RESPONSES TO COMMENTS FROM CDPHE AND EPA

ON

DRAFT FINAL TECHNICAL MEMORANDUM NO. 5 (EXPOSURE SCENARIOS) FOR OPERABLE UNIT NO. 2 ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

DECEMBER 7, 1994

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, CO

APRIL 1995

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Specific Comments

Comment 1: Section 4.4.1

DOE has not provided adequate documentation to support statements regarding beef ingestion as an incomplete exposure pathway. What is the source of data used to conclude that cattle raised in the RFETS area are not eaten by local residents?

Response: **Part 1:** The beef ingestion pathway was incorrectly reported as "incomplete" in the Exposure Assessment Technical Memorandum (EATM). The pathway should have been identified as "potentially complete but negligible" (see discussion of types of pathways in Part 2 response below) in the EATM and will be identified as such in the report for the Human Health Risk Assessment (HHRA). The pathway is potentially complete because it is theoretically possibly that RFETS contaminants transported offsite could be ingested by cattle, and the cattle in turn, could be ingested by humans. The pathway is negligible because:

(1) Exposure of cattle to contaminants from RFETS is negligible. Personal communications with local officials and others indicated that the few cattle present on a seasonal basis eat little local vegetation and must receive large amounts of supplemental feed. Furthermore, the intermittent flow in the creeks does not support consistent livestock watering.

(2) The small herds of cattle are grazed temporarily in fields near RFETS and are then shipped out of the area each season. The cattle are in the vicinity of RFETS for a relatively brief period of time and they receive supplemental feed (see above); therefore their exposure potential is minimal. Direct exposure of offsite residents via soil ingestion and inhalation is probably insignificant (although these pathways will be

quantified in the OU-2 risk assessment), and indirect exposure via ingestion of beef, if that were to occur, would be negligible in comparison.

Because the pathway is considered negligible, it is not evaluated in the risk assessment for OU-2. However, a beef ingestion pathway is being assessed in the risk assessment for OU-3 (offsite operable unit).

Part 2 (Description of Pathways): Pathways were identified in the EATM as being potentially complete or incomplete, based on the following criteria: a complete pathway requires a chemical source, chemical release mechanism, environmental transport medium, exposure point, and human intake route. If one of these elements is lacking, the pathway is considered incomplete because no human exposure can occur. Incomplete pathways will not be evaluated in the HHRA.

Potentially complete pathways include all pathways for which human exposure is possible, no matter how trivial. Potentially complete pathways were further categorized in the EATM as (1) significant, (2) relatively insignificant, or (3) negligible. Significant and relatively insignificant potentially complete pathways will be evaluated quantitatively in the HHRA. Negligible pathways will not be evaluated in the risk assessment.

A potentially complete pathway was considered to be negligible when, based on professional judgement and logic, the contribution of the pathway to overall exposure is likely negligible (orders of magnitude lower than exposure from other pathways) and the pathway is not expected to contribute significantly to overall risk to the receptor (i.e., exposure, and therefore risk, from the pathway are likely "negligible"). These potentially complete but negligible pathways are unlikely to have any bearing on mathematical estimations of total risk to receptors and therefore do not warrant further evaluation. Therefore, potentially complete negligible pathways will not be evaluated in the HHRA.

Comment 2: Section 4.4.8

This section states that future onsite gravel miners "would not be expected to come into contact with surface water in their work." Even though current gravel operations to the west of RFETS do not mine down to the water table, future gravel pits within OU-2 may very possibly contain water.

Response: Gravel mining has been determined to be an unrealistic future land use scenario in OU2 because of the minimal quantities of mineable materials. This assessment was made by representatives of Western Aggregates, who currently operate a gravel mine on the western portion of RFETS, and concurred with by EPA, CDPHE, and DOE, in a meeting on March 15, 1995. Therefore, this scenario will not be evaluated in the risk assessment for OU2.

Comment 3: Attachment 1

Table 1 does not reflect the most recent corrections agreed to by the parties. The exposure factors listed here are not acceptable, especially those that are identical for both the RME and central tendency.

Response: Exposure parameters used in the risk analysis in the HHRA will reflect recent changes agreed to by the interagency parties. A table containing the most recent agreed upon values for exposure parameters for OU2 receptors will be presented in the HHRA report.

In addition, DOE will include an area-weighting factor (AWF) for the current onsite worker (security personnel) to account for the fact that this individual spends only a fraction of the work day in contact with contaminated media in OU2. The rationale for including this factor is that the exposure assumptions for the current onsite worker that are presented in the Exposure Factors Tables failed to indicate that the current worker exposure in OU2 is transient; that is, security personnel pass through the area during their work routine, but do not spend 8 hours per day in OU2. The AWF is the area of OU2 divided by the area of RFETS, i.e., 1,100 acres/6,550 acres = 0.17 (equivalent to about 1½ hours based on an 8-hour workday). The AWF will be applied in both the CT and RME scenarios. Exposure of the current security worker is evaluated in the two areas of concern (AOCs) delineated in OU2, and the AWF will be applied to both areas, resulting in an assumption of a 1½-hour exposure time every day for 4 (CT) or 25 (RME) years in each AOC.

ENVIRONMENTAL PROTECTION AGENCY

Specific Comments

Comment 1: Page 3-3, Section 3.1.4

Part 1: No mention is made in this section of the work of the Future Site Uses Working Group. The charge of this group is to provide direction and make recommendations to DOE, EPA, CDPHE, and local decision makers regarding the future use of the Rocky Flats site. Although at this time, the group's work should be considered preliminary, it warrants serious consideration and discussion in this technical memorandum.

Part 2: The preliminary options generated by the group indicate that open space use includes recreational and/or interpretive uses. The areas being considered for more limited access are generally on the periphery of the buffer zone. Areas close to the present industrial area are being considered for more recreational uses. This information needs to be presented in this document.

Response: **Part 1:** A discussion of the Rocky Flats Future Site Uses Working Group and their preliminary findings will be added to the HHRA report.

NOTE: This group has indicated that residential development is an unrealistic future land use at RFETS, and EPA has recommended removing the onsite residential scenario from the HHRA (Martin Hestmark, USEPA Region VIII, to Steven Slaten, USDOE Rocky Flats, March 3, 1995). CDPHE will not require the onsite residential exposure scenario, but has noted several advantages to retaining it (Joe Schiefflelin, CDPHE, to Steve Slaten, USDOE Rocky Flats, February 28, 1995). DOE will retain the onsite residential exposure scenario in the HHRA for OU2 because it could support risk management decisions, such as no further action, at low hazard areas in OU2.

Part 2: An additional exposure scenario for open-space (recreational) use of the buffer zone at RFETS has been developed, based on open-space use information from Boulder and Jefferson Counties. Proposed exposure factors for this scenario are shown in Attachment 1. This scenario will be evaluated in the quantitative risk assessment for OU2.

Comment 2: Page 4-4, Section 4.4.1, Second Paragraph

Part 1: This paragraph indicates that ingestion of beef from livestock is an incomplete exposure pathway for all receptors. While this pathway is likely to be incomplete for future on-site receptors, it can be considered complete for current and future off-site receptors. Although the contribution of this pathway to overall exposure may be negligible, it is a complete pathway and should be evaluated for current and future off-site receptors in agriculturally zoned areas.

Part 2: All potentially complete exposure pathways should be quantitatively evaluated in the Human Health Risk Assessment (HHRA).

Response: **Part 1:** The beef ingestion pathway was incorrectly reported as "incomplete" in the EATM; the pathway should have been identified as "potentially complete but negligible" (see response to CDPHE Comment 1, Part 1).

Part 2: Potentially complete pathways that were classified as significant or relatively insignificant are evaluated quantitatively in the risk assessment, whereas those considered potentially complete but negligible will not be evaluated (see response to CDPHE Comment 1, Part 2). A pathway was considered negligible when, based on professional judgement and logic, the contribution of the pathway to overall exposure is expected to be orders of magnitude lower than that from other pathways. Potentially complete but negligible pathways do not warrant quantification because they are unlikely to have any bearing on mathematical estimations of total risk to receptors.

Comment 3: Page 4-5, First Indented Paragraph

This paragraph states that exposure to groundwater in the lower hydrostratigraphic unit (LHSU) is an incomplete pathway because "significant concentrations of volatile organics and metals have not been detected." The term "significant" is not defined and it is not a criterion which should be used to evaluate whether a pathway is complete or not. Significance of contamination to human health is appropriately evaluated first by applying the standard protocol for selecting "Chemicals of Concern" (COCs). Completeness of an exposure pathway is evaluated by determining whether there is a source, release mechanism, transport mechanism (for indirect exposure), and potential receptor. The COC selection protocol must be applied to chemicals detected in the LHSU and an exposure assessment must be completed for those chemicals identified as COCs which are associated with complete exposure pathways. All potentially complete exposure pathways should be quantitatively evaluated in the HHRA.

Response: Exposure to contaminants via ingestion of water contained in the LHSU is an incomplete pathway because (1) the LHSU it is not a feasible source for a domestic or commercial water supply for current or future receptors on OU2, (2) it has very limited hydraulic communication with the upper hydrostratigraphic unit (UHSU), the only potential contamination source in OU2, and (3) the potential for contaminants to migrate within the LHSU to off-site locations is negligible. The LHSU is not capable of serving as a domestic or commercial water supply source because it does not meet the typical definition of an aquifer; i.e., it cannot transmit significant quantities of water at rates fast enough to supply wells for a domestic or commercial use (Freeze and Cherry 1979, Fetter 1980, and Driscoll 1986). This is because the LHSU is comprised predominantly of very fine-grained geologic materials (i.e., claystones with some thin, discontinuous silty sandstone and clayey siltstone lenses) that have relatively low permeability (i.e., averaging in the range of 1E-06 cm/s based on the results of aquifer tests and in the range of 1E-07 cm/s based on the results of laboratory horizontal permeability tests). The discontinuous nature and low permeability of the LHSU sandstone and siltstone units results in negligible flow rates in the LHSU. This was evidenced by the very low flow rates into boreholes and wells observed during the Revised Bedrock Work Plan field investigations. Many LHSU wells required several weeks to produce sufficient water to meet development criteria. Two of the wells (22393 and 23293) failed to produce sufficient water to meet development criteria even after 4 to 5 weeks.

Because of the discontinuous nature and low permeability of the LHSU geologic units, the hydraulic communication between the UHSU and LHSU is very limited and the potential for migration of contaminants within the LHSU to off-site locations is negligible. Where LHSU sandstones and siltstones are in close vertical proximity to the UHSU, there is some limited potential for groundwater to migrate into LHSU sandstones and siltstones at low rates. However, once in the LHSU, lateral or downward migration within the LHSU is inhibited by the low permeability of the sandstone and siltstone units and by the claystone intervals separating those units. Evidence to support the conclusion that limited hydraulic communication occurs between the UHSU and LHSU and that contaminant migration potential within the LHSU is negligible includes:

- The discontinuous nature of LHSU sandstone and siltstone units.
- The substantial thickness (greater than 100 feet in places) of claystone that underlies much of the UHSU and horizontally and vertically separates LHSU sandstone and siltstone units.
- Observations of limited inflow into boreholes during drilling, and extended development times for LHSU wells.
- Water level records that indicate many LHSU wells do not recover to static water levels for weeks or more after well purging and sampling events.
- A mean hydraulic conductivity estimate for the LHSU based on aquifer tests (3E-06 cm/s) that is nearly two orders of magnitude lower than for the UHSU (7E-04 cm/s).

- Groundwater geochemical data that indicate the LHSU water type (Na/K-bicarbonate, Na/K-sulfate) is substantially different that the UHSU water type (Ca-bicarbonate).

- Contaminant concentrations in the LHSU, in those limited areas where contaminants are present, are substantially less (in some cases several orders of magnitude less) than occur in the UHSU indicating very limited hydraulic communication between the LHSU and UHSU.

Therefore, because the LHSU is not a feasible water source for current or future receptors in OU2 and has very limited communication with the UHSU, exposure to contaminants via the LHSU is considered to be an incomplete pathway.

Comment 4: Page 4-5, Last Paragraph

The EATM text states that external irradiation exposure to offsite residents is an incomplete pathway because the maximum activity of plutonium detected in off-site samples was below a "conservative (health-protective) risk-based level of 3.43 pCi/g for long term residential exposure to soil." Risk-based concentrations should not be used to evaluate the completeness of exposure pathways. External irradiation should be evaluated for all detected or modelled concentrations of gamma emitting radioactive COCs.

Response: The text states: "External irradiation exposures to offsite residents resulting from deposition of radionuclides in airborne particulate matter is considered a *negligible* pathway" (emphasis added). The RBC in the EATM was not used to evaluate the completeness of the pathway (theoretically, the pathway is potentially complete); rather the comparison of current offsite concentrations to the RBC indicates that the contribution of the pathway to risk is probably negligible and does not warrant quantification in the risk assessment. Modeled concentrations in soil offsite resulting from air deposition of particulates released from OU2 are expected to be even lower (as will be demonstrated in the RFI/RI report and risk assessment). Since offsite impacts from wind erosion are expected to minimal, the potential for external irradiation from these sources is considered negligible and will not be quantified. However, direct and indirect exposures through ingestion and inhalation will be quantified in the risk assessment, even though modeled offsite impacts are expected to be inconsequential.

Comment 5: Attachment 1, General

Part 1: The Exposure Scenarios Technical Memorandum does not consider agricultural use or recreational use. EPA understands that the open space scenarios currently being discussed as possible for Rocky Flats include access to the site for recreational purposes, similar to Jefferson County and Boulder County open space uses currently. Agricultural use is likely to be applicable to off site areas. Please develop and submit these scenarios for approval.

Part 2: EPA and CDPHE request that DOE further develop the ecological worker *scenario. At this time it is unclear what* DOE is envisioning for future use of RFETS. More concise definition of the potential ecological preserve use of RFETS along with supporting rationale will help reduce the uncertainties in the exposure parameters for associated receptors.

Part 3: EPA believes it is necessary for all agencies to begin work on the quantitative uncertainty analysis at this time. In uncertainty analysis, the central tendency values will be defined.

Response: **Part 1:** As indicated in the response to Comment 1, an additional exposure scenario based on open space use has been developed (see Attachment 1) and will be evaluated in the HHRA for OU2. A future offsite agricultural use scenario is not being developed, primarily because subsistence agriculture is not a probable future use scenario in northeast Jefferson County. Instead, the offsite residential receptor scenario, including ingestion of homegrown produce, is evaluated as a reasonable maximum exposed individual. For other OUs, the offsite residential receptor may be assessed in a comprehensive risk assessment. This possibility is currently being assessed.

Part 2: It is anticipated that the ecological researcher at RFETS will work on specific field research projects of relatively limited duration. Typical research projects involve periodic field work coupled with extensive time in the library, office, or laboratory. Dr. Ward Whicker of Colorado State University, who has performed extensive ecological research at RFETS, indicated that a reasonable estimate for a typical ecological researcher would include field work 5 days per week, 13 weeks per year for 2.5 years. These exposure parameters for the ecological researcher were reported in the EATM and will be used in the HHRA report.

Part 3: Quantitative uncertainty analysis will be developed on an OU-specific basis. It is not planned to be included in the Draft Final HHRA for OU2.

Exposure Pathway Specific Comments

Comment 1: Soil Ingestion

Part 1: The soil ingestion rate for an ecological worker should be 106 mg/day (RME) and 33 mg/day (CT) based on the Rocky Mountain Arsenal (RMA) exposure assessment work. Likewise, the exposure frequency and duration for this receptor should be 242 days/year for 19 years (RME) and 225 days/year for 7 years (CT). (A copy of the RMA exposure assessment was provided to EG&G on December 12, 1994, and they agreed to consider it.)

Part 2: The fraction ingested from contaminated source parameter must be set at 1.00 for the RME for all receptors.

Part 3: The chemical specific matrix effect parameter must be included in the Exposure Scenarios Technical Memorandum for OU2. If this is not possible, it must be formally transmitted in a letter to EPA and CDPHE for their approval before submittal of the baseline risk assessment.

Response: **Part 1:** The soil ingestion rate for an ecological worker was changed to 106 mg/day (RME) and 33 mg/day (CT), as recommended. As indicated in the response to Comment 5 (Part 2), it is anticipated that the ecological researcher at RFETS would work on special projects of limited duration, analogous to ecological research performed at RFETS by Dr. Ward Wicker of Colorado State University. Dr. Whicker indicated that a reasonable estimate for a typical researcher would include field work 5 days per week, 13 weeks per year for 2.5 years. Therefore, the exposure frequency and exposure duration used in the HHRA for the ecological researcher in OU2 will remain as 65 days/year for 2.5 years as indicated in the EATM for OU2.

Part 2: As recommended, the RME fraction ingested from contaminated source will be changed to 1 for all receptors.

Part 3: Attachment 2 to this response to comments includes numerical values for chemical-specific matrix effects and a discussion of the rationale used in developing these values. The matrix effects and discussion will also be presented in the HHRA.

Comment 2: Soil/Dust Inhalation

Part 1: The inhalation rates for the construction worker and ecological worker need to be re-examined. EPA believes the rate for the ecological worker should be 2.1 m^3 per hour based on the RMA work.

Part 2: The most current data on PM-10 measurements at RFETS should be considered in determining the respirable fraction value. EPA and CDPHE insist that the location of the PM-10 monitors be considered for their appropriateness for inclusion in the calculation of average PM-10 values. The 24-hour maximum PM-10 value will be used for the RME. The respiratory deposition factor of 0.85 from the RMA exposure assessment should be considered at RFETS.

Response: **Part 1:** The RME inhalation rates for the construction worker and ecological worker will be 1.4 m^3/hr, from EPA's Exposure Factors Handbook, p. 3-8. This value is derived assuming 7 percent time at heavy activity, 37 percent time at moderate activity, and 28 percent time at light activity.

Part 2: The air models used to estimate exposure point concentrations for particulate matter yield results in terms of PM_{10}, base on the resuspension studies performed at RFETS (OU3 Wind Tunnel Study, Volume I, Test Report, DOE Prime Contract No. DE-AC04-90DP62349, prepared by EG&G Rocky Flates, January 1994). Thus, there was no need to further account for the respirable fraction in calculating chemical intake from inhalation. The respiratory deposition factor of 0.85 will be included in the exposure assessment.

Comment 3: Soil/Dust Dermal Contact

Similar to the comments on the soil ingestion pathway, the fraction contracted from contaminated source must be 1.0 for all receptors for the RME. Delete the reference to "reasonable worst case" in footnote (2) as this term is obsolete. Its use in this document may cause confusion.

Response: As recommended, the RME fraction contacted from the contaminated source will be 1.0 for soil/dust dermal contact for all receptors. No references to "reasonable worst case" will be used in the HHRA.

Comment 4: Surface Water/Suspended Sediment Ingestion

The ecological worker scenario needs to be further defined in order to understand likely exposure frequency. EPA suggests that, at a minimum, surface water and sediment sampling activities are likely to occur once per month or 12 times per year.

Response: As recommended, the exposure frequency to surface water/suspended sediments for the ecological researcher will be increased from 7 times per year per creek to 12 times per year per creek in the HHRA.

Comment 5: Surface Water Dermal Contact

Similar to above comment. The exposure frequency parameter appears to be too low.

Response: As indicated in the response to Comment 4, the exposure frequency for the ecological researcher's exposure to surface water/suspended sediments will be increased in the HHRA to 12 exposures per year per creek.

Comment 6: Homegrown Produce Ingestion

The proposed "washoff factor" is generally not used in EPA and CDPHE risk assessments. EG&G provided the reference for their proposed factor (Transuranic Elements, Volume II) to EPA and CDPHE on December 12, 1994. Because the reference is an older document, it is appropriate to look at the RMA off post exposure assessment. Ingestion of home grown produce was considered in that assessment. EPA and CDPHE believe that if a "washoff factor" is used at all on RFETS, it should be limited to the CT estimate.

Response: As recommended, the washoff factor for the RME condition was changed to 1.0, while the washoff factor for the CT exposure condition will remain at 0.5.

Comment 7: Ground Water Ingestion

Because office workers can be exposed to groundwater via ingestion, exposure parameters must be developed for these receptors also. Rationale to support the judgement of whether this pathway is complete or incomplete should be submitted on an OU specific basis in the Exposure Scenarios Technical Memorandum. The RME ingestion rate for an office worker is 1 liter per day.

The fraction ingested from contaminated source is 1.0 (RME) and 0.3 (CT). The exposure frequency, duration, body weight, and averaging time for the office worker should be consistent with those used for this receptor in other direct exposure pathways.

Response: Exposure of future onsite office workers to groundwater via ingestion is an incomplete pathway because, as with current onsite workers, drinking water is expected to be supplied by a municipal water supply. In past and current operations at Rocky Flats, a municipal water supply has provided all of the drinking water for thousands of onsite workers.

It is inconceivable that future onsite businesses will bypass an adequate and safe municipal water supply to tap into inadequate partially saturated zones in OU2. It is therefore inconceivable that future onsite office workers would ingest groundwater from RFETS. Thus, this pathway will not be evaluated quantitatively in the HHRA. However, theoretical exposure parameters for ingestion of groundwater by future office workers will be included in intake factor tables in the HHRA report including: (1) an RME ingestion rate of 1 liter per day, (2) a fraction ingested from contaminated source of 1.0 (RME) and 0.3 (CT), and (3) values for exposure frequency, duration, body weight, and averaging time that are consistent with those used for this receptor in other direct exposure pathways.

Comment 8: Groundwater/Subsurface Soil VOC Inhalation

The assumptions about construction worker inhalation rates for outdoor exposure to particulates must make sense in comparison to assumptions about outdoor vapor inhalation from subsoil excavation at construction sites. Therefore, the inhalation rate for construction workers must be re-examined.

Response: The VOC inhalation pathway for construction workers will not be evaluated in the HHRA. However, exposure parameters for this pathway will be presented in intake factor tables in the HHRA. As indicated in the response to Comment 2, the RME inhalation rate for the construction worker for all inhalation pathways is 1.4 m^3/hour.

Comment 9: External Irradiation

The CT exposure frequency parameter must be consistent with the same parameter used in the soil ingestion exposure pathway, 245 days per year.

Response: As agreed to by EPA and CDPHE, a CT exposure frequency of 234 days/year will be used for the soil ingestion and external irradiation pathways for residential receptors. This is EPA's preliminary default CT value.

ATTACHMENT 1: OPEN SPACE USE EXPOSURE FACTORS

TABLE A
OPEN-SPACE EXPOSURE PARAMETERS
INCIDENTAL INGESTION

DUST, SURFACE SOIL, OR SEDIMENT

	Typical Exposure (CT)	High-End Exposure (RME)
Ingestion Rate - Child (mg/visit)	15 (1)	100 (1)
Ingestion Rate - Adult (mg/visit)	8 (1)	50 (1)
Matrix Effect in GI Tract (Absorption Factor)	CS	CS
Exposure Frequency (visits/yr)	10 (2)	25 (2)
Exposure Duration - Child (yr)	2	6
Exposure Duration - Adult (yr)	7	24
Body Weight - Child (kg)	15	15
Body Weight - Adult (kg)	70	70
Averaging Time - Child, Non-carcinogen (days)	730	2,190
Averaging Time - Adult, Non-carcinogen (days)	2,555	8,760
Averaging Time - Carcinogen (days)	25,550	25,550

(1) Assumes standard default *residential* rates as specified for open-space recreational users at DOE's Fernald Site and Hanford Site (RME=200 mg/day for children and 100 mg/day for adults) and at Denver's Lowry Landfill Superfund Site (CT=100 mg/day for children and 50 mg/day for adults). Assumes that Exposure Time is 1.5 hours per day (CT); 5.0 hours per day (RME) (see Note 2, Table B) and that total soil ingestion occurs over 10 daylight hours (1.5/10 = 0.15; 5.0/10 = 0.5). Using the default daily ingestion rates, soil ingestion per visit for children is calculated as RME=0.5 x 200=100 mg/visit; CT=0/15 x 100=51 mg/visit. For adults the ingestion rates are RME=50 and CT=8. Actual open-space recreational intakes would vary, depending on the activity, possibly with dirt biking at one extreme and photographing wildlife at the other.

(2) Exposure Frequency based upon Boulder County's Park and Open Space Visitor Interviews of 1985 (est. 7 days/yr, CT; 25 days/yr, RME), DOE's Hanford Site recreational user (7 days/yr, CT), and Department of Interior's (DOI) National Survey of Fishing, Hunting, and Nonconsumptive Wildlife Recreation of 1985 for Colorado (9.4 days/yr for nonconsumptive use, CT; 15.4 days/yr for fishing and hunting, CT).

TABLE B
OPEN-SPACE EXPOSURE PARAMETERS
PARTICULATE INHALATION

DUST, SURFACE SOIL, OR DRY SEDIMENT

	Typical Exposure (CT)	High-End Exposure (RME)
Inhalation Rate (m^3/hr)	0.83 (1)	1.4 (1)
Respirable Fraction (PM_{10})	0.36	0.46
Respiratory Deposition Factor	0.85	0.85
Exposure Time (hr/visit)	1.5 (2)	5.0 (2)
Exposure Frequency (visits/yr)	10 (3)	25 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time - Noncarcinogen (days)	3,285	10,950
Averaging Time - Carcinogen (days)	25,550	25,550

(1) Inhalation Rate based upon DOE's Fernald Site and Hanford Site recreational users (0.83 m^3/hr, CT) and on EPA's *Exposure Factors Handbook* (1.4 m^3/hr, RME), which assumes 7% heavy activity, 37% moderate activity, 28% light activity, and 28% resting for an adult.

(2) Exposure Time based upon Boulder County's Park and Open Space Visitor Interviews of 1992 (est. 1.6 hr/day, CT; 5.0 hr/day, RME), DOD's Rocky Mountain Arsenal Site recreational user (1.6 hr/day, CT; 5.0 hr/day, RME), and City of Boulder's Open Space Visitation Study of 1993 (1.0 hr/day, CT; 2.0 hr/day, RME).

(3) Exposure frequency based on Boulder County's Park and Open Space Visitor Interviews of 1985 (estimated 7 days/year, CT; 25 days/year, RME), DOE's Hanford Site recreational user (7 days/year, CT), and DOI's National Survey of Fishing, Hunting, and Nonconsumptive Wildlife Recreation of 1985 for Colorado (9.4 days/year for nonconsumptive use, CT; 15.4 days/year for fishing and hunting, CT).

TABLE C
OPEN-SPACE RECREATIONAL EXPOSURE PARAMETERS
DERMAL CONTACT

DUST, SURFACE SOIL, OR SEDIMENT

	Typical Exposure (CT)	High-End Exposure (RME)
Exposed Skin Surface (cm^2)	2,000 (1)	5,300 (1)
Fraction Contacted from Contaminated Source	0.15 (2)	0.5 (2)
Soil Adherence to Skin (mg/cm^2)	0.2	1
Skin Absorption Factor	CS	CS
Exposure Frequency (days/yr)	10 (3)	25 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time - Noncarcinogen (days)	3,285	10,950
Averaging Time - Carcinogen (days)	25,550	25,550

(1) Exposed Skin Surface based upon EPA's *Dermal Exposure Assessment: Principles and Applications*, which specifies typical and high-end default values for the adult outdoors (2,000 cm^2 and 5,300 cm^2). The CT exposed skin surface is limited to head and hands, while the RME value assumes head, hands, forearms, and lower legs are exposed. DOE's Fernald Site recreational user adopts a comparable RME value (5,000 cm^2). It is conservatively assumed that a persons head will contact sediments.

(2) See Table A and B, Note 2.

(3) See Table B, Note 3.

TABLE D
OPEN-SPACE EXPOSURE PARAMETERS
INGESTION WHILE WADING

SHALLOW SURFACE WATER

	Typical Exposure (CT)	High-End Exposure (RME)
Ingestion Rate (mL/hr)	25 (1)	50 (1)
Exposure Time (hr/visit)	0.5 (2)	1 (2)
Exposure Frequency (visits/yr)	5 (3)	15 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time - Noncarcinogen (days)	3,285	10,950
Averaging Time - Carcinogen (days)	25,550	25,550

(1) Ingestion Rate based upon open-space recreational user wading at Denver's Lowry Landfill Superfund Site (50 mL/day, RME; 25 mL/day, CT). For comparison, a single value of 35 mL/day is specified for DOE's Fernald Site (wading in shallow Paddy's Run).

(2) Exposure Time based upon DOE's Fernald Site recreational user (0.5 hr/day, CT) and on the Clear Creek/ Central City Superfund Site recreational user (1.0 hr/day, RME, assuming that wading time would be the same as swimming time).

(3) Assumes that CT Exposure Frequency for *wading* is one-half the EF of 10 days/yr for all visitors (0.5 x 10 = 5 days/yr) and RME is 60% of the EF of 25 (0.6 x 25 = 15 days/yr). See Table A, Note 3. On the average, users are very unlikely to wade on a year-round basis during each visit to the site.

TABLE E
OPEN-SPACE EXPOSURE PARAMETERS
DERMAL CONTACT WHILE WADING

SHALLOW SURFACE WATER

	Typical Exposure (CT)	High-End Exposure (RME)
Exposed Skin Surface (cm^2)	4,550 (1)	9,275 (1)
Dermal Permeability (cm/hr)	CS	CS
Exposure Time (hr/visit)	0.5 (2)	1 (2)
Exposure Frequency (visits/yr)	5 (3)	15 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time - Noncarcinogen (days)	3,285	10,950
Averaging Time - Carcinogen (days)	25,550	25,550

(1) Typical exposed adult skin surface while wading and reaching underwater (4,550 cm^2) assumes the lower legs, feet, and hands are exposed; high-end exposed surface (9,275 cm^2) assumes the thighs, lower legs, feet, forearms, and hands are exposed (*EPA's Exposure Factors Handbook*).

(2) See Table D, Note 2.

(3) See Table D, Note 3.

TABLE F
OPEN-SPACE EXPOSURE PARAMETERS

EXTERNAL IRRADIATION

	Typical Exposure (CT)	High-End Exposure (RME)
Gamma Exposure Time Factor (T_e)	01. (1)	0.2 (1)
Gamma Shielding Factor ($1-S_e$)	0.8	1
Exposure Frequency (visits/yr)	10 (2)	25 (2)
Exposure Duration (yr)	9	30

(1) Assumes the high-end fraction of time exposed (1.5 out of 24 hours, CT; 5.0 out of 24 hours, RME) (1.5/24 = 0.1; 5.0/24 = 0.2) (see Table B, Note 2)

(2) See Table A, Note 3.

ATTACHMENT 2: CHEMICAL-SPECIFIC MATRIX EFFECTS

For chemicals of concern in soil whose toxicity factors were derived from studies in which the agent was administered in solution, a matrix factor of 0.5 was used in calculating intake for risk assessment. Chemical-specific matrix effects for OU2 COCs in soil are listed in Table 1. The matrix effect of 0.5 is a conservative value derived from a review of literature, summarized in Table 2. The matrix effect is used to account for decreased bioavailability of ingested compounds bound to a solid matrix relative to their bioavailability from drinking water or other solutions such as corn oil, where matrices are limited or do not exist. Although these matrix effect values were initially developed for the soil ingestion pathway, they also apply to other media where significant binding of compounds to a solid matrix may occur (e.g., compounds ingested in homegrown produce). As indicated in USEPA guidance for risk assessment, adjustments of this type may be necessary if "the medium of exposure in the site exposure assessment differs from the medium of exposure assumed by the toxicity value" (USEPA 1989). The guidance further states that "a substance might be more completely absorbed following exposure to contaminated drinking water than following exposure to contaminated food or soil (e.g., if the substance does not desorb from soil in the gastrointestinal tract)."

The literature values for matrix effects shown in Table 2 are discussed in more detail below.

There are several examples of USEPA precedence for assuming decreased bioavailability of inorganics from food and soil, compared to that in water. Cadmium and manganese each have two oral RfDs, one for ingestion in food and one for ingestion in water. In deriving media-specific RfDs for cadmium, USEPA assumed that 5 percent of cadmium ingested in water is bioavailable, compared to 2.5 percent for cadmium ingested in food (USEPA 1995). The corresponding matrix effect for cadmium ingested in food is 0.5. The RfD for manganese ingested water is 28 times smaller than the RfD for manganese ingested food (USEPA 1995). Although relative bioavailability of manganese in food and water is not discussed in IRIS, one explanation for a 28-fold decrease in toxicity of manganese ingested in food is a matrix effect resulting in greatly decreased bioavailability. Another example of media-specific differences in toxicity is suggested by USEPA's RfD for cyanide. In deriving the RfD for cyanide, based on a dietary study in rats, USEPA included a safety factor of 5 to protect for an expected increase in toxicity of cyanide ingested in water (USEPA 1995).

The use of this safety factor implies that cyanide ingested in food is 0.2 times as toxic as cyanide ingested in water, corresponding to a matrix effect of 0.2.

Other evidence in the literature indicates that absolute absorption of inorganics ingested in food is less than that from water. Sixty percent of radiolabeled lead chloride administered to adult humans in water was bioavailable, compared to 3 percent for lead chloride ingested in food (Heard and Chamberlain 1982). Similarly, nickel chloride administered to adult humans in food was much less bioavailable (0.7 percent) than nickel chloride administered in water (28 percent) (Sunderland et al. 1989). Increased blood levels of manganese were observed in humans ingesting high doses in water, but not when similar doses of manganese were ingested with food (Bales et al. 1987).

The absolute absorption of inorganics ingested in soil is also less than that from water. This is expected because inorganics only partially desorb from soil. USEPA's IEUBK lead model assumes that the bioavailability of lead ingested in soil is 30 percent, compared to 50 percent bioavailability for lead ingested in water. The corresponding soil matrix value is 0.6. In rats, the bioavailability of lead ingested in soil was 8 percent of that for lead acetate ingested in water (Freeman et al. 1992). Arsenic administered to rabbits in soil was much less bioavailable (28 percent) than arsenic administered to rabbits in water (59 percent), corresponding to a soil matrix effect of 0.47 (Freeman et al. 1993).

Several studies show that organic chemicals, including pesticides, also bind tightly to soil, reducing their bioavailability through both oral and dermal exposure. Clays and organic colloids have a large surface area and cation exchange capacity, which permits significant adsorption of virtually all classes of pesticides: furthermore, the adsorbed fraction desorbs slowly and is effectively a bound fraction that increases over time as the soil-pesticide bond "ages" (Calderbank 1989). The bound fraction is estimated to be about 20 to 70 percent of the total amount applied. McConnell et al. (1984) showed, using soil containing TCDD (a dioxin) from the Minker Stout site, that 3 μg/kg-bw TCDD in corn oil resulted in 6/6 deaths among treated guinea pigs and 13.3 ppb TCDD in the liver, but 3.3 μg/kg-bw TCDD from soil caused only 2/6 deaths and 1.4 ppb in the liver, indicating about 10 percent relative bioavailability of TCDD from the soil. Shu et al. (1988) conducted further studies on TCDD and found an average 43 percent (range, 25 to 50 percent) bioavailability of TCDD to rats from soils from Times Beach. Goon et al. (1991) showed that benzo(a)pyrene (BaP) that had aged 6 months in soil was only 34 and 51 percent orally bioavailable for clayey and sandy soils, relative to BaP administered alone to rats. PCBs including aroclor, DDT, chlordane, and heptachlor, among other chemicals at the site, may be expected to adsorb strongly to soil similarly to BaP (Ney 1990), resulting in reduced bioavailability due to this matrix effect. These studies support a conservative estimate of 50 percent relative bioavailability of semivolatile organic compounds in soil compared to solution.

A matrix factor of 0.5 was used in the human health risk assessment to account for the decreased toxicity of chemicals of concern in soil, suspended sediment, and homegrown produce, relative to that in water or other solution. This value is based in part on USEPA-derived relative bioavailability factors for cadmium in food (0.5) and lead in soil (0.6), a literature-derived relative bioavailability factor of 0.47 for arsenic in soil (Freeman et al. 1993), and the evidence supporting a 50 percent relative bioavailability of semivolatile organic compounds in soil. Note that several studies indicate that the decrease in bioavailability from the matrix effects of food and soil can be substantially greater than 50 percent (as much as 95 percent), indicating that a matrix effect of 0.5 is conservative (Freeman et al. 1992; Heard and Chamberlain 1982; Sunderland et al. 1989; USEPA 1995).

As shown in Table 1, the following chemicals of concern in surface and subsurface soil have toxicity values that were derived from studies using drinking water or other solutions and were therefore evaluated using a matrix effect: Aroclors, bis(2-ethylhexyl)phthalate, tetrachloroethene, arsenic, and mercury. The following special-case chemicals of concern in surface soil were also evaluated using a matrix effect of 0.5: fluoranthene and pyrene. Where the critical toxicity study was dietary but no vehicle was indicated in IRIS, a default matrix effect of 1 was used.

For radionuclides, slope factors were derived from studies in which soluble forms were administered in food or water; consequently, it would be appropriate to consider matrix effects as well as mineralized form to estimate toxic effects from ingestion of radionuclides in a soil matrix (personal communication, Chris Nelson, USEPA 1995). However, the reduction in potential toxic effects cannot be quantified simply using a matrix effect because the adjustment must account for differential effects on target organs. Therefore, a matrix effect of 1 has been adopted for radionuclides in the present risk assessment, even though this factor probably overestimates the effects of radionuclides ingested in soil.

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TABLE 1
SOIL MATRIX EFFECTS

Chemical of Concern	Type of Critical Study (1): Oral Reference Dose	Type of Critical Study (1): Oral Slope Factor	Matrix Effect (2)
Aroclor-1254	Glycerol & corn oil vehicle (monkeys)	By analogy to Aroclor-1260	0.5
Aroclor-1260	By analogy to Aroclor-1254	Corn oil vehicle, stirred in food (rats)	0.5
Bis(2-ethylhexyl)phthalate	Dietary; vehicle not specified (guinea pigs)	Dietary; vehicle not specified (rats)	1
Tetrachloroethene	Corn oil gavage (mice)	Not determined (ECAO-CIN)	0.5
Arsenic	Drinking water (humans)	Drinking water (humans)	0.8 (3)
Cadmium	Dietary (humans)		1
Chromium	Dietary: baked in bread (rats)		1
Mercury	Parenteral HgCl2 (rats)		0.5
Americium-241		Soluble form in food or water (4)	1
Plutonium-239,240		Soluble form in food or water (4)	1
Uranium-233,234		Soluble form in food or water (4)	1
Uranium-235		Soluble form in food or water (4)	1
Uranium-238		Soluble form in food or water (4)	1
Special-Case Chemicals of Concern			
Benzo(a)pyrene (5)		Dietary; vehicle not specified (rats, mice, dogs)	1
Fluoranthene	Gavage (mice)		0.5
Pyrene	Gavage (mice)		0.5

(1) Source: IRIS, unless otherwise noted.
(2) A soil matrix effect of 0.5 supported by literature review; see text and Table 2.
(3) USEPA Region VIII.
(4) Personal communication, Chris Nelson, USEPA Risk Assessment Section, Criteria and Standards Division, February 1995). Retardation of intake from soil matrix is appropriate to consider but cannot be quantified using a simple soil matrix effect because the adjustment must account for differential effects on target organs. Therefore, a matrix effect of 1 is adopted, even though it probably overestimates bioavailability of mineralized forms of radionuclides in soils at Rocky Flats.
(5) Adopted for all carcinogenic PAHs in soil.

TABLE 2
DERIVATION OF 0.5 SOIL MATRIX EFFECT

Compound/Species	Fraction Absorbed from Food/Soil (Fm)	Fraction Absorbed from Water (Fw)	Matrix Effect	Source
Cadmium (in adults)	2.5	5	0.50 (1)	USEPA 1995; Kjellstrom and Nordberg, 1978
Manganese (adults)	--	--	0.04 (2)	USEPA 1995
Cyanide (rats)	--	--	0.20 (3)	USEPA 1995
Lead (in children)	0.3	0.5	0.60 (1)	USEPA 1994
Lead (in adults)	0.03	0.6	0.05 (1)	Heard and Chamberlain
Lead (in rats)	--	--	0.08 - 0.20 (4)	Freeman et al. 1993
Nickel (adults)	0.007	0.28	0.03 (1)	Sunderland et al. 1989
Arsenic (rabbits)	0.28	0.59	0.47 (1)	Freeman et al. 1994
TCCD (guinea pigs)	--	--	0.10 (5)	McConnell et al. 1984
Benzo(a) pyrene (rats)	--	--	0.34 - 0.51 (6)	Goon et al. 1991
Matrix Effect Selected For Use In HHRA			0.5	

(1) Based on Fm/Fw.
(2) Based on relative toxicity of manganese in water vs food (RfD water = 5E-03 mg/kg-d; RfD food = 1.4E-01 mg/kg-d; ratio = 0.04).
(3) Based on relative toxicity of cyanide in food and water; see text.
(4) Based on relative retention of lead in blood, bone, and liver.
(5) Based on relative retention of TCDD in liver.
(6) Based on relative bioavailability from soil compared to water.