RCRA FACILITY INVESTIGATION-REMEDIAL INVESTIGATION/ CORRECTIVE MEASURES STUDY-FEASIBILITY STUDY REPORT

CONTAMINANT FATE AND TRANSPORT

SECTION 8.0: ATTACHMENT 2

CD ROM, Projections of Future Conditions – Groundwater and Air

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1.0 GROUNDWATER

Integrated flow and transport modeling of volatile organic compound (VOC) migration in upper hydrostatigraphic unit (UHSU) groundwater at the Rocky Flats Environmental Technology Site (RFETS) focused on tetrachloroethene and carbon tetrachloride (and their degradation products.) The modeling was conducted to evaluate the movement and fate of each VOC and its potential impact to surface water quality from groundwater discharge areas (K-H 2004). Modeling updates are presented in the Summary of Integrated Hydrologic and VOC Transport Modeling at RFETS (K-H 2004) and its subsequent updates (K-H 2005; DOE 2005). The modeling scope included:

- Review of all historical UHSU water quality data;
- Development of a flow and transport model using historical conditions to determine appropriate parameter values; and
- Adaptation of the flow and transport model to the post-accelerated action land reconfiguration (and associated hydrologic changes) to predict long-term or maximum groundwater VOC concentrations that may discharge to surface water.

Individual VOCs were modeled because the chlorinated aliphatic hydrocarbons (CAHs) exhibit a range of transport properties. Nineteen areas of VOC-bearing UHSU groundwater were identified where one or more contaminant sources explained CAH concentrations observed at a group of groundwater monitoring locations. These model areas are referred to as Plume Signature Areas (PSAs).

Data analysis indicated that contaminant plumes sourced from most of the 19 PSAs have already discharged to surface water and, therefore, could potentially impact downgradient surface water quality unless VOC concentrations are sufficiently attenuated along the groundwater flow path (K-H 2004). Relatively constant VOC concentrations through time are observed at most groundwater monitoring locations. This suggests that most PSAs have reached a quasi-steady-state configuration typically produced by dense nonaqueous phase liquid (DNAPL) sources (K-H 2004).

Current VOC concentrations in groundwater at each PSA were evaluated using groundwater flow path analysis and sensitivity analysis of reactive transport of carbon tetrachloride and tetrachloroethene degradation chains. Flow path analysis identified 22 source areas that explained VOC concentrations in the 19 PSAs. The modeling results indicate that it is reasonable to assume that the groundwater VOC sources were introduced 30 to 50 years ago. The most important factors affecting fate and transport of VOCs in UHSU groundwater are hydraulic conductivity, depth of source, and biodegradation rates (K-H 2004). Other factors such as sorption, source concentration, and porosity were less important controls.

Transport modeling generally found that only parent compounds carbon tetrachloride and tetrachloroethene/trichloroethene were above surface water standards at groundwater discharge areas, while the daughter products were below the standards (K-H 2005;

DOE 2005). Trichloroethene and carbon tetrachloride were the most prominent and widespread. They were the only VOCs with at least one simulation of post-accelerated action conditions that predicted long-term concentrations in groundwater discharge above the surface water standard in the following areas:

- Former Building 771 area;
- Historical Ryan's Pit and 903 Pad area;
- Historical Oil Burn Pit No. 2 and Mound area; and
- Historical East Trenches area.

Thus, carbon tetrachloride or tetrachloroethene/trichloroethene may impact surface water quality downgradient of the above areas. For the Groundwater Interim Measure/Interim Remedial Action (IM/IRA) evaluations, the modeling simulations were updated with a revised Industrial Area (IA) reconfiguration and compared to relevant surface water standards (K-H 2005). The results of the updated modeling reconfirmed the earlier modeling of carbon tetrachloride and tetrachloroethene/trichloroethene discharging in these four areas above surface water standards.

2.0 AIR

2.1 Air Modeling Methodology and Results

Predicting the impact of RFETS emissions requires the use of a dispersion model to simulate the transport of pollutants from emission locations to other locations of interest (termed receptors), as well as their removal from the air to soil or water surfaces. Particles are brought down to the surface through the combined processes of turbulent diffusion, wet deposition, and gravitational settling. Once near the surface, they may be removed from the atmosphere and deposited on soil or vegetation. These processes gradually reduce the amount of particulate matter remaining in a plume as it is transported downwind.

An RFETS-specific implementation of the U.S. Environmental Protection Agency's (EPA's) Industrial Source Complex Short Term (ISCST3) dispersion and deposition model was developed as part of the Actinide Migration Evaluation (AME) air pathway investigations and 1 year of meteorological data were processed for use with this model. This work was detailed in Air Transport and Deposition of Actinides for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site (Fiscal Year [FY] 00 Report) (Radian 2000), and Air Transport and Deposition of Actinides for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site (FY01 Report) (URS 2001). The estimating method is based on wind speed, size of the contaminated areas, precipitation, recent wind erosion history, and surface soil concentrations of radionuclides within each contaminated area. Data collected in conjunction with a prescribed test burn at RFETS in April 2000 with a small wildfire that occurred in the east Buffer Zone (BZ) in July 2000 were used to determine probable post-fire emission rates.

2.2 Source Areas and Particle Properties

The most significant soil contamination areas contributing to airborne radionuclides at RFETS, historically, have been the historical 903 Pad and the adjacent "Lip" Area. During the 1950s and 1960s, the 903 Pad was contaminated with plutonium-laden cutting fluids that leaked from metal drums into the soil beneath the drums. Removal of the drums in the late 1960s and associated cleanup activities resulted in dispersion of contaminated soil east and south of the historical 903 Pad. The initial spread of the contaminated soil resulted in a plume of radionuclides in the surface soil extending east and southeast from the historical 903 Pad itself.

The present surface soil contamination patterns of plutonium and americium are largely the result of windblown suspension and subsequent deposition of soil that was contaminated by leaking drums at the historical 903 Pad, with some additional spread due to surface runoff from the contaminated area. Because suspension occurs more readily from recently disturbed soil, the particular wind speeds and directions coincident with disturbances during the initial 903 Pad remediation sequence had a strong influence on the resulting surface soil contamination patterns. The initial distribution patterns have since been altered by remediation efforts at RFETS.

Other spills and releases have resulted in smaller areas at RFETS where the surface soils are contaminated with different radionuclides (such as uranium isotopes). In addition, naturally occurring uranium deposits also result in areas of elevated surface soil uranium concentrations.

Even with completion of accelerated actions for soil removal, there still remain low levels of radionuclide contamination in surface soils over parts of RFETS. Isopleths of the expected remaining contamination are shown on Figure A2.1 through Figure A2.5. These areas estimate the extent of remaining radionuclide-emitting sources at RFETS and constitute the residual contamination areas that were included in the modeling for this report. (These figures were derived from surface soil data contained in Attachment 1 to Section 3.0 of this report, the nature and extent of soil contamination section.) All paved surfaces and building structures have been removed, therefore allowing for wind erosion from all areas. It has been assumed that no significant anthropogenic soil disturbance will occur following completion of accelerated actions. (The latter caveat is more important from an air quality standpoint in the smaller areas of highest residual contamination in that active disturbance can greatly increase emissions.) The analyses quantified wind erosion within the current RFETS property boundary (eastern boundary is Indiana Street) for americium-241, plutonium-239/240, uranium-233/234, uranium-235, and uranium-238. Only areas with residual surface soil contamination above background, after completion of accelerated actions, were modeled.

The plutonium particles in the cutting oil that leaked at the 903 Pad were small (<3 micrometers [µm] diameter). Once in contact with the soil, however, the plutonium particles became attached to soil particles. Experimental data from RFETS (Langer 1987) and elsewhere (Shinn 1999) indicate that most of the airborne plutonium activity is

carried by the >15 µm diameter size fraction. Many of these larger particles are aggregates made up of varying size soil particles held together by binding agents (for example, organic matter). Lesser amounts of plutonium may be attached to smaller, primary clay- and silt-sized particles. Because of its attachment affinity, the airborne transport of plutonium is dependent on the soil or aggregate particle properties and not the properties of the individual plutonium particles.

Americium-241 is associated with the 903 Pad area and other areas of weapons-grade plutonium contamination at RFETS due to americium ingrowth into decaying weapons-grade plutonium. (Americium 241 is formed by radioactive decay of plutonium-241 atoms.) Consequently, americium-241 contamination due to RFETS residual contamination is expected to be distributed in the soil matrix in the same manner as plutonium-239/240. Past research at RFETS has shown that coarse particles (>15 µm) also carry most of the uranium activity in windblown dust (Langer 1987). Therefore, the activity distribution among various particle size categories was assumed to be the same for each of these isotopes for purposes of estimating airborne transport.

2.3 Routine Emission Scenario

Using the previously developed RFETS-specific emission estimating method, particulate matter emissions were developed for a routine wind erosion scenario following completion of accelerated actions. While particulate matter emissions were assumed to be uniform across RFETS, radionuclide emissions will vary by source area. To model radionuclides, the estimated particulate matter emissions at each time step were combined with information regarding the activity concentration of the available particulate matter to yield estimated radionuclide emissions. At each time step, erosion potential is renewed by small-scale disturbances (burrowing animals, rainsplash, freeze/thaw cycles, plant emergence and growth, and so forth) that will generate erodible material reflecting the radionuclide concentration levels in the underlying surface soil. In addition, erosion potential is renewed by deposition, which reflects the radionuclide concentration levels in the air over RFETS.

To update the americium-241 and plutonium-239/240 analyses that were performed in FY01 to incorporate revisions to the residual contamination following completion of accelerated actions, new ISCST3 source areas were created from the final surface soil contamination data set (see Attachment 1 to Section 3.0 of this report), representing radionuclide surface soil concentrations across the site following completion of accelerated actions. ISCST3 sources were created for five isotopes: plutonium-239/240, americium-241, uranium-233/234, uranium-235, and uranium-238. (Note that wind resuspension only affects the top few millimeters of soil, so subsurface contamination is immaterial in the modeling effort.)

To generate deposition inputs to the modeling, the previously estimated deposition rates of americium-241 and plutonium-239/240 onto source areas (see FY01 Report) were revised to reflect the new ISCST3 source areas. Because the uranium isotopes were not modeled in the FY01 scenarios, uranium deposition rates over RFETS were estimated

based on 6-year average airborne uranium concentrations at the RFETS perimeter, using perimeter samplers that are part of the Radioactive Ambient Air Monitoring Program (RAAMP) (see Figure A2.6; historical air concentration data are also included in Attachment 2 to Section 6.0 of this report). Most uranium in the air over RFETS is naturally occurring and several of the perimeter RAAMP samplers appear to be located in areas with elevated natural uranium concentrations due to external influences. Therefore, use of the average off-property airborne uranium concentrations is expected to be adequately representative of, or even conservative relative to, uranium in air over RFETS itself.

Renewal of surface soil erosion potential by small-scale disturbances was previously calculated for americium-241 and plutonium-239/240 for each source area during the FY01 AME modeling. Using the same methodology, renewal of erosion potential via this mechanism was estimated for each source area for each of the five isotopes.

ISCST3 was run for the appropriate residual contamination source areas for all five isotopes, using the receptor grid employed in the FY01 modeling. Concentration predictions were copied to a spreadsheet for conversion to the appropriate units for analysis and to prepare isopleths. The results of the revised post-accelerated action scenarios are summarized in Table A2.1. Isopleths of expected annual airborne radionuclide concentrations following completion of accelerated actions are shown on Figure A2.7 through Figure A2.11.

2.4 ARARs Comparison

Applicable or relevant and appropriate requirements (ARARs) for these contaminants are contained in Section 10.0 of the Remedial Investigation/Feasibility Study (RI/FS) Report. There are two ARARs for airborne radionuclides, which establish essentially the same requirement.

40 Code of Federal Regulations (CFR) 61, Subpart H, contains requirements governing emissions of hazardous air pollutants (HAPs) from certain source types. U.S. Department of Energy (DOE) facilities such as RFETS are subject to the standards of 40 CFR 61.92, which limits radionuclide emissions from the facility so as to not exceed an annual effective dose equivalent (EDE) to the public of 10 millirem (mrem). (Although 40 CFR 61, Subpart H is not expected to apply to DOE-retained lands following physical completion, the 10-mrem benchmark represents an appropriate health-based benchmark concentration.) In addition, 10 CFR 20.1101(d) imposes a constraint on air emissions to the environment, such that an "individual member of the public likely to receive the highest dose" will not be expected to receive an annual total EDE greater than 10 mrem from air emissions.

2.5 Results of Routine Emissions Modeling

In addition to calculating airborne concentrations of radionuclides (in units of activity per unit volume of air, for example, picocuries per cubic meter [pCi/m^3]), results have also been converted to EDE. EDE is measured in units of Sieverts, rem, or, in Part 61, mrem,

and represents the amount of radiation energy absorbed per gram of tissue, weighted by its potential to do damage and the susceptibility for harm to different tissues in the human body.

Conversion from units of activity to EDE in units of mrem depends not only on the isotope and the type of radiation it emits, but also on assumptions about exposure pathways and scenarios. To simplify this, conversion factors were developed based on EPA air regulations that derive from standard assumptions about exposure pathways and scenarios. Appendix E to 40 CFR 61 gives a table of radionuclide concentrations in air that may be used to demonstrate compliance with the 10-mrem Subpart H standard. Subpart H, Section 61.93(b)(5)(iv) specifies the use of Table 2 of Appendix E to determine compliance with the standard if compliance is to be demonstrated using environmental measurements. If a person were exposed to air containing a given isotope at the concentration levels listed in Appendix E to 40 CFR 61 for a full year (under the standard exposure assumptions inherent in these values), they would receive no more than a 10-mrem EDE because compliance with the Appendix E concentrations indicates compliance with the 10-mrem standard in 40 CFR 61, Part H). Therefore, these concentration levels have been used to convert between radionuclide concentrations (in curies per cubic meter [Ci/m^3] or pCi/m^3) and EDE (in mrem) for annual scenarios based on the assumption that they must represent no more than a 10-mrem EDE.

The Nuclear Regulatory Commission (NRC) also specifies factors to convert units of activity to units of dose for airborne radionuclides (10 CFR 20). The NRC conversion factors are a factor of 2 to more than 70 times less conservative than the conversion based on 40 CFR 61, Appendix E, depending on the lung-retention classification of the radionuclide of interest. Consequently, the 40 CFR 61 conversion assumptions result in higher EDE estimates than the NRC method. Because 40 CFR 61 has been the applicable and bounding regulation for RFETS operations under the Clean Air Act (CAA), and because RFETS would be evaluated to have less potential to yield a significant dose under the 10 CFR 20 conversion method, the expression of model results as EDE has been based on the conservative 40 CFR 61 conversion assumptions for this report.

Because the modeling only projected airborne concentrations from wind erosion of areas with elevated concentrations of radionuclides remaining in surface soils, total concentrations (and resulting EDE) must also include background concentrations. Background concentrations comprise those naturally occurring and manmade radionuclides present in the global atmosphere due to fallout from weapons testing, resuspension of fallout or naturally occurring isotopes in soils, and other ubiquitous sources.

Background air concentrations of americium-241 and plutonium-239/240 were documented in the FY01 Report, Section 3.2.2, and are 4.1E-07 pCi/m^3 for plutonium-239 and 1.48E-07 pCi/m^3 for americium-241. For uranium, the perimeter averages described above were assumed to be representative of local background concentrations. Background uranium concentrations used for this analysis were uranium-233/234: 2.98E-05 pCi/m^3; uranium-235: 1.65E-06 pCi/m^3; and uranium-238: 2.94E-05 pCi/m^3.

Combining background concentrations with the modeled results shown in Table A2.1, the total maximum expected EDE is 0.23 mrem, while the expected EDE in the vicinity of the current RFETS property boundary is approximately 0.1 mrem. As noted above, an appropriate benchmark for comparison is the EPA 10-mrem dose limit in 40 CFR 61, Subpart H. The revised modeling indicates that fugitive dust emissions from residual contamination at RFETS, when combined with background levels of radionuclides in air, will be two to three orders of magnitude under this benchmark level at all locations.

Although resuspended radionuclides will also redeposit back onto the soil, no deposition values are shown in Table A2.1 because there are no ARARs to compare to projected deposition rates. While ongoing resuspension may slowly redistribute radionuclides in surface soil, there will be no buildup or increase in concentrations because no new source material is being added under the assumption of limited soil disturbance in the future.

2.6 Effect of Soil Disturbances

These results assume that no significant soil disturbance will occur, such as from excavation, grading, or other anthropogenic activities that mechanically suspend soil particles. A disturbance is an action that either renews or increases the available reservoir of erodible material (soil particles). A disturbance can take many forms, such as excavation, vehicular traffic, or that of a natural process such as a freeze/thaw cycle or rodent burrowing. The greater the disturbance, the longer it takes for the surface to be restored to an undisturbed state because the extent of disturbance affects the magnitude of the resulting reservoir of erodible particles. As a result, disturbances increase the rate of particulate matter emissions during and for a period after the disturbance occurs. Forms of disturbance that mechanically suspend soil particles (substantial traffic, excavation, grading, and so forth) would also create additional airborne emission pathways.

Over time, a soil surface that remains undisturbed will show decreasing emissions as the erodible soil particles are removed and the surface develops a crust that inhibits further wind erosion. In addition, lack of disturbance will allow vegetation to cover the surface and lower the wind speeds to which the soil surface is exposed, further decreasing wind erosion.

According to an EPA method for estimating resuspension of soils with a limited reservoir of erodible material, such as exists at RFETS, the amount of soil resuspended (and resulting downwind concentrations) can be directly related to the frequency of disturbance and the size of the area disturbed (EPA 1989, 1995). At RFETS, this linear relationship cannot be directly related to radionuclide emissions and impacts, however, because the concentration of radionuclides in the surface soil (picocuries per gram [pCi/g]) varies from place to place and must also be taken into account.

Another factor that is extremely important in determining soil resuspension following disturbance is the timing of disturbances relative to high-wind events. As noted previously, a disturbance results in a soil surface that is easily eroded by wind for some period of time. Over time, however, the surface weathers and crusts and erodibility is

reduced. The occurrence of high winds during the period before the surface has crusted can result in much larger amounts of resuspension than the same winds would cause to a less disturbed surface. Much of the initial spread of contamination from the 903 Pad, for example, is thought to have resulted from a handful of windy days following grading or weed burning operations that disturbed the contaminated soil and exposed it to the full force of the wind (Weber et al. 1998).

An example of how wind-dependent emissions compare for disturbed and undisturbed ground is shown on Figure A2.12. The data on this figure were taken from a 1993 Operable Unit (OU) 3 wind tunnel study (for more information, see FY00 Report [Radian 2000]). The "extra disturbed" line represents ground surfaces that were raked and then driven over to break up clumps of soil. At average wind speeds (around 4 meters per second [m/s] for RFETS), little difference in resuspension is noted. However, Figure A2.12 shows that the highly disturbed areas resulted in enhanced resuspension at higher wind speeds and that the difference in resuspension rate increased with increasing wind speed.

Disturbances, even substantial ones, will not necessarily result in enhanced resuspension if soil erosion is controlled during the disturbance and the area is revegetated. As discussed in Section 6.0 of this report, an internal network of air samplers in and around the IA during periods of active remediation did not indicate significant radionuclide emissions. With the completion of accelerated actions, soil disturbing activities are anticipated to be very limited in area and duration, and the emission of radionuclides from this activity will be lower than during cleanup activities.

2.7 Hypothetical Post-Fire Wind Erosion Scenario

Unplanned fires may occur at RFETS due to lightning strikes or ignition of flammable vegetation by other means. Planned fires may also be used for weed control and to decrease the potential for wildfires. In FY01, hypothetical post-fire wind erosion scenarios, in which a fire begins in an area with some of the highest residual plutonium-239/240 and americium-241 contamination following completion of all planned accelerated actions, were modeled as part of the AME air pathway investigations. For this report, the FY01 scenario was updated to consider the modified radionuclide soil action levels (RSALs). Americium-241, plutonium-239/240, uranium-233/234, uranium-235, and uranium-238 were modeled for the year following a hypothetical fire.

Immediately following the hypothetical fire, the ground surface was assumed to be bare soil overlain with ash and interspersed with stubble left from incomplete combustion of plant material. Wind erosion potential was assumed to increase after the fire due to removal of the vegetative cover. The erosion potential was assumed to decrease gradually with time until the pre-fire (baseline) erosion potential was restored. The rate of recovery after a fire would depend on factors such as the time of year that the hypothetical fire occurred, the fire intensity, and the amount and frequency of rainfall occurring after the fire. Scenarios were modeled representing gradual recovery from a hypothetical spring

fire, with a relatively rapid recovery period, and a hypothetical fall fire, with a slower recovery to baseline wind erosion conditions.

Although vegetation density may return to its pre-burned state in a matter of weeks under optimal conditions, as observed following the April 2000 RFETS test burn, it may take up to a full year or more for vegetation to recover under dry conditions. Full restoration of protection from wind erosion probably requires a layer of thatch, which is composed of dead grasses and vegetation that are pushed over and matted down by rain, wind, and snow during the fall and winter months. This is because the presence of bare soil between plants enhances the overall resuspension potential, as the bare areas should facilitate the transfer of soil particles onto plant surfaces by mechanisms such as rainsplash, in addition to providing a direct source for soil resuspension. The hypothetical spring fire scenario assumed a 12-month recovery to baseline erosion potential; the hypothetical fall fire scenario assumed an 18-month recovery period (through a second winter to ensure a layer of thatch).

The hypothetical spring and fall fires were assumed to be ignited by lightning striking near the area of the former 903 Pad. The fires were assumed to move east and downslope to the location of the South Interceptor Ditch (SID), pushed by westerly winds. The fires were assumed to consume an area bound by the SID to the south, the former 904 Pad road to the west, the former East Access road to the north, and Indiana Street to the east, where the fires were assumed to be stopped by emergency responders. Although several of these features, such as the roads, have been removed or altered during final contouring of the site, the area assumed to burn still represents a reasonable potential grass fire extent.

For the FY01 AME work, the burned area was divided into two smaller areas: one with a higher average soil contamination level (near the 903 Pad), and the other with a lower average soil contamination level. These two source areas were retained but the average radionuclide concentrations in surface soil in each area were recalculated based on the final surface soil sampling data set (see Attachment 1 to Section 3.0 of this report). The two areas used for modeling are shown on Figure A2.13.

Pre-fire emissions were modeled from the area of the hypothetical fire to provide a base case against which to compare the post-fire model results. The differences between the base case and the post-fire scenarios were that erosion potential was assumed to be greater for the unprotected (unvegetated) soil than for normal, undisturbed grassland and the rates of deposition and erosion potential generation due to small-scale disturbances were also assumed to increase. The wind tunnel studies of the April 2000 test burn area were used to characterize the increase in erosion potential that would follow a fire.

Radionuclide concentrations were estimated and compared to wind erosion impacts from the same area in an undisturbed state. Concentrations were calculated by ISCST3 and plume depletion by particle settling was ignored, resulting in conservative estimates of airborne radionuclide concentrations.

Hypothetical Post-Fire Scenario Results

The results are summarized in Table A2.2. The results indicate that recovery from a hypothetical spring fire would increase maximum annual plutonium-239/240 and americium-241 concentrations by a factor of six to seven relative to the base case. A fall fire would increase maximum annual plutonium-239/240 and americium-241 concentrations by a factor of 10 to11. If annual plutonium-239/240 and americium-241 concentrations farther from the fire are considered, such as at the current RFETS property boundary, the increases are somewhat smaller: factors of approximately four to five for a hypothetical spring fire and eight to nine for a hypothetical fall fire. For the uranium isotopes, which were estimated as a function of particulate matter increases, a spring fire would be expected to increase concentrations on and off property by a factor of two to three, while a fall fire would increase concentrations by a factor of three to four beyond the current RFETS property boundary and four to five within this current property boundary.

Because these factors only relate to the increase in concentrations from the area of the fire, these increases were added to the expected post-accelerated action concentrations from residual contamination elsewhere at RFETS, plus regional background values, to determine the total air concentrations and resulting EDE during the year following a hypothetical fire. Maximum annual total concentrations and EDEs for the five actinides were estimated to be:

- Plutonium-239/240: 1.01E-04 pCi/m^3 (0.50 mrem) hypothetical spring fire
  1.61E-04 pCi/m^3 (0.80 mrem) hypothetical fall fire
- Americium-241: 1.82E-05 pCi/m^3 (0.10 mrem) hypothetical spring fire
  2.87E-05 pCi/m^3 (0.15 mrem) hypothetical fall fire
- Uranium-233/234: 3.93E-05 pCi/m^3 (0.05 mrem) hypothetical spring fire
  4.05E-05 pCi/m^3 (0.05 mrem) hypothetical fall fire
- Uranium-235: 2.17E-06 pCi/m^3 (0.003 mrem) hypothetical spring fire
  2.55E-06 pCi/m^3 (0.004 mrem) hypothetical fall fire
- Uranium-238: 5.88E-05 pCi/m^3 (0.07 mrem) hypothetical spring fire
  5.88E-05 pCi/m^3 (0.07 mrem) hypothetical fall fire

3.0 REFERENCES

DOE, 2005, Final Interim Measure/Interim Remedial Action for Groundwater at the Rocky Flats Environmental Technology Site, Golden, Colorado, June 21.

EPA, 1989, Title 40 of the Code of Federal Regulations, Part 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon From Department of Energy Facilities," December 15 (and subsequent amendments).

EPA, 1995, Compilation of Air Pollutant Emission Factors, Fifth Edition, Volumes I and II, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, January.

K-H, 2004, Final Fate and Transport Modeling of Volatile Organic Compounds at the Rocky Flats Environmental Technology Site, Golden, Colorado, April.

K-H, 2005, Summary of Integrated Hydrologic and VOC Transport Modeling at the Rocky Flats Environmental Technology Site, Golden, Colorado, September.

Langer, G., 1987, Dust Transport-Wind Blown and Mechanical Resuspension, HS&E Applications Technology Semiannual Progress Report, p. 16, May.

Radian International, 2000, Air Transport and Deposition of Actinides for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site, FY00 Report, Rocky Flats Environmental Technology Site, Golden, Colorado, September.

Shinn, J. (Lawrence Livermore National Laboratory), 1999, Personal Communication, April.

URS, 2001, Air Transport and Deposition of Actinides for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site, FY01 Report, Rocky Flats Environmental Technology Site, Golden, Colorado, December.

Weber, J.M., A.S. Rood, and H.R. Meyer, 1998, Development of the Rocky Flats Plant 903 Area Plutonium Source Term, RAC Report No. 8, CDPHE-RFP-1998-Final, October.