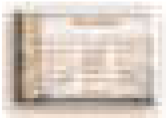

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Appendix G

Air Quality

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APPENDIX G. AIR QUALITY

Potential releases of nonradiological and radiological pollutants associated with the construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository could affect the air quality in the surrounding region. This appendix discusses the methods and additional data and intermediate results that the U.S. Department of Energy (DOE) used to estimate impacts from potential releases to air. Final results are presented in Chapter 4, Section 4.1.2, and Chapter 8, Section 8.2.2.

Nonradiological pollutants can be categorized as hazardous and toxic air pollutants, criteria pollutants, or other substances of particular interest. Repository activities would cause the release of no or very small quantities of hazardous and toxic pollutants; therefore, these pollutants were not considered in the analysis. Concentrations of six criteria pollutants are regulated under the National Ambient Air Quality Standards (40 CFR Part 50) established by the Clean Air Act. This analysis evaluated releases and potential impacts of four of these pollutants—carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10})—quantitatively. It addresses the other two criteria pollutants—lead and ozone—and the concentration of particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$), qualitatively. In addition, this analysis considers potential releases to air of cristobalite, a form of crystalline silica that can cause silicosis and is a potential carcinogen. These pollutants could be released during all project phases. Section G.1 describes the methods DOE used to calculate impacts from releases of criteria pollutants and cristobalite.

Radionuclides that repository-related activities could release to the atmosphere include the noble gas krypton-85 from spent nuclear fuel handling during the operation and monitoring phase, and naturally occurring radon-222 and its decay products from ventilation of the subsurface facility during all project phases. Other radionuclides would not be released or would be released in such small quantities they would result in very small impacts to air quality. Such radionuclides are not discussed further in this appendix. Section G.2 describes the methods DOE used to calculate impacts of radionuclide releases.

G.1 Nonradiological Air Quality

This section describes the methods DOE used to analyze potential impacts to air quality at the proposed Yucca Mountain Repository from releases of nonradiological air pollutants during the construction, operation and monitoring, and closure phases, and a retrieval scenario. It also describes intermediate results for various repository activities. Table G-1 lists the six criteria pollutants regulated under the National Ambient Air Quality Standards or the Nevada Administrative Code along with their regulatory limits and the periods over which pollutant concentrations are averaged. The criteria pollutants addressed quantitatively in this section are nitrogen dioxide, sulfur dioxide, particulate matter 10 micrometers or less in aerodynamic diameter (PM_{10}), and carbon monoxide. Lead was not considered further in this analysis because there would be no airborne sources at the repository. Particulate matter 2.5 micrometers or less in aerodynamic diameter ($PM_{2.5}$) and ozone are discussed below, as is cristobalite, a mineral occurring naturally in the subsurface rock at Yucca Mountain.

The U.S. Environmental Protection Agency revised the primary and secondary standards for particulate matter in 1997 (62 *FR* 38652, July 18, 1997), establishing annual and 24-hour $PM_{2.5}$ standards at 15 micrograms per cubic meter and 65 micrograms per cubic meter, respectively. Primary standards set limits to protect public health, including the health of "sensitive" populations. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. Because the new particulate standard will regulate $PM_{2.5}$ for the first time, the agency has allowed 5 years for the creation of a national monitoring network and the analysis of collected data to help develop state implementation plans. The new $PM_{2.5}$ standards have not been implemented and the imposition of local area controls will not be required until 2005. By definition, $PM_{2.5}$ levels can be no more than, and in the real world are always substantially less than, PM_{10} levels. In

Table G-1. Criteria pollutants and regulatory limits.

Pollutant	Period	Regulatory limit[a] Parts per million	Micrograms per cubic meter
Nitrogen dioxide	Annual	0.053	100
Sulfur dioxide	Annual	0.03	80
	24-hour	0.14	365
	3-hour	0.50	1,300
Carbon monoxide	8-hour	9	10,000
	1-hour	35	40,000
PM_{10}	Annual		50
	24-hour		150
$PM_{2.5}$[b]	Annual		15
	24-hour		65
Ozone	8-hour	0.08	157
	1-hour	0.12[c]	235
Lead	Quarterly		1.5

a. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.
b. Standard not yet implemented.
c. The 1-hour standard does not apply to Nevada because the State was in attainment when the 8-hour standard was adopted in July 1997.

general, $PM_{2.5}$ levels would be approximately one-third of the PM_{10} levels. As the analysis for PM_{10} shows, even the maximum PM_{10} levels that could be generated by the Proposed Action are substantially below the $PM_{2.5}$ standards. Thus, although no detailed $PM_{2.5}$ analysis has been conducted, the PM_{10} analysis can be regarded as a surrogate for a $PM_{2.5}$ analysis and illustrates that potential $PM_{2.5}$ levels would be well below applicable regulatory standards.

The purpose of the ozone standard is to control the ambient concentration of ground-level ozone, not naturally occurring ozone in the upper atmosphere. Ozone is not emitted directly into the air; rather, it is formed when volatile organic compounds react in the presence of sunlight. Nitrogen dioxides are also important precursors to ozone. Small quantities of volatile organic compounds would be released from repository activities; the peak annual release would be about 540 kilograms (1,200 pounds) (TRW 1999a, Table 6-2, page 75). Because Yucca Mountain is in an attainment area for ozone, the analysis compared the estimated annual release to the Prevention of Significant Deterioration of Air Quality emission threshold for volatile organic compounds from stationary sources (40 CFR 52.21). The volatile organic compound emission threshold is 35,000 kilograms (77,000 pounds) per year, so the peak annual release from the repository would be well below this level. Accordingly, the analysis did not address volatile organic compounds and ozone further, although this does not preclude future, more detailed analyses if estimates of volatile organic compound emissions change.

Cristobalite, one of several naturally occurring crystalline forms of silica (silicon dioxide), is a major mineral constituent of Yucca Mountain tuffs (TRW 1999b, page 4-81). Prolonged high exposure to crystalline silica can cause silicosis, a disease characterized by scarring of lung tissue. An increased cancer risk to humans who already have developed adverse noncancer effects from silicosis has been shown, but the cancer risk to otherwise healthy individuals is not clear (EPA 1996, page 1-5). Cristobalite is principally a concern for involved workers because it could be inhaled during subsurface excavation operations. Appendix F, Section F.1, contains additional information on crystalline silica.

While there are no limits for exposure of the general public to cristobalite, there are limits to workers for exposure (29 CFR 1000.1910). Therefore, this analysis used a comparative benchmark of 10 micrograms per cubic meter, based on a cumulative lifetime exposure of 1,000 micrograms per cubic meter multiplied by years (that is, the average annual exposure concentration times the number of years exposed). At this level, an Environmental Protection Agency health assessment (EPA 1996, pages 1-5 and 7-5) states that there is a less than 1 percent chance of silicosis. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter, which was rounded down to 10 micrograms per cubic meter to establish the benchmark.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this rock pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (TRW 1999b, page 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration, because studies of both ambient and occupational airborne crystalline silica have shown that most of this airborne material is coarse and not respirable and that larger particles will deposit rapidly on the surface (EPA 1996, page 3-26).

G.1.1 COMPUTER MODELING AND ANALYSIS

DOE used the Industrial Source Complex computer program to estimate the annual and short-term (24-hour or less) air quality impacts at the proposed Yucca Mountain Repository. The Department has used this program in recent EISs (DOE 1995, all; 1997a,b, all) to estimate nonradiological air quality impacts. The program contains both a short-term model (which uses hourly meteorological data) and a long-term model (which uses joint frequency meteorological data). The program uses steady-state Gaussian plume models to estimate pollutant concentrations from a variety of sources associated with industrial complexes (EPA 1995a, all). This modeling approach assumes that (1) the time-averaged pollutant concentration profiles at any distance downwind of the release point may be represented by a Gaussian (normal) distribution in both the horizontal and vertical directions; and (2) the meteorological conditions are constant (persistent) over the time of transport from source to receptor. The Industrial Source Complex program is appropriate for either flat or rolling terrain, and for either urban or rural environments. The Environmental Protection Agency has approved this program for specific regulatory applications. Input requirements for the program include source configuration and pollutant emission parameters. The short-term model was used in this analysis to estimate all nonradiological air quality impacts and uses hourly meteorological data that include wind speed, wind direction, and stability class to compute pollutant transport and dispersion.

Because the short-term pollutant concentrations were based on annual usage or release parameters, conversion of annual parameter values to short-term values depended on the duration of the activity. Many of the repository activities were assumed to have a schedule of 250 working days per year, so the daily release would be the annual value divided by 250.

In many cases, site- or activity-specific information was not available for estimating pollutant emissions at the Yucca Mountain site. In these cases, generic information was used and conservative assumptions were made that tended to overestimate actual air concentrations.

As noted in Section G.1, the total nonradiological air quality impacts are described in Chapter 4, Section 4.1.2, for the Proposed Action and in Chapter 8, Section 8.2.2, for the inventory modules. These impacts are the sum of air quality impacts from individual sources and activities that take place during each of the project phases and that are discussed later in this section (for example, dust emissions from the concrete batch facility during the construction phase). The maximum air quality impact (that is, air concentration) resulting from individual sources or activities could occur at different land withdrawal area boundary locations depending on the release period and the regulatory averaging time (see Section G.1.3). These maximums generally occur in a westerly or southerly direction. The total nonradiological air quality impacts presented in Sections 4.1.2 and 8.2.2 are the sum of the calculated maximum concentrations regardless of direction. Therefore, the values presented would be larger than the actual sum of the concentrations for a particular distance and direction. This approach was selected to simplify the presentation of air quality results.

G.1.2 LOCATIONS OF HYPOTHETICALLY EXPOSED INDIVIDUALS

The location of the public maximally exposed individual was determined by calculating the maximum ground-level pollutant concentrations. Because unrestricted public access would be limited to the site boundary, the analysis assumed that a hypothetical individual would be present at one point on the site boundary during the entire averaging time of the regulatory limit (Table G-1).

Table G-2 lists the distances from the North and South Portals to the land withdrawal area boundary where the analysis assumed members of the public would be present. The table does not list all directions because the land withdrawal area boundaries would not be accessible to members of the public in some directions (restricted access areas of the Nevada Test Site and Nellis Air Force Range). The distance to the nearest unrestricted public access in these directions would be so large that there would be no air quality impacts. For the east to south-southeast directions, the distances to the land withdrawal area boundary would be large, but the terrain is such that plumes traveling in these directions tend to enter Fortymile Wash and turn south. The analysis used the distance to the south land withdrawal area boundary for those sectors.

Table G-2. Distance to the nearest point of unrestricted public access (kilometers).[a,b,c]

Direction	From North Portal	From South Portal
Northwest	14	15
West-northwest	12	12
West	11	11
West-southwest	14	12
Southwest	18	16
South-southwest	23	19
South	21	18
South-southeast[d]	21	18
Southeast[d]	21	18

a. Source: DOE (1997c, all).
b. Numbers are rounded to two significant figures.
c. To convert kilometers to miles, multiply by 0.6217.
d. Distances assumed to be the same as those to the south.

G.1.3 METEOROLOGICAL DATA AND REFERENCE CONCENTRATIONS

DOE estimated the concentrations of criteria pollutants in the region of the repository by using the Industrial Source Complex program and site-specific meteorological data for 1993 to 1997 from air quality and meteorology monitoring Site 1 (TRW 1999c, electronic addendum). Site 1 is less than 1 kilometer (0.6 mile) south of the proposed North Portal surface facility location. Similar topographic exposure leads to similar prevailing northerly and southerly winds at both locations. DOE used Site 1 data because an analysis of the data collected at all the sites showed that site to be most representative of the surface facilities (TRW 1999c, page 7). Wind speed data are from the 10-meter (33-foot) level, as are atmospheric stability data, using the night-adjusted sigma-theta method (EPA 1987, pages 6-20 to 6-32). Mixing height measurements were not available for Yucca Mountain so the analysis assumed a mixing height of approximately 140 meters (470 feet), which is one-tenth of the 1,420 meters (4,700 feet) mixing-layer depth for Desert Rock, Nevada. Desert Rock is the nearest upper air meteorological station, about 44 kilometers (27 miles) east-southeast near Mercury, Nevada. The average mixing height at Desert Rock was divided by 10 to simulate the mixing height during very stable conditions, which is when the highest concentrations from a ground-level source would normally occur. All nonradiological pollutant releases were assumed to come from ground-level point sources. Both of these conservative assumptions, made because of a lack of site-specific information, tend to overestimate actual air concentrations. Fugitive dust emissions could be modeled as an area source, but the distance from the source to the exposure location would be large [more than 10 kilometers (6 miles)] so a point source provides a good approximation. Some sources would have plume rise, such as boiler emissions, but this was not considered because there is inadequate information to characterize the rise.

The analysis estimated unit release concentrations at the land withdrawal area boundary points of maximum exposure for ground-level point-source releases. The concentrations were based on release rates of 1 gram (0.04 ounce) per second for each of the five regulatory limit averaging times (annual, 24-hour, 8-hour, 3-hour, or 1-hour). Various activities at the Yucca Mountain site could result in pollutants being released over four different periods in a 24-hour day [continuously, 8-hour, 12-hour (two 6-hour periods), or 3-hour]. Eleven combinations of release periods and regulatory limit averaging times would be applicable to activities at the Yucca Mountain site.

The analysis assumed that the 8-hour pollutant releases would occur from 8 a.m. to 4 p.m. and to be zero for all other hours of the day. Similarly, it assumed that the 3-hour releases would occur from 9 a.m. to 12 p.m. and to be zero for all other hours. The 12-hour release would occur over two 6-hour periods, assumed to be from 9 a.m. to 3 p.m. and from 5 p.m. to 11 p.m.; other hours would have zero release. Continuous releases would occur throughout the 24-hour day. The estimates of all annual-average concentrations assumed the releases were continuous over the year.

Table G-3 lists the maximum unit release concentrations for the 11 combinations of the Yucca Mountain site-specific release periods and regulatory limit averaging times. The analysis estimated the unit

Table G-3. Unit release concentrations (micrograms per cubic meter based on a release of 1 gram per second) and direction to maximally exposed individual location for 11 combinations of 4 release periods and 5 regulatory limit averaging times.[a]

Direction from South Portal Operations area	Unit release concentration	Direction from North Portal Operations Area	Unit release concentration
Continuous release – annual average concentration (1995)[b]			
South-southeast	0.12	South-southeast	0.099
Continuous release – 24-hour average concentration (1993)			
Southeast	1.0	West	0.95
Continuous release – 8-hour average concentration (1995)			
Southeast	3.0	Southeast	2.5
Continuous release – 3-hour average concentration (1995)			
West	6.1	West	6.1
Continuous release – 1-hour average concentration (1995)			
West	18	West	18
8-hour release (8 a.m. to 4 p.m.) – 24-hour average concentration (1997)			
West-southwest	0.19	West-northwest	0.18
8-hour release (8 a.m. to 4 p.m.) – 8-hour average concentration (1997)			
West-southwest	0.57	West-northwest	0.52
8-hour release (8 a.m. to 4 p.m.) – 3-hour average concentration (1997)			
West-southwest	1.5	West-northwest	1.4
8-hour release (8 a.m. to 4 p.m.) – 1-hour average concentration (1997)			
West-northwest	3.3	West-northwest	3.3
12-hour release (9 a.m. to 3 p.m. and 5 p.m. to 11 p.m.) – 24-hour average concentration (1997)			
West	0.95	West	0.95
3-hour release (9 a.m. to 12 p.m.) – 24-hour average concentration (1997)			
West-northwest	0.17	West-northwest	0.17

a. Numbers are rounded to two significant figures.
b. Number in parentheses is the year from 1993 through 1997 for which meteorological data would result in the highest unit concentration.

concentrations and directions using the meteorological data during a single year from 1993 through 1997 (TRW 1999c, electronic addendum) that would result in the highest unit concentration. For all years, the unit release concentrations for a particular averaging time are within a factor of 2 of each other. Table G-3 lists the 24-hour averaged concentration for the 3- and 12-hour release scenarios because the activities associated with these scenarios would only release PM_{10}, which has annual and 24-hour regulatory limits. The estimated concentration at the point of exposure was calculated by multiplying the estimated source release rate (presented for each source in the following sections) by the maximum unit release concentration for that averaging period.

G.1.4 CONSTRUCTION PHASE

This section describes the method used to estimate air quality impacts during the 5-year construction phase. DOE would complete the surface facilities during the construction phase, as well as sufficient excavation of the subsurface to support initial emplacement activities.

This analysis used calculations of the pollutant concentrations from various construction activities to determine air quality impacts. To calculate these impacts, estimated pollutant emission rates discussed in this section were multiplied by the unit release concentration (see Section G.1.3). This produced the pollutant concentration for comparison to regulatory limits. Short-term pollutant emission rates and concentrations were estimated using the method described in Section G.1.1.

The principal emission sources of particulates would be fugitive dust from construction activities on the surface, excavation of rock from the repository, storage of material on the excavated rock pile, and dust emissions from the concrete batch facility. The principal sources of nitrogen dioxide, sulfur dioxide, and carbon monoxide would be fuel combustion in trucks, cranes, and graders and emissions from a boiler in the South Portal Operations Area. Nitrogen dioxide, sulfur dioxide, and carbon monoxide would also be emitted during maintenance of the excavated rock pile. The following sections describe these sources in more detail.

G.1.4.1 Fugitive Dust Emissions from Surface Construction

Fugitive dust would be generated during such construction activities as earth moving and truck traffic. All surface construction activities and associated fugitive dust releases were assumed to occur during 250 working days per year with one 8-hour shift per day. The preferred method suggested by the Environmental Protection Agency would be to break the construction activities into component activities (for example, earth moving, truck traffic) and calculate the emissions for each component. However, detailed information was not available for the construction phase, so a generic, conservative approach was taken. The release rate of total suspended particulates (particulates with aerodynamic diameters of 30 micrometers or less) was estimated as 0.27 kilogram per square meter (1.2 tons per acre) per month (EPA 1995b, pages 13.2.3-1 to 13.2.3-7). This estimated emission rate for total suspended particulates was based on measurements made during the construction of apartments and shopping centers.

The amount of PM_{10} (the pollutant of interest) emitted from the construction of the Yucca Mountain Repository probably would be less than 0.27 kilogram per square meter (1.2 tons per acre) per month because many of the particulates suspended during construction would be at the larger end of the 30-micrometer range and would tend to settle rapidly (Seinfeld 1986, pages 26 to 31). Experiments on dust suspension due to construction found that at 50 meters (160 feet) downwind of the source, a maximum of 30 percent of the remaining suspended particulates at respirable height were in the PM_{10} range (EPA 1988, pages 22 to 26). Based on this factor, only 30 percent of the 0.27 kilogram per square meter per month of total suspended particulates, or 0.081 kilogram per square meter (0.36 ton per acre) per month, would be emitted as PM_{10} from construction activities. Because the default emission rate was based on continuous emissions over 30 days, the daily PM_{10} emission rate would be 0.0027 kilogram per square meter (0.012 ton per acre) per day, or 0.00011 kilogram per square meter (0.00050 ton per acre) per hour. Dust suppression activities would reduce PM_{10} emissions; however, the analysis took no credit for normal dust suppression activities.

The estimation of the annual and 24-hour average PM_{10} emission rates required an estimate of the size of the area to be disturbed along with the unit area emission rate [0.00011 kilogram per square meter (0.00050 ton per acre) per hour] times 8 hours of construction per day. The analysis estimated that 20 percent of the total disturbed land area would be actively involved in construction activities at any given time. This was based on the total disturbed area at the end of the construction period divided by the 5 years construction activities would last. Table G-4 lists the total areas of disturbance at various repository operation areas. The analysis assumed that the entire land area required for excavated rock storage (for both the construction and operation phases) would be disturbed by excavated rock storage preparation activities, although only a portion of it would be used during the construction phase. The much larger volume of rock that DOE would remove during excavation for the low thermal load scenario would require that the excavated rock pile not be in the South Portal Operations Area. Rather, it would be about 5 kilometers (3 miles) east of the South Portal (TRW 1999b, pages 6-41 and 6-43). The excavated rock could be piled higher in this location [to about 15 meters (50 feet)] than in the South Portal Operations Area [where the piles could be no more than about 6 meters (20 feet) high], requiring less land area under this option and making the area required for all three thermal load scenarios about the same. Table G-5 lists fugitive dust emissions from surface construction; Table G-6 lists estimated air quality impacts from fugitive dust as the pollutant concentration in air and as the percent of the applicable regulatory limit.

Table G-4. Land area (square kilometers)[a] disturbed during the construction phase for each thermal load scenario.[b,c]

Operations area	High	Intermediate	Low
North Portal and roads	0.62	0.62	0.62
South Portal	0.15	0.15	0.15
Ventilation shafts	0.02	0.02	0.06
Total excavated rock storage	1.0	1.2	1.1
Rail construction on site[d]	0.6	0.6	0.6
Totals[b]	**2.4**	**2.6**	**2.6**
Area disturbed per year	0.48	0.52	0.50

a. To convert square kilometers to acres, multiply by 247.1.
b. Numbers are rounded to two significant figures; therefore, totals might differ from sums of values.
c. Source: Jessen (1998, all).
d. Onsite rail line assumed to be 10 kilometers (6 miles) long and 0.06 kilometer (0.04 mile) wide.

Table G-5. Fugitive dust releases from surface construction (PM_{10}).[a]

Thermal load scenario	Period	Pollutant emission (kilograms)[b]	Emission rate (grams per second[c])
High	Annual	110,000 per year	3.4
	24-hour	430 per day	15[d]
Intermediate	Annual	120,000 per year	3.6
	24-hour	460 per day	16[d]
Low	Annual	120,000 per year	3.7
	24-hour	460 per day	16[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on an 8-hour release period.

Fugitive dust from construction would produce small offsite PM_{10} concentrations. The annual and 24-hour average concentrations of PM_{10} would be about 1 percent and about 2 percent, respectively, of the regulatory limit for all three thermal load scenarios. The differences between the thermal load

Table G-6. Estimated fugitive dust air quality impacts (micrograms per cubic meter) from surface construction (PM_{10}).

Thermal load scenario	Period	Maximum concentration[a]	Regulatory limit	Percent of limit[a]
High	Annual	0.41	50	0.83
	24-hour	2.9	150	1.9
Intermediate	Annual	0.44	50	0.88
	24-hour	3.0	150	2.0
Low	Annual	0.44	50	0.88
	24-hour	3.1	150	2.0

a. Numbers are rounded to two significant figures.

scenarios would be very small; the high thermal load would have the smallest impacts due mainly to the smaller area required for excavated rock storage.

For Modules 1 and 2, the same technique was used as for the Proposed Action, but the amount of land disturbed would be about 1.1, 1.1, and 1.3 times larger than for the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively (Jessen 1998, all). The increase in disturbed land area would lead to estimated air quality impacts about 1.1, 1.1, and 1.3 times larger than the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively.

G.1.4.2 Fugitive Dust from Subsurface Excavation

Fugitive dust would be released during the excavation of rock from the repository. Subsurface excavation activities would take place 250 days per year in three 8-hour shifts per day. Excavation would generate dust in the tunnels, and some of the dust would be emitted to the surface atmosphere through the ventilation system. DOE estimated the amount of dust that would be emitted by the ventilation system by using engineering judgment and best available information (DOE 1998, page 37). Table G-7 lists the release rates of PM_{10} for excavation activities. Table G-8 lists estimated air quality impacts from fugitive dust as pollutant concentration in air and percentage of regulatory limit.

Table G-7. Fugitive dust releases from excavation activities (PM_{10}).[a]

Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Annual	920 per year	0.029
24-hour	3.7 per day	0.043[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 24-hour release period.

Table G-8. Fugitive dust (PM_{10}) and cristobalite air quality impacts (micrograms per cubic meter) from excavation activities.

Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
PM_{10}			
Annual	0.0035	50	0.0070
24-hour	0.044	150	0.029
Cristobalite			
Annual	0.0010	10[b]	0.010

a. Numbers are rounded to two significant figures.
b. This value is a benchmark; there is no regulatory limit for cristobalite. See Section G.1.

Fugitive dust emissions from excavation operations would produce small offsite PM_{10} concentrations. Both annual and 24-hour average concentrations of PM_{10} would be much less than 1 percent of the regulatory standards. The highest estimated annual and 24-hour excavation rates, and hence the highest estimated fugitive dust concentrations, would be the same for all three thermal load scenarios.

Dust generated during excavation would contain cristobalite, a naturally occurring form of crystalline silica discussed in Section G.1. The analysis estimated the amount of cristobalite released by multiplying the amount of dust released annually (shown in Table G-7) by the percentage of cristobalite in the parent rock (28 percent). Table G-8 also lists the potential air quality impacts for releases of cristobalite from excavation of the repository. Because there are no public exposure limits for cristobalite, the annual average concentration was compared to a derived benchmark level for the prevention of silicosis, as discussed in Section G.1. The offsite cristobalite concentration would be about 0.01 percent of this benchmark.

The air quality impacts from fugitive dust emissions from excavation operations under the construction phase would be the same for Modules 1 and 2 as for the Proposed Action.

G.1.4.3 Fugitive Dust from Excavated Rock Pile

The disposal and storage of excavated rock on the surface excavated rock pile would generate fugitive dust. Dust would be released during the unloading of the excavated rock and subsequent smoothing of the excavated rock pile, as well as by wind erosion of the material. DOE used the total suspended particulate emission for active storage piles from a report by Cowherd, Muleski, and Kinsey (1988, pages 4-17 to 4-37) to estimate fugitive dust emission. The equation is:

$$E = 1.9 \times (s \div 1.5) \times [(365 - p) \div 235] \times (f \div 15)$$

where E = total suspended particulate emission factor (kilogram per day per hectare [1 hectare = 0.01 square kilometer = 2.5 acres])
s = silt content of aggregate (percent)
p = number of days per year with 0.25 millimeter or more of precipitation
f = percentage of time wind speed exceeds 5.4 meters per second (12 miles per hour) at pile height

For this analysis, *s* is equal to 4 percent [no value was available for this variable, so the average silt content of limestone quarrying material (EPA 1995b, page 13.2.4-2) was used], *p* is 37.75 (Fransioli 1999, all) and *f* is 16.5 (calculated from meteorological data used in the Industrial Source Complex model). Thus, *E* is equal to 7.8 kilograms of total particulates per day per hectare (6.9 pounds per day per acre). Only about 50 percent of the total particulates would be PM_{10} (Cowherd, Muleski, and Kinsey 1988, pages 4-17 to 4-37); therefore, the emission rate for PM_{10} would be 3.9 kilograms per day per hectare (3.5 pounds per day per acre).

The analysis estimated fugitive dust from disposal and storage using the size of the area actively involved in storage and maintenance. Only a portion of the excavated rock pile would be actively disturbed by the unloading of excavated rock and the subsequent contouring of the pile, and only that portion would be an active source of fugitive dust. The analysis assumed that the rest of the excavated rock pile would be stabilized by either natural processes or DOE stabilization measures and would release small amounts of dust.

DOE based its estimate of the size of the active portion of the excavated rock pile on the amount of material it would store there each year. The volume of rock placed on the excavated rock pile from excavation activities during the construction phase (TRW 1999b, page 6-7) was divided by the height of the storage pile. The average height of the excavated rock pile would be about 6 meters (20 feet) for the high and intermediate thermal load scenarios (TRW 1999b, page 6-42) and 15 meters (50 feet) for the low thermal load scenario (TRW 1999b, page 6-43). Table G-9 lists the areas of the excavated rock pile and the active portion for each thermal load scenario. The active area of the excavated rock pile was estimated using the total area of the rock pile at the end of the construction phase divided by the number of years of construction multiplied by 2 (Smith 1999, all). As noted in Section G.1.4.1, under the low thermal load scenario the excavated rock pile would be several kilometers east of the South Portal Operations Area. Under this option the pile could be higher in this location, allowing for a smaller area of disturbance than for the excavated rock piles of the high and intermediate thermal load scenarios in the South Portal Operations Area.

Table G-9. Active area (square kilometers)[a] of excavated rock pile during the construction phase.[b,c]

Thermal load	Area	Number of years	Average annual active area
High	0.34	5	0.14
Intermediate	0.41	5	0.17
Low	0.17	5	0.066

a. To convert square kilometers to square miles, multiply by 0.3861.
b. Numbers are rounded to two significant figures.
c. The construction phase would last 5 years. Subsurface excavation and rock pile activities would continue during the operation and monitoring phase (see Section G.1.5).

Table G-10 lists the fugitive dust release rate from disposal and storage of the excavated rock pile by thermal load scenario. Table G-11 lists the air quality impacts from fugitive dust as pollutant concentration and percent of regulatory limit.

Table G-10. Fugitive dust released from the excavated rock pile during the construction phase (PM_{10}).[a]

Thermal load	Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
High	Annual	19,000 per year	0.61
	24-hour	53 per day	0.61[d]
Intermediate	Annual	23,000 per year	0.74
	24-hour	64 per day	0.74[d]
Low	Annual	9,400 per year	0.30
	24-hour	26 per day	0.30[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a continuous release.

Fugitive dust emissions from the excavated rock pile during the construction phase would produce small offsite PM_{10} concentrations. Both the annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards. The low thermal load scenario would have the smallest concentrations due to the smaller area of active disturbance, which is directly related to the taller pile with a resultant smaller surface-area-to-volume ratio.

Table G-11 also lists potential air quality impacts for releases of cristobalite. The methods used were the same as those described in Section G.1.4.2 for the construction phase, where cristobalite was assumed to be 28 percent of the fugitive dust released, based on its percentage in parent rock. The land withdrawal area boundary cristobalite concentration would be small, about 0.25 percent or less of the benchmark level discussed in Section G.1.

Table G-11. Fugitive dust (PM_{10}) and cristobalite air quality impacts (micrograms per cubic meter) from the excavated rock pile during the construction phase.

Thermal load	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
PM_{10}				
High	Annual	0.074	50	0.15
	24-hour	0.62	150	0.41
Intermediate	Annual	0.090	50	0.18
	24-hour	0.76	150	0.51
Low	Annual	0.036	50	0.071
	24-hour	0.30	150	0.19
Cristobalite				
High	Annual	0.021	10[c]	0.21
Intermediate	Annual	0.025	10[c]	0.25
Low	Annual	0.010	10[c]	0.010

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.
c. This value is a benchmark; there are no regulatory limits for cristobalite other than worker exposure limits. See Section G.1.

For Modules 1 and 2, the volume of rock excavated during the construction phase would be nearly 1.8 million cubic meters (2.3 million cubic yards) for all three thermal load scenarios (TRW 1999b, pages 6-7 and 6-53). This represents an increase of about 16 percent over the Proposed Action for the high thermal load scenario, and a slight decrease of about 5 percent for the intermediate and low thermal load scenarios. The estimated air quality impacts would change proportionately from Proposed Action impacts, increasing 16 percent for the high thermal load scenario and decreasing by 5 percent for the intermediate and low thermal load scenarios.

G.1.4.4 Fugitive Dust from Concrete Batch Facility

The concrete batch facility for the fabrication and curing of tunnel inverts and tunnel liners would emit dust. This facility would run 3 hours a day and would produce 115 cubic meters (150 cubic yards) of concrete per hour of operation (TRW 1999b, pages 4-4 and 4-5). It would operate 250 days per year. Table G-12 lists emission factor estimates for the concrete batch facility (EPA 1995b, pages 11.12-1 to 11.12-5). About 0.76 cubic meter (1 cubic yard) of typical concrete weighs 1,800 kilograms (4,000 pounds) (EPA 1995b, page 11.12-3). The size of the aggregate storage pile for the concrete batch facility would be 800 square meters (0.2 acre) (TRW 1999b, pages 4-4 and 4-5).

Table G-12. Dust release rates for the concrete batch facility (kilograms per 1,000 kilograms of concrete).[a,b]

Source/activity	Emission rate
Sand and aggregate transfer to elevated bin	0.014
Cement unloading to elevated storage silo	0.13
Weight hopper loading	0.01
Mixer loading	0.02
Wind erosion from aggregate storage	3.9 kilograms per hectare[c] per day

a. Source: EPA (1995b, page 11.12-3).
b. To convert kilograms to pounds, multiply by 2.2046.
c. 3.9 kilograms per hectare = about 21 pounds per acre.

Table G-13 lists the dust release rates of the concrete batch facility. The releases would be the same for all thermal load scenarios. Table G-14 lists estimated potential air quality impacts as the estimated pollutant concentration and percent of regulatory limit.

Table G-13. Dust release rates for the concrete batch facility during the operation and monitoring phase (PM_{10}).[a]

Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Annual	36,000 per year	1.1
24-hour	140 per day	13[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 3-hour release.

Table G-14. Particulate matter (PM_{10}) air quality impacts (micrograms per cubic meter) from the concrete batch facility during the construction phase.

Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Annual	0.14	50	0.27
24-hour	2.2	150	1.1

a. Numbers are rounded to two significant figures.

Dust emissions from the concrete batch facility during the operation and monitoring phase would produce small offsite PM_{10} concentrations. The annual and 24-hour averaged concentrations of PM_{10} would be less than 1 percent and about 1.5 percent of the regulatory standards, respectively.

For Modules 1 and 2, the air quality impacts from the concrete batch facility during the construction phase would be the same as for the Proposed Action.

G.1.4.5 Exhaust Emissions from Construction Equipment

Diesel- and gasoline-powered equipment would emit all four criteria pollutants during the construction phase. EPA (1991, pages II-7-1 to II-7-7) provided pollutant emission rate estimates for heavy-duty equipment. This analysis assumed construction equipment would emit the average of the EPA reference emission rates. Table G-15 lists the emission rates for this equipment.

Table G-15. Pollutant emission rates (kilograms[a] per 1,000 liters[b] of fuel) for construction equipment.[c]

	Estimated emission	
Pollutant	Diesel	Gasoline
Carbon monoxide	15	450
Nitrogen dioxide	39	13
PM_{10}	3.5	0.86
Sulfur dioxide	3.7	0.63

a. To convert kilograms to pounds, multiply by 2.2046.
b. To convert liters to gallons, multiply by 0.26418.
c. Source: Average of rates from EPA (1991, pages II-7-1 to II-7-7).

Table G-16 lists the estimated average amount of fuel per year for the construction of the North and South Portal Operations Areas. The fuel for the South Portal Operations Area would include fuel consumed during maintenance of the excavated rock pile.

Table G-16. Amount of fuel consumed per year during the construction phase (liters).[a,b]

	South Portal Operations Area[c]		North Portal Operations Area[d]
Thermal load	Diesel	Gasoline	Diesel
High	360,000	20,000	640,000
Intermediate	360,000	20,000	640,000
Low	560,000	20,000	640,000

a. To convert liters to gallons, multiply by 0.26418.
b. Numbers are rounded to two significant figures.
c. Source: Based on total fuel use from TRW (1999b, page 6-3).
d. Source: Based on total fuel use from TRW (1999a, Table 6.1, page 71).

Table G-17 lists pollutant releases from construction equipment for each thermal load scenario. The emission rate for the annual concentration was calculated from the total fuel consumed, assuming the same amount of fuel would be consumed each year.

Table G-17. Pollutant release rates from surface equipment during the construction phase.[a]

		Mass of pollutant per averaging period (kilograms)[b]		Emission rate[c] (grams per second)[d]	
Pollutant	Period	South	North	South	North
High and intermediate thermal load					
Nitrogen dioxide	Annual	14,000	25,000	0.46	0.80
Sulfur dioxide	Annual	1,400	2,400	0.043	0.076
	24-hour	5.4	9.6	0.019	0.33
	3-hour	2.0	3.6	0.019	0.33
Carbon monoxide	8-hour	57	39	2.0	1.3
	1-hour	7.2	4.8	2.0	1.3
PM_{10}	Annual	1,300	2,200	0.040	0.071
	24-hour	5.1	8.9	0.18	0.31
Low thermal load					
Nitrogen dioxide	Annual	22,000	25,000	0.71	0.80
Sulfur dioxide	Annual	2,100	2,400	0.067	0.076
	24-hour	8.4	9.6	0.29	0.33
	3-hour	3.2	3.6	0.29	0.33
Carbon monoxide	8-hour	69	39	2.4	1.3
	1-hour	8.7	4.8	2.4	1.3
PM_{10}	Annual	2,000	2,200	0.062	0.071
	24-hour	7.9	8.9	0.27	0.31

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release for averaging periods 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-18 lists the impacts on air quality from construction equipment emission by thermal load scenario as the pollutant concentration in air and the percent of the regulatory limit. Emissions from surface equipment during the construction phase would produce small offsite (outside the land withdrawal area) criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards.

For Modules 1 and 2, the same analysis method was used as that for the Proposed Action, but the amount of fuel used in the South Portal Operations Area would vary from the Proposed Action. Diesel fuel use would be about 7.4 times larger for the high and intermediate thermal load scenarios and about 4.8 times larger for the low thermal load scenario. Gasoline use would be two times larger for all thermal load scenarios (TRW 1999b, page 6-45). There would be no change in the amount of fuel used during the

Table G-18. Air quality impacts from construction equipment during the construction phase (micrograms per cubic meter).[a]

Pollutant	Period	Maximum concentration	Regulatory limit[b]	Percent of regulatory limit
High and intermediate thermal load				
Nitrogen dioxide	Annual	0.13	100	0.13
Sulfur dioxide	Annual	0.013	80	0.016
	24-hour	0.096	365	0.026
	3-hour	0.77	1,300	0.059
Carbon monoxide	8-hour	1.8	10,000	0.018
	1-hour	11	40,000	0.028
PM_{10}	Annual	0.012	50	0.024
	24-hour	0.090	150	0.060
Low thermal load				
Nitrogen dioxide	Annual	0.16	100	0.16
Sulfur dioxide	Annual	0.016	80	0.020
	24-hour	0.12	365	0.032
	3-hour	0.93	1,300	0.071
Carbon monoxide	8-hour	2.1	10,000	0.020
	1-hour	12	40,000	0.031
PM_{10}	Annual	0.014	50	0.029
	24-hour	0.11	150	0.072

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

construction of the North Portal. These increases in fuel use would lead to estimated air quality impacts that would be about 3.5 times larger for the high and intermediate thermal load scenarios and about 2.5 times larger for the low thermal load scenario except for carbon monoxide. Carbon monoxide air quality impacts, which are more heavily weighted towards gasoline, would be about 2.5, 2.5 and 2.0 times larger than the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively.

G.1.4.6 Exhaust from Boiler

A proposed boiler in the South Portal Operations Area would emit the four criteria pollutants. The boiler would use diesel fuel and provide steam and hot water for the heating, ventilation, and air conditioning system. The analysis assumed that this boiler would be the same size as the boiler that would operate in the North Portal Operations Area during the operation and monitoring phase (TRW 1999a, Table 6-2, page 75) but not during construction. Table G-19 lists the annual emission rates of the boiler in the South Portal Operations Area. To estimate the short-term (24 hours or less) emission rate, the analysis assumed the boiler would run 250 days (6,000 hours) per year. Given the annual boiler emissions, this was a conservative assumption because continuous operation 365 days (8,760 hours) per year would result in lower daily emissions. This assumption considered periods when the boiler would not be operating. The actual period of boiler operation is not known. In addition, specific information on the boiler stack height and exhaust air temperature (which would affect plume rise) has not been developed. The analysis assumed that releases would be from ground level, which overestimates actual concentrations. Table G-20 lists releases of criteria pollutants by the boiler. Table G-21 lists estimated potential air quality impacts as pollutant concentrations in air and percent of regulatory limit.

Table G-19. Annual pollutant release rates (kilograms per year)[a] for the South Portal Operations Area boiler.[b,c]

Pollutant	Annual emission rate
Nitrogen dioxide	58,000
Sulfur dioxide	20,000
Carbon monoxide	15,000
PM_{10}	5,600

a. To convert kilograms to tons, multiply by 0.0011023.
b. Source: TRW (1999a, Table 6-2, page 75).
c. Numbers are rounded to two significant figures.

Table G-20. Pollutant release rates from the boiler during the construction phase.[a]

Pollutant	Period	Mass of pollutant (kilograms)[b] per averaging time	Emission rate[c] (grams per second)[d]
Nitrogen dioxide	Annual	58,000	1.83
Sulfur dioxide	Annual	20,000	0.63
	24-hour	80	0.92
	3-hour	10	0.92
Carbon monoxide	8-hour	20	0.67
	1-hour	2.5	0.67
PM_{10}	Annual	5,600	0.18
	24-hour	22	0.25

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release for averaging periods of 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-21. Air quality impacts from boiler pollutant releases from the South Portal Operations Area during the construction phase (micrograms per cubic meter of pollutant).

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.22	100	0.22
Sulfur dioxide	Annual	0.076	80	0.095
	24-hour	0.94	365	0.26
	3-hour	5.5	1,300	0.43
Carbon monoxide	8-hour	2.0	10,000	0.020
	1-hour	12	40,000	0.031
PM_{10}	Annual	0.022	50	0.044
	24-hour	0.27	150	0.18

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Emissions from the boiler during the construction phase would produce small offsite (outside the land withdrawal area) criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards.

For Modules 1 and 2, the air quality impacts from the boiler during the construction phase would be the same as those for the Proposed Action.

G.1.5 OPERATION AND MONITORING PHASE

This section describes the method DOE used to estimate air quality impacts during the operation and monitoring phase (2010 to 2110). Activities during this phase would include the continued development of the subsurface facilities, which would last 22 years for all thermal load scenarios. Emplacement activities in the surface and subsurface facilities would continue concurrently with development operations for 24 years; 76 years of monitoring and maintenance would begin after the end of emplacement operations. The duration of the monitoring and maintenance period has not been finalized, but could be as long as 276 years for a 300-year operation and monitoring phase. For purposes of analysis, workers would use the following schedule for activities during the operation and monitoring phase: three 8-hour shifts a day, 5 days a week, 50 weeks a year; the maintenance of the excavated rock pile would occur in one 8-hour shift a day, 5 days a week, 50 weeks a year.

For Modules 1 and 2, the continued development of the subsurface facilities would last 36 years for all thermal load scenarios. Emplacement activities in the surface and subsurface facilities would continue concurrently with development operations for 38 years. The duration of the monitoring and maintenance period has not been finalized, but could be as long as 262 years for a 300-year operation and monitoring phase.

The analysis estimated air quality impacts by calculating pollutant concentrations from various operation and monitoring activities. Emission rates were developed for each activity that would result in pollutant releases. The emission rates were multiplied by the unit release concentrations (see Section G.1.3) to calculate the pollutant concentration for comparison to the various regulatory limits.

The principal emission sources of particulates would be dust emissions from concrete batch facility operations and fugitive dust emissions from excavation and storage on the excavated rock pile. Fuel combustion from maintenance of the excavated rock pile and emissions from the North Portal and South Portal boilers would be principal sources of nitrogen dioxide, sulfur dioxide, and carbon monoxide. The following sections describe these sources in more detail.

G.1.5.1 Fugitive Dust from Concrete Batch Facility

The concrete batch facility for the fabrication and curing of tunnel inverts and liners would emit dust. The analysis assumed that the dust emissions from the concrete batch facility would be the same as those during the construction phase. Thus, the dust release rate and potential air quality impacts would be the same as those listed in Tables G-13 and G-14.

G.1.5.2 Fugitive Dust from Subsurface Excavation

The excavation of rock from the repository would generate fugitive dust in the drifts. Some of the dust would reach the external atmosphere through the repository ventilation system. Fugitive dust emission rates from excavation during operations would be the same as those during the construction phase. Thus, the fugitive dust release rate and potential air quality impacts for excavation of rock would be the same as those listed in Tables G-7 and G-8. Air quality impacts from cristobalite released during excavation of the repository would be the same as those listed in Table G-8.

G.1.5.3 Fugitive Dust from Excavated Rock Pile

The disposal and storage of excavated rock on the excavated rock pile would release fugitive dust. The analysis used the same method to estimate fugitive dust releases from the excavated rock pile during operations that it used for the construction phase (See Section G.1.4.3). Table G-22 lists the areas of the active portion of the excavated rock pile by thermal load scenario. The total land area used for storage and the active portion of the excavated rock pile was based on the amount of rock that would be stored during operations (TRW 1999b, page 6-17). Sections G.1.4.1 and G.1.4.3 compare the excavated rock pile areas for the three thermal load scenarios.

Table G-22. Estimated active excavated rock pile area (square kilometers)[a] during subsurface excavation activities during the operation and monitoring phase.[b]

Thermal load	Storage area	Years of repository development	Annual average active area
High	0.63	22	0.058
Intermediate	0.76	22	0.069
Low	1.0	22	0.095

a. To convert square kilometers to acres, multiply by 247.1.
b. Numbers are rounded to two significant figures.

While the land area used for storage of excavated rock during the operation and monitoring phase would be nearly twice as large as that used during the construction phase for the high and intermediate thermal load scenarios, the active area per year would be about half of that for construction due to the larger number of years over which storage would occur (22 years compared to 5 years). The land area used during the operation and monitoring phase for the low thermal load scenario would be nearly 10 times that used during the construction phase. The annual active area would be larger during the operation and monitoring phase than during the construction phase, but only about twice as large because of the longer period over which storage would take place (22 years compared to 5 years). Table G-23 lists fugitive dust releases from the excavated rock pile; Table G-24 lists potential air quality impacts as the pollutant concentration and percent of the regulatory limit.

Table G-23. Fugitive dust release rate from the excavated rock pile during the operation and monitoring phase (PM_{10}).[a]

Thermal load	Period	Emissions (kilograms)[b]	Emission rate[c] (grams per second)[d]
High	Annual	8,200 per year	0.26
	24-hour	22 per day	0.26
Intermediate	Annual	9,800 per year	0.31
	24-hour	27 per day	0.31
Low	Annual	13,000 per year	0.42
	24-hour	37 per day	0.42

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on a continuous release.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-24. Fugitive dust (PM_{10}) and cristobalite air quality impacts from the excavated rock pile during the operation and monitoring phase (micrograms per cubic meter).

Thermal load	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
PM_{10}				
High	Annual	0.031	50	0.062
	24-hour	0.27	150	0.18
Intermediate	Annual	0.038	50	0.075
	24-hour	0.32	150	0.21
Low	Annual	0.051	50	0.10
	24-hour	0.43	150	0.29
Cristobalite				
High	Annual	0.0087	10[c]	0.087
Intermediate	Annual	0.011	10[c]	0.11
Low	Annual	0.014	10[c]	0.14

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.
c. This value is a benchmark; there is no regulatory limit for cristobalite. See Section G.1.

Fugitive dust emissions from the excavated rock pile during the operation and monitoring phase would produce very small offsite (outside the land withdrawal area) PM_{10} concentrations. Both annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards for all three thermal load scenarios.

Table G-24 also lists potential air quality impacts for releases of cristobalite. The methods used were the same as those described in Section G.1.4.2 for the construction phase, where cristobalite was assumed to be 28 percent of the fugitive dust released, based on its percentage in parent rock. The site boundary cristobalite concentration would be small, about 0.1 percent of the benchmark level discussed in Section G.1.

The Module 1 and 2 analysis used the same technique as for the Proposed Action, but the estimated active excavated rock pile area would be about 1.4, 1.2, and 1.1 times larger than the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively, based on the volumes of rock added annually to the pile (TRW 1999b, page 6-56). The estimated air quality impacts from the excavated rock pile would also be 1.4, 1.2, and 1.1 times larger than the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively.

G.1.5.4 Exhaust from Excavated Rock Pile Maintenance Equipment

Surface equipment would emit the four criteria pollutants during excavated rock pile maintenance. The analysis used the same method to determine air quality impacts for surface equipment during operations that it used for the construction phase (see Section G.1.4.5). Table G-15 lists the pollutant release rates of the equipment. Table G-25 lists the average amount of fuel consumed each year during the operation and monitoring phase at the South Portal Operations Area.

Table G-25. Annual amount of fuel (liters)[a] consumed during the operation and monitoring phase.[b,c]

Thermal load	Diesel	Gasoline
High	350,000	4,500
Intermediate	350,000	4,500
Low	2,800,000	9,000

a. To convert liters to gallons, multiply by 0.26418.
b. Source: Based on total fuel use from TRW (1999b, pages 6-14 and 6-21).
c. Numbers are rounded to two significant figures.

Table G-26 lists pollutant release rates for surface equipment during operations activities of the operation and monitoring phase. Monitoring activity emissions would be much smaller. Table G-27 lists potential air quality impacts.

Table G-26. Pollutant release rates from surface equipment during the operation and monitoring phase.[a]

Pollutant	Period	Mass of pollutant per averaging time (kilograms)[b]	Emission rate[c] (grams per second)[d]
High and intermediate thermal load			
Nitrogen dioxide	Annual	14,000	0.44
Sulfur dioxide	Annual	1,300	0.041
	24-hour	5.2	0.18
	3-hour	4.9	0.18
Carbon monoxide	8-hour	29	1.0
	1-hour	3.6	1.0
PM_{10}	Annual	1,200	0.039
	24-hour	4.9	0.17
Low thermal load			
Nitrogen dioxide	Annual	110,000	3.5
Sulfur dioxide	Annual	10,000	0.33
	24-hour	42	1.4
	3-hour	16	1.4
Carbon monoxide	8-hour	180	6.4
	1-hour	23	6.4
PM_{10}	Annual	9,700	0.31
	24-hour	39	1.4

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release for averaging periods of 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-27. Air quality impacts from surface equipment during the operation and monitoring phase (micrograms per cubic meter of pollutant).

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
High and intermediate thermal load				
Nitrogen dioxide	Annual	0.052	100	0.052
Sulfur dioxide	Annual	0.0049	80	0.0063
	24-hour	0.034	365	0.0094
	3-hour	0.27	1,300	0.021
Carbon monoxide	8-hour	0.58	10,000	0.0056
	1-hour	3.3	40,000	0.0084
PM_{10}	Annual	0.0046	50	0.0092
	24-hour	0.032	150	0.021
Low thermal load				
Nitrogen dioxide	Annual	0.42	100	0.42
Sulfur dioxide	Annual	0.040	80	0.051
	24-hour	0.28	365	0.076
	3-hour	2.2	1,300	0.17
Carbon monoxide	8-hour	3.7	10,000	0.036
	1-hour	21	40,000	0.053
PM_{10}	Annual	0.037	50	0.074
	24-hour	0.26	150	0.17

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Emissions from surface equipment during operation and monitoring would produce very small concentrations of offsite (outside the land withdrawal area) criteria pollutants. All estimated concentrations would be less than 1 percent of the regulatory standards.

The Module 1 and 2 analysis used the same technique as for the Proposed Action, but the amount of fuel used during the operation and monitoring phase would increase. Annual diesel fuel use during development would increase by 1.6, 3.0, and 2.0 times the Proposed Action; annual gasoline use would increase by 1.2, 1.8, and 1.5 times the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively, based on total fuel use (TRW 1999b, page 6-53). Annual diesel fuel use during emplacement would increase only by about 1 percent over the Proposed Action for all thermal load scenarios (TRW 1999b, page 6-61). Estimated air quality impacts for surface equipment during the operation and monitoring phase under Module 1 and 2 would increase by about 1.6, 3.0, and 2.0 times the Proposed Action for the high, intermediate, and low thermal load scenarios.

G.1.5.5 Exhaust from Boiler

Boilers in the North and South Portal Operations Areas would emit the four criteria pollutants. The annual emission rates of the boiler in the North Portal Operations Area would be the same as those listed in Table G-19 (the boilers were assumed to be the same size). There would be small variations in the North Portal boiler emissions for the transportation and waste packaging options because of different operational requirements. The emissions listed in Table G-19 are for the combination of legal-weight truck transport and uncanistered waste scenario, which would require the largest boiler because a larger Waste Handling Building would be required (TRW 1999a, pages 66 to 75). Other options would require a slightly smaller boiler (TRW 1999a, Table 6-2, page 75) and the release rate of pollutants would be about 15 percent smaller. The size of the boiler would not depend on the thermal load scenario. The analysis assumed the boiler would run 250 days (6,000 hours) per year. Given an annual emission rate, this was a conservative assumption because continuous operation 365 days (8,760 hours) per year would result in lower daily emissions. This assumption considered periods when the boiler would not be operating. The actual period of boiler operation is not known. Rates from the North Portal boiler for evaluating pollutant releases during the operation and monitoring phase would be the same as those listed in Table G-20 for the South Portal boiler.

Table G-28 lists estimated potential air quality impacts as pollutant concentrations in air and percent of regulatory limit. These impacts would be due to emissions from the boilers in the North and South Portal Operations Areas. Although total emissions during the operation and monitoring phase would be double those during the construction phase (when only the South Portal boiler would operate), air quality impacts would not double because of different atmospheric dispersion factors from the two operations areas to the location of the hypothetically maximally exposed individual. Emissions from the two boilers during the operation and monitoring phase would produce small offsite criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards.

Table G-28. Air quality impacts from boiler pollutant releases from both North and South Portal Operations Areas (micrograms per cubic meter of pollutant).

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.40	100	0.40
Sulfur dioxide	Annual	0.14	80	0.18
	24-hour	1.8	365	0.49
	3-hour	11	1,300	0.85
Carbon monoxide	8-hour	3.7	10,000	0.037
	1-hour	24	40,000	0.061
PM_{10}	Annual	0.039	50	0.078
	24-hour	0.51	150	0.34

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

For Module 1 or 2, the estimated air quality impacts from boilers during the operation and monitoring phase would be the same as those for the Proposed Action.

G.1.6 CLOSURE PHASE

This section describes the method used to estimate air quality impacts during the closure phase at the proposed repository. The closure phase would last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. For Modules 1 and 2, the closure phase would last 13, 17, and 27 years for the high, intermediate, and low thermal load scenarios, respectively. The work schedule would be one 8-hour shift per day, 5 days a week, 50 weeks a year.

The analysis estimated air quality impacts by calculating pollutant concentrations from various closure activities. Emission rates were developed for each activity that would result in releases of pollutants. These pollutant emission rates were then multiplied by the unit release concentration (see Section G.1.3) to calculate the pollutant concentration for comparison to the various regulatory limits.

The sources of particulates would be emissions from the backfill plant and the concrete batch facility and fugitive dust from closure activities on the surface and the reclamation of material from the excavated rock pile for backfill. The principal source of nitrogen dioxide, sulfur dioxide, and carbon monoxide during closure would be fuel combustion. The following sections describe these sources in more detail.

G.1.6.1 Dust from Backfill Plant

The Closure Backfill Preparation Plant would process (separate, crush, screen, and wash) rock from the excavated rock pile for use as backfill for the underground access openings (TRW 1999b, pages 4-77 and 4-78). The facility would have the capacity to handle 91 metric tons (100 tons) an hour (TRW 1999b, pages 4-77 and 4-78). For purposes of analysis, the backfill plant would run 6 hours a shift, 2 shifts a day, 5 days a week, 50 weeks a year.

The plant was assumed to have emissions similar to a crushed-stone processing plant. Table G-29 lists the emission rates for various activities associated with a crushed stone processing plant (EPA 1995b, pages 11.19.2-1 to 11.19.2-8). Table G-30 lists estimated pollutant release rates for the backfill plant. Table G-31 lists potential air quality impacts as pollutant concentrations in air and percent of regulatory limit.

Table G-29. Emission rates from a crushed stone processing plant.[a,b]

Source/activity	Emission rate (kilogram[c] per 1,000 kilograms of material processed)
Dump to conveyor or truck	0.00005
Screening	0.0076
Crusher	0.0012
Fine screening	0.036

a. Source: EPA (1995b, pages 11.19.2-1 to 11.19.2-8).
b. Numbers are rounded to two significant figures.
c. To convert kilograms to pounds, multiply by 2.2046.

Table G-30. Dust release rates from the backfill plant (PM_{10}).[a]

Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Annual	12,000 per year	0.39
24-hour	49 per day	1.1[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 12-hour release period.

Table G-31. Particulate matter (PM_{10}) air quality impacts from backfill plant (micrograms per cubic meter).

Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Annual	0.047	50	0.093
24-hour	1.1	150	0.71

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Dust emissions from the backfill plant would produce small PM_{10} concentrations. Both annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards for all thermal load scenarios.

For Modules 1 and 2, the estimated air quality impacts for the backfill plant would be the same as those for the Proposed Action.

G.1.6.2 Fugitive Dust from Concrete Batch Facility

A concrete batch facility for the fabrication of seals would be similar to the facility that would operate during the construction and operation and monitoring phases (see Sections G.1.4.4 and G.1.5.1). The only difference would be that it would run only ten 3-hour shifts a year per concrete seal (TRW 1999b, page 4-78). The analysis assumed that two seals per year would be produced. Table G-12 lists activities associated with the concrete batch facility and their emissions. Table G-32 lists emissions from the concrete batch facility during closure. Table G-33 lists potential air quality impacts as pollutant concentration in air and percent of regulatory limit.

Table G-32. Dust release rates from the concrete batch facility during the closure phase (PM_{10}).[a]

Period	Mass of pollutant (kilograms)[b]	Emission rate (grams per second)[c]
Annual	2,800 per year	0.090
24-hour	140 per day	13[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 3-hour release period.

Table G-33. Particulate matter (PM_{10}) air quality impacts from the concrete batch facility during the closure phase (micrograms per cubic meter).

Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Annual	0.011	50	0.022
24-hour	2.2	150	1.5

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Dust emissions from the concrete batch facility during closure would produce small offsite (outside the land withdrawal area) PM_{10} concentrations. The annual and 24-hour average concentrations of PM_{10} would be less than 1 percent and around 1.5 percent, respectively, of the regulatory standards.

For Modules 1 and 2, the estimated air quality impacts from the concrete batch facility during the closure phase would be the same as those for the Proposed Action.

G.1.6.3 Fugitive Dust from Closure Activities

Closure activities such as smoothing and reshaping the excavated rock pile and demolishing buildings would produce the same fugitive dust releases as construction activities because they would disturb nearly the same amount of land. Thus, the pollutant release and air quality impacts from fugitive dust emissions from surface closure activities would be the same as those listed in Tables G-5 and G-6, respectively.

G.1.6.4 Fugitive Dust from Excavated Rock Pile

During backfill operations, fugitive dust would occur from the removal of excavated rock from the storage pile. The analysis used the same method to estimate fugitive dust emission from the excavated rock pile during the closure phase that it used for the construction phase (Section G.1.4.3). Table G-34 lists the total area of the excavated rock pile disturbed and the active portion, based on the amount of material to be removed from the pile (TRW 1999b, page 6-39). The analysis assumed that the rock used

Table G-34. Active excavated rock pile area (square kilometers)[a] during the closure phase.[b]

Thermal load	Total area disturbed for backfill operation	Number of years of closure	Active area (per year)
High	0.21	6	0.069
Intermediate	0.27	6	0.091
Low	0.26	15	0.035

a. To convert square kilometers to acres, multiply by 247.1.
b. Numbers are rounded to two significant figures.

in backfill would be from a limited area of the excavated rock pile, rather than from all over the pile. Table G-35 lists fugitive dust releases from the excavated rock pile. Table G-36 lists potential air quality impacts from the pile as pollutant air concentration and percent of regulatory limit.

Table G-35. Fugitive dust release rates from the excavated rock pile during the closure phase (PM_{10}).[a]

Thermal load	Period	Emission (kilograms)[b]	Emission rate[c] (grams per second)[d]
High	Annual	9,800 per year	0.31
	24-hour	27 per day	0.31
Intermediate	Annual	13,000 per year	0.41
	24-hour	35 per day	0.41
Low	Annual	5,000 per year	0.16
	24-hour	14 per day	0.16

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on a continuous release.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-36. Fugitive dust (PM_{10}) and cristobalite air quality impacts from the excavated rock pile during the closure phase (micrograms per cubic meter).

Thermal load	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
PM_{10}				
High	Annual	0.037	50	0.074
	24-hour	0.32	150	0.21
Intermediate	Annual	0.049	50	0.098
	24-hour	0.42	150	0.28
Low	Annual	0.019	50	0.038
	24-hour	0.16	150	0.11
Cristobalite				
High	Annual	0.010	10[c]	0.10
Intermediate	Annual	0.014	10[c]	0.14
Low	Annual	0.0053	10[c]	0.053

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.
c. This value is a benchmark; there is no regulatory limit for cristobalite. See Section G.1.

Fugitive dust emissions from the excavated rock pile during closure would produce small offsite PM_{10} concentrations. Both the annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards for all three thermal load scenarios.

Table G-36 also lists potential air quality impacts for releases of cristobalite. The methods used were the same as those described in Section G.1.4.2 for the construction phase, where cristobalite was assumed to be 28 percent of the fugitive dust released, based on its percentage in parent rock. The land withdrawal area boundary cristobalite concentration would be small, about 0.1 percent of the benchmark level discussed in Section G.1.

For Modules 1 and 2, the same technique was used, but the estimated active excavated rock pile area would be about 20 percent larger, 4 percent smaller, and 6 percent larger than the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively, based on the volume of rock added to the pile (TRW 1999b, page 6-79). The estimated air quality impacts from the excavated rock pile would also be about 20 percent larger, 4 percent smaller, and 6 percent larger than the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively.

G.1.6.5 Exhaust Emissions from Surface Equipment

The consumption of diesel fuel and gasoline by surface equipment would emit the four criteria pollutants during closure. The analysis used the same method to determine pollutant release rates during closure that it used for the construction phase (see Section G.1.4.5). Table G-15 lists the estimated pollutant release rates of the equipment that would consume the fuel. Table G-37 lists by thermal load scenario the average amount of fuel consumed per year. The length of the closure phase would be 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. Closure of the North Portal Operations Area would last 6 years (TRW 1999a, page 79).

Table G-37. Annual amount of fuel consumed (liters)[a] during the closure phase.[b]

Thermal load	South Portal diesel[c]	North Portal diesel[d]
High	250,000	340,000
Intermediate	620,000	340,000
Low	510,000	340,000

a. To convert liters to gallons, multiply by 0.26418.
b. Numbers are rounded to two significant figures.
c. Source: Based on total fuel consumed from TRW (1999b, page 6-37).
d. Source: Based on total fuel consumed from TRW (1998, page 87).

Table G-38 lists pollutant releases from surface diesel consumption. Table G-39 lists potential air quality impacts as pollutant concentration in air and percent of regulatory limit. Concentrations would be less than 1 percent of the regulatory limit for all thermal load scenarios.

Table G-38. Pollutant release rates from surface equipment during the closure phase.[a]

		Mass of pollutant per averaging period (kilograms)[b]		Emission rate[c] (grams per second)[d]	
Pollutant	Period	South	North	South	North
High thermal load					
Nitrogen dioxide	Annual[d]	9,800	13,000	0.31	0.42
Sulfur dioxide	Annual	930	1,300	0.030	0.040
	24-hour[e]	3.7	5.1	0.13	0.18
	3-hour[f]	1.4	1.9	0.13	0.18
Carbon monoxide	8-hour[g]	15	21	0.52	0.71
	1-hour[h]	1.9	2.6	0.52	0.71
PM_{10}	Annual	870	1,200	0.028	0.038
	24-hour	3.5	4.7	0.12	0.16
Intermediate thermal load					
Nitrogen dioxide	Annual	24,000	13,000	0.77	0.42
Sulfur dioxide	Annual	2,300	1,300	0.073	0.040
	24-hour	9.2	5.1	0.32	0.18
	3-hour	3.5	1.9	0.32	0.18
Carbon monoxide	8-hour	37	21	1.3	0.71
	1-hour	4.7	2.6	1.3	0.71
PM_{10}	Annual	2,100	1,200	0.068	0.038
	24-hour	8.6	4.7	0.30	0.16
Low thermal load					
Nitrogen dioxide	Annual	20,000	13,000	0.63	0.42
Sulfur dioxide	Annual	1,900	1,300	0.060	0.040
	24-hour	7.6	5.1	0.26	0.18
	3-hour	2.8	1.9	0.26	0.18
Carbon monoxide	8-hour	31	21	1.1	0.71
	1-hour	3.8	2.6	1.1	0.71
PM_{10}	Annual	1,800	1,200	0.056	0.038
	24-hour	7.1	4.7	0.24	0.16

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release period for averaging periods of 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-39. Air quality impacts (micrograms per cubic meter) from surface construction equipment during the closure phase.

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
High thermal load				
Nitrogen dioxide	Annual	0.080	100	0.080
Sulfur dioxide	Annual	0.0076	80	0.0095
	24-hour	0.057	365	0.016
	3-hour	0.45	1,300	0.035
Carbon monoxide	8-hour	0.67	10,000	0.0065
	1-hour	4.1	40,000	0.010
PM_{10}	Annual	0.0071	50	0.014
	24-hour	0.053	150	0.035
Intermediate thermal load				
Nitrogen dioxide	Annual	0.13	100	0.13
Sulfur dioxide	Annual	0.013	80	0.016
	24-hour	0.093	365	0.025
	3-hour	0.74	1,300	0.057
Carbon monoxide	8-hour	1.1	10,000	0.011
	1-hour	6.6	40,000	0.017
PM_{10}	Annual	0.012	50	0.024
	24-hour	0.087	150	0.058
Low thermal load				
Nitrogen dioxide	Annual	0.12	100	0.12
Sulfur dioxide	Annual	0.011	80	0.015
	24-hour	0.082	365	0.022
	3-hour	0.66	1,300	0.050
Carbon monoxide	8-hour	0.98	10,000	0.0095
	1-hour	5.9	40,000	0.015
PM_{10}	Annual	0.010	50	0.020
	24-hour	0.076	150	0.051

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

For Modules 1 and 2, the same technique was used, but the amount of fuel used during the closure phase would increase. The annual diesel fuel use during closure would be 1.9, 0.81, and 1.2 times that of the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively, based on total fuel use (TRW 1999b, page 6-77). The annual diesel fuel use for closure of the North Portal facility would be the same as that for the Proposed Action for all thermal load scenarios. Estimated air quality impacts for surface equipment during the operation and monitoring phase under Modules 1 and 2 would increase by about 1.4, 0.87, and 1.1 times the Proposed Action for the high, intermediate, and low thermal load scenarios, respectively.

G.1.7 RETRIEVAL SCENARIO

This section describes the method used to estimate air quality impacts during possible retrieval at the proposed repository. The retrieval contingency includes the construction of a retrieval storage facility and storage pad, and retrieval of the waste. Retrieval would last 11 years (TRW 1999b, page 6-32), while construction of the retrieval storage facility and storage pads would last 10 years (TRW 1999a, page I-20). DOE would construct the storage facility before beginning retrieval activities. Storage pads would be constructed in modules concurrently with retrieval activities. The analysis considered concurrent air quality impacts of retrieval and construction. The retrieval scenario work schedule would be one 8-hour shift a day, 5 days a week, 50 weeks a year.

The analysis estimated air quality impacts by calculating pollutant concentrations from various activities associated with retrieval. Emission rates were developed for each activity that would result in releases of pollutants. These rates were multiplied by the unit release concentration (see Section G.1.3) to calculate pollutant concentrations for comparison to the various regulatory limits.

The principal sources of particulates would be fugitive dust emissions from construction activities associated with the waste retrieval facility. The principal source of nitrogen dioxide, sulfur dioxide, and carbon monoxide would be fuel combustion during the construction of the waste retrieval facility and during retrieval of the waste. The following sections describe these sources in more detail.

G.1.7.1 Fugitive Dust from Construction of Retrieval Storage Facility

Construction activities such as earth moving and truck traffic would produce fugitive dust during the construction of the retrieval storage facility and storage pad. The analysis used the same method to estimate fugitive dust releases during retrieval as that for construction (see Section G.1.4.1). The amount of land disturbed to build the retrieval storage facility and storage pad would be 1 square kilometer (250 acres) (TRW 1999a, Table I-2, page I-22). In addition, a 1.8-kilometer (1.1-mile) rail line (TRW 1999a, page I-16) would also be constructed. Assuming the rail line is 0.06 kilometer (0.04 mile) wide, the rail line would require an additional 0.11 square kilometer (27 acres) of land to be disturbed.

Table G-40 lists fugitive dust release rates from construction of the retrieval facility and storage pad. Table G-41 lists air quality impacts as pollutant concentration in air and percent of regulatory limit. Fugitive dust emissions from construction of the retrieval facility and storage pad would produce small offsite (outside the land withdrawal area) PM_{10} concentrations. Annual and 24-hour average concentrations of PM_{10} would be less than 1 percent for facility construction and about 2 percent for storage pad construction of the regulatory standards for all three thermal load scenarios.

Table G-40. Fugitive dust release rates from surface construction of retrieval storage facility and storage pad (PM_{10}).[a]

Period	Pollutant emission (kilograms)[b]	Emission rate (grams per second)[c]
Annual	25,000 per year	0.80
24-hour	100 per day	3.5[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on an 8-hour release period.

Table G-41. Fugitive dust (PM_{10}) air quality impacts from surface construction of the retrieval storage facility and storage pad (micrograms per cubic meter).

Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Annual	0.096	50	0.19
24-hour	0.67	150	0.44

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

G.1.7.2 Exhaust from Construction Equipment

Surface equipment would emit the four criteria pollutants during retrieval and during the construction of the retrieval storage facility and storage pad. The analysis used the same method to estimate pollutant release rates from fuel consumed by construction equipment during retrieval that was used for the construction phase (see Section G.1.4.5). During retrieval, fuel would be consumed at the South Portal

Operations Area; during the construction of the retrieval facility and storage pad, fuel would be consumed at the North Portal Operations Area. Table G-15 lists the pollutant release rates of the equipment that would consume the diesel fuel. The maximum amount of fuel used annually would be about 1.46 million liters (390,000 gallons) for surface construction (TRW 1999a, Table I-2, page I-22), about 1.7 million liters (460,000 gallons) for surface retrieval operations (TRW 1999a, Table I-3, page I-24), and about 27,000 liters (7,200 gallons) for subsurface retrieval operations (TRW 1999b, page 6-33). Total maximum annual usage would be about 1.9 million liters (500,000 gallons).

Table G-42 lists pollutant release rates for surface equipment during retrieval. Table G-43 lists the potential air quality impacts. Emissions from surface equipment during retrieval would produce small offsite criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards.

Table G-42. Pollutant release rates from surface equipment during the retrieval scenario.[a]

Pollutant	Period	Mass of pollutant per averaging time (kilograms)[b]	Emission rate[c] (grams per second)[d]
Nitrogen dioxide	Annual	75,000	2.4
Sulfur dioxide	Annual	7,100	0.22
	24-hour	28	0.98
	3-hour	11	0.98
Carbon monoxide	8-hour	110	4.0
	1-hour	14	4.0
PM_{10}	Annual	6,600	0.21
	24-hour	26	0.92

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release period for averaging periods of 24 hour or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-43. Air quality impacts from surface equipment during the retrieval scenario (micrograms per cubic meter of pollutant).

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.23	100	0.24
Sulfur dioxide	Annual	0.022	80	0.028
	24-hour	0.18	365	0.049
	3-hour	1.4	1,300	0.11
Carbon monoxide	8-hour	2.1	10,000	0.020
	1-hour	13	40,000	0.033
PM_{10}	Annual	0.021	50	0.042
	24-hour	0.17	150	0.11

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

G.2 Radiological Air Quality

This section describes the methods DOE used to analyze potential radiological impacts to air quality at the proposed Yucca Mountain Repository during the construction, operation and monitoring, and closure phases, and a possible retrieval scenario. The results are presented in Chapter 4, Section 4.1.2. It discusses the radioactive noble gas krypton-85, which would be released from surface facilities during the handling of spent nuclear fuel, and naturally occurring radon-222 and its radioactive decay products, which would be released from the rock to the subsurface facility and then to the ventilation air. The excavated rock pile would not be a notable additional source of radon-222, because the rock would not have enhanced concentrations of uranium or radium (the sources of radon-222) in comparison to surface rock. Somewhat higher concentrations of radon-222 could be present at the rock pile itself but, in general, concentrations of radon-222 released from the excavated rock pile would not differ greatly from naturally occurring surface concentrations of radon.

G.2.1 LOCATIONS OF HYPOTHETICALLY EXPOSED INDIVIDUALS AND POPULATIONS

Members of the public and noninvolved workers could be exposed to atmospheric releases of radionuclides from repository activities. Doses to the maximally exposed individual and population within 80 kilometers (50 miles) were evaluated for the public. The dose to the maximally exposed noninvolved worker and the noninvolved worker populations at the repository and at the Nevada Test Site were also evaluated.

Public

The location of the maximally exposed individual member of the public would be about 20 kilometers (12 miles) south of the repository at the land withdrawal area boundary. This was determined to be the location of unrestricted public access that would have the highest annual average concentration of airborne radionuclides (see Section G.2.2). The locations calculated for nonradiological air quality impacts (Section G.1.2) would be somewhat different because the analysis estimated exposure to nonradiological pollutants for acute (short-term) exposures (1 to 24 hours) and for annual (continuous) exposures.

Table G-44 lists the estimated population of about 28,000 within 80 kilometers (50 miles) of the repository. This is the predicted population for 2000, based on projected changes in the region, including the towns of Beatty, Pahrump, Indian Springs, and the surrounding rural areas. The population in the vicinity of Pahrump was included in Table G-44 and evaluated for air quality impacts, even though the

Table G-44. Projected year 2000 population distribution within 80 kilometers (50 miles) of repository site.[a,b,c]

	Distance (kilometers)										
Direction	8	16	24	32	40	48	56	64	72	80	Totals
S	0	0	16	238	430	123	0	10	0	0	*817*
SSW	0	0	0	315	38	0	0	7	0	0	*360*
SW	0	0	0	0	0	0	868	0	0	0	*868*
WSW	0	0	0	0	0	0	0	0	87	0	*87*
W	0	0	0	638	17	0	0	0	0	0	*655*
WNW	0	0	0	936	0	0	0	0	0	20	*956*
NW	0	0	0	28	2	0	0	0	33	0	*63*
NNW	0	0	0	0	0	0	0	0	0	0	*0*
N	0	0	0	0	0	0	0	0	0	0	*0*
NNE	0	0	0	0	0	0	0	0	0	0	*0*
NE	0	0	0	0	0	0	0	0	0	0	*0*
ENE	0	0	0	0	0	0	0	0	0	0	*0*
E	0	0	0	0	0	0	0	0	0	0	*0*
ESE	0	0	0	0	0	0	0	0	1,055	0	*1,055*
SE	0	0	0	0	3	0	13	0	0	206	*222*
SSE	0	0	0	0	23	172	6	17	6,117	16,399[d]	*22,734*
Grand Total											**27,817**

a. Source: 2000 population projected based on population data in TRW (1998, page 3-7).
b. To convert kilometers to miles, multiply by 0.62137.
c. There is a 4-kilometer (about 2.5-mile)-radius area around the North Portal, from which the analysis determined the 80-kilometer (50-mile) area.
d. Includes the Pahrump vicinity population, which extends beyond the 80-kilometer region.

population extends beyond the 80-kilometer region. The analysis calculated both annual population dose and cumulative dose for the project phases over more than 100 years of construction, operation and monitoring, and closure.

Noninvolved (Surface) Workers

The analysis assumed noninvolved workers on the surface would be at the site 2,000 hours a year (8 hours a day, 5 days a week, 50 weeks a year), or about 23 percent of the total number of hours in a year (8,760). All surface workers, regardless of work responsibility, were considered to be noninvolved workers for evaluation of exposure to radon-222 and radon decay products released from the subsurface facilities. For releases of noble gases (principally krypton-85) from spent fuel handling activities, potentially exposed noninvolved workers would be all surface workers except those in the Waste Handling and Waste Treatment Buildings. The noble gases would be released from the stack of the Waste Handling Building and workers in these facilities would not be exposed.

The maximally exposed noninvolved worker location would be in the South Portal Operations Area, where air from repository development activities would be exhausted. The analysis assumed that this worker would be in the office building about 100 meters (330 feet) northeast of the South Portal. This worker would be exposed to the annual average concentration of radon during the construction phase as radon concentrations increased with the increasing level of subsurface development. However, during operational activities, the radon level would remain approximately constant at the baseline concentration because the development area of the repository, ventilated and exhausted through the South Portal, would remain relatively constant. There would be no South Portal ventilation during monitoring activities and the closure phase, but the maximally exposed noninvolved worker would still be in the South Portal Operations Area.

The population and distribution of repository workers required to staff the North Portal Operations Area surface facilities would depend on the commercial spent nuclear fuel packaging scenario. As shown in Table G-45, the uncanistered packaging scenario would have the highest labor requirements for all project

Table G-45. Noninvolved (surface) worker population distribution for Yucca Mountain activities.[a]

	Packaging scenario		
Worker location	Uncanistered	Disposable canister	Dual-purpose canister
Construction			
North Portal	656	457	485
South Portal	70	70	70
Operation and monitoring			
Emplacement and development	781[b]	630[b]	636[b]
North Portal	1,277	962	982
South Portal	70	70	70
Monitoring and maintenance			
North Portal – decommissioning	1,354	982	1,023
North Portal – monitoring and maintenance	35	35	35
South Portal	6	6	6
Closure			
North Portal	363	256	275
South Portal	6	6	6
Retrieval			
North Portal – construction	780	780	780
North Portal – operations	108	108	108
South Portal	70	70	70

a. Sources: North Portal: TRW (1999a, pages 74, 75, and 79 to 81); South Portal: TRW (1999b, page 4-85).
b. Total workers exposed to krypton-85 releases from surface facilities. Does not include Waste Handling Building or Waste Treatment Building workers; does include 70 workers at the South Portal.

phases and activities in comparison to the disposable canister and dual-purpose canister scenarios. The number of North Portal workers would not vary for different thermal load scenarios. The estimated population of workers in the South Portal Operations Area was based on the number of full-time equivalents. This includes many workers who would be on the surface for only a portion of a day, as they prepared for underground work in the surface operations area. The number of South Portal workers was also assumed to remain constant for all thermal load scenarios.

Also evaluated as a potentially exposed noninvolved worker population were DOE workers at the Nevada Test Site. The analysis used a Nevada Test Site worker population of 6,576 workers (DOE 1996, Volume I, Appendix A, page A-69). For purposes of analysis, all these workers were assumed to be about 50 kilometers (30 miles) east-southeast of the repository at Mercury, Nevada.

G.2.2 METEOROLOGICAL DATA AND ATMOSPHERIC DISPERSION FACTORS

The basis for the atmospheric dispersion factors used in the dose calculations was a joint frequency distribution file for 1993 to 1997. These data were based on site-specific meteorological measurements made at air quality and meteorology monitoring Site 1, combined for 1993 to 1997 (TRW 1999c, page 11). Site 1 is about 1 kilometer (0.6 mile) south of the proposed North Portal surface facility location. Similar topographic exposure would lead to similar prevailing northerly and southerly winds at both locations. DOE used these data because an analysis of the data collected at all the sites showed Site 1 to be most representative of the surface facilities (TRW 1999c, page 7). The joint frequency data are somewhat different from the more detailed meteorological data used for the nonradiological air quality analysis. The dose calculations required only annual average data because they compare doses to annual limits, whereas criteria pollutant limits have 1-, 3-, 8-, or 24-hour averaging periods and the calculation of short-term criteria pollutant concentrations required hourly meteorological data. The nonradiological analysis also calculated concentrations only at the land withdrawal area boundary, not at onsite locations where workers would be.

Depending on the project phase and level of activity, subsurface ventilation air could be exhausted from any or all of three locations: the South Portal, emplacement (exhaust) shaft 1 or emplacement (exhaust) shaft 2. Both of these exhaust shafts would be on the ridge above the repository. Table G-46 lists the distribution of exhaust ventilation air among the three subsurface release points for project phases and activities. These distributions were used to calculate annual average atmospheric dispersion factors for radon releases from the subsurface.

The GENII software system (Napier et al. 1997, all) was used to calculate annual average atmospheric dispersion factors for radon released from the subsurface exhaust points and for noble gases released from the Waste Handling Building stack. The releases from the South Portal would be at ground level, while releases from the two emplacement shafts (ES-1 and ES-2) on the ridge above the repository were modeled as 60-meter (200-foot) releases. Noble gas releases from the Waste Handling Building would be from a 60-meter (200-foot) stack, also modeled as an elevated release. The population distribution data in Tables G-44 and G-45 were used to calculate population-weighted dispersion factors for public and noninvolved worker populations, which were then used to calculate collective doses. Table G-47 lists the individual and population-weighted atmospheric dispersion factors for the radon and krypton-85 release points at the site. These values do not incorporate the release distribution data in Table G-46. The radon dispersion factors would vary slightly among some combinations of project phase and thermal load scenarios because of the slight differences in release point contributions noted in Table G-46. Krypton-85 dispersion factors would not be affected.

Table G-46. Distribution (percent) of repository subsurface exhaust ventilation air.[a]

Project phase and activity	Thermal load scenario	South Portal	Emplacement (exhaust) shaft 1	Emplacement (exhaust) shaft 2
Proposed Action				
Construction	All	100		
Operation and monitoring				
Development and emplacement	High	47	53	
	Intermediate	47	53	
	Low	55	42	3
Monitoring and maintenance	All		100	
Closure	Same exhaust distribution as monitoring and maintenance			
Retrieval scenario	Same exhaust distribution as monitoring and maintenance			
Inventory Modules 1 and 2				
Construction	All	100		
Operation and monitoring				
Development and emplacement	High	46	54	
	Intermediate	39	61	
	Low	42	40	18
Monitoring and maintenance	High		100	
	Intermediate		100	
	Low		50	50
Closure	Same exhaust distribution as monitoring and maintenance			

a. Source: Rasmussen (1998, all); TRW (1999b, pages 4-33 to 4-48).

G.2.3 RADIOLOGICAL SOURCE TERMS

There would be two distinctly different types and sources of radionuclides released to the air from activities at the repository. Naturally occurring radon-222 and its radioactive decay products would be released from the subsurface facility during all phases as the repository ventilation system removed airborne particulates from development operations and exhausted air heated by the emplaced materials. Radioactive noble gases would be released from commercial spent nuclear fuel during handling and transfer operations in the surface facilities during the operation and monitoring phase. Section G.2.3.1 discusses the releases of radon-222 and radon decay products. Section G.2.3.2 discusses the releases of radioactive noble gases from commercial spent nuclear fuel.

G.2.3.1 Release of Radon-222 and Radon Decay Products from the Subsurface Facility

In the subsurface facility the noble gas radon-222 would diffuse continually from the rock into the air of the repository drifts. Radioactive decay of the radon in the air of the drift would produce radon decay products, which would begin to come into equilibrium (having the same activity) with the radon-222 because their radioactive half-lives are much shorter than the 3.8-day half-life of radon-222. Key radionuclide members of the radon-222 decay chain are polonium-218 (sometimes known as radium A) and polonium-214 (radium C′), with half-lives of 3.05 minutes and 164 microseconds, respectively. Exhaust ventilation would carry the radon-222 and the radon decay products from the repository.

The estimates of radon-222 and radon decay product releases were based on concentration observations made in the Exploratory Studies Facility subsurface areas during site characterization. Because the repository would encompass the subsurface areas of the Exploratory Studies Facility, the analysis assumed that these observations would be a reasonable baseline. Concentrations at the 7,350-meter (4.6-mile) measuring station in the South Ramp ranged from 0.65 to 163 picocuries per liter with the ventilation system operating (TRW 1999c, electronic file attachment 7350EBF.XLS). The measured 50th-percentile concentration was 24 picocuries per liter, with 5th- and 95th-percentile concentrations of 1.7 and 124 picocuries per liter, respectively. Because the distribution of these concentration data was

Table G-47. Atmospheric dispersion factors for potentially exposed individuals and populations from releases at the repository site.[a]

Release location[b]	Release type[c]	Receptor type	Receptor location	Dispersion factor[d]
Radon releases[e]				
Public				
South Portal	G	individual	20 km[f] south	2.2×10^{-8}
South Portal	G	population	80 km radius	1.2×10^{-4}
Emplacement shafts 1, 2[g]	E	individual	20 km south	6.0×10^{-9}
Emplacement shafts 1, 2[g]	E	population	80 km radius	3.0×10^{-5}
Noninvolved workers				
South Portal	G	individual	100 meters[h] northeast	6.2×10^{-5}
South Portal	G	population	South Portal Operations Area	3.2×10^{-3}
South Portal	G	individual	North Portal 2.8 km north-northeast[j]	1.9×10^{-7}
South Portal	G	individual	Nevada Test Site, 50 km east-southeast[j]	6.9×10^{-10}
Emplacement shaft 1	E	individual	North Portal 4.2 km southeast	9.0×10^{-9}
Emplacement shaft 1	E	individual	South Portal 6.3 km south-southeast	2.0×10^{-8}
Emplacement shaft 2	E	individual	North Portal, 4.5 km east-southeast	4.9×10^{-9}
Emplacement shaft 2	E	individual	South Portal, 5.3 km southeast	6.7×10^{-9}
Emplacement shafts 1, 2[g]	E	individual	Nevada Test Site, 50 km east-southeast	2.7×10^{-10}
Krypton-85 releases				
Public				
Waste Handling Bldg. stack	E	individual	20 km south	6.0×10^{-9}
Waste Handling Bldg. stack	E	population	80 km radius	3.0×10^{-5}
Noninvolved workers				
Waste Handling Bldg. stack	E	individual	North Portal, 0.4 km north-northwest	1.5×10^{-6}
Waste Handling Bldg. stack	E	individual	South Portal, 2.8 km south-southwest	5.4×10^{-8}
Waste Handling Bldg. stack	E	population	Uncanistered packaging scenario	2.4×10^{-4}
Waste Handling Bldg. stack	E	population	Disposable canister packaging scenario	1.9×10^{-4}
Waste Handling Bldg. stack	E	population	Dual-purpose canister packaging scenario	1.9×10^{-4}
Waste Handling Bldg. stack	E	individual	Nevada Test Site, 50 km east-southeast[i]	2.7×10^{-10}

a. Numbers are rounded to two significant figures.
b. Source: Radon releases: TRW (1999b, pages 4-33 to 4-48); krypton-85 releases: TRW (1999a, page 41).
c. G = ground level; E = elevated.
d. Dispersion factor units are seconds per cubic meter for individuals, and person-seconds per cubic meter for populations.
e. Radon includes radon-222 and its radioactive decay products.
f. To convert kilometers to miles, multiply by 0.62137.
g. Difference in dispersion between the two emplacement shafts is small for this application.
h. To convert meters to feet, multiply by 3.2808.
i. The population dose was calculated at this point by multiplying the individual dispersion factor times population size.

highly skewed, the analysis assumed that the 50th-percentile value was most representative of the entire concentration range.

Exhaust ventilation flowrates in the South Ramp when the radon concentration measurements were made measured from about 100 to 125 cubic meters per second (214,000 to 265,000 cubic feet per minute) (TRW 1999c, electronic file attachment DECRPT.XLS). A value of 110 cubic meters per second (230,000 cubic feet per minute) was used as a representative South Ramp flowrate. This information, combined with an Exploratory Studies Facility excavated volume of 360,000 cubic meters (470,000 cubic yards) (TRW 1999b, page 4-27), yielded a calculated repository air exchange rate of about 1 per 3,300 seconds (about one exchange per hour) and a baseline for radon-222 releases. The exchange rate is the excavated volume (in cubic meters) divided by the ventilation flowrate (in cubic meters per second). The analysis assumed these conditions would be representative for the Exploratory Studies Facility through the beginning of the construction phase. The estimated release of radon-222 and radon decay products for this configuration would be about 80 curies per year.

Table G-48 lists the key input parameters, namely the beginning and ending excavated repository volumes, repository average ventilation rates, and repository average air exchange rates, for each of the phases and thermal load scenarios of the Proposed Action. The analysis assumed that increases in excavated repository volume and ventilation flowrate would occur linearly. In addition, Table G-48 lists the estimated releases of radon-222 and radon decay products annually and by phase.

Table G-48. Estimated radon-222 releases for repository activities for the Proposed Action inventory.[a]

Period and thermal load	Repository volume (millions of cubic meters)[b,c]		Average ventilation rate (cubic meters per second)	Average air exchange rate	Annual average radon[d] release (curies)	Total radon[d] release (curies)
	Beginning	Ending				
Construction (5 years)						
High	0.36	1.9	205	6,200	300	1,500
Intermediate	0.36	2.2	205	7,200	340	1,700
Low	0.36	2.2	205	7,200	340	1,700
Operations (24 years)						
High	1.9	4.7	570	6,700	880	21,000
Intermediate	2.2	5.7	570	7,900	1,000	25,000
Low	2.2	14	680	13,000	1,900	46,000
Monitoring (76 years)						
High	4.7	4.7	190	24,000	1,100	83,000
Intermediate	5.7	5.7	190	29,000	1,300	99,000
Low	14	14	490	28,000	3,200	240,000
Total Operation and Monitoring Phase (100 years)						
High					1,000	100,000
Intermediate					1,200	120,000
Low					2,900	290,000
Closure phase (6, 6, and 15 years)						
High	4.7	4.7	190	24,000	1,100	6,600
Intermediate	5.7	5.7	190	29,000	1,300	7,900
Low	14	14	490	28,000	3,200	48,000
Total, all phases (111, 111, 120 years)						
High						110,000
Intermediate						130,000
Low						340,000
Retrieval scenario (14 years)						
High	4.7	4.7	190	24,000	1,100	14,000

a. Numbers are rounded to two significant figures; totals might not equal sums of values due to rounding.
b. Source: TRW (1999b, pages 4-27, 6-6, and 6-16).
c. To convert cubic meters to cubic yards, multiply by 1.3079.
d. Includes radon-222 and radon decay products.

Construction Phase

During the 5 years of construction, 1.5 million cubic meters (1.96 million cubic yards) of rock would be removed for the high thermal load scenario and 1.9 million cubic meters (2.4 million cubic yards) for the intermediate and low thermal load scenarios (TRW 1999b, page 6-6). During the same period, the ventilation flow would increase from 110 cubic meters per second (230,000 cubic feet per minute) to 270 cubic meters per second (570,000 cubic feet per minute) (TRW 1999b, pages 4-33 to 4-38). Releases of radon-222 would be low but would vary within 15 percent among all three thermal load scenarios, because they would have the same ventilation flow rates but different repository volumes.

Operation and Monitoring Phase

Operation Activities. Development activities would last 22 years during operation and monitoring. During this period about 2.9 million, 3.4 million, and 11.8 million cubic meters (3.8 million, 4.5 million, and 15.4 million cubic yards) of rock would be removed for the high, intermediate, and thermal load scenarios, respectively (TRW 1999b, page 6-16). The repository excavation would be complete during the last two years of the operation activity period, as emplacement activities continued. The flowrate for the repository during emplacement and development activities of the high and intermediate thermal load scenarios would be the maximum development side flowrate [270 cubic meters per second (570,000 cubic feet per minute)], and the maximum emplacement side flowrate [300 cubic meters per second (640,000 cubic feet per minute)] (TRW 1999b, pages 4-33 to 4-38). The flowrate during the low thermal load scenario would vary from 570 to 740 cubic meters per second (1.2 million to 1.6 million cubic feet per minute), depending on the stage of emplacement activities.

The estimation of radon releases for the high and intermediate thermal load scenarios was based on development and emplacement activities taking place only in the upper (primary) block. However, for the low thermal load scenario development and emplacement would be incremental, beginning in the upper block, moving on to the lower block, and finally to the Area 5 block (TRW 1999b, page 3-3). When emplacement in a block was complete, that block would enter an interim period of monitoring and maintenance as activities continued in the other blocks. The analysis assumed that the upper block would be in this interim status for 10 years and the lower block for 5 years.

The high and intermediate thermal load scenarios would have the lowest radon releases because they would use only the upper (primary) block. The low thermal load scenario would have a higher radon release because of the greater repository volume, which would require three blocks, and the added contribution from exhaust ventilation during the interim monitoring and maintenance of the upper and lower blocks.

Monitoring Activities. No excavation would take place during monitoring, and the exhaust flowrate would remain constant. The much greater repository volume for the low thermal load scenario, which would require larger exhaust flowrates, would result in larger releases of radon-222 and radon decay products to the atmosphere through the exhaust ventilation.

Monitoring and maintenance activities would last from 26 to 276 years. Total releases of radon over 26 years would be approximately 29,000, 34,000, and 84,000 curies for the high, intermediate, and low thermal load scenarios, respectively. Total releases of radon over 276 years would be approximately 300,000, 360,000, and 890,000 curies for the high, intermediate, and low thermal load scenarios, respectively. The estimated annual radon release and concentration would be the same as those listed for monitoring in Table G-48.

For 100 years of operation and monitoring, the low thermal load scenario would involve approximately 2.5 times more radon release than the high or intermediate thermal load scenario. About 70 to 75 percent of the radon would be released during the monitoring and maintenance period for all three thermal load scenarios, not including the interim monitoring and maintenance for the low thermal load scenario.

Closure Phase

Annual releases of radon-222 and radon decay products during the closure phase would be the same as for the monitoring period. Differences in the lengths of the closure phases for the three thermal load scenarios would lead to differences in the total amount of radon released. Differences among the thermal load scenarios would be for the same reasons as for the monitoring period, namely the larger repository volume and exhaust ventilation flowrate of the low thermal load scenario.

Retrieval

Only the high thermal load scenario was evaluated for a postulated retrieval scenario. Annual releases of radon-222 and radon decay products would be the same as for the monitoring activities and closure phases. Releases were estimated for 13 years, including 2 years of retrieval-related construction activities plus 11 years of retrieval operations.

Inventory Modules 1 and 2

Releases of radon-222 and radon decay products for Inventory Modules 1 and 2 were estimated using the same methods as for the Proposed Action. The major differences would be the larger repository volumes and higher ventilation flowrates, which would result in larger releases of radon. In addition, 38 years would be required to complete operations (which includes 36 years of development), 62 years would be required for monitoring, and the closure phase would be longer. Table G-49 lists the estimates of radon release and key parameter values. Releases of radon would be higher for the inventory modules than for the Proposed Action in all cases.

Table G-49. Estimated radon-222 releases for repository activities for Inventory Modules 1 or 2.[a]

Thermal load	Repository volume (millions of cubic meters)[b,c]		Average ventilation rate (cubic meters per second)	Average air exchange rate(s)	Annual average radon release (curies)	Total radon release (curies)
	Beginning	Ending				
Construction (5 years)						
High	0.36	2.1	205	6,900	330	1,600
Intermediate	0.36	2.1	205	6,900	330	1,600
Low	0.36	2.1	205	6,900	330	1,600
Operations (38 years)						
High	2.1	8.7	590	9,500	1,300	49,000
Intermediate	2.1	9.0	690	8,200	1,300	51,000
Low	2.1	24	800	16,000	3,100	120,000
Monitoring (62 years)						
High	8.7	8.7	300	29,000	2,000	125,000
Intermediate	9.0	9.0	490	18,000	2,100	130,000
Low	24	24	890	27,000	5,500	340,000
Total operation and monitoring phase (100 years)						
High					1,700	170,000
Intermediate					1,800	180,000
Low					4,600	460,000
Closure (13, 17, and 27 years)						
High	8.7	8.7	300	29,000	2,000	26,000
Intermediate	9.0	9.0	490	18,000	2,100	35,000
Low	24	24	890	27,000	5,500	150,000
Totals (118, 122, and 132 years)						
High						200,000
Intermediate						220,000
Low						610,000

a. Numbers are rounded to two significant figures; totals might not equal sums of values due to rounding.
b. Source: TRW (1999b, pages 4-27, 6-47, and 6-55).
c. To convert cubic meters to cubic yards, multiply by 1.3079.

G.2.3.2 Release of Radioactive Noble Gases from the Surface Facility

The unloading and handling of commercial spent nuclear fuel would produce the only routine emissions of manmade radioactive materials from repository facilities. No releases would occur as a result of emplacement activities. Shipping casks containing uncanistered spent nuclear fuel in dual-purpose canisters would be opened in the transfer pool of the Waste Handling Building at the North Portal Operations Area. Shipping casks containing spent nuclear fuel in disposable canisters would be opened in a dry transfer cell. During spent fuel handling and transfer, radionuclides could be released from a small percentage of fuel elements with pinhole leaks in the fuel cladding; only noble gases would escape the pool and enter the ventilation system of the Waste Handling Building (TRW 1999a, page 17). The largest release of radionuclides from surface facilities would be krypton-85, with about 2,600 curies released annually from the uncanistered and dual-purpose canister packaging options. Krypton-85 would also be the major dose contributor from the airborne pathway. Releases of other noble gas radionuclides would be very small, with estimated annual releases of about 0.0000010 curie of krypton-81, 0.000033 curie of radon-219, 0.014 curie of radon-220, 0.0000046 curie of radon-222, and small quantities of xenon-127 (TRW 1999a, page 75). The same annual releases would occur for both the Proposed Action and for the inventory modules. Table G-50 lists estimated annual average releases of krypton-85 from fuel handling by packaging option. All spent nuclear fuel and DOE high-level radioactive waste in disposable canisters would be transferred from shipping casks to disposal containers inside shielded rooms (hot cells) in the Waste Handling Building. Because all DOE material would be in disposable canisters under all packaging scenarios, no radionuclide releases from these materials would occur.

Table G-50. Krypton-85 releases (curies) from surface facility handling activities for commercial spent nuclear fuel during the operation and monitoring phase. [a]

Packaging option	Annual release[b]	Proposed Action (24 years)	Inventory Module 1 or 2 (38 years)
Uncanistered	2,600	61,000	97,000
Disposable canister	90	2,200	3,500
Dual-purpose canister	2,600	62,000	98,000

a. Numbers are rounded to two significant figures.
b. Source: TRW (1999a, page 75).

Releases from the surface facility would be the same for the three thermal load scenarios. These releases were based on the following assumptions for commercial spent nuclear fuel (TRW 1999a, pages 18 and 19):

- Pressurized-water reactor burnup of about 40 gigawatt-days per metric ton of uranium with 3.6-percent enrichment and an average of 26 years decay
- Boiling-water reactor burnup of 32 gigawatt-days per metric ton of uranium with 3.0-percent enrichment and an average of 27 years decay
- A failure rate of 0.25 percent for fuel assemblies in the canisters, allowing gaseous radionuclides (isotopes of krypton, radon, and xenon) to escape
- Radionuclides other than noble gases (such as cobalt-60, cesium-137, and strontium-90) would not escape the transfer pool if released from fuel assemblies

G.2.4 DOSE CALCULATION METHODOLOGY

The previous three sections provided information on the location and distribution of potentially affected individuals and populations (Section G.2.1), atmospheric dispersion (Section G.2.2), and the type and quantity of radionuclides released to air (Section G.2.3) in the Yucca Mountain region. The analysis used these three types of information to estimate the radionuclide concentration in air (in picocuries of radionuclide per liter of air) at a specific location or for an area where there would be a potentially exposed population. The estimation of the radiation dose to exposed individuals or populations from concentrations of radionuclides in air used this information and published or derived dose factors. This section describes the concentration-to-dose conversion factors that the analysis used to estimate radiation dose to members of the public and noninvolved workers from releases of radionuclides at the repository.

G.2.4.1 Dose to the Public

The analysis estimated doses to members of the public using screening dose factors from the National Council on Radiation Protection and Measurements (NCRP 1996, Volume I, pages 113 and 125). The analysis considered all exposure pathways, including inhalation, ingestion, and direct external radiation from radionuclides in the air and on the ground. For noble gases such as krypton-85, only direct external exposure from the radionuclides in the air would be a contributing pathway. For radon-222, the short-lived decay products would account for essentially all of the dose. The screening dose factors indicate that direct external radiation from radionuclides deposited on the ground would account for about 40 percent of the dose; ingestion of these decay products in foodstuffs and inadvertently consumed soil would account for about 60 percent, based on the published screening dose factors. Inhalation and external irradiation from radionuclides in the air would be minor exposure pathways. The analysis calculated the estimated dose from a specific radionuclide by multiplying the radionuclide-specific dose factor by the estimated air concentration at the exposure location. The results are reported in Chapter 4, Section 4.1.2. Table G-51 lists the screening dose factors for krypton-85 and radon-222 for members of the public. Results are presented in Chapter 4, Section 4.1.2.

Table G-51. Factors for estimating dose to the public and noninvolved workers per concentration of radionuclide in air (millirem per picocurie per liter per hour) for krypton-85 and radon-222.[a,b]

Radionuclide	Public[c]	Noninvolved worker
Krypton-85	0.0000013	0.0000013
Radon-222	0.25[d]	0.029[e]

a. Numbers are rounded to two significant figures.
b. Dose factors for radon-222 include dose contribution from decay products.
c. Source: NCRP (1996, page 61); assumed an exposure time of 8,000 hours per year.
d. Includes all exposure pathways.
e. Source: ICRP (1994, pages 5 and 24); 100 percent equilibrium between radon and decay products; inhalation pathway only.

G.2.4.2 Dose to Noninvolved Workers

The analysis used a National Council on Radiation Protection and Measurements screening dose factor to calculate doses to noninvolved workers from krypton-85 because the exposure pathway is simple (air submersion only) and is the same as for members of the public. Table G-51 also lists this factor. However, the analysis did not use a National Council on Radiation Protection and Measurements screening dose factor to estimate the dose to noninvolved workers from radon-222 and its decay products. The parameters and exposure scenarios used to derive the National Council on Radiation Protection and Measurements screening dose factors for radon-222 and its decay products would not be appropriate for the potential exposure scenario for noninvolved workers at the Yucca Mountain site. Dose to noninvolved workers on the surface would be due mainly to inhalation of the radon decay products, and not from the other exposure pathways noted above for the public. Therefore, the analysis developed a Yucca Mountain repository-specific exposure scenario using site-specific parameters where appropriate. The dose conversion factor is from Publication 65 of the International Commission on Radiological Protection (ICRP 1994, page 24). This dose factor, which is 0.5 rem per working level month for inhalation of radon decay products by workers, corresponds to 0.029 millirem per picocurie per liter per hour, with radon decay products in 100 percent equilibrium (equilibrium factor of 1.0) with the radon-222 parent (ICRP 1994, page 5).

In estimating dose from radon and radon decay products released from the subsurface facility, the analysis assumed the maximally exposed noninvolved worker would be in an office about 100 meters (330 feet) northeast of the South Portal. For the construction phase and development activities, the noninvolved worker exposure analysis used the distribution of radon concentration measurements made at the 7,350-meter (4.6-mile) station in the South Ramp of the Exploratory Studies Facility. These were the best available data for estimating releases of radon from the facility (TRW 1999c, page 12). There would be no releases from the South Portal during the other project phases. Measured concentrations ranged from 0.65 to 163 picocuries per liter, with a median value of 24 picocuries per liter, as noted in Section G.2.3.1. In addition, the analysis considered the distribution of the measured values of the equilibrium fraction between radon-222 and the decay products. This value ranged from 0.0022 to 0.44, with a median of 0.14 (TRW 1999c, electronic file attachment RNFBF.XLS). The annual average atmospheric dispersion factor from the South Portal to the office building would be approximately 6.2×10^{-5} seconds per cubic meter for both the construction phase and development activities (Table G-47), although differences in exhaust flowrate (205 and 269 cubic meters per second, respectively, would result in minor differences in dispersion. The analysis assumed the maximally noninvolved worker would be exposed from 1,600 to 2,000 hours per year.

The estimated median dose to a maximally exposed noninvolved worker during the construction phase would be approximately 5 (4.7 to 5.4) millirem per year. The dose from the Proposed Action intermediate and low thermal load scenarios would be somewhat higher than that from the high thermal load scenario because of the larger average repository volume for these two scenarios during the construction phase (Table G-48). The estimated 5th-percentile dose would be about 0.2 millirem per year for both cases and the 95th-percentile dose would be 42 and 48 millirem per year, respectively. The dose during development activities would be the same for all three thermal load scenarios, with a median dose of about 3.4 millirem per year. The estimated 5th-percentile dose would be about 0.2 millirem per year and the 95th-percentile dose about 29 millirem per year. These estimates were made using a Monte Carlo uncertainty analysis. There would be a small contribution from external radiation, but the analysis did not consider it because it would be indistinguishable from normal external background radiation. The estimated dose from Module 1 or 2 would be about the same as those for the intermediate and low thermal load scenarios.

During the construction phase the maximally exposed noninvolved worker would receive a somewhat larger potential dose because of a larger average repository volume, which would be exhausted through the South Portal, and additional radon release. During operations the ventilation systems for the subsurface development and emplacement areas would be separate. The analysis assumed that the volume during Exploratory Studies Facility operations would represent the volume of the development side exhausted through the South Portal. This volume is somewhat smaller than the estimated average construction phase repository volume.

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