptions Document*. B00000000-01717-4600-00032 REV 04, ICN 4. Las Vegas, Nevada: Author.
MOL.19980511.0260 (REV 04, ICN 4) and MOL.19980408.0604 (REV 04, ICN 3).
(Note: The two accession numbers shown contain the entire information needed to retrieve the CDA version used.)
- 5.4 Not used.
- 5.5 CRWMS M&O 1997. *Overall Development and Emplacement Ventilation Systems*. BCA000000-01717-0200-00015 REV 00. Las Vegas, Nevada: Author.
MOL.19980123.0661.
- 5.6 CRWMS M&O 1998. *Air Quality Control Design Analysis*. BCAD00000-01717-0200-00008 REV 00. Las Vegas, Nevada: Author.
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- 5.7 Bise, C.J. 1986. *Mining Engineering Analysis*. Littleton, Colorado: Society of Mining Engineers, Inc.
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- 5.9 Hartman, H.L.; Mutmanský, J.M.; Ramani, R.V.; Wang, Y.J. 1997. *Mine Ventilation and Air Conditioning*. New York, New York: John Wiley & Sons, Inc. Third Edition. MOL.19980421.0495.
- 5.10 CRWMS M&O 1998. Activity Evaluation for Subsurface Construction Ventilation Design (WP12472375M2). Las Vegas, Nevada: Author. MOL.19980630.0046.
- 5.11 Not used.
- 5.12 Hustrulid, W.A. 1982. *Underground Mining Methods Handbook*. New York, New York: Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. HQZ.19870301.0814.
- 5.13 CRWMS M&O 1997. *Subsurface Construction and Development Analysis*, BCA000000-01717-0200-00014 REV 00. Las Vegas, Nevada: Author. MOL.19971210.0560.
- 5.14 CRWMS M&O 1997. *Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996, Draft*. BA0000000-01717-5705-00001 REV 00. Las Vegas, Nevada: Author. MOL.19971017.0268.
- 5.15 Conveyor Equipment Manufacturers Association 1997. *Belt Conveyors for Bulk Materials*. USA: The Conveyor Equipment Manufacturers Association. Fifth Edition. ISBN: 1-891171-18-6
- 5.16 American Conference of Governmental Industrial Hygienists 1992. *Industrial Ventilation 21st Edition: A Manual of Recommended Practice*. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists. TIC Catalog Number: 102811
- 5.17 CRWMS M&O 1998. Fan Curves Used to Support Construction Ventilation Calculations, BCAJ00000-01717-0200-00001 REV 00. Las Vegas, Nevada: Author. MOL.19980701.0518
- 5.18 YMP 1989. *Reference Information Base*, "Geologic Characteristics: Rock Physical Properties. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. DTN: MO8902RIB00016.003.

6. USE OF COMPUTER SOFTWARE

Spreadsheets that perform mathematical calculations used in this analysis were done using Lotus 1-2-3, Release 5, and Microsoft Excel 97. User defined formulas are shown where they are used.

7. DESIGN ANALYSIS

7.1 INTRODUCTION

This analysis describes ventilation approaches to various conditions that could occur during construction and development of the subsurface repository. Construction includes all openings (main drifts, shafts, and first panel of emplacement drifts) excavated prior to emplacement of waste packages. Development is simultaneous with emplacement and includes the excavation of all remaining openings (emplacement drifts and performance confirmation facilities) needed to complete the subsurface facility.

This analysis assesses the ventilation needs for the key construction activities identified in the five construction and development phases described in the *Subsurface Construction and Development Analysis* (Reference 5.13, Section 7.10), which was performed as part of the Viability Assessment design. This current analysis addresses the ventilation needs for the five construction phases in terms of four specific ventilation conditions which are anticipated conditions that could occur in the License Application design when the design is completed. Table 7-1 shows the relationship between the five construction phases and the four ventilation conditions.

Table 7-1. Construction Phases vs. Ventilation Conditions

Construction Phase	Ventilation Condition
I, II & IV	1
II & III	2
III & IV	3
V	4

A description of each ventilation condition is described below:

- Condition 1 (Construction Ventilation) – Roadheaders would excavate three cross-block drift turnouts, three assembly chambers, three disassembly chambers, and two shaft access drifts. Three cross-block drifts and one performance confirmation drift would be excavated by a 5.5 m diameter TBM. A 7.62 m diameter TBM would excavate the perimeter of the repository (South Ramp Extension, West Main, North Main, East Main North Extension, and North Ramp Extension). The Development Intake Shaft would be excavated by a V-mole excavator.
- Condition 2 (Construction Ventilation) – The 7.62 m diameter TBM would excavate the Exhaust Main. The ventilation raises connecting the three cross-block drifts to the Exhaust main would be excavated by a raise borer. Excavation would begin on the Emplacement Exhaust Shaft by a V-mole excavator. The conveyor system would be removed from the North Ramp, East Main, East Main North Extension, and North Ramp Extension and installation of the cast-in-place concrete liner would take place in all these drifts plus the three cross-block drifts.

During this condition, the Development Intake Shaft would become available for temporary use.

- **Condition 3 (Construction/Development Ventilation)** – In this condition, the 7.62 m diameter TBM would be disassembled and removed to the surface. The Emplacement Exhaust Shaft would be completed and available for use. The conveyor system would be removed from the North Main, West Main, South Ramp Extension, and Exhaust Main and installation of the cast-in-place concrete liner would take place in all these drifts. Roadheaders would begin excavation of the turnouts. The 5.5 m diameter TBM would begin excavation of the emplacement drifts. Ventilation raises connecting the emplacement drifts to the Exhaust Main would be excavated by the raise borer. When the first panel of five emplacement drifts are complete, isolation airlocks will be installed in the main drifts to separate the emplacement side and the development side into two independent systems (Criteria 4.2.2), and the first panel of emplacement drifts would be commissioned for emplacement use.
- **Condition 4 (Development Ventilation)** – Roadheaders would complete the excavation of the remaining turnouts. The 5.5 m diameter TBM would complete excavation of the remaining emplacement drifts as well as excavate the Performance Confirmation Main and four performance confirmation drifts. Ventilation raises connecting the remaining emplacement drifts to the Exhaust Main would be excavated by a raise borer.

One ventilation system, the flow-through system, was described for global construction ventilation in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Section 7.6). The flow-through system and two other systems were described for global development ventilation in the same analysis (Reference 5.5, Section 7.7.6). One is the ducted intake and ducted exhaust system and the other is the ducted exhaust system.

The three ventilation systems identified are defined in this analysis as Option A--ducted intake and ducted exhaust system; Option B--flow-through system; and Option C--ducted exhaust system. A summary of these three options is provided below.

- **Option A - Ducted intake/ducted exhaust system:** Intake air is ducted from one surface location to the entrance of the working drift where the working face is located. The fans for the intake air are located outside of the portal entrance and the air is ducted into the portal and through a bulkhead. The exhaust air is ducted from the working drift to another surface location. If the exhaust volume were equal to the intake volume, then essentially no air would flow in the main drifts outside the ducts. Therefore, more intake air is supplied than is removed in the exhaust duct so that the difference in volume between the intake duct and the exhaust duct will flow in the main drifts to other working locations outside of a working drift and must be cleaned of dust.

- Option B - Flow-through ventilation system: Intake air is supplied through the main drift from a surface location to the entrance of the working drift where the working face is located. The exhaust air is carried away through the main drift to become intake to downstream operations and exhausts at another surface location.
- Option C - Ducted exhaust system: Intake air is supplied through the main drift from a surface location to the entrance of the working drift where the working face is located. The fans for the intake air are located outside of the portal entrance and the air is ducted into the portal and through a bulkhead. The exhaust air is ducted from the working face to another surface location. This system is similar to the one used during excavation of the ESF.

The global ventilation options only supply and exhaust air to and from the entrance of the working drift. Local ventilation systems would supply and exhaust air to and from the working face within the working drifts. The three local systems discussed in this analysis are found in Section 7.3.

All ventilation options and alternatives use mechanical ventilation to supply air to the underground working areas required by 29 CFR 1926.800(k)(1)(ii). The direction of airflow being reversible as required by 29 CFR 1929.800(k)(4) is not addressed in this analysis. The design of ventilation doors required by 29 CFR 1926.800(k)(6) is not addressed in this analysis. (See Criteria 4.2.8)

The *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5) did not address the following functions described in the *Subsurface Ventilation System Description Document* (SDD) (Reference 5.2):

- The ability of the three systems to maintain air quality standards in the subsurface development area (SDD 1.1.2);
- A method of providing the monitored status of system and equipment operation (SDD 1.1.7);
- A method of providing operating parameters and air-related environmental data to the facility control system (SDD 1.1.10); and
- How the system would mitigate the spread of combustion products emitted from a potential subsurface fire (SDD 1.1.11).

This analysis will address these functions and their impacts on the ventilation system in terms of fire hazards, dust control, and monitoring and control systems. This analysis will also examine the applicability of the other two global systems to the construction ventilation and evaluate all three systems for the whole construction/development ventilation scheme.

7.2 VENTILATION FACTORS

7.2.1 Fire Hazards and Mitigation

Dealing with fire hazards is considered the highest priority for the safety and health of workers. A fire and its by-products has the potential to seriously harm or cause death to personnel within a very short period of time. Therefore, it is important to identify potential fire hazards to determine the impact to the subsurface ventilation system and,

ultimately, the workers. This analysis does not attempt to address escape scenarios or do a fire hazards analysis; both items are the subject of other analyses.

The U.S. Department of Energy (DOE) has a policy stating that an identified fire hazard must be mitigated by an automatic fire suppression system or be in the acceptable loss category of less than \$1 million (Reference 5.8, Page 20). Most, if not all, of the mobile equipment is expected to have onboard, pre-engineered automatic and manual suppression systems for electrical components as well as combustible fluids. The other equipment is also expected to have systems to mitigate against potential fire hazards. However, for the purpose of this analysis, the worst-case fire scenarios assume the mitigating actions have failed. The impact on the ventilation system design and how this impact could endanger the safety of the workers is then examined.

7.2.1.1 Fire Sources

7.2.1.1.1 Mobile Equipment

The mobile equipment used for construction and/or development that could be a potential fire source includes, but may not be limited to: TBMs, roadheaders, electric locomotives, maintenance railcars, load-haul-dump (LHD) vehicles, shuttlecars, and drill jumbos. The mobile equipment will be battery operated (Assumption 4.3.12) but either carries or operationally contains combustible fluids that include, but may not be limited to: hydraulic fluid, lubrication oil, waste oil, and bearing grease. The mobile equipment also contains electrical parts that are potential fire sources that include, but may not be limited to: dry transformers, starters, batteries, contactors, wires, and controls. The LHDs, shuttlecars, and drill jumbos additionally have rubber tires that are a source of combustible material.

7.2.1.1.2 Electrical Power Distribution Equipment

All electrical equipment has the potential of being a fire source. Since power distribution systems have extensive electrical equipment associated with them, they are potential fire hazards. The power distribution systems include, but may not be limited to: switchgears, rectifiers, transformers, and cables.

7.2.1.1.3 Conveyor System

Since the conveyor system will be used extensively in construction and development of the repository, it is a potential fire hazard. The belts are constructed of fire resistant materials but, if ignited, releases toxic gases and can burn quickly. The mechanical equipment that operates the conveyor contains movable parts that induce friction and electrical parts which have already been discussed as fire hazards.

7.2.1.1.4 Other Hazards

Other potential fire hazards that may be used in construction and development of the repository include, but may not be limited to: welding and cutting operations,

oxygen and acetylene tanks, temporary timber rail ties, ventilation duct, paper, clean-up rags, and trash.

7.2.1.2 Fire Scenarios

This analysis will address the worst-case fire scenarios in general and their impact on the ventilation system that could endanger the safety of the workers. Four scenarios have been identified and are described below.

7.2.1.2.1 Scenario 1

Scenario 1 is a fire onboard a TBM or roadheader operating at the excavation face of a working drift which is a dead-end heading. A dead-end heading is defined as having the only escape route through the drift behind the excavation.

7.2.1.2.2 Scenario 2

Scenario 2 is a fire between a TBM or roadheader at the working face and the intersection of the working drift and the main drift.

7.2.1.2.3 Scenario 3

Scenario 3 is a fire that occurs in the main drift somewhere between the entrance to the working drift and the fresh air source. The fresh air source varies depending on the global option and the ventilation condition. For Options A and C, the fresh air source is the North Portal for Condition 1 and the Development Intake Shaft for Conditions 2-4. For Option B, the fresh air source is the North Portal for Conditions 1-3 and the Development Intake Shaft for Conditions 3-4. The fresh air source changes locations during Condition 3.

7.2.1.2.4 Scenario 4

Scenario 4 is a fire that occurs in the main drift somewhere between the entrance to the working drift and the exhaust air destination. The exhaust air destination varies depending on the global option and the ventilation condition. For Options A and C, the exhaust air destination is the South Portal with a limited amount through the North Portal during Condition 1. The exhaust air destination is the South Portal for all remaining conditions. For Option B, the exhaust air destination is the South Portal for all conditions.

7.2.2 Dust Control

Dust control is a major factor in the design of the ventilation systems used during excavation of the subsurface repository. The reason is the presence of crystalline silica in the Topopah Spring member of the Paintbrush Tuff where the repository will be located. Crystalline silica can cause silicosis. Because of the crystalline silica in the rock, the threshold limit value (TLV) for respirable dust produced during excavation could be as low as 0.15 mg/m^3 (Assumption 4.3.3).

All of the ventilation systems presented in this analysis should provide acceptable air quality during construction and development of the repository. For all options, the air quality is dependent on dust scrubbers to some extent. Some systems will, however, be inherently more effective than others. When comparing systems, the fact that one system is said to be more effective or more desirable than other systems means that the favored system has a design feature that enhances the effectiveness over that of the other systems, often under specific conditions.

All the excavation is assumed to be mechanical (Assumptions 4.3.1, 4.3.9, 4.3.10) and, therefore, there will be considerable dust generated continuously as excavation progresses. This dust then becomes a major influence on the design of the ventilation system. The major sources of respirable dust during construction and development operations are as follows:

- TBM Excavation
- Roadheader Excavation
- Ventilation Raise Excavation
- Shaft Excavation
- The Conveyor System
- The Rail Haulage System
- Ventilation Ducts
- Housekeeping Operations

Even though fire hazards and subsequent dispersal of smoke are considered the highest priority, the probability of them happening are low. The second highest priority is dust control. Dust will be an ongoing concern anytime there is any kind of work being performed. Therefore, the design must have substantial mitigation for dust control. Mitigating actions will include, but not be limited to: air scrubbers, water sprays, dust hoods at transfer points, use of respirators by personnel working in areas of high dust concentrations, and scheduling of operational activities to limit the amount of dust created.

7.2.2.1 TBM Excavation

The amount of dust generated by the 7.62 m diameter TBM used to excavate the ESF was measured in April of 1997 (CRWMS M&O interoffice correspondence, C.W. Parker to R.R. Dresel, LV.MOSH.CWP.5/97-071, May 7, 1997, MOL.19971029.0588). The concentration of dust downstream from the dry scrubber (post-scrubber) is summarized in Table 7-2 (Assumption 4.3.6). The post-scrubber air volume was 1,316.56 m³/min or 21.94 m³/s (Assumption 4.3.6). It should be noted that fresh air was brought into the TBM through the tunnel itself. The concentrations of dust measured in the ducts were not the fresh air supplied to the miners. The numbers represent total dust and not just the respirable dust fraction of the dust. The respirable dust was, however, a very large percentage of the total based on information in the referenced document.

Given the dust concentration in lbs/hr and the airflow rate allows calculation of the concentration of dust (mg/m³) in the air after it has passed through the scrubber. The calculation is as follows: Dust concentration (mg/m³) = (Dust weight in lbs/hr) x (conversion factor) / (airflow in m³/s). The conversion factor is (1x10⁶ mg/kg / (3600 s/hr x 2.2 lbs/kg)) = 126.26 mg hr/s lbs.

Table 7-2. ESF Dust Concentrations--TBM Post-scrubber

Test	Post-Scrubber (lbs/hr)	Post-Scrubber (mg/m ³)	Scrubber Efficiency
Test D	1.29	7.42	88.25%
Test D (worst case)	2.67	15.36	92.39%
Test EHS-002	18.64	107.27	80.75%
Test EHS-004	1.88	10.82	24.50%
TBM-002	1.47	8.46	92.18%

The concentrations shown in Table 7-2 are preliminary and were measured to check scrubber efficiency. Not enough is known about the conditions under which the samples were taken to apply them to design of the TBM scrubber system or the overall ventilation system. The numbers merely indicate that scrubber efficiency under operating conditions are variable. In the series of tests illustrated in Table 7-2, the efficiency varied from 24% to 92%. The low value of 24% does not imply that the scrubber always operated at 24% efficiency or that it would preclude the use of scrubbers. To the contrary, most of the samples indicate that the scrubber efficiency was in the 81% to 92% range. No suggestion is made or intended that the numbers presented in Table 7-2 should be used to design any repository equipment.

The 7.62 meter diameter TBM used to excavate the ESF loop was not equipped with water sprays on the head. If properly designed water sprays were used on the TBM as recommended in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Section 7.5.2), dust concentrations might be reduced by approximately 60% (Assumption 4.3.7) or (dust concentration lbs/hr x 40%). This number is a result documented for a specific TBM and not presented as the maximum or minimum result to be expected by applying water sprays to the cutting head of a TBM used during excavation of the repository. However, if a similar result was achieved by installing water sprays, then the dust concentrations shown in Table 7-2 would be reduced as shown in Table 7-3.

Table 7-3. Dust Concentration if Water Sprays Were Used on the Cutter Head
TBM Post-scrubber

Test	Post-Scrubber (lbs/hr)	Post-Scrubber (mg/m ³)	Scrubber Efficiency
Test D	0.52	2.99	88.25%
Test D (worst case)	1.07	6.16	92.39%
Test EHS-002	7.46	42.93	80.75%
Test EHS-004	0.75	4.32	24.50%
TBM-002	0.59	3.39	92.18%

The concentration of dust in the post-scrubber air stream in Table 7-3 is above the TLV for respirable dust as presented in Section 7.2.2. This concentration of dust may be entirely acceptable depending on the local ventilation system that is used. For example, if the post-scrubber air were directed into a duct and exhausted away from the TBM, then the concentration of dust in the scrubber exhaust as shown in Table 7-3 could be acceptable because the exhaust is not contained in the air stream breathed by people. If the post-scrubber air was not ducted away from the TBM, but was introduced back into the air stream that people breathed, then the concentration of dust in the post-scrubber air stream would not be acceptable because the concentration of dust is above the TLV as presented in Section 7.2.2.

One way to reduce the concentration of dust would be to use scrubbers in series. For example, if two scrubbers were purchased, each scrubber having an efficiency of 95%, and they were installed in series, the concentration of dust in the highest post-scrubber sample shown in Table 7-3 (42.93 mg/m^3) could be reduced below the TLV. The result would be 0.11 mg/m^3 $((1-95\%) \times (1-95\%) \times 42.93 \text{ mg/m}^3)$. The value of 95% is used as an example and is not suggested or intended to be a design input for any repository ventilation equipment. The value of 42.93 mg/m^3 is not suggested as or intended to be a design parameter for determining the design efficiency requirement for scrubbers. The number 0.11 mg/m^3 is not suggested as or intended to be a design goal for post-scrubber dust concentrations.

The example demonstrates that considering the post-scrubber dust concentrations observed in the samples cited, more than one scrubber may be required to reduce the concentration of dust in the post-scrubber air stream if people breathe that air.

The amount of dust generated by a 5.5 m diameter TBM has not been estimated. For this analysis, it is assumed that the concentrations are the same as a 7.62 m diameter TBM as a conservative approach.

7.2.2.2 Roadheader Excavation

The amount of dust generated when a roadheader is excavating has not been estimated. The *Underground Mining Methods Handbook* (Reference 5.12, Page 1688) indicates that approximately 50,000 mg/mt (Assumption 4.3.8) of airborne respirable dust is generated when a cutter is cutting hard rock.

If the roadheader cuts $15 \text{ m}^3/\text{hr}$ (Parameter 4.1.3) which is equal to approximately 33.3 mt/hr ($15 \text{ m}^3/\text{hr} \times 2.219 \text{ mt/m}^3$) (Parameter 4.1.1), it will generate approximately 1.67 million mg/hour ($33.3 \text{ mt/hr} \times 50,000 \text{ mg/mt}$). This amounts to approximately 464 mg/s. If water sprays are used and they prevent 60% of the dust from becoming airborne (Assumption 4.3.7), then the roadheader with water sprays would produce about 186 mg/s.

The plan is to provide about $34.3 \text{ m}^3/\text{s}$ of air to each roadheader (Parameter 4.1.2). A portion of this air, $12.89 \text{ m}^3/\text{s}$ (Assumption 4.3.11), would be drawn past the operator and then across the cutting area to a duct leading to a scrubber. The incoming fresh air would have a dust concentration of approximately 0.05 mg/m^3 (Assumption 4.3.4).

The $12.89 \text{ m}^3/\text{s}$ of air going by the operator and cutter to the scrubber would have a concentration of approximately $14.4 \text{ mg}/\text{m}^3$ ($186 \text{ mg}/\text{s} / 12.89 \text{ m}^3/\text{s}$). The operator would not be exposed to this concentration because the fresh air would flow from the intake, past the operator, and then into the duct leading to the scrubber. However, if there were to be a great deal of turbulence and air recirculates from the cutting head back toward the operator, then the operator's dust concentration exposure would increase.

Based on Section 7.2.2.1, if two scrubbers, each with an efficiency of 95%, were placed in series, the concentration of the dust from the two-stage scrubber would be approximately $0.036 \text{ mg}/\text{m}^3$ $((1-95\%) \times (1-95\%) \times 14.4 \text{ mg}/\text{m}^3)$.

The scrubber exhaust air quantity, $12.89 \text{ m}^3/\text{s}$, would rejoin the remaining exhaust air quantity, $21.41 \text{ m}^3/\text{s}$, resulting in an exhaust quantity that matches the original intake quantity, $34.3 \text{ m}^3/\text{s}$. The concentration of dust in the total exhaust air would be approximately $0.045 \text{ mg}/\text{m}^3$ $((12.89 \text{ m}^3/\text{s} \times 0.036 \text{ mg}/\text{m}^3) + (21.41 \text{ m}^3/\text{s} \times 0.05 \text{ mg}/\text{m}^3)) / 34.3 \text{ m}^3/\text{s}$. This dust concentration is substantially less than the TLV which is $0.15 \text{ mg}/\text{m}^3$ (Assumption 4.3.3). The air could be scrubbed by a portable scrubber downstream as necessary.

7.2.2.3 Ventilation Raise Excavation

Ventilation raise excavation is accomplished by raise boring methods wherein a pilot hole is drilled down and then back-reamed to the desired diameter. People will not be in the raise during excavation. Dust can be confined in the raise by allowing muck to build up in the bottom of the raise and by wetting the muck pile during the startup of the raise excavation (Reference 5.6, Figure 9). As excavation continues, a chute is added at the bottom of the raise to catch the muck and direct it into railcars. Dust is then confined in the raise itself and dust collectors would be added around the chute and railcars.

7.2.2.4 Shaft Excavation

Shaft excavation by V-mole is accomplished by drilling a pilot hole down, back reaming a larger hole upward, and then using the V-mole to excavate downward to the desired diameter. All muck during boring and V-mole excavation falls down to the bottom of the shaft. Personnel are required to work in the shaft during excavation. Therefore, a limited amount of air can be directed down the shaft so that any dust generated will be carried away from the shaft crew. The major ventilation for the crew will be supplied by a positive-pressure ventilation-duct blowing fresh air into the shaft and exhausting back up the shaft. At the bottom of the shaft, water sprays can be used to suppress the dust on the muck pile and brattice curtains can be hung to contain the dust (Reference 5.6, Figure 12).

7.2.2.5 The Conveyor System

Conveyors produce respirable dust when the belt and the muck dry out. For example, the muck on the carrying side of the belt becomes dry and releases respirable dust as the muck on the belt passes over the carrying idlers. The return side of the belt, if dry, releases respirable dust as the belt passes over the return idlers. Belt scrapers or wipers also produce dust as they dislodge material from the carrying side of the belt. If the

conveyor is shut down for a short period of time and then is restarted, dust from the dried out muck falls off the belt and becomes airborne. Finally, dust is released when muck falls from one level to another, either as the belt is being loaded or at transfer points.

The primary agent for dust control on conveyors is water. Water can be used to wet the muck as it is loaded on the conveyor and at transfer points. Water can be used at wiper stations to both clean the carrying side of the belt as well as to suppress dust produced by the wiper. The designs of cleaning devices for conveyors, including belt-washing stations, are routine. Several methods are shown in *Belt Conveyors for Bulk Materials* (Reference 5.15, Pages 284-290).

The design of hoods for conveyor transfers is well understood and is documented in *Industrial Ventilation 21st Edition: A Manual of Recommended Practice* (Reference 5.16, Figures VS-50-22, VS-50-21, and VS-50-20). Although conveyor covers are shown in the referenced document, they are not recommended for the repository conveyors during any of the construction or development conditions because of the maintenance and cleanup problems that they cause. Covers will also require an additional capital investment.

If ventilation ducts were near the conveyor, then the exhaust air from conveyor transfer hoods would be pulled into that duct. If ducts were not nearby, scrubbers would be used to treat the exhaust air from the conveyor transfer hoods.

7.2.2.6 The Rail Haulage System

Dust is generated by rail haulage systems in much the same way as conveyor systems generate dust. When the railcars are loaded, dust is created by the rock falling from the loading level into the railcars. While the train travels between the excavation and the dump location, high relative velocity between the train and the air stream could blow dust off the railcar as the muck dries out. Finally, when the muck is dumped, dust is generated as the muck falls from the railcar onto the conveyor.

Dust mitigation methods for rail haulage systems are similar to those used for conveyors. Water sprays should be used at transfer points and deflectors should be installed to keep high velocity airflows from blowing dust from the muck at dump points. Ventilation hoods are planned where railcars transfer muck onto the conveyor (Reference 5.13, Section 8.1.4).

7.2.2.7 Ventilation Ducts

Two types of ducts are considered in the analysis, flexible and rigid. The ducts for local ventilation alternatives are short and have one fan. Depending upon the location of the fan, the duct will be under positive or negative pressure. Flexible duct must be under positive pressure to avoid collapse of the duct. Rigid duct, however, can be under either positive or negative pressure.

Global ventilation options have long ducts with multiple fans. For example, the distance between a TBM excavating the West Main and the South Portal could be as much as 9,000 meters. Therefore, if air is to be carried to and/or from the TBM to the South

Portal, the duct(s) would be just as long. When multiple fans are placed in long ducts, some areas are under positive pressure with respect to the tunnel and some areas are under negative pressure. In the negative pressure areas, air leaks from the tunnel into the duct. In the positive pressure areas, air leaks from the duct into the tunnel. This leakage is called recirculation. The amount of recirculation varies from 15% for good ventilation practices to 25% for average ventilation practices (Assumption 4.3.5). Because of leakage and subsequent recirculation, ventilation ducts can reduce air quality.

If exhaust air is carried in the ventilation duct, there are three methods for reducing the recirculation effect.

- Reduce the leakage by reducing the number of joints in the duct. This can be accomplished by using flexible ducting in 500 m or 1,000 m lengths as opposed to rigid ducting which is generally supplied in 6 m lengths. The use of flexible duct is generally applied to relatively short distances.
- Reduce the concentration of dust in the duct. The concentration of dust in the duct can be reduced by scrubbing the air before the air enters (intake) or leaves (exhaust) the duct. This applies to both short and long ducts.
- Reduce the length of the duct. The length of the duct can be reduced by the way the construction is scheduled. For example, the shafts could be available for use early in construction if they were excavated by conventional drill-and-blast methods rather than by V-mole. This approach can be applied to the long distance of TBM excavation on the west side of the repository.

7.2.2.8 Housekeeping Operations

Although, housekeeping operations are intended to control dust, they can be a source of dust when cleanup of the inverters and conveyors or equipment is performed. Generally, muck that has fallen off the conveyor or muck train needs to be removed. Either personnel with shovels or mobile equipment specific to this type of work will perform this task. The muck dries out as it lies on the floor and, therefore, can produce dust when cleaned up.

Housekeeping operations are used to control dust for the most part. Washing down the drift walls, inverters, and equipment with water will help keep dust out of the ventilation air.

7.2.3 Construction Logistics

Construction logistics involves how the ventilation system is constructed and how it interfaces with other operations. Construction logistics include the transportation of ventilation equipment, the installation of the ventilation system, and the removal of the ventilation system. Any of these activities could have an impact on other operations. For example, transporting ventilation equipment to the working face could interfere with muck handling operations.

7.2.4 Monitoring And Control Systems

General instrumentation and monitoring requirements for the construction and development ventilation options are listed in Section 4.2 of this document. They include providing an indication of the operational status and position of equipment and valves or dampers as well as monitoring the parameters listed below:

Requirements (Criteria 4.2.3) dictate that the system shall be capable of monitoring specific parameters of the construction and development ventilation which are as follows:

- Airflow rate in development areas and in ventilation ducts.
- Air pressure differential across air locks and ventilation fans.
- Air temperature in development areas and ventilation ducts.
- Humidity of air in main intake and exhaust airflows.
- Non-radioactive particulate in all underground working locations and in the main intake and exhaust airflows.
- Concentration of carbon monoxide in all underground working locations and in the main intake and exhaust airflows.

Requirements (Criteria 4.2.4) also state that the system shall provide operational status of equipment such as positioning of equipment; open-close status of valves and air locks; and speed, voltage, current, and on-off status of fans. The system also includes the capability of monitoring other parameters in order to protect the life of the equipment such as vibration sensors and motor bearing temperatures of equipment. There are control parameters that facilitate system operations such as remote starting and stopping of equipment, remote opening and closing of valves or air locks, and alarms.

Specific instrumentation items needed to implement the monitoring and control requirements are shown in Table 7-4. Graphical representation of these instrumentation items are shown in the P&ID figures for Conditions 1 through 4 for each option. See Figures 7-9 through 7-16 in Section 7.4.1.5 for Option A, Figures 7-21 and 7-22 in Section 7.4.2.5 for Option B, and Figures 7-27 through 7-34 in Section 7.4.3.5 for Option C.

7.3 LOCAL VENTILATION SYSTEM

A local ventilation system is defined in this analysis as the ventilation that extends from the intersection of the working drift and a main drift into the working drift to the working face where excavation progresses. It is used to ventilate a dead-end working face; i.e., the only opening and, therefore retreat for the workers, is behind the excavation. This analysis surmises that the local ventilation system is the same for either a TBM or a roadheader. A local ventilation system is relatively short as compared to a global system described in Section 7.4. The three alternatives for a local ventilation system are described below.

Table 7-4. Specific Instrumentation Items

Item No.	Equipment or Location	Measured Variables	Local Items					Remote Items				
			Switch	Element	Indicator	Transmitter	Controller	Switch	Indicator	Recorder	Alarm	Controller
1.	Constant speed fans: construction ventilation, intake booster and exhaust booster											
1.1	Equipment control and monitoring											
1.1.1		Start-stop	Yes	--	Yes	--	--	Yes	--	--	--	--
1.1.2		Forward-reverse	Yes	--	--	--	--	Yes	--	--	--	--
1.1.3		Local-remote	Yes	--	--	--	--	Yes	--	--	--	--
1.1.4		Motor bearing temperature	--	Yes	--	Yes	--	--	Yes	--	Yes	--
1.1.5		Fan vibration	--	Yes	--	Yes	--	--	Yes	--	Yes	--
1.1.6		Motor current	--	--	Yes	Yes	--	--	Yes	--	--	--
1.1.7		Motor power	--	--	--	--	--	--	Yes	--	--	--
1.2	Process control and monitoring											
1.2.1		Differential pressure	--	Yes	Yes	Yes	--	--	Yes	--	Yes	--
1.2.2		Duct temperature	--	Yes	Yes	Yes	--	--	Yes	--	--	--
2.	Variable-speed fans: Development Intake Shaft											
2.1	Equipment control and monitoring											
2.1.1		Start-stop	Yes	--	Yes	--	--	Yes	--	--	--	--
2.1.2		Forward-reverse	Yes	--	--	--	--	Yes	--	--	--	--
2.1.3		Local-remote	Yes	--	--	--	--	Yes	--	--	--	--
2.1.4		Motor bearing temperature	--	Yes	--	--	--	--	Yes	--	Yes	--
2.1.5		Fan vibration	--	--	--	Yes	--	--	Yes	--	Yes	--
2.1.6		Motor current	--	--	Yes	Yes	--	--	Yes	--	--	--
2.1.7		Motor power	--	--	--	--	--	--	Yes	--	--	--
2.1.8		Speed	--	--	Yes	Yes	Yes	--	Yes	--	--	Yes
2.2	Process control and monitoring											
2.2.1		Differential pressure	--	Yes	Yes	Yes	--	--	Yes	--	Yes	--
2.2.2		Duct temperature	--	Yes	Yes	Yes	--	--	Yes	--	--	--
3.	Isolation (on-off) valves or dampers: branch connections											
3.1		Open-close	Yes	--	--	--	--	Yes	--	--	--	--
3.2		Local-remote	Yes	--	--	--	--	Yes	--	--	--	--
3.3		Position	Yes	--	--	Yes	--	--	Yes	--	--	--
4.	Flow (throttling) valve or damper: bottom of Development Intake Shaft (Option A)											
4.1		Local-remote	Yes	--	--	--	--	Yes	--	--	--	--
4.2		Position	--	--	Yes	Yes	Yes	--	Yes	--	--	Yes

Table 7-4. Specific Instrumentation Items (Continued)

Item No.	Equipment or Location	Measured Variables	Local Items					Remote Items				
			Switch	Element	Indicator	Transmitter	Controller	Switch	Indicator	Recorder	Alarm	Controller
5.	Surface monitoring: North Portal area, South Portal area, and top of Development Intake Shaft (when in service)											
5.1		Non-radioactive particulate	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
5.2		Humidity	--	Yes	Yes	Yes	--	--	Yes	Yes	--	--
5.3		Temperature	--	Yes	Yes	Yes	--	--	Yes	Yes	--	--
6.	Intake and exhaust monitoring: North Ramp, South Ramp, and bottom of Development Intake Shaft (when in service)											
6.1		Flow	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
6.2		Non-radioactive particulate	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
6.3		Humidity	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
6.4		Carbon monoxide	--	Yes	Yes	Yes	--	--	Yes	--	Yes	--
6.5		Temperature	--	Yes	Yes	Yes	--	--	Yes	Yes	--	--
7.	Main and cross-block drift monitoring: East Main (north and south sides), North Main, South Ramp Extension, West Main (north and south sides), and cross-block drifts											
7.1		Flow	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
7.2		Temperature	--	Yes	Yes	Yes	--	--	Yes	Yes	--	--
8.	Working areas: TBM and roadheader operations											
8.1		Non-radioactive particulate	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
8.2		Carbon monoxide	--	Yes	Yes	Yes	--	--	Yes	--	Yes	--
9.	Ducts: each branch											
9.1		Flow	--	Yes	Yes	Yes	--	--	Yes	--	--	--
9.2		Temperature (see fan variables, Section 1.2.2)										
10.	Exhaust stacks: North Portal and South Portal											
10.1		Humidity	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
10.2		Temperature	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--
		Flow	--	Yes	Yes	Yes	--	--	Yes	Yes	Yes	--

The fan location in a local system is based on whether the duct is under positive or negative pressure. For a duct under positive pressure, the fan shall be located at the intake end of the duct. For a duct under negative pressure, the fan shall be located at the exhaust end of the duct. Fans for intake and exhaust air shall be located a sufficient distance apart to avoid recirculation of exhaust air (Criteria 4.2.6).

7.3.1 Alternative 1--Intake Through Duct, Exhaust Through Drift

In Alternative 1, intake air passes through a supply fan and an optional scrubber as needed in the main drift and is carried in a duct from the main drift to the working face. The volume of air supplied by the duct is greater than the capacity of the fan and the scrubber. Therefore, part of the air from the duct passes through the working face, is scrubbed, and then discharged behind the working face. The remaining air ventilates the rest of the working area and then joins the air from the scrubber. The combined exhaust air flows through the working drift to the main drift away from the working face. Dust from other operations in the working drift such as conveying or rail haulage enters the air stream as it flows away from the working face.

Intake air is supplied by a fan located either in the main drift outside and upstream of the working drift or at the working face itself. When the fan is located in the main drift outside the working drift, the duct is under positive pressure and flexible duct can be used. When the fan is located at the working face, the duct is under negative pressure and only rigid duct can be used.

When the intake duct is under positive pressure, it leaks fresh air into the working drift air stream which tends to dilute the dust concentration in the drift itself. When the duct is under negative pressure, air from the drift enters the duct and causes a decrease in air quality in the duct.

Under these conditions, flexible duct under positive pressure is most desirable. If flexible duct were used, then the number of joints in the line would be decreased and the leakage would be reduced so that better quality air would be supplied to the working face.

A negative pressure rigid duct is less desirable because leakage tends to increase the dust concentration in the duct. As a result, the air quality delivered to the working face is decreased.

In this option, the scrubber used to remove dust from the working face must be of high efficiency to produce good quality air less than TLV because it is introduced into the air stream behind the working face.

Figure 7-1 depicts both a flexible duct and rigid duct configuration for Alternative 1 (Reference 5.6, Attachment II). The figure shows emplacement drift TBM excavation, but the alternative is applicable to TBM excavation of the mains and roadheader excavation. Also shown on the figure is the direction of duct leakage and the dust concentrations at the working face, in the ducts, and in the drift for each configuration. The dust concentrations are used for comparison of the different alternatives and are for reference only (Reference 5.6, Attachment II).

SITUATION # 3

SITUATION # 4

AT FACE	VOL (m ³ /s)	DUST (mg/m ³)	DUST (mg/sec)
TOTAL	12.75	-	-
IN TURNOUT			
IN DUCT	12.75	(0.27+0.04)	3.95
LEAKAGE	4.25	0.04	0.17
TOTAL	17	0.242	4.12

(SHOWN FOR REFERENCE ONLY)

AT FACE	VOL (m ³ /s)	DUST (mg/m ³)	DUST (mg/sec)
TOTAL	12.75	-	-
IN DUCT	4.25	(0.27+0.03)	1.275
LEAKAGE	17	0.075	1.275
TOTAL	12.75	(0.27+0.04)	3.95

(SHOWN FOR REFERENCE ONLY)

FIGURE 7-1
LOCAL VENT ALTERNATIVE 1
DUCTED INTAKE/ DRIFT EXH

7.3.2 Alternative 2--Intake Through Drift, Exhaust Through Duct

In Alternative 2, intake air flows from the main drift through the working drift to the working face. All the air passes through the working face, is scrubbed, and then flows into a duct. The entire exhaust air flows through the duct through the working drift away from the working face to the main drift. Dust from other operations in the working drift such as conveying or rail haulage enters the air stream as it flows through the working drift towards the working face.

A fan located at the working face or outside and downstream of the working drift pulls the exhaust air through a duct from the working face back through the drift to discharge into the main drift downstream of the working drift. When the fan is located at the working face, the duct will be under positive pressure and flexible duct can be used. When the fan is located in the main drift outside the working drift, the duct is under negative pressure and only rigid duct can be used.

When the exhaust duct is under positive pressure, exhaust air from the duct leaks through joints in the duct into the intake air in the working drift causing a decrease in air quality delivered to the working face. Using flexible duct would reduce the leakage and increase the air quality delivered to the working face by reducing the number of joints. When the exhaust duct is under negative pressure, air from the drift dilutes the dust in the duct increasing the air quality in the duct.

Figure 7-2 depicts both a flexible duct and rigid duct configuration for Alternative 2 (Reference 5.6, Attachment II). The figure shows emplacement drift TBM excavation, but the alternative is applicable to TBM excavation of the mains and roadheader excavation. Also shown on the figure is the direction of duct leakage and the dust concentrations at the working face, in the ducts, and in the drift for each configuration. The dust concentrations are used for comparison of the different alternatives and are for reference only (Reference 5.6, Attachment II).

Comparing Figures 7-1 and 7-2 shows that Alternative 1 produces lower dust concentrations than Alternative 2 at the working face. The better system is Alternative 1 using a duct under positive pressure to supply intake air to the working face. The reasons are that the duct is under positive pressure so that the intake air is not diluted with dusty air and because any dust produced between the working face and main drift is directed away from the working face toward the main drift. The air quality at the working face is, however, dependent on the efficiency of the scrubber which removes dust from the working face.

7.3.3 Alternative 3--Intake Through Duct, Exhaust Through Duct

Alternative 3 is a combination of Alternatives 1 and 2. Intake air is supplied through the working drift to the working face in a duct as in Alternative 1. The air passes through the working face, is scrubbed, and then most of the exhaust air is carried from the working face in a duct back through the working drift to the main drift as in Alternative 2. The amount of intake air to the working face will exceed the amount of air carried away from the working face in the exhaust duct. The difference in volume will become exhaust air and will flow in the working drift away from the working face to rejoin the ducted

AT FACE	VOL (m ³ /s)	DUST (mg/m ³)	DUST (mg/sec)
IN DRIFT	12.75	0.04	0.51
LEAKAGE	4.25	10.27 ± 0.03	1.275
TOTAL	17	0.105	1.785
IN TURNOUT			
TOTAL	12.75	0.27	3.44

(SHOWN FOR REFERENCE ONLY)

AT FACE	VOL (m ³ /s)	DUST (mg/m ³)	DUST (mg/sec)
TOTAL	12.75	0.04	0.51
IN TURNOUT			
IN DUCT	12.75	0.27	3.44
LEAKAGE	4.25	0.04	0.17
TOTAL	17	0.212	3.61

(SHOWN FOR REFERENCE ONLY)

SITUATION # 1

SITUATION # 2

FIGURE 7-2
LOCAL VENT ALTERNATIVE 2
DRIFT INTAKE/DUCTED EXH

exhaust air in the main drift as it does in Alternative 1. Dust from other operations in the tunnel such as conveying or rail haulage enters the air stream as it flows away from the TBM. The system provides the same air quality at the working face as Alternative 1.

The best configuration for Alternative 3 would be an intake duct under positive pressure and an exhaust duct under negative pressure. This means that the intake fan is located in the main drift outside and upstream the working drift using flexible duct and the exhaust fan is located in the main drift outside and downstream of the working drift using rigid duct. As an alternate, flexible duct could be used by locating the fan at the working face which puts the exhaust duct under positive pressure. In that case, the flexible duct would decrease the amount of leakage and the system would approach the performance of a rigid duct under negative pressure.

Although the dust concentration at the working face is the same, Alternative 3 is preferable to Alternative 1 because the system is less dependent upon the efficiency of the scrubber used to remove dust from the exhaust air from the working face because the exhaust air is ducted away from the working face.

Figure 7-3 depicts both a flexible duct and rigid duct configuration for Alternative 3 (Reference 5.6, Attachment II). Situation #6 was not contained in the referenced document; however, it was created from the other situations to depict the rigid duct concept for this alternative. The figure shows emplacement drift TBM excavation, but the alternative is applicable to TBM excavation of the mains and roadheader excavation. Also shown on the figure is the direction of duct leakage and the dust concentrations at the working face, in the ducts, and in the drift for each configuration. The dust concentrations are used for comparison of the different alternatives and are for reference only (Reference 5.6, Attachment II).

7.4 GLOBAL VENTILATION SYSTEM

This section details the three global ventilation systems introduced in Section 7.1. Option A is intake air ducted from one surface location to the working drift and exhaust is ducted from the working drift to another surface location. Option B is a flow-through system in that there are no ducts in the main drifts at all. The intake air is carried from one surface location through the main drifts to the working drifts and the exhaust air is carried through the main drifts to another surface location. Option C is intake air is carried from one surface location through the main drifts to the working drift and exhaust is ducted from the working drift to another surface location.

The main fans for a global system are located at either the portals or at the top of the shafts. The intake fans at the portal are located outside of the tunnel and the air is ducted into the portal through a bulkhead for all global options. The main fans for intake and exhaust air shall be located at the portals or shafts apart from each other to avoid recirculation of exhaust air (Criteria 4.2.6).

AT FACE	VOL (m ³ /s)	DUST (mg/m ³)	DUST (mg/sec)
TOTAL	12.75	-	-
IN TURNOUT			
LEAKAGE	4.25	0.04	0.17
IN DRIFT	12.00	(0.27 ± 0.04)	3.72
IN EXHAUST	0.75	0.27	0.203
TOTAL	17	0.241	4.093

(SHOWN FOR REFERENCE ONLY)

DUST CONCENTRATIONS
NOT AVAILABLE FOR
THIS SITUATION.

SITUATION # 5

SITUATION # 6

FIGURE 7-3
LOCAL VENT ALTERNATIVE 3
DUCTED INTAKE/ DUCTED EXH

There are three local ventilation systems that are considered for each global system. They are described in Section 7.3. Alternative 1 is intake air ducted from main drift through the working drift to the working face. The exhaust air is carried from the working face back through the working drift to discharge into the main drift. Alternative 2 is intake air is carried through the working drift to the working face. The exhaust air is ducted back through the working drift to discharge into the main drift. Alternative 3 is intake air is ducted from the main drift through the working drift to the working face. The exhaust air separates with most of the dust-laden air ducted back through the working drift to discharge into the main drift. The remaining exhaust air is carried back through the working drift to join the air from the duct in the main drift. All air in the working drifts, whether ducted or carried through the drift, will have to be scrubbed of dust to the extent needed.

The ventilation conditions are described in Section 7.1. The global systems and local systems represent the ventilation plan for the conditions as construction and development progress. Regardless of the condition, the global and local system combinations are the same throughout the construction/development conditions. That means that each combination will stay the same throughout the four ventilation conditions. Table 7-5 depicts a matrix that shows this relationship. However, even though the conditions have no impact on the evaluation of the systems, they must be considered in the overall ventilation system calculations to determine the total system requirements, such as total volume required, total horsepower, number of fans, and total amount of duct.

7.4.1 Option A--Ducted Intake/Ducted Exhaust System

Intake air is ducted from the fresh air source at the surface to the working face and dust-laden exhaust air is ducted from the working face to the exhaust air destination at the South Portal. If the exhaust volume were equal to the intake volume at the working face, then essentially no air would flow in the tunnel behind the working face. Therefore, more intake air is supplied than is removed in the exhaust duct so that most of the exhaust air will flow in the tunnel behind the working face which must be cleaned of contaminants. This remaining air must provide ventilation for operations taking place in other parts of the tunnel, such as installing the cast-in-place concrete liners.

This system requires two sets of extremely long ventilation ducts and multiple fans. Since the majority of the drift ventilation air is carried by ducts, the integrity of the ducts and fans is essential to ventilation management.

7.4.1.1 Ventilation System

The ventilation system details needed to support Option A at a global level for each ventilation condition are calculated in Table II-1 in Attachment II. These include airflow quantity, length of duct, horsepower, and number of fans. The global ventilation system for Option A is shown in Figures 7-4, 7-5, 7-6, and 7-7 for Conditions 1, 2, 3, and 4, respectively.

Table 7-5. Matrix of Global & Local Ventilation Systems vs. Ventilation Conditions

GLOBAL	LOCAL	VENTILATION CONDITION			
		Condition 1 (Excavation of perimeter mains, Dev. Intake Shaft, cross- block drifts, PC Drift #1, and various secondary openings.)	Condition 2 (Excavation of Exhaust Main, begin Empl. Exhaust Shaft, and begin concrete lining operations.)	Condition 3 (Complete Empl. Exhaust Shaft; complete concrete lining operations; begin turnouts, ventilation raises, and emplacement drifts; and commission first emplacement panel.)	Condition 4 (Excavation of PC Main, and remaining turnouts, ventilation raises, emplacement drifts, and PC drifts.)
Option A(Ducted Intake/ Ducted Exhaust)	Alternative 1 (Ducted Intake/ Drift Exhaust)				
	Alternative 2 (Drift Intake/ Ducted Exhaust)				
	Alternative 3 (Ducted Intake/ Ducted Exhaust)	X	X	X	X
Option B(Flow- Through)	Alternative 1 (Ducted Intake/ Drift Exhaust)	X	X	X	X
	Alternative 2 (Drift Intake/ Ducted Exhaust)	X	X	X	X
	Alternative 3 (Ducted Intake/ Ducted Exhaust)	X	X	X	X
Option C(Ducted Exhaust)	Alternative 1 (Ducted Intake/ Drift Exhaust)				
	Alternative 2 (Drift Intake/ Ducted Exhaust)	X	X	X	X
	Alternative 3 (Ducted Intake/ Ducted Exhaust)	X	X	X	X

CONDITION 1 - OPTION A. DUCTED INTAKE/DUCTED EXHAUST

Cross-Block, First PC & West Main TBM Drives

Intake	Air Quan ft³/min D	Air Quan m³/sec	Airway Dia. inches D	Length L (m)	Length L (ft)	Total BHP % Tot Eff	Fan Unit cfm Fan Pressure, in. wg/ Motor BHP	No of Fan Units in Line	Space bet. Fans m
NORTH RAMP DRIFT	80,000	37.76	300	7,877.2	25,844	3	80,000@11"/250	1	Main Fan Load
NORTH RAMP, 72" DUCT (RH#5.5 TBM)	160,000	75.52	72	4,027.8	13,215	3,909	160,000@15"/550	7	575
SOUTH RAMP, 72" DUCT (RH#7.6 TBM)	212,300	100.21	72	7,944.9	26,066	18,011	212,300@14"/700	27	294
SPLIT 112,300 cfm AFTER EMPL. SHAFT	Split	72	2,001.8	6,568	672	112,300@14"/400		2	1001
TOTAL	452,300	213.49			22,594			37	

Exhaust	Air Quan ft³/min D	Air Quan m³/sec	Airway Dia. inches D	Length L (m)	Length L (ft)	Total BHP % Tot Eff	Fan Unit cfm Fan Pressure, in. wg/ Motor BHP	No of Fan Units in Line	Space bet. Fans m
NORTH RAMP, EXISTING 66" DUCT	52,800	24.92	66	4,027.8	13,215	217	52,800@10"/125	2	2014
SOUTH RAMP, EXISTING 66" DUCT	62,300	29.41	66	2,335.7	7,663	207	62,300@8"/125	2	1168
SPLIT 62,300 cfm TO 54" DUCT AFTER EXH. MAIN	Split	54	2,611	24,970	1,837	62,300@16"/250		8	951
SOUTH RAMP DRIFT	337,200	159.16	300	2,335.7	7,663	59			
TOTAL	452,300	213.49			2,320			12	

Total BHP 24,915 Total Fan Units 49 (with 1 Main Fan Load)

FIGURE 7-4
CONDITION 1 - OPTION A
DUCTED INTAKE/DUCTED EXHAUST

FIGURE 7-6
CONDITION 3 - OPTION A
DUCTED INTAKE/DUCTED EXHAUST

CONDITION 4 - OPTION A. DUCTED INTAKE/DUCTED EXHAUST

Construction/Development Ventilation Concurrent with Emplacement									
Intake	Air Quan ft ³ /min Q	Air Quan m ³ /sec q	Airway Dia. Inches D	Length L (m)	Length L (ft)	Total BHP @ 70% Eff	Fan Unit cfm Pressure, In-Hg/ Motor BHP	No of Fan Units in Line	Space bet. Fans m
EAST MAIN, 72" DUCT	220,000	103.84	72	4,934	16,188	12,447	220,000@14"/700	18	274
EXHAUST MAIN DRIFT	100,000	47.20	276	4,132	13,556	4			
WEST MAIN, 66" DUCT	100,000	47.20	66	4,077	13,376	1,492	100,000@16.5"/7350	4	1019
WEST MAIN DRIFT	240,000	113.28	276	4,077	13,376	56			
SOUTH RAMP EXTENSION AIRLOCK	35,000	16.52	276	844	2,900	0			SURFACE
TRIBUTARY DEV SH & DRIFT 695,000 cfm			240	412	1,352	378	695,000@6.5"/2000	1	
TRIBUTARY EXH MAIN DRIFT 135,000 cfm			276	402	1,319	1	PRIMARY FAN		
Exhaust									
EAST MAIN, 66" DUCT	78,500	37.05	66	4,138	13,576	733	78,500@11"/200	4	1035
EAST MAIN DRIFT	468,500	221.13	276	4,132	13,556	426			
EXHAUST MAIN, 66" DUCT	60,000	28.32	66	4,132	13,556	327	60,000@10"/150	3	1377
WEST MAIN, 54" DUCT	53,000	25.02	54	4,479	14,695	666	53,000@10"/125	6	747
SOUTH RAMP EXTENSION AIRLOCK	35,000	16.52	276	0	0	0			
TRIBUTARY SR EXT, 66" DUCT 113,000 cfm			66	884	2,900	467	113,000@18.5"/450	1	884
TRIBUTARY S RAMP, 72" DUCT 191,500 cfm			72	1,500	4,921	2,496	191,500@16"/700	4	375
TRIBUTARY S RAMP DRIFT, 503,500 cfm			276	1,500	4,921	192			
TOTAL	695,000	328.04				5,306		18	
						Total BHP 19,685	TOTAL FAN UNITS 41 (WITH 1 SURFACE PRIMARY FAN)		

NOTE:
EMPLACEMENT SIDE SHOWN FOR
REFERENCE ONLY.

FIGURE 7-7
CONDITION 4 - OPTION A
DUCTED INTAKE/DUCTED EXHAUST

7.4.1.2 Local Alternative 1 (Intake Through Duct, Exhaust Through Drift) / Conditions 1 - 4

This alternative is not practical for Option A regardless of the condition because all dust-laden global system exhaust is ducted to the surface. Therefore, this alternative will not be discussed further for Option A.

7.4.1.3 Local Alternative 2 (Intake Through Drift, Exhaust Through Duct) / Conditions 1 - 4

This alternative is not practical for Option A regardless of the condition because all global system intake is ducted from the surface. Therefore, this alternative will not be discussed further for Option A.

7.4.1.4 Local Alternative 3 (Intake Through Duct, Exhaust Through Duct) / Conditions 1 - 4**7.4.1.4.1 Fire Hazards**

Fire Scenario 1: A fire onboard either a TBM or roadheader at the working face would release fire by-products into both the working drift and the ducted exhaust system which would then discharge to a portal. The fire by-products would rapidly spread throughout the downstream main drift(s). For a flexible duct system, a large fire could cause the local exhaust fan to shut down and may damage the adjacent duct. The supply system would continue to operate and would carry the fire by-products out of the working drift into the main drift. For a rigid duct system, the exhaust fan would be located in the main drift and would likely continue to function. Some duct damage could occur without causing significant ventilation degradation. A large fire would likely cause the intake fan to shut down without much effect.

Since fire by-products would spread throughout the working drift and the downstream main drift(s), the life safety of workers in both locations is threatened.

Fire Scenario 2: A fire in a working drift between the TBM or roadheader and the main drift would release fire by-products into the working drift toward the main drift where they would rapidly spread throughout the downstream main drift(s). For a flexible duct system, a large fire would likely damage the adjacent ducts on both intake and exhaust systems, causing collapse of the duct from the fire zone to the TBM/roadheader and from the fire zone to the main drift. The remaining exhaust section with the fan would recirculate fire by-products from the fire zone to the TBM/roadheader and exhaust toward the main drift. For a rigid duct system, a large fire could cause duct damage with possible short-circuiting of by-products to the TBM/roadheader and into the main drift(s).

Since the fire by-products would be initially carried out of the working drift toward the main drift(s), workers at the TBM/roadheader would have time to take mitigating life safety actions. The life safety of workers in downstream drifts would be threatened. If fan and duct integrity fail, fire by-products could spread throughout the working drift threatening all workers.

Fire Scenario 3: A fire in a main drift between the entrance to the working drift and the fresh air source would release fire by-products into the main drift ventilation which would rapidly spread throughout the downstream main drift(s). If fan and duct integrity were maintained, such a fire would have no impact on downstream working drifts. If fan and duct integrity were compromised adjacent to the fire, fire by-products could then be drawn into the working drifts by the ventilation system.

The life safety of all workers downstream of the fire zone is threatened.

Fire Scenario 4: A fire in a main drift between the entrance to a working drift and the exhaust air destination at the South Portal would release fire by-products into the main drift ventilation air downstream of the fire. If fan and duct integrity were maintained, such a fire would have no impact on upstream working drifts. If fan and duct integrity were compromised adjacent to the fire, fire by-products could then be drawn into the upstream working drifts by the ventilation system.

The life safety of all workers downstream of this fire scenario is threatened.

7.4.1.4.2 Dust Control

Intake air is ducted through the main drifts from the surface through the working drift to the working face. Most of the exhaust air is ducted from the working face to the surface. The remaining exhaust air is carried back through the working drift to discharge into the main drifts.

Figure 7-3 in Section 7.3.3 shows the local ventilation Alternative 3. In this alternative, the intake air is ducted from the surface, through the main drift, into the working drift to the working face. Most of the exhaust air is ducted from the working face through the working drift all the way to the surface. The rest of the exhaust air is carried through the working drift to discharge into the main drift. The exhaust air in the drift must be scrubbed of dust since it is discharged into the main drifts where personnel must travel.

If flexible duct is used, both the intake and exhaust duct must be under positive pressure. Therefore, the leakage from the duct is out of the duct and is added to the dust in the working drift which would have to be scrubbed more before discharging into the main drift. This would be better for the intake duct since the air would be cleaner entering the working face. If rigid duct is used, then both intake and exhaust ducts can be under positive or negative pressure. If they are under positive pressure, the leakage from the ducts is the same as using flexible duct. If the ducts are under negative pressure, the leakage is from the working drift into the duct which would pollute the intake air and would have to be scrubbed more before entering the working face. This would be better for the exhaust duct since the dust would leak into the duct and be carried all the way to the surface.

The recirculation between the exhaust duct and the air in the working drift and main drift causes the dust concentration in those drifts to increase as it travels

away from the working face toward the surface. As a result, global Option A provides the best quality of air at the entrance to the working drift in the main drift and lower quality air as the exhaust air travels away from the working drift to the surface.

Since most of the exhaust air is ducted from the working face to the surface, the efficiency of the scrubber at the working face is not as critical as it is in Option B in Section 7.4.2. Portable dust collectors may be required in the working drift to remove dust generated by other operations such as rail haulage or conveying.

Because Option A delivers the best quality air to the working drift in the main drift and Alternative 3 delivers the best quality air to the working face, Option A combined with Alternative 3 is the best combination for dust control.

7.4.1.4.3 Construction Logistics

This combination of option and alternative would be the most difficult from a construction logistics point of view since both the global option and the local alternative use ducts for both intake and exhaust. Transporting, installing, or removing the duct in the main drifts for the global system would interfere with all operations. Transporting, installing, or removing the duct in the working drifts for the local system would interfere with the operations within those particular drifts.

7.4.1.5 Monitoring and Control Systems

For clarity, the monitoring and control systems are only identified for the global system. Inclusion of the local systems would only make these systems more complex. A description of the monitoring and control systems needed for each ventilation condition is shown below. Each description is detailed in a process and instrumentation diagram (P&ID) figure. A legend sheet for the P&ID figures is found in Figure 7-8.

- Condition 1 (see Figures 7-9 and 7-10): General main and drift ventilation requirements are supplemented using constant-speed fans located at the North Portal. Intake and exhaust fans are located at both the North Portal and South Portal and transport air in large diameter ducts to and from the working drifts of the repository. Parameters monitored include non-radioactive particulate, humidity, temperature, airflow, and carbon monoxide at the surface and in the ramps, mains and drifts. In addition, non-radioactive particulate and carbon monoxide are monitored in all active working areas. Due to the large number of booster fans required in the system, the fans are automatically controlled from a central location. Fan controls and equipment protection devices are detailed in the figure.
- Condition 2 (see Figures 7-11 and 7-12): General main and drift ventilation requirements continue to be supplemented by the construction ventilation fans at the North Portal. However, outside air for the working faces is supplied from the Development Intake Shaft and exhausted through the South Portal. A modulating valve or damper on each intake duct is used for adjusting the air supply.

INSTRUMENT IDENTIFICATION
TYPICAL LETTER COMBINATIONS

FIRST LETTERS	INITIATING OR MEASURED VARIABLE	CONTROLLERS		READOUT DEVICES		SWITCHES AND ALARM DEVICES			TRANSMITTERS		SOLENOIDS, RELAYS, COMPUTING DEVICES	PRIMARY ELEMENT	VIEWING DEVICE, GLASS	SAFETY DEVICE	VALVES, DAMPERS
		INDICATING	BLIND	RECORDING	INDICATING	HIGH	LOW	COMB	INDICATING	BLIND					
A	ANALYSIS	AIC	AC	AR	AI	ASH	ASL	ASHL	AIT	AT	AY	AE			
B	BURNER/COMBUSTION	BIC	BC	BR	BI	BSH	BSL	BSHL	BIT	BT	BY	BE	BG		
C	CONTROLLER OUTPUT			CR	CI										
D	EXTRACTOR										OY				
E	VOLTAGE	EIC	EC	ER	EI	ESH	ESL	ESHL	EIT	ET	EY	EE			
F	FLOW	FIC	FC	FR	FI	FSH	FSL	FSHL	FIT	FT	FY	FE	FG		FV
FD	FLOW QUANTITY	FOIC		FOR	FOI	FOSH	FOSL		FOIT	FOT	FOY	FOE			
FF	FLOW RATIO	FFIC	FFC	FFR	FFI	FFSH	FFSL					FE			FFV
G	USER'S CHOICE														
H	HAND	HIC	HC					HS							HV
I	CURRENT	IIC		IR	II	ISH	ISL	ISHL	IIT	IT	IY	IE			
J	POWER	JIC		JR	JI	JSH	JSL	JSHL	JIT	JT	JY	JE			
K	TIME	KIC	KC	KR	KI	KSH	KSL	KSHL	KIT	KT	KY	KE			
L	LEVEL	LIC	LC	LR	LI	LSH	LSL	LSHL	LIT	LT	LY	LE	LG		LV
M	USER'S CHOICE														
N	USER'S CHOICE														
O	USER'S CHOICE														
P	PRESSURE/VACUUM	PIC	PC	PR	PI	PSH	PSL	PSHL	PIT	PT	PY	PE			PV
PD	PRESSURE/DIFFERENTIAL	PDIC	PDC	PDR	PDJ	PDSH	PDSL		PDIT	PDT	PDY	PE	PSV, PSE		PDV
O	QUANTITY	OIC		OR	OJ	OSH	OSL	OSHL	OIT	OT	OY	OE			
R	RADIATION	RIC	RC	RR	RJ	RSH	RSL	RSHL	RIT	RT	RY	RE			
S	SPEED/FREQUENCY	SIC	SC	SR	SI	SSH	SSL	SSHL	SIT	ST	SY	SE			
T	TEMPERATURE	TIC	TC	TR	TJ	TSH	TSL	TSHL	TIT	TT	TY	TE			TV
TD	TEMPERATURE DIFFERENTIAL	TDIC	TDC	TDR	TDJ	TDSH	TDSL		TDIT	TDT	TDY	TE	TSE		TDV
U	MULTIVARIABLE			UR	UI						UY				
V	VIBRATION			VR	VI	VSH	VSL	VSHL	VIT	VT	VY	VE			
W	WEIGHT/FORCE	WIC	WC	WR	WI	WSH	WSL	WSHL	WIT	WT	WY	WE			
X	ISOLATION OR SIGNAL														
Y	EVENT/STATE/PRESENCE	YIC	YC	YR	YI	YSH	YSL		YIT	YT	YY	YE			
Z	POSITION/DIMENSION	ZIC	ZC	ZR	ZI	ZSH	ZSL	ZSHL	ZIT	ZT	ZY	ZE			

INSTRUMENT IDENTIFICATION NOTES:

1. REFER TO ISA STANDARD S5.1 FOR LETTERS OR LETTER MEANINGS THAT DO NOT APPEAR IN TABLE.
2. INSTRUMENT IDENTIFICATION IS MADE UP OF TWO TO FOUR LETTERS FROM THIS TABLE FOLLOWED BY A LOOP NUMBER. (TO BE DETERMINED)
3. READILY RECOGNIZED SELF-DEFINING CHEMICAL SYMBOLS SUCH AS CO MAY BE USED IN CONJUNCTION WITH ANALYSIS INSTRUMENTS. THE SYMBOL WILL BE PLACED OUTSIDE THE INSTRUMENT BALLOON.
4. THE GRAMMATICAL FORM OF THE SUCCEEDING LETTER MEANING MAY BE MODIFIED AS REQUIRED. FOR EXAMPLE, I MAY BE USED FOR INDICATOR OR INDICATING.
5. THE LETTERS F (RATIO) & D (DIFFERENTIAL) MAY BE USED AS MODIFIERS WITH AN APPROPRIATE FIRST LETTER TO BETTER DEFINE THE FUNCTIONAL ASPECTS OF THE SYSTEM. FOR EXAMPLE: FFIC = FLOW RATIO INDICATING CONTROLLER AND PDSH = PRESSURE DIFFERENTIAL SWITCH HIGH.

TAGGING AND LOOP IDENTIFICATION:

A UNIQUE NUMBER (TO BE DETERMINED) SHALL BE ASSIGNED TO EACH PLC FUNCTION AND TO EACH CONTROL OR MONITOR LOOP AND EACH INSTRUMENT IN THAT LOOP SHALL BE IDENTIFIED BY THE SAME NUMBER.

ITEMS SUCH AS PRESSURE GAGES, THERMOMETERS, PRESSURE SAFETY VALVES AND ANY INSTRUMENT USED INDIVIDUALLY SHALL BE TREATED AS AN INDIVIDUAL CONTROL OR MONITOR LOOP.

SYMBOL DESCRIPTION

EQUIPMENT AND VALVES

CENTRIFUGAL FAN

AXIAL FAN

FABRIC FILTER/BAGHOUSE

BUTTERFLY

KNIFE GATE

BLAST OR SLIDE GATE

LOUVER OR DAMPER

INSTRUMENT LINES AND SYMBOLS

CONNECTION TO PROCESS, MECHANICAL LINK OR INSTRUMENT AIR SUPPLY

ELECTRICAL SIGNAL

DIGITAL SOFTWARE LINK

PRIMARY PROCESS LINE

LIMITS OF PACKAGE EQUIPMENT

INSTRUMENT LOCAL/PANEL/LOCAL PANEL MOUNTED

INSTRUMENT PANEL/LOCAL PANEL MOUNTED BEHIND LOCAL PANEL

PILOT LIGHT FIELD/PANEL/LOCAL PANEL MOUNTED

SHARED DISPLAY (NORMALLY ACCESSIBLE TO OPERATOR)

CONTROLLER, COMPUTATION ETC. (NOT NORMALLY ACCESSIBLE TO OPERATOR)

PROGRAMMABLE LOGIC CONTROLLER FUNCTION, INTEGRAL TO DCS (NOT NORMALLY ACCESSIBLE TO OPERATOR)

GENERALIZED - FOR UNDEFINED OR COMPLEX INTERLOCK LOGIC

FIGURE 7-8
VENTILATION P&ID
LEGEND SHEET

NOTES:

1. CONSTRUCTION FANS FOR DEVELOPMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 1, OPTION A VENTILATION PLAN, SEE FIGURE 7-4.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-9
CONDITION 1 - OPTION A
VENTILATION P&ID, SHEET 1 of 2

NOTES:

1. CONSTRUCTION FANS FOR EMPLACEMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 2, OPTION A, VENTILATION PLAN, SEE FIGURE 7-5.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-11
CONDITION 2 - OPTION A
VENTILATION P&ID, SHEET 1 of 2

NOTES:

1. CONSTRUCTION FANS FOR EMPLACEMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 2, OPTION A, VENTILATION PLAN, SEE FIGURE 7-5.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-12
CONDITION 2 - OPTION A
VENTILATION P&ID, SHEET 2 of 2

- Condition 3 (see Figures 7-13 and 7-14): In this condition, intakes for the clean air supply fans are moved to the South Ramp Extension. The construction ventilation fans at the North Portal remain in service and the exhaust system continues to be ducted to the South Portal.
- Condition 4 (see Figures 7-15 and 7-16): During this condition, simultaneous emplacement and development activities are underway. Intake air to the development side mains and other drifts is supplied by variable-speed fans. As in Condition 3, clean air to the working faces is supplied from the South Ramp Extension and exhausted through the South Portal. Flow is monitored throughout the development side of the repository as well as the differential pressure between the development and emplacement sides. The speed of the operating primary intake fan is adjusted as necessary to maintain the required design airflows and differential pressure.

Option A is the most complex from a controls perspective. This is primarily due to operating a large number of booster fans in series that must be started sequentially (i.e., nearest fan to the intake air supply is started first) to avoid collapsing the distribution ducts.

7.4.2 Option B--Flow-Through System

Intake air is supplied through the drift from a surface location to the last open drift that intersects the drift where the working face is located. The exhaust air is carried away through the drift to another surface location.

7.4.2.1 Ventilation System

The ventilation system details needed to support Option B at a global level for each ventilation condition are calculated in Table II-2 in Attachment II. These include airflow quantity, length of duct, horsepower, and number of fans. The global ventilation system for Option B is shown in Figures 7-17, 7-18, 7-19, and 7-20 for Conditions 1, 2, 3, and 4, respectively.

7.4.2.2 Local Alternative 1 (Intake Through Duct, Exhaust Through Drift) / Conditions 1 - 4

7.4.2.2.1 Fire Hazards

Fire Scenario 1: A fire onboard either a TBM or roadheader at the working face would release fire by-products into the working drift ventilation air. The fire by-products would rapidly spread throughout the drift and into the downstream areas of the main drift(s). For a flexible duct system, a large fire would likely damage the duct adjacent to the fire, but the fan would be located in the main drift and would continue to function. For a rigid duct system, a large fire would likely cause the ventilation fan, which would be adjacent to the TBM/roadheader, to shut down.

NOTES:

1. CONSTRUCTION FANS FOR EMPLACEMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 3, OPTION A, VENTILATION PLAN, SEE FIGURE 7-6.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-13
CONDITION 3 - OPTION A
VENTILATION P&ID, SHEET 1 of 2

NOTES:

1. CONSTRUCTION FANS FOR EMPLACEMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 3, OPTION A, VENTILATION PLAN, SEE FIGURE 7-6.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-14
CONDITION 3 - OPTION A
VENTILATION P&ID, SHEET 2 of 2

- NOTES:
- 1. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
 - 2. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
 - 3. FOR GENERAL ARRANGEMENT OF CONDITION 4, OPTION A, VENTILATION PLAN, SEE FIGURE 7-7.
 - 4. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-15
CONDITION 4 - OPTION A
VENTILATION P&ID, SHEET 1 of 2

- NOTES:
- 1. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
 - 2. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
 - 3. FOR GENERAL ARRANGEMENT OF CONDITION 4, OPTION A, VENTILATION PLAN, SEE FIGURE 7-7.
 - 4. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-16
CONDITION 4 - OPTION A
VENTILATION P&ID, SHEET 2 of 2

FIGURE 7-17
 CONDITION 1 - OPTION B
 FLOW-THROUGH

FIGURE 7-18
CONDITION 2 - OPTION B
FLOW-THROUGH

Since fire by-products would spread throughout the working drift and downstream main drift(s), the life safety of workers in both locations would be threatened.

Fire Scenario 2: A fire in the working drift between a TBM or roadheader and the main drift would release fire by-products into the working drift toward the main drift where they would rapidly spread throughout the downstream main drift(s). For a flexible duct system, a large fire would likely damage the adjacent duct, causing collapse of the duct from the fire toward the TBM/roadheader. The remaining section with the fan would continue to push fire by-products from the fire zone into the main drift. For a rigid duct system, a large fire could cause duct damage with possible short-circuiting of by-products to the TBM/roadheader.

Since fire by-products would initially be carried out of the working drift toward the main drift(s), workers at the TBM/roadheader have time to take mitigating life safety actions. The life safety of workers in downstream drifts would be threatened. If fan and duct integrity fail, fire by-products could spread toward the TBM/roadheader threatening all workers.

Fire Scenario 3: A fire in a main drift between the entrance to a working drift and the fresh air source would release fire by-products into the main drift ventilation air which would rapidly spread throughout the downstream main drift(s). Fire by-products would then be drawn into the working drifts by the local ventilation system.

The life safety of all workers downstream of the fire zone would be threatened.

Fire Scenario 4: A fire in a main drift between the entrance to a working drift and the exhaust air destination at the South Portal would release fire by-products into the main drift ventilation air downstream of the fire. The fire by-products would rapidly spread throughout the main drift(s) between the fire and the South Portal. Such a fire would have no impact on upstream working drifts.

The life safety of all workers downstream of the fire zone would be threatened.

7.4.2.2.2

Dust Control

In Option B there are no ducts in the main drifts for the global system. The global system relies on dilution, air scrubbers at the working face, and portable scrubbers in the working drifts to maintain air quality in the global system. This is necessary because the exhaust air from one working drift becomes the intake for downstream operations.

Figure 7-1 in Section 7.3.1 shows the local ventilation Alternative 1. In this alternative, the intake air is ducted from the main drift through the working drift to the working face and, therefore, the air must be scrubbed of dust before entering the working face. All of the exhaust air is carried from the working face through the working drift to discharge back into the main drift. The exhaust air must be scrubbed of dust since it becomes the intake air for downstream working drifts.

If flexible duct is used, the intake duct must be under positive pressure. Therefore, the leakage is out of the duct and is added to the dust in the working drift which would have to be scrubbed before discharging into the main drift. This would be better for the intake duct since the air would be cleaner entering the working face. If rigid duct is used, then the duct can be under positive or negative pressure. If it is under positive pressure, the leakage from the duct is the same as using flexible duct. If the duct is under negative pressure, the leakage is from the working drift into the duct which would pollute the intake air and would have to be scrubbed before entering the working face.

In Option B, the system relies on dilution, air scrubbers at the TBM, and portable scrubbers to maintain air quality in the global system. This is necessary because the exhaust air from one operation becomes the intake for downstream operations. Any of the local alternative systems can be used with Option B as long as the amount of dust delivered to the global system can be diluted or scrubbed.

All of the Option B combinations are less desirable than the Option A/Alternative 3 combination for dust control because of the heavy reliance on dust scrubbers to maintain air quality.

7.4.2.2.3 Construction Logistics

The construction logistics of this combination would not be very difficult. Since the global system is a flow-through system, there are no ducts in the main drifts and, therefore, no interferences with other operations. For the local system there is an intake duct in the working drifts which would interfere with the operations within those particular drifts.

7.4.2.3 Local Alternative 2 (Intake Through Drift, Exhaust Through Duct) / Conditions 1 - 4

7.4.2.3.1 Fire Hazards

Fire Scenario 1: A fire onboard either a TBM or roadheader at the working face would release fire by-products into the ducted exhaust system which then discharges into the main drift ventilation system at the main drift. The fire by-products would rapidly spread throughout the downstream main drift(s). For a flexible duct system, a large fire would likely cause the exhaust fan to shut down and damage the duct. For a rigid duct system, the fan would be located in the main drift and would continue to function. Some duct damage could occur without causing significant ventilation degradation.

Since fire by-products would be exhausted to the main drift, the life safety of workers in the working drift would not be threatened, but that of workers in the downstream main drift would be.

Fire Scenario 2: A fire in the working drift between a TBM or roadheader and a main drift would release fire by-products into the working drift air toward the TBM/roadheader. The exhaust duct system would then exhaust the fire by-products into the main drift where they would rapidly spread throughout the

downstream main drift(s). For a flexible duct system, a large fire would likely damage the adjacent duct, causing collapse of the duct from the fire zone to the main drift. The remaining exhaust section with the fan would recirculate fire by-products from the fire zone to the TBM/roadheader. For a rigid duct system, a large fire could cause duct damage with possible short-circuiting of by-products to the main drift.

Since fire by-products would spread throughout the working drift and downstream main drift(s), the life safety of workers in both locations would be threatened.

Fire Scenario 3: A fire in a main drift between the entrance to a working drift and the fresh air source would release fire by-products into the main drift ventilation air downstream of the fire. Fire by-products would then be drawn into the working drifts by the local ventilation system.

The life safety of all workers downstream of the fire zone would be threatened.

Fire Scenario 4: A fire in the main drift between the entrance to a working drift and the exhaust air destination at the South Portal would release fire by-products into the main drift ventilation air downstream of the fire. Such a fire would have no impact on upstream working drifts.

The life safety of all workers downstream of the fire zone is threatened.

7.4.2.3.2 Dust Control

Just like Option B, Alternative 1 the global system does not contain any ducts in the main drifts and relies on dilution, air scrubbers at the working face, and portable scrubbers in the working drifts to maintain air quality in the global system. This is necessary because the exhaust air from one working drift becomes the intake for downstream operations.

Figure 7-2 in Section 7.3.2 shows the local ventilation Alternative 2. In this alternative, the intake air is carried from the main drift through the working drift to the working face and, therefore, the air must be scrubbed of dust before entering the working face. All of the exhaust air is ducted from the working face through the working drift to discharge back into the main drift. The exhaust air in the duct must be scrubbed of dust since it is the intake air for downstream working drifts.

If flexible duct is used, the exhaust duct must be under positive pressure. Therefore, the leakage from the duct is out of the duct and is added to the dust in the working drift which would have to be scrubbed before reaching the working face. If rigid duct is used, then the exhaust duct can be under positive or negative pressure. If it is under positive pressure, the leakage from the duct is the same as using flexible duct. If the duct is under negative pressure, the leakage is from the working drift into the duct which would be better since the dust would leak into the duct.

In Option B, the system relies on dilution, air scrubbers at the TBM, and portable scrubbers to maintain air quality in the global system. This is necessary because the exhaust air from one operation becomes the intake for downstream operations. Any of the local alternative systems can be used with Option B as long as the amount of dust delivered to the global system can be diluted or scrubbed.

All of the Option B combinations are less desirable than the Option A/Alternative 3 combination for dust control because of the heavy reliance on dust scrubbers to maintain air quality.

7.4.2.3.3 Construction Logistics

Just like Option B, Alternative 1 the construction logistics of this combination would not be very difficult. Since the global system is a flow-through system, there are no ducts in the main drifts and, therefore, no interferences with other operations. For the local system there is an exhaust duct in the working drifts which would interfere with the operations within those particular drifts.

7.4.2.4 Local Alternative 3 (Intake Through Duct, Exhaust Through Duct) / Conditions 1 - 4

7.4.2.4.1 Fire Hazards

Fire Scenario 1: A fire onboard either a TBM or roadheader at the working face would release fire by-products into both the working drift and the ducted exhaust system which then discharges into the main drift ventilation system at the main drift. The fire by-products would rapidly spread throughout the downstream main drift(s). For a flexible duct system, a large fire would likely cause the exhaust fan to shut down and damage the duct. The intake system would continue to carry fire by-products in the TBM/roadheader and out of the working drift into the main drift. For a rigid duct system, the exhaust fan would be located in the main drift and would continue to function. Some duct damage could occur without causing significant ventilation degradation. A large fire would likely cause the adjacent supply fan to shutdown without much effect.

Since fire by-products would spread throughout the working drift and downstream main drift(s), the life safety of workers in both locations would be threatened.

Fire Scenario 2: A fire in a working drift between a TBM or roadheader and a main drift would release fire by-products into the working drift air toward the main drift where they would rapidly spread throughout the downstream main drift(s). For a flexible duct system, a large fire would likely damage the adjacent duct on both supply and exhaust systems, causing collapse of the duct from the fire zone to the TBM/roadheader and from the fire zone to the main drift. The remaining exhaust section with the fan would recirculate fire by-products from the fire zone to the TBM/roadheader and exhaust toward the main drift. For a rigid duct system, a large fire could cause duct damage with possible short-circuiting of by-products to the TBM/roadheader.

Since the fire by-products would initially be carried out of the working drift toward the main drift(s), workers at the TBM/roadheader have time to take mitigating life safety actions. The life safety of workers in downstream drifts would be threatened. If fan and duct integrity fail, fire by-products could spread throughout the working drift threatening all workers.

Fire Scenario 3: A fire in a main drift between the entrance to a working drift and the fresh air source would release fire by-products into the main drift ventilation air which would rapidly spread throughout the downstream main drift(s). Fire by-products would then be drawn into the working drifts by the local ventilation system.

The life safety of all workers downstream of the fire zone would be threatened.

Fire Scenario 4: A fire in a main drift between the entrance to a working drift and the exhaust air destination at the South Portal would release fire by-products into the main drift ventilation air downstream of the fire. Such a fire would have little impact on upstream working drifts.

The life safety of all workers downstream of the fire zone would be threatened.

7.4.2.4.2 Dust Control

Just like Option B, Alternatives 1 and 2, the global system contains no ducts in the main drifts and relies on dilution, air scrubbers at the working face, and portable scrubbers in the working drifts to maintain air quality in the global system. This is necessary because the exhaust air from one working drift becomes the intake for downstream operations.

Figure 7-3 in Section 7.3.3 shows the local ventilation Alternative 3. In this alternative, the intake air is ducted from the main drift through the working drift to the working face and, therefore, the air must be scrubbed of dust before entering the working face. Most of the exhaust air is ducted from the working face through the working drift to discharge back into the main drift. The rest of the exhaust air is carried through the working drift to join the exhaust air from the duct. The exhaust air in both the duct and the drift must be scrubbed of dust since it becomes the intake air for downstream working drifts.

If flexible duct is used, both the intake and exhaust duct must be under positive pressure. Therefore, the leakage direction is out of the duct and is added to the dust in the working drift which would have to be scrubbed before discharging into the main drift. This would be better for the intake duct since the air would be cleaner entering the working face. If rigid duct is used, then both intake and exhaust ducts can be under positive or negative pressure. If they are under positive pressure, the leakage from the ducts is the same as using flexible duct. If the ducts are under negative pressure, the leakage is from the working drift into the duct which would pollute the intake air and would have to be scrubbed before entering the working face. This would be better for the exhaust duct since the dust would enter into the duct to be carried all the way to the surface.

In Option B, the system relies on dilution, air scrubbers at the TBM, and portable scrubbers to maintain air quality in the global system. This is necessary because the exhaust air from one operation becomes the intake for downstream operations. Any of the local alternative systems can be used with Option B as long as the amount of dust delivered to the global system can be diluted or scrubbed.

Since Local alternative 3 produces the best air quality at the TBM, it should be considered for use with global Option B. The combined systems would require the following:

- High efficiency on the scrubber removing dust from the TBM cutters because this air will be released into the fresh air for downwind operations.
- Portable scrubbers to lower the dust concentration in the tunnel because this air will become the intake for downstream operations.

All of the Option B combinations are less desirable than the Option A/Alternative 3 combination for dust control because of the heavy reliance on dust scrubbers to maintain air quality.

7.4.2.4.3 Construction Logistics

The construction logistics of this combination would be more difficult than Option B, Alternatives 1 and 2 but not nearly as difficult as Option A, Alternative 3. Since the global system is a flow-through system, there are no ducts in the main drifts and, therefore, no interferences with other operations. For the local system there is both an intake duct and an exhaust duct in the working drifts which would interfere with the operations within those particular drifts.

7.4.2.5 Monitoring and Control Systems

For clarity, the monitoring and control systems are only identified for the global system. Inclusion of the local systems would only make these systems more complex. A description of the monitoring and control systems needed for each ventilation condition is shown below. Each description is detailed in a P&ID figure. A legend sheet for the P&ID figures is found in Figure 7-8 in Section 7.4.1.5.

- Conditions 1 - 3 (see Figure 7-21): All requirements for main and other drift ventilation are met using constant-speed fans located at the North Portal. Air flows through the repository and is exhausted through the South Portal. Dust from TBM and roadheader operations that is exhausted from working faces is controlled locally by fabric dust collectors and returned to the main ventilation airflow. This eliminates the in-line booster fans, ductwork and associated controls required in the other ventilation options. Monitoring requirements include non-radioactive particulates, humidity, temperature, airflow, and carbon monoxide at the surface, at the ramps and in the mains, drifts and working areas for personnel protection and overall system operation.

FIGURE 7-21
CONDITION 1 THROUGH 3-OPTION B
VENTILATION P&ID

- Condition 4 (see Figure 7-22): During simultaneous emplacement and development, ventilation of the development mains and drifts is supplied by variable-speed fans located at the surface of the Development Intake Shaft. The speed of the operating fan is varied as necessary to maintain the desired airflow through the development side and the desired differential pressure between the development side and emplacement side. Local dust collectors continue to be used to clean air returned to the mains from the working faces.

Option B is the least complicated from a controls perspective since the complexities associated with in-line booster fans and ductwork are avoided. Monitoring requirements for non-radioactive particulates, humidity, temperature, airflow, and carbon monoxide are the same as in the other ventilation options.

7.4.3 Option C--Ducted Exhaust System

Intake air is supplied through the drift from a surface location to the last open drift that intersects the drift where the working face is located. The exhaust air is ducted from the working face to another surface location. This system is similar to the one used during excavation of the ESF.

7.4.3.1 Ventilation System

The ventilation system details needed to support Option C at a global level for each ventilation condition are calculated in Table II-3 in Attachment II. These include airflow quantity, length of duct, horsepower, and number of fans. The global ventilation system for Option C is shown in Figures 7-23, 7-24, 7-25, and 7-26 for Conditions 1, 2, 3, and 4, respectively.

7.4.3.2 Local Alternative 1 (Intake Through Duct, Exhaust Through Drift) / Conditions 1 - 4

This alternative is not practical for Option C regardless of the condition because all dust-laden global system exhaust is ducted to the surface. It is impractical to exhaust through the drift under these conditions. Therefore, this alternative will not be discussed further for Option C.

7.4.3.3 Local Alternative 2 (Intake Through Drift, Exhaust Through Duct) / Conditions 1 - 4

7.4.3.3.1 Fire Hazards

Fire Scenario 1: A fire onboard either a TBM or roadheader at the working face would release fire by-products into the ducted exhaust system which would then discharge to a portal. For a flexible duct system, a large fire would likely cause the adjacent exhaust fan to shutdown and damage the duct, collapsing the next section. For a rigid duct system, some duct damage could occur without causing significant ventilation degradation.

Since fire by-products would be exhausted to the portal, the life safety of workers in the working drift and downstream main drift(s) would not be threatened.

FIGURE 7-23
CONDITION 1 - OPTION C
DUCTED EXHAUST

FIGURE 7-24
CONDITION 2 - OPTION C
DUCTED EXHAUST

FIGURE 7-25
CONDITION 3 - OPTION C
DUCTED EXHAUST

NOTES:
1. EMPLACEMENT SIDE SHOWN FOR REFERENCE ONLY.

FIGURE 7-26
CONDITION 4 - OPTION C
DUCTED EXHAUST

Fire Scenario 2: A fire in a working drift between a TBM or roadheader and a main drift would release fire by-products into the working drift air toward the TBM/roadheader. The exhaust duct system would then exhaust the fire by-products to a portal. For a flexible duct system, a large fire would likely damage adjacent duct, causing collapse of the duct from the fire zone to the main drift. The remaining section with the fan would recirculate fire by-products from the fire zone to the TBM/roadheader. For a rigid duct system, some duct damage could occur without causing significant ventilation degradation.

Since fire by-products would spread throughout the working drift and downstream main drift(s), the life safety of workers in both locations would be threatened.

Fire Scenario 3: A fire in a main drift between the entrance to a working drift and the fresh air source would release fire by-products into the main drift ventilation air downstream of the fire. Fire by-products would then be drawn into the working drifts by the local ventilation system.

The life safety of workers downstream of this fire scenario is threatened.

Fire Scenario 4: A fire in a main drift between the entrance to a working drift and the exhaust air destination at the South Portal would release fire by-products into the main drift ventilation air downstream of the fire. If fan and duct integrity were maintained, such a fire would have no impact on upstream working drifts. If fan and duct integrity were compromised adjacent to the fire, ventilation in the upstream working drifts could cease.

The life safety of all workers downstream of the fire zone would be threatened.

7.4.3.3.2 Dust Control

Intake air is carried through the main drifts from the surface through the working drift to the working face. All of the exhaust air is ducted from the working face to the surface.

Figure 7-2 in Section 7.3.2 shows the local ventilation Alternative 2. In this alternative, the intake air is carried from the main drift through the working drift to the working face and, therefore, the air must be scrubbed of dust before entering the working face. All of the exhaust air is ducted from the working face through the working drift all the way to the surface.

If flexible duct is used for local ventilation, the exhaust duct must be under positive pressure. Therefore, the leakage from the duct is out of the duct and is added to the dust in the working drift which would have to be scrubbed more before entering the working face. If rigid duct is used, then the exhaust duct can be under positive or negative pressure. If it is under positive pressure, the leakage from the duct is the same as using flexible duct. If the duct is under negative pressure, the leakage is from the working drift into the exhaust duct which would be better since the dust would enter into the duct.

Combining Alternative 2 with global Option C would produce a system that exhausts air from the working face to the surface in a duct. Fresh air is carried in the main drifts and working drifts. Unlike the Option B combinations and the Option C/Alternative 3 combination, exhaust air from one working drift does not become the intake for downstream operations. The fact that the exhaust from one working drift does not become the intake for the downstream operations makes the Option C/Alternative 2 superior to Option C/alternative 3.

7.4.3.3.3 Construction Logistics

The construction logistics of this combination would be more difficult than all the alternatives in Option B but not as difficult as in Option A. The global system intake is through the main drifts but the exhaust is ducted from the working drifts all the way to the surface. Therefore, there are interferences with other operations on the exhaust side of the system. For the local system there is an exhaust duct in the working drifts which would interfere with the operations within those particular drifts.

7.4.3.4 Local Alternative 3 (Intake Through Duct, Exhaust Through Duct) / Conditions 1 - 4

7.4.3.4.1 Fire Hazards

Fire Scenario 1: A fire onboard either a TBM or roadheader at the working face would release fire by-products into the working drift and the ducted exhaust system which would then discharge to a portal. For a flexible duct system, a large fire would likely cause the adjacent exhaust fan to shut down and damage the duct, collapsing the next section. The intake system would continue to operate and would carry the fire by-products into the TBM/roadheader and out of the working drift into the main drift. For a rigid duct system, some duct damage could occur without causing significant ventilation degradation. A large fire would likely cause the adjacent supply fan to shut down without much effect.

Since fire by-products would spread throughout the working drift and downstream main drift(s), the life safety of workers in both locations would be threatened.

Fire Scenario 2: A fire in a working drift between a TBM or roadheader and a main drift would release fire by-products into the working drift air toward the main drift where they would rapidly spread throughout the downstream main drift(s). For a flexible duct system, a large fire would likely damage the adjacent duct on both intake and exhaust systems, causing collapse of the duct from the fire zone to the TBM/roadheader and from the fire zone to the main drift. The remaining exhaust section with the fan would recirculate fire by-products from the fire zone to the TBM/roadheader and exhaust toward the main drift. For a rigid duct system, a large fire could cause duct damage to both intake and exhaust systems. Fire by-products could be carried toward the TBM/roadheader and exhausted into the main drift(s) and also the damaged exhaust duct.

Since the fire by-products would be initially carried out of the working drift toward the main drift(s), workers at the TBM/roadheader have time to take

mitigating life safety actions. The life safety of workers in downstream drifts would be threatened. If fan and duct integrity fail, fire by-products could spread throughout the working drift threatening all workers.

Fire Scenario 3: A fire in a main drift between the entrance to a working drift and the fresh air source would release fire by-products into the main drift ventilation air downstream of the fire. Fire by-products would then be drawn into the working drifts by the local ventilation system.

The life safety of all workers downstream of the fire zone would be threatened.

Fire Scenario 4: A fire in a main drift between the entrance to a working drift and the exhaust air destination at the South Portal would release fire by-products into the main drift ventilation air downstream of the fire. If fan and duct integrity were maintained, such a fire would have no impact on upstream working drifts. If fan and duct integrity were compromised adjacent to the fire, ventilation in the upstream working drifts could cease.

The life safety of all workers downstream of the fire zone would be threatened.

7.4.3.4.2 Dust Control

Intake air is carried through the main drifts from the surface to the working drift and ducted through the working drift to the working face. Most of the exhaust air is ducted from the working face to the surface. The remaining exhaust air is carried back through the working drift to discharge into the main drift to become the intake for downstream operations.

Figure 7-3 in Section 7.3.3 shows the local ventilation Alternative 3. In this alternative, the intake air is ducted from the main drift through the working drift to the working face and, therefore, the air must be scrubbed of dust before entering the working face. Most of the exhaust air is ducted from the working face through the working drift all the way to the surface. The rest of the exhaust air is carried through the working drift to discharge into the main drifts. The exhaust air in both the duct and the drift must be scrubbed of dust since it becomes the intake air for downstream working drifts.

If flexible duct is used, both the intake and exhaust duct must be under positive pressure. Therefore, the leakage direction is out of the duct and is added to the dust in the working drift which would have to be scrubbed before discharging into the main drift. This would be better for the intake duct since the air would be cleaner entering the working face. If rigid duct is used, then both intake and exhaust ducts can be under positive or negative pressure. If they are under positive pressure, the leakage from the ducts is the same as using flexible duct. If the ducts are under negative pressure, the leakage is from the working drift into the duct which would pollute the intake air and would have to be scrubbed more before entering the working face. This would be better for the exhaust duct since the dust would enter into the duct and be carried all the way to the surface.

In the Option C/Alternative 3, the exhaust from one working drift would become the intake for downstream operations which makes the intake side of the system similar to the Option B systems. As a result, the system requires portable scrubbers to lower dust concentration in the fresh air stream. The system is more effective than the Option B combinations because exhaust from the working face is ducted all the way to the surface. The system is less effective than the Option A/Alternative 3 combination because the fresh air quality in the main drifts will be decreased by leakage from the exhaust duct.

7.4.3.4.3 Construction Logistics

The construction logistics of this combination would be slightly more difficult than Option C, Alternative 2. The global system intake is through the main drifts but the exhaust is ducted from the working drifts all the way to the surface. Therefore, there are interferences with other operations on the exhaust side of the system. For the local system there is an intake duct and an exhaust duct in the working drifts which would interfere with the operations within those particular drifts.

7.4.3.5 Monitoring and Control Systems

For clarity, the monitoring and control systems are only identified for the global system. Inclusion of the local systems would only make these systems more complex. A description of the monitoring and control systems needed for each ventilation condition is shown below. Each description is detailed in a P&ID figure. A legend sheet for the P&ID figures is found in Figure 7-8 in Section 7.4.1.5.

- Condition 1 (see Figures 7-27 and 7-28): In this condition, air is drawn through the North Portal to meet general main and drift ventilation requirements by constant-speed fans located at and exhausting from the South Portal. Air from the working faces of the repository is collected in large-diameter ducts and exhausted through the South Portal with a limited amount exhausting through the North Portal. Although the number of in-line booster fans is lower than in Option A because intake ducts are not required, the quantities are significant enough to require automatic control from a central location. Fan controls are detailed in the figure along with general monitoring requirements at the surface and in the ramps, mains, drifts and working areas that include non-radioactive particulates, humidity, temperature, airflow, and carbon monoxide.
- Condition 2 (see Figures 7-29 and 7-30): The construction ventilation fans continue to operate as in the previous condition, but the exhaust ducts and booster fans to the North Portal are no longer required. General monitoring requirements for personnel protection and overall system operation remain in place. The Development Intake Shaft is available as an air supply but is normally not used.

NOTES:

1. CONSTRUCTION FANS FOR DEVELOPMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 1, OPTION C VENTILATION PLAN, SEE FIGURE 7-23.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-27
CONDITION 1 - OPTION C
VENTILATION P&ID, SHEET 1 of 2

- NOTES:
1. CONSTRUCTION FANS FOR DEVELOPMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
 2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
 3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
 4. FOR GENERAL ARRANGEMENT OF CONDITION 1, OPTION C VENTILATION PLAN, SEE FIGURE 7-23.
 5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-28
CONDITION 1 - OPTION C
VENTILATION P&ID, SHEET 2 of 2

NOTES:

1. CONSTRUCTION FANS FOR EMPLACEMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 2, OPTION C, VENTILATION PLAN, SEE FIGURE 7-24.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-29
CONDITION 2 - OPTION C
VENTILATION P&ID, SHEET 1 of 2

- Condition 3 (see Figures 7-31 and 7-32): In Condition 3, the Development Intake Shaft supplements the North Portal, if necessary, as an air supply to the repository mains and other drifts. The construction ventilation fans continue to operate, the general repository monitoring parameters continue to be tracked, and air from the working faces is exhausted through stacks at the South Portal.
- Condition 4 (see Figures 7-33 and 7-34): Variable-speed fans supply ventilation air to the development side of the repository during simultaneous emplacement and development operations. The speed of the operating fan is adjusted as required to maintain the desired airflow through the mains and other drifts and the desired differential pressure between the development and emplacement sides of the repository. Exhaust air from the working faces continues to be discharged through a series of ducts at the South Portal. General monitoring requirements throughout the ramps, mains, and other drifts of the repository also continue to be tracked.

Option C has exhaust booster fans that must be monitored and controlled, but it contains no intake booster fans as in Option A. This makes Option C more complex than Option B which does not require booster fans at all but less complex than Option A. General monitoring parameters are the same for all of the options.

7.5 EVALUATIONS

Evaluation criteria were generated to evaluate the different ventilation options. The criteria contain five categories that were determined to be the main factors influencing the ventilation system. These categories include supply of air, health & safety, air control & system reliability, construction logistics, and cost. Each category has a weighting factor for the category itself ranking from the most important down and all adding up to 100%. The categories, subcategories, and weighting factors were all determined by a committee of engineers familiar with ventilation systems, including the people listed as contributors to this analysis on the cover sheet. Table 7-6 shows the evaluation criteria.

The air supply category is the determining factor that decides whether an option warrants being evaluated. This is a pass or fail evaluation. The option must be able to supply the amount of air required by 29 CFR 1926.800(k)(1)(i) or it is no longer considered as an option (Criteria 4.2.8).

The health & safety category is the most important aspect of the design and was given the highest overall weighting. It is valued at more than the total of the other categories combined so that they do not overshadow it. Therefore, the health & safety was assigned 55% of the total weighting. The health & safety category is broken down into three subcategories with their own rankings that add up to 100%. Since fire hazards can cause serious harm or death to workers in a very short period of time, it is the priority of the health & safety category. It is given a weighting of 55% so the other two subcategories together do not overshadow it. Dust control is next as a priority because it can cause serious harm or death to workers over a longer period of time. It is given a weighting of 30%. Dust control includes leakage and air recirculation. The last priority is noise. It cannot cause death to workers but can cause them harm so is still a health & safety concern. It is given a weighting of 15%.

FIGURE 7-31
CONDITION 3 - OPTION C
VENTILATION P&ID, SHEET 1 of 2

NOTES:

1. CONSTRUCTION FANS FOR EMPLACEMENT SIDE VENTILATION SHAFT SINKING ARE CONTROLLED LOCALLY AND ARE NOT SHOWN ON THIS SCHEMATIC.
2. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
3. BOOSTER FAN SEQUENTIAL STARTING INTERLOCKS NOT SHOWN.
4. FOR GENERAL ARRANGEMENT OF CONDITION 2, OPTION C, VENTILATION PLAN, SEE FIGURE 7-25.
5. FOR SYMBOL DESCRIPTIONS AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-32
CONDITION 3 - OPTION C
VENTILATION P&ID, SHEET 2 of 2

FIGURE 7-33
CONDITION 4 - OPTION C
VENTILATION P&ID, SHEET 1 OF 2

- NOTES:
1. BOOSTER FAN NUMBERS VARY WITH LOCATION OF THE WORK.
 2. BOOSTER FAN SEQUENTIAL STARTER INTERLOCK NOT SHOWN.
 3. FOR GENERAL ARRANGEMENT OF VENTILATION PLAN, SEE FIGURE 7-26.
 4. FOR SYMBOL DESCRIPTION AND INSTRUMENT IDENTIFICATION, SEE FIGURE 7-8.

FIGURE 7-34
CONDITION 4 - OPTION C
VENTILATION P&ID, SHEET 2 OF 2

Table 7-6. Evaluation Criteria

Category	Category Weighting	Subcategory Weighting
Supply of Air	Pass / Fail	N/A
<u>Health & Safety</u>	55%	
- Fire Hazards		55%
- Dust Control & Air Quality		30%
- Noise		15%
<u>Air Control & System Reliability</u>	25%	
- System Reliability		60%
- Monitoring & Air Control		40%
<u>Construction Logistics</u>	15%	
- Transport of Equipment		33.33%
- Installation		33.33%
- Removal		33.33%
<u>Cost</u>	5%	
- Capital		60%
- Operating		40%

The air control & system reliability category is considered the next most important aspect of the design. Difficulty in controlling and managing the system can lead to costly maintenance and health & safety issues. It is assigned 25% of the total weighting. The air control & system reliability category is divided into three subcategories with their own rankings that add up to 100%. System reliability is the more important aspect because the system should operate as designed and be available when needed. It is given a weighting of 60%. Monitoring and air control is required and is important because the amount of air required for each working area must be supplied and monitoring will assure that it is. Also, the entire system must be monitored for air quality and accident situations. It is given a weighting of 40%.

Construction logistics is the third most important aspect of the design. If the ventilation system is difficult to construct and interferes with other operations, it can be very costly and time consuming. It is assigned 15% of the total weighting. The construction logistics category is divided into three subcategories with their own rankings that add up to 100%. The three subcategories are transport of equipment, installation, and removal. They are all considered to be equal in terms of their impact to the design so are all given the same weighting of 33.33%.

Cost is the last aspect of the design. It is given a lower ranking because the ventilation system will be constructed to the regulatory and safety requirements no matter how much it costs, although an attempt is made at keeping costs as low as possible. It is assigned 5% of the total weighting. The cost category is divided up into two subcategories with their own rankings that add up to 100%. Capital is the more important aspect because it is subject to the budget available and it is incurred up front because most of the ventilation equipment must be procured at the beginning of the project. It is given a weighting of 60%. Operating costs are more of a fixed cost incurred every year

throughout the period of operations, although they are subject to the amount of construction accomplished during the year. It is given a weighting of 40%.

There are a total of six evaluations to determine the better ventilation systems that are possible for construction and development of the subsurface repository. The evaluations are in terms of the global option with a local alternative. The evaluations are as follows:

- Option A (Duct Intake/Ducted Exhaust), Alternative 3 (Ducted Intake/Ducted Exhaust)
- Option B (Flow-Through), Alternative 1 (Ducted Intake)
- Option B (Flow-Through), Alternative 2 (Ducted Exhaust)
- Option B (Flow-Through), Alternative 3 (Ducted Intake/Ducted Exhaust)
- Option C (Ducted Exhaust), Alternative 2 (Ducted Exhaust)
- Option C (Ducted Exhaust), Alternative 3 (Ducted Intake/Ducted Exhaust)

Monitoring and controls as well as cost are applied to the global systems. Therefore, the information for each alternative will be the same within each global system. Table 7-7 contains the evaluation of the global options and local alternatives. Ratings were devised based on the six evaluations with 6 being the best and 1 being the worst. The evaluations were done by a committee of engineers familiar with ventilation systems, including the people listed as contributors to this analysis on the cover sheet. Table 7-8 contains the totals for the evaluation. The totals were generated by first multiplying the rating by the subcategory weighting and then summing those into a subtotal for the category. The subtotal was then multiplied by the category weighting and then summing those into the total for the evaluation. Each option/alternative combination was determined in this manner.

The evaluations show that the best combination of global and local systems is Option C (Ducted Exhaust)/Alternative 2 (Ducted Exhaust). However, Option B (Flow-Through)/Alternatives 1 (Ducted Intake) and 2 (Ducted Exhaust) come in close behind and may be viable if the health and safety category can be increased. These two options/alternatives are the better system combinations for all other categories relative to Option C/Alternative 2. The combination of Option B (Flow-Through)/Alternative 3 (Ducted Intake/Ducted Exhaust) could also be a viable option since it is relatively close to the other Option B combinations, although is lower rated for all categories except health and safety which it rates better. The last two combinations of Option C (Ducted Exhaust)/Alternative 3 (Ducted Intake/Ducted Exhaust) and Option A (Ducted Intake/Ducted Exhaust)/Alternative 3 (Ducted Intake/Ducted Exhaust) are the lowest evaluations even though the health and safety ratings were the highest. They are rated the worst for all other categories.

An evaluation was not done as to which duct to use for the local ventilation system. If an evaluation were to be done between using flexible duct versus rigid duct, it is likely that the flexible duct would be better overall. This is because it is better for dust control, construction logistics, and capital cost. It is better for dust control because the flexible duct is always under positive pressure which delivers better quality air to its destination. The construction logistics are better because 500 m of duct can fold into a small pile to transport and feeds out of a magazine when installed. The rigid duct comes in 6 meter segments which are difficult to transport as well as to install. Because of the construction logistics, the capital costs are much lower for flexible duct than with rigid duct.

Table 7-7. Evaluation of Options/Alternatives (Ratings)

	Option A/ Alternative 3	Option B/ Alternative 1	Option B/ Alternative 2	Option B/ Alternative 3	Option C/ Alternative 2	Option C/ Alternative 3
Supply of Air	Pass	Pass	Pass	Pass	Pass	Pass
Health & Safety						
- Fire Hazards	5	1	3	2	6	4
- Dust Control & Air Quality	6	2	1	3	4	5
- Noise	1	6	5	4	3	2
Air Control & System Reliability						
- Sytem Reliability	1	6	5	4	3	2
- Monitoring & Air Control	1	6	5	4	3	2
Construction Logistics						
- Transport of Equipment	1	6	5	4	3	2
- Installation	1	6	5	4	3	2
- Removal	1	6	5	4	3	2
Cost						
- Capital	1	6	5	4	3	2
- Operating	1	6	5	4	3	2

Ratings: 6 - best 1 - worst

Table 7-8. Evaluation Totals (Ratings x Percentages)

	Category Weighting	Subcategory Weighting	Option A/ Alternative 3	Option B/ Alternative 1	Option B/ Alternative 2	Option B/ Alternative 3	Option C/ Alternative 2	Option C/ Alternative 3
Supply of Air	Pass/Fail		Pass	Pass	Pass	Pass	Pass	Pass
Health & Safety	55%							
- Fire Hazards		55%	2.75	0.55	1.65	1.10	3.30	2.20
- Dust Control & Air Quality		30%	1.80	0.60	0.30	0.90	1.20	1.50
- Noise		15%	0.15	0.90	0.75	0.60	0.45	0.30
Subtotal			2.59	1.13	1.49	1.43	2.72	2.20
Air Control & System Reliability	25%							
- Sytem Reliability		60%	0.60	3.60	3.00	2.40	1.80	1.20
- Monitoring & Air Control		40%	0.40	2.40	2.00	1.60	1.20	0.80
Subtotal			0.25	1.50	1.25	1.00	0.75	0.50
Construction Logistics	15%							
- Transport of Equipment		33.33%	0.33	2.00	1.67	1.33	1.00	0.67
- Installation		33.33%	0.33	2.00	1.67	1.33	1.00	0.67
- Removal		33.33%	0.33	2.00	1.67	1.33	1.00	0.67
Subtotal			0.15	0.90	0.75	0.60	0.45	0.30
Cost	5%							
- Capital		60%	0.60	3.60	3.00	2.40	1.80	1.20
- Operating		40%	0.40	2.40	2.00	1.60	1.20	0.80
Subtotal			0.05	0.30	0.25	0.20	0.15	0.10
TOTAL			3.03	3.83	3.73	3.23	4.07	3.10

However, there is a slight disadvantage with using flexible duct. Flexible duct is more susceptible to compromising the integrity of the duct during a fire if the fire is large enough to cause damage. Rigid duct is assumed for all global duct options because of the long drifts involved.

8. CONCLUSIONS

1. There are three ventilation options that can be applied to the License Application design as shown in Figures 7-4 through 7-7 in Section 7.4.1.1 for Option A (Ducted Intake/Ducted Exhaust), Figures 7-17 through 7-20 in Section 7.4.2.1 for Option B (Flow-Through), and Figures 7-23 through 7-26 in Section 7.4.3.1 for Option C (Ducted Exhaust).
2. The best ventilation system (global option and local alternative combined) is Option C (Ducted Exhaust)/Alternative 2 (Ducted Exhaust) because it provides the best rating for fire hazards as shown on Table 7-8 in Section 7.5 and shown in Figures 7-23 through 7-26 in Section 7.4.3.1. The rankings of other viable options/alternatives are also shown on the table. Option B (Flow-Through)/Alternatives 1 (Ducted Intake) and 2 (Ducted Exhaust) come in close behind in the rankings and may be viable if the health and safety evaluation, mainly with respect to fire hazards, can be increased. These two options/alternatives are the better system combinations for all other categories.

The concepts for ventilation are based upon ventilation concepts presented throughout the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5). The ventilation conditions expected are based on the construction phases in the *Subsurface Construction and Development Analysis* (Reference 5.13). The results of this analysis are valid for the inputs used and could change if the inputs change.

Duct sizes, air quantities, and fan sizes are depicted on the figures cited in conclusion 1 and in Attachment II.

The construction ventilation for the concepts presented in this analysis comply with the criteria as stated in Section 4.2.

The inputs identified in Section 4 as TBV are carried through to the outputs of this analysis. Therefore, the outputs with TBVs may not be used for construction, procurement, or fabrication without being controlled in accordance with NLP-3-15, *To Be Verified (TBV) and To Be Determined (TBD) Monitoring System*.

9. ATTACHMENTS

ATTACHMENT	DESCRIPTION
I	Justification for 7.62 m TBM Scrubber Quantity in Assumption 4.3.11
II	Ventilation System Calculations

ATTACHMENT I
JUSTIFICATION FOR 7.62 M TBM SCRUBBER
QUANTITY IN ASSUMPTION 4.3.11

(See attached Lotus Note)

To: BILL KENNEDY, Daniel McKenzie, Ralph Dresel
cc: Jerry Naaf, Alden Segrest, Tommy Touchstone, Robert Sandifer, Dick McDonald, Robert Law, Jeff LeFever, Charles Parker, David Barreres, Dan Chapman, Leslie Eisler, Larry Morrison
From: Romeo Jurani
Date: 09/20/96 09:48:26 AM
Subject: TBM Spot Dust Scrubber Information

Please contact me at 295-9125 if you have comments or questions.

ESF TBM Dust Control

This IOC is the result of the search for a spot dust scrubber customized to fit the needs of the ESF TBM operation. Filter/scrubber performance, product configuration and availability for ease in adapting to the TBM operation were considered. After discussion with several suppliers and evaluation of options available, the following information is released for **design, procurement, installation, operation and maintenance** of the TBM Spot Dust Scrubber.

Objective: To provide at least a 30,000 cfm clean air at the TBM.

Method: A dry dust scrubber will be installed at Deck 12 of the TBM with an axial fan and two stage filter media. Dust laden air from the TBM trombone area will be pulled through a two stage filter by an axial fan (See Figures 1 & 2 for TBM Deck 12 configuration and Figures 3 & 4 for filter assembly). Clean air is defused in the tunnel to form a fresh air wall that will block off dust laden air from the TBM face. A curtain will be hung between the clean and the dust laden air to further enhance the separation.

First Stage Filter Media Feature

Design maximum capacity:

16.99 m³/s (36,000 cfm) with minimum 14.16 m³/s (30,000 cfm)

Ambient Air Temperature:

70 to 90°F at 50 to 87% relative humidity

Estimated ambient air total dust loading:

@ 1 to 2 mg/m³ : 1.47 to 2.94 kg/day (3.23 to 6.46 lb/day)

Mineral dust content:

Dominantly feldspar with considerable quartz, cristobalite & tridymite and small amounts of glass, mica & smectite

Dust particle sizes:

Dominantly respirable dust at less than 10 microns.

Dust Efficiency Removal (Prefilter Stage):

39 % on 1 micron, 90% on 2 microns, 97% on 4 microns and about 99 % on 6 microns

Filter Size Configuration:

Total cross area, 10' W x 8' H x 4" Deep, with 20 units of filter pads @ 24" x 24" x 3 ¼ deep each

Projected pressure loss:

Initial clean filter @ 0.4" Water Gage (WG) , Final @ 1.9" WG (max replacement)

Delivery/Procurement:

Available on stock. Procure 80 pads and install 20 with 60 spares

Maintainability & Cost:

Disposable filter pads, potentially once in every 2 weeks. Replacement pad cost, \$6.28 each

Brand Name & Supplier:

M-80 Prefilter Pad P/N 2031441 by American Air Filter, Louisville, Kentucky

Second Stage High Efficiency ASHRAE Filter Feature

Design maximum capacity:

16.99 m³/s (36,000 cfm) with minimum 14.16 m³/s (30,000 cfm)

Ambient Air Temperature:

70 to 90°F at 50 to 87% relative humidity

Estimated ambient air total dust loading:

Leftovers of dust after the first stage filtration. The second stage helps ensure a clean air output of the scrubber

Mineral dust content:

Dominantly feldspar with considerable quartz, cristobalite & tridymite and small amounts of glass, mica & smectite

Dust particle sizes:

Dominantly respirable dust at less than 10 microns.

Dust Efficiency Removal:

90 to 95% on 1 micron and 85% on 0.5 micron

Filter Size Configuration:

Total cross area, 10' W x 8' H x 12" deep; with 20 units of filter cells @ 24" x 24" x 12" deep each with gasket material

Projected pressure loss:

Initial clean filter @ 0.6" WG, final @ 1.2" WG (Max replacement)

Delivery/Procurement:

Available on stock, procure 40 cells (each with gasket) and install 20 units with 20 spares

Maintainability & Cost:

Disposable filter cells, potentially once in every two to three months. Replacement cost of filter cell (Varicel), \$ 95.00 each; and gasket, \$ 7.50 each

Brand Name & Supplier:

Varicel 90% (Single Header) P/N 331 946 148 complete with gasket P/N 324 966 042 by American Air Filter, Louisville, Kentucky

Filter Frame

Frame/Filter Holder:

Metal frame, heavy duty gage to hold the 20 filter units in one face. Actual detention 24" x 24", one for each filter cell

Delivery/Procurement:

Available on stock, procure 25 frames and install 20 units with 5 spares

Maintainability & Cost:

Low maintenance item. Procurement or replacement cost of filter frame, \$ 87.00 each

Brand Name & Supplier:

Galvanized steel frame P/N 1575745-4 by American Air Filter, Louisville, Kentucky

Prefilter Clamp/Retainer:

Prefilter Retainer:

Filter media retaining grid to hold the 20 prefilter units in place before the second stage high efficiency filter media

Delivery/Procurement:

Available on stock, procure 25 prefilter media retaining grid and install 20 units with 5 spares

Maintainability & Cost:

Low maintenance item.

Procurement or replacement cost of prefilter media retaining grid, \$ 18.00 each

Brand Name & Supplier:

Media Retaining Grid P/N 42006-1 by American Air Filter, Louisville, Kentucky

Filter Frame Accessories:

Caulk (P/N 26654) and rivets (P/N 36635-9) to attached and seal filter frames are included free of charge.

Joy Axial Fan (currently available backup TBM fan)

Joy Model 36-26-1778, Series 2000 (60 hp/460 volts/3 phase), SF 65673,

Performance: Adjust to blade setting # 0.9 (action item for R. Jurani to adjust blade at 42.5° tip angle with Kiewit assistance) to deliver 36,000 cfm at 5.3 inches water gage total pressure. The same blade setting will deliver 30,000 cfm at 8.0 inches water gage total pressure. An estimated 2.5 inches water gage of pressure losses is allowed for velocity pressure and local bends and adapters. The sum of resistances for the two filter media can not exceed a total of 2.8 inches water gage pressure loss to maintain the maximum 36,000 cfm system. (Note: The fan unit is a back-up fan for the TBM. Kiewit should be informed to replace this with a substitute unit from the NTS inventory.)

Plenum Housing Adapter, Filter Media to Axial Fan:

Design plenum box with metal construction to withstand 30 pounds per square foot of negative pressure. Separate sketch will be provided for this concept.

Fan Exhaust Diffuser

Roll an 18 gage galvanized duct, 36-inch in diameter by 20 feet long. One end has an adapter flange to connect to the fan silencer and the other end provided with a cap and perforations. Provide several 2" diameter holes spread along one side of the duct. This may be drilled in the last 10 feet section within the 225° perimeter of the diffuser duct. The total open area of the perforation has to be at least 10 square feet. Special opening that feeds the air to the clean room will be in separate sketch. Provide stopper/block for movement of mapping gantry to prevent damage to diffuser duct.

Curtain:

To enhance separation of the clean air from the tunnel air, a curtain will be installed around Deck 12. Specific location will be in separate instruction. The curtain will be similar unit that Kiewit has already installed near the TBM dance floor.

Monitor

Pressure Gages:

To determine when the filters are due for replacement, pressure gage monitor will be installed on the three of the 20 filter sets at locations: a) Filter 2 above the floor, second column; b) Filter 3 above the floor, third column; and c) Filter 2 above the floor, fourth column.

Adapter tubes for the pressure monitor will be mounted to determine the pressure resistances between the following: 1) prefilter pressure losses 2) second stage filter pressure losses 3) total pressure losses of the two filters 4) static and velocity pressures of the inlet and outlet of the axial fan. Separate instruction will be provided when filters are to be replaced and how they are to be handled.

Dust Monitor:

To determine the effectiveness of the dust scrubber, an 8-hr dust dose sample will be collected before and after the dust scrubber, initially once a day for three days and once a week thereafter.

PARTIAL ELEVATION
OF DECK 12

Figure 1 - TBM Spot Dust Scrubber

Figure 2 - TBM Spot Dust Scrubber

ATTACHMENT II VENTILATION SYSTEM CALCULATIONS

II.1 General Ventilation Inputs

The air quantity requirements for construction and development are based mainly on the use of two sizes of TBMs and a roadheader. The drift air quantity requirements for each unit are established in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Table 7.4.2) and are for use with all ventilation options in this analysis. The air quantities from the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Section 7.4.1.1) are based on velocities that exceed 30 ft/min (9.15 m/min) as required by 29 CFR 1926.800(k)(3) [Criteria 4.2.8]. The unit requirements are as follows (Parameter 4.1.2):

7.62 m TBM	36.49 m ³ /s (77,300 cfm)
5.5 m TBM	16.28 m ³ /s (34,500 cfm)
Roadheader	34.31 m ³ /s (72,700 cfm) for Conditions 1 through 3 and 34.22 m ³ /s (72,500 cfm) for Condition 4

Requirements (Criteria 4.2.1) dictate that the system shall provide a minimum quantity of fresh air to accommodate a maximum of 305 persons in the construction and development areas. Since 200 cfm (5.7 m³/min) per person is required for each underground worker (Criteria 4.2.5), the minimum quantity required underground is 61,000 cfm (1,738.5 m³/min). Each option is designed with a ventilation system configuration to provide sufficient airflow quantity to meet these requirements. All options pass the test to satisfy airflow quantity and distribution requirements. The ventilation system calculations for each option and ventilation condition are found in Table II-1 for Option A, Table II-2 for Option B, and Table II-3 for Option C. The data for Condition 4 of each option were extracted from the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Attachment IV). The airflow quantities are shown in Section 7.4 in Figures 7-4 through 7-7 for Option A; Figures 7-17 through 7-20 for Option B; and Figures 7-23 through 7-26 for Option C.

A ventilation plan is made for all options to satisfy the airflow requirements defined above. Airflow balance and size of primary and auxiliary ventilation equipment were determined and calculated as shown in Tables II-1, II-2, and II-3. The following input data are used and applied common to all options and are TBV.

1. For Options A, B, and C for Conditions 1 through 3, the lengths of drift development for duct lengths are based on the repository layout used in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Attachment I, Page I-2) and are shown in Figure II-1. Lengths are depicted between nodes. The lengths of drifts used in the calculations for Conditions 1 through 3 are combinations of these node lengths. A list of the lengths of drifts and their corresponding node combinations are found in Table II-4.

Lengths of drifts for Options A, B, and C for Condition 4 are based on the lengths found in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Attachment IV).

2. Common friction factors (K) used (Reference 5.5, Attachment IV):

Duct (54-inch, 66-inch, and 72-inch diameter)	20×10^{-10}
Ventilation Shaft	95×10^{-10}
Service Mains	70×10^{-10}

Common friction factor (K) used with accompanying justification:

Duct (48-inch diameter)	18×10^{-10}
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The friction factor for the 48-in duct is reasonable and comparable to the experience in the ESF. To have a structurally stable metal duct that can hold high negative pressures in the range of 25-35 in-WG, the ESF used a 66-in metal duct with corrugation at 11-12 mm high. The 66-in metal duct has a friction factor of 20×10^{-10} . The estimated corrugation for the 48-in metal duct to be used in Option A, Condition 2 is about 5-8 mm high. Therefore, the conservative assumption for the friction factor for the 48-in duct is 18×10^{-10} .

3. Average equivalent diameter (inches) of openings (Reference 5.5, Attachment IV):

Main drift and ramps after concreting and permanent invert	276
Development Intake and Emplacement Exhaust Shafts	
after concreting	240
Ventilation Duct	54
Ventilation Duct	66
Ventilation Duct	72

Average equivalent diameter (inches) of openings with accompanying justifications:

Main drift and ramps before concreting or steel support	300
Ventilation Duct	48

The 7.62 m TBM rough opening diameter of 300 inches was used for Conditions 1 through 3 for all options because it assumed that the airway does not contain the concrete lining since the concrete operations spanned two conditions. For Condition 4, the concrete lining is complete and so the opening diameter was decreased.

The use of 48-inch duct following the Exhaust Main TBM in Option A, Condition 2 is a new installation to handle the exhaust air of 35,000 cfm. This will produce an average air velocity of 2,800 ft/min in the duct to avoid dust settlement per the experience in the ESF. To use bigger diameter ducts will slow down the air velocity and risk dust settlement.

4. General fan selection for all options (Assumption 4.3.2):

Based on air quantity and calculated total pressure losses of the airway, an axial fan with a matching air quantity and potential maximum pressure performance (with at least 70% fan efficiency) is selected from the fan curves in Joy Catalogs J-670 and J-610 (Reference 5.17). The duty pressure performance of each fan is distributed in equal space over the entire length of the duct system. Horsepower requirements are determined with the equation/formula given in the calculations.

Surface primary fans are based on the one developed in the *Overall Development and Emplacement Ventilation Systems* analysis (Reference 5.5, Section 7.11.2.1).

5. The following technical formulas are used in the calculations.

Resistance: $R = KPL / (5.2 * A^3)$ (Reference 5.7, Page 23 & 26)

where: R = Resistance ($\text{in} \cdot \text{min}^2 / \text{ft}^6$)

K = Friction factor (dimensionless)

P = Perimeter (ft)

L = Length (ft)

A = Cross-sectional area (ft^2)

Head Loss: $H = RQ^2$ (Reference 5.7, Page 26)

where: H = Head loss (in water gage)

R = Resistance ($\text{in} \cdot \text{min}^2 / \text{ft}^6$)

Q = Quantity (cfm)

Horsepower: $BHP = HQ / (6346)$ (Reference 5.9, Page 165)

where: BHP = Break horsepower (hp)

H = Head loss (in water gage)

Q = Quantity (cfm)

Note: The horsepower needed for the ventilation system is dependent on the minimum efficiency of the fans. Therefore, the horsepower is divided by the efficiency to obtain the actual operating horsepower needed.

II.2 Specific Inputs for Option A

There must be additional air to support the airflow balance in the working drift for the case of Option A and the ventilation design delivery is as follows:

7.62 m TBM	112,300 cfm ($53.0 \text{ m}^3/\text{s}$), ducted intake air
	77,300 cfm ($36.49 \text{ m}^3/\text{s}$), exhaust air in working drift (Parameter 4.1.2)
	35,000 cfm ($16.52 \text{ m}^3/\text{s}$), ducted exhaust air (Assumption 4.3.11)
5.5 m TBM	60,000 cfm ($28.32 \text{ m}^3/\text{s}$), ducted intake air
	34,500 cfm ($16.28 \text{ m}^3/\text{s}$), exhaust air in working drift (Parameter 4.1.2)
	25,500 cfm ($12.04 \text{ m}^3/\text{s}$), ducted exhaust air (Assumption 4.3.11)

Roadheader 100,000 cfm (47.2 m³/s), ducted intake air

72,700 cfm (34.31 m³/s), exhaust air in working drift for Conditions 1 through 3 (Parameter 4.1.2); and 72,500 cfm (34.22 m³/s), exhaust air in working drift for Condition 4 (Parameter 4.1.2)

27,300 cfm (12.89 m³/s), ducted exhaust air for Conditions 1 through 3 (Assumption 4.3.11); and 27,500 cfm (12.98 m³/s), ducted exhaust air for Condition 4 (Assumption 4.3.11)

II.2.1 Option A, Condition 1 (Figure 7-4)

Ducted intake air quantity of 160,000 cfm in the North Ramp through a 72-inch diameter duct to support a roadheader at 100,000 cfm and a 5.5 m TBM at 60,000 cfm. The 72-inch diameter duct is the maximum size that can be installed in the 7.62 m drift to maintain sufficient space for the desired equipment envelope. Total ducted exhaust air through a 66-inch diameter duct is 52,800 cfm from scrubbers at the roadheader (27,300 cfm) and the 5.5 m TBM (25,500 cfm).

Ducted intake air quantity of 212,300 cfm in the South Ramp through a 72-inch diameter duct to support a roadheader at 100,000 cfm and a 7.62 m TBM at 112,300 cfm. Total ducted exhaust air through a 54-inch diameter duct is 62,300 cfm from scrubbers at the roadheader (27,300 cfm) and at the 7.62 m TBM (35,000 cfm). After the Exhaust Main, the exhaust duct is increased to a 66-in diameter duct.

Drift intake air quantity for the North Ramp is 80,000 cfm. Drift intake air quantity for the cross-block drift is 20,000 cfm.

The 66-inch diameter ducts installed in the ESF in the North Ramp and South Ramp are used as the exhaust ducts.

II.2.2 Option A, Condition 2 (Figure 7-5)

Ducted intake air quantity of 212,300 cfm from the Development Shaft to the West Main through the existing 72-inch diameter duct and fan system (no change in equipment) is available to support a roadheader in the East or West Main at 100,000 cfm and a 5.5 m TBM at 60,000 cfm, if needed, with an excess capacity of 52,300 cfm. Total ducted exhaust air through a 54-inch diameter duct is 62,300 cfm from scrubbers at the roadheader (27,300 cfm) and the 5.5 m TBM (25,500 cfm), if they are used, with an excess capacity of 9,500 cfm. The exhaust duct is increased to a 66-in diameter duct at the Exhaust Main where the duct merges with the Exhaust Main duct.

Ducted intake air quantity of 112,300 cfm from the Development Shaft to the Exhaust Main through a 66-inch diameter duct to support the 7.62 m Exhaust Main TBM. Total ducted exhaust air through a 48-inch diameter duct is 35,000 cfm from the scrubber of the 7.62 m TBM.

Drift intake air quantity for the North Ramp is 80,000 cfm. Drift intake air quantity for the cross-block drifts is 20,000 cfm.

The 66-inch diameter duct installed in the ESF in the South Ramp is used as the exhaust duct.

II.2.3 Option A, Condition 3 (Figure 7-6)

Ducted intake air quantity of 160,000 cfm from the Development Shaft to the East Main through Duct #1, a 72-inch diameter duct, to support a roadheader at 100,000 cfm and a 5.5 m TBM at 60,000 cfm. Ducted intake air quantity from the Development Shaft to the East Main through Duct #2, a 72-inch diameter duct, to support a second roadheader at 100,000 cfm and, if needed to support the schedule, a second 5.5 m TBM at 60,000 cfm. Total ducted exhaust air through a 66-inch diameter duct is 105,600 cfm from scrubbers at two roadheaders (27,300 cfm each) and two 5.5 m TBMs (25,500 cfm each).

Drift intake air quantity supplied by the North Ramp is 80,000 cfm. Drift intake air quantity for the cross-block drifts is 20,000 cfm. Drift intake air quantity for the Exhaust Main is 200,000 cfm with 100,00 cfm supplied from both the East Main and West Main. Drift intake air quantity supplied by the Development Intake Shaft to the West Main is 80,000 cfm.

The 66-inch diameter duct installed in the ESF in the South Ramp is used as the exhaust duct.

II.2.4 Option A, Condition 4 (Figure 7-7)

Ducted intake air quantity of 220,000 cfm from the Development Shaft to the East Main through a 72-inch diameter duct, to support a roadheader at 100,000 cfm and two 5.5 m TBMs at 60,000 cfm each, if a second TBM is needed to support the schedule. Total ducted exhaust air through a 66-inch diameter duct is 78,500 cfm from scrubbers at the roadheader (27,500 cfm) and the 5.5 m TBMs (25,500 cfm each).

Ducted intake air quantity of 100,000 cfm from the Development Shaft to the West Main through a 66-inch diameter duct, to support a roadheader at 100,000 cfm. Total ducted exhaust air through a 54-inch diameter duct is 53,000 cfm from scrubbers at the roadheader (27,500 cfm) and ventilation raise boring operations (25,500 cfm).

Ducted exhaust air from ventilation raise boring operations in the Exhaust Main through a 66-inch diameter duct is 60,000 cfm.

Drift intake air quantity supplied by the Development Intake Shaft is split into three airstreams: 240,000 cfm to the West Main; 100,000 cfm to the Exhaust Main; and 35,000 cfm to the South Ramp Extension.

A 72-inch duct is installed in the South Ramp for use as the exhaust duct.

II.3 Option B, Conditions 1 Through 4 (Figures 7-17 through 7-20)

Since Option B is a flow-through system, the requirements for ventilation for each excavation unit will be the same for all Conditions. Drift intake/exhaust air quantity for 7.62 m TBM operations is 77,300 cfm. Drift intake/exhaust air quantity for 5.5 m TBM

operations is 34,500 cfm. Drift intake/exhaust air quantity for roadheader operations is 72,700 cfm. Drift intake/exhaust air quantity for the cross-block drifts is 20,000 cfm.

For Condition 1 (Figure 7-17), total intake air quantity supplied by the North Ramp is 337,200 cfm which is split into two airstreams: 150,000 cfm to the West Main; and 187,200 cfm to the East Main.

For Condition 2 (Figure 7-18), total intake air quantity supplied by the North Ramp is 334,500 cfm which is split into three airstreams: 90,000 cfm to the West Main; 124,500 cfm to the first Cross-Block Drift (20,000 cfm) and the Exhaust Main (104,500 cfm); and 120,000 to the East Main.

For Condition 3 (Figure 7-19), total intake air quantity supplied by the North Ramp is 311,900 cfm which is split into three airstreams: 140,000 cfm to the West Main; 80,000 cfm to the Exhaust Main; and 91,900 cfm to the East Main North Extension.

For Condition 4 (Figure 7-20), total intake air quantity supplied by the Development Intake Shaft is 560,000 cfm which is split into three airstreams: 415,000 cfm to the West Main; 110,000 cfm to the Exhaust Main; and 35,000 cfm to the South Ramp Extension.

II.4 Specific Inputs for Option C

II.4.1 Option C, Condition 1 (Figure 7-23)

Ducted exhaust air quantity of 107,200 cfm in the North Ramp through a 66-inch diameter duct to support a roadheader at 72,700 cfm and a 5.5 m TBM at 34,500 cfm.

Ducted exhaust air quantity of 150,000 cfm in the South Ramp through a 72-inch diameter duct to support a roadheader at 72,700 cfm and a 7.62 m TBM at 77,300 cfm.

Total intake air quantity supplied by the North Ramp is 337,200 cfm. Intake air quantity for the cross-block drifts is 20,000 cfm.

II.4.2 Option C, Condition 2 (Figure 7-24)

Ducted exhaust air quantity of 150,000 cfm in the South Ramp through existing Duct #1, 72-inch diameter duct, and fan system to support a roadheader in the East or West Main at 72,700 cfm and a 5.5 m TBM at 34,500 cfm, if they are used, with an excess capacity of 42,800 cfm. Ducted exhaust air quantity of 77,300 cfm through Duct #2, a 66-inch diameter duct, to support the 7.62 m Exhaust Main TBM.

Intake air quantity supplied by the North Ramp is 140,000 cfm. Intake air quantity for the cross-block drifts is 20,000 cfm. Intake air quantity supplied by the Development Intake Shaft is split into three airstreams: 90,000 cfm to the West Main; 77,300 cfm to the Exhaust Main; and 35,000 cfm to the South Ramp Extension.

II.4.3 Option C, Condition 3 (Figure 7-25)

Ducted exhaust air quantity of 107,200 cfm in the South Ramp through existing Duct #1, 72-inch diameter duct which was moved from the West Main to the East Main, to support a roadheader at 72,700 cfm and a 5.5 m TBM at 34,500 cfm. Ducted exhaust air quantity of 107,200 cfm through Duct #2, a 66-inch diameter duct, to support a second roadheader at 72,700 cfm and, if needed to support the schedule, a second 5.5 m TBM at 34,500 cfm.

Intake air quantity supplied by the North Ramp is 80,000 cfm. Intake air quantity for the cross-block drifts is 20,000 cfm. Intake air quantity supplied by the Development Intake Shaft is split into three airstreams: 160,000 cfm to the West Main; 80,000 cfm to the Exhaust Main; and 35,000 cfm to the South Ramp Extension.

II.4.4 Option C, Condition 4 (Figure 7-26)

Ducted exhaust air quantity of 141,500 cfm in the East Main through a 66-inch diameter duct to support a roadheader at 72,500 cfm and two 5.5 m TBMs at 34,500 cfm each, if a second TBM is needed to support the schedule.

Ducted exhaust air quantity of 106,500 cfm in the West Main through a 66-inch diameter duct to support a roadheader at 72,500 cfm and ventilation raise boring operations at 34,000 cfm.

Ducted exhaust air quantity of 60,000 cfm in the Exhaust Main through a 66-inch diameter duct to support ventilation raise boring operations.

The three 66-in exhaust ducts merge at the South Ramp into two 72-in exhaust ducts via an equalizer loop. The exhaust air quantity in each 72-in duct in the South Ramp is 154,000 cfm.

Intake air quantity supplied by the Development Intake Shaft is split into three airstreams: 415,000 cfm to the West Main; 110,000 cfm to the Exhaust Main; and 35,000 cfm to the South Ramp Extension.

Condition 1 -- Cross Block, First PC & West Main TBM Drives

Condition 2 -- Exhaust Main Drive, Concrete Lining of North Ramp & East Main

Condition 3 -- Emplacement Drift Development, Concrete lining of West Main and Exhaust Main

	Air Quantity ft ³ /min Q _m	Air Quantity m ³ /s Q	Airway Diameter (in.) D	X-Sept Area A (ft ²) (3.1416(D/2) ²)	Perimeter P (ft) (3.1416)*D	Length L (m) L _m	Length L (ft) L _m	K Factor n*(10 ⁻¹⁰)	Resistance (in*min ² /ft ⁶) KPL(5.2*A ³ *G)	Head Loss (H) Inches-WG RQ ²	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (QF) Fan Pressure, in-WG (HF)	No of Fan Units in Line H/(HF)	Fan Unit BHP Load @70% Eff HF*QF/(6346)/(0.7)	Space Between Fans (m) L _m /(no. fans)
Intake																
North Ramp Drift	80,000	37.76	300	490.88	78.54	7,877.2	25,843.8	70	0.23	0.15	3	60-30-1180	80,000@77/250	1	Main Fan Load	
Dev Shaft/East Main, 72-in Duct #1	160,000	75.52	72	28.27	18.85	5,020.9	16,472.8	20	52.83	135.26	4,872	M72-50-1180	160,000@157/550	9	540	558
Dev Shaft/East Main, 72-in Duct #2	160,000	75.52	72	28.27	18.85	5,020.9	16,472.8	20	52.83	135.26	4,872	M72-50-1180	160,000@157/550	9	540	558
Dev Shaft/West Main Concreting	80,000	37.76	300	490.88	78.54	7,209.0	23,651.6	70	0.21	0.14	2	60-30-1180	135,000@77/250	3	Main Fan Load	
Total	480,000	226.56			72-in duct	10,041.8	32,945.5				9,750			22	(with four Main Fan Loads)	
Exhaust																
North Ramp, 66-in Duct	0		Removed													
South Ramp, 66-in Duct	105,600	49.84	66	23.76	17.28	5,588.8	18,336.0	20	90.86	101.33	2,409	M60-36-1780	105,600@117/300	9	262	621
South Ramp Drift	374,400	176.72	300	490.88	78.54	2,335.7	7,663.1	70	0.07	0.96	81					
Total	480,000	226.56			66-in duct	5,588.8	18,336.0				2,490			9		
					Total ducting for Condition 3	15,630.6	51,281.5				12,240			31	(with four Main Fan Loads)	

Table II-1. Ventilation System Calculations for Option A, Conditions 1 Through 4 (Continued)

Condition 4 -- Construction/Development Ventilation Concurrent with First Emplacement Activity

	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sect Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10 ⁻¹⁰)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A ³)	Head Loss (H) Inches-WG RQ ²	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (Qf) Fan Pressure, in-WG (Hf) Motor BHP	No. of Fan Units in Line H/(Hf)	Fan Unit BHP Load @70% Eff HP*Qf/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
Intake																
East Main, 72-in Duct	220,000	103.84	72	28.27	18.85	4,934.0	16,187.7	20	51.92	251.29	12,447	M72-50-1180	220,000@14"/700	18		274
Exhaust Main Drift	100,000	47.20	276	415.48	72.26	4,132.0	13,556.4	70	0.18	0.18	4					
West Main, 66-in Duct	100,000	47.20	66	23.76	17.28	4,077.0	13,376.0	20	66.29	66.29	1,492	M60-36-1780	100,000@16.5"/350	4		1,019
West Main Drift	240,000	113.28	276	415.48	72.26	4,077.0	13,376.0	70	0.18	1.04	56					
South Ramp Extension Airlock	35,000	16.52	276	415.48	72.26	884.0	2,900.3	70	0.04	0.00	0	M132-72-900	695,000@6.5"/2,000	1	Surf. Primary Fan	
Tributary Dev Shaft & Drift 695,000 cfm			240	314.16	62.83	412.0	1,351.7	95	0.05	2.42	378		Surface Primary Fan		Dev. Shaft Collar	
Tributary Exhaust Main Drift 100,000 cfm			276	415.48	72.26	402.0	1,318.9	70	0.02	0.03	1					
Total	695,000	328.04				66-in duct 72-in duct	4,077.0 4,934.0				14,379			23	(with one Surface Primary Fan)	
Exhaust																
East Main, 66-in Duct	78,500	37.05	66	23.76	17.28	4,138.0	13,576.1	20	67.28	41.46	733	48-26-1770	78,500@11"/200	4		1,035
East Main Drift	468,500	221.13	276	415.48	72.26	4,138.0	13,576.1	70	0.18	4.04	426					
Exhaust Main, 66-in Duct	60,000	28.32	66	23.76	17.28	4,132.0	13,556.4	20	67.18	24.18	327	48-26-1770	60,000@10"/150	3		1,377
West Main, 54-in Duct	53,000	25.02	54	15.90	14.14	4,479.0	14,694.9	20	198.61	55.79	666	48-26-1770	53,000@10"/125	6		747
South Ramp Extension Airlock	35,000	16.52	276	415.48	72.26	0.0	0.0	70	0.00	0.00	0					
Tributary SRExt, 66-in Duct 113,000 cfm			66	23.76	17.28	884.0	2,900.3	20	14.37	18.35	467	M60-36-1780	113,000@18.5"/450	1		884
Tributary South Ramp, 72-in Duct 191,500 cfm			72	28.27	18.85	1,500.0	4,921.3	20	15.78	57.88	2,496	M72-50-1180	191,500@16"/700	4		375
Tributary South Ramp Drift 503,500 cfm			276	415.48	72.26	1,500.0	4,921.3	70	0.07	1.69	192					
Total	695,000	328.04				54-in duct 66-in duct 72-in duct	4,479.0 9,154.0 1,500.0				5,306 19,685			18 41	(with one Surface Primary Fan)	
Total ducting for Condition 4						24,144.0	79,212.7	Total BHP for Condition 4		19,685		Total Fans for Condition 4		41 (with one Surface Primary Fan)		

Table II-2. Ventilation System Calculations for Option B (Flow-Through), Conditions 1 Through 4

Condition 1 -- Cross Block, First PC & West Main TBM Drives

	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sect Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10 ⁻¹⁰)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A ³)	Head Loss (H) Inches-WG RQ ²	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (Qf) Fan Pressure, in-WG (Hf) Motor BHP	No. of Fan Units in Line H/(Hf)	Fan Unit BHP Load @70% Eff HP*Qf/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)	
Intake																	
North Ramp, 337,200 cfm split into																	
Support 7.62 m TBM, 72-in Duct	77,300	36.49	72	28.27	18.85	3,705.4	12,156.8	20	38.99	23.30	405	60-30-1180-2S	77,300@12"/250	2	209	1,853	
Support RH/Shaft Dev, 72-in Duct	72,700	34.31	72	28.27	18.85	1,703.6	5,589.2	20	17.93	9.47	155	60-30-1180-2S	72,700@12"/250	1	196	1,704	
Support 5.5 m TBM+RH	107,200	50.60	300	490.88	78.54	5,100.4	18,180.8	70	0.16	0.19	4	60-30-1180	112,400@7"/250	3	Main Fan Load		
West/East Main Flow	80,000	37.76	300	490.88	78.54	7,877.2	25,843.8	70	0.23	0.15	3						
Total	337,200	159.16				72-in duct	5,409.0				567				6 (with three Main Fan Loads)		
Exhaust																	
South Ramp	337,200	159.16	300	490.88	78.54	7,877.2	25,843.8	70	0.23	2.63	199						
Total	337,200	159.16				72-in duct	0.0				199				0		
Total ducting for Condition 1						5,409.0	17,746.1	Total BHP for Condition 1				766	Total Fans for Condition 1				6 (with three Main Fan Loads)

Condition 2 -- Exhaust Main Drive, Concrete Lining of North Ramp & East Main

	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sect Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10 ⁻¹⁰)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A ³)	Head Loss (H) Inches-WG RQ ²	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (Qf) Fan Pressure, in-WG (Hf) Motor BHP	No. of Fan Units in Line H/(Hf)	Fan Unit BHP Load @70% Eff HP*Qf/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
Intake																
North Ramp: 334,500 cfm split into																
Main + RH	150,000	70.80	300	490.88	78.54	7,877.2	25,843.8	70	0.23	0.52	18	60-30-1180	111,500@7"/250	3	Main Fan Load	
Emplacement/PC 5.5m TBM + RH	107,200	50.60	300	490.88	78.54	5,100.4	18,180.8	70	0.16	0.19	4					
Exhaust Main 7.62m TBM, 72-inch Duct	77,300	36.49	72	28.27	18.85	922.3	3,025.9	20	9.71	5.80	101	60-30-1180-2S	77,300@6"/250	1	104	922
Total	334,500	157.88				72-in duct	922.3				122			4	(with three Main Fan Loads)	
Exhaust																
South Ramp (North to South)	334,500	157.88	300	490.88	78.54	7,877.2	25,843.8	70	0.23	2.58	195					
Total	334,500	157.88				72-in duct	0.0				195			0		
						Total ducting for Condition 2	922.3				Total BHP for Condition 2	317		Total Fans for Condition 2	4	(with three Main Fan Loads)

Table II-2. Ventilation System Calculations for Option B (Flow-Through), Conditions 1 Through 4 (Continued)

Condition 3 -- Emplacement Drift Development, Concrete Lining of West Main and Exhaust Main

Intake	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sept Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10 ⁻¹⁰)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A ³)	Head Loss (H) Inches-WG RQ ²	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (Qf) Fan Pressure, in-WG (Hf) Motor BHP	No. of Fan Units in Line H/(Hf)	Fan Unit BHP Load @70% Eff HF*Qf/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
North Ramp: 311,900 cfm split into																
North Ramp to Exhaust Main	77,300	36.49	300	490.88	78.54	3,938.6	12,921.9	70	0.12	0.07	1	60-30-1180	104,000@7"7/250	3	Main Fan Load	
North Ramp to East Main	77,300	36.49	300	490.88	78.54	2,550.2	9,090.4	70	0.08	0.05	1					
North Ramp to West Main	77,300	36.49	300	490.88	78.54	2,550.2	9,090.4	70	0.08	0.05	1					
North Ramp (West/East Spare Flow)	80,000	37.76	Accounted													
Total	311,900	147.22									3				3 (all three Main Fan Loads)	
Exhaust																
South Ramp (North to South)	311,900	147.22	300	490.88	78.54	7,877.2	25,843.8	70	0.23	2.25	158					
Total	311,900	147.22									158				0	
Total BHP for Condition 3											161	Total Fans for Condition 3		3	(all three Main Fan Loads)	

Condition 4 -- Construction/Development Ventilation Concurrent with First Emplacement Activity

Intake	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sept Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10 ⁻¹⁰)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A ³)	Head Loss (H) Inches-WG RQ ²	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (Qf) Fan Pressure, in-WG (Hf) Motor BHP	No. of Fan Units in Line H/(Hf)	Fan Unit BHP Load @70% Eff HF*Qf/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
West Main	415,000	195.88	276	415.48	72.26	4,077.0	13,376.0	70	0.18	3.12	292					
Exhaust Main	110,000	51.92	276	415.48	72.26	4,132.0	13,556.4	70	0.18	0.22	6					
South Ramp Extension Airlock	35,000	16.52	276	415.48	72.26	884.0	2,900.3	70	0.04	0.00	0					
Tributary Dev Shaft & Drift 560,000 cfm			240	314.16	62.83	412.0	1,351.7	95	0.05	1.57	198	M132-72-900	*635,000@15"7/2,000	1	Surface Primary Fan	
Tributary Dev Shaft to Exh Main 145,000 cfm			276	415.48	72.26	402.0	1,318.9	70	0.02	0.04	1		Surface Primary Fan		Dev. Shaft Collar	
Total	560,000	264.32									497	* Fan sized for flexibility		1	(with one Surface Primary Fan)	
Exhaust																
East Main	525,000	247.80	276	415.48	72.26	4,138.0	13,576.1	70	0.18	5.07	600					
South Ramp Extension Airlock	35,000	16.52	276	415.48	72.26	0.0	0.0	70	0.00	0.00	0					
Tributary South Ramp 560,000 cfm			276	415.48	72.26	1,500.0	4,921.3	70	0.07	2.09	264					
Total	560,000	264.32									864	Total Fans for Condition 4		1	(with one Surface Primary Fan)	
Total BHP for Condition 4											1,360	Total Fans for Condition 4		1	(with one Surface Primary Fan)	

Table II-3. Ventilation System Calculations for Option C (Ducted Exhaust), Conditions 1 Through 4

Condition 1 -- Cross Block, First PC & West Main TBM Drives

Intake	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sept Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10 ⁻¹⁰)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A ³)	Head Loss (H) Inches-WG RQ ²	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (Qf) Fan Pressure, in-WG (Hf) Motor BHP	No. of Fan Units in Line H/(Hf)	Fan Unit BHP Load @70% Eff HF*Qf/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
North Ramp Drift	337,200	159.16	300	490.88	78.54	5,100.4	16,733.6	70	0.15	1.70	129	60-30-1180	112,400@7"7/250	3	Main Fan Load	
Total	337,200	159.16									129				3 (all three Main Fan Loads)	
Exhaust																
North Ramp, 66-in Duct, RH+TBM	107,200	50.60	66	23.76	17.28	4,027.8	13,214.6	20	65.49	75.25	1,816	M60-36-1780	107,200@11"7/300	7	265	575
South Ramp, 72-in Duct, RH+TBM	150,000	70.80	72	28.27	18.85	7,944.9	26,065.9	20	83.60	188.11	6,353	M72-50-1180	150,000@15"7/550	13	507	611
South Ramp Drift	80,000	37.76	300	490.88	78.54	2,335.7	7,663.1	70	0.07	0.04	1					
Total	337,200	159.16				66-in duct	4,027.8				8,170			20		
Total ducting for Condition 1											8,299	Total Fans for Condition 1		23	(with three Main Fan Loads)	
Total BHP for Condition 1											8,299	Total Fans for Condition 1		23	(with three Main Fan Loads)	

Table II-3. Ventilation System Calculations for Option C (Ducted Exhaust), Conditions 1 Through 4 (Continued)

Condition 2 -- Exhaust Main Drive, Concrete Lining of North Ramp & East Main

Intake	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sect Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10^-10)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A^3)	Head Loss (H) Inches-WG RQ^2	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (QD) Fan Pressure, in-WG (HD) Motor BHP	No. of Fan Units in Line H/(HF)	Fan Unit BHP Load @70% Eff HP*QD/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
North Ramp Drift	140,000	66.08	300	490.88	78.54	5,100.4	16,733.6	70	0.15	0.29	9	60-30-1180	140,000@7°/250	1	Main Fan Load	
Exhaust Main Drift	77,300	36.49	300	490.88	78.54	4,480.0	14,698.2	70	0.13	0.08	1	60-30-1180				
South Ramp Extension Drift	35,000	16.52	300	490.88	78.54	883.9	2,899.9	70	0.03	0.00	0					
West Main Drift	90,000	42.48	300	490.88	78.54	7,209.0	23,651.6	70	0.21	0.17	3	60-30-1180	101,150@7°/250	2	Main Fan Load	
Total	342,300	161.57									13			3	(all three Main Fan Loads)	
Exhaust	0	Removed														
North Ramp, 66-in Duct	77,300	36.49	66	23.76	17.28	6,815.7	22,361.2	20	110.81	66.21	1,152	48-26-1770-2S	77,300@10°/200	7	174	974
South Ramp, 66-in Duct	150,000	70.80	72	28.27	18.85	7,944.9	26,065.9	20	83.60	188.11	6,353	M72-50-1180	150,000@15°/550	13	507	611
South Ramp Drift	115,000	54.28	300	490.88	78.54	2,335.7	7,663.1	70	0.07	0.09	2					
Total	342,300	161.57				66-in duct	6,815.7	22,361.2			7,508			20		
						72-in duct	7,944.9	26,065.9			7,521			23	(with three Main Fan Loads)	
						Total ducting for Condition 2	14,760.6	48,427.2								

Condition 3 -- Emplacement Drift Development, Concrete Lining of West Main and Exhaust Main

Intake	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sect Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10^-10)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A^3)	Head Loss (H) Inches-WG RQ^2	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (QD) Fan Pressure, in-WG (HD) Motor BHP	No. of Fan Units in Line H/(HF)	Fan Unit BHP Load @70% Eff HP*QD/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
North Ramp Drift	80,000	37.76	300	490.88	78.54	5,100.4	16,733.6	70	0.15	0.10	2	60-30-1180	80,000@7°/250	1	Main Fan Load	
Exhaust Main Drift	80,000	37.76	300	490.88	78.54	4,909.6	16,107.6	70	0.14	0.09	2					
South Ramp Extension Drift	35,000	16.52	300	490.88	78.54	883.9	2,899.9	70	0.03	0.00	0					
West Main Drift	160,000	75.52	300	490.88	78.54	4,424.9	14,517.4	70	0.13	0.33	12	60-30-1180	137,500@7°/250	2	Main Fan Load	
Total	355,000	167.56									15			3	(all three Main Fan Loads)	
Exhaust																
South Ramp, 66-in Duct	107,200	50.60	66	23.76	17.28	5,588.8	18,336.0	20	90.86	104.42	2,520	M60-36-1780	107,200@11°/300	9	265	621
South Ramp, 72-in Duct	107,200	50.60	72	28.27	18.85	5,588.8	18,336.0	20	58.81	67.58	1,631	M60-36-1780	107,200@11°/300	6	265	931
South Ramp Drift	140,600	66.36	300	490.88	78.54	2,335.7	7,663.1	70	0.07	0.14	4					
Total	355,000	167.56				66-in duct	5,588.8	18,336.0			4,156			15		
						72-in duct	5,588.8	18,336.0			4,171			18	(with three Main Fan Loads)	
						Total ducting for Condition 3	11,177.6	36,671.9								

Condition 4 -- Construction/Development Ventilation Concurrent with First Emplacement Activity

Intake	Air Quantity ft ³ /min Qm	Air Quantity m ³ /s Q	Airway Diameter (in) D	X-Sect Area A (ft ²) (3.1416)(D/2) ²	Perimeter P (ft) (3.1416)*D	Length (m) Lm	Length L (ft) Lm/(0.3048)	K Factor n*(10^-10)	Resistance (in*min ² /ft ⁶) KPL/(5.2*A^3)	Head Loss (H) Inches-WG RQ^2	Total BHP @70% Eff HQ/(6346)/(0.7)	Axial Fan Fan Model Spec JOY	Fan Unit cfm (QD) Fan Pressure, in-WG (HD) Motor BHP	No. of Fan Units in Line H/(HF)	Fan Unit BHP Load @70% Eff HP*QD/(6346)/(0.7)	Space Between Fans (m) Lm/(no. fans)
West Main Drift	415,000	195.88	276	415.48	72.26	4,077.0	13,376.0	70	0.18	3.12	292					
Exhaust Main Drift	110,000	51.92	276	415.48	72.26	4,132.0	13,556.4	70	0.18	0.22	6					
South Ramp Extension Airlock	35,000	16.52	276	415.48	72.26	884.0	2,900.3	70	0.04	0.00	0					
Tributary Dev Shaft & Drift 560,000 cfm			240	314.16	62.83	412.0	1,351.7	95	0.05	1.57	198	M132-72-900	*635,000@15°/2,000	1	Surface Primary Fan	
Tributary Exhaust Main Drift 145,000 cfm			276	415.48	72.26	402.0	1,318.9	70	0.02	0.04	1		Surface Primary Fan		Dev. Shaft Collar	
Total	560,000	264.32									497		* Fan sized for flexibility	1	(with one Surface Primary Fan)	
Exhaust																
East Main, 66-in Duct	141,500	66.79	66	23.76	17.28	4,138.0	13,576.1	20	67.28	134.70	4,291	M72-50-1180	141,500@14°/450	10		414
East Main Drift	217,000	102.42	276	415.48	72.26	4,138.0	13,576.1	70	0.18	0.87	42					
Exhaust Main, 66-in Duct	60,000	28.32	66	23.76	17.28	4,132.0	13,556.4	20	67.18	24.18	327	48-26-1770	60,000@10°/150	3		1,377
West Main, 66-in Duct	106,500	50.27	66	23.76	17.28	4,479.0	14,694.9	20	72.82	82.60	1,981	M60-36-1780	106,500@17°/450	5		896
South Ramp Extension Airlock	35,000	16.52	276	415.48	72.26	0.0	0.0	70	0.00	0.00	0					
SR Ext, 66-in Duct #1 83,250 cfm			66	23.76	17.28	884.0	2,900.3	20	14.37	9.96	187	60-30-1180	83,250@10°/250	1		884
SR Ext, 66-in Duct #2 83,250 cfm			66	23.76	17.28	884.0	2,900.3	20	14.37	9.96	187	60-30-1180	83,250@10°/250	1		884
South Ramp, 72-in Duct #1 154,000 cfm			72	28.27	18.85	1,500.0	4,921.3	20	15.78	37.43	1,298	M72-50-1180	154,000@15°/500	3		500
South Ramp, 72-in Duct #2 154,000 cfm			72	28.27	18.85	1,500.0	4,921.3	20	15.78	37.43	1,298	M72-50-1180	154,000@15°/500	3		500
South Ramp Drift 252,000 cfm			276	415.48	72.26	1,500.0	4,921.3	70	0.07	0.42	24					
Total	560,000	264.32				66-in duct	14,517.0	47,628.0			9,634			26		
						72-in duct	3,000.0	9,842.5			10,131			27	(with one Surface Primary Fan)	
						Total ducting for Condition 4	17,517.0	57,470.5

Table II-4. Lengths of Drifts for Options A, B, and C -- Conditions 1 Through 3

Option A--Condition 1 (Cross Block, First PC & West Main TBM Drives)

Intake	Length (m) Lm	Node Coverage*
North Ramp Drift	7,877.2	1,2,135,155,175,195,112,198,199,100
North Ramp, 72-in Duct (RH+5.5 TBM)	4,027.8	1,2,135,155,175
South Ramp, 72-in Duct (RH+7.62 TBM)	7,944.9	100,199,799,299,298,212,295,275,255,235,215,203,200,700
Split 112,300 cfm after Empl Shaft	2,001.8	700,102,103,115,135
Exhaust		
North Ramp, Existing 66-in Duct	4,027.8	175,155,135,2,1
South Ramp, Existing 66-in Duct	2,335.7	100,199,799
Split 62,300 cfm to 54-in Duct after Exh Main	7,611.0	799,299,298,212,295,275,255,235,215,203,200,700,102,103,115,135
South Ramp Drift	2,335.7	100,199,799

Option A--Condition 2 (Exhaust Main Drive, Concrete Lining of North Ramp & East Main)

Intake	Length (m) Lm	Node Coverage*
North Ramp Drift	7,877.2	1,2,135,155,175,195,112,198,199,100
Dev Shaft/Exhaust Main, 66-in Duct	4,882.0	298,299,799,712,795,775,755,735,715,703
Dev Shaft/West Main, 72-in Duct	7,209.0	298,212,295,275,255,235,215,203,200,700,102,103,115,135
Exhaust		
North Ramp, 66-in Duct	0.0	
South Ramp, Existing 66-in Duct	2,335.7	100,199,799
Split 35,000 cfm to 48-in Duct for Exhaust Main	4,480.0	799,712,795,775,755,735,715,703
Split 62,300 cfm to 54-in Duct for West Main	7,611.0	799,299,298,212,295,275,255,235,215,203,200,700,102,103,115,135
South Ramp Drift	1,451.8	100,199

Option A--Condition 3 (Emplacement Drift Development, Concrete lining of West Main and Exhaust Main)

Intake	Length (m) Lm	Node Coverage*
North Ramp Drift	7,877.2	1,2,135,155,175,195,112,198,199,100
Dev Shaft/East Main, 72-in Duct #1	5,020.9	799,199,198,112,195,175,155,135,115
Dev Shaft/East Main, 72-in Duct #2	5,020.9	799,199,198,112,195,175,155,135,115
Dev Shaft/West Main Concreting	7,209.0	298,212,295,275,255,235,215,203,200,700,102,103,115,135
Exhaust		
North Ramp, 66-in Duct	0.0	
South Ramp, 66-in Duct	5,588.8	100,199,198,112,195,175,155,135,115
South Ramp Drift	2,335.7	100,199,799

* See Figure II-1 for node locations and lengths.

Table II-4. Lengths of Drifts for Options A, B, and C -- Conditions 1 Through 3 (Continued)

Option B--Condition 1 (Cross Block, First PC & West Main TBM Drives)

Intake	Length (m) Lm	Node Coverage*
North Ramp: 337,200 cfm split into		
Support 7.62 m TBM, 72-in Duct	3,705.4	235,215,203,200,700,102,103,115,135
Support RH/Shaft Dev, 72-in Duct	1,703.6	235,215,203,200,700
Support 5.5 m TBM+RH	5,100.4	1,2,135,155,175,195,112
West/East Main Flow	7,877.2	1,2,135,155,175,195,112,198,199,100
Exhaust		
South Ramp	7,877.2	1,2,135,155,175,195,112,198,199,100

Option B--Condition 2 (Exhaust Main Drive, Concrete Lining of North Ramp & East Main)

Intake	Length (m) Lm	Node Coverage*
North Ramp: 334,500 cfm split into		
Main + RH	7,877.2	1,2,135,155,175,195,112,198,199,100
Emplacement/PC 5.5m TBM + RH	5,100.4	1,2,135,155,175,195,112
Exhaust Main 7.62m TBM, 72-inch Duct	922.3	735,715,703
Exhaust		
South Ramp (North to South)	7,877.2	1,2,135,155,175,195,112,198,199,100

Option B--Condition 3 (Emplacement Drift Development, Concrete Lining of West Main and Exhaust Main)

Intake	Length (m) Lm	Node Coverage*
North Ramp: 311,900 cfm split into		
North Ramp to Exhaust Main	3,938.6	1,2,135,155,175,195,112,198,199,100 -- half the distance**
North Ramp to East Main	2,550.2	1,2,135,155,175,195,112 -- half the distance**
North Ramp to West Main	2,550.2	1,2,135,155,175,195,112 -- half the distance**
North Ramp (West/East Spare Flow)		
Exhaust		
South Ramp (North to South)	7,877.2	1,2,135,155,175,195,112,198,199,100

* See Figure II-1 for node locations and lengths.

** The lengths of the intake drifts were divided by two to compensate for the horsepower of the exhaust fan.

Table II-4. Lengths of Drifts for Options A, B, and C -- Conditions 1 Through 3 (Continued)

Option C--Condition 1 (Cross Block, First PC & West Main TBM Drives)

Intake	Length (m) Lm	Node Coverage*
North Ramp Drift	5,100.4	1,2,135,155,175,195,112
Exhaust		
North Ramp, 66-in Duct, RH+TBM	4,027.8	1,2,135,155,175
South Ramp, 72-in Duct, RH+TBM	7,944.9	100,199,799,299,298,212,295,275,255,235,215,203,200,700
South Ramp Drift	2,335.7	100,199,799

Option C--Condition 2 (Exhaust Main Drive, Concrete Lining of North Ramp & East Main)

Intake	Length (m) Lm	Node Coverage*
North Ramp Drift	5,100.4	1,2,135,155,175,195,112
Exhaust Main Drift	4,480.0	799,712,795,775,735,715,703
South Ramp Extension Drift	883.9	799,199
West Main Drift	7,209.0	298,212,295,275,255,235,215,203,200,700,102,103,115,135
Exhaust		
North Ramp, 66-in Duct	0.0	
South Ramp, 66-in Duct	6,815.7	100,199,799,712,795,775,735,715,703
South Ramp, 72-in Duct	7,944.9	100,199,799,299,298,212,295,275,255,235,215,203,200,700
South Ramp Drift	2,335.7	100,199,799

Option C--Condition 3 (Emplacement Drift Development, Concrete Lining of West Main and Exhaust Main)

Intake	Length (m) Lm	Node Coverage*
North Ramp Drift	5,100.4	1,2,135,155,175,195,112
Exhaust Main Drift	4,909.6	799,712,795,775,735,715,703, 701
South Ramp Extension Drift	883.9	799,199
West Main Drift	4,424.9	298,212,295,275,255,235,215,203
Exhaust		
South Ramp, 66-in Duct	5,588.8	100,199,198,112,195,175,155,135,115
South Ramp, 72-in Duct	5,588.8	100,199,198,112,195,175,155,135,115
South Ramp Drift	2,335.7	100,199,799

* See Figure II-1 for node locations and lengths.