

# **NOTICE**

**All drawings located at the end of the document.**

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**Final  
Phase III RFI/RI**

**Rocky Flats Plant  
881 Hillside Area  
(Operable Unit No. 1)**

**June 1994**

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## List of Acronyms and Abbreviations

%R	percent recoveries
µg/kg	micrograms per kilogram
µg/l	micrograms per liter
µg/m <sup>3</sup>	micrograms per cubic millimeter
ADL	Authur D. Little
AEC	Atomic Energy Commission
ATSDK	Agency for Toxic Substances and Disease Registry
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGS	Colorado Geological Survey
CNS	central nervous system
COC	contaminants of concern
COL	colluvium
CRAVE	carcinogen risk assessment verification endeavor
CRQL	contract required detection limit
CSM	conceptual site model
D&D	decontamination and decommissioning
DL	detection limit
DNA	deoxyribonucleic acid
DQO	data quality objectives
EE	Ecological Evaluation
EFH	Exposure Factors Handbook
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
HI	hazard index
HQ	hazard quotient
H&S	health and safety
HEAST	Health Effects Assesment Summary Tables
IHSS	individual hazardous substance site
IRIS	Integrated Risk Information System
KAR	Arapahoe
keV	kiloelectron vole
LCS	Laboratory Control Sample
LOAEL	Lowest Observed Adverse Effect Level
mg/kg/day	milligrams per kilograms per day
MS	matrix spikes
MSD	matrix spike duplicates
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOEL	No Observed Effect Level
NOAEL	No Observed Adverse Effect Level
NRF	normalized risk factor
OSHA	Occupational Safety and Health Administration
OU1	Operable Unit No. 1
PAH	polynuclear aromatic hydrocarbons
PARCC	precision, accuracy, representativeness, completeness, and comparability

PCE	perchloroethylene
pCi/g	picoCuries per gram
pCi/l	picoCuries per liter
PHE	Public Health Evaluation
ppm	parts per million
QA/QC	quality assurance/quality control
QAA	Quality Assurance Addendum
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RFA	Rocky Flats Alluvium
RfCs	reference concentrations
RfD	reference dose
RFEDS	Rocky Flats Environmental Database System
RFLII	Rocky Flats Local Impacts Initiative
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
RME	reasonable maximum exposure
Rockwell	Rockwell International
RPD	relative percent difference
SF	slope factors
SID	south interceptor ditch
SQL	sample quantitation limit
UCL	Upper Confidence Level
UHSU	Upper Hydrostratigraphic Unit
VF	volatilization fraction
VFA	Valley Fill Alluvium
VOC	volatile organic compound
WCS	Weathered Claystone

## SECTION F1 INTRODUCTION

The Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation (RFI/RI) at Operable Unit No. 1 (OU1) 881 Hillside Area at Rocky Flats Plant (RFP) includes a Baseline Risk Assessment. The Baseline Risk Assessment is comprised of an Ecological Evaluation (EE) and a Public Health Evaluation (PHE). This document presents the results of the PHE.

### F1.1 PURPOSE

The purpose of the OU1 PHE is to develop a quantitative description and assessment of the risk to the public posed by the contaminants of concern (COCs) at OU1. This PHE is incorporated in its entirety as part of the Baseline Risk Assessment for OU1. The resulting analysis of the human health risks posed by OU1 responds to and fulfills Attachment 2, Section VII.D Interagency Agreement requiring an analysis acceptable to both the U.S. Environmental Protection Agency (EPA) and the Colorado Department of Health (CDH). Pursuant to this requirement, the method of evaluation was taken from the EPA *Risk Assessment Guidance for Superfund* (EPA, 1989a).

### F1.2 REPORT ORGANIZATION

The report is divided into nine sections and contains four attachments. Section F1 provides a brief introduction including the purpose, objectives, and scope of the PHE. Section F2 provides a brief summary of the presentations and findings of the RI report including a site description, meteorology and climate, hydrogeology, flora and fauna, demographics and local land use, determination of contaminants, nature and extent of contamination, and contaminant migration pathways.

Section F3 presents the methodology and its application in the identification and selection of COCs. First, a summary of all contaminants measured in the field is presented by medium. Then the COCs screening process is presented and applied. Finally, the usability and treatment of data are presented.

A description of how scenarios and pathways are identified and selected for quantitative evaluation is provided in Section F4, and the exposure assessment including a generalized approach for each major pathway and a description of how each pathway in each scenario is quantitatively evaluated is provided in Section F5.

Section F6 provides the toxicity assessment. This includes a description of the general approaches used for evaluating exposures to carcinogenic and noncarcinogenic COCs and toxicity profiles for each COC.

The risk characterization is presented in Section F7. First, the reasonable maximum exposure (RME) point estimates of risk are provided for each scenario. Then a quantitative uncertainty analysis is presented separately.

Section F8 summarizes the PHE, and Section F9 contains the references. A list of the Attachments included in this report are as follows:

- Attachment F-1: OU1 Domestic Water Supply Simulations
- Attachment F-2: Transport Model Descriptions and Applications
- Attachment F-3: Oak Ridge National Laboratory Toxicity Distributions
- Attachment F-4: OU1 COCs 95 Percent Upper Confidence Limits

### **F1.3 OBJECTIVES**

The objectives of the PHE are to:

- Identify COCs
- Identify Current and Hypothetical Future Exposure Scenarios and Pathways
- Estimate Receptor Intakes

- Identify Toxicity Constants
- Estimate Potential Risks to Current and Hypothetical Future Populations
- Analyze the Uncertainty Involved with Risk Estimates

#### **F1.4 SCOPE OF THE INVESTIGATION**

The OU1 area is located on the south side of the RFP security area, is south-facing, and slopes toward Woman Creek from Building 881. Individual hazardous substance sites (IHSSs) within the OU1 study area were designated as high priority because it is possible that COCs have been released at these sites based on historical accounts of use or accidental releases (Rockwell International [Rockwell], 1987). The following sites are designated as IHSSs at OU1:

- Oil Sludge Pit Site (IHSS 102)
- Chemical Burial Site (IHSS 103)
- Liquid Dumping Site (IHSS 104)
- Out-of-Service Fuel Tank Sites (IHSSs 105.1 and 105.2)
- Outfall Site (IHSS 106)
- Hillside Oil Leak Site (IHSS 107)
- Multiple Solvent Spill Sites (IHSSs 119.1 and 119.2)
- Radioactive Site - 800 Area Site No. 1 (IHSS 130)
- Sanitary Waste Line Leak Site (IHSS 145)

The PHE report contains a variety of information pertinent to potential public health risks at OU1. Potential COCs are identified, along with the data quality objectives (DQOs) applicable to them. An exposure assessment links those COCs to potentially exposed populations through a series of scenarios involving current and future land use and hypothetical exposures. This exposure assessment is based on existing site conditions, including the presence of the French Drain and the treatment system. Levels of COCs to which the population is exposed are compared with EPA guidance (EPA, 1993a,b). These evaluations are accompanied by an uncertainty analysis, which discusses the assumptions used in the risk assessment.

## **F1.5 RECENT INVESTIGATIONS**

This report includes evaluations of data gathered from several field activities at OU1 including Phase I, Phase II, and Phase III RIs. An initial (Phase I) field program was completed at OU1 in 1987, and a draft Phase I RI report was submitted to EPA and CDH in July 1987 (Rockwell, 1987). Based on the results of that investigation, a second phase of field work was conducted at OU1 in the fall of 1987. A draft Phase II RI report was submitted to EPA and CDH in March 1988 (Rockwell, 1988); and in October 1988, DOE received EPA's and CDH's written comments on the report. A draft Phase III RFI/RI work plan was submitted to EPA and CDH in February 1990 (DOE, 1990b), and a final Phase III RFI/RI work plan that incorporated EPA's and CDH May 1990 comments was submitted to EPAs and CDHs in October 1990 (DOE, 1990d). Revision 1 of the final Phase III RFI/RI work plan was submitted in March 1991 (DOE, 1991), and incorporated EPA and CDH comments on the October 1990 submittal. Field work for the Phase III RFI/RI began in April 1991 and was completed in January 1992. Based on the Phase I and II investigations, an interim measure/interim remedial action plan has been developed to collect and treat contaminated alluvial groundwater at OU1 (DOE, 1990c). The plan was released for public comment during October and November 1989, and finalized in January 1990. Construction of the interim measure/interim remedial action was started in November 1991 (EG&G, 1991a) and completed in April 1992. A final remedial action will be proposed based on Phase I, II, and III investigations, as well as the feasibility study.

**SECTION F2**  
**SUMMARY OF RFI/RI**

**F2.1 PHYSICAL SETTING**

**F2.1.1 Site Description**

RFP is located in northern Jefferson County, approximately 16 miles northwest of Denver (Figure F2-1). Other nearby cities include Boulder, Westminster and Arvada, which are located less than 10 miles to the northwest, east and southeast, respectively. The plant consists of approximately 6,500 acres of federally owned land in Sections 1 through 4 and 9 through 15 of Township 2 South, Range 70 West. Major buildings are located within the plant security area, which encompasses approximately 400 acres. A buffer zone of approximately 6,150 acres surrounds the secured area (Figure F2-2).

OU1 comprises approximately 18 acres at 881 Hillside, which is located in the southeastern part of RFP (Figure F2-3). The topographic slope over much of the area is moderately steep, dropping about 100 feet over a 600 foot distance. The elevation near Building 881, the highest point at the site, is about 6,000 feet above mean sea level (msl), and the lowest point is in Woman Creek, at about 5,830 feet above msl.

Eleven IHSSs have been identified at OU1 (Figure F2-4):

- Oil Sludge Pit (IHSS 102)
- Chemical Burial Site (IHSS 103)
- Liquid Dumping Site (IHSS 104)
- Out-of-Service Fuel Tanks (IHSSs 105.1 and 105.2)
- Outfall Site (IHSS 106)
- Hillside Oil Leak (IHSS 107)
- Multiple Solvent Spill Sites (IHSSs 119.1 and 119.2)
- Radioactive Site-800 Area (IHSS 130)
- Sanitary Waste Line Leak (IHSS 145)

As part of an Interim Measures/Interim Remedial Action (IM/IRA), a French Drain has been installed to capture contaminated groundwater originating from OU1 (Figure F2-4).

### **F2.1.2 Meteorology and Climate**

The RFP area has a semi-arid climate and receives about 15 inches of annual precipitation, 40 percent of which falls in the spring. Thunderstorms from June to August contribute approximately 30 percent of the annual precipitation. Snowfall averages 85 inches per year. Temperatures are moderate, ranging from 55 to 85° F in the summer and 20 to 45° F in winter. The average relative humidity is 46 percent. Winds at RFP are predominantly from the northwest.

### **F2.1.3 Hydrogeology**

#### **F2.1.3.1 Groundwater**

Groundwater at OU1 is present in the unconsolidated surficial material, consisting of the Rocky Flats Alluvium, colluvial material, and the Valley Fill Alluvium. Groundwater is also inferred to occur locally in the upper portion (i.e., 0 to 25 feet) of the Laramie claystone bedrock. These units contain unconfined groundwater and comprise the upper hydrostratigraphic unit (UHSU). Groundwater also occurs in deeper (> 25 feet) bedrock sandstones and claystones of the upper Laramie Formation. This bedrock unit is labeled the lower hydrostratigraphic unit (LHSU) and groundwater here is confined in places.

Over most of the site, UHSU groundwater flow occurs in northwest-southeast trending channels that have been scoured into the bedrock surface. Bedrock highs and lithologic variability, notably the presence of clay lenses, act to retard the rate of groundwater flow. Flow has been observed in glide planes bounding a slump block present at OU1. Parts of OU1, particularly in the eastern portion, are only seasonally wet, and contain groundwater only in the spring months when there is high precipitation. Groundwater levels across the site are higher in spring than in the remainder of the year.

Recharge to the UHSU is primarily through infiltration of precipitation, which ranges from 2 inches per hour for initial infiltration, to 0.5 inches per hour for final (saturated) infiltration. Localized sources of recharge include seepage from the Rocky Flats Alluvium to colluvial materials, and former recharge from the Building 881 footing drain, which has since been rerouted to the French Drain collection system. Flow from this drain averages 3.5 gallons per minute. Discharge occurs largely through evapotranspiration and discharge at boundaries such as seeps, Woman Creek, the South Interceptor Ditch, and the French Drain.

From aquifer test data, the average linear flow velocity was estimated at 70 feet per year in the vicinity of IHSS 119.1; 8 feet per year in the vicinity of Building 881, and 180 feet per year within the Valley Fill Alluvium. The volume of UHSU groundwater at OU1 was estimated at 5.8 acre-feet in January 1992, to 5 acre-feet in April 1992. The decrease was due to rerouting of the Building 881 footing drain, which had previously discharged to the hillside south of Building 881.

Based on the available groundwater level data from the French Drain monitoring wells, the recently installed French Drain system appears to be effective in capturing UHSU groundwater migrating from OU1.

#### **F2.1.3.2 Surface Water**

Woman Creek flows west to east and drains the area south of OU1 (Figure F2-4). This stream is a losing stream in the area south of OU1, except for a couple of months in the spring. The South Interceptor Ditch (SID) lies between OU1 and Woman Creek and also flows west to east (Figure F2-4). Water from local drainages that traverse the hillside and from overland flow is captured by the SID. In the western part of OU1, the SID may gain or lose water depending on the elevation of the localized water table. In the eastern part of the site, the SID appears to lose flow to the underlying shallow groundwater flow system, as the plunge pools along this reach are almost always dry.

Seeps are present at OU1 and represent points of groundwater discharge. Seeps may be related to the contact of the Rocky Flats Alluvium and the bedrock at the top of the hill. Other seeps

are related to the slumps along the hillside. These features are bounded by glide planes that can transport groundwater.

#### **F2.1.4 Flora/Fauna**

The majority of the plant species at OU1 contributing to the terrestrial communities belong to two groups — vascular cryptograms and vascular plants. Grassland habitats are dominant, representing about 82 percent of the total area. Nine percent of the area is either developed or disturbed. Marsh habitats occupy 4 percent, woodland habitat constitutes 4 percent, and shrub habitats account for the remaining area. Wildlife species are typical of those in similar habitats throughout the foothills area.

As a result of limited and inconsistent surface water supplies, aquatic species with short life cycles and smaller habitat requirements, such as benthic macroinvertebrates, have developed more diverse communities than fish.

#### **F2.1.5 Potentially Exposed Populations**

##### **F2.1.5.1 Demography**

A recent demographic study shows that approximately 2.2 million people live within 50 miles of RFP and about 9,100 people live within 5 miles of the plant. The most populated sector is to the southeast, toward the center of Denver.

RFP is located in a rural area that is bordered by three counties. Approximately 50 percent of the area within 10 miles of the plant is in Jefferson County, 40 percent in Boulder County, and 10 percent in Adams County. Some of the surrounding land that had been unused, or used for agriculture, has recently been converted to housing.

The potentially exposed populations were characterized primarily using DOE's *1989 Population, Economic, and Land Use Data for Rocky Flats Plant* (1990a), developed by the Denver Regional Council of Governments (DRCOG). This DRCOG study encompassed a 50-mile (81-kilometer)

radius area from the center of RFP and included all or part of 14 counties and 72 incorporated cities with a 1989 combined population of 2,206,550. The DRCOG study projected populations through the year 2010. The majority of the development of the plains to the east of RFP has occurred since the plant was built, and according to projections by DRCOG, future development is expected to continue (DOE, 1992).

Within a 4-mile (6.9-kilometer) radius of the center of RFP, there is little residential or commercial development. Between 4 and 10 miles (6.4 and 16 kilometers), development increases, with approximately 316,000 residents within a 10-mile (16-kilometer) radius. The most significant development exists to the southeast, in the cities of Westminster, Arvada, and Wheat Ridge. The cities of Boulder, to the northwest; Broomfield, Lafayette, and Louisville, to the northeast; and Golden, to the south, also contain significant developments within this 10-mile (16-kilometer) radius (DOE, 1992).

The nearest school is Witt Elementary School, which is approximately 2.7 miles (4.3 kilometers) east of the RFP buffer zone (EG&G, 1992a). All other sensitive population facilities (such as hospitals and nursing homes) are located beyond the 5-mile (8-kilometer) radius from the center of RFP. There are 93 schools, 8 nursing homes, and 4 hospitals within a 10-mile (16-kilometer) radius of RFP (DOE, 1992).

Standley Lake Park, a recreational area and drinking water supply for the cities of Thornton, Northglenn, Westminster, and Federal Heights, is located 3.5 miles (5.6 kilometers) to the southeast of RFP. From the reservoir, water is piped to each city's water treatment facilities. Boating, picnicking, and limited overnight camping is permitted at Standley Lake Park.

#### **F2.1.5.2 Land Use**

Potential future land use has been classified into five categories: (1) residential, (2) commercial/industrial, (3) recreational, (4) ecological reserve, and (5) agricultural. Current on-site activity includes only commercial/industrial use. Current off-site activities include all categories except ecological reserve. Potential future on-site uses include recreational use (credible), commercial/industrial and ecological reserve (credible), and agricultural or residential

use (improbable). Potential future off-site uses include residential, commercial/industrial, and recreational scenarios (all credible), agricultural use (improbable), and ecological reserve (improbable).

## **F2.2 NATURE AND EXTENT OF CONTAMINATION**

All of the Phase III chemical data were carefully assessed to determine which analytes are contaminants at OU1. The assessment included statistical comparisons of OU1 concentrations to background, examination of spatial and temporal concentration distributions at OU1, and evaluation of the potential for laboratory introduced sample contamination. Details of this evaluation are provided in Appendix D.

### **F2.2.1 Background Geochemical Characterization**

The concentration of an analyte is one factor in determining if the analyte is a contaminant. Whether the concentration is deemed high or low is in relation to the background concentration. This is because, with few exceptions, the metals and radionuclides for which analysis was obtained also occur naturally (e.g., iron, lead, uranium, etc.).

For several years, a background geochemical characterization program has been in progress for the RFP. This program has quantified the spatial and temporal variations in inorganic analytes in soils, groundwater, and surface water in areas near the plant that are undisturbed by plant operations. Data and summary statistics for organic analytes also exist for surface water, groundwater, and sediments. The September 1992 *Background Geochemical Characterization Report, Rocky Flats Plant, Golden, Colorado* (EG&G, 1992) summarizes the results and findings from the program. The Environmental Protection Agency (EPA) and the Colorado Department of Health (CDH) have been continuously involved in the background geochemical characterization program. The 1992 report incorporates their comments and suggestions on data presentation and analysis based on their review of previous submittals. The data in this document is recognized by the regulatory agencies as being the basis for statistical comparisons to OU data. The data and statistics provided in this report have been used to determine the analytes, by medium, that exceed background concentrations at OU1.

The background program did not include characterization of surface soils. Background surface soil data were collected from the Rock Creek drainage west of the plant under a separate program described in Technical Memorandum 5 for OU1. Technical Memorandum 5 was reviewed by EPA and CDH and their comments and concerns were addressed. Semivolatile organic compound (SVOC), pesticide/ polychlorinated biphenyl (PCB), metal, and radionuclide data were collected for the background surface soils. All data generated from this program are presented in Appendix C1. These surface soil data are the basis for determining the analytes that exceed background concentrations in surface soil at OU1.

Background values for each analyte, by medium (and geologic unit within each medium, as appropriate, are presented in Table D-1, Appendix D. The values are from the Final Background Geochemical Characterization Report (EG&G, 1992), or were computed from the surface soil data collected for the Rock Creek drainage. These background values are the upper limit of a one-sided 95% tolerance interval (95% confidence and including 95% of the population). If the background data for a particular medium geologic (or unit within the medium) include less than 50% detections, then the maximum concentration is reported as the background value. Less than 50% detections is considered an inadequate basis for computing tolerance interval statistics.

#### **F2.2.2      Overview of Methodology to Determine Contaminants at OU1**

The determination of organic and inorganic contaminants at OU1 relied heavily on analysis of temporal and spatial concentration distributions; however, selection of inorganic contaminants also involved statistical comparisons of site data with background concentrations. The procedures for determining OU1 contaminants and PHE COCs are illustrated on Figures F2-5, F2-6, and Figure F2-7. EPA/CDH approved the procedures in their comments on the November 1993 draft of the OU1 RFI/RI report. However, EPA noted that the procedures should not be cited as a precedent for other OUs at the RFP or other CERCLA sites as the methodology deviates somewhat from standard EPA practice.

The contaminants, by medium, determined from application of these procedures are addressed in Sections 4 and 5 of the RFI/RI Report (nature and extent as well as fate and transport), in this

PHE, and in the EE. The PHE and EE further define unique COCs, which are subsets of these contaminants, using PHE and EE specific screening procedures.

A detailed description of the contaminant selection process for inorganic and organic analytes is presented in Appendix D.

### **F2.2.3      Inorganic Analytes**

The inorganic analytes are of particular importance because many of these substances occur naturally and thus will be detected in most media during most sampling events. Thus, the mere presence of many of these substances does not necessarily indicate a site contaminant. The flow chart developed to guide the determination of which substances are actual site contaminants is shown in Figure F2-5. At each decision point on the flow chart, each analyte was evaluated and either eliminated or passed on as a potential site contaminant.

The first step in the screening process involved comparing an analyte's concentrations for a specific medium (or unit within the medium) to the appropriate background upper tolerance limit (UTL) (or the maximum value) as determined from the RFP background geochemical characterization. If all of an analytes concentrations for a specific medium were less than the UTL (or maximum background value) for a given analyte, that analyte was determined not to be a site contaminant of that medium (or unit). If any analyte concentration was greater than the UTL (or maximum background value), then the analyte was passed on to the next step as a potential site contaminant of that medium (or unit).

The second step involved an analysis of variance (ANOVA) comparison in which the mean of the background concentrations were compared to the mean of the site concentrations for a given medium (or unit within the medium). Selection of the appropriate ANOVA test to determine significant differences between background and non-background populations followed the procedure identified in the Final Background Geochemical Characterization Plan (EG&G, 1992) (Figure F2-8). If the appropriate ANOVA test indicated the means were not equal at the 5% significance level, then the analyte was considered a potential site contaminant of that medium (or unit) and was subjected to further conceptual analysis (scientific reasoning as discussed

below) to evaluate if the analyte was actually a contaminant. If the means were equal at the 5% significance level, then the analyte was not considered a site contaminant of that medium (or unit).

Those analytes passing the ANOVA test as having a significantly different mean concentration relative to background were further assessed using scientific reasoning to determine if the analyte is actually a site contaminant. The scientific reasoning included examination of three criteria: 1) spatial distribution of concentrations within a medium, 2) temporal distribution of concentrations at a well or surface water station, and 3) laboratory or field sampling artifact.

#### **F2.2.4      Organic Analytes**

The approach utilized to determine whether organic compounds are site contaminants is different than that used for the inorganic analytes because many of the organic compounds are not naturally occurring compounds. A flow chart indicating the sequence of steps used to determine whether organic compounds were site contaminants is presented on Figure F2-6. The initial step in the determination of organic site contaminants was to list all of the volatile and semivolatile organic compounds (VOCs and SVOCs, respectively) detected at OU1. This list was compared to the list of organic compounds known to have been disposed at OU1 and their degradation (biotic and abiotic) products. Any organic compounds detected in OU1 samples that are known to be constituents of wastes stored at the site, or are degradation products of one of these constituents, were determined to be site contaminants. (Degradation products must also not be laboratory or field sampling artifacts [see below] to be considered contaminants.)

For all other detected organic compounds, scientific reasoning using the same three criteria identified for the inorganic substances (i.e., spatial and temporal concentration distributions, and assessment of laboratory or field sampling introduced sample contamination) were used to further evaluate whether these organic compounds were site contaminants.

## **F2.2.5 Contaminants Identified at OU1**

Based on the foregoing analysis, metals, radionuclides, VOCs, and SVOCs are contaminants at OU1 (Table F2-1). As noted in the table, none of these contaminants are present in every medium. Table F2-2 lists the analytes determined not to be contaminants. Details of the evaluation are provided in Appendix D.

## **F2.2.6 Contaminant Sources and Extent**

### **F2.2.6.1 Volatile Organic Compounds**

VOCs are present in subsurface soils and occur, in some locations, at high concentrations in groundwater ( $> 1.0$  mg/l). Chlorinated solvents occur sporadically and at low concentrations ( $< 1.0$  mg/kg) in subsurface soils throughout the IHSSs. Sources for the high concentrations of these VOCs in groundwater have not been sampled but there is adequate circumstantial evidence to conclude that subsurface soils with high chlorinated solvent concentrations (sources) exist (see IHSS 119.1 discussion). Toluene occurs throughout OU1 in subsurface soils at relatively low concentrations; however, the source of the toluene is unknown. The occurrence of toluene in the OU1 samples may be a result of laboratory or field-introduced contamination, but the associated laboratory QC samples do not fully support this contention. Regardless, for the purposes of this PHE, it is assumed to be a contaminant at OU1.

Three general source areas for VOCs in groundwater at OU1 have been identified (Figure F2-9). Within these three general areas, multiple release points appear likely based on concentration gradients and chemical fingerprints. The three general source areas include:

#### **The Area South of Building 881**

Groundwater in this area contains low  $\mu\text{g/l}$  concentrations of chlorinated solvents. However, the spatial distribution of the detections does not clearly indicate a discrete source. In addition, the description of the historical activities at IHSSs 145, 107, and 106 does not clearly indicate use or disposal of chlorinated compounds.

A maximum detection of 130  $\mu\text{g}/\ell$  of 1,1,1-TCA in samples collected from well 1-87 may indicate IHSS 145 is a source. However, the results of a soil gas survey presented in the Phase I RI Report revealed no 1,1,1 TCA in the soil gas sample collected closest to well 1-87.

Soil gas survey results reveal a high concentration of PCE in soil gas approximately 30 feet southwest of well 5287 and is shown on Figure F2-9 as a suspected source area. This detection is the second highest out of several hundred soil gas samples collected at OU1, suggesting a source for PCE in subsurface soils and the possible existence of residual dense, non-aqueous phase liquid (DNAPL). The lack of PCE detections in groundwater samples collected from wells downgradient of the soil gas detection (well 5487/5387) suggest that either the solvent release did not reach the water table (as a free phase wetting front) or that groundwater is not present at the location of the release.

Although several sources for VOCs in groundwater may exist in the Building 881 vicinity, groundwater contamination does not extend beyond the South Interceptor Ditch.

### IHSS 119.1

Documented waste storage practices at this IHSS resulted in the release of chlorinated solvents which now pose a continuing source for VOCs in groundwater. VOC concentrations are highest in the southwest portion of the IHSS. This fact, coupled with the apparent presence of drummed waste as seen in historical aerial photographs, permits approximate definition of the source area in the southwest portion of the IHSS (Figure F2-9). Within this source area, individual releases from drums cannot be resolved due to their small areal extent. However, the results of the Phase I soil gas survey suggest several locations which may represent the actual release points (See Figure F2-10). A comparison of the chemical suite detected in groundwater at several locations within the drum storage area revealed at least two distinct chemical mixtures. One is dominated by TCE and 1,1,1-TCA (well 974) and the other is dominated by carbon tetrachloride ( $\text{CCl}_4$ ) (well 1074), which supports the multiple release point concept.

Given the assumed release mechanism, namely leaking drums on the ground surface, it is reasonable to assume that a gravity driven wetting front of chlorinated solvents advanced through

the vadose zone and at least a portion of the saturated zone. As the wetting front passed, it left behind residual free-phase chlorinated solvents in both the vadose and saturated zone. This residual constitutes a continuing source for VOCs in groundwater at this location.

The extent of VOC contamination in groundwater down gradient of the western portion of IHSS 119.1 is currently limited by the French Drain, which based on available water level data, appears to be acting as a hydraulic barrier in the UHSU. The historical maximum extent of VOCs in groundwater is defined by well 4787. Well 4787 has had sporadic low level detections of VOC contaminants (Figure F2-11).

Repeated low level detections of trichloroethylene (TCE) have been noted in pre-existing monitoring well (687) hydraulically downgradient of the eastern portion of IHSS 119.1. Soil gas, soil chemistry and groundwater chemistry data indicate no source areas in the eastern portion of the IHSS. However, given the large size of the IHSS and the amount of materials stored across the IHSS in the past, it is conceivable that a small source area remains undetected within the eastern portion of IHSS 119.1.

The extent of contamination originating from the unidentified source is unknown. Well 687 was destroyed during the construction of the French Drain. Based on available water data, it currently appears that the French Drain captures all UHSU groundwater that once flowed through the area occupied by well 687.

#### **IHSS 119.2 and 903 Pad Area**

Low ( $\mu\text{g}/\ell$ ) concentrations of chlorinated solvents (carbon tetrachloride, tetrachloroethene, and trichloroethene) detected in two closely-spaced monitoring wells downgradient of IHSS 119.2 (6286 and 6386) (see Figure F2-11) are attributed to potential VOC release areas at both IHSS 119.2 and the 903 Pad. The occurrences of VOCs (carbon tetrachloride, tetrachloroethene, trichloroethene, and chloroform) in groundwater within the IHSS include one-time low  $\mu\text{g}/\ell$  detections in UHSU well 34791 and LHSU well 4587, with the exception of chloroform, which occurred three times at low  $\mu\text{g}/\ell$  levels in well 4587.

The occurrence of chlorinated solvents in subsurface soils is limited to low  $\mu\text{g}/\text{kg}$  detections in one borehole (BH5887). The occurrence of VOCs in soil gas is limited to low levels of tetrachloroethene and 1,1,1-trichloroethane at one location within the IHSS. However, the magnitude of the soil gas detections is several orders of magnitude less than those noted at Building 881 and IHSS 119.1 and are more representative of the local background around IHSS 119.2. Nevertheless, as was the case at IHSS 119.1, the presence of a VOC release point within IHSS 119.2 boundaries is suspected based on the downgradient groundwater chemistry.

Wells 6286 and 6386 contain contaminated groundwater and are located in a drainage hydraulically downgradient from IHSS 119.2. Therefore, a VOC release point is suspected and is shown on Figure F2-9 based on the location of suspected waste disposal features depicted on aerial photographs. The location and size of this suspected VOC release point is uncertain. It is possible that contamination from the 903 Pad is also responsible for the VOCs detected in monitoring wells on the Hillside. The 903 Pad is upgradient of the impacted wells and is known to be a source for carbon tetrachloride and other dissolved chlorinated solvents in groundwater.

#### **F2.2.6.2 Metals**

Metal contaminants include vanadium and selenium, both of which are significantly elevated in groundwater. These elements are not elevated in surface or subsurface soils. Although these substances were not reported to have been associated with wastes stored or disposed of at OU1, they appear to be elevated primarily in areas where VOC wastes were stored at OU1. It is postulated that these metals are undocumented constituents of wastes stored at IHSS 119.1. It is unlikely they were leached from the soil by the organic wastes disposed of at OU1 as hydraulic oil and chlorinated solvents have poor chelation properties, and are not strongly acidic or basic. Nevertheless, the potential for leaching of these metals exists. Alternatively, these constituents may be naturally occurring; however, there is insufficient data to support this conclusion. Therefore, selenium and vanadium are considered contaminants at OU1. Four areas have been identified at OU1 with elevated selenium and/or vanadium as discussed below.

### IHSS 119.1

Multiple detections of selenium and vanadium were noted in monitoring wells located in the southwestern portion of the IHSS (Figure F2-12). Typically, the elevated metals were seen in association with VOCs. In particular, the highest metal concentration (2200  $\mu\text{g}/\ell$  of Se) was detected in a well with one of the highest VOC concentrations anywhere at OU1 (Well 1074). The maximum downgradient extent of selenium in groundwater at IHSS 119.1 appears to be in the vicinity of well 487.

The occurrence of elevated selenium in bedrock wells (37891 and 39191) is not easily explained. These wells do not exhibit significant VOC concentrations (0 to 5  $\mu\text{g}/\ell$ ). However, because selenium is an anion and is expected to be very mobile, it may have migrated vertically into the upper portion of the Laramie claystone.

The occurrence of vanadium is similar to selenium except that vanadium only occurs above background in UHSU wells.

### Area South of Building 881

One detection of vanadium is noted at well 5387 at approximately six times the background UTL of 30  $\mu\text{g}/\ell$ . This well exhibits concentrations of various chlorinated compounds in the 1 to 25  $\mu\text{g}/\ell$  range (Figure F2-11). Several potential VOC source areas have been identified in the area south of Building 881, however well 5387 is not particularly close to the suspected source areas. Nevertheless, it is conceivable that the vanadium present in groundwater at 5387 represents a plume originating from one of the VOC source areas previously discussed (Figure F2-11). The extent of vanadium concentrations above the background UTL near Building 881 appears to be limited to the immediate vicinity around well 5387.

### Area East of IHSS 102

One detection of vanadium and three detections of selenium were noted above the background UTL in well 6986. No detections of VOCs have been noted at this well. It is unclear whether

these detections represent contamination or naturally occurring levels as the maximum vanadium and selenium concentrations represent 126 percent and 194 percent of background, respectively. Based on these relatively low levels, a contaminant source is not suspected in this area.

#### **Southeast Corner of IHSS 130**

Vanadium is the only contaminant detected at this location over background levels. A maximum of 403  $\mu\text{g}/\ell$  was detected at well 37191 which represents approximately five times the background UTL. Only exceedingly low levels of VOC contamination ( $<0.5 \mu\text{g}/\ell$ ) were found in association with the vanadium. The extent of vanadium and selenium contamination in the southeast corner of IHSS 130 appears to be limited to the immediate vicinity around well 37191.

#### **F2.2.6.3 Semivolatile Organic Compounds**

The only SVOCs that are contaminants at OU1 are polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Although PAHs are considered to be OU1 contaminants they are not considered to be of OU1 origin. PAHs occur over most of OU1 in surface soils and tend to decrease in concentration with depth. PAHs have also been detected in sediments. Several areas of OU1 have been identified where PAHs appear more concentrated relative to the surrounding area. The areas do not coincide with IHSS locations (Figure F2-13). Although the precise origin of PAHs is unknown, the sources are presumed to include general urban fallout including asphalt dust and larger particles, vehicle exhaust and furnace exhaust.

#### **F2.2.6.4 Polychlorinated Biphenyls**

PCB occurrence is restricted to IHSS 119.1 and 119.2 surface and subsurface soils (Figure F2-13). One PCB detection has been also noted in sediments. However, this detection was at the western OU1 boundary and is not considered of OU1 origin. The contaminant release mechanism for PCBs is unknown.

#### **F2.2.6.5 Radionuclides**

Americium, plutonium, and uranium have been identified as OU1 contaminants and are elevated in surface and subsurface soil. In addition, plutonium and americium are evaluated in surface water and sediment. The widespread plutonium and americium contamination appears to be a result of deposition of wind-disseminated plutonium/americium-contaminated dust originating from the 903 Pad Area. A general decrease in activities is noted from east to west ranging from a maximum of 22.7 pCi/g to 0.0076 pCi/g of plutonium and 4.15 pCi/g to 0.0129 pCi/g of americium (Figure F2-14).

In contrast to the wide-spread plutonium/americium contamination, localized "hot spots" are present at OU1 that are markedly contaminated with either plutonium/americium or uranium. These "hot spots" are postulated to have arisen from releases of radionuclide-contaminated liquids stored in drums at OU1.

Plutonium at activities greater than 10 nano Curies per gram (nCi/g), which is three to four orders of magnitude higher than the activity of any other soil sample at OU1, was found in soil samples from "hot spot" SS100493 located in IHSS 119.1 (Figure F2-14). This is the original location that prompted a "hot spot" investigation. The plutonium activity was 6670 pCi/g at the lowest depth sampled (9 to 10 inches below ground surface), which suggests the potential presence of significant plutonium contamination in deeper soils at this location. Plutonium was below background levels at SS100193 and SS100293 but was 22.7 pCi/g (0 to 0.25 inches) at SS100393 located in 119.2. However, this activity is consistent with the OU2 surface soil data, indicating the 903 Pad as the plutonium source, although it should be noted that the 0- to 1-foot composite sample had an activity of 14.7 pCi/g, which is somewhat inconsistent with a near surface contamination hypothesis.

Unlike plutonium/americium, uranium contamination is not wide-spread, but like plutonium/americium, it is significantly elevated at discrete locations in surface and subsurface soils at OU1 (Figure F2-15). Uranium was below background levels at SS100393, slightly above background at SS100493, and significantly above background at SS100193 and SS100293. The low, albeit above background, levels at SS100493 coupled with uranium-233,234/uranium-

238 ratios of approximately 1 to 2 suggest the uranium may be naturally occurring. The highest activities of uranium at SS100193 and SS100293 occur just beneath the surface as the deeper composites have the higher activities. The maximum total uranium activity at SS100193 is approximately 550 pCi/g with a uranium-233,234/uranium-238 activity ratio of 3.5. This suggests contamination with enriched uranium. The maximum total uranium activity at SS100293 is approximately 240 pCi/g with an activity ratio as high as 160. This suggests contamination with uranium-233 as the activity ratio far exceeds that for enriched uranium.

## **F2.2.7      Contaminant Migration Pathways**

### **F2.2.7.1      Volatile Organic Compounds**

The release mechanisms for VOCs at OU1 are varied including spent solvent leakage from stored drums, possible leakage of dilute aqueous solutions of VOCs from pipelines, and seepage of aqueous VOC solutions or spent solvent from impoundments and disposal pits. In the area south of Building 881, the release mechanisms likely include leaking pipelines, and leakage from impoundments and disposal pits. In the western portion of OU1 (IHSS 119.1), the release mechanism is most likely leakage from drums stored on the land surface.

Once the contaminant is released, the pathways for VOC migration include gravity driven wetting fronts of aqueous solutions and/or spent solvent through the vadose zone to the water table. In the case of spent solvent, the specific gravity of the liquid ( $> 1.0$ ) would allow the contaminant to migrate vertically through the saturated zone. The migration as a dense non-aqueous phase liquid (DNAPL) would be arrested once the wetting front of contamination became depleted by the process in which residual DNAPL is retained by soils and rock. Alternatively, the migration would stop once the DNAPL came to rest in a topographic low on an impermeable surface (possibly the Laramie claystone) (Figure F2-16). At this point, migration would continue in the form of a dissolved phase hydrocarbon plume (if groundwater is present). The dissolved phase plume would migrate with the groundwater being retarded to varying degrees as a function of the physical and chemical properties of the contaminant, geologic materials, and groundwater.

At OU1, the shallow groundwater, which carries most of the contamination, is controlled to a large degree by the topography of the bedrock surface. Channels scoured into the bedrock are covered by unconsolidated material of varying thickness that is variably saturated. Typically, groundwater will flow towards the axis of the bedrock channel and continue downgradient along the axis of the channel potentially to the Woman Creek Alluvium (Figure F2-17). Therefore, at OU1, an aqueous phase hydrocarbon plume in groundwater has the potential to discharge to Woman Creek. However, available water level data indicate that the existing French Drain appears to act as a hydraulic barrier preventing the discharge of contaminated groundwater in the western and central portions of OU1 to Woman Creek. In the eastern portion of OU1, the potential exists for continuous contaminant migration pathways in groundwater from the suspect source area (903 Pad) to Woman Creek. However, conclusive evidence of this occurrence has not been found.

VOC-contaminated groundwater may also discharge to surface water through seeps. This phenomenon was historically observed at OU1. While VOCs in surface water have been previously detected in the South Interceptor Ditch, available data suggest the French Drain appears to have intercepted this pathway.

Other migration pathways for VOCs include volatilization of pure product into soil gas and subsequent migration of soil gas laterally and vertically away from the source area. VOCs can also partition out of contaminated groundwater into soil gas or desorb from organic matter into the soil gas.

VOCs would not be expected to migrate in significant quantities through surface water or wind transport of VOC contaminated surface soil. This is based on the assumption that VOCs would quickly volatilize from the respective media. One apparent exception to this is the occurrence of toluene in OU1 surface soils. Although there is no evidence to suggest that toluene is migrating through surface water or wind, it apparently is persistent in near surface soils despite its relative high volatility.

#### **F2.2.7.2 Metals**

The mechanism for the release of metal contaminants into the environment is less clear than for VOCs. It is presumed that selenium and vanadium are undocumented RFP wastes that were associated with the VOC wastes stored and disposed of at OU1. In either case, the primary migration pathway is as a dissolved phase contaminant plume in groundwater. This migration pathway was previously presented for VOCs.

#### **F2.2.7.3 Semivolatile Organic Compounds**

It is presumed that PAHs were deposited at OU1 as fallout of combustion products or wind blown asphalt dust. Asphalt dust and larger particles may also have been transported and deposited by vehicles traversing OU1 or by disposal of asphalt waste at OU1.

Once in place, the dispersion mechanisms include vertical migration by infiltrating surface water carrying small particles composed of PAHs. The low solubility of PAHs precludes mobilization of significant quantities in the dissolved form, therefore, transport via groundwater is not significant. Other transport mechanisms include surface water and wind transport of particulate.

Transport mechanisms relevant for PCBs are the same as for PAHs, however, the source areas for PCBs are more discrete than for PAHs.

#### **F2.2.7.4 Radionuclides**

Transport mechanisms relevant to radionuclides are the same as for PAHs.

**Table F2-1**

**Summary of Contaminants at OU1**

	Surface Soil	Subsurface Soil	Groundwater	Surface Water/ Seeps	Sediments
<b>Inorganic Analytes</b>					
Selenium			X		
Vanadium			X		
Plutonium	X*	X*		X**	X**
Americium	X	X*		X**	X**
Uranium	X*	X*			
<b>Volatile Organic Compounds</b>					
1,1,1-Trichloroethane		X	X	X	X
Trichloroethene		X	X	X	
Tetrachloroethene		X	X	X	
Carbon Tetrachloride		X	X		
1,2-Dichloroethane		X	X	X	
Chloroform		X	X		
1,1-Dichloroethene		X	X	X	
1,2-Dichloroethene			X	X	
cis-1,2-Dichloroethene			X		
1,1,2-Trichloroethane			X		
1,1-Dichloroethane			X	X	
Toluene		X	X	X	X
Total Xylenes		X	X	X	
<b>Semivolatile Organic Compounds</b>					
Polynuclear Aromatic Hydrocarbons	X	X			X
Aroclor-1254	X				X
Aroclor-1248	X				

\* Presence in these media is based on recently collected hot spot data.

\*\* Presumed to be present as a contaminant of these media because of the widespread nature of the contamination originating from an off-site source.

Table F2-2

Eliminated as OU1 Site Contaminants

Inorganic Parameters

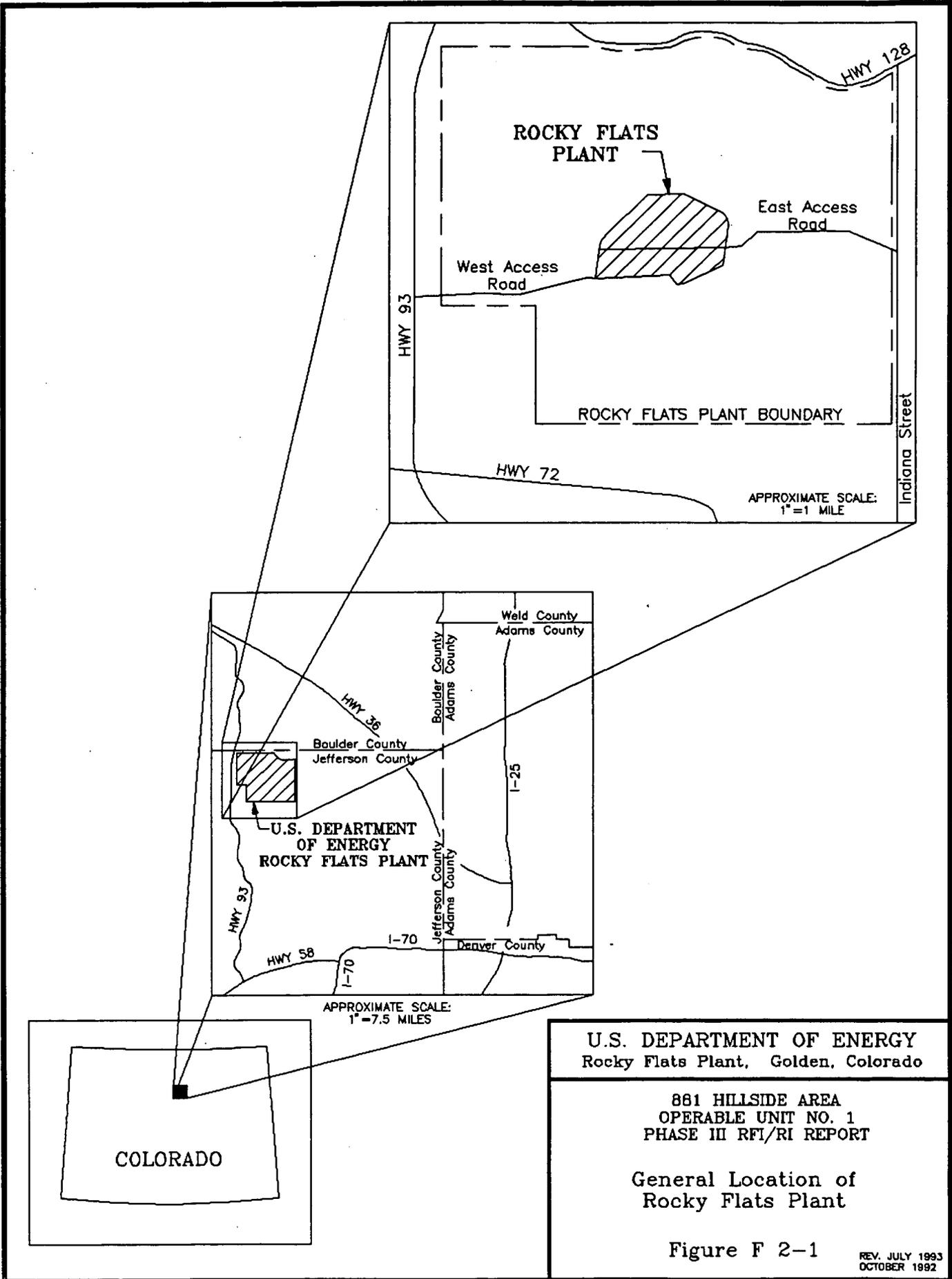
Aluminum	Cesium	Lead	Potassium	Strontium
Antimony	Cesium-134	Lithium	Radium-226	Strontium-89,90
Arsenic	Cesium-137	Magnesium	Radium-228	Thallium
Barium	Chromium	Manganese	Silicon	Tin
Beryllium	Cobalt	Mercury	Silver	Tritium
Cadmium	Copper	Molybdenum	Sodium	Zinc
Calcium	Iron	Nickel		

Volatile Organic Compounds

Acetone	Dibromochloromethane	p-Cymene
Benzene	Dichlorodifluoromethane	sec-Butylbenzene
Benzene 1,2,4-Trimethyl	Ethylbenzene	Styrene
2-Butanone	2-Hexanone	Trans 1,3-Dichloropropene
Carbon Disulfide	4-Methyl-2-Pentanone	tert-Butylbenzene
Chlorobenzene	m-Xylene	Trichlorofluoromethane
1,2 Dichloropropane	Methylene Chloride	Vinyl Chloride
1,4 Dichlorobenzene	p-Chlorotoluene	Vinyl Acetate

Semivolatile Organic Compounds

Benzoic Acid	1,4-Dichlorobenzene	2-Methylnaphthalene
Benzyl Alcohol	2,6-Dinitrotoluene	4-Methylphenol
Beta-BHC	Di-n-Butyl Phthalate	Naphthalene
Bis(2-ethylhexyl)Phthalate	Di-n-Octyl Phthalate	4-Nitrophenol
Butyl Benzyl Phthalate	Dibenzofuran	N-Nitrosodipheylamine
4,4'-DDT	Diethyl Phthalate	Pentachlorophenol



R74225.MB082093

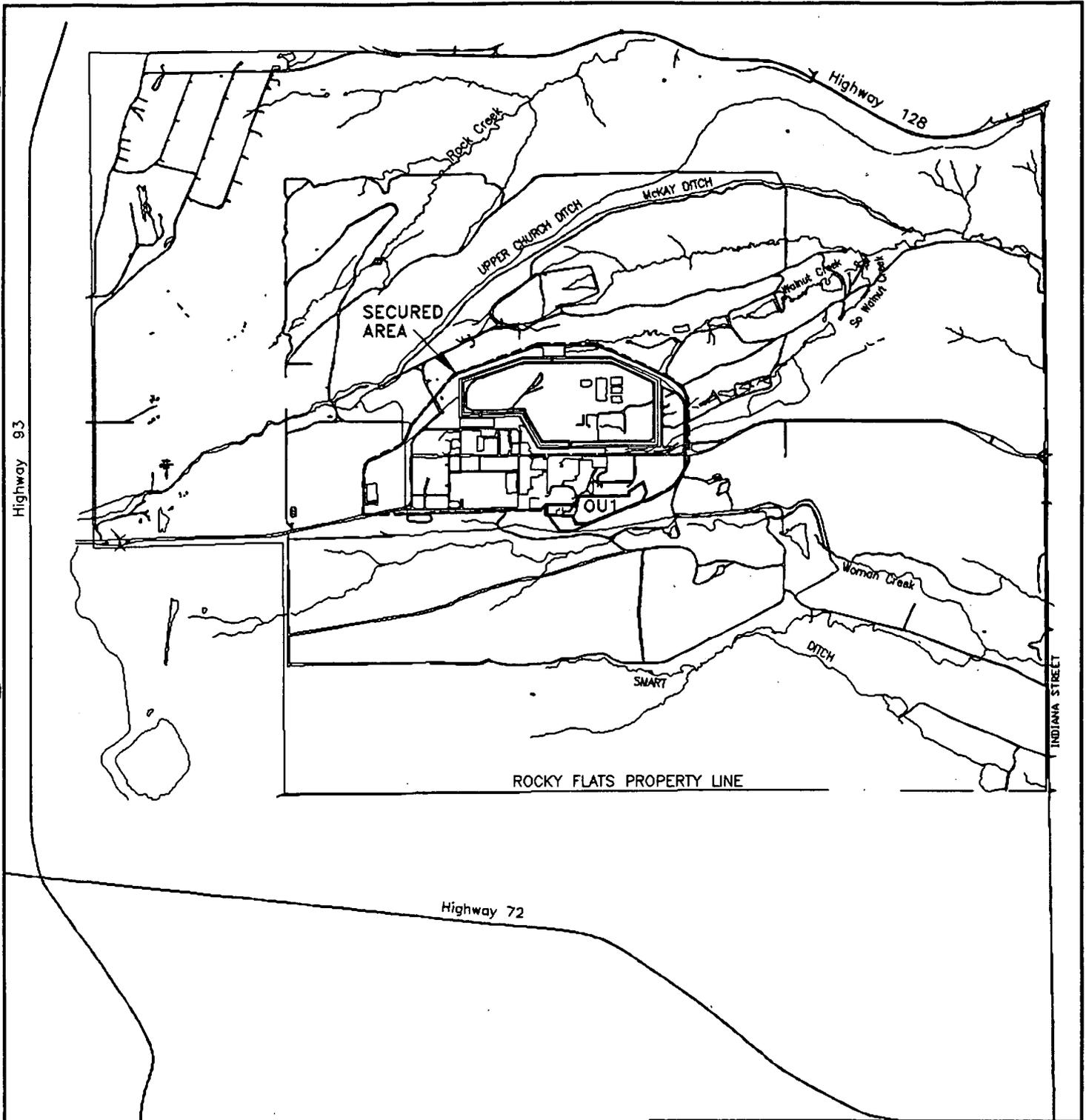
**U.S. DEPARTMENT OF ENERGY**  
 Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFI/RI REPORT

**General Location of  
 Rocky Flats Plant**

Figure F 2-1

REV. JULY 1993  
 OCTOBER 1992



U.S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden, Colorado

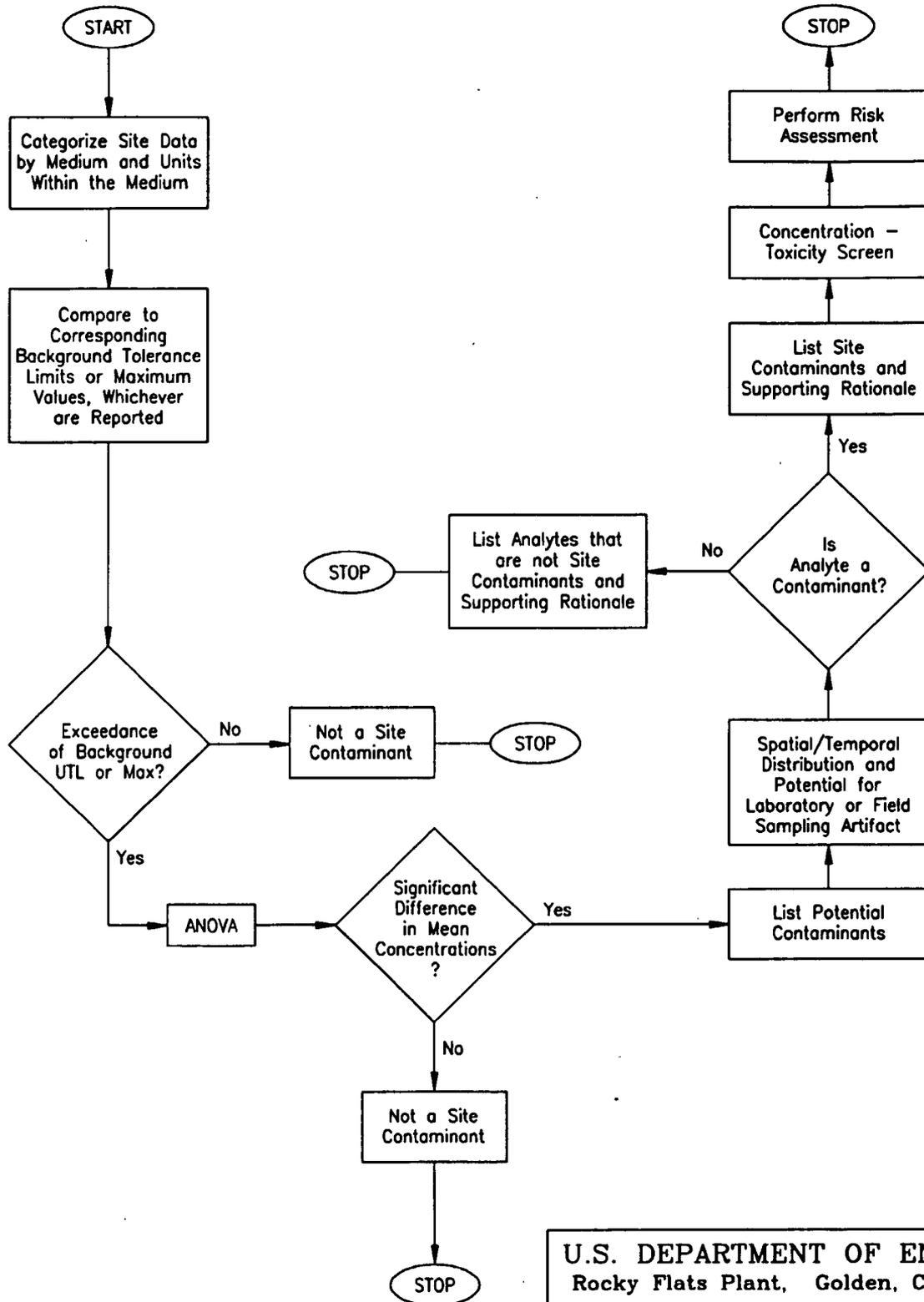
881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFI/RI REPORT

Rocky Flats Plant, Buffer Zone  
 and Secured Area

Figure F 2-2

AUGUST 1993

RT4225.MC082055



R74029.MBCW-061094

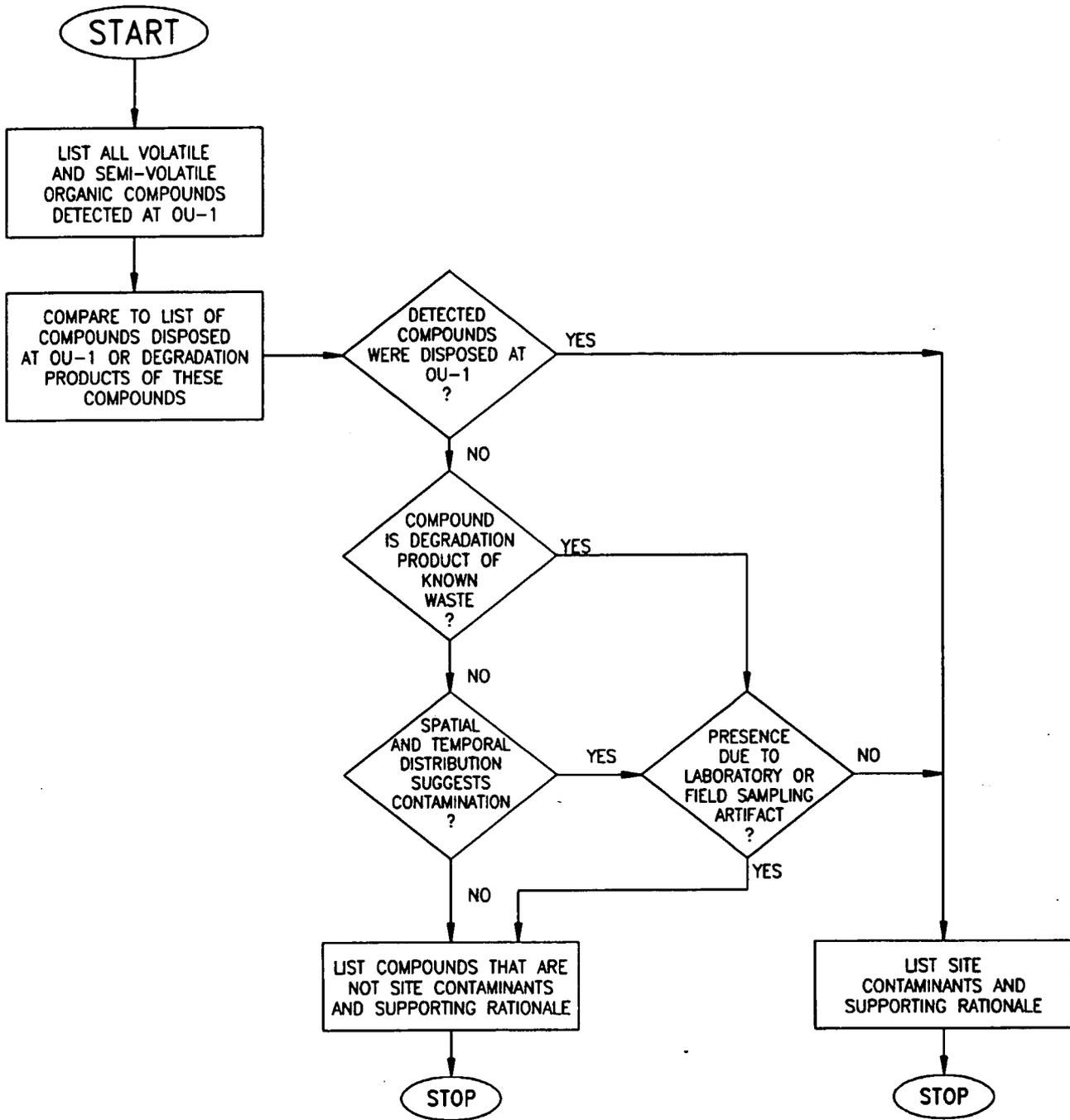
U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

Determination of Site Contaminants  
Inorganic Analytes

Figure F2-5

REV. JUNE 1994  
AUGUST 1993



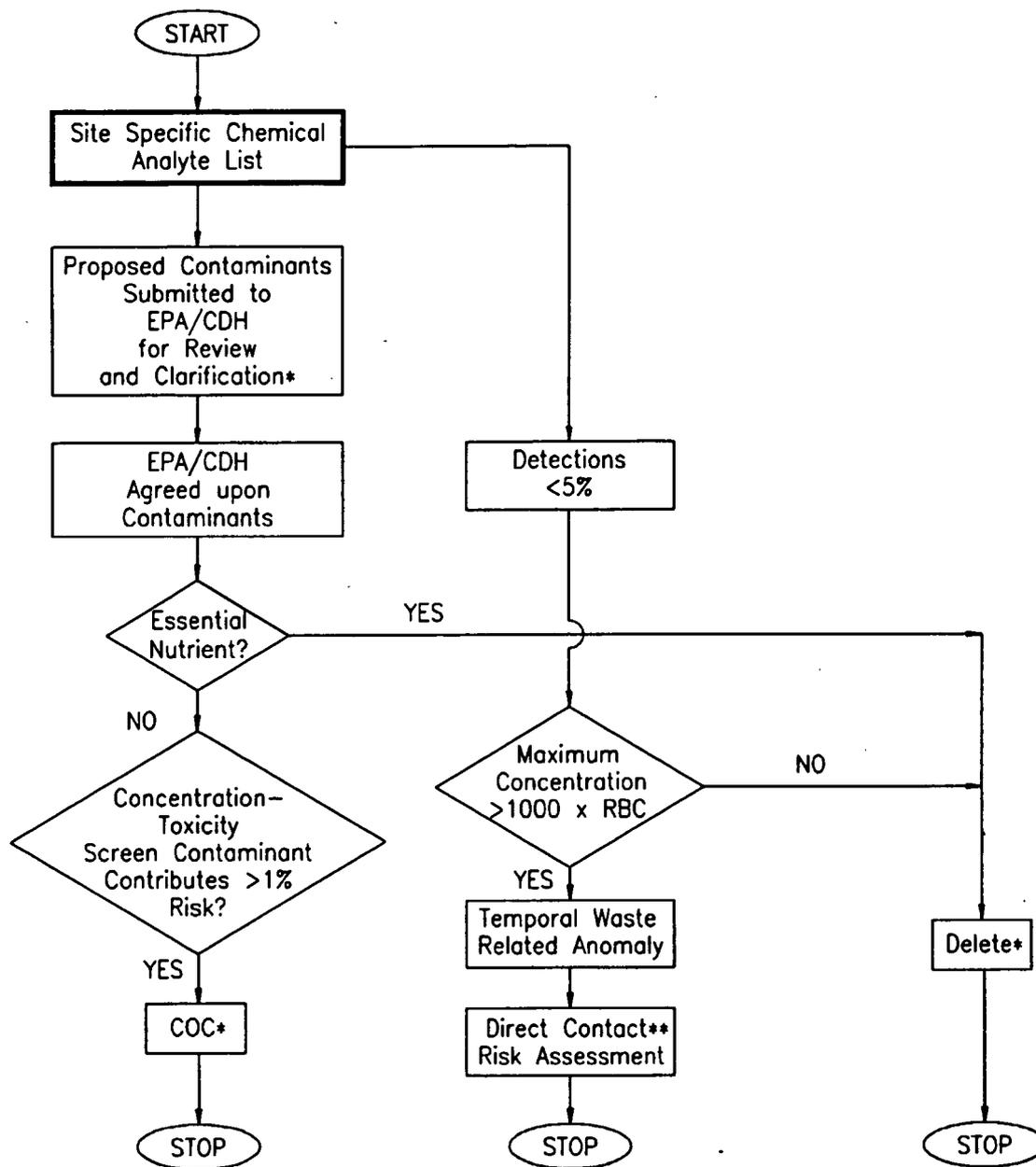
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**U.S. DEPARTMENT OF ENERGY**  
 Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFI/RI REPORT  
 Determination of Site Contaminants  
 Volatile and Semi-Volatile  
 Organic Analyte

Figure F2-6

REV. JUNE 1994  
 AUGUST 1993



• PROFESSIONAL JUDGEMENT MAY BE USED TO RETAIN OR DELETE A CHEMICAL.

\*\* DIRECT EXPOSURE THROUGH INGESTION, INHALATION OR DERMAL EXPOSURE AS APPLICABLE.

UTL = Upper Tolerance Limit  
 ANOVA = Analysis of Variance  
 RBC = Risk Based Concentration

U.S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden, Colorado

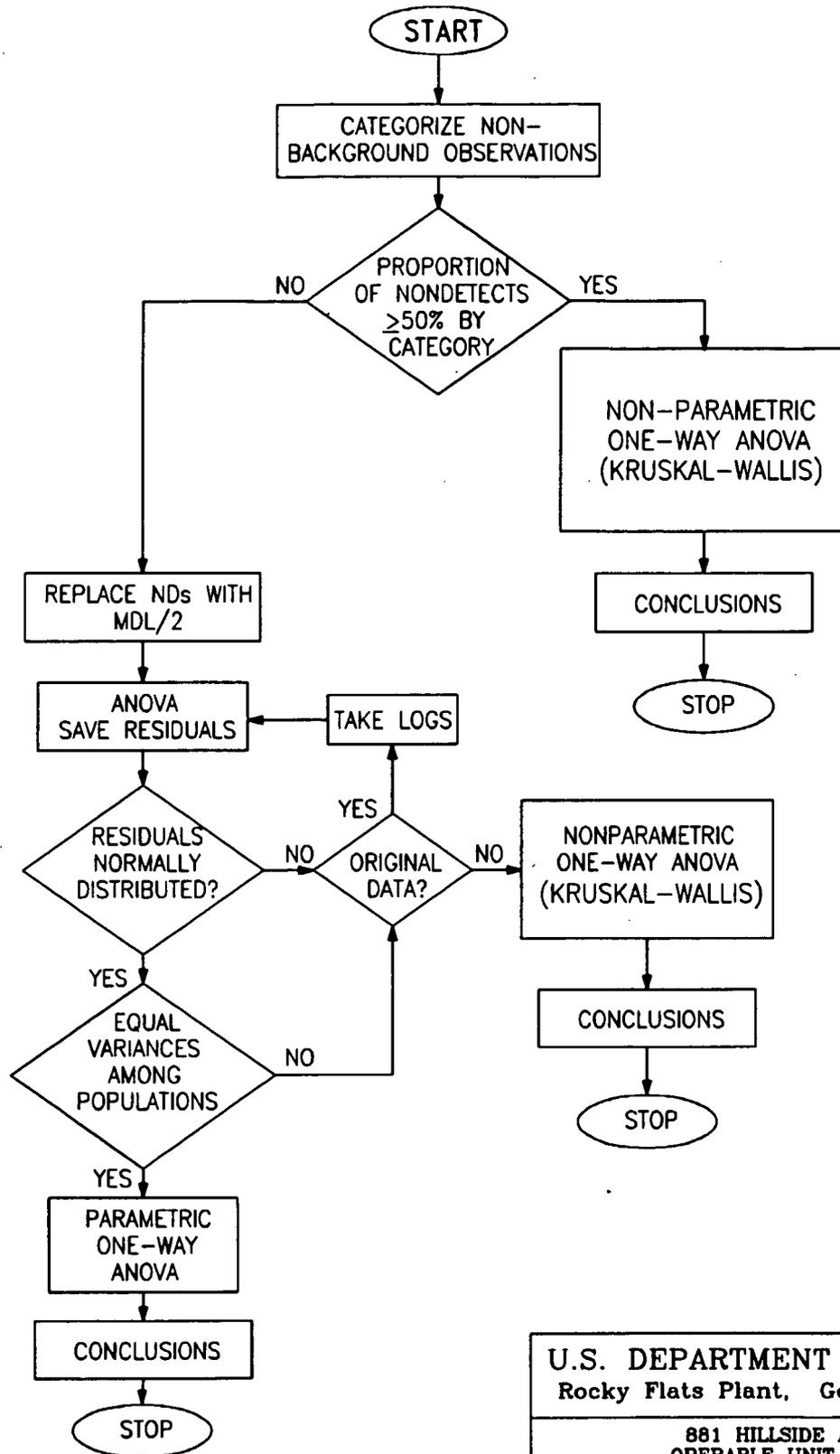
881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RF1/RI REPORT

Contaminants of Concern  
 Screening Flow Chart

Figure F2-7

REV. FEBRUARY 1994  
 AUGUST 1993

R74266.PJMBPJ-053194



U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RF1/RI REPORT

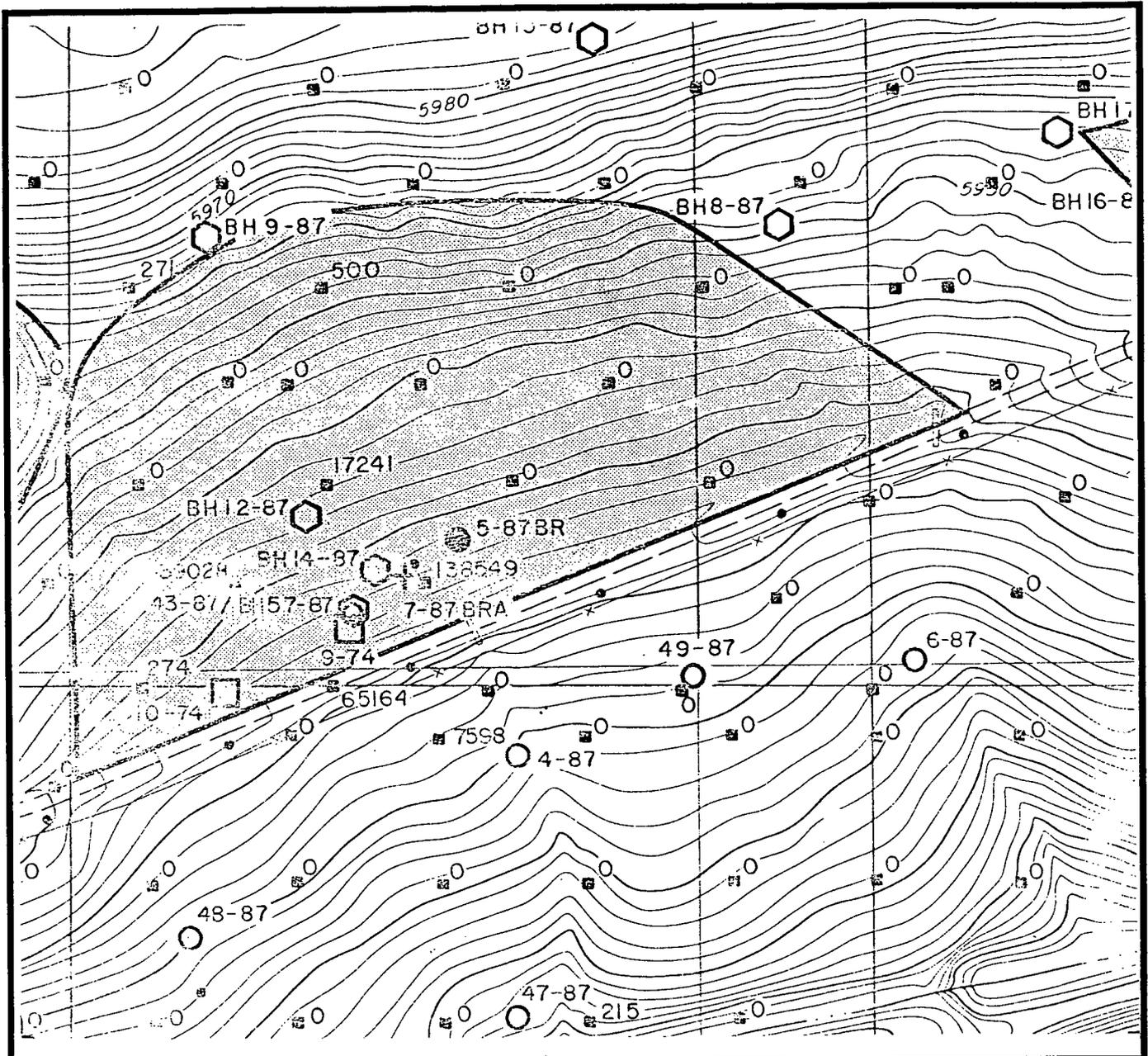
Selection of Statistical Method for  
Comparison of Background and  
Non-Background Populations

Figure F2-8

REV. OCTOBER 1993  
AUGUST 1993

ADAPTED FROM EPA, 1989

R74156.PJMB051194



**EXPLANATION**



SWMU Location



Soil Gas Sample Location



4-87 Alluvial Monitor Well



5-87BR Bedrock Monitor Well



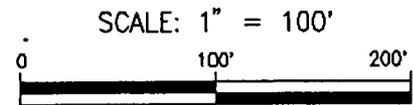
10-74 Pre-1986 Monitor Well



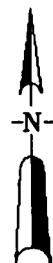
138549 Abandoned Hole



BH14-87 Borehole



Contour Interval = 2'



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Rocky Flats Plant, Golden, Colorado

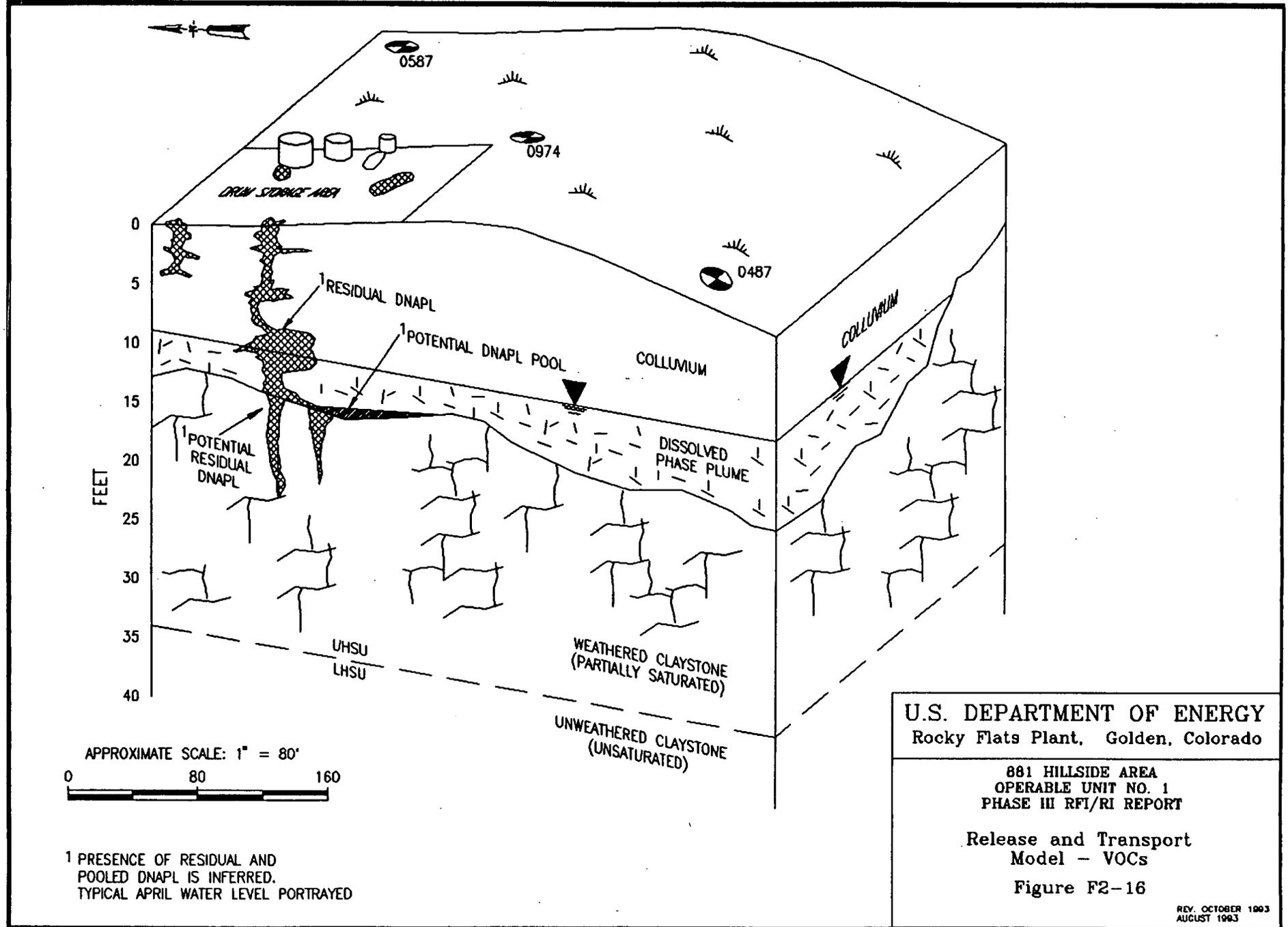
861 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

Trichloroethene Molecular Counts  
in Soil Gas Near IHSS 119.1

Figure F2-10

REV. OCTOBER 1993  
MARCH 1988

R74242.PJMB102093-082393



U.S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFI/RI REPORT

Release and Transport  
 Model - VOCs  
 Figure F2-16

1 PRESENCE OF RESIDUAL AND POOLED DNAPL IS INFERRED. TYPICAL APRIL WATER LEVEL PORTRAYED

## SECTION F3 CONTAMINANTS OF CONCERN

### F3.1 INTRODUCTION

Hazard identification is the process of assessing whether exposure to a substance can be associated with an increase in the incidence of an adverse health effect (NRC, 1983). For the PHE, it involves identifying those contaminants that potentially represent the most toxic contaminants at the site based on environmental fate characteristics, toxicity, and the concentration of contaminants present at a site. Figure F3-1 illustrates the contaminant identification process applied for the Phase III RFI/RI through PHE COC identification. The goal is to identify those OU1 contaminants that present the most significant risk to current and future populations given the OU1 exposure scenarios and pathways (Section F4).

Generally each step in the COC identification process represents a screening criterion which, after evaluation, either retains or eliminates a specific contaminant for consideration in the PHE. For the OU1 contaminants, the process is initiated using the environmental data aggregated for use in the Phase III RFI/RI (Section F2) for groundwater, subsurface soils, and surface soils within the OU boundaries. The PHE COC identification focuses on these media because each is observed within the OU1 IHSS areas, representing the actual physical characteristics of the contaminated portions of the site. As a result, the contaminants identified in these media are considered to be representative of the primary contaminant sources at OU1.

As illustrated in Figure F3-1, after consultation with the EPA and CDH, a specific contaminant brought into the PHE COC identification process is either a site contaminant identified via the RFI/RI process as described in Section F2 or a potential anomaly. The process is applied on a medium-specific basis (i.e., groundwater, subsurface soil, surface soil) and accommodates the contaminants as follows:

- Contaminants identified by the RFI/RI process have concentrations elevated with respect to background (as discussed in Section F2 and presented in Table F2-1). The contaminants are evaluated for the PHE using medium-specific concentration-

toxicity screens. The screens are conducted independently for carcinogens and noncarcinogens. The results of the independent concentration-toxicity screens are then combined for each medium to form the COC list for that medium.

- Contaminants and analytes with a low frequency of detection are evaluated using a risk-based concentration (RBC) screen. This screen ensures that anomalous contaminants eliminated by the RI process because of infrequent or unexplained detection in OU1 media are not overlooked if they are measured at concentrations that could pose a significant risk.

Section F3.2 presents a data summary of the data set used for the PHE and discusses contaminants identified by the field investigation. The PHE screening of contaminants is presented in Section F3.3, and a summary of contaminants is provided in Section F3.4. Section F3.5 summarizes the data usability, and Section F3.6 describes the treatment of the data.

### **F3.2 CONTAMINANTS IDENTIFIED BY THE FIELD INVESTIGATION**

As discussed in Section F2, the OU1 contaminants were identified through a series of quantitative and qualitative evaluations with respect to contaminant source knowledge and contaminant background characterization. These contaminants are summarized, by medium, in Table F2-1 and represent the outcome of the nature and extent assessment for OU1. The contaminants presented on Table F2-1 are evaluated to identify the COCs for the purpose of conducting the PHE.

The chemical-specific data used in the Phase III RFI/RI evaluations, COC identification process, and the risk characterization are summarized in Tables F3-1 through F3-14. The tables are divided by media, i.e., groundwater, subsurface soil, and surface soil, and subdivided within each medium by lithologic unit, i.e., Rocky Flats Alluvium (RFA), Valley Fill Alluvium (VFA), Colluvium (COL), Weathered Claystone (WCS), Arapahoe (KAR), if appropriate. These data are summarized across lithologic units for groundwater and subsurface soil. The chemical-specific data are presented in terms of:

- Detection frequency
- Contract required quantitation limit (CRQL)

- Range of sample quantitation limit (SQL) observed
- Minimum detected concentration
- Maximum detected concentration
- Arithmetic mean

Surface water and sediments in the SID and Woman Creek can potentially receive contamination from OU1 via overland flow and/or air dispersion and subsequent deposition. Influence to surface water and sediments from other contaminated media within OU1 (i.e., groundwater and subsurface soil) has been minimized by the construction of the French Drain, which acts as a hydraulic barrier; thus, impact to the drainage areas from these media is negligible. The SID and Woman Creek also receive potentially contaminated runoff from other operable units and are planned for investigation as part of OU5 (Woman Creek priority drainage). Contaminant information from these locations is not considered for COC identification in the PHE. The COCs for surface soil are evaluated for use in the risk characterization of surface water and sediment in the vicinity of OU1 under the potential exposure scenarios involving those media.

### **F3.3 SCREENING OF CONTAMINANTS**

A chemical enters into the COC screening process as either a site contaminant or a low-detection-frequency contaminant. This designation dictates which of the screening processes (i.e., concentration-toxicity screen or RBC screen) is applied to determine if the contaminant is considered in quantitative risk characterization. The COCs identified via this process are used to complete the contaminant fate and transport assessment as part of the PHE exposure assessment and risk characterization.

The purpose of the concentration-toxicity screen is to focus the quantitative risk assessment on those contaminants posing the greatest risk given the exposure scenarios considered. Based on the findings in the RFI/RI, the OU1 contaminants in groundwater, subsurface soil, and surface soil are subjected to the screen. To conduct the concentration-toxicity screen, noncarcinogens and carcinogens identified in each media are grouped accordingly and combined with toxicity constants identified in EPA's Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST). It should be noted that toxicity constants are revised

by EPA toxicologists using professional judgement. Revision of these toxicity constants could alter the concentration-toxicity screen. The maximum concentration for each of the OUI contaminants is multiplied by the inverse of the reference dose (1/RfD) for the noncarcinogenic contaminants. The maximum concentration for carcinogens is multiplied by the slope factor. The multiplication described yields a risk factor for each of the potential contaminants (noncarcinogens and carcinogens). Because the risk factors are evaluated relative to each other, the absolute units do not matter as long as concentration units among chemicals in a medium are the same. By summing the risk factors for each group, the contribution to the total risk is calculated on a percentage basis. Those contaminants contributing to greater than one percent of the total risk are retained for quantitative assessment in the PHE.

The purpose of the RBC screen is to ensure that anomalous analytes eliminated by the RFI/RI contaminant identification process because of infrequent (i.e., <5%) or unexplained (i.e., no correlation with contaminant source information) occurrence are not overlooked if they are measured at concentrations that could pose a significant risk. This screen serves as a safety-net for such low-detection-frequency analytes. The RBC screen is conducted by comparing, on a media-specific basis, the maximum concentration of a specific chemical to a multiple of the calculated media-specific concentration based on a given risk level (i.e., for carcinogens a risk level of  $1 \times 10^{-6}$  was used). The maximum concentration in a given medium was compared with a concentration of 1,000 times the RBC.

Similar to the concentration toxicity screen, toxicity constants from IRIS or HEAST are used to calculate the RBC under set exposure assumptions. The RBCs are based on human-health effects from direct contact with environmental media. The March 1, 1993 memorandum from Stanford/Schneider, Region IX Preliminary Remediation Goals, First Quarter 1993, was used as the source of RBC values. In general, the RBCs are based on ingestion assumptions that should be sufficiently conservative (health-protective) to assure that this route is the predominate route of exposure, when compared with other routes such as dermal contact or inhalation.

### **F3.3.1**      **Groundwater**

The concentration-toxicity screens for the OU1 organic and inorganic contaminants in groundwater are summarized in Table F3-15 for noncarcinogens and Table F3-16 for carcinogens. These tables include the OU1 contaminants input to the screen, the associated maximum concentration values and toxicity constants used in calculating the percent contribution to risk, and the percent contribution. As indicated by the results (i.e., percent contribution of total risk) of the concentration-toxicity screen, five contaminants are included for quantitative evaluation in the PHE: 1,1,1-trichloroethane, carbon tetrachloride, 1,1-dichloroethene, tetrachloroethene, and selenium.

As indicated on Table F3-17, none of the low-detection-frequency-contaminant concentrations are in excess of 1,000 times the chemical-specific RBCs. Inclusion of these analytes in the PHE is not warranted.

Antimony and manganese were detected in groundwater but were not identified as site contaminants due to lack of a spatial or temporal pattern that distinguishes them from background. At the request of the EPA, the ingestion of antimony and manganese in groundwater are evaluated quantitatively for the future on-site resident. This additional information is provided in Section 7.3.

### **F3.3.2**      **Subsurface Soil**

The concentration-toxicity screens for the OU1 organic and inorganic contaminants in subsurface soil are summarized in Table F3-18 for noncarcinogens. A carcinogen screen for chemicals was not necessary. Table F3-19 summarizes the concentration-toxicity screen for radionuclides in subsurface soil. These tables include the OU1 contaminants input to the screen, the associated maximum concentration values and toxicity constants used in calculating the percent contribution to risk, and the percent contribution. Seven contaminants survived the screening process: americium-241, plutonium-239, -240, uranium-238, uranium-233, -234, fluoranthene, pyrene, and toluene. These contaminants are included for quantitative evaluation in the PHE.

As for groundwater, none of the low-detection-frequency-contaminant concentrations are in excess of 1,000 times the chemical-specific RBCs. Inclusion of these contaminants in the PHE is not warranted. The RBC screen for subsurface soil is presented in Table F3-20.

### **F3.3.3      Surface Soil**

The concentration-toxicity screens for the OU1 organic and inorganic contaminants in surface soil are summarized in Table F3-21 for noncarcinogens and Table F3-22 for chemical carcinogens. Table F3-23 summarizes the concentration-toxicity screen for radionuclides in surface soil. These tables include the OU1 contaminants input to the screen, the associated maximum concentration values and toxicity constants used in calculating the percent contribution to risk, and the percent contribution. Contaminants contributing to greater than one percent of the risk are: americium-241, plutonium-239, -240, uranium-233, -234, uranium-238, arochlor-1254, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, pyrene, fluoranthene, fluorene, and acenaphthene. These contaminants are included for quantitative evaluation in the PHE.

As indicated on Table F3-24, none of the low-detection-frequency-contaminant concentrations are in excess of the chemical-specific RBCs. Inclusion of these contaminants in the PHE is not warranted.

### **F3.3.4      Surface Water and Sediments**

As discussed in Section F3.2, surface water and sediment data are not screened independently to identify COCs for the OU1 PHE because they are technically not part of OU1 proper. However, because of potential influence to surface water and sediment from surface soil within OU1, the concentrations of individual surface soil COCs in each of these media are evaluated. The chemical-specific data for each medium are assessed for positive identification (i.e., any observed positive detection) of each surface soil COC. If a positive detection is observed, the contaminant becomes a COC for that medium. The evaluation results in the following surface water COCs: americium-241, plutonium-239, -240, uranium-233, -234, and uranium-238. The

sediment COCs are: americium-241, plutonium-239, -240, uranium-233, -234, uranium-238, aroclor-1254, benzo(b)fluoranthene, benzo(k)fluoranthene, pyrene, and fluoranthene.

#### **F3.4 SUMMARY OF CONTAMINANTS OF CONCERN**

By combining the outcomes of the toxicity-concentration screen and the RBC screen, the COCs for the OU1 PHE are identified. The results of this process are summarized by media on Tables F3-25 through F3-44. A COC matrix with summary statistics is provided in Table F3-45.

The volatile organic components identified in groundwater are moderately mobile in the environment because they are soluble in water. Many of the volatile organic compounds identified as COCs are transformation products. The transformation reactions are sequential, so not all of the degradation compounds are expected to be present. The matrix on Table F3-46 provides a qualitative assessment of the potential transformation products of the identified COCs. With the exception of vinyl chloride, which is at the end of the reaction series for most of the COCs, all of the volatile organic COCs are potentially interrelated through degradation.

The radioactive COCs in subsurface soil, and radioactive and organic COCs identified in surface soils are considered immobile because both analyte groups are relatively insoluble in water. As a result, each group is considered persistent in the environment. Degradation or transformation products for the organic constituents observed in surface soil are not routinely observed; however, some of the radionuclides decay to daughter products. For example, americium-241 decays by alpha emission to neptunium-237, while plutonium-239 decays to uranium-235. Given the half-lives for these radionuclides (americium-241 has a half-life of 432 years, plutonium-239 has a half-life of 24,110 years), detectable concentrations for these decay products are not presently observed.

The radioactive COCs in surface soil are carried over to the surface water and sediment COC lists. A few of the surface soil polynuclear aromatic hydrocarbons (PAHs) and aroclor-1254 were also identified in the sediment. Because of the insolubility of these contaminant groups,

suspended particulate transport in either air or overland flow could have redeposited these contaminants in the South Interceptor Ditch or the Woman Creek Drainage.

### **F3.5 DATA USABILITY SUMMARY**

The OU1 Phase III RFI/RI was conducted in accordance with the *Sitewide Quality Assurance Project Plan* (EG&G, 1990d) and the Standard Operations Procedures (SOPs) (Rockwell, International, 1989) as amended by the *Rocky Flats Environmental Management Department Standard Operating Procedures* (EG&G, 1991a). Sampling and analysis activities were implemented using these procedures and all addenda to these procedures, as identified in Section 2 of the RFI/RI Report.

Data Quality Objectives (DQOs) were established in the *Final 881 Hillside Area Phase III RFI/RI Work Plan* (DOE, 1990d) and detailed in the Quality Assurance Addendum (QAA) to the Work Plan for the OU. DQOs were established for each analyte group and each matrix (i.e., aqueous, nonaqueous) sampled as part of the Phase III Work Plan implementation. Per EPA guidance, DQOs are expressed in quantitative and qualitative terms of precision, accuracy, representativeness, completeness, and comparability. These parameters are routinely referred to as the PARCC parameters.

This section presents a data quality and usability summary for the RFI/RI. The data usability summary evaluates how the data quality supports or limits the achievement of the prescribed DQOs, and how it effects data usability for the PHE. Achievement of the individual PARCC parameters in relation to matrix, where appropriate, is described along with broad impacts to the data sets used for the PHE.

#### **F3.5.1 Data Validation**

Analytical data were generated using EPA and other well-established methods identified in the General Routine and Radiochemical Analytical Services Protocol (EG&G, 1990c). EPA Contract Laboratory Program (CLP) methods and protocols were used in the analysis of Target

Analyte List (TAL) metal parameters and Target Compound List (TCL) organic parameters. Methods for non-CLP analytes, for example, major ions and radionuclides, are based on EPA and other published references. The analytical data were reviewed and validated independently of the laboratory, and the results were documented in data validation reports. EPA data validation functional guidelines were used for validating organics and metals data for CLP analytes. Non-CLP analytical data were validated using data validation guidelines developed by the Rocky Flats Environmental Management Department (EMD) because such guidelines have not been published by EPA. These non-CLP guidelines are based on EPA validation functional guideline concepts and tailored to non-CLP analytical methods.

Three classes of data quality are used by EMD: (1) V — Valid and usable without qualification; (2) A — Acceptable for use with qualification(s); and (3) R — Rejected (unacceptable). Valid data meet the following objective standards, where applicable:

- \*1. analytical methods followed
2. acceptance criteria achieved
3. sufficient number and type of QC samples analyzed
- \*4. QC limits achieved
- \*5. compounds and analytes correctly identified
- \*6. equipment/instrumentation calibration criteria achieved
7. sample holding times met

\* primary validation criteria

Data that are acceptable with qualifications meet most, but not all, of the above standards. At the minimum, all of the primary validation criteria are achieved within acceptable limits. Rejected data fail to meet primary validation criteria. As shown in Appendix C, analytical results are coded with the appropriate data qualifier (V, A, or R) based on the results of the data validation. For the purposes of the OUI Phase III RFI/RI and PHE, valid and acceptable data were considered of equal utility. Rejected data have not been used in any statistical computations or in the PHE and EE. It should be noted that data that have not yet been validated have been used out of necessity, i.e., to provide an adequate quantity of data for conceptual analysis and for statistical analysis with an acceptable level of confidence. Use of

unvalidated data should not reduce the soundness of the conclusions drawn because most of the data (96%) that have been validated are either valid or acceptable.

Table G-1, Appendix G, summarizes the Phase III data validation status for OU1 geologic material, groundwater, sediments, seep water, surface soils, and surface water. Table F3-47 provides the percentage of results that have been validated and the percentage of rejected data for those results that were validated. At present, 66% of the Phase III data had been validated. The low percentage of data validation for volatile organics and metals data are the single largest contributors to a two-thirds overall percent validation, e.g., note the low percent validation for volatile organics and metals in groundwater, seep water, and surface water.

With two-thirds of the data having been validated, it is important to note that, overall, only 4% of these data have been rejected. Of all the analyte groups, radiochemistry data have the highest percentage of rejected data, typically 20% but as low as 10% and as high as 41% (Table F3-47). These rejected data have not been used in any conceptual or statistical analysis. The overall low percentage of rejected data indicates that use of nonvalidated data to perform conceptual and statistical analysis should not compromise the validity of the resulting conclusions.

Approximately 71% of the Phase I/II data were validated and determined to be valid or acceptable.

### **F3.5.2      Assessment of Data Usability**

#### **F3.5.2.1      Precision**

Precision is a measure of mutual agreement among individual measurements of the same property, under identical conditions. Precision is assessed by means of laboratory duplicate/field replicate sample analysis. The objective of calculating sampling and analytical precision is to demonstrate that reproducibility of measurements between similar samples is acceptable.

Precision is quantified by calculating the relative percent difference (RPD), i.e., the quotient of the difference between the duplicate analytical results and the average of those results for the given analyte expressed as a percentage:

$$\% \text{ RPD} = 100(C1 - C2)/(C1 + C2)/2$$

where:

RPD = Relative percent difference  
C1 = Concentration of analyte in the sample  
C2 = Concentration of analyte in the duplicate

It should be noted that prior to use in the RFI/RI, duplicate sample results were averaged to compensate for variabilities observed in the results. By averaging the duplicates, a representative concentration was obtained, minimizing the effects of potential bias and, in turn, promoting data usability. Results of all field duplicate analyses and the calculated RPDs are presented in Appendix G.

### Field Precision

The procedure for collection of field duplicates is dependent on the medium being sampled. With respect to groundwater and surface water samples, the field duplicates are collected following the actual sample collection using the same sampling technique. For soil samples, it is necessary to obtain splits of the interval being sampled, with the sample and duplicate being collected using the same technique.

As mentioned above, the data from the sample and field duplicate provide a measure of the sampling precision and sample homogeneity, i.e., the amount of error in the data attributed to sampling technique, or to variability in the analyte concentration in the medium being sampled. The field precision objective specified in the QAA is to obtain a RPD of  $\leq 30$  for aqueous samples and  $\leq 40$  for homogeneous, nonaqueous samples. For metals at concentrations near the quantitation limit it is acceptable to assess precision of results by the CRQL (i.e., the precision is acceptable if the results fall within  $\pm$  the CRQL of each other) rather than

calculating RPD. This rule for metals has been applied to other analytes as it represents a logical extension of the concept. A summary of the degree to which the field precision goals were met is provided in Table F3-48. This table provides precision summaries for both filtered and unfiltered metals and radionuclide data: however, the PHE utilized only the unfiltered data.

With respect to unfiltered (Table G-14) and filtered (Table G-15) aqueous metals, the field precision goal was achieved in 92.9% and 98.7% of the duplicate samples (Table F3-48), respectively. The metals aluminum, iron, manganese, and zinc show the highest variability in these aqueous samples. Aluminum, iron, and manganese (and zinc most likely through adsorption) are associated with aluminosilicate clay particles and/or exist as metal oxides. It is noted that the variability in the concentrations of these metals is higher for the unfiltered metals than for the dissolved (filtered) metals. The variability may be due to the inherent variability of the suspended solids (clays) concentrations in the water. Because the dissolved concentrations are "mechanically" defined, i.e., that which passes a  $0.45\mu$  filter, the variability in the dissolved fraction may simply reflect this variability in the suspended solids concentrations.

Many of the aqueous radionuclide duplicate sample RPDs (Tables G-16 and G-17) were in excess of 30%; however, the activities observed were at levels indistinguishable from the minimum detectable activity and in many cases were negative values. Reproducibility under these circumstances is difficult to achieve because of analytical limitations and, therefore, does not reflect poor field precision. Considering only the RPD criterion, only 35.4% and 56.4% of the unfiltered and filtered duplicates achieved the goal, respectively. However, when accounting for variability for those concentrations near the CRQL (actually MDA for radionuclides), 93.1% and 87.2% of the field precision estimates were acceptable for the unfiltered and filtered radionuclide duplicates.

The aqueous field duplicate samples did not contain significant concentrations of volatile, semivolatile or PCB/pesticide compounds (Tables G-11 through G-13). The calculated RPD ranged from 0 to 191%; however, because of the near-detection-limit observations, this does not reflect poor field precision as 98.4% of the RPDs exceeded the precision goal, and 99.8% of the duplicates exceeded the precision goal considering the CRQL criterion (Table F3-48).

Metal concentration reproducibility between field duplicates is usually more difficult to achieve in solid matrices because of the inherent heterogeneous nature of the samples. The subsurface soil and surface soil sample results were the most difficult to reproduce with an RPD range from 0 to 183% (Tables G-14). Calcium, aluminum, iron, and manganese frequently resulted in RPD values in excess of 40% and, to a lesser extent, nickel, barium, chromium, and copper. The RPDs for sediment field duplicates were all < 40%. The field precision goal for the metals in nonaqueous samples was attained in 92.6% of the field duplicates.

The duplicate analyses for radionuclide analyses in solid media (Table G-16) were more reproducible than the aqueous samples primarily because the activities are higher. The range of RPDs calculated was from 0 to 200% with an average of approximately 40%. The field precision goal for radionuclides in nonaqueous samples was attained in 88.9% of the field duplicates considering the CRQL criterion.

Similar to the aqueous sample duplicates, the nonaqueous field duplicate samples did not contain significant concentrations of volatile, semivolatile or PCB/pesticide compounds (Tables G-11 through G-13). The near-detection-limit concentrations adversely affected the precision of the analyses. Nevertheless, 97.4% of the duplicates achieved the field precision goal.

### **Laboratory Precision**

Laboratory precision is evaluated through the use of laboratory duplicates for inorganic analyses and matrix spikes (MS) and matrix spike duplicates (MSD) for the organic analyses. Duplicate precision is calculated as RPD; MS/MSD precision is assessed by calculating a RPD between the percent recoveries (%R) observed for the method-specific spiked compounds. Laboratory precision goals are mandated by the analytical method for each analyte group and assessed for achievement during data validation. Data not meeting the precision goals are normally qualified for use.

Review of the validation summary presented in Appendix G, Tables G-1 and G-2 indicates that poor analytical precision was not a recurring problem resulting in data rejection. With the

exception of the radiological analyses, data were not rejected due to precision problems, i.e., replicate precision was routinely achieved. Radiological data were rejected due to precision related problems as noted by validation rejection reason citations of; replicate analysis not performed, replicate precision criteria not met, LCS relative percent error criteria not met, etc. (Table G-2).

### **F3.5.2.2 Accuracy**

The accuracy of data obtained in an investigation is a function of the sampling technique, potential for sample contamination, and analytical capabilities of the laboratory. Accuracy means the nearness of a result, or the mean of a set of results, to the true value. Accuracy is assessed by analysis of reference samples of known concentration (i.e., Laboratory Control Sample [LCS]), percent recoveries for spiked samples, and by review of blank data (i.e., field blanks, trip blanks, method blanks) which may have an affect on measurement accuracy.

#### **Field Accuracy**

Field accuracy is assessed by comparing sample analyte concentrations to those present in associated field blanks. Field blanks and equipment rinsate blanks were collected to quantify the analyte concentration in a sample that may be attributable to desorption from sampling equipment. A field blank determines to what extent the sample bottle is a source for the observed analyte concentration in a sample. A field blank (or trip blank) is collected by filling a sample bottle with laboratory grade water in the field. Equipment rinsate blanks are used to monitor for sample cross-contamination and the effectiveness of the decontamination process. The blanks are collected by rinsing decontaminated sampling equipment with laboratory grade water, placing it in the appropriate container, and preserving as required. Tables G3-a through G-10a summarize the analytes found in field blanks and their detection frequency. Table G-3b through G-10b provide the analytical results for the blank samples.

As discussed below, the field and equipment rinsate blank data indicate, with few exceptions, that the sampling equipment are not significant sources contributing to the observed analyte

concentrations in the OUI samples. This is concluded because of the absence of low concentrations of analytes in the blanks relative to the samples.

As shown in Table G-3a, for the volatile organics, acetone and methylene chloride were frequently present in the field blanks. As noted in the functional guidelines for organic data validation, these are common laboratory solvents and are often inadvertently introduced into samples from exposure to the laboratory atmosphere. In accordance with CLP protocol, the data validators assess whether the occurrence of these compounds in samples is due to laboratory contamination by comparing the sample results to laboratory blank results, and drawing their conclusions based on the magnitude of the difference. In some cases, it was determined that the occurrence of these compounds in the samples was laboratory artifact (datum is qualified with a U), but in many others cases, the data validators determined that these compounds may actually be present in the samples, even though also present in the laboratory blank (datum qualified with a B). The frequent occurrence of these compounds in the field blanks (68% and 48% for acetone and methylene chloride, respectively), at magnitudes as high as 36  $\mu\text{g}/\ell$  (Table G-3b, Appendix G), strongly suggests that these compounds are not site contaminants (and therefore not COCs) for the PHE. Background data and other observations of the samples support this conclusion, and are discussed further in Appendix D.

With respect to semivolatile organics, Table G-4a indicates that phthalates occurred most frequently in the field blanks, albeit at low frequencies (approximately 10% of the samples) and low magnitude (1 to 17  $\mu\text{g}/\ell$ ) (Table G-4b). The CLP recognizes phthalate esters as common laboratory contaminants arising from plasticizers and sample contact with plastics. As discussed in Appendix D, these data together with other supporting data indicate that phthalates are not site contaminants (and therefore not COCs for the PHE), but rather, their presence in field samples indicates laboratory or field sampling artifact.

As shown in Table G-5 (Appendix G), pesticide/PCBs did not occur in the field blanks.

Comparison of CRQLs and the concentrations of metals, radionuclides, and water quality parameters in the field blanks (Tables G-6 through G-10) indicates that, with few exceptions,

concentrations in the blanks are below the CRQL, indicating the field sample data are not biased due to laboratory or sampling introduced contamination.

In conclusion, with few exceptions the magnitude of the analyte concentrations observed in the blank samples are inconsequential in relation to the analyte concentrations observed in the field samples. The frequency of detection of analytes in the blank samples is also relatively low. Therefore, inadequate field accuracy was not a factor compromising the usability of the data for the PHE.

### **Laboratory Accuracy**

Accuracy of the chemical laboratory data is assessed through the calculation of %R from MS samples for inorganic analytes, MS/MSD samples for organic analytes, and any in-house or blind certified standards (i.e., LCS) that the laboratory analyzes as part of its ongoing quality assurance/quality control (QA/QC) program. Acceptable recovery for the inorganic MS samples is routinely 75 to 125%. The %R for the organic MS/MSD analyses is mandated by the analytical method for the specific spiked compounds. Acceptable accuracy of the LCS is %R between 80 to 120%. Use of method blank analyses in the laboratory also assists in assessing the analytical accuracy. All of these measures of analytical accuracy are evaluated during the method data validation process. When analytical accuracy goals are not achieved, data are normally qualified for use.

Evaluation of the validation summary presented in Appendix G, Tables G-1 and G-2 indicates rejection of data is often associated with accuracy problems. Most of the reason codes cited for data rejection are related to accuracy. However, as discussed in Section F3.5.1 only 4% of the validated data have been rejected; radiochemistry having the highest percentage of rejected data. As shown in Table G-2, radiochemistry data were often rejected because calibration verification criteria were not met, LCS recovery criteria were not met, or LCS data were not submitted, etc.

### **F3.5.2.3 Representativeness**

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter that is most concerned with proper network design, sampling locations, and the sampling methods.

Representativeness of the extent of contamination in OU1 media is supported by the extensiveness of the phased sampling efforts to characterize the OU. The Phase III RFI/RI Work Plan was designed based on the data needs identified in two previous RI phases. The sampling activities were designed and conducted to maximize the use of existing wells and optimize the network by new well placement. Representativeness is considered in project planning and supported by the Phase III RFI/RI Work Plan, QAA, and associated operating procedures. The plans and procedures are reviewed and approved by appropriate technical and agency representatives. As a result, the network and sampling design for the Phase III RFI/RI are assumed to be representative of site conditions.

### **F3.5.2.4 Comparability**

Comparability is used to express the confidence with which one set of data can be compared to another set. Comparability is promoted by using similar sampling and analytical methods and reporting data in uniform units. To achieve comparability of data, all analyses prescribed in the Work Plan and performed in support of the Phase III RFI/RI are EPA-accepted or equivalent methods. Comparability of the data supporting the Phase III has also been promoted by using approved and standardized sampling techniques. The data are reported in uniform units: micrograms per liter ( $\mu\text{g}/\ell$ ), micrograms per kilogram ( $\mu\text{g}/\text{kg}$ ), picoCuries per liter ( $\text{pCi}/\ell$ ), and picoCuries per gram ( $\text{pCi}/\text{g}$ ); however, variations in the quantitation limits are indicative of the differing analytical methods used for the previous investigations versus the Phase III RFI/RI. This observation is most notable for the volatile organic analyses where a low-detection-limit method was prescribed to better evaluate the contamination at OU1. A demonstration of the

comparability of the data is the general consistency in the results between Phase I, II, and III for all media sampled, as discussed in Sections 4.3 through 4.8 of this RFI/RI Report.

#### **F3.5.2.5      Completeness**

The objective for completeness is that the investigation provides enough planned data so that the objectives of the project are met. Completeness for the Phase III RFI/RI is evaluated by comparing the planned to the actual number of samples collected and analyzed. The analytical results should be validated and deemed valid or acceptable to be considered in an assessment of completeness. The overall completeness goal for the project is 90%.

It is difficult to quantify completeness in strict accordance with the above noted guidelines. For example, over 30% of the data was not validated (but is considered usable for the reasons set forth in Section F3.5.1), the frequency of groundwater and surface water sampling was not specified, the number of samples collected from boreholes is based on the conditions encountered, etc. Therefore, a simpler, albeit less accurate, approach to quantifying completeness has been taken to perform the assessment. Table F3-49 summarizes the number of planned sampling locations and the number of locations actually sampled during the Phase III RFI/RI. For the most part, the number of samples collected and types of analyses performed at each sampling location were as specified in the Work Plan. Samples not collected (or sampling stations not installed) were due to extenuating circumstances related to cultural features preventing access, unexpected geologic conditions (e.g., insufficient depth of colluvium for colluvial well construction), weather, etc. As shown in Table F3-49, the RFI/RI data are approximately 87% complete.

### **F3.6    TREATMENT OF DATA**

Section 4.1 of the Phase III RFI/RI Report provides a thorough description of the data preparation and treatment prior to use in the Phase III RFI/RI or the PHE. This data treatment, the data sets used, and the statistical computations performed are summarized in Section F2. Data used for the Phase III RFI/RI (and PHE) are extracted from the Rocky Flats Environmental

Database System (RFEDS). RFEDS is an electronic database that houses all environmental data collected at the RFP. As described in the Phase III RFI/RI Report, unique data files were created for each analyte group excluding rejected data, and QC samples. Sample medium could be determined by the appropriate field in the database.

Summary statistics were calculated for all chemicals in the Phase III RFI/RI for background comparison purposes. The statistical methods used are described in Section F2. Excerpts from the statistics summaries are presented in Tables F3-1 through F3-14. The mean, standard deviation, and number of samples were used to calculate the 95 percent Upper Confidence Level (95% UCL) per the following equation.

$$95\% UCL = \bar{x} + t (s/\sqrt{n})$$

where:

$\bar{x}$	=	mean of the untransformed data
s	=	standard deviation
t	=	Student-t statistic
n	=	number of samples

The 95% UCL concentration values are used for calculating receptor intakes for the RME scenarios. OU-wide 95% UCL concentration values are presented for COCs in Table F3-45. Pathway and COC-specific 95% UCL concentrations are presented, as applied in the quantitative risk calculations, in Section F5 and Attachment F-4.

**Table F3-1a**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (RFA)**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
ALUMINIUM	100	200		12,800.00	56.90	2,211.0900
IRON	100	100		7,740.00	50.10	2,223.7100
LEAD	90	5	1.00 - 1.00	9.50	1.70	3.8700
LITHIUM	100	100		91.90	5.50	30.4200
MAGNESIUM	100	5000		50,600.00	18,400.00	34,455.0000
MANGANESE	100	15		592.00	59.80	252.8150
MERCURY	0	0.2	0.20 - 0.20	NA	NA	NC
MOLYBDENUM	80	200	2.00 - 3.00	13.40	3.50	7.6600
NICKEL	70	40	3.00 - 17.00	112.00	2.50	27.3000
POTASSIUM	100	5000		9,470.00	1,160.00	4,838.0000
SILICON	100	100		33,200.00	7,630.00	16,132.5000
SILVER	10	10	2.00 - 2.10	3.30	3.30	1.4650
SODIUM	100	5000		234,000.00	23,600.00	133,880.0000
STRONTIUM	100	200		1,970.00	507.00	1,040.7000
THALLIUM	0	10	1.00 - 2.00	NA	NA	NC
TIN	30	200	9.40 - 23.00	57.20	25.60	16.4950
ANTIMONY	40	60	8.00 - 19.80	60.00	41.40	27.6750
ARSENIC	50	10	1.00 - 2.00	3.00	1.00	1.5100

NA = Not Applicable  
NC = Not Calculated

**Table F3-1a (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (RFA)**

<b>Contaminant</b>	<b>Detection Frequency %</b>	<b>CRQL ug/L</b>	<b>Range of SQL Observed ug/L</b>	<b>Maximum Concentration Detected ug/L</b>	<b>Minimum Concentration Detected ug/L</b>	<b>Calculated Mean Concentration ug/L</b>
BARIUM		200		221.00	30.50	154.3000
BERYLLIUM	0	5	0.60 - 1.00	NA	NA	NC
CADMIUM	20	5	1.00 - 2.30	4.10	2.50	1.6850
CESIUM	11	1000	20.00 - 500.00	60.00	60.00	45.4000
CHROMIUM	80	10	2.00 - 5.00	36.40	2.30	14.8700
COBALT	50	50	2.00 - 4.00	6.90	4.70	3.3850
COPPER	90	25	2.30 - 2.30	90.00	5.00	26.4750
VANADIUM	90	50	3.50 - 3.50	34.70	2.90	9.4800
ZINC	100	20		117.00	8.30	55.2950
CALCIUM	100	5000		139,000.00	74,000.00	105,890.0000
SELENIUM	70	5	1.00 - 2.00	15.00	1.00	4.3300

NA = Not Applicable

NC = Not Calculated

**Table F3-1b**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (VFA)**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
ALUMINUM	100	200		6,940.00	220.00	2,799.9167
IRON	100	100		6,350.00	393.00	2,871.2778
LEAD	78	5	1.00 - 1.00	8.20	1.80	4.0361
LITHIUM	89	100	50.00 - 50.00	71.70	4.85	30.1847
MAGNESIUM	100	5000		48,300.00	8,890.00	26,253.6111
MANGANESE	100	15		1,210.00	71.50	407.1722
MERCURY	0	0.2	0.20 - 0.20	NA	NA	NC
MOLYBDENUM	58	200	2.00 - 10.00	18.30	3.50	6.2958
NICKEL	89	40	8.50 - 8.50	19.50	3.60	9.6667
POTASSIUM	89	5000	2,000.00 - 2,000.00	6,170.00	1,190.00	2,845.0000
SILICON	100	100		15,800.00	6,370.00	11,363.3333
SILVER	22	10	1.00 - 5.00	3.70	2.45	1.5042
SODIUM	100	5000		183,000.00	108.00	70,258.2778
STRONTIUM	100	200		1,440.00	237.50	751.0000
THALLIUM	0	10	1.00 - 2.00	NA	NA	NC
TIN	0	200	10.00 - 100.00	NA	NA	NC
ANTIMONY	33	60	8.00 - 50.00	47.40	6.30	13.7194
ARSENIC	22	10	1.00 - 2.00	2.40	0.85	0.9097

NA = Not Applicable  
NC = Not Calculated

**Table F3-1b (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (VFA)**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
BARIUM	100	200		254.00	111.00	159.1250
BERYLLIUM	11	5	1.00 - 2.00	1.60	1.60	0.7250
CADMIUM	33	5	1.00 - 3.00	1.90	1.60	1.3167
CESIUM	25	1000	23.00 - 500.00	70.00	50.00	51.7500
CHROMIUM	67	10	5.00 - 5.00	66.35	2.90	15.6097
COBALT	56	50	3.00 - 10.00	19.60	3.10	6.0528
COPPER	89	25	10.00 - 10.00	18.70	6.10	9.4472
VANADIUM	100	50		14.90	3.60	8.8694
ZINC	100	20		69.50	14.20	33.5097
CALCIUM	100	5000		147,000.00	38,700.00	92,684.7222
SELENIUM	44	5	1.00 - 2.00	7.20	2.70	2.8806

**Table F3-1c**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (COL)**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
ALUMINUM	100	200		205,000.00	87.55	18,042.7622
IRON	100	100		193,000.00	29.20	17,433.1100
LEAD	88	5	1.00 - 2.00	86.40	1.60	15.2489
LITHIUM	94	100	25.00 - 50.00	368.00	11.20	56.5456
MAGNESIUM	100	5000		80,400.00	16,200.00	41,807.2222
MANGANESE	97	15	25.50 - 25.50	3,660.00	16.60	417.3422
MERCURY	18	0.2	0.20 - 0.20	0.56	0.22	0.1480
MOLYBDENUM	94	200	2.00 - 10.00	466.00	3.20	45.8333
NICKEL	82	40	2.00 - 21.50	1,410.00	3.30	192.7233
POTASSIUM	97	5000		23,500.00	753.00	4,034.7333
SILICON	100	100		132,000.00	6,940.00	34,054.0000
SILVER	34	10	2.00 - 5.00	16.85	2.00	2.2363
SODIUM	100	5000		237,000.00	48,100.00	137,624.4440
STRONTIUM	100	200		2,130.00	644.00	1,233.6667
THALLIUM	9	10	1.00 - 2.00	2.00	1.00	0.6994
TIN	26	200	9.40 - 200.00	50.75	18.10	18.5050
ANTIMONY	45	60	8.00 - 50.00	210.00	10.90	26.6411
ARSENIC	76	10	1.00 - 2.00	11.40	1.00	3.4200

**Table F3-1c (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (COL)**

<b>Contaminant</b>	<b>Detection Frequency %</b>	<b>CRQL ug/L</b>	<b>Range of SQL Observed ug/L</b>	<b>Maximum Concentration Detected ug/L</b>	<b>Minimum Concentration Detected ug/L</b>	<b>Calculated Mean Concentration ug/L</b>
BARIUM	100	200		1,880.00	52.10	269.8578
BERYLLIUM	44	5	0.60 - 2.00	12.70	0.95	1.7161
CADMIUM	55	5	1.00 - 3.00	6.80	1.20	2.1122
CESIUM	19	1000	2.00 - 500.00	90.00	30.00	39.7262
CHROMIUM	85	10	2.00 - 5.00	2,360.00	2.50	236.4022
COBALT	65	50	2.70 - 10.00	76.30	3.30	9.2967
COPPER	94	25	2.00 - 10.00	2,440.00	2.40	233.0311
VANADIUM	100	50		403.00	4.50	48.9556
ZINC	97	20	2.50 - 2.50	2,730.00	11.50	321.5683
CALCIUM	100	5000		269,000.00	66,100.00	150,043.3330
SELENIUM	48	5	1.00 - 20.00	2,200.00	2.10	210.2606

**Table F3-1d**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (WCS)**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
ALUMINUM	100	200		41,200.00	303.00	12,598.0167
IRON	100	100		56,500.00	545.00	14,931.8833
LEAD	87	5	1.00 - 1.00	59.10	1.00	15.8633
LITHIUM	100	100		485.00	41.30	183.9217
MAGNESIUM	100	5000		94,400.00	12,800.00	43,605.0000
MANGANESE	100	15		1,480.00	9.00	329.6417
MERCURY	0	0.2	0.20 - 0.20	NA	NA	NC
MOLYBDENUM	93	200	3.00 - 3.00	41.50	4.70	14.7117
NICKEL	93	40	17.00 - 17.00	72.90	4.60	27.8400
POTASSIUM	100	5000		17,800.00	2,020.00	9,278.3333
SILICON	100	100		61,700.00	11,000.00	41,550.0000
SILVER	43	10	2.00 - 2.10	4.40	2.00	1.9292
SODIUM	100	5000		239,000.00	48,900.00	132,961.6670
STRONTIUM	100	200		3,720.00	463.00	1,654.1500
THALLIUM	7	10	1.00 - 2.00	1.00	1.00	0.7283
TIN	33	200	9.40 - 23.00	34.90	20.90	15.0433
ANTIMONY	54	60	8.00 - 19.80	87.50	20.80	30.6167
ARSENIC	60	10	1.00 - 2.00	6.60	2.00	2.9100

NA = Not Applicable  
NC = Not Calculated

**Table F3-1d (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (WCS)**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
BARIUM	100	200		511.00	62.10	195.1467
BERYLLIUM	33	5	0.60 - 1.00	3.00	1.10	0.9967
CADMIUM	79	5	1.00 - 2.30	3.70	1.30	2.3842
CESIUM	23	1000	30.00 - 500.00	50.00	30.00	36.3000
CHROMIUM	100	10		109.00	11.60	41.4450
COBALT	73	50	2.70 - 3.00	28.40	3.10	7.6825
COPPER	100	25		91.70	3.90	28.3183
VANADIUM	100	50		127.00	8.10	43.2550
ZINC	100	20		303.00	15.30	103.8567
CALCIUM	100	5000		312,000.00	40,200.00	154,420.0000
SELENIUM	100	5		1,240.00	54.00	400.0400

**Table F3-1e**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (KAR)**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
ALUMINIUM	100	200		25,400.00	53.30	4,428.6188
IRON	100	100		35,200.00	18.50	7,124.8625
LEAD	77	5	1.00 - 2.00	65.30	2.40	10.3275
LITHIUM	100	100		507.00	36.80	165.5125
MAGNESIUM	100	5000		94,600.00	7,340.00	38,177.5000
MANGANESE	100	15		701.00	11.90	169.0225
MERCURY	0	0.2	0.20 - 0.20	NA	NA	NC
MOLYBDENUM	92	200	10.00 - 10.00	29.70	5.00	15.4325
NICKEL	85	40	3.00 - 17.00	213.00	6.40	61.7813
POTASSIUM	100	5000		13,900.00	3,800.00	7,880.0000
SILICON	100	100		54,400.00	5,260.00	18,222.5000
SILVER	46	10	2.00 - 2.00	32.50	2.20	3.1275
SODIUM	100	5000		213,000.00	79,300.00	143,293.7500
STRONTIUM	100	200		3,550.00	365.00	1,628.8750
THALLIUM	0	10	1.00 - 2.00	NA	NA	NC
TIN	38	200	10.00 - 200.00	61.00	18.00	18.8213
ANTIMONY	75	60	8.00 - 18.00	108.00	9.30	40.2250
ARSENIC	69	10	2.00 - 2.00	9.30	2.00	3.7763

NA = Not Applicable  
NC = Not Calculated

**Table F3-1e (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater (KAR)**

<b>Contaminant</b>	<b>Detection Frequency %</b>	<b>CRQL ug/L</b>	<b>Range of SQL Observed ug/L</b>	<b>Maximum Concentration Detected ug/L</b>	<b>Minimum Concentration Detected ug/L</b>	<b>Calculated Mean Concentration ug/L</b>
BARIUM	100	200		294.00	32.70	85.2088
BERYLLIUM	33	5	1.00 - 2.00	4.30	1.30	1.5938
CADMIUM	62	5	1.00 - 10.00	7.60	1.30	2.3875
CESIUM	31	1000	2.00 - 51.00	80.00	60.00	35.5938
CHROMIUM	92	10	5.00 - 5.00	218.00	6.80	85.1488
COBALT	62	50	2.00 - 10.00	26.10	4.20	6.0813
COPPER	100	25		72.20	2.30	25.8488
VANADIUM	100	50		96.40	3.40	19.5275
ZINC	92	20	12.00 - 12.00	272.00	10.60	60.8775
CALCIUM	100	5000		316,000.00	25,700.00	129,250.0000
SELENIUM	38	5	1.00 - 2.00	233.00	130.00	43.3063

**Table F3-1f**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater**

Contaminant	Detection Frequency	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Average Concentration ug/L
ALUMINIUM	100	200		205,000.00	53.30	8,016.0809
IRON	100	100		193,000.00	18.50	8,916.9687
LEAD	85	5	1.00 - 2.00	86.40	1.00	9.8692
LITHIUM	96	100	25.00 - 50.00	507.00	4.85	93.3169
MAGNESIUM	100	5000		94,600.00	7,340.00	36,859.6667
MANGANESE	99	15	25.50 - 25.50	3,660.00	9.00	315.1987
MERCURY	7	0.2	0.20 - 0.20	0.56	0.22	0.1480
MOLYBDENUM	88	200	2.00 - 10.00	466.00	3.20	17.9867
NICKEL	84	40	2.00 - 21.50	1,410.00	2.50	63.8623
POTASSIUM	98	5000	2,000.00 - 2,000.00	23,500.00	753.00	5,775.2133
SILICON	100	100		132,000.00	5,260.00	24,264.4667
SILVER	33	10	1.00 - 5.00	32.50	2.00	2.0524
SODIUM	100	5000		239,000.00	108.00	123,603.6278
STRONTIUM	100	200		3,720.00	237.50	1,261.6783
THALLIUM	5	10	1.00 - 2.00	2.00	1.00	0.7139
TIN	27	200	9.40 - 200.00	61.00	18.00	17.2162
ANTIMONY	49	60	8.00 - 50.00	210.00	6.30	27.7754
ARSENIC	63	10	1.00 - 2.00	11.40	0.85	2.5052

NC = Not calculated

**Table F3-1f (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Groundwater**

Contaminant	Detection Frequency	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Average Concentration ug/L
BARIUM	100	200		1,880.00	30.50	172.7277
BERYLLIUM	31	5	0.60 - 2.00	12.70	0.95	1.2579
CADMIUM	53	5	1.00 - 10.00	7.60	1.20	1.9771
CESIUM	22	1000	2.00 - 500.00	90.00	30.00	41.7540
CHROMIUM	86	10	2.00 - 5.00	2,360.00	2.30	78.6951
COBALT	63	50	2.00 - 10.00	76.30	3.10	6.4997
COPPER	95	25	2.00 - 10.00	2,440.00	2.30	64.6241
VANADIUM	99	50	3.50 - 3.50	403.00	2.90	26.0175
ZINC	98	20	2.50 - 12.00	2,730.00	8.30	115.0214
CALCIUM	100	5000		316,000.00	25,700.00	126,457.6110
SELENIUM	59	5	1.00 - 20.00	2,200.00	1.00	132.1635

**Table F3-2a**  
**Summary Statistics**  
**Radionuclides - Groundwater (RFA)**

Contaminant	Detection Frequency %	CRQL pCi/L	Range of SQL Observed pCi/L	Maximum Concentration Detected pCi/L	Minimum Concentration Detected pCi/L	Calculated Mean Concentration pCi/L
PLUTONIUM-239,-240	91	0.01	0.000 - 0.000	0.009	(0.000)	0.0013
TRITIUM	91	400	170.000 - 400.000	617.900	(41.400)	136.2273
CESIUM-137	86	1	0.920 - 0.920	0.050	(0.721)	(0.0540)
STRONTIUM-90	100	N/R		0.896	0.896	0.8960
URANIUM-233,-234	100	0.6		31.400	11.040	21.2200
STRONTIUM-89,-90	100	1		0.180	0.180	0.1800
PLUTONIUM-238	100	N/R		(0.000)	(0.000)	(0.0003)
RADIUM-226	100	0.5		1.680	0.710	1.1950
AMERICIUM-241	100	0.01		0.010	(0.000)	0.0049
URANIUM-235	100	0.6		1.010	0.990	1.0000
URANIUM-238	100	0.6		21.900	6.990	13.9150

N/R = Not Reported

( ) = The value is negative

**Table F3-2b**  
**Summary Statistics**  
**Radionuclides - Groundwater (VFA)**

Contaminant	Detection Frequency %	CRQL pCi/L	Range of SQL Observed pCi/L	Maximum Concentration Detected pCi/L	Minimum Concentration Detected pCi/L	Calculated Mean Concentration pCi/L
PLUTONIUM-239,-240	100	0.01		0.039	(0.002)	0.0031
TRITIUM	100	400		270.000	(75.850)	147.5550
CESIUM-137	100	1		0.441	(0.562)	0.0339
URANIUM-233,-234	100	N/R		5.320	0.780	3.0500
STRONTIUM-89,-90	100	0.6		0.530	0.530	0.5300
PLUTONIUM-238	100	1		0.0025	0.0003	0.0014
AMERICIUM-241	100	N/R		0.0349	0.0005	0.0050
URANIUM-235	100	0.5		0.160	0.080	0.1200
URANIUM-238	100	0.01		4.640	0.440	2.5400

N/R = Not Reported

**Table F3-2c**  
**Summary Statistics**  
**Radionuclides - Groundwater (COL)**

Contaminant	Detection Frequency %	CRQL pCi/L	Range of SQL Observed pCi/L	Maximum Concentration Detected pCi/L	Minimum Concentration Detected pCi/L	Calculated Mean Concentration pCi/L
PLUTONIUM-239,-240	98	0.01	0.003 - 0.003	0.053	(0.001)	0.0103
TRITIUM	96	400		925.800	(182.000)	145.8235
CESIUM-137	95	1	0.610 - 0.650	0.609	(0.964)	0.0382
STRONTIUM-90	100	N/R		0.973	(0.066)	0.3094
URANIUM-233,-234	100	0.6		19.980	5.580	13.0175
STRONTIUM-89,-90	100	1		0.200	0.110	0.1550
PLUTONIUM-238	100	N/R		0.016	0.000	0.0070
RADIUM-226	100	0.5		0.880	0.060	0.4700
AMERICIUM-241	100	0.01		0.036	(0.001)	0.0064
URANIUM-235	100	0.6		1.500	0.290	0.7134
URANIUM-238	100	0.6		13.630	4.980	8.6643

N/R = Not Reported

( ) = The value is negative

**Table F3-2d**  
**Summary Statistics**  
**Radionuclides - Groundwater (WCS)**

Contaminant	Detection Frequency %	CRQL pCi/L	Range of SQL Observed pCi/L	Maximum Concentration Detected pCi/L	Minimum Concentration Detected pCi/L	Calculated Mean Concentration pCi/L
PLUTONIUM-239,-240	100	0.01		0.016	(0.001)	0.0051
TRITIUM	100	400		411.200	(358.000)	59.4485
CESIUM-137	100	1		0.529	(0.414)	0.1427
URANIUM-233,-234	100	N/R		4.200	4.200	4.2000
STRONTIUM-89,-90	100	0.6		0.390	0.100	0.3100
PLUTONIUM-238	100	1		0.000	0.000	0.0001
AMERICIUM-241	100	N/R		0.023	0.000	0.0076
URANIUM-235	100	0.5		0.200	0.200	0.2000
URANIUM-238	100	0.01		2.600	2.600	2.6000

N/R = Not Reported

( ) = The value is negative

**Table F3-2e**  
**Summary Statistics**  
**Radionuclides - Groundwater (KAR)**

Contaminant	Detection Frequency %	CRQL pCi/L	Range of SQL Observed pCi/L	Maximum Concentration Detected pCi/L	Minimum Concentration Detected pCi/L	Calculated Mean Concentration pCi/L
PLUTONIUM-239,-240	100	0.01		0.028	(0.001)	0.0036
TRITIUM	96	400		203.400	(105.000)	40.2100
CESIUM-137	100	1		1.156	(0.539)	0.1443
STRONTIUM-90	100	N/R		0.020	0.020	0.0199
URANIUM-233,-234	100	0.6		0.700	0.600	0.6500
STRONTIUM-89,-90	100	1		0.200	0.200	0.2000
PLUTONIUM-238	100	N/R		0.010	0.000	0.0040
AMERICIUM-241	97	0.5	0.0060 - 0.0060	0.084	(0.008)	0.0053
URANIUM-235	100	0.01		0.000	0.000	NC
URANIUM-238	100	0.6		0.300	0.050	0.1750

N/R = Not Reported

( ) = The value is negative

NC = Not Calculated; positive results were not observed

**Table F3-2f**  
**Summary Statistics**  
**Radionuclides - Groundwater**

Contaminant	Detection Frequency	CRQL pCi/L	Range of SQL Observed pCi/L	Maximum Concentration Detected pCi/L	Minimum Concentration Detected pCi/L	Calculated Average Concentration pCi/L
PLUTONIUM-239,-240	99	0.01	0.000 - 0.003	0.058	(0.002)	0.0047
TRITIUM	96	400	120.00 - 400.00	925.800	(358.000)	105.8529
CESIUM-137	97	1	0.61 - 0.92	1.156	(0.964)	0.0610
STRONTIUM-90	100	N/R		0.973	(0.869)	0.4084
URANIUM-233,-234	100	0.6		31.400	0.600	8.4275
STRONTIUM-89,-90	100	1		0.530	0.100	0.2750
PLUTONIUM-238	100	N/R		0.016	0.000	0.0024
RADIUM-226	100	0.5		1.680	0.060	0.8325
AMERICIUM-241	99	0.01	0.006 - 0.006	0.084	(0.008)	0.0058
URANIUM-235	100	0.6		1.500	0.000	0.5084
URANIUM-238	100	0.6		21.900	0.050	5.5789

N/R = Not Reported

( ) = The value is negative

**Table F3-3  
Summary Statistics  
Volatile Organics - Groundwater**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
1,1,1,2-TETRACHLOROETHANE	0	0.04	0.10 - 20.00	NA	NA	NC
1,1,1-TRICHLOROETHANE	14	0.04	0.10 - 8,400.00	19,000.00	1.00	363.2938
1,1,2,2-TETRACHLOROETHANE	0	0.2	0.10 - 500.00	NA	NA	NC
1,1,2-TRICHLOROETHANE	3	0.03	0.10 - 500.00	84.00	7.00	2.6874
1,1-DICHLOROETHANE	5	0.03	0.20 - 500.00	33.00	2.00	2.1043
1,1-DICHLOROETHENE	13	0.05	0.20 - 8,400.00	18,000.00	2.00	283.2304
1,1-DICHLOROPROPENE	0	0.02	0.10 - 20.00	NA	NA	NC
1,2,3-TRICHLOROBENZENE	0	0.04	0.10 - 30.00	NA	NA	NC
1,2,3-TRICHLOROPROPANE	0	0.03	0.10 - 30.00	NA	NA	NC
1,2,4-TRICHLOROBENZENE	0	0.2	0.10 - 30.00	NA	NA	NC
1,2-DIBROMOETHANE	0	0.02	0.20 - 50.00	NA	NA	NC
1,2-DICHLOROBENZENE	0	0.05	0.10 - 30.00	NA	NA	NC
1,2-DICHLOROETHANE	2	0.02	0.10 - 500.00	29.00	7.00	6.0963
1,2-DICHLOROETHENE	4	5	5.00 - 500.00	12,000.00	10.00	106.6552
1,2-DICHLOROPROPANE	<1	0.02	0.10 - 500.00	0.35	0.35	1.3913
1,3-DICHLOROBENZENE	0	0.05	0.10 - 20.00	NA	NA	NC
1,3-DICHLOROPROPANE	0	0.04	0.10 - 20.00	NA	NA	NC
1,4-DICHLOROBENZENE	0	0.04	0.10 - 20.00	NA	NA	NC
2-BUTANONE	3	10	10.00 - 1,000.00	580.00	2.00	11.6379
2-CHLOROETHYL VINYL ETHER	0	10	10.00 - 10.00	NA	NA	NC
2-HEXANONE	1	10	10.00 - 1,000.00	43.00	43.00	5.2184
4-METHYL-2-PENTANONE	1	10	10.00 - 1,000.00	25.00	25.00	5.0985

NA = Not Applicable  
NC = Not Calculated

**Table F3-3 (Continued)**  
**Summary Statistics**  
**Volatile Organics - Groundwater**

Contaminant	Detection Frequency	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
ACETONE	33	10	5.00 - 1,000.00	1,400.00	1.00	26.9801
BENZENE	<1	0.03	0.20 - 500.00	3.00	3.00	1.4134
BENZENE, 1,2,4-TRIMETHYL	2	0.04	0.10 - 20.00	0.12	0.12	0.4989
BENZENE, 1,3,5-TRIMETHYL-	0	0.02	0.10 - 20.00	NA	NA	NC
BROMOBENZENE	0	0.11	0.20 - 20.00	NA	NA	NC
BROMOCHLOROMETHANE	0	0.07	0.40 - 50.00	NA	NA	NC
BROMODICHLOROMETHANE	0	0.03	0.20 - 500.00	NA	NA	NC
BROMOFORM	0	0.2	0.50 - 500.00	NA	NA	NC
BROMOMETHANE	0	0.06	0.40 - 1,000.00	NA	NA	NC
CARBON DISULFIDE	1	5	5.00 - 500.00	2.25	2.25	2.4988
CARBON TETRACHLORIDE	16	0.08	0.10 - 500.00	4,500.00	0.20	81.2005
CHLOROBENZENE	0	0.03	0.10 - 500.00	NA	NA	NC
CHLOROETHANE	0	0.02	0.50 - 1,000.00	NA	NA	NC
CHLOROFORM	19	0.02	0.10 - 500.00	170.00	0.11	4.8797
CHLOROMETHANE	0	0.05	0.20 - 1,000.00	NA	NA	NC
CUMENE	0	0.1	0.20 - 20.00	NA	NA	NC
DIBROMOCHLOROMETHANE	0	0.07	0.20 - 500.00	56.00	56.00	1.7110
DIBROMOMETHANE	0	0.03	0.20 - 50.00	NA	NA	NC
DICHLORODIFLUOROMETHANE	5	0.11	0.40 - 50.00	2.82	0.81	1.4599
ETHYLBENZENE	<1	0.03	0.20 - 500.00	1.00	1.00	1.4085
HEXACHLOROBUTADIENE	0	0.04	0.10 - 30.00	NA	NA	NC
METHYLENE CHLORIDE	45	0.09	2.00 - 250.00	620.00	0.30	8.9475
NAPHTHALENE	4	0.04	0.20 - 20.00	2.40	0.19	0.1294

NA = Not Applicable

NC = Not Calculated

Table F3-3 (Continued)  
 Summary Statistics  
 Volatile Organics - Groundwater

Contaminant	Detection Frequency	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
PROPANE, 1,2-DIBROMO-3-CHLORO-	0	0.05	0.30 - 100.00	NA	NA	NC
STYRENE	1	0.06	0.10 - 500.00	0.23	0.08	1.3930
TETRACHLOROETHENE	28	0.05	0.04 - 2,000.00	6,000.00	0.07	103.4808
TOLUENE	10	0.08	0.10 - 500.00	270.00	0.20	4.6751
TOTAL XYLENES	3	5	0.30 - 500.00	120.00	1.00	3.2276
TRICHLOROETHENE	34	0.02	0.04 - 9,400.00	14,000.00	0.10	371.6499
TRICHLOROFLUOROMETHANE	5	0.07	0.20 - 50.00	10.20	1.10	1.2827
VINYL ACETATE	1	10	10.00 - 1,000.00	8.00	8.00	5.0200
VINYL CHLORIDE	<1	0.04	0.20 - 1,000.00	0.19	0.19	2.7745
cis-1,2-DICHLOROETHENE	5	0.06	0.10 - 20.00	0.86	0.18	0.5158
cis-1,3-DICHLOROPROPENE	0	0.06	0.10 - 500.00	NA	NA	NC
m-XYLENE	2	0.03	0.20 - 20.00	0.39	0.39	0.2941
n-BUTYLBENZENE	0	0.03	0.20 - 20.00	NA	NA	NC
n-PROPYLBENZENE	0	0.06	0.20 - 20.00	NA	NA	NC
o-CHLOROTOLUENE	0	0.05	0.20 - 30.00	NA	NA	NC
o-XYLENE	0	0.06	0.20 - 20.00	NA	NA	NC
p-CHLOROTOLUENE	2	0.05	0.20 - 30.00	0.60	0.60	0.8217
p-CYMENE	2	0.26	0.20 - 20.00	0.38	0.38	0.6301
sec-BUTYLBENZENE	9	0.12	0.20 - 20.00	0.92	0.38	0.6766
sec-DICHLOROPROPANE	0	0.05	0.20 - 50.00	NA	NA	NC
tert-BUTYLBENZENE	2	0.33	0.20 - 30.00	4.00	4.00	0.8824
trans-1,2-DICHLOROETHENE	0	0.03	0.10 - 170.00	NA	NA	NC
trans-1,3-DICHLOROPROPENE	0	0.06	0.10 - 500.00	NA	NA	NC

NA = Not Applicable

NC = Not Calculated

**Table F3-4**  
**Summary Statistics**  
**Semivolatile Organics - Groundwater**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
1,2,4-TRICHLOROBENZENE	0	10	10.00 - 10.00	NA	NA	NC
1,2-DICHLOROBENZENE	0	10	10.00 - 10.00	NA	NA	NC
1,3-DICHLOROBENZENE	0	10	10.00 - 10.00	NA	NA	NC
1,4-DICHLOROBENZENE	0	10	10.00 - 10.00	NA	NA	NC
2,4,5-TRICHLOROPHENOL	0	50	50.00 - 50.00	NA	NA	NC
2,4,6-TRICHLOROPHENOL	0	10	10.00 - 10.00	NA	NA	NC
2,4-DICHLOROPHENOL	0	10	10.00 - 10.00	NA	NA	NC
2,4-DIMETHYLPHENOL	0	10	10.00 - 10.00	NA	NA	NC
2,4-DINITROPHENOL	0	50	50.00 - 50.00	NA	NA	NC
2,4-DINITROTOLUENE	0	10	10.00 - 10.00	NA	NA	NC
2,6-DINITROTOLUENE	4	10	10.00 - 10.00	2.00	2.00	4.9167
2-CHLORONAPHTHALENE	0	10	10.00 - 10.00	NA	NA	NC
2-CHLOROPHENOL	0	10	10.00 - 10.00	NA	NA	NC
2-METHYLNAPHTHALENE	0	10	10.00 - 10.00	NA	NA	NC
2-METHYLPHENOL	0	10	10.00 - 10.00	NA	NA	NC
2-NITROANILINE	0	50	50.00 - 50.00	NA	NA	NC
2-NITROPHENOL	0	10	10.00 - 10.00	NA	NA	NC
3,3'-DICHLOROBENZIDINE	0	20	20.00 - 20.00	NA	NA	NC
3-NITROANILINE	0	50	50.00 - 50.00	NA	NA	NC
4,6-DINITRO-2-METHYLPHENOL	0	50	50.00 - 50.00	NA	NA	NC
4-BROMOPHENYL PHENYL ETHER	0	10	10.00 - 10.00	NA	NA	NC
4-CHLORO-3-METHYLPHENOL	0	10	10.00 - 10.00	NA	NA	NC

NA = Not Applicable

NC = Not Calculated

Table F3-4 (Continued)  
 Summary Statistics  
 Semivolatile Organics - Groundwater

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
4-CHLOROANILINE	0	10	10.00 - 10.00	NA	NA	NC
4-CHLOROPHENYL PHENYL ETHER	0	10	10.00 - 10.00	NA	NA	NC
4-METHYLPHENOL	0	10	10.00 - 10.00	NA	NA	NC
4-NITROANILINE	0	50	50.00 - 50.00	NA	NA	NC
4-NITROPHENOL	0	50	50.00 - 50.00	NA	NA	NC
ACENAPHTHENE	0	10	10.00 - 10.00	NA	NA	NC
ACENAPHTHYLENE	0	10	10.00 - 10.00	NA	NA	NC
ANTHRACENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(a)ANTHRACENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(a)PYRENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(b)FLUORANTHENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(ghi)PERYLENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(k)FLUORANTHENE	0	10	10.00 - 10.00	NA	NA	NC
BENZOIC ACID	5	50	50.00 - 50.00	14.00	14.00	24.6333
BENZYL ALCOHOL	0	10	10.00 - 10.00	NA	NA	NC
BIS(2-CHLOROETHOXY)METHANE	0	10	10.00 - 10.00	NA	NA	NC
BIS(2-CHLOROETHYL)ETHER	0	10	10.00 - 10.00	NA	NA	NC
BIS(2-CHLOROISOPROPYL)ETHER	0	10	10.00 - 10.00	8.00	2.00	5.2083
BIS(2-ETHYLHEXYL)PHTHALATE	8	10	10.00 - 25.00	NA	NA	NC
BUTYL BENZYL PHTHALATE	0	10	10.00 - 10.00	NA	NA	NC
CHRYSENE	0	10	10.00 - 10.00	3.00	2.00	4.6944
DI-n-BUTYL PHTHALATE	15	10	10.00 - 10.00			

NA = Not Applicable  
 NC = Not Calculated

Table F3-4 (Continued)  
 Summary Statistics  
 Semivolatile Organics - Groundwater

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
4-CHLOROANILINE	0	10	10.00 - 10.00	NA	NA	NC
4-CHLOROPHENYL PHENYL ETHE	0	10	10.00 - 10.00	NA	NA	NC
4-METHYLPHENOL	0	10	10.00 - 10.00	NA	NA	NC
4-NITROANILINE	0	50	50.00 - 50.00	NA	NA	NC
4-NITROPHENOL	0	50	50.00 - 50.00	NA	NA	NC
ACENAPHTHENE	0	10	10.00 - 10.00	NA	NA	NC
ACENAPHTHYLENE	0	10	10.00 - 10.00	NA	NA	NC
ANTHRACENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(a)ANTHRACENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(a)PYRENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(b)FLUORANTHENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(ghi)PERYLENE	0	10	10.00 - 10.00	NA	NA	NC
BENZO(k)FLUORANTHENE	0	10	10.00 - 10.00	NA	NA	NC
BENZOIC ACID	5	50	50.00 - 50.00	14.00	14.00	24.6333
BENZYL ALCOHOL	0	10	10.00 - 10.00	NA	NA	NC
BIS(2-CHLOROETHOXY)METHANE	0	10	10.00 - 10.00	NA	NA	NC
BIS(2-CHLOROETHYL)ETHER	0	10	10.00 - 10.00	NA	NA	NC
BIS(2-CHLOROISOPROPYL)ETHER	0	10	10.00 - 10.00	NA	NA	NC
BIS(2-ETHYLHEXYL)PHTHALATE	8	10	10.00 - 25.00	8.00	2.00	5.2083
BUTYL BENZYL PHTHALATE	0	10	10.00 - 10.00	NA	NA	NC
CHRYSENE	0	10	10.00 - 10.00	NA	NA	NC
DI-n-BUTYL PHTHALATE	15	10	10.00 - 10.00	3.00	2.00	4.6944

NA = Not Applicable  
 NC = Not Calculated

**Table F3-5  
Summary Statistics  
Pesticides / PCBs - Groundwater**

Contaminant	Detection Frequency %	CRQL ug/L	Range of SQL Observed ug/L	Maximum Concentration Detected ug/L	Minimum Concentration Detected ug/L	Calculated Mean Concentration ug/L
HEPTACHLOR EPOXIDE	0	0.050	0.050 - 0.050	NA	NA	NC
ENDOSULFAN SULFATE	0	0.100	0.100 - 0.100	NA	NA	NC
AROCLOR-1260	0	1.000	1.000 - 1.000	NA	NA	NC
AROCLOR-1254	0	1.000	1.000 - 1.000	NA	NA	NC
AROCLOR-1221	0	0.500	0.500 - 0.500	NA	NA	NC
AROCLOR-1232	0	0.500	0.500 - 0.500	NA	NA	NC
AROCLOR-1248	0	0.500	0.500 - 0.500	NA	NA	NC
AROCLOR-1016	0	0.500	0.500 - 0.500	NA	NA	NC
ALDRIN	0	0.050	0.050 - 0.050	NA	NA	NC
alpha-BHC	0	0.050	0.050 - 0.050	NA	NA	NC
beta-BHC	7	0.050	0.050 - 0.050	0.055	0.055	0.027
delta-BHC	0	0.050	0.050 - 0.050	NA	NA	NC
ENDOSULFAN II	0	0.100	0.100 - 0.100	NA	NA	NC
4,4'-DDT	0	0.100	0.100 - 0.100	NA	NA	NC
alpha-CHLORDANE	0	0.500	0.500 - 0.500	NA	NA	NC
gamma-CHLORDANE	0	0.500	0.500 - 0.500	NA	NA	NC
AROCLOR-1242	0	0.500	0.500 - 0.500	NA	NA	NC
ENDRIN KETONE	0	0.100	0.100 - 0.100	NA	NA	NC
gamma-BHC (LINDANE)	0	0.050	0.050 - 0.050	NA	NA	NC
DIELDRIN	0	0.100	0.100 - 0.100	NA	NA	NC
ENDRIN	0	0.100	0.100 - 0.100	NA	NA	NC

NA = Not Applicable  
NC = Not Calculated

**Table F3-5 (Continued)**  
**Summary Statistics**  
**Pesticides / PCBs - Groundwater**

<b>Contaminant</b>	<b>Detection Frequency %</b>	<b>CRQL ug/L</b>	<b>Range of SQL Observed ug/L</b>	<b>Maximum Concentration Detected ug/L</b>	<b>Minimum Concentration Detected ug/L</b>	<b>Calculated Mean Concentration ug/L</b>
METHOXYCHLOR	0	0.500	0.500 - 0.500	NA	NA	NC
4,4'-DDD	0	0.100	0.100 - 0.100	NA	NA	NC
4,4'-DDE	0	0.100	0.100 - 0.100	NA	NA	NC
HEPTACHLOR	0	0.050	0.050 - 0.050	NA	NA	NC
TOXAPHENE	0	1.000	1.000 - 1.000	NA	NA	NC
ENDOSULFAN I	0	0.050	0.050 - 0.050	NA	NA	NC

NA = Not Applicable

NC = Not Calculated

**Table F3-6a**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil (RFA)**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
ALUMINUM	100	40.0		3,870.00	2,410.00	3,140.0000
IRON	100	20.0		7,170.00	2,430.00	4,800.0000
LEAD	100	1.0		3.95	2.50	3.2250
LITHIUM	100	20.0		2.45	1.10	1.7750
MAGNESIUM	100	2,000		1,330.00	960.50	1,145.2500
MANGANESE	100	3.0		142.50	26.10	84.3000
MERCURY	0	0.2	0.11 - 0.11	NA	NA	NC
MOLYBDENUM	0	40.0	0.32 - 0.32	NA	NA	NC
NICKEL	100	8.0		8.95	4.00	6.4750
POTASSIUM	100	2,000		695.00	300.00	497.5000
SILVER	0	2.0	0.43 - 0.44	NA	NA	NC
SODIUM	100	2,000		43.80	35.50	39.6500
STRONTIUM	100	40.0		60.90	10.10	35.5000
THALLIUM	50	2.0	0.22 - 0.22	0.22	0.22	0.1638
TIN	0	40.0	3.60 - 3.60	NA	NA	NC
ANTIMONY	100	12.0		6.60	2.95	4.7750
ARSENIC	100	2.0		3.90	2.40	3.1500

NA = Not Applicable

NC = Not Calculated

**Table F3-6a (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil (RFA)**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
BARIUM	100	40.0		33.00	28.80	30.9000
BERYLLIUM	100	1.0		0.41	0.37	0.3875
CADMIUM	0	1.0	0.43 - 0.44	NA	NA	NC
CESIUM	50	200	11.10 - 11.10	15.00	15.00	10.2750
CHROMIUM	100	2.0		22.85	7.40	15.1250
COBALT	100	10.0		2.45	0.76	1.6050
COPPER	100	5.0		10.75	10.60	10.6750
VANADIUM	100	10.0		11.90	10.10	11.0000
ZINC	100	4.0		8.50	6.10	7.3000
CALCIUM	100	2,000		116,000.00	4,095.00	60,047.5000
SELENIUM	0	1.0	0.42 - 0.44	NA	NA	NC

NA = Not Applicable

NC = Not Calculated

**Table F3-6b**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil (COL)**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
ALUMINUM	100	40.0		30,000.00	3,150.00	13,097.6070
IRON	100	20.0		68,900.00	3,060.00	15,641.2933
LEAD	100	1.0		78.70	3.40	16.3004
LITHIUM	53	20.0	5.40 - 29.80	31.50	2.05	11.1921
MAGNESIUM	100	2,000		7,610.00	824.00	3,488.9322
MANGANESE	100	3.0		1,873.50	19.20	271.2413
MERCURY	16	0.2	0.05 - 0.24	0.27	0.07	0.0714
MOLYBDENUM	35	40.0	0.32 - 29.80	33.00	0.70	5.8236
NICKEL	96	8.0	8.50 - 9.80	70.10	6.60	16.3528
POTASSIUM	74	2,000	535.00 - 1,300.00	3,710.00	457.00	1,346.9645
SILICON	100	0.0		1,120.00	23.70	471.4017
SILVER	11	2.0	0.23 - 3.00	6.20	0.49	0.6941
SODIUM	59	2,000	235.00 - 1,300.00	7,060.00	81.00	517.2467
STRONTIUM	54	40.0	21.80 - 298.00	172.00	19.20	61.7585
THALLIUM	30	2.0	0.11 - 3.00	0.88	0.17	0.5361
TIN	7	40.0	3.00 - 41.20	65.50	19.30	9.3410
ANTIMONY	64	12.0	6.10 - 16.10	57.00	2.60	12.3408
ARSENIC	89	2.0	1.25 - 113.00	18.10	0.96	4.0843

**Table F3-6b (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil (COL)**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
BARIUM	99	40.0	45.60 - 45.60	836.00	44.10	176.3509
BERYLLIUM	69	1.0	0.86 - 1.50	2.40	0.28	1.0007
CADMIUM	10	1.0	0.22 - 1.50	1.70	0.29	0.4235
CESIUM	20	200	3.30 - 298.00	29.80	2.10	56.7838
CHROMIUM	100	2.0		101.00	5.00	17.3273
COBALT	63	10.0	9.50 - 14.90	36.00	2.10	7.4685
COPPER	99	5.0	6.10 - 6.10	41.25	5.70	17.2363
VANADIUM	100	10.0		71.70	11.10	32.9894
ZINC	100	4.0		161.00	14.60	55.9159
CALCIUM	100	2,000		78,900.00	1,810.00	14,055.9411
SELENIUM	13	1.0	0.20 - 3.35	1.30	0.19	0.3557

**Table F3-6c**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil (WCS)**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
ALUMINUM	100	40.0		17,250.00	2,940.00	7,921.8750
IRON	100	20.0		24,000.00	1,980.00	10,568.8889
LEAD	100	1.0		41.50	6.80	18.0974
LITHIUM	89	20.0	11.30 - 22.40	12.60	1.40	5.4780
MAGNESIUM	100	2,000		7,030.00	1,260.00	2,432.1795
MANGANESE	100	3.0		731.00	16.90	151.2609
MERCURY	19	0.2	0.05 - 0.18	0.23	0.11	0.0765
MOLYBDENUM	48	40.0	0.34 - 22.40	3.20	0.67	1.1078
NICKEL	98	8.0	9.00 - 9.00	35.30	5.10	13.3304
POTASSIUM	98	2,000	1,120.00 - 1,120.00	1,870.00	246.00	822.0064
SILICON	100	0.0		671.50	265.00	501.2143
SILVER	15	2.0	0.43 - 2.20	0.82	0.35	0.3449
SODIUM	89	2,000	452.00 - 1,120.00	1,720.00	37.70	329.5237
STRONTIUM	98	40.0	224.00 - 224.00	158.00	20.10	70.5753
THALLIUM	53	2.0	0.11 - 2.20	0.47	0.22	0.2535
TIN	10	40.0	3.10 - 23.60	392.00	6.50	11.8392
ANTIMONY	86	12.0	1.60 - 13.50	27.40	2.70	9.6345
ARSENIC	100	2.0		13.90	0.95	3.6303

**Table F3-6c (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil (WCS)**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
BARIUM	100	40.0		442.00	27.30	123.5242
BERYLLIUM	98	1.0	1.10 - 1.10	2.30	0.46	0.9974
CADMIUM	17	1.0	0.22 - 1.10	3.60	0.21	0.4282
CESIUM	25	200	3.50 - 224.00	29.60	10.90	18.8658
CHROMIUM	100	2.0		19.55	3.10	9.2813
COBALT	97	10.0	2.30 - 11.20	22.60	2.10	6.7375
COPPER	100	5.0		32.70	8.30	18.0905
VANADIUM	98	10.0	11.20 - 11.20	43.05	11.10	20.9752
ZINC	100	4.0		148.00	19.70	55.5585
CALCIUM	100	2,000		47,500.00	3,020.00	8,889.9199
SELENIUM	27	1.0	0.11 - 1.10	1.80	0.17	0.2813

**Table F3-6c**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil (WCS)**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
ALUMINUM	100	40.0		17,250.00	2,940.00	7,921.8750
IRON	100	20.0		24,000.00	1,980.00	10,568.8889
LEAD	100	1.0		41.50	6.80	18.0974
LITHIUM	89	20.0	11.30 - 22.40	12.60	1.40	5.4780
MAGNESIUM	100	2,000		7,030.00	1,260.00	2,432.1795
MANGANESE	100	3.0		731.00	16.90	151.2609
MERCURY	19	0.2	0.05 - 0.18	0.23	0.11	0.0765
MOLYBDENUM	48	40.0	0.34 - 22.40	3.20	0.67	1.1078
NICKEL	98	8.0	9.00 - 9.00	35.30	5.10	13.3304
POTASSIUM	98	2,000	1,120.00 - 1,120.00	1,870.00	246.00	822.0064
SILICON	100	0.0		671.50	265.00	501.2143
SILVER	15	2.0	0.43 - 2.20	0.82	0.35	0.3449
SODIUM	89	2,000	452.00 - 1,120.00	1,720.00	37.70	329.5237
STRONTIUM	98	40.0	224.00 - 224.00	158.00	20.10	70.5753
THALLIUM	53	2.0	0.11 - 2.20	0.47	0.22	0.2535
TIN	10	40.0	3.10 - 23.60	392.00	6.50	11.8392
ANTIMONY	86	12.0	1.60 - 13.50	27.40	2.70	9.6345
ARSENIC	100	2.0		13.90	0.95	3.6303

**Table F3-6d**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Average Concentration mg/kg
				30,000.00	2,410.00	8,053.1607
ALUMINIUM	100	40.0		68,900.00	1,980.00	10,336.7274
IRON	100	20.0		78.70	2.50	12.5409
LEAD	100	1.0		31.50	1.10	6.1484
LITHIUM	64	20.0	5.40 - 29.80	7,610.00	824.00	2,355.4539
MAGNESIUM	100	2,000		1,873.50	16.90	168.9341
MANGANESE	100	3.0		0.27	0.07	0.0740
MERCURY	17	0.2	0.00 - 0.20	33.00	0.67	3.4657
MOLYBDENUM	39	40.0	0.30 - 29.80	70.10	4.00	12.0527
NICKEL	97	8.0	8.50 - 9.80	3,710.00	246.00	888.8236
POTASSIUM	81	2,000	535.00 - 1,300.00	1,120.00	23.70	486.3080
SILICON	100	0.0		6.20	0.35	0.5195
SILVER	12	2.0	0.20 - 3.00	7,060.00	35.50	295.4735
SODIUM	68	2,000	235.00 - 1,300.00	172.00	10.10	55.9446
STRONTIUM	67	40.0	21.80 - 298.00	0.88	0.17	0.3178
THALLIUM	37	2.0	0.10 - 3.00	392.00	6.50	10.5901
TIN	8	40.0	3.00 - 41.20	57.00	2.60	8.8800
ANTIMONY	70	12.0	1.60 - 16.10	18.10	0.95	3.6215
ARSENIC	92	2.0	1.30 - 113.00			

**Table F3-6d (Continued)**  
**Summary Statistics**  
**Metals and Inorganics - Subsurface Soil**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
BARIUM	99	40.0	45.60 - 45.60	836.00	27.30	110.2584
BERYLLIUM	78	1.0	0.90 - 1.50	2.40	0.37	0.7952
CADMIUM	12	1.0	0.20 - 1.50	3.60	0.21	0.4259
CESIUM	21	200	3.30 - 298.00	29.80	2.10	28.6415
CHROMIUM	100	2.0		101.00	3.10	13.9112
COBALT	73	10.0	2.30 - 14.90	36.00	0.76	5.2703
COPPER	99	5.0	6.10 - 6.10	41.25	5.70	15.3339
VANADIUM	99	10.0	11.20 - 11.20	71.70	10.10	21.6549
ZINC	100	4.0		161.00	6.10	39.5915
CALCIUM	100	2,000		116,000.00	1,810.00	27,664.4537
SELENIUM	17	1.0	0.10 - 3.40	1.80	0.17	0.3185

**Table F3-7a  
Summary Statistics  
Radionuclides - Subsurface Soil (RFA)**

Contaminant	Detection Frequency %	CRQL pCi/g	Range of SQL Observed pCi/g	Maximum Concentration Detected pCi/g	Minimum Concentration Detected pCi/g	Calculated Mean Concentration pCi/g
PLUTONIUM-239,-240	100	0.03		7,400.00	0.00	87.1575
TRITIUM	100	400		250.00	235.00	242.5000
CESIUM-137	100	0.10		0.00	0.00	NC
URANIUM-233,-234	100	0.30		420.00	0.43	4.5010
STRONTIUM-89,-90	100	1.00		0.77	0.23	0.5000
RADIUM-226	100	0.50		0.71	0.22	0.4650
AMERICIUM-241	100	0.02		4,260.00	0.01	30.6319
URANIUM-235	100	0.30		0.02	0.01	0.0125
RADIUM-228	100	0.50		0.51	0.00	0.2550
URANIUM-238	100	0.30		122.00	0.64	1.8701

Maximum and mean concentrations for plutonium-239,-240; uranium-233,-234; americium-241; and uranium-238 include "hot spot" results.  
NC = Not Calculated; positive results were not observed

**Table F3-7b**  
**Summary Statistics**  
**Radionuclides - Subsurface Soil (COL)**

Contaminant	Detection Frequency %	CRQL pCi/g	Range of SQL Observed pCi/g	Maximum Concentration Detected pCi/g	Minimum Concentration Detected pCi/g	Calculated Mean Concentration pCi/g
PLUTONIUM-239,-240	98	0.03	0.0000 - 0.0010	25.54	(0.01)	0.3202
TRITIUM	96	400		570.00	(1,160.00)	142.9916
CESIUM-137	100	0.10		0.21	(0.03)	0.0563
STRONTIUM-90	100	N/R		0.83	(0.30)	0.1336
URANIUM-233,-234	100	1.00		2.51	0.31	1.0513
STRONTIUM-89,-90	95	0.50	0.0700 - 0.2300	2.23	0.01	0.2650
RADIUM-226	100	0.02		2.60	0.00	0.9728
AMERICIUM-241	96	0.30	(0.0170) - 0.1700	2.60	(0.00)	0.0341
PLUTONIUM-239	100	N/R		0.07	0.00	0.0172
URANIUM-235	100	0.30		0.28	0.00	0.0548
RADIUM-228	100	0.50		3.10	0.00	1.5845
URANIUM-238	100	0.30		3.24	0.45	1.0805

N/R = Not Reported

( ) = The value is negative

**Table F3-7c**  
**Summary Statistics**  
**Radionuclides - Subsurface Soil (WCS)**

Contaminant	Detection Frequency	CRQL pCi/g	Range of SQL Observed pCi/g	Maximum Concentration Detected pCi/g	Minimum Concentration Detected pCi/g	Calculated Mean Concentration pCi/g
PLUTONIUM-239,-240	100	0.03		1.102	(0.003)	0.0334
TRITIUM	100	400		530.000	(114.000)	121.7576
CESIUM-137	100	0.10		0.010	(0.050)	(0.0127)
STRONTIUM-90	100	N/R		0.150	0.150	0.1500
URANIUM-233,-234	100	1.00		2.920	0.393	1.0602
STRONTIUM-89,-90	100	0.50		6.540	(0.014)	0.3206
RADIUM-226	100	0.02		2.090	0.700	1.0076
AMERICIUM-241	100	0.30		1.975	(0.003)	0.0744
PLUTONIUM-239	100	N/R		0.002	0.002	0.0020
URANIUM-235	100	0.30		0.250	0.000	0.0626
RADIUM-228	100	0.50		2.228	0.000	1.5374
URANIUM-238	100	0.30		14.130	0.649	1.3914

N/R = Not Reported

( ) = The value is negative

**Table F3-7d**  
**Summary Statistics**  
**Radionuclides - Subsurface Soil**

Contaminant	Detection Frequency	CRQL pCi/g	Range of SQL Observed pCi/g	Maximum Concentration Detected pCi/g	Minimum Concentration Detected pCi/g	Calculated Average Concentration pCi/g
PLUTONIUM-239,-240	99	0.03	0.000 - 0.001	7,400.00	(0.01)	29.1704
TRITIUM	97	400	(170.000) - 320.000	570.00	(1,160.00)	169.0831
CESIUM-137	100	0.10		0.21	(0.05)	0.0218
STRONTIUM-90	100	N/R		0.83	(0.30)	0.1418
URANIUM-233,-234	100	1.00		420.00	0.31	2.2042
STRONTIUM-89,-90	97	0.50	0.070 - 0.230	6.54	(0.01)	0.3619
RADIUM-226	100	0.02		2.60	0.00	0.8151
AMERICIUM-241	97	0.30	(0.017) - 0.170	4,260.00	(0.00)	10.2468
PLUTONIUM-239	100	N/R		0.07	0.00	0.0096
URANIUM-235	100	0.30		0.28	0.00	0.0433
RADIUM-228	100	0.50		3.10	0.00	1.1256
URANIUM-238	100	0.30		122.00	0.45	1.4473

N/R = Not Reported  
( ) = Negative Number

Table F3-8  
Summary Statistics  
Volatile Organics - Subsurface Soil

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
1,1,1-TRICHLOROETHANE	<1	5	5.00 - 58.50	5.0000	4.0000	3.0135
1,1,2,2-TETRACHLOROETHANE	0	5	5.00 - 58.50	NA	NA	NC
1,1,2-TRICHLOROETHANE	0	5	5.00 - 58.50	NA	NA	NC
1,1-DICHLOROETHANE	0	5	5.00 - 58.50	NA	NA	NC
1,1-DICHLOROETHENE	<1	5	5.00 - 58.50	12.0000	2.0000	3.0529
1,2-DICHLOROETHANE	<1	5	5.00 - 58.50	5.0000	5.0000	3.4853
1,2-DICHLOROETHENE	0	5	5.00 - 58.50	NA	NA	NC
1,2-DICHLOROPROPANE	0	5	5.00 - 58.50	NA	NA	NC
2-BUTANONE	6	10	1.00 - 115.00	29.0000	1.0000	6.1483
2-CHLOROETHYL VINYL ETHER	0	N/R	9.00 - 115.00	NA	NA	NC
2-HEXANONE	1	10	9.00 - 115.00	2.0000	1.0000	5.9320
4-METHYL-2-PENTANONE	2	10	6.00 - 115.00	3.0000	1.0000	5.8867
ACETONE	47	10	7.00 - 130.00	93.0000	1.0000	10.6096
BENZENE	0	5	5.00 - 58.50	NA	NA	NC
BROMODICHLOROMETHANE	0	5	5.00 - 58.50	NA	NA	NC
BROMOFORM	0	5	5.00 - 58.50	NA	NA	NC
BROMOMETHANE	0	10	9.00 - 115.00	NA	NA	NC
CARBON DISULFIDE	2	5	2.50 - 58.50	2.0000	1.0000	2.9706
CARBON TETRACHLORIDE	<1	5	5.00 - 58.50	18.0000	11.0000	3.0923
CHLOROBENZENE	<1	5	5.00 - 58.50	5.0000	5.0000	2.9932
CHLOROETHANE	0	10	9.00 - 115.00	NA	NA	NC
CHLOROFORM	<1	5	3.00 - 58.50	5.0000	5.0000	3.0017

N/R = Not Reported  
NA = Not Applicable  
NC = Not Calculated

Table F3-8 (Continued)  
 Summary Statistics  
 Volatile Organics - Subsurface Soil

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
CHLOROMETHANE	0	10	6.00 - 115.00	NA	NA	NC
DIBROMOCHLOROMETHANE	0	5	5.00 - 58.50	NA	NA	NC
ETHYLBENZENE	<1	5	5.00 - 58.50	2.0000	2.0000	2.9860
METHYLENE CHLORIDE	50	5	2.00 - 58.50	230.0000	1.0000	7.1650
STYRENE	1	5	5.00 - 58.50	28.0000	1.0000	3.1907
TETRACHLOROETHENE	2	5	5.00 - 58.50	47.0000	1.0000	3.3726
TOLUENE	97	5	5.00 - 43.00	2000.0000	1.0000	107.9291
TOTAL XYLENES	<1	5	5.00 - 58.50	3.0000	3.0000	2.9939
TRICHLOROETHENE	2	5	5.00 - 58.50	140.0000	1.0000	4.2547
VINYL ACETATE	0	10	5.00 - 115.00	NA	NA	NC
VINYL CHLORIDE	0	10	9.00 - 115.00	NA	NA	NC
cis-1,3-DICHLOROPROPENE	0	5	5.00 - 58.50	NA	NA	NC
o-XYLENE	0	N/R	5.00 - 140.00	NA	NA	NC
trans-1,2-DICHLOROETHENE	0	5	5.00 - 7.00	NA	NA	NC
trans-1,3-DICHLOROPROPENE	<1	5	5.00 - 58.50	5.0000	5.0000	2.9927

N/R = Not Reported  
 NA = Not Applicable  
 NC = Not Calculated

Table F3-9  
 Summary Statistics  
 Semivolatile Organics - Subsurface Soil

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
1,2,4-TRICHLOROBENZENE	0	330	330.00 - 880.00	NA	NA	NC
1,2-DICHLOROBENZENE	0	330	330.00 - 880.00	NA	NA	NC
1,3-DICHLOROBENZENE	0	330	330.00 - 880.00	NA	NA	NC
1,4-DICHLOROBENZENE	2	330	330.00 - 880.00	110.00	78.00	187.1345
2,4,5-TRICHLOROPHENOL	0	1600	1,700.00 - 4,400.00	NA	NA	NC
2,4,6-TRICHLOROPHENOL	0	330	330.00 - 880.00	NA	NA	NC
2,4-DICHLOROPHENOL	0	330	330.00 - 880.00	NA	NA	NC
2,4-DIMETHYLPHENOL	0	330	330.00 - 880.00	NA	NA	NC
2,4-DINITROPHENOL	0	1600	1,700.00 - 4,400.00	NA	NA	NC
2,4-DINITROTOLUENE	0	330	330.00 - 880.00	NA	NA	NC
2,6-DINITROTOLUENE	0	330	330.00 - 880.00	NA	NA	NC
2-CHLORONAPHTHALENE	0	330	330.00 - 880.00	NA	NA	NC
2-CHLOROPHENOL	0	330	330.00 - 880.00	NA	NA	NC
2-METHYLNAPHTHALENE	1	330	330.00 - 880.00	655.00	655.00	282.8333
2-METHYLPHENOL	0	330	330.00 - 880.00	NA	NA	NC
2-NITROANILINE	0	1600	1,700.00 - 4,400.00	NA	NA	NC
2-NITROPHENOL	0	330	330.00 - 880.00	NA	NA	NC
3,3'-DICHLOROBENZIDINE	0	660	670.00 - 1,800.00	NA	NA	NC
3-NITROANILINE	0	1600	1,700.00 - 4,400.00	NA	NA	NC
4,6-DINITRO-2-METHYLPHENOL	0	1600	350.00 - 4,400.00	NA	NA	NC
4-BROMOPHENYL PHENYL ETHER	0	330	205.00 - 880.00	NA	NA	NC
4-CHLORO-3-METHYLPHENOL	0	330	330.00 - 880.00	NA	NA	NC

N/R = Not Reported  
 NA = Not Applicable  
 NC = Not Calculated

**Table F3-9 (Continued)**  
**Summary Statistics**  
**Semivolatile Organics - Subsurface Soil**

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
4-CHLOROANILINE	0	330	330.00 - 880.00	NA	NA	NC
4-CHLOROPHENYL PHENYL ETHER	0	330	330.00 - 880.00	NA	NA	NC
4-METHYLPHENOL	0	330	330.00 - 880.00	NA	NA	NC
4-NITROANILINE	0	1600	1,700.00 - 4,400.00	NA	NA	NC
4-NITROPHENOL	1	1600	1,700.00 - 4,400.00	997.50	590.00	1,369.3490
ACENAPHTHENE	2	330	330.00 - 880.00	1,995.00	63.00	286.1655
ACENAPHTHYLENE	0	330	330.00 - 880.00	NA	NA	NC
ANTHRACENE	3	330	330.00 - 880.00	2,670.00	91.00	288.8767
BENZENAMINE	0	N/R	1,700.00 - 4,400.00	NA	NA	NC
BENZIDINE	0	N/R	1,700.00 - 4,400.00	NA	NA	NC
BENZO(a)ANTHRACENE	2	330	330.00 - 880.00	4,030.00	170.00	296.8630
BENZO(a)PYRENE	2	330	330.00 - 880.00	3,335.00	220.00	295.2648
BENZO(b)FLUORANTHENE	2	330	330.00 - 880.00	2,850.00	230.00	293.0502
BENZO(ghi)PERYLENE	1	330	330.00 - 880.00	1,870.00	280.00	287.9589
BENZO(k)FLUORANTHENE	1	330	330.00 - 880.00	3,345.00	330.00	294.1689
BENZOIC ACID	1	1600	19.00 - 4,400.00	1,030.00	77.50	1,346.9178
BENZYL ALCOHOL	0	330	330.00 - 880.00	NA	NA	NC
BIS(2-CHLOROETHOXY)METHANE	0	330	330.00 - 880.00	NA	NA	NC
BIS(2-CHLOROETHYL)ETHER	0	330	330.00 - 880.00	NA	NA	NC
BIS(2-CHLOROISOPROPYL)ETHER	0	330	330.00 - 880.00	NA	NA	NC
BIS(2-ETHYLHEXYL)PHTHALATE	16	330	40.00 - 1,400.00	4,500.00	38.00	282.6785
BUTYL BENZYL PHTHALATE	1	330	180.00 - 880.00	49.00	49.00	278.5959

N/R = Not Reported  
 NA = Not Applicable  
 NC = Not Calculated

Table F3-9 (Continued)  
 Summary Statistics  
 Semivolatile Organics - Subsurface Soil

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
CHRYSENE	2	330	330.00 - 880.00	3,935.00	180.00	296.7489
DI-n-BUTYL PHTHALATE	22	330	330.00 - 880.00	630.00	41.00	248.3767
DI-n-OCTYL PHTHALATE	1	330	330.00 - 880.00	112.50	58.00	278.9589
DIBENZO(a,h)ANTHRACENE	0	330	330.00 - 880.00	NA	NA	NC
DIBENZOFURAN	1	330	330.00 - 880.00	930.00	930.00	281.6343
DIETHYL PHTHALATE	1	330	330.00 - 880.00	520.00	520.00	281.9521
DIMETHYL PHTHALATE	0	330	330.00 - 880.00	NA	NA	NC
FLUORANTHENE	6	330	190.00 - 880.00	8,000.00	38.00	313.1221
FLUORENE	1	330	330.00 - 880.00	1,710.00	134.50	286.5639
HEXACHLOROBENZENE	0	330	330.00 - 880.00	NA	NA	NC
HEXACHLOROBUTADIENE	0	330	330.00 - 880.00	NA	NA	NC
HEXACHLOROCYCLOPENTADIENE	0	330	330.00 - 880.00	NA	NA	NC
HEXACHLOROETHANE	0	330	330.00 - 880.00	NA	NA	NC
INDENO(1,2,3-cd)PYRENE	1	330	330.00 - 880.00	1,950.00	275.00	288.3014
ISOPHORONE	0	330	330.00 - 880.00	NA	NA	NC
N-NITROSO-DI-n-PROPYLAMINE	0	330	330.00 - 880.00	NA	NA	NC
N-NITROSODIMETHYLAMINE	0	330	670.00 - 1,800.00	NA	NA	NC
N-NITROSODIPHENYLAMINE	1	330	190.00 - 880.00	113.50	44.00	279.3048
NAPHTHALENE	2	330	330.00 - 880.00	2,485.00	91.00	248.2254
NITROBENZENE	0	330	330.00 - 880.00	NA	NA	NC
PENTACHLOROPHENOL	1	1600	1,700.00 - 4,400.00	1,010.00	390.00	1,367.4372

N/R = Not Reported  
 NA = Not Applicable  
 NC = Not Calculated

Table F3-9 (Continued)  
 Summary Statistics  
 Semivolatile Organics - Subsurface Soil

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
PHENANTHRENE	5	330	185.00 - 880.00	8,950.00	100.00	318.7900
PHENOL	0	330	330.00 - 880.00	NA	NA	NC
PYRENE	7	330	190.00 - 880.00	7,300.00	40.00	307.9315

N/R = Not Reported

NA = Not Applicable

NC = Not Calculated

**Table F3-10  
Summary Statistics  
Pesticides / PCBs - Subsurface Soil**

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
HEPTACHLOR EPOXIDE	0	8.00	8.00 - 500.00	NA	NA	NC
ENDOSULFAN SULFATE	0	16.00	16.00 - 1,000.00	NA	NA	NC
AROCLOR-1260	0	160.00	160.00 - 10,000.00	NA	NA	NC
AROCLOR-1254	0	160.00	160.00 - 10,000.00	NA	NA	NC
AROCLOR-1221	0	80.00	80.00 - 5,000.00	NA	NA	NC
AROCLOR-1232	0	80.00	80.00 - 5,000.00	NA	NA	NC
AROCLOR-1248	0	80.00	80.00 - 5,000.00	NA	NA	NC
AROCLOR-1016	0	80.00	80.00 - 5,000.00	NA	NA	NC
ALDRIN	0	8.00	8.00 - 500.00	NA	NA	NC
alpha-BHC	0	8.00	8.00 - 500.00	NA	NA	NC
beta-BHC	0	8.00	8.00 - 500.00	NA	NA	NC
delta-BHC	0	8.00	8.00 - 500.00	NA	NA	NC
ENDOSULFAN II	0	16.00	16.00 - 1,000.00	NA	NA	NC
4,4'-DDT	0	16.00	16.00 - 1,000.00	NA	NA	NC
alpha-CHLORDANE	0	80.00	53.95 - 5,000.00	NA	NA	NC
gamma-CHLORDANE	0	80.00	53.95 - 5,000.00	NA	NA	NC
AROCLOR-1242	0	80.00	80.00 - 5,000.00	NA	NA	NC
ENDRIN KETONE	0	16.00	16.00 - 1,000.00	NA	NA	NC
gamma-BHC (LINDANE)	0	8.00	8.00 - 500.00	NA	NA	NC
DIELDRIN	0	16.00	16.00 - 1,000.00	NA	NA	NC
ENDRIN	0	16.00	16.00 - 1,000.00	NA	NA	NC

NA = Not Applicable  
NC = Not Calculated

**Table F3-10 (Continued)**  
**Summary Statistics**  
**Pesticides / PCBs - Subsurface Soil**

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
METHOXYCHLOR	0	80.00	9.70 - 5,000.00	NA	NA	NC
4,4'-DDU	0	16.00	16.00 - 1,000.00	NA	NA	NC
4,4'-DDE	0	16.00	16.00 - 1,000.00	NA	NA	NC
HEPTACHLOR	0	8.00	8.00 - 500.00	NA	NA	NC
TOXAPHENE	0	160.00	160.00 - 10,000.00	NA	NA	NC
ENDOSULFAN I	0	8.00	8.00 - 500.00	NA	NA	NC

NA = Not Applicable

NC = Not Calculated

**Table F3-11**  
**Summary Statistics**  
**Metals and Inorganics - Surface Soil**

Contaminant	Detection Frequency %	CRQL mg/kg	Range of SQL Observed mg/kg	Maximum Concentration Detected mg/kg	Minimum Concentration Detected mg/kg	Calculated Mean Concentration mg/kg
ALUMINUM	100	40.0		27,600.00	6,370.00	12,281.8750
IRON	100	20.0		29,700.00	11,600.00	16,187.5000
LEAD	97	1.0	1.05 - 1.05	228.00	7.10	33.2406
LITHIUM	100	20.0		15.00	4.50	9.3902
MAGNESIUM	100	2,000		5,440.00	2,130.00	3,120.8929
MANGANESE	100	3.0		476.00	145.00	283.7232
MERCURY	15	0.2	0.03 - 0.08	0.07	0.06	0.0355
MOLYBDENUM	81	40.0	0.70 - 1.90	5.10	1.60	2.2662
NICKEL	100	8.0		79.75	10.00	19.7027
POTASSIUM	100	2,000		4,600.00	1,730.00	2,851.4286
SILICON	100	0.0		1,560.00	81.00	400.1554
SILVER	0	2.0	1.00 - 1.40	NA	NA	NC
SODIUM	100	2,000		362.00	70.20	147.3339
STRONTIUM	100	40.0		104.00	23.30	54.3170
THALLIUM	65	2.0	0.11 - 0.29	0.51	0.22	0.2479
TIN	71	40.0	14.35 - 38.10	106.95	28.30	38.2509
ANTIMONY	3	12.0	8.40 - 12.00	9.80	9.80	4.8295
ARSENIC	97	2.0	0.11 - 0.11	8.50	3.00	4.9259

NA = Not Applicable  
NC = Not Calculated

**Table F3-11 (Continued)  
Summary Statistics  
Metals and Inorganics - Surface Soil**

<b>Contaminant</b>	<b>Detection Frequency %</b>	<b>CRQL mg/kg</b>	<b>Range of SQL Observed mg/kg</b>	<b>Maximum Concentration Detected mg/kg</b>	<b>Minimum Concentration Detected mg/kg</b>	<b>Calculated Mean Concentration mg/kg</b>
BARIUM	100	40.0		325.00	64.00	160.2616
BERYLLIUM	100	1.0		6.20	0.55	0.8951
CADMIUM	21	1.0	0.60 - 0.86	1.30	0.71	0.4786
CESIUM	100	200		4.40	1.50	2.6201
CHROMIUM	100	2.0		98.35	8.40	20.3777
COBALT	100	10.0		11.70	5.20	7.5607
COPPER	100	5.0		181.00	13.20	21.5777
VANADIUM	100	10.0		69.60	25.90	38.1563
ZINC	100	4.0		182.00	51.40	73.9205
CALCIUM	100	2,000		42,100.00	4,160.00	11,820.9821
SELENIUM	52	1.0	0.10 - 0.50	0.75	0.20	0.2453

NA = Not Applicable

NC = Not Calculated

**Table F3-12**  
**Summary Statistics**  
**Radionuclides - Surface Soil**

Contaminant	Detection Frequency %	CRQL pCi/g	Range of SQL Observed pCi/g	Maximum Concentration Detected pCi/g	Minimum Concentration Detected pCi/g	Calculated Mean Concentration pCi/g
PLUTONIUM-239,-240 (1)	100	0.03		11,100.00	0.07	295.0000
URANIUM-233,-234 (1)	100	0.30		25.40	0.68	2.1400
RADIUM-226	100	0.50		1.09	0.65	0.8655
AMERICIUM-241 (1)	100	0.02		2,650.00	0.01	83.3000
URANIUM-235	100	0.30		0.12	(0.01)	0.0537
RADIUM-228	100	0.50		2.29	1.33	1.7708
URANIUM-238 (1)	100	0.30		4.69	0.63	1.3800

Footnote (1) "Hotspot" sample concentration incorporated into summary

**Table F3-13**  
**Summary Statistics**  
**Semivolatile Organics - Surface Soil**

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
1,2,4-TRICHLOROBENZENE	0	330	340.00 - 470.00	NA	NA	NC
1,2-DICHLOROBENZENE	0	330	340.00 - 470.00	NA	NA	NC
1,3-DICHLOROBENZENE	0	330	340.00 - 470.00	NA	NA	NC
1,4-DICHLOROBENZENE	0	330	340.00 - 470.00	NA	NA	NC
2,4,5-TRICHLOROPHENOL	0	1600	1,600.00 - 2,300.00	NA	NA	NC
2,4,6-TRICHLOROPHENOL	0	330	340.00 - 470.00	NA	NA	NC
2,4-DICHLOROPHENOL	0	330	340.00 - 470.00	NA	NA	NC
2,4-DIMETHYLPHENOL	0	330	340.00 - 470.00	NA	NA	NC
2,4-DINITROPHENOL	0	1600	1,600.00 - 2,300.00	NA	NA	NC
2,4-DINITROTOLUENE	0	330	340.00 - 470.00	NA	NA	NC
2,6-DINITROTOLUENE	0	330	340.00 - 470.00	NA	NA	NC
2-CHLORONAPHTHALENE	0	330	340.00 - 470.00	NA	NA	NC
2-CHLOROPHENOL	0	330	340.00 - 470.00	NA	NA	NC
2-METHYLNAPHTHALENE	0	330	340.00 - 470.00	NA	NA	NC
2-METHYLPHENOL	0	330	340.00 - 470.00	NA	NA	NC
2-NITROANILINE	0	1600	1,600.00 - 2,300.00	NA	NA	NC
2-NITROPHENOL	0	330	340.00 - 470.00	NA	NA	NC
3,3-DICHLOROBENZIDINE	0	660	670.00 - 940.00	NA	NA	NC
3-NITROANILINE	0	1600	1,600.00 - 2,300.00	NA	NA	NC
4,6-DINITRO-2-METHYLPHENOL	0	1600	1,600.00 - 2,300.00	NA	NA	NC
4-BROMOPHENYL PHENYL ETHER	0	330	340.00 - 470.00	NA	NA	NC
4-CHLORO-3-METHYLPHENOL	0	330	340.00 - 470.00	NA	NA	NC

NA= Not Applicable

NC = Not Calculated

( ) = The result is negative

Note: Maximum and mean concentrations for plutonium-239,-240; uranium-233,-234; americium-241; and uranium-238 include "hotspot" results.

Table F3-13 (Continued)  
Summary Statistics  
Semivolatile Organics - Surface Soil

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
4-CHLOROANILINE	0	330	340.00 - 470.00	NA	NA	NC
4-CHLOROPHENYL PHENYL ETHER	0	330	340.00 - 470.00	NA	NA	NC
4-METHYLPHENOL	0	330	340.00 - 470.00	NA	NA	NC
4-NITROANILINE	0	1600	1,600.00 - 2,300.00	NA	NA	NC
4-NITROPHENOL	0	1600	1,600.00 - 2,300.00	NA	NA	NC
ACENAPHTHENE	21	330	340.00 - 470.00	270.00	45.00	178.5714
ACENAPHTHYLENE	4	330	340.00 - 470.00	110.00	110.00	185.5357
ANTHRACENE	21	330	340.00 - 470.00	330.00	47.00	183.8929
BENZO(a)ANTHRACENE	46	330	350.00 - 470.00	830.00	140.00	286.6071
BENZO(a)PYRENE	50	330	350.00 - 470.00	750.00	120.00	258.3929
BENZO(b)FLUORANTHENE	46	330	350.00 - 470.00	810.00	115.00	259.8214
BENZO(gh)PERYLENE	39	330	340.00 - 470.00	350.00	82.00	188.4643
BENZO(k)FLUORANTHENE	43	330	350.00 - 470.00	740.00	115.00	248.0714
BENZOIC ACID	0	1600	1,600.00 - 2,300.00	NA	NA	NC
BENZYL ALCOHOL	0	330	340.00 - 470.00	NA	NA	NC
BIS(2-CHLOROETHOXY)METHANE	0	330	340.00 - 470.00	NA	NA	NC
BIS(2-CHLOROETHYL)ETHER	0	330	340.00 - 470.00	NA	NA	NC
BIS(2-CHLOROISOPROPYL)ETHER	0	330	340.00 - 470.00	NA	NA	NC
BIS(2-ETHYLHEXYL)PHTHALATE	18	330	340.00 - 470.00	150.00	48.00	171.4286
BUTYL BENZYL PHTHALATE	0	330	340.00 - 470.00	NA	NA	NC
CHRYSENE	57	330	350.00 - 470.00	780.00	120.00	294.4643
DI-n-BUTYL PHTHALATE	18	330	340.00 - 470.00	49.00	40.00	164.1786

NA= Not Applicable

NC = Not Calculated

( ) = The result is negative

Note: Maximum and mean concentrations for plutonium-239,-240; uranium-233,-234; americium-241; and uranium-238 include 'hotspot' results.

Table F3-13 (Continued)  
 Summary Statistics  
 Semivolatile Organics - Surface Soil

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
DI-n-OCTYL PHTHALATE	0	330	340.00 - 470.00	NA	NA	NC
DIBENZO(a,h)ANTHRACENE	15	330	340.00 - 470.00	92.00	43.00	171.5558
DIBENZOFURAN	7	330	340.00 - 470.00	86.00	37.00	179.5714
DIETHYL PHTHALATE	0	330	340.00 - 470.00	NA	NA	NC
DIMETHYL PHTHALATE	0	330	340.00 - 470.00	NA	NA	NC
FLUORANTHENE	68	330	350.00 - 470.00	1,900.00	240.00	579.6429
FLUORENE	18	330	340.00 - 470.00	230.00	54.00	178.0714
HEXACHLOROENZENE	0	330	340.00 - 470.00	NA	NA	NC
HEXACHLOROBUTADIENE	0	330	340.00 - 470.00	NA	NA	NC
HEXACHLOROCYCLOPENTADIENE	0	330	340.00 - 470.00	NA	NA	NC
HEXACHLOROETHANE	0	330	340.00 - 470.00	NA	NA	NC
INDENO(1,2,3-cd)PYRENE	39	330	180.00 - 470.00	280.00	88.00	186.2143
IOPHORONE	0	330	340.00 - 470.00	NA	NA	NC
N-NITROSO-DI-n-PROPYLAMINE	0	330	340.00 - 470.00	NA	NA	NC
N-NITROSODIPHENYLAMINE	0	330	340.00 - 470.00	NA	NA	NC
NAPHTHALENE	4	330	340.00 - 470.00	110.00	110.00	185.3571
NITROBENZENE	0	330	340.00 - 470.00	NA	NA	NC
PENTACHLOROPHENOL	0	1800	1,800.00 - 2,300.00	NA	NA	NC
PHENANTHRENE	57	330	340.00 - 470.00	1,800.00	180.00	419.5538
PHENOL	0	330	340.00 - 470.00	NA	NA	NC
PYRENE	64	330	350.00 - 470.00	1,800.00	220.00	525.0893

NA= Not Applicable

NC = Not Calculated

**Table F3-14  
Summary Statistics  
Pesticides / PCBs - Surface Soil**

Contaminant	Detection Frequency %	CRQL ug/kg	Range of SQL Observed ug/kg	Maximum Concentration Detected ug/kg	Minimum Concentration Detected ug/kg	Calculated Mean Concentration ug/kg
HEPTACHLOR EPOXIDE	0	8.00	0.05 - 11.00	NA	NA	NC
ENDOSULFAN SULFATE	0	16.00	0.10 - 23.00	NA	NA	NC
AROCLOR-1260	0	160.00	1.00 - 230.00	NA	NA	NC
AROCLOR-1254	10	160.00	1.00 - 230.00	1200.0000	132.5000	145.4107
AROCLOR-1221	0	80.00	0.50 - 110.00	NA	NA	NC
AROCLOR-1232	0	80.00	0.50 - 110.00	NA	NA	NC
AROCLOR-1248	3	80.00	0.50 - 110.00	670.0000	670.0000	67.1339
AROCLOR-1016	0	80.00	0.50 - 110.00	NA	NA	NC
ALDRIN	0	8.00	0.05 - 11.00	NA	NA	NC
alpha-BHC	0	8.00	0.05 - 11.00	NA	NA	NC
beta-BHC	0	8.00	0.05 - 11.00	NA	NA	NC
delta-BHC	0	8.00	0.05 - 11.00	NA	NA	NC
ENDOSULFAN II	0	16.00	0.10 - 23.00	NA	NA	NC
4,4'-DDT	0	16.00	0.10 - 23.00	NA	NA	NC
alpha-CHLORDANE	0	80.00	0.50 - 110.00	NA	NA	NC
gamma-CHLORDANE	0	80.00	0.50 - 170.00	NA	NA	NC
AROCLOR-1242	0	80.00	0.50 - 110.00	NA	NA	NC
ENDRIN KETONE	0	16.00	0.10 - 23.00	NA	NA	NC
gamma-BHC (LINDANE)	0	8.00	0.05 - 11.00	NA	NA	NC
DIELDRIN	0	16.00	0.10 - 23.00	NA	NA	NC
ENDRIN	0	16.00	0.10 - 23.00	NA	NA	NC

NA = Not Applicable  
NC = Not Calculated

**Table F3-14 (Continued)**  
**Summary Statistics**  
**Pesticides / PCBs - Surface Soil**

<b>Contaminant</b>	<b>Detection Frequency %</b>	<b>CRQL ug/kg</b>	<b>Range of SQL Observed ug/kg</b>	<b>Maximum Concentration Detected ug/kg</b>	<b>Minimum Concentration Detected ug/kg</b>	<b>Calculated Mean Concentration ug/kg</b>
METHOXYCHLOR	0	80.00	0.50 - 110.00	NA	NA	NC
4,4'-DDD	0	16.00	0.10 - 23.00	NA	NA	NC
4,4'-DDE	0	16.00	0.10 - 23.00	NA	NA	NC
HEPTACHLOR	0	8.00	0.05 - 11.00	NA	NA	NC
TOXAPHENE	0	160.00	1.00 - 230.00	NA	NA	NC
ENDOSULFAN I	0	8.00	0.05 - 11.00	NA	NA	NC

NA = Not Applicable  
 NC = Not Calculated

**Table F3-15**  
**Groundwater – Organic/Inorganic**  
**Noncarcinogenic Contaminants – Toxicity Screen**

Contaminant	Maximum Concentration (ug/L)	Reference Dose* (mg/kg/day)	Risk Factor <sup>1</sup>	Percentage Of Total Risk <sup>2</sup>
<b>Inorganics</b>				
selenium	2.82E+04	5.00E-03	5.64E+06	34%
vanadium	4.03E+02	7.00E-03	5.76E+04	< 1%
<b>Organics</b>				
carbon tetrachloride	4.50E+03	5.71E-04	7.88E+06	48%
chloroform	1.70E+02	1.00E-02	1.70E+04	< 1%
1,1-dichloroethene	1.80E+04	9.00E-03	2.00E+06	12%
cis-1,2 dichloroethene	8.60E-01	1.00E-02	8.60E+01	< 1%
tetrachloroethene	6.00E+03	1.00E-02	6.00E+05	4%
toluene	2.70E+02	1.00E-01	2.70E+03	< 1%
1,1,1-trichloroethane	1.90E+04	9.00E-02	2.11E+05	1%
trichloroethene	1.40E+04	NA	NA	NA
<b>TOTALS</b>			1.64E+07	100%

NA = Not Available

RfD = Reference Dose

\*Based on the most conservative RfD [oral(ingestion) or inhalation]

<sup>1</sup>Risk Factor formula: If RfD = "NA" Then Risk Factor = "NA"; Else Risk Factor = (Max. Conc.)x(1/RfD)

<sup>2</sup>Percentage of Risk formula: If Risk Factor = "NA" Then Percentage = "NA"; Else

Percentage = [(Risk Factor for analyte)/(Total of all analyte Risk Factors)]x100

**Table F3-16**  
**Groundwater – Organic/Inorganic**  
**Carcinogenic Contaminants – Toxicity Screen**

Contaminant	Maximum Concentration (ug/L)	Slope Factor* (mg/kg/day) <sup>-1</sup>	Risk Factor <sup>1</sup>	Percentage Of Total Risk <sup>2</sup>
<b>Inorganics</b>				
selenium	2.82E+04	NA	NA	NA
vanadium	4.03E+02	NA	NA	NA
<b>Organics</b>				
carbon tetrachloride	4.50E+03	1.30E-01	585	5%
chloroform	1.70E+02	7.70E-02	13.09	< 1%
1,1-dichloroethene	1.80E+04	6.00E-01	10800	92%
cis-1,2 dichloroethene	8.60E-01	NA	NA	NA
tetrachloroethene	6.00E+03	5.10E-02	306	3%
toluene	2.70E+02	NA	NA	NA
1,1,1-trichloroethane	1.90E+04	NA	NA	NA
trichloroethene	1.40E+04	NA	NA	NA
<b>TOTALS</b>			<b>1.17E+04</b>	<b>100%</b>

NA = Not Applicable

\*Based on the most conservative Slope Factor [oral(ingestion) or inhalation]

<sup>1</sup>Risk Factor formula: If Slope Factor = "NA" Then Risk Factor = "NA"; Else Risk Factor = (Max. Conc.)x(Slope Factor)

<sup>2</sup>Percentage of Risk formula: If Risk Factor = "NA" Then Percentage = "NA"; Else

**Table F3-17**  
**Groundwater – Organic/Inorganic**  
**Risk-Based Concentration Screen**

Contaminant	Maximum Concentration (mg/L)	RBC (mg/L)	1000 x RBC (mg/L)	Consider Anomaly ?
<b>Organics</b>				
1,1,2-trichloroethane	8.40E-02	2.50E-04	2.50E-01	No
1,2-dichloroethane	2.90E-02	1.60E-04	1.60E-01	No
2-butanone	5.80E-01	NA	NA	No
2-hexanone	4.30E-02	NA	NA	No
4-methyl-2-pentanone	2.50E-02	NA	NA	No
1,2,4-trimethylbenzene	1.00E-04	NA	NA	No
carbon disulfide	2.25E+00	2.10E-02	2.10E+01	No
styrene	2.30E-01	1.20E+00	1.20E+03	No
total xylenes	1.20E-01	5.20E-01	5.20E+02	No
p-chlorotoluene	6.00E-04	NA	NA	No
p-cymene	3.80E-01	NA	NA	No
tert-butylbenzene	4.00E-03	NA	NA	No
2,6-dinitrotoluene	2.00E-03	1.30E-04	1.30E-01	No
1,1-dichloroethane	3.50E-02	8.10E-01	8.10E+02	No
naphthalene	2.40E-03	NA	NA	No
vinyl chloride	1.90E-04	2.50E-05	2.50E-02	No
1,2-dichloroethene	1.20E+01	5.50E-02	5.50E+01	No
1,2-dichloropropane	3.50E-04	2.10E-04	2.10E-01	No
benzene	3.00E-03	4.90E-04	4.90E-01	No
dibromochloromethane	5.60E-02	1.00E-03	1.00E+00	No
ethyl benzene	1.00E-03	1.30E+00	1.30E+03	No
vinyl acetate	8.00E-03	3.70E+01	3.70E+04	No
m-xylene	3.90E-04	1.40E+00	1.40E+03	No

**Table F3-18**  
**Subsurface Soil – Organic/Inorganic**  
**Noncarcinogenic Contaminants – Toxicity Screen**

Contaminant	Maximum Concentration (ug/kg)	Reference Dose (mg/kg/day)	Risk Factor <sup>1</sup>	Percentage Of Total Risk <sup>2</sup>
<b>Organics</b>				
fluoranthene	8.00E+03	4.00E-02	2.00E+05	43%
phenanthrene	8.95E+03	NA	NA	NA
pyrene	7.30E+03	3.00E-02	2.43E+05	53%
toluene	2.00E+03	1.00E-01	2.00E+04	4%
<b>TOTALS</b>			<b>4.63E+05</b>	<b>100%</b>

NA = Not Applicable  
RfD = Reference Dose

\*Based on the most conservative RfD [oral(ingestion) or inhalation]

<sup>1</sup>Risk Factor formula: If RfD = "NA" Then Risk Factor = "NA"; Else Risk Factor = (Max. Conc.)x(1/RfD)

<sup>2</sup>Percentage of Risk formula: If Risk Factor = "NA" Then Percentage = "NA"; Else

Percentage = [(Risk Factor for analyte)/(Total of all analyte Risk Factors)]x100

**Table F3-19**  
**Subsurface Soil – Radionuclides**  
**Carcinogenic Contaminants – Toxicity Screen**

Analyte	Maximum Concentration (pCi/g)	Slope Factor* (pCi) <sup>-1</sup>	Risk Factor <sup>1</sup>	Percentage Of Total Risk <sup>2</sup>
<b>RADIONUCLIDES</b>				
americium – 241	4.26E+03	3.20E-08	1.36E-04	31%
plutonium – 239,240	7.40E+03	3.80E-08	2.81E-04	65%
uranium – 233,234	4.20E+02	2.70E-08	1.13E-05	3%
uranium – 235	2.80E-01	2.50E-08	7.00E-09	< 1%
uranium – 238	1.22E+02	5.20E-08	6.34E-06	1%
		TOTAL	4.35E-04	100%

NA = Not Applicable

\*Based on the most conservative Slope Factor [oral(ingestion) or inhalation]

<sup>1</sup>Risk Factor formula: If Slope Factor = "NA" Then Risk Factor = "NA"; Else Risk Factor = (Max. Conc.)x(Slope Factor)

<sup>2</sup>Percentage of Risk formula: If Risk Factor = "NA" Then Percentage = "NA"; Else  
 Percentage = [(Risk Factor for analyte)/(Total of all analyte Risk Factors)]x100

**Table F3-20**  
**Subsurface Soil – Organic/Inorganic**  
**Risk Based Concentration Screen**

Contaminant	Maximum Concentration (mg/kg) <sup>1</sup>	RBC (mg/kg) <sup>1</sup>	1000 x RBC (mg/kg) <sup>1</sup>	Consider Anomaly?
<b>Organics</b>				
2-hexanone	2.00E-03	NA	NA <sup>2</sup>	No
4-methyl-2-pentanone	3.00E-03	NA	NA	No
carbon disulfide	2.00E-03	5.30E+01	5.30E+04	No
naphthalene	2.49E+00	1.10E+04	1.10E+07	No
styrene	2.80E-02	1.30E+04	1.30E+07	No
tetrachloroethene	4.70E-02	6.50E-02	6.50E+01	No
trichloroethene	1.40E-01	3.40E+01	3.40E+04	No
1,4-dichlorobenzene	1.10E-01	1.70E+01	1.70E+04	No
2-methylnaphthalene	6.55E-01	NA	NA	No
4-nitrophenol	9.98E-01	NA	NA	No
butyl benzyl phthalate	4.90E-02	1.60E+04	1.60E+07	No
chrysene	3.94E+00	2.90E+02	2.90E+05	No
dibenzofuran	9.30E-01	NA	NA	No
diethyl phthalate	5.20E-01	6.30E+04	6.30E+07	No
fluorene	1.71E+00	2.80E+01	2.80E+04	No
indeno(1,2,3-cd)pyrene	1.95E+00	2.90E+00	2.90E+03	No
n-nitrosodiphenylamine	1.14E-01	3.50E+02	3.50E+05	No
pentachlorophenol	1.01E+00	1.40E+01	1.40E+04	No
benzoic acid	1.03E+00	1.00E+05	1.00E+08	No
chloroform	5.00E-03	9.60E-01	9.60E+02	No
ethyl benzene	2.00E-03	6.80E+01	6.80E+04	No
trans-1,3-dichloropropene	5.00E-03	1.00E+00	1.00E+03	No
phenanthrene	8.95E+00	NA	NA	No
acenaphthene	2.00E+00	3.60E+01	3.60E+04	No
anthracene	2.67E+00	1.90E+00	1.90E+03	No
benzo(a)anthracene	4.03E+00	2.90E+00	2.90E+03	No
benzo(a)pyrene	3.34E+00	2.90E-01	2.90E+02	No
benzo(b)fluoranthene	2.85E+00	2.90E+00	2.90E+03	No
benzo(ghi)perylene	1.87E+00	NA	NA	No
benzo(k)fluoranthene	3.35E+00	2.90E+00	2.90E+03	No
di-n-octyl phthalate	1.13E-01	1.60E+03	1.60E+06	No
carbon tetrachloride	1.80E-02	9.21E-01	9.21E+02	No
chlorobenzene	5.00E-03	3.00E+02	3.00E+05	No
1,1-dichloroethene	1.20E-02	7.00E-02	7.00E+01	No
1,2-dichloroethane	5.00E-03	8.40E-01	8.40E+02	No
1,1,1-trichloroethane	5.00E-03	4.90E+01	4.90E+04	No
total xylenes	3.00E-03	9.90E+01	9.90E+04	No

<sup>1</sup> radionuclide units expressed as pCi/g

<sup>2</sup> NA = Not Available

Table F3-21  
Surface Soil – Organic/Inorganic  
Noncarcinogenic Contaminants – Toxicity Screen

Contaminant	Maximum Concentration (ug/kg)	Oral Reference Dose (mg/kg/day)	Risk Factor <sup>1</sup>	Percentage Of Total Risk <sup>2</sup>
<b>Organics</b>				
benzo(a)anthracene	8.30E+02	NA	NA	NA
benzo(a)pyrene	7.50E+02	NA	NA	NA
benzo(b)fluoranthene	8.10E+02	NA	NA	NA
benzo(k)fluoranthene	7.40E+02	NA	NA	NA
dibenzo(a,h)anthracene	9.20E+01	NA	NA	NA
pyrene	1.80E+03	3.00E-02	6.00E+04	51%
fluoranthene	1.90E+03	4.00E-02	4.75E+04	40%
fluorene	2.30E+02	4.00E-02	5.75E+03	5%
acenaphthene	2.40E+02	6.00E-02	4.00E+03	3%
arochlor-1254	1.20E+03	NA	NA	NA
chrysene	7.90E+02	NA	NA	NA
indeno(1,2,3-cd)pyrene	2.80E+02	NA	NA	NA
phenanthrene	1.60E+03	NA	NA	NA
acenaphthylene	1.10E+02	NA	NA	NA
anthracene	3.30E+02	3.00E-01	1.10E+03	<1%
benzo(ghi)perylene	3.50E+02	NA	NA	NA
<b>TOTALS</b>			<b>1.18E+05</b>	<b>100%</b>

NA = Not Applicable  
RfD = Reference Dose

<sup>1</sup>Risk Factor formula: If RfD = "NA" Then Risk Factor = "NA"; Else Risk Factor = (Max. Conc.)x(1/RfD)

<sup>2</sup>Percentage of Risk formula: If Risk Factor = "NA" Then Percentage = "NA"; Else  
Percentage = [(Risk Factor for analyte)/(Total of all analyte Risk Factors)]x100

**Table F3-22**  
**Surface Soil – Organic/Inorganic**  
**Carcinogenic Contaminants – Toxicity Screen**

<b>Contaminant</b>	<b>Maximum Concentration (ug/kg)</b>	<b>Slope Factor* (mg/kg/day) -1</b>	<b>Risk Factor<sup>1</sup></b>	<b>Percentage Of Total Risk<sup>2</sup></b>
<b>Organics</b>				
benzo(a)anthracene	8.30E+02	7.30E-01	6.06E+02	3%
benzo(a)pyrene	7.50E+02	7.30E+00	5.48E+03	32%
benzo(b)fluoranthene	8.10E+02	7.30E-01	5.91E+02	3%
benzo(k)fluoranthene	7.40E+02	7.30E-01	5.40E+02	3%
dibenzo(a,h)anthracene	9.20E+01	7.30E+00	6.72E+02	4%
pyrene	1.80E+03	NA	NA	NA
fluoranthene	1.90E+03	NA	NA	NA
fluorene	2.30E+02	NA	NA	NA
acenaphthene	2.40E+02	NA	NA	NA
aroclor-1254	1.20E+03	7.70E+00	9.24E+03	53%
chrysene	7.90E+02	7.30E-03	5.77E+00	<1%
indeno(1,2,3-cd)pyrene	2.80E+02	7.30E-01	2.04E+02	<1%
phenanthrene	1.60E+03	NA	NA	NA
anthracene	3.30E+02	NA	NA	NA
benzo(ghi)perylene	3.50E+02	NA	NA	NA
<b>TOTALS</b>			<b>1.73E+04</b>	<b>99%</b>

NA = Not Applicable

\*Based on the most conservative Slope Factor [oral(ingestion) or inhalation]

<sup>1</sup>Risk Factor formula: If Slope Factor = "NA" Then Risk Factor = "NA"; Else Risk Factor = (Max. Conc.)x(Slope Factor)

<sup>2</sup>Percentage of Risk formula: If Risk Factor = "NA" Then Percentage = "NA"; Else Percentage = [(Risk Factor for analyte)/(Total of all analyte Risk Factors)]x100

**Table F3-23**  
**Surface Soil – Radionuclides**  
**Carcinogenic Contaminants – Toxicity Screen**

Analyte	Maximum Concentration (pCi/g)	Slope Factor* (pCi) <sup>-1</sup>	Risk Factor <sup>1</sup>	Percentage Of Total Risk <sup>2</sup>
<b>RADIONUCLIDES</b>				
americium – 241	2.65E+03	3.20E-08	8.48E-05	17%
plutonium-239,240	1.11E+04	3.80E-08	4.22E-04	83%
uranium-233,234 <sup>3</sup>	2.54E+01	2.70E-08	6.86E-07	<1%
uranium-235	1.22E-01	2.50E-08	3.05E-09	<1%
uranium-238 <sup>3</sup>	4.69E+00	5.20E-08	2.44E-07	<1%
		<b>TOTAL</b>	5.08E-04	100%

NA = Not Applicable

\*Based on the most conservative Slope Factor [oral(ingestion) or inhalation]

<sup>1</sup>Risk Factor formula: If Slope Factor = "NA" Then Risk Factor = "NA"; Else Risk Factor = (Max. Conc.)x(Slope Factor)

<sup>2</sup>Percentage of Risk formula: If Risk Factor = "NA" Then Percentage = "NA"; Else

Percentage = [(Risk Factor for analyte)/(Total of all analyte Risk Factors)]x100

<sup>3</sup>The "hot spot" concentrations for Am-241 and Pu-239/-240 have biased the concentration toxicity screen.

The contaminants have been included as COCs based on professional judgement and results from previous concentration – toxicity screens.

**Table F3-24  
Surface Soil – Organic/Inorganic  
Risk Based Concentration Screen**

<b>Contaminant</b>	<b>Maximum Concentration (mg/kg)</b>	<b>RBC (mg/kg)</b>	<b>1000 x RBC (mg/kg)</b>	<b>Consider Anomaly ?</b>
<b>Organics</b>				
naphthalene	1.10E-01	1.10E+04	1.10E+07	No
aroclor-1248	6.70E-01	1.10E-01	1.10E+02	No
acenaphthylene	1.10E-01	NA	NA	No

NA = Not Available

**Table F3-39  
Contaminant and COC Screening Process  
Surface Water Total Radiochemistry**

Isotope	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant?	OU1 Contaminant? (a)
AMERICIUM-241	177/205	86.34	YES	YES	RETAINED	YES	YES
CESIUM-137	151/172	87.79	YES	YES	ELIMINATED	NO	NO
PLUTONIUM-239, -240	151/164	92.07	YES	ID	RETAINED	YES	YES
RADIUM-226	17/18	94.44	NO	NA	NA	NO	NO
RADIUM-228	4/4	100	ID	ID	ELIMINATED	NO	NO
STRONTIUM-89,-90	65/77	84.42	YES	ID	ELIMINATED	NO	NO
TRITIUM	153/229	66.81	YES	NO	NA	NO	NO
URANIUM-233, -234	122/122	100.00	YES	ID	ELIMINATED	NO	YES <sup>(a)</sup>
URANIUM-235	105/122	86.07	YES	NO	ELIMINATED	NO	NO
URANIUM-238	122/122	100.00	YES	YES	ELIMINATED	NO	YES <sup>(b)</sup>

- (a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect
- (b) Risk assessment contaminants in surface water were assessed using surface soil COCs. The "hot spot" concentrations for Am-241 and Pu-239/ -240 have biased the concentrations toxicity screen. The contaminants have been included as COCs based on professional judgement and results from previous concentration - toxicity screens
- NA Not applicable
- ID Insufficient data

**Table F3-40  
Contaminant and COC Screening Process  
Surface Water Organics**

Compound	Detections/ Observations	Percent Detected	Known Waste?	Known Degradation Product?	Spatial/ Temporal Considerations?	Laboratory Artifact Considerations?	OU1 Contaminant?	OU1 Contaminant of Concern? (a)
1,1,1-TRICHLOROETHANE	2/235	0.85	YES	NA	NA	NA	YES	NO
1,1-DICHLOROETHANE	1/235	0.43	NO	YES	RETAINED	RETAINED	YES	NO
1,1-DICHLOROETHENE	1/233	0.43	NO	YES	NA	RETAINED	YES	NO
1,2-DICHLOROETHANE	3/235	1.28	NO	NO	RETAINED	RETAINED	YES	NO
1,2-DICHLOROETHENE	1/235	0.43	NO	YES	NA	RETAINED	YES	NO
1,2-DICHLOROPROPANE	1/235	0.43	NO	NO	ELIMINATED	NA	NO	NO
2-BUTANONE	7/223	3.14	NO	NO	ELIMINATED	ELIMINATED	NO	NO
ACETONE	60/205	29.27	NO	NO	ELIMINATED	ELIMINATED	NO	NO
BENZYL ALCOHOL	1/42	2.38	NO	NO	ELIMINATED	NA	NO	NO
BIS(2-ETHYLHEXYL)PHTHALATE	6/42	14.29	NO	NO	ELIMINATED	ELIMINATED	NO	NO
CARBON DISULFIDE	3/230	1.30	NO	NO	ELIMINATED	NA	NO	NO
DI-n-BUTYL PHTHALATE	1/42	2.38	NO	NO	ELIMINATED	ELIMINATED	NO	NO
ETHYLBENZENE	1/236	0.42	NO	NO	ELIMINATED	NA	NO	NO
METHYLENE CHLORIDE	120/234	51.28	NO	NO	ELIMINATED	ELIMINATED	NO	NO
N-NITROSODIPHENYLAMINE	1/42	2.38	NO	NO	ELIMINATED	NA	NO	NO
STYRENE	1/235	0.43	NO	NO	ELIMINATED	NA	NO	NO
TETRACHLOROETHENE	15/235	6.38	YES	NA	NA	NA	YES	NO
TOLUENE	8/235	3.39	NO	NO	RETAINED	RETAINED	YES	NO
TOTAL XYLENES	1/236	0.42	NO	NO	RETAINED	RETAINED	YES	NO
TRICHLOROETHENE	9/235	3.83	YES	NA	NA	NA	YES	NO

(a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect  
 NA Not applicable

**Table F3-42  
Contaminant and COC Screening Process  
Sediment Water Quality Parameters**

<b>Analyte</b>	<b>Detections/ Observations</b>	<b>Percent Detected</b>	<b>UTL Exceedance?</b>	<b>Significant Difference by ANOVA?</b>	<b>Spatial/ Temporal Considerations?</b>	<b>OU1 Contaminant?</b>	<b>OU1 Contaminant of Concern? (a)</b>
BICARBONATE AS CaCO <sub>3</sub>	2/2	100.00	NO	NA	NA	NO	NO
CARBONATE	2/2	100.00	NO	NA	NA	NO	NO
NITRATE/NITRITE	6/10	60.00	NO	NA	NA	NO	NO
pH	10/10	100.00	NO	NA	NA	NO	NO

(a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect  
 NA Not applicable

Table F3-43  
 Contaminant and COC Screening Process  
 Sediment Total Radiochemistry

OU1 Contaminant of Concern? (a)	OU1 Contaminant?	Spatial/ Temporal Considerations?	Significant Difference by ANOVA?	UTL Exceedance?	Percent Detected	Detections/ Observations	Isotope
YES	YES	RETAINED	NA	NO	100.00	11/11	AMERICIUM-241
NO	NO	ELIMINATED	NP	NP	100.00	4/4	CESIUM-134
NO	NO	NA	NA	NO	100.00	12/12	CESIUM-137
YES	YES	RETAINED	ID	YES	100.00	12/12	PLUTONIUM-239-240
NO	NO	NA	NA	NO	100.00	3/3	RADIUM-226
NO	NO	NA	NA	NO	100.00	6/6	RADIUM-228
NO	NO	ELIMINATED	NO	YES	100.00	12/12	STRONTIUM-89-90
NO	NO	NA	NA	NO	100.00	7/7	TRITIUM
YES	NO	NA	NA	NO	100.00	12/12	URANIUM-233-234
NO	NO	NA	NA	NO	100.00	12/12	URANIUM-235
YES	NO	NA	NA	NO	100.00	12/12	URANIUM-238

(a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect

NA Not applicable  
 ID Insufficient data  
 NP Not Performed

**Table F3-44  
Contaminant and COC Screening Process  
Sediment Organics**

Compound	Detections/ Observations	Percent Detected	Known Waste?	Known Degradation Product?	Spatial/ Temporal Considerations?	Laboratory Artifact Considerations?	OU1 Contaminant?	OU1 Contaminant of Concern? (a)
1,1,1-TRICHLOROETHANE	1/11	9.09	YES	NA	NA	NA	YES	NO
2-BUTANONE	5/13	38.46	NO	NO	ELIMINATED	ELIMINATED	NO	NO
4,4'-DDT	1/10	10.00	NO	NO	ELIMINATED	NA	NO	NO
4-METHYLPHENOL	2/13	15.38	NO	NO	ELIMINATED	NA	NO	NO
ACETONE	10/13	76.92	NO	NO	ELIMINATED	ELIMINATED	NO	NO
AROCLOP-1254	2/10	20.00	NO	NO	RETAINED	RETAINED	YES	YES
BENZO(B)FLUORANTHENE	1/13	7.69	YES	NA	NA	NA	YES	YES
BENZO(K)FLUORANTHENE	1/13	7.69	YES	NA	NA	NA	YES	YES
BIS(2-ETHYLHEXYL)PHTHALATE	11/13	84.62	NO	NO	ELIMINATED	ELIMINATED	NO	NO
BUTYL BENZYL PHTHALATE	1/13	7.69	NO	NO	ELIMINATED	ELIMINATED	NO	NO
CHRYSENE	2/13	15.38	YES	NA	NA	NA	YES	NO
DI-n-BUTYL PHTHALATE	6/13	46.15	NO	NO	ELIMINATED	ELIMINATED	NO	NO
DI-n-OCTYL PHTHALATE	1/13	7.69	NO	NO	ELIMINATED	ELIMINATED	NO	NO
FLUORANTHENE	4/13	30.77	YES	NA	NA	NA	YES	YES
METHYLENE CHLORIDE	10/13	76.92	NO	NO	ELIMINATED	ELIMINATED	NO	NO
PHENANTHRENE	1/13	7.69	YES	NA	NA	NA	YES	NO
PYRENE	4/13	30.77	YES	NA	NA	NA	YES	YES
TOLUENE	2/13	15.38	NO	NO	RETAINED	RETAINED	YES	NO

(a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect  
 NA Not applicable  
 ID Insufficient data

**Table F3-45**  
**OU1 Contaminants of Concern 95 Percent Upper Concentration Limits (UCLs)**  
**Sitewide Data including Source**

Contaminant	Arithmetic Mean (x)	Standard Deviation (sd)	Number of Observations (n)	t Statistic (t)	UCL
<b>Groundwater (ug/L)</b>					
1,1-Dichloroethene	283	1449	211	1.645	447
Carbon Tetrachloride	81.2	500	211	1.645	138
Tetrachloroethene	103	481	211	1.645	157
1,1,1-Trichloroethane	363	1722	211	1.645	558
Selenium	132	172.3	5 *	2.132	296
<b>Surface Soils (ug/kg) or (pCi/g)</b>					
Americium-241	83.2807	460.997	32	1.697	221.6
Plutonium-239,240	294.6888	1776.33	38	1.684	779.9
Benzo (a) anthracene	266.6	156.8	28	1.703	317.1
Benzo (a) pyrene	258.4	136.5	28	1.703	302.3
Benzo (b) fluoranthene	259.8	139.2	28	1.703	304.6
Benzo (k) fluoranthene	246.1	133.5	28	1.703	289.1
Dibenzo (a,h) anthracene	171.6	50.8	27	1.706	188.3
Aroclor-1254	145	230	29	1.701	217.6
Pyrene	525	422	28	1.703	660.8
Fluoranthene	579.6	455	28	1.703	726.0
Fluorene	178.1	42.6	28	1.703	191.8
Acenaphthene	178.6	47.3	28	1.703	193.8
Uranium-233,234	2.1422	4.135	38	1.684	3.272
Uranium-238	1.3758	0.7157	38	1.684	1.571
<b>Subsurface Soils (ug/kg) or (pCi/g)</b>					
Americium-241	10.247	17.654	3 *	2.92	40.01
Plutonium-239,240	29.170	50.218	3 *	2.92	113.8
Pyrene	308	302	187	1.645	344.3
Fluoranthene	313	329	187	1.645	352.6
Toluene	107.9	181.8	432	1.645	122.3
Uranium-233,234	2.204	1.989	3 *	2.92	5.557
Uranium-238	1.186	0.178	3 *	2.92	1.486
<b>Surface Water (pCi/L)</b>					
Americium-241	0.0208	0.0381	173	1.645	0.0256
Plutonium-239,240	0.0071	0.0052	143	1.645	0.0078
Uranium-233,234	2.1047	1.5672	106	1.658	2.357
Uranium-238	3.5319	5.984	106	1.658	4.496
<b>Sediments (ug/kg) or (pCi/g)</b>					
Americium-241	0.027	0.0167	11	1.812	0.0361
Plutonium-239,240	1.305	3.2178	12	1.796	2.973
Benzo (b) fluoranthene	260	32	13	1.782	275.8
Benzo (k) fluoranthene	254.9	38	13	1.782	273.7
Aroclor-1254	132	47	10	1.833	159.2
Pyrene	224.6	69.7	13	1.782	259.0
Fluoranthene	222.7	74.2	13	1.782	259.4
Uranium-233,234	0.9753	0.624	12	1.796	1.299
Uranium-238	0.9394	0.4463	12	1.796	1.171

$UCL = x + t(sd/(n)^{.5})$

\* = Calculated from arithmetic means for each lithologic unit

**Table F3-46****Potential Volatile Organic COC Transformation Products**

<b>Compound</b>	<b>Potential Transformation Products</b>
1,1,1-Trichloroethane	1,1-Dichloroethene cis and trans 1,2-Dichloroethene Chloroethane Vinyl chloride
1,2-Dichloroethene	Vinyl chloride
Chloroform	Methylene chloride
Trichloroethene	cis and trans 1,2-Dichloroethene Vinyl chloride
Tetrachloroethene	Trichloroethene cis and trans 1,2-Dichloroethene Vinyl chloride
Carbon tetrachloride	Chloroform
1,1-Dichloroethene	Vinyl chloride
Methylene chloride	None listed

**Table F3-47****Percent Results Validated / Percent of Validated Results Rejected**

	VOCs	SVOCs	Pesticide/PCBs	Metals	RADs
Geologic Materials	75/6	79/1	49/0	85/1	62/23
Groundwater	40/5	85/2	93/0	67/1	72/10
Sediments	87/14	93/1	90/0	93/1	82/22
Seep/Spring Water	47/12	100/2	100/0	41/4	72/12
Surface Soils	*	99/0	100/1	97/1	43/41
Surface Water	48/3	45/1	64/0	53/3	72/20
* Not analyzed					

**Table F3-48**

**Field Precision Summary\***

Analyte Group	Matrix							
	Aqueous				Nonaqueous		Totals	
	Unfiltered		Filtered		Passing RPD Criterion	Passing RPD or CRQL Criteria	Passing RPD Criterion	Passing RPD or CRQL Criteria
	Passing RPD Criterion	Passing RPD or CRQL Criteria	Passing RPD Criterion	Passing RPD or CRQL Criteria				
Organics	98.4	99.8	NA	NA	96.7	97.4	97.1	98.0
Metals	83.7	92.9	90.3	98.7	86.5	92.6	86.8	94.3
Radionuclides	35.4	93.1	56.4	87.2	57.4	88.9	55.6	89.2
Total	89.4	97.5	84.2	96.6	85.2	95.3	86.0	95.9

- Table shows percent of duplicate data passing the relative percent difference (RPD) criteria ( $\leq 30\%$  RPD for aqueous samples and  $\leq 40\%$  RPD for nonaqueous samples). Also shown are the percent duplicates passing the RPD criterion or the Contract Required Detection Limit (CRQL) criterion (difference in duplicate concentrations is less than or equal to the CRQL), the latter accounting for instrumentation limitations when concentrations approach the CRQL.

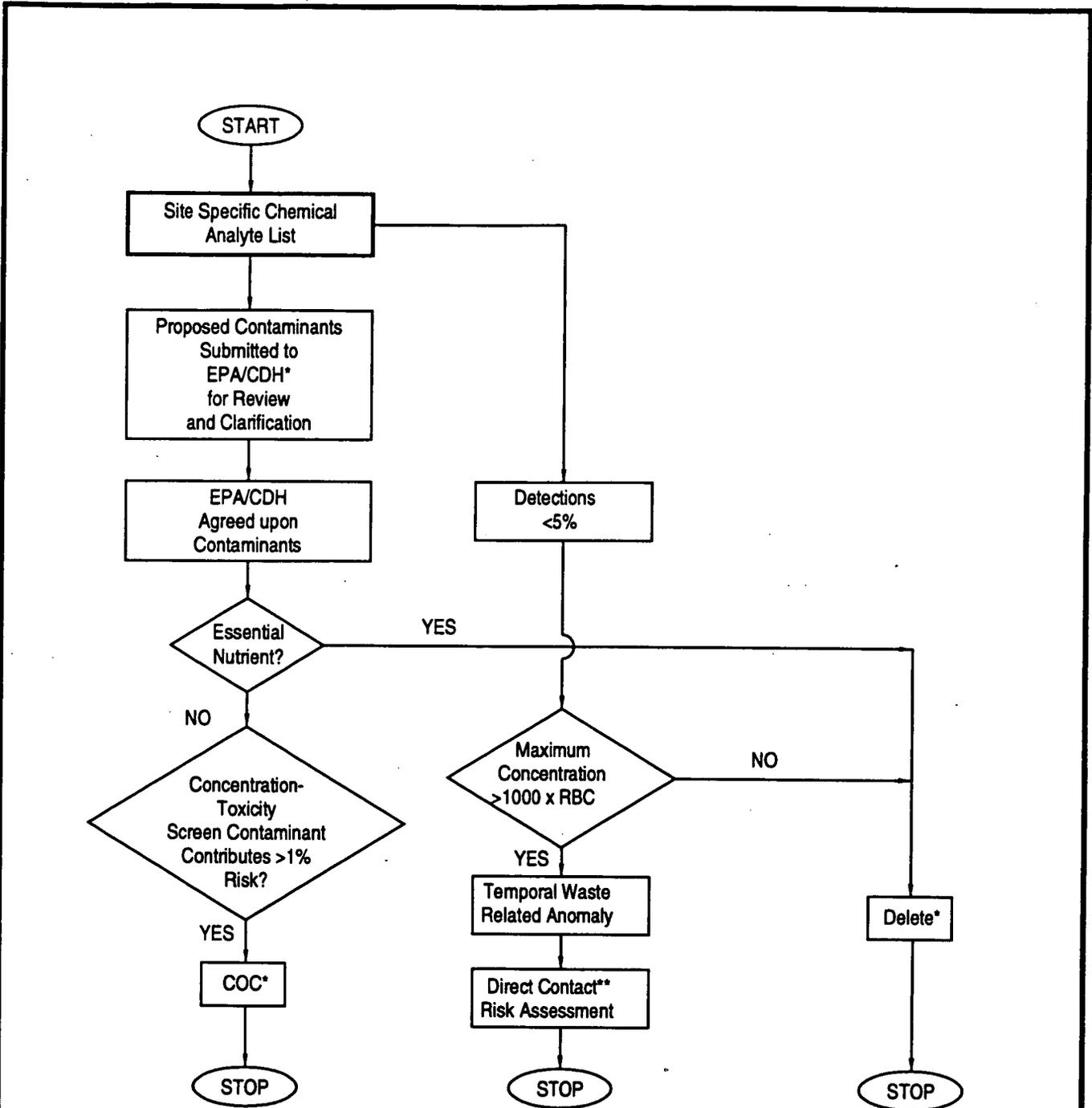
NA = Not applicable

Table F3-49

Summary of Data Completeness  
Number of Sampling Stations

	Planned	Installed
Boreholes	54	56
Monitoring Wells	37	26
Surface Water Stations	21	15
Sediment Stations	8	7
Total	120	104

Overall approximate percent completeness = 86.7%



\* PROFESSIONAL JUDGEMENT MAY BE USED TO RETAIN OR DELETE A CHEMICAL.

\*\* DIRECT EXPOSURE THROUGH INGESTION, INHALATION OR DERMAL EXPOSURE AS APPLICABLE.

UTL = Upper Tolerance Limit  
 ANOVA = Analysis of Variance  
 RBC = Risk Based Concentration

**U.S. DEPARTMENT OF ENERGY**

Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFI/RI REPORT

Contaminants of Concern  
 Screening Flow Chart

Figure F3-1

REV. FEBRUARY 1994  
 AUGUST 1993

R74266.P.JMBPJ-051794

## SECTION F4

### IDENTIFICATION OF SCENARIOS AND PATHWAYS

Potential scenarios and exposure pathways are identified using existing and potential land uses. The reasonable maximum exposure (RME) is defined as the highest exposure that is reasonably expected to occur according to the EPA's concept of RME at a site (EPA, 1989a). The term "potential" means "a reasonable chance of occurrence within the context of the reasonable maximum exposure scenario" (EPA, 1990b). Using this approach, potential exposure routes are evaluated using a conceptual site model (CSM). In the CSM, exposure pathways are evaluated by their potential contribution to exposure and classified as significant, insignificant, and negligible or incomplete. Significant pathways are those that involve relatively direct exposure or only moderately reduced concentrations due to contaminant fate and transport. Insignificant pathways are those that are expected to result in exposure concentrations one or more orders of magnitude lower than significant exposure pathways. In addition, negligible or incomplete pathways are those where either direct exposure is negligible or fate and transport is expected to reduce contaminant concentrations by several orders of magnitude or more in comparison to significant exposure pathways. Significant and insignificant exposure pathways are evaluated quantitatively in Section F5.

The subsections that follow present both off-site and on-site current and future potential land uses, potential human receptors, relevant exposure pathways, and the CSM for the site.

#### F4.1 LAND USE

Current and potential land uses were introduced in Section F2, Site Description. Land uses are further evaluated in this section to identify exposure scenarios that may be quantitatively evaluated to provide useful information for risk management. Current and future off-site land uses are presented first, followed by a discussion of current and future on-site land uses.

#### **F4.1.1      Off-Site Land Use**

Off-site land uses are considered according to current and future uses. Current uses are identified through county zoning maps and observation. Future uses are projected based on present use, growth patterns, and community development plans.

##### **F4.1.1.1      Current**

Land use in the area surrounding RFP is shown in the Jefferson County Land Use Inventory (Figure F4-1). Table F4-1 is a summary of zoning and land use according to the Jefferson County Land Use Inventory. In general, land surrounding RFP includes recreational, open space, agricultural, residential, and commercial/industrial uses. The northeastern Jefferson County and the RFP area is one of the most concentrated areas of industrial development in the Denver metropolitan area (Jefferson County, 1989b).

Land use in the area relevant to the OU1 exposure scenarios (immediately southeast of RFP and OU1) includes all of the uses mentioned, with the predominant uses appearing to be open space, single-family detached dwellings, and horse-boarding operations. Two small cattle herds (approximately 10 to 20 cattle in each herd) existed in the area in 1993: one to the southeast, where 96th Avenue turns into Alkire and crosses Woman Creek; and one to the east of RFP, between Alkire and Simms Streets and north of 100th Avenue. Industrial facilities within the relevant area, to the south, include the TOSCO Laboratory, Great Western Inorganics Plant, and Frontier Forest Products (EG&G, 1992a).

##### **F4.1.1.2      Future**

Future land use generally follows existing land use patterns. Jefferson County, in its *Northeast Jefferson County, Community Profile Report* (Jefferson County, 1989b), a socioeconomic study of its northeastern area, developed a baseline profile of growth and land use. Using the baseline profile and historic trends, future scenarios were developed. At the time of this study, Jefferson County expected that industrial land uses would continue to dominate the northeastern portion of the county. Along with the increase in industrial development, the county expected income

and employment growth to increase dramatically, while household and population growth were expected to increase only moderately. Although the changing plant mission may eventually influence growth in the area, this is not likely to be significant until decontamination and decommissioning (D&D) and environmental restoration are completed in approximately 30 years.

Industrial and commercial development of the area is attractive to businesses and developers for several reasons:

- The availability of undeveloped and, therefore, lower-cost lands.
- The lower taxes associated with locating in an unincorporated portion of the county.
- The possible future alignment of W-470, a segment of proposed highway providing access to the area.

The proposed Colorado highway W-470 would complete a loop encircling the entire Denver metropolitan area and would have significant impacts on growth in the area. The highway, in its proposed alignment, will skirt the southern and eastern boundaries of RFP. Commercial growth, particularly light industrial and office development, is expected to occur along the highway (Jefferson County, 1989b).

Residential development may not be as attractive as industrial development of the area for several reasons including the proposed alignment of W-470, the proximity to and possible expansion of Jefferson County Airport, the current industry in the area, and proposed business park/retail/commercial/residential/open space development by the Jefferson Center Metropolitan District. The decreased desirability of living near a major highway or an airport, for traffic and noise reasons, is a deterrent to residential development. The proximity of RFP and the general industrial nature of the area also decreases the desirability of housing in the area.

Future land use in the area is the topic of the *North Plains Community Plan* (Jefferson County, 1990). The plan is intended as a guide to the county and cities to achieve compatible land use and development decisions, regardless of the jurisdiction in which they are proposed. The plan was cooperatively developed by representatives of Jefferson County and five cities (Arvada,

Broomfield, Golden, Superior, and Westminster), and participants from a variety of interest groups including homeowners, businesses, builders/developers, and environmentalists. The plan identifies RFP and the Jefferson County Airport as constraints to future residential development in the area, and recommends office and light industrial development. The plan further identifies the acquisition of lands for open-space uses as a high priority for the area, recommending that large amounts of undeveloped land be provided for this purpose (Jefferson County, 1990).

The North Plains Community Development Plan Study Area Summary Map (Figure F4-2) and the Jefferson Center Comprehensive Development Plan (Figure F4-3) show that the predominant future land uses to the south and southeast of RFP will consist of commercial, industrial, and office space. Directly to the east, the zoning and usage are expected to remain open space, and agricultural/vacant. As illustrated in these maps, the areas closest to RFP are planned for industrial, commercial, or office space, with the areas farther from RFP designated for residential development.

To the north of RFP, in Boulder County, the predominant land uses include open space, park land, and industrial development. Two areas adjacent to RFP have been annexed by the cities of Broomfield and Superior. These two cities have participated in the Jefferson County cooperative planning process and are planning business, industrial, and mixed land uses for the area (Jefferson County, 1990).

Future adjacent land use east, southeast, south, and west of RFP is expected to consist mostly of open space and commercial and rural industrial, with smaller areas of mixed commercial/rural residential. Approximately 1 mile west of RFP, the area is mountainous and is expected to remain sparsely populated and primarily government owned. Suburban residential developments are expected to occur farther east, probably at least 4 miles from the center or 2 miles from the boundary of RFP. The timing for transition of some existing agricultural lands to open space is not known.

#### **F4.1.2      On-Site Land Use**

On-site land uses are considered according to current and future uses. Current uses are identified through various RFP documents and information obtained during interviews with knowledgeable plant personnel. Future uses are projected based on statements by the Secretary of Energy and various DOE planning documents.

##### **F4.1.2.1      Current**

Current activities in OU1 consist of environmental investigations and routine security surveillance. RFP is planning for D&D, which is expected to begin in the near future. RFP maintenance activities do not occur in the OU1 area.

##### **F4.1.2.2      Future**

In the January 1992 State of the Union Address, the President of the United States canceled production of the Trident II missile and its W-88 nuclear warhead. The W-88 program was at that time the main program at RFP. As a result of the President's announcement, the primary mission of RFP was altered. RFP is now in a "transition" - process of converting the land from its historical mission to its current mission (DOE, 1993). Plant activities are deactivation and decommissioning of facilities, environmental restoration, waste management, and economic development.

Occupation by private industry is planned for the future use of the on-site production areas at RFP, according to a June 12, 1992, speech by Secretary of Energy James Watkins. Watkins characterized RFP as an attractive site for manufacturers and other businesses. Private industry could relocate to existing buildings and use existing equipment at RFP, after necessary decontamination is complete. One organization interested in the impacts of changes at the plant is the Rocky Flats Local Impacts Initiative (RFLII). This group is a coalition of local governments, workers, community-based public interest groups, private sector interests, surrounding landowners, and citizens working together to identify, assess, and mitigate impacts resulting from the change of mission at RFP and to plan for its future. The work plan of the

group is to formulate a strategy to transform future changes at RFP into economic, socioeconomic, educational, land use, environmental, and infrastructural advantages. One of this group's goals is to convene and coordinate an inclusive planning process to determine long-term land and facilities uses and policies desired by the community, and to coordinate plans for implementation.

When the Atomic Energy Commission (AEC) acquired the undeveloped land surrounding the production area, it established plans to preserve the land as open space (AEC, 1972). With the present open space located nearby, it is plausible that the buffer zone and OUI area will be preserved as open space. The buffer zone is being considered as a potential ecological preserve or National Environmental Research Park.

There are at least three reasons why Rocky Flats would make an exceptional environmental research area. First, the site presents an excellent sample of a shortgrass prairie/montane ecotone.... Second, it also provides an almost unique opportunity to conduct environmental research in an area which abuts a major metropolitan area.... Third, ...the site has an abundance of wetlands and would be an excellent outdoor laboratory for a variety of wetland related ecological research (Knight, 1992).

Ecological surveys of the buffer zone, performed in compliance with the Threatened and Endangered Species Act, may indicate the presence of several listed species at RFP. Additional threatened and endangered species surveys are ongoing and may be performed in the future to identify and provide for the protection of any threatened and endangered species at the site, if necessary (EG&G, 1992b). Because the buffer zone has not been impacted by commercial development for many years, thus allowing progressive re-establishment of quality native habitats, the future use of this area as an ecological reserve is reasonable. This usage is consistent with DOE policy and plans (DOE, 1993). In addition, this type of site use is consistent with the Jefferson County Planning Department's recommendations for the provision of large areas of undeveloped land (Jefferson County, 1990).

Extensive development of the OUI area would face the difficulties of limited availability of water and steep topography in parts of the drainages. The Denver Water Board controls most of the metropolitan water supply and currently provides much of the suburban area's water. The

Denver Water Board, however, is under no obligation to supply water to the suburbs, making the future supply questionable (Jefferson County, 1989b). Existing facilities within RFP are already served by municipal water supplies from the City of Golden, increasing the likelihood that existing structures will be targeted for use by industry and businesses. Similar difficulties facing extensive residential or commercial development may be encountered with the slopes associated with the Woman Creek drainage. Due to the potential hazards associated with unstable slopes, landslides, and slope failures, Jefferson County emphasizes that development should only occur on slopes with grades of 30 percent or less (Jefferson County, 1990).

The residential/commercial structure associated with the future on-site receptor is hypothetical and does not consider the specific geotechnical feasibility of such a construction on the hillside. A study of an area that is geologically and geotechnically similar to the 881 Hillside area was conducted, however, in the Green Mountain area, (Jefferson County, Colorado [Schneider, 1978]). This study identified geologic hazards at Green Mountain, including, slope hazards, expansive soil and rock hazards, erosion and sedimentation hazards, and subsidence hazards. The characterization involved a literature review, aerial photograph interpretation, field investigations, exploratory drilling, and laboratory classification and testing of drill samples. The classification of geologic hazards and appropriate land use designations depend on "...the degree to which human health and safety, property and/or structures will be threatened if development occurs without regard to geologic conditions and processes" (Schneider, 1978). Accordingly, four classifications of hazards were developed: high, moderate, low, and very low. Areas with a high hazard designation include two or more categories of geologic hazards. According to Schneider (1978), "Development in high hazard areas should not be permitted unless it can be demonstrated that remedial engineering practices, careful site selection, proper preplanning and land reclamation (as necessary) will effectively minimize the hazards. Remedial engineering in high hazard areas may be prohibitively expensive for most types of developments."

The study by Schneider (1978) follows the guidelines presented in Rogers et al. (1974) of the Colorado Geological Survey (CGS). Other CGS publications dealing with geologic hazards are Jochim et al. (1988) and Wold and Candace (1989). These works emphasize geologic-hazard recognition and list guidelines and criteria for administration and designation of geologic hazards

for local governments. Specifically, a qualified engineer/geologist must assess each site. If necessary, field studies similar to those conducted by Schneider (1978) should be completed before sound engineering judgement can be made.

Relating the guidelines presented by the CGS (Rogers et al., 1974) and the study by Schneider (1978) to construction at the 881 Hillside area, construction of residential or commercial structures may not be practical or feasible. Evidence in support of this was obtained during the construction of the French Drain and Phase III investigation. The *French Drain Geotechnical Investigation* (EG&G, 1991b) indicates that the potential for swelling soils exists in the colluvium and that the recent construction of the French Drain has reactivated old slumps and landslides. Thus, the 881 Hillside area could be classified as a high hazard area according to Schneider (1978), which indicates that a detailed geotechnical study is needed for each potential construction project in the 881 Hillside area.

In summary, residential development of the OU1 area is unlikely due to the industrial nature of the RFP site; the proximity of the proposed W-470 corridor and water supply; and slope stability challenges. Future residential land use is inconsistent with current Jefferson County and DOE land-use plans for the area. Future land use generally follows existing land-use patterns and would likely involve industrial/office or open-space uses.

#### **F4.2 EVALUATION OF LAND USES AND POTENTIAL HUMAN RECEPTORS**

Current and future human population groups on and near the site are potential candidates for evaluation as receptors based on their likelihood of exposure to site-related contaminants of concern. The improbable and credible future land-use patterns for off-site and on-site areas are described in Sections F4.2.1 and F4.2.2, respectively. For the purpose of a qualitative evaluation of potential receptors, future land-use scenarios have been categorized as either improbable (unlikely to occur because of serious constraints) or credible (expected to occur given the right set of circumstances). Table F4-2 presents the probability classification for the future land use categories (residential, commercial/industrial, recreational, ecological reserve, and agricultural), as well as summarizes the current land uses.

#### **F4.2.1 Improbable Future Land Uses**

Future land uses considered to be improbable include on-site residential, on-site agriculture, off-site agricultural, and off-site ecological reserve. Both on-site agriculture and on-site residential are considered improbable because of the increasing public interest in preserving unplowed prairie and wetland habitats and protecting wildlife. This is evidenced by ongoing acquisition of open space including large tracts near RFP, by Jefferson County, Boulder County, and the City of Boulder and the recent designation of the Rocky Mountain Arsenal as a wildlife refuge by the U.S. Fish and Wildlife Service. Like RFP, the Arsenal is a large 27-square-mile RCRA/CERCLA site that was protected from grazing or development because of weapons production and the need for an extensive buffer zone. Additionally, agriculture would offer poor economics compared to commercial/industrial development.

Off-site agriculture is less likely than residential, commercial/industrial, or recreational uses because of economics as well as increasing public and community interest in preserving open space. This is also consistent with existing regional zoning and land use designations shown on Figures F4-1 through F4-3. Therefore, although agriculture occurs in nearby off-site areas, it is anticipated that this use will gradually diminish and eventually disappear from parcels closest to the site.

Use of off-site areas as ecological reserves is considered improbable because of the disturbed nature of most parcels (e.g., cultivation or heavy grazing) and the proximity to planned commercial/industrial or mixed commercial/residential uses. Exceptions might be existing open space areas or stands of cottonwoods near Standley Reservoir, where bald eagles were observed in the winter of 1992-1993.

#### **F4.2.2 Credible Future Land Uses**

Future on-site land uses considered to be credible include commercial/industrial, recreational, and ecological reserve. Commercial/industrial uses would be appropriate, at least for the present industrialized area of RFP, because of the existing infrastructure, economic advantages, and reduced liability concerns. On-site recreational and ecological reserves would be consistent with

the ecological diversity and scenic quality of the site, the existing wildlife use and presence of several species of special concern, the increasing regional interest in habitat preservation and undeveloped recreational areas, and minimal liability issues.

Credible future off-site uses include commercial/industrial, residential, and recreational. All these are consistent with recent growth and development patterns in the northwestern Denver metropolitan area and are projected in various planning documents as discussed in Section F4.1.1.2.

### **F4.3 RECEPTORS SELECTED FOR QUANTITATIVE RISK ASSESSMENT**

Human populations on and near the site were evaluated to assess their likelihood of exposure to site-related COCs. EPA guidance does not require an exhaustive assessment of every potential receptor and exposure scenario (EPA, 1992d). Rather, the highest potential exposures that are reasonably expected to occur should be evaluated, along with an assessment of any associated uncertainty (EPA, 1989a). The receptor populations selected for evaluation are those most likely to be exposed and potentially to have the greatest degree of exposure to site-related contaminants.

Receptors and risk assessment areas selected for evaluation in the human health risk assessment for OU1 are summarized in Table F4-3 and include current off-site residents, future on-site residents, current and future on-site workers, and future on-site ecological researchers. Risk assessment areas include OU1-wide, at the source (identified by the nature and extent investigation as IHSS 119.1), and OU1-wide with the source removed. Each of these receptors is described in further detail in Sections F4.3.1 through F4.3.3.

#### **F4.3.1 Current Off-Site and Future On-Site Residents**

The human health risk assessment evaluates potential health risks for current off-site residents at existing locations, since the public is restricted from access to RFP, and access to OU1 is generally limited to certain on-site workers. Present levels of security at RFP include secure fencing, frequent armed security patrols, and modern electronic security and surveillance

systems. Fencing is posted to warn potential intruders that they are trespassing on Federal property and, if caught, will be arrested. Plant security personnel report that there have been no incidents of trespassing in the buffer zone in the past 7 years. Thus, even if trespassing were to occur at RFP, it is highly unlikely that such events would occur repeatedly for the same individual.

The off-site resident scenario evaluates the current reasonable maximum risk. The closest current residents live just east of the southeast boundary of RFP, and current risks are evaluated at this location. Since residents are likely to spend the greatest amount of time at or near their home, the residential scenario represents the maximum frequency and duration of exposure that is reasonably expected to occur.

Although on-site residences are not consistent with future land-use plans, a hypothetical future on-site resident exposure scenario is evaluated in the health risk assessment. The future on-site resident is assumed to live within the OU1 study area boundary.

In addition, four special cases of the on-site residential scenario have been included to show the impact of the use of groundwater and to evaluate risk at the source. The first case includes use of groundwater for an OU1-wide area. The second and third cases include the use of groundwater at the source and exposure to elevated concentrations of radionuclides in surface soil at the source (i.e., hot spots). As indicated by Attachment F-1, OU1 Domestic Water Supply Simulations, the yield of contaminated groundwater in IHSS 119.1 is inadequate to support a household of four people. However, to meet the direct ingestion requirements of RCRA, the second case residential scenario assumes that adequate well water supply exists. For comparison, the third case assumes that the inadequate well water capacity is used and supplemented with water from a public supply. A fourth use was also included to show the risk with the source(s) (groundwater VOCs and surface soil radionuclide hot spots) removed. In summary, the special case scenarios are:

- Future On-Site Resident (Sitewide with Groundwater)
- Future On-Site Resident (Assuming Adequate Groundwater at Source)

- Future On-Site Resident (Groundwater at Source with Public Water)
- Future On-site Resident Scenario without Source (without Groundwater/ without Source).

#### **F4.3.2 Current and Future On-Site Workers**

Although the health and safety (H&S) of on-site workers is monitored under a site H&S plan, a current on-site worker exposure scenario is evaluated in the human health risk assessment. The current RFP workers who spend the greatest amount of time in OU1 are plant security personnel. Security guards conduct routine patrols within OU1.

The human health risk assessment will evaluate current and future on-site workers. The H&S of on-site workers is presently monitored under a comprehensive H&S program at RFP. H&S activities at RFP are directed by the Associate General Manager for Support Operations and supported by several divisions including Radiological Operations, Occupational Safety, Health and Safety Area Engineering, Industrial Hygiene, Radiological Engineering, and Occupational Health (EG&G, 1990). For environmental restoration work at RFP, EG&G (RFP) and DOE adopted the Federal Occupational Safety and Health Administration's (OSHA) standards for hazardous-waste site workers (EG&G, 1990). EG&G has superseded some of the OSHA standards with more stringent policies established by EG&G, DOE, or other governmental agencies (EG&G, 1990).

At RFP, H&S plans are written for everyday activities as well as specific projects. All subcontractors to EG&G must prepare their own site/project-specific H&S plans, and they must require and enforce standards that are at least as stringent as EG&G's requirements (EG&G, 1990). Several programs exist at RFP to support the H&S plans, including the following:

- Radiation Protection
- Emergency Response
- Occupational Safety
- Vehicular and Pedestrian Safety
- Fire Protection
- Contractor Safety (EG&G, 1992c)

The written programs contain the requirements and procedures to ensure a work environment that is free from exposure to chemical, physical, and biological hazards (EG&G, 1992c). Additionally, responsibility for all aspects of compliance with the programs and plans is established, and an audit program exists to evaluate compliance. RFP personnel are trained in personal hygiene and safety, use of protective clothing, and emergency response procedures. The H&S of current workers at RFP is thoroughly monitored with required baseline, annual, and exit physical examinations. The exposure of these workers to COCs is controlled and limited by monitoring to acceptable levels and is ensured by reporting requirements.

A future on-site worker, not protected by a similar H&S program will also be quantitatively evaluated in the health risk assessment. This worker is assumed to be unprotected and untrained in H&S matters. Based on the future industrial development plans for the area, the future on-site workers are assumed to be industrial or office workers, and a construction worker. The setting for the industrial or office worker is likely to have extensive paved areas and well-maintained landscaping. The future on-site construction worker is assumed to have direct contact with soil during excavation activities associated with the construction of future commercial buildings on site.

#### **F4.3.3 Future On-Site Ecological Researcher**

Since the future use of the on-site, nonproduction areas at RFP will most likely involve an open-space/ecological reserve scenario; this scenario will be evaluated for the OU1 area. The receptors in an open-space scenario would include day hikers and a research biologist/ecologist conducting area studies. Of these two potential receptors, the research biologist is likely to spend more time at the RFP site and come in close contact with the soils, plants, and surface water, as specimens are studied. Field work may involve kneeling or lying on bare ground or vegetation, and contacting site soils, sediments, and surface water. The day hiker would most likely spend less time at the site and come in less contact with the site's soils and surface water than an ecological researcher. Therefore, the most reasonable receptor in this setting is the hypothetical future ecological researcher. This receptor is quantitatively evaluated in the risk assessment.

#### **F4.4 EXPOSURE PATHWAYS**

This section discusses the potential release and transport of chemicals from OU1 and identifies exposure pathways by which the receptor populations may potentially be exposed to site contaminants.

An exposure pathway describes a specific environmental pathway by which an individual can be exposed to contaminants present at or originating from a site. An exposure pathway includes five necessary elements:

- 1) A Source of Chemicals
- 2) A Mechanism of Chemical Release
- 3) An Environmental Transport Medium
- 4) An Exposure Point
- 5) A Human Intake Route

Each one of these five elements must be present for an exposure pathway to be complete. An incomplete pathway means that no human exposure can occur. An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms, and identified receptors for that exposure pathway. Environmental media that may transport COCs from OU1 to exposure points are described in the CSM presented in Section F4.5.

An exposure route is the pathway through which a contaminant enters or impacts an organism. There are four basic human exposure routes:

- 1) Dermal Absorption
- 2) Inhalation
- 3) Ingestion
- 4) External Irradiation if Radionuclides are Present

Exposure pathways by which these mechanisms may occur include inhalation of VOCs and airborne particulates, soil ingestion, surface and groundwater ingestion, and dermal contact with soil or surface water.

Dermal absorption of low-solubility metals from contact with soil is generally not considered a significant uptake route. Dermal contact with soil will only be assessed quantitatively for organic COCs. For radionuclides, EPA guidance states that "dermal uptake is generally not an important route of uptake for radionuclides, which have small dermal permeability constants" (EPA, 1989a).

#### **F4.5 CONCEPTUAL SITE MODEL**

Information concerning waste sources, waste constituent release and transport mechanisms, and locations of potentially exposed receptors is used in this section to develop a conceptual understanding of the site in terms of potential human exposure pathways. Figure F4-4 shows a CSM of potential human exposure pathways for OU1 based on findings of the field investigation.

The CSM is a schematic representation of the primary contaminant source areas, contaminant release mechanisms, environmental transport media, potential human intake routes, and potential human receptors. The purpose of the CSM is to:

- Provide a framework for problem definition.
- Identify exposure pathways that may result in human health risks.
- Aid in identifying data gaps.
- Aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

Contaminant release mechanisms, environmental transport media, and potential human intake routes to the contaminated site soil are identified for each potentially exposed receptor and are discussed in Sections F4.5.2.1 through F4.5.2.5.

In the CSM, potentially complete and significant exposure pathways are designated by an "S", and potentially complete and relatively insignificant exposure pathways are designated by an "I". Both potentially complete exposure pathways and relatively insignificant exposure pathways are

quantitatively addressed in the risk assessment. Quantitatively addressing potentially complete and relatively insignificant exposure pathways provides risk estimates that do not underestimate actual risks. Negligible or incomplete exposure pathways are designated by an "N" and are not addressed in the risk assessment. In the following discussion and in the CSM, potentially complete dermal exposure pathways are designated as insignificant and are only assessed quantitatively for organic chemicals.

Several exposure pathways are identified that are negligible or incomplete for all receptors. These are presented first, followed by a scenario by scenario discussion of potentially complete pathways.

#### **F4.5.1 Site-Wide Negligible or Incomplete Exposure Pathways**

The CSM indicates that the following OU1 exposure pathways are negligible or incomplete for all receptors. With few exceptions, these incomplete pathways are not quantitatively addressed in the risk assessment.

- As discussed in Section F3, surface water and sediment media are technically not part of OU1 proper. However, because of potential influence to surface water and sediment from surface soil within OU1, direct exposure pathways involving surface water and sediment are evaluated in a preliminary manner. Exposure to surface water and sediment media will be addressed again in the OU5 RI/FS.
- Secondary surface water exposure pathways such as ingestion of fish caught from Woman Creek, and ingestion of livestock watered by the creek are negligible for all receptors. Woman Creek is an intermittent creek. High-flow periods for this creek generally occur from March to June. The amount of flow varies significantly from no-flow in dry years to approximately four times the predicted annual flow (Advanced Sciences, Inc., 1990).

Due to its intermittent nature, the creek does not support significant numbers of fish, and subsistence fishing is unlikely. Similarly, the intermittent creek flow does not support consistent livestock watering. Therefore, ingestion of fish and ingestion of livestock watered by this creek are negligible exposure pathways for current off-site residential receptors.

Subsistence fishing and homegrown beef ingestion are also negligible pathways under future conditions. Unless the creek is significantly altered, the intermittent creek flow will remain the same in the future and remain insufficient to support subsistence

fishing. Similarly, development pressures in the area make it unlikely that agriculture will be economically viable in the future. Therefore, subsistence fishing and homegrown beef ingestion are considered a negligible exposure pathway for future on-site residential receptors.

The current and future on-site workers are unlikely to raise cattle or catch fish on site since they are expected to work the entire time while on site. Therefore, this pathway is considered negligible for these receptors. Ingestion of animals or fish in the future scenario by the ecological researcher is an incomplete pathway because it is unlikely that the researcher will ingest animal or fish specimens collected for research.

- Inhalation of chemicals that have volatilized from site soils or groundwater to outdoor air are negligible pathways for all receptors because volatile chemicals in surface soils have already volatilized, and volatile chemicals released from groundwater are expected to be significantly retarded through the vadose zone and diluted in the ambient air. A possible exception to this may occur if one assumes that a construction worker is immediately present in an excavation involving VOC contamination. This possible exception is evaluated quantitatively.
- Measured surface soil concentrations include soil that has been resuspended and deposited locally on-site. Direct ingestion of soil accounts for soil that is undisturbed and for soil that has been resuspended and deposited locally on-site. Therefore, ingestion of soil that has been resuspended and deposited locally on-site is not evaluated separately.
- Based on groundwater flow simulations presented in Attachment F-1, ingestion of groundwater from the Upper Hydrostratigraphic Unit (UHSU) is not capable of supporting a household of four. Therefore, direct ingestion of groundwater from the UHSU is an incomplete pathway. However, to meet RCRA requirements, special case scenarios assuming groundwater use are evaluated.
- External radiation from alpha emitters is generally insignificant. For example, americium-241's gamma emission, although the strongest of the OU1 COCs, is weak and typically unimportant at the environmental levels such as those found at OU1. To illustrate, assume a receptor spends 30 years at a location uniformly contaminated with the OU1 site-wide concentration of 0.41 pCi/g Am-241. The external exposure risk is calculated with the toxicity constant 4.9E-9/yr per pCi/g (EPA, 1993b) as follows:

$$\text{Am-241 Risk} = 0.41 \text{ pCi/g} \times 30 \text{ years} \times \frac{4.9 \text{ E-9/yr}}{\text{pCi/g}} = 6.0 \text{ E-08}$$

Similarly, the risk due to external radiation from other COCs can be estimated as follows:

$$\text{Pu-239,240 Risk} = 2.41 \text{ pCi/g} \times 30 \text{ years} \times \frac{1.7 \text{ E-11/yr}}{\text{pCi/g}} = 1.2 \text{ E-09}$$

$$\text{U-233,234 Risk} = 1.15 \text{ pCi/g} \times 30 \text{ years} \times \frac{4.2 \text{ E-11/yr}}{\text{pCi/g}} = 1.4 \text{ E-09}$$

$$\text{U-238 Risk} = 1.21 \text{ pCi/g} \times 30 \text{ years} \times \frac{2.1 \text{ E-11/yr}}{\text{pCi/g}} = 7.6 \text{ E-10}$$

Elevated levels of these radionuclides were identified in the focused sampling designed to detect "hot spots." The concentrations in hot spots were not included in these examples because they are typically less than 1 m<sup>2</sup> in size and cannot be used with the EPA external radiation risk values that assume uniform contamination for a 200 m<sup>2</sup> area. In addition, it is unlikely that a resident would remain in such a small area for more than a short time. Based on this, external radiation is an insignificant pathway and is not quantitatively evaluated.

#### **F4.5.2 Potentially Complete Exposure Pathways**

Exposure pathways that result in potential exposure to identified receptors are discussed in the following sections and summarized in Table F4-4.

##### **F4.5.2.1 Current Off-Site Resident**

The CSM for the current off-site receptor indicates that the following release mechanisms are the potential contaminant release mechanisms from contaminated site soils to the environment:

- Leaching
- Runoff
- Volatilization
- Resuspension
- Direct Contact
- Plant Uptake

Of these release mechanisms, only the exposure routes associated with wind resuspension are potentially complete for the current off-site resident, as detailed in the discussion below. Direct contact with site soils and ingestion of vegetables and fruits/plants grown in on-site soils are also

potential release mechanisms, but are eliminated as exposure pathways to this receptor because site access is restricted. Similarly, the French Drain and the SID intercept groundwater and runoff, respectively, rendering these pathways incomplete.

Contaminants bound to soil that are released by wind as particulate matter represent potential inhalation, oral, and dermal exposure pathways. Current off-site residents may be directly exposed to airborne particulate matter through inhalation. For the purpose of the PHE, it is assumed that indoor air particulate concentrations are equal to outdoor air particulate concentrations. Therefore, for all potentially exposed receptor populations, potential risks from inhalation of indoor particulates will be accounted for by the quantitative evaluation of potential risks from inhalation of outdoor particulates. Homegrown garden vegetables, contaminated by deposition of airborne particulates from the site, represent a potentially complete ingestion pathway. Similarly, soil that is contaminated by particulate deposition represents potentially complete oral and dermal exposure pathways for this receptor.

In summary, potentially complete human exposure pathways for the current off-site resident are:

- Inhalation of Airborne Particulates
- Soil Ingestion (i.e., Following Deposition of Particulates on Residential Soil)
- Dermal Contact with Soil (i.e., Following Airborne Deposition of Particulates)
- Ingestion of Homegrown Vegetables/Fruit (i.e., Following Surface Deposition and Uptake of Particulates)

#### **F4.5.2.2 Current On-Site Worker**

The CSM for the current on-site receptor indicates that the following release mechanisms are the potential contaminant release mechanisms from contaminated site soils to the environment:

- Leaching
- Runoff
- Volatilization
- Resuspension

- Direct Contact
- Plant Uptake

Of these release mechanisms, only wind resuspension, runoff, and direct contact result in associated potential exposure routes for the current on-site worker.

If released by runoff, site contaminants may be transported to surface water and/or sediments. Surface water may be observed in Woman Creek and in the SID. Incidental ingestion of and dermal contact with surface water and suspended sediments are unlikely exposure pathways for current on-site workers (security guards). OU1 security patrols consist of vehicular travel along roads that permit visual inspection of the area and total less than 0.5 hours per day. The tops of the slopes afford the best vantage point, while, surface water is located at the bottom of slopes. However, surface water and sediment exposure is evaluated as a precautionary measure.

Semivolatile organic and inorganic chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral, or dermal exposure pathways. Current on-site workers may be directly exposed to airborne particulate matter through inhalation. Direct contact with directly contaminated soil or soil that has been contaminated through the deposition of airborne particulates will be evaluated via direct measurement of chemicals in surface soil on site. This pathway is accounted for by the direct contact release mechanism shown in Figure F4-4. Ingestion of contaminated vegetables is an incomplete pathway because gardening is not expected in an occupational setting.

Direct contact with soils represents potentially complete ingestion and dermal contact exposure pathways for current workers at the site. Currently, no offices or other permanent structures are located in OU1. Thus, the inhalation of VOCs indoors is an incomplete exposure pathway.

In summary, potentially complete human exposure pathways for the current on-site worker are:

- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- Sediment ingestion

- Dermal contact with sediment
- Surface water ingestion
- Dermal contact with surface water

#### **F4.5.2.3 Future On-Site Worker**

The CSM for the future on-site receptor, both office and construction workers, indicates that the following release mechanisms are the potential chemical release mechanisms from contaminated site soils to the environment.

- Leaching
- Runoff
- Volatilization
- Resuspension
- Direct contact
- Plant uptake

All of these release mechanisms except plant uptake result in associated potential exposure routes for the future on-site office worker. For the future on-site construction worker, volatilization, wind resuspension, and direct contact result in associated potential exposures.

If released via stormwater runoff, site contaminants may be transported to surface water and/or sediments. Surface water is technically not part of OU1 proper, but is present in Woman Creek and in the SID. Because of potential influence of OU1 surface soil on surface water and sediment, long-term exposure (25 years) to surface water and sediment is preliminarily evaluated for the office worker. Future on-site construction workers are assumed to perform excavation (and contact surface soil and sub-surface soil contaminants) for a building in OU1. Building excavation of the size assumed for OU1 typically takes several days. After this, excavating equipment and operators are moved to other sites. Due to the short duration of excavation activities and the lack of surface water in OU1, incidental ingestion of and dermal contact with surface water and suspended sediments are not evaluated for the construction worker.

Chemicals that volatilize from groundwater and/or site soils and are released to indoor air represent a potentially complete inhalation pathway for the future on-site office worker. During

excavation, construction workers may be exposed to chemicals volatilized from the soil and dispersed by the wind.

Semivolatile organic and inorganic chemicals bound to soil, that are released via wind as particulate matter, represent potential inhalation, oral, or dermal exposure pathways. Both types of future on-site workers may be directly exposed to airborne particulate matter via inhalation. Potential oral and dermal exposures will be evaluated via the direct contact release mechanism (see Figure F4-4). Ingestion of contaminated vegetables is an incomplete pathway because gardening is not expected in an occupational setting. Direct contact with soils represents potentially complete ingestion and dermal contact exposure pathways for future workers at the site.

In summary, potentially complete human exposure pathways for the future on-site office and construction workers are:

- Inhalation of VOCs in Indoor Air (i.e., Office Worker Only) and Outdoor Air (i.e., Construction Worker Only)
- Inhalation of Airborne Particulates
- Soil Ingestion
- Dermal Contact with Soil
- Sediment Ingestion (i.e., Office Worker Only)
- Dermal Contact with Sediment (i.e., Office Worker Only)
- Surface Water Ingestion (i.e., Office Worker Only)
- Dermal Contact with Surface Water (i.e., Office Worker Only)

#### **F4.5.2.4 Future On-Site Ecological Researcher**

The CSM for the future on-site receptor indicates that the following release mechanisms are the potential chemical release mechanisms from contaminated site soils to the environment:

- Leaching
- Runoff
- Volatilization
- Resuspension
- Direct Contact
- Plant Uptake

Except for volatilization and plant uptake, all of these release mechanisms have associated exposure routes that are potentially complete for the future ecological researcher.

If released by runoff, site contaminants may be released to surface water and/or sediments. Incidental ingestion of surface water and sediments is a potentially complete exposure pathway for the ecological researcher who may be wading in Woman Creek. Dermal contact with the surface water and sediments is a relatively insignificant but potentially complete exposure pathway for this receptor.

Chemicals that volatilize from site soils or groundwater may be released to indoor air and outdoor air. Inhalation of VOCs in outdoor air is considered an incomplete exposure pathway because volatile chemicals in surface soils have already volatilized, and volatile chemicals in groundwater are expected to be significantly retarded through the vadose zone and diluted in the ambient air. Inhalation of indoor air is also an incomplete exposure pathway because the researchers will spend time outdoors while at OU1.

Chemicals bound to soil that are released by wind as particulate matter represent potential inhalation, oral, and dermal exposure pathways. The future on-site ecological researcher may be directly exposed to airborne particulate matter via inhalation, the ingestion of contaminant-containing soil, or dermal absorption of contaminants in soil. These pathways will be quantitatively evaluated as described previously for on-site workers. Direct contact with surface soils represents potentially complete oral and dermal absorption exposure pathways for the future ecological researcher. Ingestion of contaminated plants is an incomplete pathway because it is unlikely that the ecological researcher will ingest plant specimens collected for research.

In summary, potentially complete human exposure pathways for the future ecological researcher are:

- Inhalation of Airborne Particulates
- Soil Ingestion
- Dermal Contact with Soil
- Sediment Ingestion
- Dermal Contact with Sediment
- Surface Water Ingestion
- Dermal Contact with Surface Water

#### **F4.5.2.5 Future On-Site Resident**

The CSM for the future on-site receptor indicates that the following release mechanisms are the potential chemical release mechanisms from contaminated site soils to the environment:

- Leaching
- Runoff
- Volatilization
- Resuspension
- Direct Contact
- Plant Uptake

All these primary release mechanisms provide potential exposure routes to the future on-site resident.

Contaminants that are released by runoff may be transported to surface water and/or sediments in Woman Creek. Incidental ingestion of surface water and/or sediments is a potentially complete exposure pathway for the future on-site resident. Dermal contact with surface water and sediments in the future scenario is a relatively insignificant but potentially complete exposure pathway for this receptor.

Contaminants that volatilize from site groundwater and/or soils and are released to indoor air represent a potentially complete inhalation pathway to future on-site residents. Inhalation of outdoor VOCs is considered incomplete due to the expected dispersal and dilution.

Semivolatile organic and inorganic contaminants bound to soil that are released via wind as particulate matter represent potential inhalation, oral, and dermal exposure pathways. Future on-site residents may be directly exposed to airborne particulate matter via inhalation. Homegrown vegetables contaminated by deposition of airborne particulates from the site represent a potentially complete ingestion pathway. Contact with soil that is similarly contaminated represents potentially complete oral and dermal exposure pathways for the future on-site resident, and will be accounted for as direct contact exposures in Figure F4-4.

As shown in the CSM, plant uptake of contaminants in soil may potentially occur. This uptake pathway is considered complete. Chemical concentrations in garden vegetables, due to surface deposition of contaminants onto plants, are expected to be greater than contaminants taken up by vegetables from the soil contaminated by particulate deposition. It is also expected that direct contact exposures to surface soil, dermal absorption, and ingestion will greatly exceed chemical intakes associated with plant uptake. Nonetheless, plant uptake and subsequent ingestion by future off-site residents resulting in exposure to contaminants of concern are evaluated.

In summary, potentially complete human exposure pathways for the future on-site resident are:

- Inhalation of Indoor VOCs From Basement Vapor
- Inhalation of Particulates
- Soil Ingestion
- Dermal Contact with Soil
- Sediment Ingestion
- Dermal Contact with Sediment
- Surface Water Ingestion
- Dermal Contact with Surface Water
- Ingestion of Homegrown Vegetables/Fruit (i.e., Following Surface Deposition of Particulates and Uptake)

#### **F4.5.2.6 Special Case Scenarios**

As presented in Section F4.3.1, special case scenarios involving residential groundwater use and/or evaluating risk at the source are included for quantitative evaluation. These scenarios involve the same pathways for the on-site residential scenario presented in F4.5.2.5 with the addition of:

- Groundwater Ingestion
- Dermal Contact with Groundwater
- Inhalation of VOCs from Indoor Water Use

A summary of potentially complete exposure pathways that are quantitatively evaluated for all receptors in the baseline human health risk assessment is provided in Table F4-4.

**Table F4-1**

**Current Surrounding Land Use in Jefferson County  
Rocky Flats Plant OU1**

<b>Parcel #</b>	<b>Current Use/Project Name</b>	<b>Zoning<sup>a</sup></b>	<b>Land Use Type</b>
22009			
44001	Vacant	A-2	Vacant
44002			
44003	Vacant	I-1	Industrial
44004	Vacant	A-2	Vacant
44005			
44006	Vacant	I-3	Industrial
44007	Vacant	A-2	Vacant
45001			
45002	Walnut Creek Unit 1	P-D	Single Family - Detached
45002	Walnut Creek Unit 1	P-D	Retail
45003	Vacant	A-2	Vacant
45004	Single Family - Detached	A-2	Single Family - Detached
45005	Single Family - Detached	A-2	Vacant
45006	Water	A-2	Water
45007	Single Family - Detached	A-2	Single Family - Detached
45007	SF-D	A-2	Farm/Ranching
46005	Vacant	A-2	Single Family - Detached
46006	Triple C Quarter Horses	A-2	Retail
46007	Horse Barn-Boarding & Breeding	A-2	Retail
46008	Single Family - Detached	A-1	Single Family - Detached
46009	Single Family - Detached	SR-2	Single Family - Detached
46011	Mountain View Tech Center	P-D	Industrial
46012	Jefcope	P-D	Industrial
46017	Water	A-2	Water
46019	Single Family - Detached	A-2	Single Family - Detached
47036	Vacant	SR-2	Single Family - Detached

**Table F4-1 (continued)**

**Current Surrounding Land Use in Jefferson County  
Rocky Flats Plant OU1**

<b>Parcel #</b>	<b>Current Use/Project Name</b>	<b>Zoning*</b>	<b>Land Use Type</b>
47040			
71001	Rocky Flats	A-2	Industrial
72001	Vacant	I-2	Industrial
72002	Vacant	A-2	Vacant
72003	Single Family - Detached	A-2	Single Family - Detached
72004	Vacant	I-2	Vacant
72004	Vacant	I-2	Industrial
72005	Tosco Flg 1	I-2	Industrial
72006	Rocky Flats Ind Park Flg 2	I-2	Industrial
72007	Rocky Flats Ind District Flg 1	I-2	Industrial
72008	Water Tank Ralston Val Stn 2	I-2	Utilities
72009	Vacant - Rocky Flats	A-2	Industrial
72010	Vacant	I-2	Industrial
72011	Northwest Industrial	I-2	Industrial
72012	Vacant	A-2	Vacant
72013			
73001	Vacant	A-2	Vacant
73005	Wheat Ridge Gardens	A-2	Vacant
73019	Vacant	A-1	Vacant
73020	Single Family - Detached	SR-2	Single Family - Detached
73021	Vacant	RC	Office/Retail
73022	Westminster Gardens	A-2	Single Family - Detached
99001	Great Western Aggregate Quarry	I-1	Industrial

Table F4-1 (continued)

Current Surrounding Land Use in Jefferson County  
Rocky Flats Plant OU1

Parcel #	Current Use/Project Name	Zoning*	Land Use Type
99005	Sawmill Operation	I-2	Industrial
99006	Great Western Aggregates	I-2	Industrial
99007	Vacant	I-2	Industrial
99008	Colorado Brick Comp Clay Mine	M-C	Mining
99009	Vacant	I-2	Industrial
100001	Rock Creek Ind Park Vacant	P-D	Industrial
100002	Vacant	I-1	Industrial
100003	Rocky Flats - Vacant	I-1	Industrial
100004	Rocky Flats - Clay Extraction	M-C	Industrial
100005	Rocky Flats - Vacant	I-2	Industrial
100006	Electric Substation	M-C	Utilities
100006	Gravel Mine	M-C	Industrial
101001	Vacant	A-2	Vacant
101002	Vacant	M-C	Industrial
101003	Vacant	I-2	Industrial
101004	Mine and Water	I-2	Industrial
101005	Northwest Industrial	I-2	Industrial
101006	Vacant	M-C	Industrial
101007	Sanitary Landfill and Gravel	P-DA	Industrial
101008	Rocky Flats Lake	M-C	Water

\*Zoning Abbreviations are:

A-1	=	Agricultural 1
A-2	=	Agricultural 2
I-1	=	Industrial 1
I-2	=	Industrial 2
I-3	=	Industrial 3
M-C	=	Mining-Conservation
P-D	=	Planned Development
P-DA	=	Planned Development Amended
RC	=	Restricted Commercial
SR-2	=	Suburban Residential 2

Source: Jefferson County

**Table F4-2**

**Summary of Current and Future Land Uses<sup>a,b</sup>**

Land Use Category	Current		Future <sup>a,b</sup>	
	Off-Site	On-Site	Off-Site	On-Site
Residential	Yes	No	Credible	Improbable
Commercial/Industrial	Yes	Yes	Credible	Credible <sup>c</sup>
Recreational	Yes	No	Credible	Credible <sup>d</sup>
Ecological Reserve	No	No	Improbable	Credible <sup>d</sup>
Agricultural	Yes	No	Improbable	Improbable

<sup>a</sup> Credible is used to indicate scenarios that may reasonably occur.

<sup>b</sup> Improbable is used to indicate scenarios that are unlikely to occur.

<sup>c</sup> Expected in the currently developed area of the plant site.

<sup>d</sup> Expected in the buffer zone.

**Table F4-3**

**Potentially Exposed Receptors to be Quantitatively Evaluated**

Receptor	Risk Assessment Area or Location			
	Off-Site Risk <sup>a</sup>	OU-Wide Risk	Source Risk	OU-Wide w/o Source Risk
Current Off-Site Resident	x			
Current On-Site Security Worker		x		
Future Commercial/Industrial Worker		x		
Future Ecological Researcher		x		
Future Resident No Groundwater Ingestion		x		x
Future Resident Assuming Groundwater Ingestion = 2 l/d		x	x	
Future Resident with Ingestion of Available Groundwater			x	

<sup>a</sup> The current nearest off-site receptor location is just east of the southeast boundary of the RFP

l/d = liters per day



NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000653

Titled: Jefferson County

Land Use Inventory

Fiche location: A-0001-M3

**SECTION F5**  
**EXPOSURE ASSESSMENT**

Pathway-specific exposures or intakes are quantified through the use of intake equations, exposure parameters, and exposure concentrations. Intake equations are pathway-specific, while exposure parameters and exposure concentrations are both scenario-specific and pathway-specific. Depending on the pathway, exposure concentrations may be statistically derived directly from field investigation data, or may be modeled using fate and transport models or estimation techniques. Accordingly, this section first presents pathway-specific information (intake equations and modeling) followed by information that is both scenario-specific and pathway-specific (exposure parameters, exposure concentrations, and calculated intakes).

**F5.1 INTAKE EQUATIONS AND MODELING**

The generalized intake equations associated with each pathway are presented in Sections F5.1.1 through F5.1.6. For pathways where fate and transport modeling or exposure concentration estimation techniques are used to identify exposure point concentrations, a brief description of the model is provided. More detailed information regarding fate and transport model description and application is provided in Attachment F-2. The scenario-specific and pathway-specific exposure concentrations calculated by the models are presented along with exposure parameters and calculated intakes in Tables F5-1 through F5-46.

As discussed in Section F3, surface water and sediment media are technically not part of OU1 proper. However, because of potential influence to surface water and sediment from surface soil within OU1, surface water and sediment pathways are evaluated in a preliminary manner. Since routine exposure to media outside of OU1 is not expected, EPA guidance concerning occasional contact with surface water while swimming is used. It is assumed that wading in Woman Creek (it is too shallow for swimming) will occur with the same frequency as recreational swimming. Exposure to surface water and sediment media will be addressed again in the OU5 RI/FS.

### F5.1.1 Ingestion of Water

The equation used for ingestion of contaminated water is presented below. The ingestion rate was adjusted in accordance with the scenario.

$$\text{Intake (mg/kg/day)} = \frac{\text{CW} \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (1)$$

where:

CW	=	Chemical concentration in water (mg/liter)
IR	=	Ingestion rate (liter/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged - days)

Ingestion rates used are standard EPA values with the exception of occupational ingestion of surface water. The shallow surface water makes it unlikely that these professional workers will incidentally ingest the amount of water associated with swimming. Therefore, the amount of water contained in the pore volume of saturated sediments that are assumed to be incidentally ingested (Section F5.1.4) is used.

For calculation of radionuclide intakes, the concentration is expressed in pCi/l, and the expression is not divided by body weight and averaging time. The intake for radionuclides is expressed in pCi.

### F5.1.2 Dermal Contact With Water

The equation used for dermal contact with contaminants in water is presented below. This equation calculates the actual adsorbed dose (i.e., intake), not the amount of chemical that comes in contact with the skin.

$$\text{Absorbed Dose (mg/kg/day)} = \frac{\text{CW} \times \text{SA} \times \text{PC} \times \text{ET} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \quad (2)$$

where:

CW	=	Chemical concentration in water (mg/liter)
SA	=	Skin surface area available for contact (cm <sup>2</sup> )
PC	=	Chemical-specific dermal permeability constant (cm/hr)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
CF	=	Volumetric conversion factor for water (1 liter/1000 cm <sup>3</sup> )
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged - days)

The surface area available for contact is dependent on the exposure media and pathway. Residents exposed to groundwater during showering are assumed to be exposed over their entire skin area. Exposure to the few inches of surface water in Woman Creek is assumed to result in a reasonable worst case exposure to surface area including the body extremities and the head.

Dermal permeability constants are taken directly from EPA's *Dermal Exposure Assessment: Principles and Applications* (EPA, 1992c). If specific contaminants have no values identified, then a value is calculated in accordance with the guidance by EPA (1992c). Refer to Table F5-1 for a listing of the chemical-specific dermal permeability constants.

### **F5.1.3 Inhalation of Airborne Contaminants**

Each exposure scenario evaluated in this PHE includes intake of airborne contaminants. The contaminants may be either in the vapor phase or, in the case of metals and radionuclides, in particulates. Dermal absorption of vapor-phase contaminants is considered to be a negligible

portion of inhalation intakes and, therefore, is disregarded in accordance with Risk Assessment Guidance for Superfund (RAGS) (EPA, 1991b). The following equation was used:

$$\text{Intake (mg/kg/day)} = \frac{\text{CA} \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (3)$$

where:

CA	=	Contaminant concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )
IR	=	Inhalation rate (m <sup>3</sup> /day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged - days)

For calculation of intakes from inhalation of particulates, only the fraction of the particulate concentration in air that is considered to be respirable (< 10 μm) is evaluated. The respiratory model developed by the International Commission on Radiological Protection indicates that particles with sizes above 10 μm are relatively unimportant contributors to internal dose (NCRP, 1985). For calculation of radionuclide intakes, the concentration is expressed in pCi/m<sup>3</sup> and the expression is not divided by body weight and averaging time. The intake for radionuclides is expressed in pCi.

#### F5.1.3.1 Soil Gas Transport

Soil gas modeling is used to predict the transport and resulting concentrations of volatile contaminants through the soil gas exposure pathway. The migration of volatile contaminants into a residential/commercial structure is identified as a potential exposure pathway (Figure F4-4). The residential/commercial structure associated with the future on-site receptor is hypothetical and did not consider the specific geotechnical feasibility of such construction on the hillside, which is discussed in Section F4. Figure F5-1 illustrates the conceptual model for the future on-site receptor at OU1.

Phase III data indicate most contamination is in the groundwater at OU1. Therefore, a soil gas model developed by Johnson and Ettinger (1991) has been chosen to represent the most

applicable model for soil gas simulations at OU1. This model will be referenced as the Johnson model hereafter. The Johnson model estimates the volatilization of organic compounds from contaminated groundwater and the resulting concentration of these compounds in hypothetical buildings above the contaminated groundwater source (Figure F5-2). Attachment F-2 contains a detailed discussion of soil gas model limitations, assumptions, and application to conditions at OU1. The Johnson model does not consider a depleting source and predicted building concentrations are constant through time (i.e., steady state). Therefore, results from the Johnson model are conservative building concentrations for the future on-site receptors (commercial and residential), with groundwater as the contaminant source.

Chemical, material property, environmental, and building characteristic data necessary for soil gas modeling are summarized in Attachment F-2. Table F-2-1 (Attachment F-2) shows the average input values for the soil gas data. Several constant chemical parameters have been obtained from literature, which are listed as constants in Table F-2-1. Attachment F-2 describes the soil gas model parameters that were estimated by published equations. These parameters include the adsorption distribution coefficients, molecular diffusion coefficients for air and water, and the effective diffusion coefficients. Environmental parameters necessary for soil gas are listed in Table F-2-2 (Attachment F-2) and include average material properties and residential/commercial building characteristics. These data are not specific to OU1 but have been collected at RFP or obtained from literature. Attachment F-2 contains a discussion of ventilation rate selection for residential and commercial structures used in the model.

Three source concentration scenarios were considered in the model simulations. These scenarios are:

- Sitewide, Includes all Wells in OU1
- IHSS 119.1, Includes Only Wells in IHSS 119.1
- Sitewide Without IHSS 119.1, Include All Wells in OU1 Except Wells in IHSS 119.1.

Modeled residential/commercial building concentrations for volatile contaminants are presented for the future on-site commercial/industrial worker and the future on-site residential scenarios

in Tables F5-12, F5-23, F5-28, F5-33, F5-38, and F5-43. These results are steady-state and represent a conservative approximation of building concentrations.

### **F5.1.3.2 Volatiles From Indoor Water Use**

Based primarily on experimental data on the volatilization of radon from household uses of water, Andelman (1990) derived a volatilization constant that defines the relationship between the concentration of a contaminant in household water and the average concentration of the volatilized contaminant in air. In the derivation, all uses of household water are considered (e.g., showering, laundering, dish washing). Certain reasonable assumptions are made in deriving the volatilization fraction (VF). For example, assumptions are made about water usage for a family of four, the volume of the dwelling and the air exchange rate. Furthermore, it is assumed that the average transfer efficiency weighted by the type of water use is 50 percent (i.e., half of the concentration of each chemical in water will be transferred into air by all types of water uses).

An upper-bound value for the VF of 0.5 mg/m<sup>3</sup> air per mg/l water can be multiplied times the average concentration of contaminant in water to yield the RME airborne concentration. Equivalently, a central tendency value for the VF of 0.065 mg/m<sup>3</sup> air per mg/l water (Andelman, 1990) may be multiplied times the upper-bound concentration of contaminant in water (95 percent UCL of the arithmetic mean) to yield the RME airborne concentration. Since upper-bound water concentrations are used for the ingestion and dermal contact pathways, the latter method is used to estimate the RME concentration of contaminant in air.

### **F5.1.3.3 Atmospheric Emissions and Transport**

Air modeling is performed to provide estimates of emissions, dispersion, and deposition of contaminants present in OU1 surface soils. Potential exposure pathways involving airborne contaminants are identified in Figure F4-4. The scope of this effort included modeling both near-field (i.e., on-site) and far-field (i.e., off-site) scenarios. Far-field models are more complex and include most of the requirements of near-field models, with the addition of transport, dispersion, and deposition of contaminants.

### Far-Field Model

The MILDOS-AREA code (Yuan et al., 1989) is used to model OU1 particulate emissions from the source, transport in air, and deposition at the receptor locations. The MILDOS-AREA code was selected over other common models due to the capability to model particulate emissions coupled to the joint frequency distributions of wind speed, direction, and stability. Many other features of MILDOS-AREA are similar to other common Gaussian dispersion models. MILDOS-AREA is used to estimate the amount of contaminants released and unit contaminant concentration factors at the receptor location based on unit concentrations in soil at the source. A 15-centimeter (cm) root zone/plow model is used to convert the output of the MILDOS-AREA code from surface concentrations (due to deposition) to soil concentrations in the root zone. Attachment F-2 describes the use of the dispersion and root-zone models. On-site soil concentrations (95 percent UCL) are multiplied by the relative concentration factors calculated by MILDOS-AREA (Table F-2-10) to obtain off-site air and soil contaminant concentrations.

### Near-Field Model

The concentrations of respirable contaminants in air over OU1 are calculated to assess the potential health impacts to current or future users of the site. The result from the MILDOS-AREA is used to estimate the total relative annual emission from the site based on a unit concentration of uranium-238 in soil. This annual emission rate is coupled with a simple box model and source concentration for each COC to estimate concentrations of COCs in air above the source. The equations used to calculate concentrations of contaminants in air and a description of the application of the near field model is provided in Attachment F-2. On-site particulate contaminant concentrations are obtained by multiplying the respirable dust concentration ( $3.6E-04 \text{ g/m}^3$ ) by the on-site soil concentrations (95 percent UCL).

Modeled concentrations for airborne particulates, particulate deposition on surface soils, and plant uptake from the top 15 cm of soil following deposition of particulates are presented in Table F5-3, F5-7, F5-12, F5-13, F5-19, F5-23, F5-28, F5-33, F5-38, and F5-43.

#### **F5.1.4 Incidental Ingestion of Soil and Sediments**

For the scenarios summarized in Tables F5-1 and F5-2, receptor exposures to COCs may result from incidental ingestion and dermal contact with soil or sediment.

The following equation is used in calculating the intake from incidental ingestion of contaminants in soil for each of the scenarios:

$$\text{Intake (mg/kg/day)} = \frac{\text{CS} \times \text{IR} \times \text{CF} \times \text{FI} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (4)$$

where:

CS	=	Chemical concentrations in soil (mg/kg or pCi/kg)
IR	=	Ingestion rate (mg soil/day)
CF	=	Conversion factor ( $10^{-6}$ kg/mg)
FI	=	Fraction ingested from contaminated source (unitless)
EF	=	Exposure frequency (days/years)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged - days)

For calculation of radionuclide intakes, the concentration is expressed in pCi/kg, and the expression is not divided by body weight and averaging time. The intake for radionuclides is expressed in pCi.

#### **F5.1.5 Dermal Contact With Soil and Sediments**

The exposure from dermal contact with contaminants in soil and sediments is calculated using the following equation which results in an estimate of the absorbed dose, not the amount of chemical in contact with the skin (i.e., intake):

$$\text{Absorbed Dose (mg/kg/day)} = \frac{\text{CS} \times \text{CF} \times \text{SA} \times \text{AF} \times \text{ABS} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (5)$$

where:

CS	=	Chemical concentration in soil or sediments (mg/kg)
CF	=	Conversion factor (10 <sup>-6</sup> kg/mg)
SA	=	Skin surface area available for contact (cm <sup>2</sup> /event)
AF	=	Soil to skin adherence factor (mg/cm <sup>2</sup> )
ABS	=	Absorption factor (unitless)
EF	=	Exposure frequency (events/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged - days)

The skin surface area available for contact depends on the parts of the body assumed to be exposed. According to EPA guidance, exposure to soil and sediment is assumed to result in a reasonable worst case exposure to surface area including the body extremities and the head (EPA, 1992c).

Information on dermal absorption factors is given in the EPA's Region I *Supplemental Risk Assessment Guidance for the Superfund Program* (EPA, 1989c). If specific values are not identified for contaminants, then a value is used from the range given. Refer to Table F5-1 for a listing of the chemical-specific dermal absorption factors.

#### **F5.1.6 Ingestion of Garden Fruits and Vegetables**

The contaminant intakes for ingestion of garden produce are calculated using the following equation:

$$\text{Intake (mg/kg/day)} = \frac{\text{CF} \times \text{IR} \times \text{FI} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (6)$$

where:

CF	=	Contaminant concentration in food (mg/kg)
IR	=	Ingestion rate (kg/day)
FI	=	Fraction ingested from contaminated source (unitless)

EF	=	Exposure frequency (days/years)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged - days)

For calculation of radionuclide intakes, the concentration is expressed in pCi/kg, and the expression is not divided by body weight and averaging time. The intake for radionuclides is expressed in pCi.

For the on-site and off-site residential scenarios, contaminant concentrations in crops are assessed by estimating uptake and accumulation through roots from the soil as well as through deposition. The concentrations due to root uptake and deposition are then summed to arrive at a total plant concentration. The equations are presented below.

When possible, separate calculations are performed for vegetative (i.e., leaf and root) and reproductive (i.e., fruit and seed) portions of crops. Root uptake concentration is determined by the following equation:

$$U_v = B_v \times C_s \quad (7)$$

where:

$U_v$	=	Concentration in vegetative crop portion ( $\mu\text{g}/\text{kg}$ ) or (pCi/kg)
$B_v$	=	Soil to plant (vegetative) transfer coefficient (dry weight) (unitless)
$C_s$	=	Concentration in root zone (dry weight)

or

$$U_r = B_r \times C_s \quad (8)$$

where:

$U_r$	=	Concentration in reproductive crop portion ( $\mu\text{g}/\text{kg}$ ) or (pCi/kg)
$B_r$	=	Soil to plant (reproductive) transfer coefficient (dry weight) (unitless).

As recommended by EPA (1991b), values for  $B_v$  and  $B_r$  are taken from Baes et al. (1984). If no  $B_v$  or  $B_r$  values are available, then  $B_v$  is calculated using the method identified in Travis and

Arms (1988); and the percent intake from the vegetative crop is assumed to be 100%. The equation for calculating  $B_v$  is:

$$\log B_v = 1.588 - 0.578 \log K_{ow} \quad (9)$$

To determine the concentration (i.e., wet weight):

$$WC_x = U_x \times DWC_x \quad (10)$$

where:

- x = Vegetative or reproductive
- WC = Weight concentration ( $\mu\text{g}/\text{kg}$ ) or (pCi/kg)
- DWC = Dry-to-wet conversion (unitless)
- = 0.428 reproductive
- = 1.0 vegetative (Baes et al. 1984)

The weighted average homegrown crop concentration is

$$C_c = \left[ \frac{I_v}{[I_v + I_r]} \right] \times WC_v \times \left[ \frac{I_r}{[I_v + I_r]} \right] \times WC_r \quad (11)$$

where:

- $C_c$  = Crop concentration ( $\mu\text{g}/\text{kg}$ ) or (pCi/kg)
- $I_v$  = % Intake of vegetative crop (g/d) = 0.058
- $I_r$  = % Intake of reproductive crop (g/d) = 0.942 (Baes et al., 1984)

Contaminant concentration due to deposition was calculated using the following equation:

$$CVD = (C_a * F_p * \bar{V}_d * r/Y) * (T_{1/2} / \ln 2) \quad (12)$$

where:

- CVD = Vegetation concentration due to atmospheric deposition ( $\mu\text{g}/\text{kg}$ )
- $C_a$  = Chemical concentration in air ( $\mu\text{g}/\text{m}^3$ )
- $F_p$  = Fraction of chemical sorbed, assumed to be 100%
- $\bar{V}_d$  = Atmospheric deposition velocity (0.002 m/sec)  
(Hattemer-Frey and Travis, 1991)
- $r/Y$  = Intercept fraction - to - productivity ratio (0.32  $\text{m}^2/\text{kg}$ )  
(Baes et al., 1984)

$$T_{1/2} = \text{weathering half life in sec (14 days) (Baes et al., 1984)} \\ (T_{1/2} / \ln 2) = 1745084$$

The maximum theoretical interception fraction of 0.39 (Baes et al., 1984) was divided by an upper bound value for productivity of 1.2 kg/m<sup>2</sup> to yield an interception fraction-to-productivity ratio of 0.32 m<sup>2</sup>/kg.

The contaminant concentrations due to root uptake and deposition are then summed to arrive at a total plant concentration.

## **F5.2 CALCULATED INTAKES FOR EACH SCENARIO**

Information presented in this section (i.e., exposure parameters, exposure concentrations, and calculated intakes) is scenario-specific and pathway-specific. Exposure scenarios and pathways are identified in Section F4 and summarized in Table F4-4. Exposure parameters and exposure concentrations for each scenario pathway are used as input to the intake equations presented in Section F5.1. The resulting calculated intakes are presented by each scenario pathway.

Exposure parameters were identified using EPA guidance, published literature, and professional judgement. In accordance with the RME concept, some exposure parameters are used at their reasonable upper-bound values (e.g., exposure frequency and duration) and some are used at central tendency values (e.g., body weight). The combination of these variables results in estimates of the RME.

Accurate estimates of contaminant concentrations at points of human exposure are a prerequisite for evaluating the contaminant intake of potentially exposed individuals. Modeling and site characterization data are used to estimate contaminant release from the site and contaminant fate and transport through environmental media to the receptor. The estimated concentrations of COCs in each medium are used with intake equations to estimate the intakes.

The COC concentrations used in the equations are intended to be conservative estimates of the average values, therefore the 95 percent upper confidence limit of the arithmetic mean is used.

Two general methods for the treatment of non-detects, or below detection limit (DL) observations, were investigated. A simple substitution method of one-half the DL was compared to a more robust method involving probability plotting performed with a FORTRAN code, MDL, written by Helsel and Cohn (1988). Helsel and Cohn recommend that substitution methods be used if non-detects exceed 80 percent of the data set. The substitution method of one-half the DL is used for all data sets to be consistent with RFI/RI evaluations. However, it is recognized that MDL is a more robust method for the treatment of data with multiple detection limits.

An additional consideration of contaminant concentration is the aggregation of data to provide risk information about contaminants that are unevenly distributed across the site. Accordingly, data are aggregated to yield sitewide (OU1) risk, risk at the source, and sitewide risk if the source were removed.

For the purposes of risk assessment, elevated contaminants in groundwater in IHSS 119.1 are treated as a source. Radionuclide hot spots in soil were also identified in IHSS 119.1, and this data are also included in the scenarios considering source risk. The hot spot data are aggregated into surface (top 0.25 inches) and subsurface (composite intervals below surface). It is important to note that the hot spot data were included using a simple average. Thus, the hot spots greatly bias the concentration. They were included in this manner to be consistent with the treatment of groundwater data. Section 7.3.1 discusses the effect of using an area-weighted average.

To evaluate sitewide risk, site-wide data (including groundwater source and radionuclide hot spot data) are used to identify contaminant concentrations for the following scenarios:

- Current On-Site Worker (Security Specialist)
- Current Off-Site Resident
- Future On-Site Worker (Office and Construction)
- Future On-Site Ecological Researcher
- Future On-Site Resident (Sitewide without Groundwater)

- Future On-Site Resident (Sitewide with Groundwater)

To evaluate risk at the source, source data (groundwater and radionuclide hot spot data) are used to identify contaminant concentrations (for all pathways except those involving surface water and sediment) for the following scenarios:

- Future On-Site Resident (Assuming Adequate Groundwater at Source)
- Future On-Site Resident (Groundwater at Source with Public Water)

To evaluate sitewide risk if the source were removed, the source data for groundwater VOCs and surface soil (0.25-inch depth) radionuclide hot spots is removed from the site-wide data and applied to the following scenario:

- Future On-site Resident Scenario without Source (without Groundwater/ without Source).

Information regarding the exposure parameters, exposure concentrations, and calculated intakes is presented in tabular form and organized sequentially by scenario. For example, the first scenario presented is that of the current on-site worker (security specialist). Table F5-2 presents the exposure parameters for that scenario for the pathways involving inhalation of particulates, soil ingestion, dermal contact with soil, ingestion of sediment, dermal contact with sediment, ingestion of surface water, and dermal contact with surface water. Similarly, Table F5-3 presents the exposure concentrations for the same scenario for each contaminant for airborne particulates, surface soil, sediment, and surface water. For each pathway and contaminant, exposure parameters and exposure concentrations are used as input to the relevant pathway equation (presented in Section F5.1). The resulting calculated carcinogenic and noncarcinogenic intakes for the current on-site worker (security specialist) scenario are presented by pathway and contaminant in Tables F5-4 and F5-5.

Exposure parameters, exposure concentrations, and calculated intakes are presented in Tables F5-2 through F5-46 for each of the nine scenarios. The intakes calculated in this section are

combined with toxicity constants presented in Section F6, and the resulting risk estimates are presented in Section F7.

Table F5-1

Chemical-Specific Dermal Exposure Constants

Chemicals	Dermal Permeability Constants (PC)	Reference	Absorption Factor (ABS)	Reference
1,1-Dichloroethene	1.60E-02	EPA, 1992c	(b)	N/A
Carbon Tetrachloride	2.20E-02	EPA, 1992c	(b)	N/A
Tetrachloroethene	4.80E-02 *	EPA, 1992c	(b)	N/A
1,1,1-Trichloroethane	1.70E-02	EPA, 1992c	(b)	N/A
Acenaphthene	(a)	N/A	4.00E-01	EPA, 1989c
Fluoranthene	(a)	N/A	4.00E-01	EPA, 1989c
Benzo(a)anthracene	(a)	N/A	5.00E-02	EPA, 1989c
Benzo(a)pyrene	(a)	N/A	5.00E-02	EPA, 1989c
Benzo(b)fluoranthene	(a)	N/A	5.00E-02	EPA, 1989c
Benzo(k)fluoranthene	(a)	N/A	5.00E-02	EPA, 1989c
Dibenzo(a,h)anthracene	(a)	N/A	5.00E-02	EPA, 1989c
Aroclor-1254	(a)	N/A	5.00E-02	EPA, 1989c
Fluorene	(a)	N/A	4.00E-01	EPA, 1989c
Pyrene	(a)	N/A	4.00E-01	EPA, 1989c
Toluene	(a)	N/A	4.00E-01	EPA, 1989c
Selenium	1.0E-03	N/A	N/A (b)	N/A
Uranium-233, 234	N/A (c)	N/A	N/A (c)	N/A
Uranium-238	N/A (c)	N/A	N/A (c)	N/A
Americium-241	N/A (c)	N/A	N/A (c)	N/A
Plutonium-239, 240	N/A (c)	N/A	N/A (c)	N/A

\* EPA also reports a higher value determined by measurement under conditions not representative of washing or showering.

(a) = Not identified as a COC in groundwater or surface water

(b) = Not identified as a COC in soils or sediments

(c) = Dermal exposure to metals will be evaluated qualitatively

N/A = Not applicable

Table F5-2

## Exposure Parameters - Current On-Site Worker (Security Specialist)

Pathway	Parameter	Worker Value	Reference
Inhalation of Particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	EPA, 1991b
	EF = Exposure frequency (days/year) (250 d/y) × (0.5 h/day in OUI) ÷ (8 h/day)	16	prof. judgement
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b
Soil Ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	NA
	IR = Ingestion rate (mg/day)	50	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	NA
	FI = Fraction ingested (unitless)	1	prof. judgement
	EF = Exposure frequency (days/year) (250 d/y) × (0.5 h/day in OUI) ÷ (8 h/day)	16	prof. judgement
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b

Table F5-2 (Continued)

## Exposure Parameters - Current On-Site Worker (Security Specialist)

Pathway	Parameter	Worker Value	Reference
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year) (250 d/y) × (0.5 h/day in OUI) ÷ (8 h/day)	16	prof. judgement
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	NA
	IR = Ingestion rate (mg/day)	50	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	NA
	FI = Fraction ingested (unitless)	1	prof. judgement
	EF = Exposure frequency (days/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b

Table F5-2 (Continued)

## Exposure Parameters - Current On-Site Worker (Security Specialist)

Pathway	Parameter	Worker Value	Reference
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	NA
	IR = Ingestion rate (l/event) (the amount of water contained in 50 mg of saturated sediments assuming a wet density of 1.4 g/cm <sup>3</sup> and a porosity of 50%) (See Section F5.1.1)	0.00002	prof. judgement
	EF = Exposure frequency (events/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b

Table F5-2 (Continued)

## Exposure Parameters - Current On-Site Worker (Security Specialist)

Pathway	Parameter	Worker Value	Reference
Dermal contact with surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	0.5	prof. judgement
	EF = Exposure frequency (days/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	NA
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b

Table F5-3

Estimated RME Concentrations of COCs for the Current On-Site Worker (Security Specialist)

Contaminants	Airborne Particulates (*m <sup>3</sup> ) (a)	Surface Soil (*kg)	Sediments (*kg)	Surface Water (*l)
1,1-Dichloroethene	NA	NA	NA	NA
Carbon Tetrachloride	NA	NA	NA	NA
Tetrachloroethene	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	NA
Toluene	NA	NA	NA	NA
Acenaphthene	6.96E-08	1.94E-01	NA	NA
Fluoranthene	2.61E-07	7.26E-01	2.59E-01	NA
Benzo(a)anthracene	1.14E-07	3.17E-01	NA	NA
Benzo(a)pyrene	1.09E-07	3.02E-01	NA	NA
Benzo(b)fluoranthene	1.09E-07	3.05E-01	2.76E-01	NA
Benzo(k)fluoranthene	1.04E-07	2.89E-01	2.74E-01	NA
Dibenzo(a,h)anthracene	6.76E-08	1.88E-01	NA	NA
Fluorene	6.89E-08	1.92E-01	NA	NA
Pyrene	1.25E-07	6.61E-01	2.59E-01	NA
Aroclor-1254	9.90E-08	2.18E-01	1.59E-01	NA
Selenium	NA	NA	NA	NA
Americium-241	7.95E-02	2.22E+05	3.61E-02	2.56E-02
Plutonium-239,240	2.80E-01	7.80E+05	2.97E+00	7.80E-03
Uranium-233,234	1.17E-03	3.27E+03	1.30E+00	2.36E+00
Uranium-238	5.64E-04	1.57E+03	1.17E+00	4.50E+00

\* Units are in mg or pCi, as applicable  
(a) Modeled values; see Attachment F-2

Table F5-4. RME Carcinogenic Intakes – Current On-Site Worker (Security Specialist)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	----
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	----
Acenaphthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(a)anthracene	-	3.5E-09	NA	NA	2.1E-08	NA	NA	-	NA	2.4E-08
Benzo(a)pyrene	-	3.4E-09	NA	NA	2.0E-08	NA	NA	-	NA	2.3E-08
Benzo(b)fluoranthene	-	3.4E-09	1.3E-09	NA	2.0E-08	7.8E-09	NA	-	NA	3.2E-08
Benzo(k)fluoranthene	-	3.2E-09	1.3E-09	NA	1.9E-08	7.8E-09	NA	-	NA	3.1E-08
Aroclor-1254	-	2.4E-09	1.8E-09	NA	1.4E-08	1.0E-08	NA	-	NA	2.8E-08
Fluorene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Dibenzo(a,h)anthracene	-	2.1E-09	NA	NA	1.2E-08	NA	NA	-	NA	1.4E-08
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	----
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Uranium-233,234	-	6.5E+01	1.1E-02	8.2E-03	NA	NA	NA	-	9.4E+00	7.5E+01
Uranium-238	-	3.1E+01	1.0E-02	1.6E-02	NA	NA	NA	-	4.5E+00	3.6E+01
Americium-241	-	4.4E+03	3.2E-04	9.0E-05	NA	NA	NA	-	6.4E+02	5.1E+03
Plutonium-239,-240	-	1.6E+04	2.6E-02	2.7E-05	NA	NA	NA	-	2.2E+03	1.8E+04

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium or no toxicity factor is available

Table F5-5. RME Noncarcinogenic Intakes – Current On-Site Worker (Security Specialist)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	---
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	---
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	---
Acenaphthene	-	6.1E-09	NA	NA	2.8E-07	NA	NA	-	NA	2.9E-07
Fluoranthene	-	2.3E-08	3.5E-09	NA	1.1E-06	1.6E-07	NA	-	NA	1.2E-06
Benzo(a)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Benzo(a)pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Benzo(b)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Benzo(k)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Aroclor-1254	-	NA	NA	NA	NA	NA	NA	-	NA	---
Fluorene	-	6.0E-09	NA	NA	2.8E-07	NA	NA	-	NA	2.8E-07
Pyrene	-	2.1E-08	3.5E-09	NA	9.6E-07	1.6E-07	NA	-	NA	1.1E-06
Dibenzo(a,h)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	---
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Uranium-233,234	-	NA	NA	NA	NA	NA	NA	-	NA	---
Uranium-238	-	NA	NA	NA	NA	NA	NA	-	NA	---
Americium-241	-	NA	NA	NA	NA	NA	NA	-	NA	---
Plutonium-239,-240	-	NA	NA	NA	NA	NA	NA	-	NA	---

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium or no toxicity factor is available

Table F5-6

Exposure Parameters - Current Off-Site Resident

Pathway	Parameter	Adult Value	Child Value	Reference
Inhalation of Particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190 25,550	EPA, 1991b
Soil Ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190 25,550	EPA, 1991b

Table F5-6 (Continued)

Exposure Parameters - Current Off-Site Resident

Pathway	Parameter	Adult Value	Child Value	Reference
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190 25,550	EPA, 1991b
Ingestion of fruits and vegetables:	CF = Concentration in crops (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (kg/day)	0.078	0.039	EPA, 1989d
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190 25,550	EPA, 1991b

Table F5-7

Estimated RME Concentrations of COCs for the Current Off-Site Resident

Contaminants	Airborne Particulates (a) (* /m <sup>3</sup> )	Surface Soil (a) (* /kg)	Fruits and Vegetables (a) (* /kg)
1,1-Dichloroethene	NA	NA	NA
Carbon Tetrachloride	NA	NA	NA
Tetrachloroethene	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA
Toluene	NA	NA	NA
Acenaphthene	6.59E-11	4.05E-06	6.97E-07
Fluoranthene	2.47E-10	1.52E-05	1.90E-07
Benzo(a)anthracene	1.08E-11	6.63E-06	1.47E-07
Benzo(a)pyrene	1.03E-10	6.32E-06	1.53E-08
Benzo(b)fluoranthene	1.04E-10	6.37E-06	1.63E-08
Benzo(k)fluoranthene	9.83E-11	6.04E-06	1.15E-08
Dibenzo(a,h)anthracene	6.40E-11	3.94E-06	8.73E-08
Fluorene	6.52E-11	4.01E-06	5.96E-07
Pyrene	1.19E-10	7.29E-06	1.20E-07
Aroclor-1254	9.38E-11	5.76E-06	4.08E-08
Selenium	NA	NA	NA
Americium-241	7.53E-05	4.63E+00	8.58E-02
Plutonium-239,240	2.65E-04	1.63E+01	3.25E-01
Uranium-238	5.34E-07	3.28E-02	6.64E-04
Uranium -233,234	1.11E-06	6.84E-02	1.38E-03

\* Units are in mg or pCi, as applicable  
(a) Modeled values; see Attachment F-2

Table F5-8. RME Carcinogenic Intakes – Current Off-Site Resident (Adult)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	-	-	NA	-	-	-	NA	----
Carbon Tetrachloride	NA	NA	-	-	NA	-	-	-	NA	----
Tetrachloroethene	NA	NA	-	-	NA	-	-	-	NA	----
1,1,1-Trichloroethane	NA	NA	-	-	NA	-	-	-	NA	----
Acenaphthene	NA	NA	-	-	NA	-	-	-	NA	----
Fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(a)anthracene	5.4E-11	3.1E-12	-	-	9.0E-12	-	-	-	NA	6.6E-11
Benzo(a)pyrene	5.6E-12	3.0E-12	-	-	8.6E-12	-	-	-	NA	1.7E-11
Benzo(b)fluoranthene	6.0E-12	3.0E-12	-	-	8.7E-12	-	-	-	NA	1.8E-11
Benzo(k)fluoranthene	4.2E-12	2.8E-12	-	-	8.2E-12	-	-	-	NA	1.5E-11
Aroclor-1254	1.5E-11	2.7E-12	-	-	7.8E-12	-	-	-	NA	2.5E-11
Fluorene	NA	NA	-	-	NA	-	-	-	NA	----
Pyrene	NA	NA	-	-	NA	-	-	-	NA	----
Dibenzo(a,h)anthracene	3.2E-11	1.9E-12	-	-	5.4E-12	-	-	-	NA	3.9E-11
Selenium	NA	NA	-	-	NA	-	-	-	NA	----
Toluene	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-233,234	9.0E-01	5.7E-02	-	-	NA	-	-	-	1.9E-01	1.1E+00
Uranium-238	4.4E-01	2.8E-02	-	-	NA	-	-	-	9.0E-02	5.5E-01
Americium-241	5.6E+01	3.9E+00	-	-	NA	-	-	-	1.3E+01	7.3E+01
Plutonium-239,-240	2.1E+02	1.4E+01	-	-	NA	-	-	-	4.5E+01	2.7E+02

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

Table F5-9. RME Noncarcinogenic Intakes - Current Off-Site Resident (Adult)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact of Soil (mg/kg/d)	Dermal Contact of Sediment (mg/kg/d)	Dermal Contact of Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	-	-	NA	-	-	-	NA	---
Carbon Tetrachloride	NA	NA	-	-	NA	-	-	-	NA	---
Tetrachloroethene	NA	NA	-	-	NA	-	-	-	NA	---
1,1,1-Trichloroethane	NA	NA	-	-	NA	-	-	-	NA	---
Acenaphthene	7.4E-10	5.5E-12	-	-	1.3E-10	-	-	-	NA	8.8E-10
Fluoranthene	2.0E-10	2.1E-11	-	-	4.8E-10	-	-	-	NA	7.1E-10
Benzo(a)anthracene	NA	NA	-	-	NA	-	-	-	NA	---
Benzo(a)pyrene	NA	NA	-	-	NA	-	-	-	NA	---
Benzo(b)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	---
Benzo(k)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	---
Acroclor-1254	NA	NA	-	-	NA	-	-	-	NA	---
Fluorene	6.4E-10	5.5E-12	-	-	1.3E-10	-	-	-	NA	7.7E-10
Pyrene	1.3E-10	1.0E-11	-	-	2.3E-10	-	-	-	NA	3.7E-10
Dibenzo(a,h)anthracene	NA	NA	-	-	NA	-	-	-	NA	---
Selenium	NA	NA	-	-	NA	-	-	-	NA	---
Toluene	NA	NA	-	-	NA	-	-	-	NA	---
Uranium-233,234	NA	NA	-	-	NA	-	-	-	NA	---
Uranium-238	NA	NA	-	-	NA	-	-	-	NA	---
Americium-241	NA	NA	-	-	NA	-	-	-	NA	---
Plutonium-239,-240	NA	NA	-	-	NA	-	-	-	NA	---

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium or no toxicity factor is available

Table F5-10. RME Noncarcinogenic Intakes – Current Off-Site Resident (Child)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	-	-	NA	-	-	-	NA	----
Carbon Tetrachloride	NA	NA	-	-	NA	-	-	-	NA	----
Tetrachloroethene	NA	NA	-	-	NA	-	-	-	NA	----
1,1,1-Trichloroethane	NA	NA	-	-	NA	-	-	-	NA	----
Acenaphthene	1.7E-09	5.2E-11	-	-	2.4E-10	-	-	-	NA	2.0E-09
Fluoranthene	4.7E-10	1.9E-10	-	-	8.9E-10	-	-	-	NA	1.6E-09
Benzo(a)anthracene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(a)pyrene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(b)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(k)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Aroclor-1254	NA	NA	-	-	NA	-	-	-	NA	----
Fluorene	1.5E-09	5.1E-11	-	-	2.4E-10	-	-	-	NA	1.8E-09
Pyrene	3.0E-10	9.3E-11	-	-	4.3E-10	-	-	-	NA	8.2E-10
Dibenzo(a,h)anthracene	NA	NA	-	-	NA	-	-	-	NA	----
Selenium	NA	NA	-	-	NA	-	-	-	NA	----
Toluene	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-233,234	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-238	NA	NA	-	-	NA	-	-	-	NA	----
Americium-241	NA	NA	-	-	NA	-	-	-	NA	----
Plutonium-239,-240	NA	NA	-	-	NA	-	-	-	NA	----

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

Table F5-11

## Exposure Parameters - Future On-Site Worker

Pathway	Parameter	Office Worker Value	Construction Worker Value	Reference
Inhalation of volatiles (basement vapors)	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	250	10	EPA, 1991b/ prof. judgement
	ED = Exposure duration (years)	25	1	EPA, 1991b/ prof. judgement
	BW = Body weight (kg)	70	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	365 25,550	EPA, 1991b
Inhalation of particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	250	10	EPA, 1991b/ prof. judgement
	ED = Exposure duration (years)	25	1	EPA, 1991b/ prof. judgement
	BW = Body weight (kg)	70	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	365 25,550	EPA, 1991b

Table F5-11 (Continued)

## Exposure Parameters - Future On-Site Industrial Worker

Pathway	Parameter	Office Worker value	Construction worker value	Reference
Soil ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	50	50	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	250	10	EPA, 1991b/ prof. judgement
	ED = Exposure duration (years)	25	1	EPA, 1991b/ prof. judgement
	BW = Body weight (kg)	70	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	365 25,550	EPA, 1991b
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	5,800	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	250	10	EPA, 1991b/ prof. judgement
	ED = Exposure duration (years)	25	1	EPA, 1991b/ prof. judgement
	BW = Body weight (kg)	70	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	365 25,550	EPA, 1991b

Table F5-11 (Continued)

## Exposure Parameters - Future On-Site Worker

Pathway	Parameter	Office worker value	Construction worker value	Reference
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	NA	NA
	IR = Ingestion rate (mg/day)	50	NA	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	NA	NA
	FI = Fraction ingested (unitless)	1	NA	prof. judgement
	EF = Exposure frequency (days/year)	7	NA	EPA, 1989a
	ED = Exposure duration (years)	25	NA	EPA, 1991b
	BW = Body weight (kg)	70	NA	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	NA	EPA, 1991b
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	NA	NA
	CF = Conversion factor (kg/mg)	1E-6	NA	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	NA	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	NA	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	NA	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	NA	EPA, 1989a
	ED = Exposure duration (years)	25	NA	EPA, 1991b
	BW = Body weight (kg)	70	NA	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	NA	EPA, 1991b

Table F5-11 (Continued)

## Exposure Parameters - Future On-Site Worker

Pathway	Parameter	Office worker value	Construction worker value	Reference
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	NA	NA
	IR = Ingestion rate (l/event) (the amount of water contained in 50 mg of saturated sediments assuming a wet density of 1.4 g/cm <sup>3</sup> and a porosity of 50%) (See Section F5.1.1)	0.00002	NA	prof. judgement
	EF = Exposure frequency (events/year)	7	NA	EPA, 1989a
	ED = Exposure duration (years)	25	NA	EPA, 1991b
	BW = Body weight (kg)	70	NA	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	NA	EPA, 1991b
	Dermal contact with surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	NA
SA = Body surface area (cm <sup>2</sup> ) (extremities and head)		5,800	NA	EPA, 1992c
PC = Dermal permeability (cm/hr)		Chemical specific	NA	EPA, 1992c
ET = Exposure time (hr/day)		0.5	NA	prof. judgement
EF = Exposure frequency (days/year)		7	NA	EPA, 1989a
ED = Exposure duration (years)		25	NA	EPA, 1989a
CF = Conversion factor (l/cm <sup>3</sup> )		0.001	NA	NA
BW = Body weight (kg)		70	NA	EPA, 1991b
AT = Averaging time (days) Noncarcinogenic Carcinogenic		9,125 25,550	NA	EPA, 1991b

Table F5-12

Estimated RME Concentrations of COCs for the Future On-Site Office Worker

Contaminants	Indoor Air from Basement (a) (mg/m <sup>3</sup> )	Airborne Particulates (* /m <sup>3</sup> ) (a)	Surface Soil (* /kg)	Sediments (* /kg)	Surface Water (* /l)
1,1-Dichloroethene	1.84E-02	NA	NA	NA	NA
Carbon Tetrachloride	2.79E-03	NA	NA	NA	NA
Tetrachloroethene	1.61E-03	NA	NA	NA	NA
1,1,1-Trichloroethane	2.84E-02	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA
Acenaphthene	NA	6.96E-08	1.94E-01	NA	NA
Fluoranthene	NA	2.61E-07	7.26E-01	2.59E-01	NA
Benzo(a)anthracene	NA	1.14E-07	3.17E-01	NA	NA
Benzo(a)pyrene	NA	1.09E-07	3.02E-01	NA	NA
Benzo(b)fluoranthene	NA	1.09E-07	3.05E-01	2.76E-01	NA
Benzo(k)fluoranthene	NA	1.04E-07	2.89E-01	2.74E-01	NA
Dibenzo(a,h)anthracene	NA	6.76E-08	1.88E-01	NA	NA
Fluorene	NA	6.89E-08	1.92E-01	NA	NA
Pyrene	NA	1.25E-07	6.61E-01	2.59E-01	NA
Aroclor-1254	NA	9.90E-08	2.18E-01	1.59E-01	NA
Selenium	NA	NA	NA	NA	NA
Americium-241	NA	7.95E-02	2.22E+05	3.61E-02	2.56E-02
Plutonium-239,240	NA	2.80E-01	7.80E+05	2.97E+00	7.80E-03
Uranium -233,234	NA	1.17E-03	3.27E+03	1.30E+00	2.36E+00
Uranium-238	NA	5.64E-04	1.57E+03	1.17E+00	4.50E+00

\* Units are in mg or pCi, as applicable

(a) Modeled values; see Attachment F-2

Table F5-13

Estimated RME Concentrations of COCs for the Future On-Site Construction Worker

Contaminants	Inhalation Volatiles (mg/m <sup>3</sup> ) (a)	Airborne Particulates (a) (* /m <sup>3</sup> )	Sub-Surface Soil (* /kg)
1,1-Dichloroethene	1.84E-02	NA	NA
Carbon Tetrachloride	2.79E-03	NA	NA
Tetrachloroethene	1.61E-03	NA	NA
1,1,1-Trichloroethane	2.84E-02	NA	NA
Toluene	NA	7.70E-09	1.22E-01
Acenaphthene	NA	NA	NA
Fluoranthene	NA	NA	3.52E-01
Benzo(a)anthracene	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA
Fluorene	NA	NA	NA
Pyrene	NA	NA	3.44E-01
Aroclor-1254	NA	NA	NA
Selenium	NA	NA	NA
Americium-241	NA	2.54E-06	3.06E+04
Plutonium-239,240	NA	7.22E-06	8.70E+04
Uranium -233,234	NA	3.74E-07	4.50E+03
Uranium-238	NA	1.23E-07	1.49E+03

\* Units are in mg or pCi, as applicable

(a) Modeled values; see Attachment F-2

Table F5-14. RME Carcinogenic Intakes - Future On-Site Worker (Office)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Inhalation of Const Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	1.3E-03	NA	-	1.3E-03
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	1.9E-04	NA	-	1.9E-04
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	1.1E-04	NA	-	1.1E-04
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Aceraphthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Fluoranthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Benzo(a)anthracene	-	5.5E-08	NA	NA	3.2E-07	NA	NA	NA	NA	-	3.8E-07
Benzo(a)pyrene	-	5.3E-08	NA	NA	3.1E-07	NA	NA	NA	NA	-	3.6E-07
Benzo(b)fluoranthene	-	5.3E-08	1.3E-09	NA	3.1E-07	7.8E-09	NA	NA	NA	-	3.7E-07
Benzo(k)fluoranthene	-	5.1E-08	1.3E-09	NA	2.9E-07	7.8E-09	NA	NA	NA	-	3.5E-07
Aroclor-1254	-	3.8E-08	2.8E-08	NA	2.2E-07	1.6E-07	NA	NA	NA	-	4.4E-07
Fluorene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Pyrene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Dibenzo(a,h)anthracene	-	3.3E-08	NA	NA	1.9E-07	NA	NA	NA	NA	-	2.2E-07
Selenium	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Toluene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Uranium-233,234	-	1.0E+03	1.1E-02	8.2E-03	NA	NA	NA	NA	1.5E+02	-	1.2E+03
Uranium-238	-	4.9E+02	1.0E-02	1.6E-02	NA	NA	NA	NA	7.1E+01	-	5.6E+02
Americium-241	-	6.9E+04	3.2E-04	9.0E-05	NA	NA	NA	NA	9.9E+03	-	7.9E+04
Plutonium-239,-240	-	2.4E+05	2.6E-02	2.7E-05	NA	NA	NA	NA	3.5E+04	-	2.8E+05

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

Table P5-15. RMB Noncarcinogenic Intakes - Future On-Site Worker (Office)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Inhalation of Const Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	5.6E-03	NA	-	5.6E-03
Acenaphthene	-	9.5E-08	NA	NA	4.4E-06	NA	NA	NA	NA	-	4.5E-06
Fluoranthene	-	3.6E-07	3.5E-09	NA	1.6E-05	1.6E-07	NA	NA	NA	-	1.7E-05
Benzo(a)anthracene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Benzo(a)pyrene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Benzo(b)fluoranthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Benzo(k)fluoranthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Aroclor-1254	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Fluorene	-	9.4E-08	NA	NA	4.4E-06	NA	NA	NA	NA	-	4.4E-06
Pyrene	-	3.2E-07	3.5E-09	NA	1.5E-05	1.6E-07	NA	NA	NA	-	1.5E-05
Dibenzo(a,h)anthracene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Selenium	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Toluene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Uranium-233,234	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Uranium-238	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Americium-241	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----
Plutonium-239,-240	-	NA	NA	NA	NA	NA	NA	NA	NA	-	----

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

Table P5-16 RMB Carcinogenic Intakes - Future On-Site Worker (Construction)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Sub Soil (mg/kg/d)	Ingestion of Surf. Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Sub Soil (mg/kg/d)	Dermal Contact Surf. Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Inhalation of Coars Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.1E-06	NA	NA	2.1E-06
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.1E-07	NA	NA	3.1E-07
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.8E-07	NA	NA	1.8E-07
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acrophthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benz(a)anthracene	NA	NA	3.7E-12	NA	NA	NA	NA	2.2E-11	NA	NA	NA	NA	2.5E-11
Benz(a)pyrene	NA	NA	3.5E-12	NA	NA	NA	NA	2.1E-11	NA	NA	NA	NA	2.4E-11
Benz(b)fluoranthene	NA	NA	3.6E-12	NA	NA	NA	NA	2.1E-11	NA	NA	NA	NA	2.4E-11
Benz(k)fluoranthene	NA	NA	3.4E-12	NA	NA	NA	NA	2.0E-11	NA	NA	NA	NA	2.3E-11
Acrid - 1254	NA	NA	2.5E-12	NA	NA	NA	NA	1.5E-11	NA	NA	NA	NA	1.7E-11
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene	NA	NA	2.2E-12	NA	NA	NA	NA	1.3E-11	NA	NA	NA	NA	1.5E-11
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium - 233,234	NA	9.5E-02	6.9E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6E-01
Uranium - 238	NA	3.1E-02	3.3E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.4E-02
Americium - 241	NA	6.4E-01	4.7E+00	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.3E+00
Plutonium - 239, - 240	NA	1.8E+00	1.6E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.8E+01

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor



Table F5-18

## Exposure Parameters - Future On-Site Ecological Researcher

Pathway	Parameter	Worker Value	Reference
Inhalation of particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	EPA, 1991b
	EF = Exposure frequency (days/year)	250	EPA, 1991b
	ED = Exposure duration (years)	25	EPA, 1989d
	BW = Body weight (kg)	70	EPA, 1989d
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1989d
Soil ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	NA
	IR = Ingestion rate (mg/day)	50	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	NA
	FI = Fraction ingested (unitless)	1	prof. judgement
	EF = Exposure frequency (days/year)	250	EPA, 1991b
	ED = Exposure duration (years)	25	EPA, 1989d
	BW = Body weight (kg)	70	EPA, 1989d
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1989d

Table F5-18 (Continued)

## Exposure Parameters - Future On-Site Ecological Researcher

Pathway	Parameter	Worker Value	Reference
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	250	EPA, 1991b
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	NA
	IR = Ingestion rate (mg/day)	.50	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	NA
	FI = Fraction ingested (unitless)	1	prof. judgement
	EF = Exposure frequency (days/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1989a

Table F5-18 (Continued)

## Exposure Parameters - Future On-Site Ecological Researcher

Pathway	Parameter	Worker Value	Reference
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	NA
	IR = Ingestion rate (l/event) (the amount of water contained in 50 mg of saturated sediments assuming a wet density of 1.4 g/cm <sup>3</sup> and a porosity of 50%) (See Section F5.1.1)	0.00002	prof. judgement
	EF = Exposure frequency (events/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	BW = Body weight (kg)	70	EPA 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b

Table F5-18 (Continued)

Exposure Parameters - Future On-Site Ecological Researcher

Pathway	Parameter	Worker Value	Reference
Dermal contact with surface water:	CW = Concentration in water (mg/ℓ or pCi/ℓ)	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	2.6	EPA, 1989a
	EF = Exposure frequency (days/year)	7	EPA, 1989a
	ED = Exposure duration (years)	25	EPA, 1991b
	CF = Conversion factor (ℓ/cm <sup>3</sup> )	0.001	NA
	BW = Body weight (kg)	70	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	9,125 25,550	EPA, 1991b

Table F5-19

Estimated RME Concentrations of COCs for the Future On-Site Ecological Researcher

Contaminants	Airborne Particulates (a) (*/ $m^3$ )	Surface Soil (*/ $kg$ )	Sediments (*/ $kg$ )	Surface Water (*/ $l$ )
1,1-Dichloroethene	NA	NA	NA	NA
Carbon Tetrachloride	NA	NA	NA	NA
Tetrachloroethene	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	NA
Toluene	NA	NA	NA	NA
Acenaphthene	6.86E-08	1.94E-01	NA	NA
Fluoranthene	2.61E-07	7.26E-01	2.59E-01	NA
Benzo(a)anthracene	1.14E-07	3.17E-01	NA	NA
Benzo(a)pyrene	1.09E-07	3.02E-01	NA	NA
Benzo(b)fluoranthene	1.09E-07	3.05E-01	2.76E-01	NA
Benzo(k)fluoranthene	1.04E-07	2.89E-01	2.74E-01	NA
Dibenzo(a,h)anthracene	6.76E-08	1.88E-01	NA	NA
Fluorene	6.89E-08	1.92E-01	NA	NA
Pyrene	1.25E-07	6.61E-01	2.59E-01	NA
Aroclor-1254	9.90E-08	2.18E-01	1.59E-01	NA
Selenium	NA	NA	NA	NA
Americium-241	7.95E-02	2.22E+05	3.61E+02	2.56E-02
Plutonium-239,240	2.80E-01	7.80E+05	2.97E+00	7.80E-03
Uranium -233,234	1.17E-03	3.27E+03	1.30E+00	2.36E+00
Uranium-238	5.64E-04	1.57E+03	1.17E+00	4.50E+00

\* Units are in mg or pCi, as applicable  
(a) Modeled values; see Attachment F-2

Table F5-20. RME Carcinogenic Intakes - Future On-Site Ecological Researcher

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	---
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	---
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	---
Acenaphthene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Benzo(a)anthracene	-	5.5E-08	NA	NA	3.2E-07	NA	NA	-	NA	3.8E-07
Benzo(a)pyrene	-	5.3E-08	NA	NA	3.1E-07	NA	NA	-	NA	3.6E-07
Benzo(b)fluoranthene	-	5.3E-08	4.8E-08	NA	3.1E-07	2.8E-07	NA	-	NA	6.9E-07
Benzo(k)fluoranthene	-	5.1E-08	4.8E-08	NA	2.9E-07	2.8E-07	NA	-	NA	6.7E-07
Aroclor-1254	-	3.8E-08	2.8E-08	NA	2.2E-07	1.6E-07	NA	-	NA	4.4E-07
Fluorene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Dibenzo(a,h)anthracene	-	3.3E-08	NA	NA	1.9E-07	NA	NA	-	NA	2.2E-07
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	---
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Uranium-233,234	-	1.0E+03	4.1E-01	2.9E-01	NA	NA	NA	-	1.5E+02	1.2E+03
Uranium-238	-	4.9E+02	3.7E-01	5.6E-01	NA	NA	NA	-	7.1E+01	5.6E+02
Americium-241	-	6.9E+04	1.1E-02	3.2E-03	NA	NA	NA	-	9.9E+03	7.9E+04
Plutonium-239,-240	-	2.4E+05	9.3E-01	9.8E-04	NA	NA	NA	-	3.5E+04	2.8E+05

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

Table F5-21. RME Noncarcinogenic Intakes - Future On-Site Ecological Researcher

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	---
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	---
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	---
Acenaphthene	-	9.5E-08	NA	NA	4.4E-06	NA	NA	-	NA	4.5E-06
Fluoranthene	-	3.6E-07	1.3E-07	NA	1.6E-05	5.9E-06	NA	-	NA	2.3E-05
Benzo(a)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Benzo(a)pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Benzo(b)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Benzo(k)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Aroclor-1254	-	NA	NA	NA	NA	NA	NA	-	NA	---
Fluorene	-	9.4E-08	NA	NA	4.4E-06	NA	NA	-	NA	4.4E-06
Pyrene	-	3.2E-07	1.3E-07	NA	1.5E-05	5.9E-06	NA	-	NA	2.1E-05
Dibenzo(a,h)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	---
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	---
Uranium-233,234	-	NA	NA	NA	NA	NA	NA	-	NA	---
Uranium-238	-	NA	NA	NA	NA	NA	NA	-	NA	---
Americium-241	-	NA	NA	NA	NA	NA	NA	-	NA	---
Plutonium-239,-240	-	NA	NA	NA	NA	NA	NA	-	NA	---

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

Table F5-22

Exposure Parameters - Future On-Site Resident (Sitewide Without Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Inhalation of volatiles (basement vapors)	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Inhalation of particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Soil ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-22 (Continued)

Exposure Parameters - Future On-Site Resident (Sitewide Without Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 191bd
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2190	EPA, 1991b

Table F5-22 (Continued)

## Exposure Parameters - Future On-Site Resident (Sitewide Without Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/event)	0.05	0.05	EPA, 1989a
	EF = Exposure frequency (events/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-22 (Continued)

## Exposure Parameters - Future On-Site Resident (Sitewide Without Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Dermal contact with surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	2	2.6	EPA, 1989d
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Ingestion of fruits and vegetables:	CF = Concentration in crops (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (kg/day)	0.078	0.039	EPA, 1989d
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-23

## Estimated RME Concentrations of COCs for the Future On-Site Resident (Sitewide Without Groundwater)

Contaminants	Indoor Air from Basement Use (a) (mg/m <sup>3</sup> )	Airborne Particulates (a) (* /m <sup>3</sup> )	Surface Soil (* /kg)	Sediments (* /kg)	Surface Water (* /l)	Fruits and Vegetables (a) (* /kg)
1,1-Dichloroethene	1.84E-02	NA	NA	NA	NA	NA
Carbon Tetrachloride	2.79E-03	NA	NA	NA	NA	NA
Tetrachloroethene	1.61E-03	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	2.84E-02	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	6.96E-08	1.94E-01	NA	NA	3.33E-02
Fluoranthene	NA	2.61E-07	7.26E-01	2.59E-01	NA	9.06E-03
Benzo(a)anthracene	NA	1.14E-07	3.17E-01	NA	NA	7.02E-03
Benzo(a)pyrene	NA	1.09E-07	3.02E-01	NA	NA	7.25E-04
Benzo(b)fluoranthene	NA	1.09E-07	3.05E-01	2.76E-01	NA	7.74E-04
Benzo(k)fluoranthene	NA	1.04E-07	2.89E-01	2.74E-01	NA	5.45E-04
Dibenzo(a,h)anthracene	NA	6.76E-08	1.88E-01	NA	NA	4.17E-03
Fluorene	NA	6.89E-08	1.92E-01	NA	NA	2.85E-02
Pyrene	NA	1.25E-07	6.61E-01	2.59E-01	NA	5.74E-03
AROCLOR-1254	NA	9.90E-08	2.18E-01	1.59E-01	NA	1.95E-03
Selenium	NA	NA	NA	NA	NA	NA
Americium-241	NA	7.94E-02	2.22E+05	3.61E-02	2.56E-02	1.82E+02
Plutonium-239,-240	NA	2.80E-01	7.80E+05	2.97E+00	7.80E-03	1.75E+03
Uranium -233,234	NA	1.71E-03	3.27E+03	1.30E+00	2.36E+00	8.19E+00
Uranium-238	NA	5.64E-04	1.57E+03	1.17E+00	4.50E+00	3.93E+00

\* Units are in mg, or pCi as applicable  
(a) RME values; see Attachment F-2

Table F5-24. RME Carcinogenic Intakes – Future On-Site Resident (Adult)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	1.3E-03	NA	1.3E-03
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	2.0E-04	NA	2.0E-04
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	1.1E-04	NA	1.1E-04
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	2.6E-06	1.5E-07	NA	NA	4.3E-07	NA	NA	NA	NA	3.2E-06
Benzo(a)pyrene	2.7E-07	1.4E-07	NA	NA	4.1E-07	NA	NA	NA	NA	8.2E-07
Benzo(b)fluoranthene	2.8E-07	1.4E-07	2.6E-09	NA	4.1E-07	7.5E-09	NA	NA	NA	8.5E-07
Benzo(k)fluoranthene	2.0E-07	1.4E-07	2.6E-09	NA	3.9E-07	7.5E-09	NA	NA	NA	7.4E-07
Aroclor-1254	7.1E-07	1.0E-07	1.5E-09	NA	2.9E-07	4.3E-09	NA	NA	NA	1.1E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.5E-06	8.8E-08	NA	NA	2.6E-07	NA	NA	NA	NA	1.9E-06
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	5.4E+03	2.7E+03	2.2E-02	2.0E+01	NA	NA	NA	NA	2.0E+02	8.3E+03
Uranium-238	2.6E+03	1.3E+03	2.0E-02	3.8E+01	NA	NA	NA	NA	9.5E+01	4.0E+03
Americium-241	1.2E+05	1.9E+05	6.1E-04	2.2E-01	NA	NA	NA	NA	1.3E+04	3.2E+05
Plutonium-239,-240	1.1E+06	6.6E+05	5.0E-02	6.6E-02	NA	NA	NA	NA	4.7E+04	1.8E+06

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

Table F5-25. RME Noncarcinogenic Intakes – Future On-Site Resident (Adult)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	5.8E-03	NA	5.8E-03
Acenaphthene	3.6E-05	2.7E-07	NA	NA	6.2E-06	NA	NA	NA	NA	4.2E-05
Fluoranthene	9.7E-06	9.9E-07	7.1E-09	NA	2.3E-05	1.6E-07	NA	NA	NA	3.4E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	3.0E-05	2.6E-07	NA	NA	6.1E-06	NA	NA	NA	NA	3.7E-05
Pyrene	6.1E-06	9.1E-07	7.1E-09	NA	2.1E-05	1.6E-07	NA	NA	NA	2.8E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium or no toxicity factor is available

Table F5-26. RME Noncarcinogenic Intakes - Future On-Site Resident (Child)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	3.6E-02	NA	3.6E-02
Acenaphthene	8.3E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	9.7E-05
Fluoranthene	2.3E-05	9.3E-06	6.6E-08	NA	4.3E-05	3.0E-07	NA	NA	NA	7.5E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	7.1E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	8.5E-05
Pyrene	1.4E-05	8.5E-06	6.6E-08	NA	3.9E-05	3.0E-07	NA	NA	NA	6.2E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium or no toxicity factor is available

Table F5-27

## Exposure Parameters - Future On-Site Resident (Sitewide With Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of groundwater:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/day)	2	1	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with groundwater:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (entire surface)	23,200	9,180	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	0.2	0.2	EPA, 1989a
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-27 (Continued)

Exposure Parameters - Future On-Site Resident (Sitewide With Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Inhalation of volatiles, indoor water use:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2190	EPA, 1991b
Inhalation of volatiles (basement vapors):	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Inhalation of particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-27 (Continued)

## Exposure Parameters - Future On-Site Resident (Sitewide With Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Soil ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b	

Table F5-27 (Continued)

Exposure Parameters - Future On-Site Resident (Sitewide With Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-27 (Continued)

## Exposure Parameters - Future On-Site Resident (Sitewide With Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/event)	0.05	0.05	EPA, 1989a
	EF = Exposure frequency (events/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	2	2.6	EPA, 1989d
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-27 (Continued)

Exposure Parameters - Future On-Site Resident (Sitewide With Groundwater)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of fruits and vegetables:	CF = Concentration in crops (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (kg/day)	0.078	0.039	EPA, 1989d
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-28

## Estimated RME Concentrations of COCs for the Future On-Site Resident (Sitewide With Groundwater)

Contaminants	Groundwater (mg/l)	Indoor Air from Water use (a) (mg/m <sup>3</sup> )	Indoor Air from Basement Use (mg/m <sup>3</sup> ) (a)	Airborne Particulates (* /m <sup>3</sup> ) (a)	Surface Soil (* /kg)	Sediments (* /kg)	Surface Water (* /l)	Fruits and Vegetables (* /kg) (a)
1,1-Dichloroethene	4.47E-01	2.91E-02	1.84E-02	NA	NA	NA	NA	NA
Carbon Tetrachloride	1.38E-01	8.97E-03	2.78E-03	NA	NA	NA	NA	NA
Tetrachloroethene	1.57E-01	1.02E-02	1.61E-03	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	5.58E-01	3.63E-02	2.84E-02	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	6.96E-08	1.94E-01	NA	NA	3.34E-02
Fluoranthene	NA	NA	NA	2.61E-07	7.26E-01	2.59E-01	NA	9.06E-03
Benzo(a)anthracene	NA	NA	NA	1.14E-07	3.17E-01	NA	NA	7.02E-03
Benzo(a)pyrene	NA	NA	NA	1.09E-07	3.02E-01	NA	NA	7.25E-04
Benzo(b)fluoranthene	NA	NA	NA	1.09E-07	3.05E-01	2.76E-01	NA	7.74E-04
Benzo(k)fluoranthene	NA	NA	NA	1.04E-07	2.89E-01	2.74E-01	NA	5.45E-04
Dibenzo(a,h)anthracene	NA	NA	NA	6.76E-08	1.88E-01	NA	NA	4.17E-03
Fluorene	NA	NA	NA	6.89E-08	1.92E-01	NA	NA	2.85E-02
Pyrene	NA	NA	NA	1.25E-07	6.61E-01	2.59E-01	NA	5.74E-03
Aroclor-1254	NA	NA	NA	9.90E-08	2.18E-01	1.59E-01	NA	1.95E-03
Selenium	2.96E-01	NA	NA	NA	NA	NA	NA	NA
Americium-241	NA	NA	NA	7.95E-02	2.22E+05	3.61E-02	2.56E-02	1.82E+02
Plutonium-239,240	NA	NA	NA	2.80E-01	7.80E+05	2.97E+00	7.80E-03	1.75E+03
Uranium -233,234	NA	NA	NA	1.17E-03	3.27E+03	1.30E+00	2.36E+00	8.19E+00
Uranium-238	NA	NA	NA	5.64E-04	1.57E+03	9.42E-01	4.50E+00	3.93E+00

\* Units are in mg or pCi, as applicable

(a) Modified values; see Attachment F-2

Table P5-29. RME Carcinogenic Intakes - Future On-Site Resident (Adult)  
(Sitewide With Groundwater)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Gradwater (mg/kg/d)	Dermal Contact Gradwater (mg/kg/d)	Inhalation Volatiles Gradwater (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	1.3E-03	NA	4.2E-03	1.6E-04	1.7E-05	5.7E-03
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	2.0E-04	NA	1.3E-03	6.6E-05	5.3E-06	1.6E-03
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	1.1E-04	NA	1.5E-03	1.6E-04	6.0E-06	1.8E-03
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	2.6E-06	1.5E-07	NA	NA	4.3E-07	NA	NA	NA	NA	NA	NA	NA	3.2E-06
Benzo(a)pyrene	2.7E-07	1.4E-07	NA	NA	4.1E-07	NA	NA	NA	NA	NA	NA	NA	8.2E-07
Benzo(b)fluoranthene	2.8E-07	1.4E-07	2.6E-09	NA	4.1E-07	7.5E-09	NA	NA	NA	NA	NA	NA	8.5E-07
Benzo(k)fluoranthene	2.0E-07	1.4E-07	2.6E-09	NA	3.9E-07	7.5E-09	NA	NA	NA	NA	NA	NA	7.4E-07
Aroclor-1254	7.1E-07	1.0E-07	1.5E-09	NA	2.9E-07	4.3E-09	NA	NA	NA	NA	NA	NA	1.1E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.5E-06	8.8E-08	NA	NA	2.6E-07	NA	NA	NA	NA	NA	NA	NA	1.9E-06
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	5.4E+03	2.7E+03	2.2E-02	2.0E+01	NA	NA	NA	NA	2.0E+02	NA	NA	NA	8.3E+03
Uranium-238	2.6E+03	1.3E+03	1.6E-02	3.8E+01	NA	NA	NA	NA	9.5E+01	NA	NA	NA	4.0E+03
Americium-241	1.2E+05	1.9E+05	6.1E-04	2.2E-01	NA	NA	NA	NA	1.3E+04	NA	NA	NA	3.2E+05
Plutonium-239,-240	1.1E+06	6.6E+05	5.0E-02	6.6E-02	NA	NA	NA	NA	4.7E+04	NA	NA	NA	1.8E+06

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium, or toxicity factor not available

-- = not a complete pathway for this receptor

Table F5-30. RME Noncarcinogenic Intakes – Future On-Site Resident (Adult)  
(Sitewide With Groundwater)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact Groundwater (mg/kg/d)	Inhalation Volatiles Groundwater (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2E-02	4.5E-04	NA	1.3E-02
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.8E-03	1.9E-04	NA	4.0E-03
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.3E-03	4.8E-04	NA	4.8E-03
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	5.8E-03	NA	1.5E-02	6.0E-04	6.2E-05	2.2E-02
Acenaphthene	3.6E-05	2.7E-07	NA	NA	6.2E-06	NA	NA	NA	NA	NA	NA	NA	4.2E-05
Fluoranthene	9.7E-06	9.9E-07	7.1E-09	NA	2.3E-05	1.6E-07	NA	NA	NA	NA	NA	NA	3.4E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	3.0E-05	2.6E-07	NA	NA	6.1E-06	NA	NA	NA	NA	NA	NA	NA	3.7E-05
Pyrene	6.1E-06	9.1E-07	7.1E-09	NA	2.1E-05	1.6E-07	NA	NA	NA	NA	NA	NA	2.8E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.1E-03	1.9E-05	NA	8.1E-03
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium, or toxicity factor not available

- = not a complete pathway for this receptor

Table F5-31. RME Noncarcinogenic Intakes - Future On-Site Resident (Child)  
(Sitewide With Groundwater)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact Groundwater (mg/kg/d)	Inhalation Volatiles Groundwater (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.9E-02	8.4E-04	NA	2.9E-02
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.8E-03	3.6E-04	NA	9.2E-03
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-02	8.8E-04	NA	1.1E-02
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	3.6E-02	NA	3.6E-02	1.1E-03	3.9E-04	7.3E-02
Acenaphthene	8.3E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	NA	NA	NA	9.7E-05
Fluoranthene	2.3E-05	9.3E-06	6.6E-08	NA	4.3E-05	3.0E-07	NA	NA	NA	NA	NA	NA	7.5E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Fluorene	7.1E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	NA	NA	NA	8.5E-05
Pyrene	1.4E-05	8.5E-06	6.6E-08	NA	3.9E-05	3.0E-07	NA	NA	NA	NA	NA	NA	6.2E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.9E-02	3.5E-05	NA	1.9E-02
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium, or toxicity factor not available

- = not a complete pathway for this receptor

Table F5-32

## Exposure Parameters - Future On-Site Resident (Assuming Adequate Ground Water At Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of groundwater:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/day)	2	1	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with groundwater:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (entire surface)	22,800	9,180	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	0.2	0.2	EPA, 1989a
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-32 (Continued)

## Exposure Parameters - Future On-Site Resident (Assuming Adequate Ground Water At Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Inhalation of volatiles, indoor water use:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2190	EPA, 1991b
Inhalation of volatiles (basement vapors):	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Inhalation of particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-32 (Continued)

## Exposure Parameters - Future On-Site Resident (Assuming Adequate Ground Water At Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Soil ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-32 (Continued)

## Exposure Parameters - Future On-Site Resident (Assuming Adequate Ground Water At Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-32 (Continued)

## Exposure Parameters - Future On-Site Resident (Assuming Adequate Ground Water At Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/event)	0.05	0.05	EPA, 1989a
	EF = Exposure frequency (events/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	2	2.6	EPA, 1989d
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-32 (Continued)

Exposure Parameters - Future On-Site Resident (Assuming Adequate Ground Water At Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of fruits and vegetables:	CF = Concentration in crops (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (kg/day)	0.078	0.039	EPA, 1989d
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-33

Estimated RME Concentrations of COCs for the Future On-Site Resident (Assuming Adequate Groundwater At Source)

Contaminants	Groundwater (mg/l)	Indoor Air from Water use (a) (mg/m <sup>3</sup> )	Indoor Air from Basement Use (a) (mg/m <sup>3</sup> )	Airborne Particulates (* /m <sup>3</sup> ) (a)	Surface Soil (* /kg)	Sediments (* /kg)	Surface Water (* /l)	Fruits and Vegetables (a) (* /kg)
1,1-Dichloroethene	5.96E+00	3.87E-01	2.18E-01	NA	NA	NA	NA	NA
Carbon Tetrachloride	1.84E+00	1.20E-01	3.56E-02	NA	NA	NA	NA	NA
Tetrachloroethene	2.03E+00	1.32E-01	1.96E-02	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	7.27E+00	4.73E-01	3.30E-01	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	6.96E-08	1.94E-01	NA	NA	3.33E-02
Fluoranthene	NA	NA	NA	2.61E-07	7.26E-01	2.59E-01	NA	9.06E-03
Benzo(a)anthracene	NA	NA	NA	1.14E-07	3.17E-01	NA	NA	7.02E-03
Benzo(a)pyrene	NA	NA	NA	1.09E-07	3.02E-01	NA	NA	7.25E-04
Benzo(b)fluoranthene	NA	NA	NA	1.09E-07	3.05E-01	2.76E-01	NA	7.74E-04
Benzo(k)fluoranthene	NA	NA	NA	1.04E-07	2.89E-01	2.74E-01	NA	5.45E-04
Dibenzo(a,h)anthracene	NA	NA	NA	6.76E-08	1.88E-01	NA	NA	4.17E-03
Fluorene	NA	NA	NA	6.89E-08	1.92E-01	NA	NA	2.85E-02
Pyrene	NA	NA	NA	1.25E-07	6.61E-01	2.59E-01	NA	5.74E-03
Aroclor-1254	NA	NA	NA	9.90E-08	2.18E-01	1.59E-01	NA	1.94E-03
Selenium	9.15E-01	NA	NA	NA	NA	NA	NA	NA
Americium-241	NA	NA	NA	7.98E-01	2.22E+06	3.61E-02	2.56E-02	1.82E+03
Plutonium-239,240	NA	NA	NA	3.34E+00	9.31E+06	2.97E+00	7.80E-03	2.08E+04
Uranium -233,234	NA	NA	NA	8.22E-03	2.29E+04	1.30E+00	2.36E+00	5.74E+01
Uranium-238	NA	NA	NA	1.67E-03	4.66E+03	1.16E+00	4.5E+00	1.17E+01

(a) Modeled values; see Attachment F-2

\* Units are in mg or pCi, as applicable

Table F5-34. RME Carcinogenic Intakes – Future On-Site Resident (Adult)  
(Assuming Adequate Groundwater At Source)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Gradwater (mg/kg/d)	Dermal Contact Gradwater (mg/kg/d)	Inhalation Volatiles Gradwater (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	1.5E-02	NA	5.6E-02	2.1E-03	2.3E-04	7.4E-02
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	2.5E-03	NA	1.7E-02	8.8E-04	7.0E-05	2.1E-02
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	1.4E-03	NA	1.9E-02	2.1E-03	7.7E-05	2.3E-02
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	2.6E-06	1.5E-07	NA	NA	4.3E-07	NA	NA	NA	NA	NA	NA	NA	3.2E-06
Benzo(a)pyrene	2.7E-07	1.4E-07	NA	NA	4.1E-07	NA	NA	NA	NA	NA	NA	NA	8.2E-07
Benzo(b)fluoranthene	2.8E-07	1.4E-07	2.6E-09	NA	4.1E-07	7.5E-09	NA	NA	NA	NA	NA	NA	8.5E-07
Benzo(k)fluoranthene	2.0E-07	1.4E-07	2.6E-09	NA	3.9E-07	7.5E-09	NA	NA	NA	NA	NA	NA	7.4E-07
Aroclor-1254	7.1E-07	1.0E-07	1.5E-09	NA	2.9E-07	4.3E-09	NA	NA	NA	NA	NA	NA	1.1E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.5E-06	8.8E-08	NA	NA	2.6E-07	NA	NA	NA	NA	NA	NA	NA	1.9E-06
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	3.8E+04	1.9E+04	2.2E-02	2.0E+01	NA	NA	NA	NA	1.4E+03	NA	NA	NA	5.8E+04
Uranium-238	7.7E+03	3.9E+03	1.9E-02	3.8E+01	NA	NA	NA	NA	2.8E+02	NA	NA	NA	1.2E+04
Americium-241	1.2E+06	1.9E+06	6.1E-04	2.2E-01	NA	NA	NA	NA	1.3E+05	NA	NA	NA	3.2E+06
Plutonium-239,-240	1.4E+07	7.8E+06	5.0E-02	6.6E-02	NA	NA	NA	NA	5.6E+05	NA	NA	NA	2.2E+07

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium, or toxicity factor not available

- = not a complete pathway for this receptor

Table F5-35. RME Noncarcinogenic Intakes - Future On-Site Resident (Adult)  
(Assuming Adequate Groundwater At Source)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Gradwater (mg/kg/d)	Dermal Contact Gradwater (mg/kg/d)	Inhalation Volatiles Gradwater (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6E-01	6.1E-03	NA	1.7E-01
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.0E-02	2.6E-03	NA	5.3E-02
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.6E-02	6.2E-03	NA	6.2E-02
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	6.8E-02	NA	2.0E-01	7.9E-03	8.1E-04	2.8E-01
Acenaphthene	3.6E-05	2.7E-07	NA	NA	6.2E-06	NA	NA	NA	NA	NA	NA	NA	4.2E-05
Fluoranthene	9.7E-06	9.9E-07	7.1E-09	NA	2.3E-05	1.6E-07	NA	NA	NA	NA	NA	NA	3.4E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	3.0E-05	2.6E-07	NA	NA	6.1E-06	NA	NA	NA	NA	NA	NA	NA	3.7E-05
Pyrene	6.1E-06	9.1E-07	7.1E-09	NA	2.1E-05	1.6E-07	NA	NA	NA	NA	NA	NA	2.8E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.5E-02	5.8E-05	NA	2.5E-02
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium, or toxicity factor not available

- = not a complete pathway for this receptor

Table F5-36. RMB Noncarcinogenic Intakes - Future On-Site Resident (Child)  
 (Assuming Adequate Groundwater At Source)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surt Water (mg/kg/d)	Dermal Contact of Soil (mg/kg/d)	Dermal Contact of Sediment (mg/kg/d)	Dermal Contact of Surt Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact of Groundwater (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.8E-01	1.1E-02	NA	3.9E-01
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2E-01	4.8E-03	NA	1.2E-01
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3E-01	1.1E-02	NA	1.4E-01
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	4.2E-01	NA	4.6E-01	1.5E-02	5.0E-03	NA	9.1E-01
Acenaphthene	8.3E-05	2.5E-06	NA	1.1E-05	NA	NA	3.0E-07	NA	NA	NA	NA	NA	9.7E-05
Fluoranthene	2.3E-05	9.3E-06	6.6E-08	4.3E-05	NA	NA	NA	NA	NA	NA	NA	NA	7.5E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acrotoxin-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	7.1E-05	2.5E-06	NA	1.1E-05	NA	NA	NA	NA	NA	NA	NA	NA	8.5E-05
Pyrene	1.4E-05	8.5E-06	6.6E-08	3.9E-05	NA	3.0E-07	NA	NA	NA	NA	NA	NA	6.2E-05
Dibenz(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.8E-02	1.1E-04	NA	5.9E-02
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233/234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium, or toxicity factor not available  
 - = not a complete pathway for this receptor

Table F5-37

## Exposure Parameters - Future On-Site Resident (Groundwater At Source With Public Water)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of groundwater:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/day)	2	1	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with groundwater:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (entire surface)	22,800	9,180	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	0.2	0.2	EPA, 1989a
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-37 (Continued)

Exposure Parameters - Future On-Site Resident (Groundwater At Source With Public Water)

Pathway	Parameter	Adult Value	Child Value	Reference
Inhalation of volatiles, indoor water use:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2190	EPA, 1991b
Inhalation of volatiles (basement vapors):	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Inhalation of particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-37 (Continued)

Exposure Parameters - Future On-Site Resident (Groundwater At Source With Public Water)

Pathway	Parameter	Adult Value	Child Value	Reference
Soil ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-37 (Continued)

## Exposure Parameters - Future On-Site Resident (Groundwater At Source With Public Water)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-37 (Continued)

## Exposure Parameters - Future On-Site Resident (Groundwater At Source With Public Water)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/event)	0.05	0.05	EPA, 1989a
	EF = Exposure frequency (events/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Dermal contact with surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	2	2.6	EPA, 1989d
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-37 (Continued)

Exposure Parameters - Future On-Site Resident (Groundwater At Source With Public Water)

Pathway	Parameter	Adult Value	Child Value	Reference
Ingestion of fruits and vegetables:	CF = Concentration in crops (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (kg/day)	0.078	0.039	EPA, 1989d
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-38

## Estimated RME Concentrations of COCs for the Future On-Site Resident (Groundwater At Source With Public Water)

Contaminants	Groundwater (mg/l)	Indoor Air from Water use (a) (mg/m <sup>3</sup> )	Indoor Air from Basement Use (a) (mg/m <sup>3</sup> )	Airborne Particulates (* /m <sup>3</sup> )	Surface Soil (* /kg)	Sediments (* /kg)	Surface Water (* /l)	Fruits and Vegetables (* /kg) (a)
1,1-Dichloroethene	6.20E-01	4.03E-02	2.18E-01	NA	NA	NA	NA	NA
Carbon Tetrachloride	1.90E-01	1.24E-02	3.56E-02	NA	NA	NA	NA	NA
Tetrachloroethene	2.10E-01	1.37E-02	1.96E-02	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	7.50E-01	4.88E-02	3.30E-01	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	6.96E-08	1.94E-01	NA	NA	3.33E-02
Fluoranthene	NA	NA	NA	2.61E-07	7.26E-01	2.59E-01	NA	9.06E-03
Benzo(a)anthracene	NA	NA	NA	1.14E-07	3.17E-01	NA	NA	7.02E-03
Benzo(a)pyrene	NA	NA	NA	1.09E-07	3.02E-01	NA	NA	7.25E-04
Benzo(b)fluoranthene	NA	NA	NA	1.09E-07	3.05E-01	2.76E-01	NA	7.74E-04
Benzo(k)fluoranthene	NA	NA	NA	1.04E-07	2.89E-01	2.74E-01	NA	5.45E-04
Dibenzo(a,h)anthracene	NA	NA	NA	6.76E-08	1.88E-01	NA	NA	4.17E-03
Fluorene	NA	NA	NA	6.89E-08	1.92E-01	NA	NA	2.85E-02
Pyrene	NA	NA	NA	1.25E-07	6.61E-01	2.59E-01	NA	5.74E-03
Aroclor-1254	NA	NA	NA	9.90E-08	2.18E-01	1.59E-01	NA	1.94E-03
Selenium	9.50E-02	NA	NA	NA	NA	NA	NA	NA
Americium-241	NA	NA	NA	7.98E-01	2.22E+06	3.61E-02	2.56E-02	1.82E+03
Plutonium-239,240	NA	NA	NA	3.34E+00	9.31E+06	2.97E+00	7.80E-03	2.07E+04
Uranium -233,234	NA	NA	NA	8.22E-03	2.99E+04	1.30E+00	2.36E+00	5.74E+01
Uranium-238	NA	NA	NA	1.67E-03	4.66E+03	1.17E+00	4.5E+00	1.17E+01

(a) Modeled values; see Attachment F-2

\* Units are in mg or pCi, as applicable

Table P5-39. RME Carcinogenic Intakes - Future On-Site Resident (Adult)  
(Groundwater At Source With Public Water)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact Groundwater (mg/kg/d)	Inhalation Volatiles Groundwater (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	1.5E-02	NA	5.8E-03	2.2E-04	2.4E-05	2.1E-02
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	2.5E-03	NA	1.8E-03	9.1E-05	7.3E-06	4.4E-03
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	1.4E-03	NA	2.0E-03	2.2E-04	8.0E-06	3.6E-03
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Benzo(a)anthracene	2.6E-06	1.5E-07	NA	NA	4.3E-07	NA	NA	NA	NA	NA	NA	NA	3.2E-06
Benzo(a)pyrene	2.7E-07	1.4E-07	NA	NA	4.1E-07	NA	NA	NA	NA	NA	NA	NA	8.2E-07
Benzo(b)fluoranthene	2.8E-07	1.4E-07	2.6E-09	NA	4.1E-07	7.5E-09	NA	NA	NA	NA	NA	NA	8.5E-07
Benzo(k)fluoranthene	2.0E-07	1.4E-07	2.6E-09	NA	3.9E-07	7.5E-09	NA	NA	NA	NA	NA	NA	7.4E-07
Aroclor-1254	7.1E-07	1.0E-07	1.5E-09	NA	2.9E-07	4.3E-09	NA	NA	NA	NA	NA	NA	1.1E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Dibenzo(a,h)anthracene	1.5E-06	8.8E-08	NA	NA	2.6E-07	NA	NA	NA	NA	NA	NA	NA	1.9E-06
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Uranium-233,234	3.8E+04	1.9E+04	2.2E-02	2.0E+01	NA	NA	NA	NA	1.4E+03	NA	NA	NA	5.8E+04
Uranium-238	7.7E+03	3.9E+03	2.0E-02	3.8E+01	NA	NA	NA	NA	2.8E+02	NA	NA	NA	1.2E+04
Americium-241	1.2E+06	1.9E+06	6.1E-04	2.2E-01	NA	NA	NA	NA	1.3E+05	NA	NA	NA	3.2E+06
Plutonium-239,-240	1.4E+07	7.8E+06	5.0E-02	6.6E-02	NA	NA	NA	NA	5.6E+05	NA	NA	NA	2.2E+07

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium, or toxicity factor not available

-- = not a complete pathway for this receptor

Table P5-40. RMB Noncarcinogenic Intakes - Future On-Site Resident (Adult)  
 (Groundwater At Source With Public Water)

Chemical	Vegetables of Ingestion (mg/kg/d)	Soil of Ingestion (mg/kg/d)	Sediment of Ingestion (mg/kg/d)	Swrl. Water of Ingestion (mg/kg/d)	Soil Contact of Dermal (mg/kg/d)	Sediment Contact of Dermal (mg/kg/d)	Swrl. Water Contact of Dermal (mg/kg/d)	Volatiles of Inhalation (mg/kg/d)	Dust of Inhalation (mg/kg/d)	Groundwater Ingestion (mg/kg/d)	Groundwater Contact of Dermal (mg/kg/d)	Groundwater Inhalation (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.7E-02	6.3E-04	NA	1.8E-02
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.2E-03	2.7E-04	NA	5.5E-03
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.8E-03	6.4E-04	NA	6.4E-03
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.1E-02	8.1E-04	8.3E-05	8.9E-02
Acenaphthene	3.6E-05	2.7E-07	NA	NA	6.2E-06	NA	NA	NA	NA	NA	NA	NA	4.2E-05
Fluoranthene	9.7E-06	9.9E-07	7.1E-09	NA	2.3E-05	1.6E-07	NA	NA	NA	NA	NA	NA	3.4E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthylene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	3.0E-05	2.6E-07	NA	NA	6.1E-06	NA	NA	NA	NA	NA	NA	NA	3.7E-05
Pyrene	6.1E-06	9.1E-07	7.1E-09	NA	2.1E-05	1.6E-07	NA	NA	NA	NA	NA	NA	2.8E-05
Dibenz(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6E-03	6.6E-06	NA	2.6E-03
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

1 units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium, or toxicity factor not available  
 -- = not a complete pathway for this receptor

Table F5-41. RMB Noncarcinogenic Intakes - Future On-Site Resident (Child)  
 (Groundwater At Source With Public Water)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surt Water (mg/kg/d)	Dermal Contact of Soil (mg/kg/d)	Dermal Contact of Sediment (mg/kg/d)	Dermal Contact of Surt Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	Ingestion of Gradwater (mg/kg/d)	Dermal Contact of Gradwater (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2E-02	1.2E-03	NA	4.1E-02
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2E-02	4.9E-04	NA	1.3E-02
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3E-02	1.2E-03	NA	1.5E-02
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	4.2E-01	NA	4.8E-02	1.5E-03	5.2E-04	4.7E-01
Acenaphthene	8.3E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	NA	NA	NA	9.7E-05
Fluoranthene	2.3E-05	9.3E-06	6.6E-08	NA	4.3E-05	3.0E-07	NA	NA	NA	NA	NA	NA	7.5E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acrotoxin-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	7.1E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	NA	NA	NA	8.5E-05
Pyrene	1.4E-05	8.5E-06	6.6E-08	NA	3.9E-05	3.0E-07	NA	NA	NA	NA	NA	NA	6.2E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.1E-03	1.1E-05	NA	6.1E-03
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

<sup>1</sup> units equal mg/kg-day, radionuclide units equal pCi  
 NA = not a COC for this medium, or toxicity factor not available  
 - = not a complete pathway for this receptor

Table F5-42

## Exposure Parameters - Future On-Site Resident (Without Groundwater / Without Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Inhalation of volatiles (basement vapors)	CA = Concentration in air (mg/m <sup>3</sup> pCi/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Inhalation of particulates:	CA = Concentration in air (mg/m <sup>3</sup> or pCi/m <sup>3</sup> )	Chemical specific	Chemical specific	NA
	IR = Inhalation rate (m <sup>3</sup> /day)	20	20	EPA, 1991b
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Soil ingestion:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-42 (Continued)

## Exposure Parameters - Future On-Site Resident (Without Groundwater / Without Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Dermal contact with soil:	CS = Concentration in soil (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 191bd
Ingestion of sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (mg/day)	100	200	EPA, 1991b
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2190	EPA, 1991b

Table F5-42 (Continued)

## Exposure Parameters - Future On-Site Resident (Without Groundwater / Without Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Dermal contact with sediment:	CS = Concentration in sediment (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	CF = Conversion factor (kg/mg)	1E-6	1E-6	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	AF = Adherence factor (mg/cm <sup>2</sup> )	1	1	EPA, 1992c
	ABS = Dermal absorption factor (unitless)	Chemical specific	Chemical specific	EPA, 1992c EPA, 1989c
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Ingestion of surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (l/event)	0.05	0.05	EPA, 1989a
	EF = Exposure frequency (events/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-42 (Continued)

## Exposure Parameters - Future On-Site Resident (Without Groundwater / Without Source)

Pathway	Parameter	Adult Value	Child Value	Reference
Dermal contact with surface water:	CW = Concentration in water (mg/l or pCi/l)	Chemical specific	Chemical specific	NA
	SA = Body surface area (cm <sup>2</sup> ) (extremities and head)	5,800	2,295	EPA, 1992c
	PC = Dermal permeability (cm/hr)	Chemical specific	Chemical specific	EPA, 1992c
	ET = Exposure time (hr/day)	2	2.6	EPA, 1989d
	EF = Exposure frequency (days/year)	7	7	EPA, 1989a
	ED = Exposure duration (years)	24	6	EPA, 1991b
	CF = Conversion factor (l/cm <sup>3</sup> )	0.001	0.001	NA
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b
Ingestion of fruits and vegetables:	CF = Concentration in crops (mg/kg or pCi/kg)	Chemical specific	Chemical specific	NA
	IR = Ingestion rate (kg/day)	0.078	0.039	EPA, 1989d
	FI = Fraction ingested (unitless)	1	1	prof. judgement
	EF = Exposure frequency (days/year)	350	350	EPA, 1991b
	ED = Exposure duration (years)	24	6	EPA, 1991b
	BW = Body weight (kg)	70	15	EPA, 1991b
	AT = Averaging time (days) Noncarcinogenic Carcinogenic	8,760 25,550	2,190	EPA, 1991b

Table F5-43

Estimated RME Concentrations of COCs for the Future On-Site Resident (Without Groundwater / Without Source)

Contaminants	Indoor Air from Basement (a) (mg/m <sup>3</sup> )	Airborne Particulates (* /m <sup>3</sup> ) (a)	Surface Soil (* /kg)	Surface Water (* /ℓ)	Sediments (* /kg)	Fruits and Vegetables (* /kg) (a)
1,1-Dichloroethene	6.59E-05	NA	NA	NA	NA	NA
Carbon Tetrachloride	1.61E-04	NA	NA	NA	NA	NA
Tetrachloroethene	3.18E-05	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	8.13E-05	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	6.96E-08	1.94E-01	NA	NA	3.33E-02
Fluoranthene	NA	2.61E-07	7.26E-01	NA	2.59E-01	9.06E-03
Benzo(a)anthracene	NA	1.14E-07	3.17E-01	NA	NA	7.02E-03
Benzo(a)pyrene	NA	1.09E-07	3.02E-01	NA	NA	7.25E-04
Benzo(b)fluoranthene	NA	1.09E-07	3.05E-01	NA	2.76E-01	7.74E-04
Benzo(k)fluoranthene	NA	1.04E-07	2.89E-01	NA	2.74E-01	5.45E-04
Dibenzo(a,h)anthracene	NA	6.76E-08	1.88E-01	NA	NA	4.17E-03
Fluorene	NA	6.89E-08	1.92E-01	NA	NA	2.85E-02
Pyrene	NA	1.25E-07	6.61E-01	NA	2.59E-01	5.74E-03
Aroclor-1254	NA	9.90E-08	2.18E-01	NA	1.59-01	1.98E-03
Selenium	NA	NA	NA	NA	NA	NA
Americium-241	NA	2.06E-04	5.73E+02	2.56E-02	3.61E-02	4.70E-01
Plutonium-239,240	NA	1.23E-03	3.42E+03	7.80E-03	2.97E+00	7.67E+00
Uranium -233,234	NA	4.37E-04	1.30E+03	2.36E-00	1.30E+00	3.26E+00
Uranium-238	NA	4.60E-04	1.28E+03	4.50E-00	1.17E+00	3.21E+00

\* Units are in mg or pCi, as applicable

(a) Modeled values; see Attachment F-2

Table F5-44. RME Carcinogenic Intakes – Future On-Site Resident (Adult)  
(Without Groundwater / Without Source)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	4.6E-06	NA	4.6E-06
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	1.1E-05	NA	1.1E-05
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	2.2E-06	NA	2.2E-06
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	2.6E-06	1.5E-07	NA	NA	4.3E-07	NA	NA	NA	NA	3.2E-06
Benzo(a)pyrene	2.7E-07	1.4E-07	NA	NA	4.1E-07	NA	NA	NA	NA	8.2E-07
Benzo(b)fluoranthene	2.8E-07	1.4E-07	2.6E-09	NA	4.1E-07	7.5E-09	NA	NA	NA	8.5E-07
Benzo(k)fluoranthene	2.0E-07	1.4E-07	2.6E-09	NA	3.9E-07	7.5E-09	NA	NA	NA	7.4E-07
Aroclor-1254	7.3E-07	1.0E-07	1.5E-09	NA	2.9E-07	4.3E-09	NA	NA	NA	1.1E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.5E-06	8.8E-08	NA	NA	2.6E-07	NA	NA	NA	NA	1.9E-06
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	2.1E+03	1.1E+03	2.2E-02	2.0E+01	NA	NA	NA	NA	7.8E+01	3.3E+03
Uranium-238	2.1E+03	1.1E+03	2.0E-02	3.8E+01	NA	NA	NA	NA	7.7E+01	3.3E+03
Americium-241	3.1E+02	4.8E+02	6.1E-04	2.2E-01	NA	NA	NA	NA	3.5E+01	8.2E+02
Plutonium-239,-240	5.0E+03	2.9E+03	5.0E-02	6.6E-02	NA	NA	NA	NA	2.1E+02	8.1E+03

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

-- = not a complete pathway for this receptor

Table F5-45. RME Noncarcinogenic Intakes – Future On-Site Resident (Adult)  
(Without Groundwater / Without Source)

Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.7E-05	NA	1.7E-05
Acenaphthene	3.6E-05	2.7E-07	NA	NA	6.2E-06	NA	NA	NA	NA	4.2E-05
Fluoranthene	9.7E-06	9.9E-07	7.1E-09	NA	2.3E-05	1.6E-07	NA	NA	NA	3.4E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	3.0E-05	2.6E-07	NA	NA	6.1E-06	NA	NA	NA	NA	3.7E-05
Pyrene	6.1E-06	9.1E-07	7.1E-09	NA	2.1E-05	1.6E-07	NA	NA	NA	2.8E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

-- = not a complete pathway for this receptor

Table F5-46. RME Noncarcinogenic Intakes – Future On-Site Resident (Child)  
(Without Groundwater / Without Source)

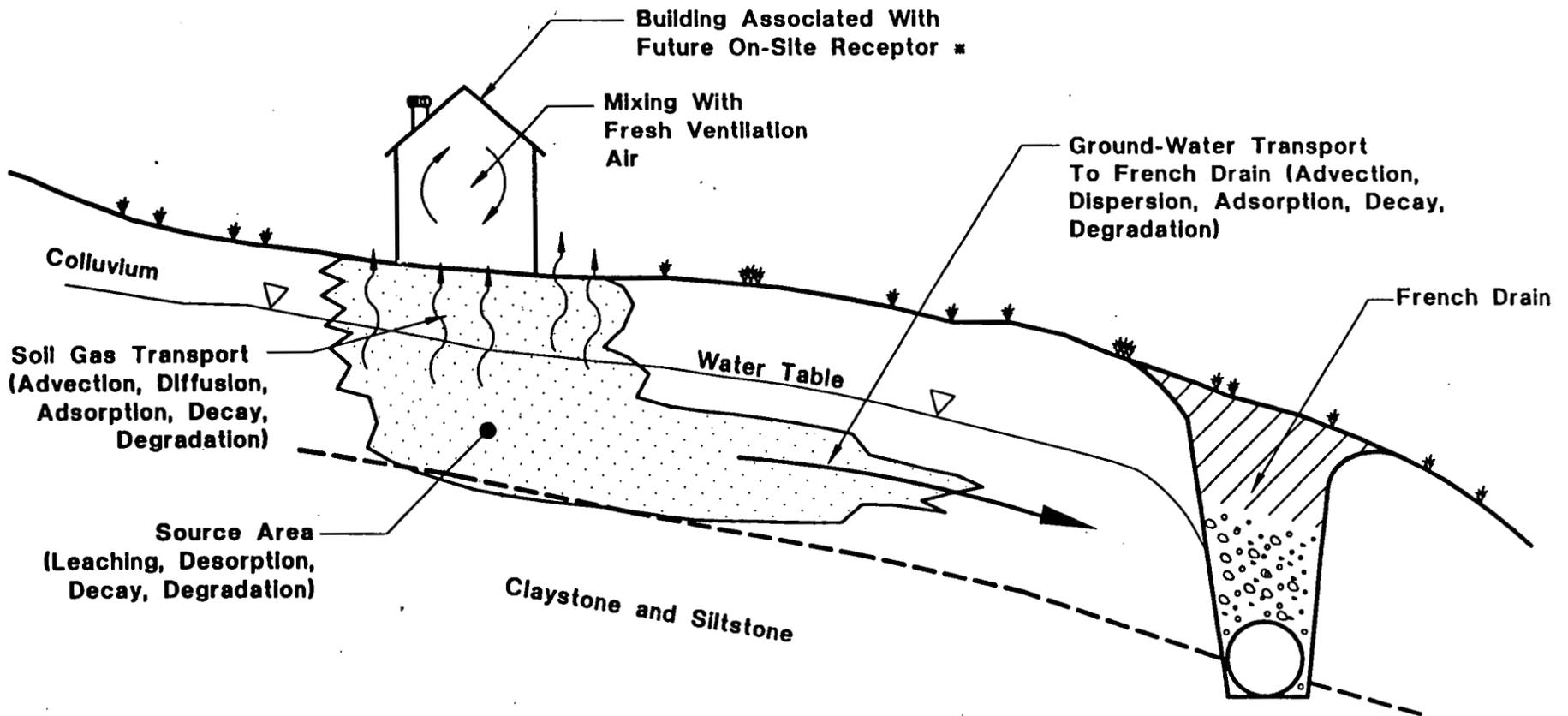
Chemical	Ingestion of Vegetables (mg/kg/d) <sup>1</sup>	Ingestion of Soil (mg/kg/d)	Ingestion of Sediment (mg/kg/d)	Ingestion of Surf. Water (mg/kg/d)	Dermal Contact Soil (mg/kg/d)	Dermal Contact Sediment (mg/kg/d)	Dermal Contact Surf. Water (mg/kg/d)	Inhalation of Volatiles (mg/kg/d)	Inhalation of Dust (mg/kg/d)	TOTAL (mg/kg/d)
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.0E-04	NA	1.0E-04
Acenaphthene	8.3E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	9.7E-05
Fluoranthene	2.3E-05	9.3E-06	6.6E-08	NA	4.3E-05	3.0E-07	NA	NA	NA	7.5E-05
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	7.1E-05	2.5E-06	NA	NA	1.1E-05	NA	NA	NA	NA	8.5E-05
Pyrene	1.4E-05	8.5E-06	6.6E-08	NA	3.9E-05	3.0E-07	NA	NA	NA	6.2E-05
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

<sup>1</sup> Units equal mg/kg-day, radionuclide units equal pCi

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

BUILD.DWG



\* The geotechnical feasibility of on-site construction is unfavorable (Section 3.5.2.1).

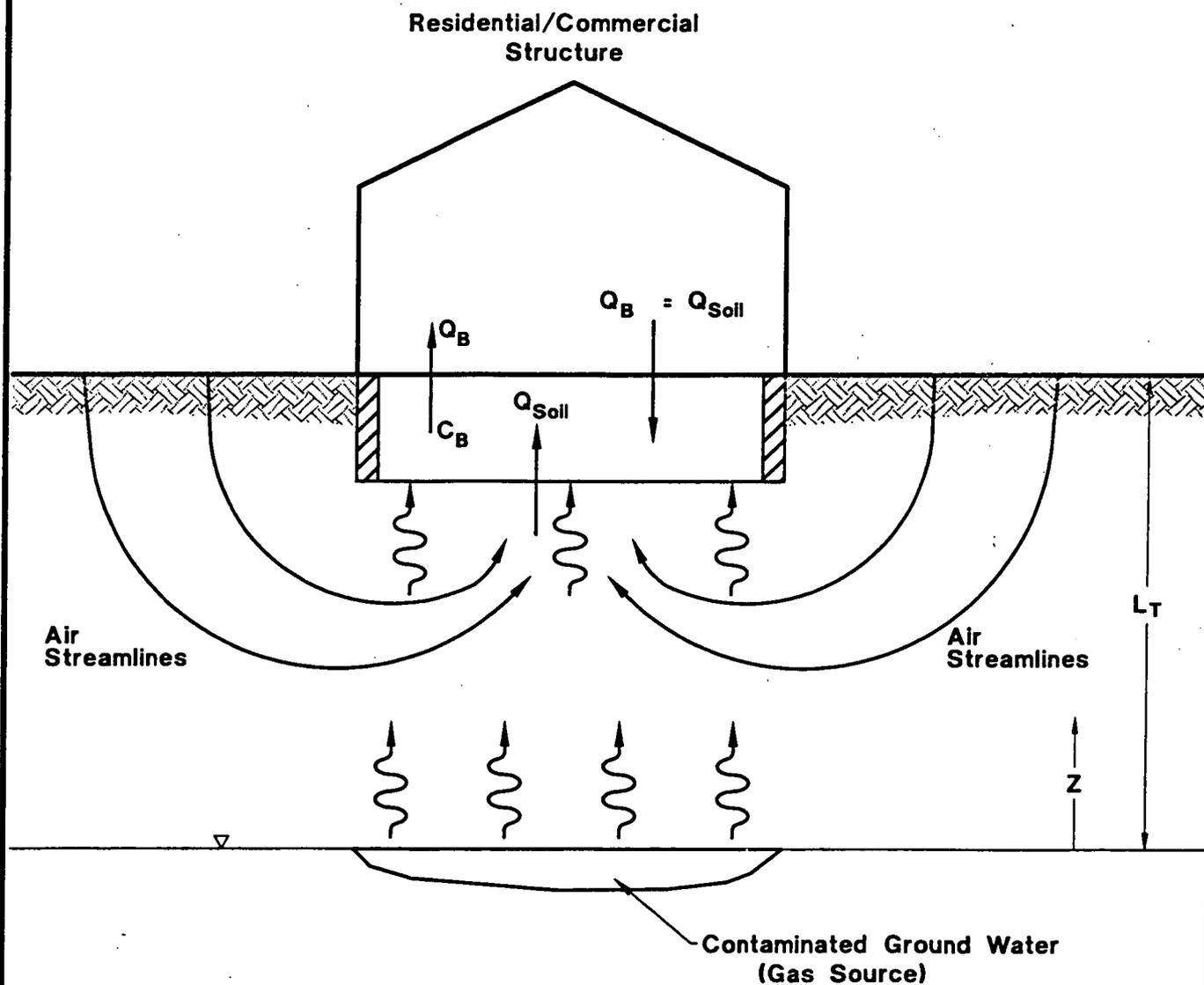
U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

Future OU1 Soil Gas Conceptual  
Model with On-Site Receptor  
Figure F5-1

REV. JUNE 1993  
OCTOBER 1992

JOHNSON and ETTINGER (1991)



U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

Schematic of OU1 Soil Gas Simulation  
for Johnson Model

Figure F5-2

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OCTOBER 1992

## SECTION F6 TOXICITY ASSESSMENT

The purpose of this section is to provide the toxicity constants that will be used for risk characterization purposes (in Section F7) and to summarize toxicological information for the radioactive and nonradioactive COCs at OU1. For this assessment, and consistent with EPA's RAGS (EPA, 1989a), the toxicity information will be summarized for two broad categories of potential effects: noncarcinogenic and carcinogenic effects. These two categories were selected because of the slightly differing methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens.

The toxicity constants used in this risk assessment are obtained from several sources. The primary source of information was EPA's Integrated Risk Information System (IRIS) (EPA, 1993a). IRIS contains only those toxicity values that have been verified by EPA's Reference Dose or Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work Groups. The IRIS database is updated monthly and, per RAGS, supersedes all other sources of toxicity information. If the necessary data are not available in IRIS, EPA's HEAST (EPA, 1993b) is used. The tables are published annually and updated approximately two times per year. HEAST contains a comprehensive listing of provisional risk assessment information that has undergone review and has the concurrence of individual EPA Program Offices, but has not had enough review to be recognized as high-quality, Agency-wide consensus information (EPA, 1993b). Previous years of IRIS (EPA, 1992a) and HEAST (EPA, 1991a, 1992b) are reviewed to track changing values. Additional, secondary sources of information used in this risk assessment include the EPA Region III and Region VIII Toxicologists.

### **F6.1 TOXICITY ASSESSMENT FOR NONCARCINOGENIC EFFECTS**

Potential noncarcinogenic effects will be evaluated in Section F7 by comparing daily intakes (calculated previously in Section F5) with chronic RfDs (reference doses) developed by EPA. This section provides a definition of an RfD and discusses how it will be applied in the risk assessment. Table F6-1 provides the RfD values for each of the COCs identified at OU1.

A chronic RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure that can be incurred during a lifetime, without an appreciable risk of a noncancer effect being incurred in human populations, including sensitive subgroups (EPA, 1989a).<sup>1</sup> The RfD is based on the assumption that thresholds exist for noncarcinogenic toxic effects (e.g., liver or kidney damage). It is a benchmark dose operationally derived by the application of one or more order of magnitude uncertainty factors to doses thought to represent a lowest or no observed adverse effect level in humans. Thus, there should be no adverse effects associated with chronic daily intakes below the RfD value. Conversely, if chronic daily intakes exceed this threshold level, there is a potential that some adverse noncarcinogenic health effects might be observed in exposed individuals.

RfDs (in units of milligrams per kilograms per day [mg/kg/day]) are typically calculated by dividing a NOEL, NOAEL, or LOAEL dose (in units of mg/kg/day) by an uncertainty or safety factor that typically ranges from 10 to 10,000. Thereafter, the RfD is rounded to one significant figure. The NOEL, NOAEL, and LOAEL are defined as follows (EPA, 1989a):

**NOEL:** No Observed Effect Level—The dose at which there are no statistically or biologically significant increases in the frequency or severity of effects between the exposed population and the corresponding control population (i.e., no measurable effects are produced at this dose).

**NOAEL:** No Observed Adverse Effect Level—The dose at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and the corresponding control population. Effects are produced at this dose, but they are not considered adverse.

**LOAEL:** Lowest Observed Adverse Effect Level—The lowest dose of a chemical in a study or group of studies that produces statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control.

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<sup>1</sup> Recently, EPA has begun to publish subchronic RfDs. Subchronic RfDs are similar to chronic RfDs, except that the exposure duration is less than a lifetime.

RfDs are derived from the NOEL, NOAEL, or the LOAEL for the critical toxic effect by the consistent, conservative application of uncertainty factors (UFs) and modifying factors (MFs), as follows:

$$\text{RfD} = \text{CE}/(\text{UF} \times \text{MF}) \quad (1)$$

where:

RfD	=	Chronic (or subchronic) Reference Dose (rounded to one significant figure)
CE	=	Lowest critical or no effect level (i.e., NOEL, NOAEL, or LOAEL)
UF	=	The <u>product</u> of one or more uncertainty factors
MF	=	Modifying factor

UFs are generally applied as multiples of 10 (although values less than 10 are sometimes used), with each factor representing a specific range of uncertainty inherent in extrapolating data to derive a "safe concentration" for human exposure.

To derive the RfDs, UFs are applied as follows:

- If the NOAEL is based on human data, a UF of 10 is usually applied to account for variation in sensitivities among individuals. It is intended to protect sensitive subpopulations (e.g., the elderly and children).
- If the NOAEL is based on animal data, an additional UF of 10 is used to account for the interspecies variability between humans and laboratory animals.
- If the NOAEL is derived from a subchronic instead of a chronic study, an additional UF of 10 is applied to extrapolate a subchronic value to a chronic value.
- If an LOAEL is used instead of an NOAEL, an additional UF of 10 is used to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to the UFs listed above, an MF can be applied. MFs range from 1 to 10 and reflect a qualitative professional assessment of additional uncertainties, such as adequacy of the database, not specifically addressed by the above-mentioned UFs. The default MF value is 1.0.

As an example of how an RfD is derived, a LOAEL of 12.9 mg/kg/day was established for chloroform based on the development of fatty cysts in the liver of dogs. A UF of 10 was applied to this LOAEL to account for the fact that the LOAEL was not based on human data, which was intended to protect sensitive subpopulations. An additional UF of 10 was applied to account for the interspecies variability between humans and dogs. Finally, an additional UF of 10 was applied to convert the chronic LOAEL measured in the laboratory to a chronic NOAEL. An MF of 1.0 was also assumed. Thus, dividing the LOAEL for dogs (12.9 mg/kg/day) by a UF of 1000 and an MF of 1.0 yields a chronic oral RfD of 0.01 after rounding to the nearest significant digit.

It should be noted that RfDs have been derived by EPA for both oral and inhalation exposures. However, in January 1991, EPA decided to replace inhalation RfDs with Reference Concentrations (RfCs). RfCs are expressed in terms of concentrations in air ( $\text{mg}/\text{m}^3$ ), not in terms of "dose" ( $\text{mg}/\text{kg}/\text{day}$ ). This decision was based on two factors: 1) EPA felt that it was technically more accurate to base toxicity values directly on measured air concentrations instead of making the metabolic, pharmacokinetic, and/or other adjustments required to estimate an internal dose; and 2) for compounds that elicit route-of-entry effects (e.g., sensitizers and irritants), where the toxic effect is to the respiratory system or exchange boundary, it was felt that a measure of internal dose might inappropriately imply effects to other organ systems or effects from other exposure routes (EPA, 1993b).

Table F6-1 lists the chronic oral and inhalation RfDs and RfCs, where available, for the COCs associated with OU1. In addition, Table F6-1 provides information on the UFs used to derive the RfDs, the overall confidence in the RfD (as provided in IRIS), and the target organs and critical effects that are the basis of the RfD. As indicated, inhalation RfDs were derived either through a route-to-route extrapolation from the oral RfD, or through extrapolation from the RfC. For purposes of evaluating potential noncarcinogenic hazards associated with potential short-term, higher concentration exposures, Table F6-1 provides subchronic RfDs and RfCs, where

available. The impacts associated with such short-term exposures are discussed in the uncertainty section (Section F7.3).

As indicated in this table, inhalation and oral RfDs are not available from IRIS or HEAST for several of the COCs. The potential significance of this missing information on the overall risk conclusions will be evaluated qualitatively in the uncertainty section.

For risk characterization purposes, potential health effects of chronic exposure to noncarcinogenic compounds will be assessed by calculating a hazard quotient (HQ) for each COC. A HQ will be derived by dividing the estimated daily intake by a chemical-specific RfD as shown in this equation:

$$\text{HQ} = \text{Intake/Rfd} \quad (1)$$

An HQ greater than 1.0 indicates that exposure to that contaminant (at the concentrations and for the duration and frequencies of exposure estimated in the exposure assessment) may cause adverse health effects in exposed populations. However, it is important to note that the level of concern associated with exposure to noncarcinogenic compounds does not increase linearly as HQ values exceed 1.0. In other words, HQ values do not represent a probability or a percentage. For example, an HQ of 10 does not indicate that adverse health effects are 10 times more likely to occur than an HQ value of 1.0. All one can conclude is that HQ values greater than 1.0 indicate that noncarcinogenic health impacts are possible and that the more an HQ value exceeds unity, the greater the concern about potential adverse health effects.

Consistent with RAGS, chemical-specific HQs will be summed across pathways to calculate a hazard index (HI). Individual pathway HI values will then be summed to determine a cumulative HI value for all exposure pathways and COCs. This approach may result in a situation where a pathway HI value exceeds unity even when none of the chemical-specific HQ values exceed unity. If an individual or cumulative HI value exceeds 1.0, and as recommended by EPA (EPA, 1989a), the chemicals will be segregated by critical effect on a target organ or system. The hazard indices will then be calculated separately for each target organ/system. For example, all COCs that affected liver histopathology would be separated and used to calculate

a target-specific HI. If any of these target- or organ-specific HI values exceed unity, adverse noncarcinogenic health effects are possible. In the absence of direct knowledge about the possible additive, synergistic, or antagonistic effects of simultaneous exposure to multiple compounds, simple additivity is assumed for similar target organs or systems.

## **F6.2 TOXICITY ASSESSMENT FOR CARCINOGENIC EFFECTS**

Potential carcinogenic risks will be expressed as an estimated probability that an individual might develop cancer from lifetime exposure. This probability is based on projected intakes and chemical-specific dose-response data called cancer slope factors (SFs). Cancer SFs and the estimated daily intake of a compound, averaged over a lifetime of exposure, will be used to estimate the incremental risk that an individual exposed to that compound may develop cancer. This estimate is derived using the following equation:

$$\text{Risk} = \text{Intake} \times \text{SF} \quad (2)$$

With regard to the COCs identified at OU1, there are two classes of potential carcinogens: chemical carcinogens and radionuclides. For the purposes of this toxicity assessment, each of these two classes of elements or compounds will be discussed separately.

### **F6.2.1 Toxicity Assessment for Chemical Carcinogens**

Evidence of chemical carcinogenicity originates primarily from two sources: (1) lifetime studies with laboratory animals, and (2) human (epidemiological) studies. For most chemical carcinogens, animal data from laboratory experiments represent the primary basis for the extrapolation. Major assumptions arise from the necessity of extrapolating experimental results: across species (i.e., from laboratory animals to humans); from high-dose regions (i.e., to which laboratory animals are exposed) to low-dose regions (i.e., levels to which humans are likely to be exposed in the environment); and, across routes of administration (i.e., inhalation versus ingestion). Federal regulatory agencies have traditionally estimated human cancer risks associated with exposure to chemical carcinogens on the administered-dose basis according to the following approach:

- The relationship between the administered dose and the incidence of cancer in animals is based on experimental animal bioassay results.
- The relationship between the administered dose and the incidence of cancer in the low-dose range is based on mathematical models.
- The dose-response relationship is assumed to be the same for both humans and animals, if the administered dose is measured in the proper units.

Thus, effects from exposure to high (i.e., administered) doses are based on experimental animal bioassay results, while effects associated with exposure to low doses of a chemical are generally estimated from mathematical models.

For chemical carcinogens, EPA assumes a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and tumor induction. This mechanism for carcinogenesis is referred to as stochastic, which means that there is theoretically no level of exposure to a given chemical that does not pose a small, but finite, probability of generating a carcinogenic response. Since risk at low exposure levels cannot be measured directly either in laboratory animals or human epidemiology studies, various mathematical models have been proposed to extrapolate from high to low doses (i.e., to estimate the dose-response relationship at low doses). The three most frequently used models are (1) the one-hit model, (2) the log-probit model, and (3) the multistage model (Armitage and Doll, 1961). The one-hit model is based on the premise that a single molecule of a contaminant can be the single event that precipitates tumor induction (Cornfield, 1977). In other words, there is some finite response associated with any exposure. The log-probit model assumes that a response is normally distributed with the logarithm of the dose (Mantel et al., 1971). This theory seems to have little scientific basis, although some physiological parameters are lognormally distributed. This model usually yields much lower potency estimates due to the implied threshold at lower doses.

Currently, regulatory decisions are based on the output of the linearized multistage model (EPA, 1989a). The basis of the linearized multistage model is that multiple events (versus the single-event paradigm of the one-hit model) may be needed to yield tumor induction (Crump et al., 1977). The linearized multistage model reflects the biological variability in tumor frequencies

observed in animals or human studies. The dose-response relationship predicted by this model at low doses is essentially linear. Use of this model provides dose-response estimates intermediate between the one-hit and the log-probit models. It should be noted that the SFs calculated for nonradiological carcinogens using the multistage model represent the 95th percentile upper confidence limit on the probability of a carcinogenic response. Consequently, risk estimates based on these SFs are conservative estimates representing upper-bound estimates of risk where there is only a 5 percent probability that the actual risk is greater than the estimated risk.

Most models produce quantitatively similar results in the range of observable data, but yield estimates that can vary by three or four orders of magnitude at lower doses. Animal bioassay data are simply not adequate to determine whether any of the competing models are better than the others. Moreover, there is no evidence to indicate that the precision of low-dose risk estimates increases through the use of more sophisticated models. Thus, if a carcinogenic response occurs at the exposure level studied, it is assumed that a similar response will occur at all lower doses, unless evidence to the contrary exists.

Uncertainties in the toxicity assessment for chemical carcinogens are dealt with by classifying each chemical into one of several groups, according to the weight of evidence from epidemiological studies and animal studies, as follows:

- Group A - Human Carcinogen (sufficient evidence of carcinogenicity in humans)
- Group B - Probable Human Carcinogen (B1-limited evidence of carcinogenicity in humans; B2-sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
- Group C - Possible Human Carcinogen (limited evidence of carcinogenicity in the animals and inadequate or lack of human data)
- Group D - Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)
- Group E - Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

Table F6-2 provides the SFs, in  $(\text{mg}/\text{kg}/\text{day})^{-1}$ , for each of the COCs identified at OU1, and the weight-of-evidence for each COC. In addition, as with RfDs, the CRAVE Work Group believes that a unit conversion is required to present inhalation SFs in the units of  $(\text{mg}/\text{kg}/\text{day})^{-1}$ . Consequently, SFs are also provided for the inhalation route as unit risks in the form  $(\mu\text{g}/\text{m}^3)^{-1}$ .

It should be noted that the SFs for PAHs were derived somewhat differently than other chemical carcinogens. Specifically, the methodology for estimating carcinogenic potencies of PAHs outlined in EPA's Environmental Criteria and Assessment Office's (ECAO's) *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons* (EPA, 1993c) was followed. The guidance uses a toxicity weighting factor approach to estimate the oral cancer SFs for several PAHs relative to the SF for benzo(a)pyrene. This methodology was developed because while EPA has classified seven PAHs as Group B2-probable human carcinogens, data are sufficient to accurately measure dose-response (and by extension calculate SF) only for benzo(a)pyrene (BaP).

To obtain an estimate of total carcinogenic risk resulting from modeled exposures to carcinogens at the site, cancer risks will be summed across all exposure pathways for each Class A, B, or C carcinogen. Cancer risks from exposure to multiple carcinogens across multiple pathways will be assumed to be additive, based on EPA carcinogen risk assessment guidelines (EPA, 1986).

### **F6.2.2      Toxicity Constants for Radionuclides**

An extensive body of literature exists that describes the health effects of radionuclides on humans and animals. Intensive research by national and international commissions has resulted in the establishment of universally accepted limits to which workers and the public may be exposed without clinically detectable effects. This literature has resulted in EPA classifying all radionuclides as Group A carcinogens because they emit ionizing radiation, which, at high doses, has been associated with increased cancer incidence in humans. For radionuclides, human epidemiological data collected from the survivors of the Hiroshima and Nagasaki bomb attacks form the basis for the most recent extrapolation put forth by the National Academy of Science (1980). Conversely, for most nonradiological carcinogens, animal data from laboratory studies represent the primary basis for the extrapolation. Another fundamental difference between the

assessment of potential toxicity associated with exposure to radionuclide and nonradionuclide carcinogens is that SFs for radionuclides are typically best estimates (mean or median values rather than upper 95th percentile values). Furthermore, in the past, risk factors for radionuclides have generally been based on fatalities (i.e., the number of people who actually died from cancer), while SFs for nonradiological carcinogens are based on incidence (i.e., the number of people who developed cancer). Finally, the SFs for radionuclides are expressed in different units, i.e., risk per picocurie (pCi)<sup>-1</sup> rather than (mg/kg/day)<sup>-1</sup>. Table F6-2 lists the radionuclide SFs. These nonthreshold SFs account for the following: the amount of radionuclide transported into the bloodstream, the decay of radioactive progeny within the body, the distribution and retention of the radionuclide and its progeny (if any) in the body, the radiation dose delivered to specific organs and tissues, and the age and sex of the exposed individuals (EPA, 1993b).

### **F6.3 CHEMICALS WITHOUT TOXICITY DATA**

A major limitation of this assessment is the lack of chemical-specific toxicity data for all exposure pathways and COCs. In addition, many of the COCs do not have verified RfDs or cancer SFs. Tables F6-1 and F6-2 note these toxicity data gaps.

### **F6.4 TOXICITY PROFILES FOR THE COCS**

The following sections present general and contaminant-specific information on health effects relating to the COCs evaluated in the risk assessment for OU1. Health effects described in Tables F6-1 and F6-2 may not necessarily be incurred by exposure to contaminant levels present at OU1. All information presented below is from IRIS (EPA, 1993a) unless otherwise specified.

#### **F6.4.1 Carbon Tetrachloride**

Carbon tetrachloride is an organic solvent which was, until recently, widely used as an industrial and household cleaning fluid. Recently, its household and industrial use has been severely restricted. Carbon tetrachloride, like chloroform, has anesthetic properties, which may lead to confusion and coma. Liver damage may result from either acute or chronic exposure. Fatty

liver and centrilobular necrosis readily develop at low levels of chronic exposure, and in humans this is often followed by kidney failure, which may be the ultimate cause of death (Agency for Toxic Substances and Disease Registry [ATSDR], 1989a).

This compound has been more extensively studied regarding its toxic effects than any other aliphatic hydrocarbon. Carbon tetrachloride may cause damage to the heart, liver, kidneys, and the central nervous system (CNS) after high oral or inhalation exposures. At lower exposures, it may cause biochemical alterations (e.g., lipid peroxidation), nausea, and headaches (Arthur D. Little [ADL], 1987). The chronic oral RfD for carbon tetrachloride is  $7 \times 10^{-4}$  mg/kg/day with a UF of 1000 (to account for interspecies and intrahuman variability). At the LOAEL exposures to carbon tetrachloride produced liver lesions in rats. Although the principal study from which the RfD was derived was well done, and good dose-response data were available from a variety of other studies, confidence in the RfD was judged to be medium since supporting studies on possible reproductive and teratogenic effects are not available (EPA, 1993a). An inhalation reference concentration is not available in IRIS (EPA, 1993a).

The carcinogenicity of carbon tetrachloride, through both the inhalation and ingestion pathway, has been established with a variety of test animals and a number of gavage studies. Carbon tetrachloride has produced hepatocellular carcinomas in rats, mice, and hamsters (EPA, 1993a). It is classified as a Group B2 carcinogen with an oral SF of  $0.13 \text{ (mg/kg/day)}^{-1}$ . Since risk estimates generated from oral cancer studies varied by two orders of magnitude, EPA calculated the SF using the geometric mean of the available data to account for deficiencies in several of the studies (EPA, 1993a). The inhalation unit risk is  $1.5 \times 10^{-5} \text{ (}\mu\text{g/m}^3\text{)}^{-1}$  or  $0.052 \text{ (mg/kg/day)}^{-1}$ . The inhalation unit risk is based on the oral exposure data and assumes a 40% absorption rate by humans (EPA, 1993a). Several studies of workers who may have used carbon tetrachloride have suggested that these individuals may have an excess cancer risk (EPA, 1993a).

#### **F6.4.2      1,1-Dichloroethene**

1,1-Dichloroethene (1,1-DCE) is a colorless liquid with a chloroform-like odor. It is widely used in the manufacture of 1,1,1-trichloroethane and as a cleaning solvent and degreaser. The

major source of 1,1-DCE in the environment is the volatilization during its use in and production of 1,1,1-trichloroethane (ATSDR, 1989b).

The chronic oral RfD for 1,1-DCE is  $9 \times 10^{-3}$  mg/kg/day with a UF of 1000 (10 each for the use of a LOAEL, interspecies variation, and protection of sensitive human subpopulations) (EPA, 1993a). The critical effect associated with chronic oral exposure to 1,1-DCE is the appearance of hepatic lesions in rats. The liver appears to be the most sensitive target organ, and rats the most sensitive species. Confidence in the oral RfD was judged to be medium since the key study on which the oral RfD is based was conducted using appropriate numbers of animals from two strains of rats, measured several endpoints, and was of chronic duration. In addition, corroborative chronic and subchronic oral bioassay data are available (EPA, 1993a). Exposure to high concentrations of 1,1-DCE in air results in CNS depression, while long-term effects include liver and kidney damage. 1,1-DCE has been shown to be fetotoxic, but not teratogenic to rodents after exposure in drinking water or by inhalation. An inhalation RfD and reference concentration is currently under review by EPA.

1,1-DCE is classified as a Group C carcinogen. This classification is based on studies that indicate that 1,1-DCE is mutagenic (in some, but not all mutagenicity bioassays), and a metabolite is known to alkylate and to bind covalently to deoxyribonucleic acid (DNA). Further, in one study, malignant kidney tumors were observed in male mice exposed to 25 parts per million (ppm) of 1,1-DCE in air, although a dose of 10 ppm had no effect. Although tumors were observed in one mouse strain following exposure through inhalation, supporting studies are inadequate. Based on the above discussion, EPA has derived an inhalation unit risk factor of  $5 \times 10^{-5}$  ( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup> and an SF-inh of  $0.175$  ( $\text{mg}/\text{kg}/\text{day}$ )<sup>-1</sup> (after accounting for metabolism and pharmacokinetics). EPA also derived an oral SF of  $0.6$  ( $\text{mg}/\text{kg}/\text{day}$ )<sup>-1</sup>. However, this was based on a dataset in which there was no statistically significant increase in adrenal tumors. Nonetheless, EPA concluded that it was appropriate to derive an oral SF, since the SF derived from the data was within a factor of 2 of the SF based on inhalation data.

EPA toxicologist Gerald Hiatt has noted a number of negative cancer studies on 1,1-DCE. Five oral carcinogenicity studies have been conducted on 1,1-DCE, including a lifetime joint study by the National Cancer Institute and the National Toxicology Program. All of these oral cancer

studies were negative. Eleven studies on 1,1-DCE evaluated carcinogenic potential through inhalation, ten were negative. One study, by Maltoni, did produce evidence of carcinogenic potential in mice, although this interpretation was blurred by the lack of a clear dose-response relationship. A similar study by the same group of investigators did not produce cancer in rats, even through doses up to 6-fold higher were administered. Thus the evidence supporting a classification of 1,1-DCE as a "carcinogen" is especially weak.

### **F6.4.3      Polycyclic Aromatic Hydrocarbons**

PAHs is a group of chemicals formed during the incomplete burning of organic substances. PAHs can occur due to either man-made or natural activity (e.g., forest fire). All of the carcinogenic PAHs of concern for OU1 are classified as Group B2 carcinogens. Some produced tumors in mice when administered orally, dermally, or by subcutaneous injection and have been shown to be mutagenic. Lung cancers have been shown to be induced in humans by exposure to PAH mixtures, including coal tar, coke oven emissions, and cigarette smoke, that include BaP and benz(a)anthracene. An Oral SF has been determined only for BaP which has been shown to be carcinogenic and genotoxic in animals. The oral SF for BaP is  $7.3 \text{ (mg/kg/day)}^{-1}$  (EPA, 1993a). All other slope factors for carcinogenic PAHs of concern are derived from BaP and presented in Table F6-2. IRIS provides profiles suitable for summary for noncarcinogenic PAHs of concern. These are provided in the subsections which follow.

#### **F6.4.3.1      Acenaphthene**

Subchronic exposure to acenaphthene resulted in liver problems and hepatotoxicity in mice. The oral RfD is 0.06 mg/kg/day with an UF of 3000. Confidence in this RfD was judged to be low because developmental, reproductive, and chronic toxicity data following oral exposure to acenaphthene have not been gathered or analyzed.

#### **F6.4.3.2      Fluoranthene**

Subchronic exposure to fluoranthene causes nephropathy, increased liver weight, hematological alterations, and other clinical effects in mice. The oral RfD is 0.04 mg/kg/day with an UF of

3000. Confidence in this RfD was judged to be low, although the key study identified both a LOAEL and a NOAEL for several sensitive endpoints using an adequate number of animals, because development, reproductive, and other toxicity data in a second species were lacking. The carcinogenicity weight-of-evidence classification for fluoranthene is Group D. Fluoranthene was tested as a mouse carcinogen in skin-painting studies, although results of these studies were consistently negative. Evidence regarding the potential mutagenicity of fluoranthene is ambiguous (EPA, 1993a).

#### **F6.4.3.3 Fluorene**

Subchronic exposure to fluorene resulted in decreased red blood cells, hemoglobin, and packed cell volumes in mice. The oral RfD is 0.04 mg/kg/day with an UF of 3000. Confidence in this RfD is judged to be low because developmental, reproductive, and chronic toxicity data following oral exposure to fluorene have not been gathered. The weight-of-evidence carcinogenicity classification for fluorene is Group D.

#### **F6.4.3.4 Pyrene**

Exposure to pyrene caused renal toxicity in mice. The oral RfD for pyrene is 0.03 mg/kg/day with a UF of 3000. EPA has low confidence in this RfD, since the principal study examined a variety of toxicological endpoints and identified both an NOAEL and an LOAEL for the critical effect, but data supporting the subchronic, chronic, and developmental/reproductive effects were lacking. An inhalation RfD is not available. The weight-of-evidence carcinogenicity classification for Pyrene is Group D.

#### **F6.4.4 Polychlorinated Biphenyls (Aroclor 1254)**

Aroclor 1254 belongs to the class of compounds known as polychlorinated biphenyls (PCBs). PCB mixtures are classified as Group B2 carcinogens. Data on carcinogenicity in humans following exposures to PCBs are inadequate due to confounding exposures or lack of exposure quantification (EPA, 1993a). Exposure to commercial PCB mixtures caused hepatocellular cancer in rats and mice, while most genotoxic and mutagenic bioassays with PCBs have been

negative. The oral SF for PCBs (as a mixture) is  $7.7 \text{ (mg/kg/day)}^{-1}$  (EPA, 1993a). Neither an inhalation or oral RfD, nor an inhalation SF is available in IRIS. It should be noted that the oral SF for Aroclor 1254 may not be the same as the SF calculated for PCB mixtures.

#### F6.4.5 Radionuclides

EPA classifies all radionuclides as Group A carcinogens because they emit ionizing radiation and based on the extensive weight-of-evidence provided by epidemiological studies of radiation-induced cancers in humans. Ionizing radiation has sufficient energy to interact with matter and produce an ejected electron and a positively charged ion. These positively charged ions, known as free radicals, are highly reactive and may combine with other elements or compounds within a cell to produce toxins or otherwise disrupt the chemical balance, which results in mutations or other deleterious effects. Radionuclides are characterized by the type and energy level of the radiation emitted. Radiation emissions fall into two major categories: (1) particulate (e.g., electrons, alpha particles, beta particles, protons) or (2) electromagnetic (e.g., gamma and x-rays) radiation.

The general health effects of radiation can be divided into stochastic and nonstochastic effects, i.e., those health effects not related to threshold dose and those related to threshold dose. Developing cancer from exposure to any amount of radiation is a stochastic effect. Examples of nonstochastic effects include acute radiation syndrome and cataract formation, both of which occur only at high levels of exposures.

Radiation can damage cells in different ways. First, the radiation can cause damage to the strands of genetic material, DNA, in the cell. The cell may not be able to recover from this type of damage, or the cell may live on but function abnormally. If the abnormally functioning cell divides and reproduces, a tumor or mutation in the tissue may develop. The rapidly dividing cells that line the intestines and the stomach and the cells that make blood in the bone marrow are very sensitive to this kind of damage. Organ damage results from the damage caused to the individual cells. This type of damage has been reported with doses of 10 to 500 rads. Acute radiation sickness is seen only after doses of greater than 50 rads. This dose is usually only received by personnel in close proximity to serious nuclear accident.

When the cells damaged by radiation are reproductive cells, genetic damage can occur in the offspring of the person exposed. The developing fetus is especially sensitive to radiation. The type of malformation that may occur is related to the stage of fetal development and the cells that are differentiating at the time of exposure. Radiation damage to children exposed while in the womb is related to the dose the pregnant mother received. Mental retardation is another possible effect of fetal radiation exposure.

Primary routes of exposure to ionizing radiation are external exposure, ingestion, and inhalation. Dermal absorption is not a relevant exposure for most radionuclides. The radiation dose delivered from an ingested radionuclide is a function of the radionuclide fraction that is absorbed into the blood ( $f_1$ ). An  $f_1$  value of 1.0 indicates 100 percent absorption.

Principal adverse effects associated with exposure to ionizing radiation are carcinogenicity, mutagenicity, and teratogenicity.

#### **F6.4.5.1 Americium-241**

Americium-241 is an artificially produced isotope which is produced by the beta decay of plutonium-241. This isotope has been distributed widely in the environment as a result of nuclear weapons fallout. Americium-241 decays by alpha emission, which makes it an important isotope for internal exposure, whether it is ingested or inhaled. The alpha decay is accompanied by emission of a 60 kiloelectron volt (keV) gamma-ray with an abundance of 36 percent, which is of concern where americium-241 is concentrated, but is not important at environmental levels. The International Committee on Radiological Protection (ICRP) has assigned a value of  $5 \times 10^{-4}$  to  $f_1$  for all compounds of americium. For inhalation exposures, the ICRP recommends assigning all compounds of americium to inhalation Group W. Most (90 percent) of the americium entering the blood stream is deposited in the liver and the bone; only a small amount goes to the gonads. The biological half-lives in the liver and the bone are 40 years and 100 years, respectively. The amount in the gonads is considered to remain permanently. For the purposes of dosimetry, all isotopes are assumed to be uniformly distributed over the bone surfaces at all times after deposition (ICRP, 1988). The SF is expressed per unit intake or exposure and is a function of the route of entry. The inhalation risk is  $4 \times 10^{-8}$  (pCi)<sup>-1</sup>, the

ingestion risk is  $3.1 \times 10^{-10} \text{ (pCi)}^{-1}$ , and the external exposure risk from surface contamination is  $1.6 \times 10^{-12} \text{ (yr/[pCi/m}^2\text{)]}^{-1}$ . The pathway-specific unit risk is the excess total cancer risk per unit exposure integrated over a 70-year lifespan. It is  $2.1 \times 10^{-2} \text{ (pCi/m}^3\text{)}^{-1}$  for air,  $1.6 \times 10^{-5} \text{ (pCi/l)}^{-1}$  for water,  $1.6 \times 10^{-5} \text{ (pCi/g)}^{-1}$  for external exposure, and  $8.4 \times 10^{-7} \text{ (pCi/g)}^{-1}$  for soil ingestion.

#### F6.4.5.2 Plutonium-239, 240

Plutonium-239 is a fissile radionuclide that has been used in weapons and nuclear reactors. Plutonium reactor fuel is about 7 percent plutonium-239 and 20 percent plutonium-240. Weapons-grade plutonium is about 93 percent plutonium-239 and 7 percent plutonium-240. The main source of plutonium in the environment is from nuclear-weapons testing, with smaller contributions from accidents and space power systems burn-up in the atmosphere. Most of the plutonium released has been plutonium-239, in the form of  $\text{PuO}_2$ . It is estimated that United States soil contains about  $5 \times 10^{-2} \text{ pCi/g}$  of plutonium in the top 5 cm (Electric Power Research Institute [EPRI], 1976). Plutonium-239 has a physical half-life of  $2.4 \times 10^4$  years, and plutonium-240 has a half-life of  $6.6 \times 10^3$  years. Both isotopes decay by alpha emission and spontaneous fission. Both modes of decay are accompanied by emission of various X and gamma rays that are unimportant at environmental levels.

Absorption of plutonium from the gastro-intestinal tract is low ( $f_1 = 10^{-3}$  for general population; all compounds via the food chain [ICRP, 1986]). The EPA lists  $f_1$  values for the oxides of plutonium that are an order of magnitude lower. The  $f_1$  value is reflected in the toxicity values and is not used to make additional adjustments to quantitative risk. Plutonium, which is absorbed into the blood stream, is deposited mainly in the liver and bones (ASTDR, 1989c). For dosimetric purposes, all isotopes are assumed to be uniformly distributed over all bone surfaces at all times following deposition.

For inhalation exposures, plutonium oxide is relatively insoluble, which results in long residence times in the lung and high alpha dose to lung tissues. The slope factor, which is the age-averaged excess total cancer risk per unit intake (pCi) or external exposure ( $[\text{yr}/[\text{pCi/m}^2]]^{-1}$ ), varies with the chemical form of the isotope and route of exposure. For inhalation, the slope

factor is  $4.1 \times 10^{-8}$  (pCi)<sup>-1</sup>. For ingestion, the slope factor is  $3.1 \times 10^{-10}$  (pCi)<sup>-1</sup>, except for oxides, which have an SF of exactly one order of magnitude lower. For external exposure, the SF for plutonium-239 is  $2.6 \times 10^{-14}$  (yr/[pCi/m<sup>2</sup>])<sup>-1</sup>, and the SF for plutonium-240 is  $5.9 \times 10^{-14}$  ((yr/[pCi/m<sup>2</sup>])<sup>-1</sup>. For each exposure pathway, isotope, and form (i.e., oxide/non-oxide), there is a pathway-specific unit risk that is the age-averaged lifetime excess cancer risk per unit daily intake or exposure for 70 years. However, except for the case of drinking water ingestion, the variation is slight. The soil ingestion unit risk is  $8.4 \times 10^{-8}$  (pCi/g)<sup>-1</sup>. For external exposure, the unit risk is  $2.6 \times 10^{-7}$  (pCi/g)<sup>-1</sup> for plutonium-239 and  $5.9 \times 10^{-7}$  (pCi/g)<sup>-1</sup> for plutonium-240. For inhalation exposure, the unit risk is  $2.6 \times 10^{-2}$  per pCi/m<sup>3</sup> for plutonium-239 and  $2.1 \times 10^{-2}$  per pCi/m<sup>3</sup> for plutonium-240. For drinking water ingestion, the unit risk is  $1.6 \times 10^{-5}$  (pCi/l)<sup>-1</sup>, except for the oxides, which have a unit risk of one order of magnitude lower.

#### F6.4.5.3 Uranium -234, 235, 238

Natural uranium contains three isotopes U-234, U-235 and U-238. The percent abundance of each isotope in natural uranium is, respectively, 0.006%, 0.72%, and 99.27% (ATSDR, 1990d). Uranium can be found in the earth's crust at an average concentration of 2 ppm. The ambient air concentration of uranium in the United States ranges from 0.3-0.011 fCi/m<sup>3</sup> (1fCi=10<sup>-3</sup> pCi). The concentration in drinking waters ranges from 0.07-653 pCi/l with a median value of 0.1-0.2 pCi/l. The average daily intake of uranium has been established to be .007 pCi/day from air (0.01 µg/day), 0.7-1 pCi/day from food (1-1.4 µg/day), and 0.6-2.0 pCi/day (0.83-2.78 µg/day) from drinking water.

In natural uranium, the radioactivity from U-238 accounts for about half the total radioactivity, and the radiation from U-234 and U-235 accounts for the other half. Uranium emits primarily alpha particles which are unable to penetrate skin, but can travel short distances in the body if they are inhaled or ingested. Natural uranium emits very small amounts of gamma rays, which can penetrate the skin, so there is little, if any, danger from this type of radiation from uranium (ATSDR, 1990d). Moreover, no human or animal studies have definitively linked inhalation or oral exposure to natural uranium to development of cancer. However, humans exposed to enriched uranium or other high-specific-activity isotopes would be at greater risk (ATSDR, 1990b). Based on the specific activity of the uranium isotopes, HEAST lists the oral SF for

U-233 and U-234 as  $1.6\text{E-}11$  (pCi)<sup>-1</sup>, with an inhalation SF of  $2.7\text{E-}8$  (pCi)<sup>-1</sup>. For U-238 the oral SF is  $2.8\text{E-}11$  (pCi)<sup>-1</sup> and the inhalation SF is  $5.2\text{E-}8$  (pCi)<sup>-1</sup> (EPA, 1993b).

With regard to noncancer health risks associated with uranium, exposure to natural concentrations of uranium in food, water, air, and soil does not appear to have any toxic effects. Animals that have had oral, inhalation, or dermal exposure to large amounts of uranium have developed damage to the kidney tubules, but other systems were not affected.

The only significant systemic health risk in humans from exposure to non-enriched uranium is potential damage to the kidneys. However, epidemiological studies have not noted an increase in deaths from urogenital or renal diseases, and intravenous studies have failed to identify significant damage to human kidneys following exposure to uranium (ATSDR, 1990d). Overall, studies in animals and humans also indicate that exposure to uranium is unlikely to produce immunological or neurological effects. Although the data are conflicting, animal studies indicate that exposure to uranium may affect fetal weight and skeletal development in animals, and may possibly alter the ratio of male to female live births in areas where people have excessive exposure to uranium (ATSDR, 1990b). With the exception of soluble salts, no oral or inhalation RfDs are available for uranium on IRIS or HEAST, nor has ATSDR established minimum risk levels for different environmental media (EPA, 1993a,b; ATSDR, 1990b).

#### **F6.4.6      Selenium**

Selenium is an essential nutrient in humans. Its toxicity is related to chemical form. Acute toxicities of selenium compounds vary greatly; while the chronic effects of most forms are similar. Acute effects in both animals and humans include degeneration of the liver, kidneys, and myocardia, hemorrhages in the digestive tract, and brain damage. Eye, nose, and throat irritation may also occur with inhalation exposure. Chronic effects include depression, nervousness, dermatitis, gastrointestinal disturbances, dental caries and discoloration, lassitude, and thickening and partial loss of hair and nails (EPA, 1985). Clinical signs of exposure to selenium also include a characteristic "garlic breath." The chronic oral RfD for selenium is 0.005 mg/kg/day, with the critical effect being clinical selenosis. A UF of only 3 was applied, and confidence in the RfD was judged high, because it is based on a human epidemiology in

which a sizable population with sensitive subpopulations was studied, and because many animal studies and other epidemiological studies support the principal study (EPA, 1993a). No data are provided in IRIS regarding an inhalation RfD or RfC. However, the clinical effects of selenium exposure are similar through all routes of exposure (EPA, 1985).

Evidence of carcinogenicity of selenium in humans is lacking or inadequate. In several animal studies, the data are conflicting and difficult to interpret because of the apparent anticarcinogenic activity and high toxicity of some selenium salts. Data on the mutagenicity of selenium and its compounds are also equivocal. As a result, the weight-of-evidence classification for selenium is Group D (EPA, 1993a). Of note, selenium sulfide is listed in IRIS as a B2 carcinogen; however, an SF is not provided (EPA, 1993a).

#### **F6.4.7      Tetrachloroethene**

Tetrachloroethene, also known as perchloroethylene (PCE), has widespread use in the dry-cleaning and textile industries. It is also used in the cold cleaning and vapor degreasing of metals, as a chemical intermediate in the synthesis of fluorocarbons, as a component of aerosol laundry treatment products, as a solvent for silicones, as the insulating fluid and cooling gas in electrical transformers, and in typewriter correction fluid. PCE is not known to occur naturally, but contributes to water pollution through leaching from vinyl liners in asbestos-cement water pipelines and as wastewater from metal finishing, laundries, aluminum-forming, organic chemical/plastics manufacturing, and municipal treatment plants. Air contamination is the result of emissions and vaporization losses from dry cleaning and industrial metal cleaning (ATSDR, 1992).

Primarily, exposure occurs through inhalation of contaminated air or ingestion of contaminated water. PCE can cause lightheadedness, dizziness, euphoria, blindness, cardiac arrhythmias, hypotension, cyanosis, respiratory depression, pulmonary hemorrhages, and CNS depression in acute dosages. When chronically dosed, trigeminal nerve impairment, liver injury, and chapped skin can occur. PCE is metabolized and excreted very slowly. Individuals with diseases of the heart, liver, kidneys, and lungs are the most vulnerable to PCE poisoning. It has also been known to cause jaundice in newborns from PCE excretion in the breast milk (ATSDR, 1992).

Historically, few acute or chronic industrial toxicity problems have arisen from the use of this solvent, although researchers have reported both hepatotoxicity and CNS effects. Ingested or inhaled PCE is mostly excreted by the lungs. The metabolism of PCE is very slow; a very low percentage is excreted in the urine as metabolites. No inhalation RfD has been developed for PCE. Oral RfDs have been calculated based on research with rodents. Primary effects associated with PCE exposure include liver and kidney damage and CNS depression. The oral RfD for chronic exposures is  $1 \times 10^{-2}$  mg/kg/day with a UF of 1000. There is medium confidence in this RfD because no one study combined the features required for deriving a high-confidence RfD. Confidence in the principal study is low, because it lacked complete histopathological examination at the NOAEL, and corroborative studies on its teratogenic and reproductive impacts are lacking (EPA, 1993a).

Perchloroethylene was formerly listed as a Group B2 carcinogen in IRIS. This classification was based on studies performed on rodents, where inhalation produced both leukemia and tumors of the liver. However, the carcinogenicity assessment for PCE is now under further review and is pending (EPA, 1993a). PCE is for the most part nonmutagenic and has not been shown to cause reproductive toxicity (ADL, 1987).

#### **F6.4.8      Toluene**

Toluene-induced neurotoxicity has been documented in humans over a broad spectrum of severity that correlates well with concentration. Numerous case studies on chronic toluene abusers (repeatedly exposed to greater than 30,000 ppm in air) have demonstrated functional deficits of the CNS, accompanied by abnormal morphology of cerebellar and cortical areas of the brain. Under acute exposure conditions (short exposures to greater than 10,000 ppm), toluene produces CNS narcosis. Lower concentrations (400-800 ppm) have been associated with drowsiness, ataxia, visual impairment, and headache. The chronic oral RfD for toluene is 0.2 mg/kg/day, with the lowest effect level resulting in changes in liver and kidney weights in rats. An inhalation RfC has been established for toluene at  $0.4 \text{ mg/m}^3$ , based on neurological effects detected in a human occupational health study and based on degeneration of nasal epithelium in rats. Confidence in the RfC was judged to be medium, because of the lack of long-term data on neurotoxicity or irritation endpoints and because reproductive/development studies were not

comprehensive. The weight-of-evidence carcinogenicity classification for toluene is Group D. Toluene did not produce positive results in the majority of genotoxic or mutagenicity bioassays (EPA, 1993a).

#### **F6.4.9      1,1,1-Trichloroethane**

1,1,1-Trichloroethane (methyl chloroform) is used as an industrial solvent and in consumer products. Because of its reactivity with magnesium, aluminum, and their alloys, inhibitors are usually added to increase the stability of the solvent. Volatilization during production and use is the principal source of this chemical in the atmosphere. Methyl chloroform has received widespread acceptance as an industrial solvent since it has many of the solvent and volatility characteristics of carbon tetrachloride. Like other halogenated hydrocarbon solvents, it is a CNS depressant. Test animals require exposure to near-lethal concentrations before hepatotoxicity is observed. Human subjects exposed to 500 ppm, 7 hours/day for 5 days exhibited no indication of abnormal organ function, as evidenced by a variety of clinical laboratory tests. Rodents have survived for 7 hours when exposed to 8,000 ppm (ATSDR, 1990a).

Effects of 1,1,1-trichloroethane are as a CNS and respiratory depressant and a skin and mucous membrane irritant. After acute exposure, hypotension, respiratory depression, and cardiac arrhythmias due to myocardial sensitization have been reported. An acute lethal dose to humans has been established at 500 to 5,000 mg/kg. The chronic toxicity of this chemical at ambient air levels commonly encountered appears to be extremely low. Acute effects produced by exposure to higher levels (more than 350 ppm) are symptomatic of neurological disfunction including disturbances of equilibrium, lightheadedness, and irritation of the throat. Although the liver is the primary site of 1,1,1-trichloroethane metabolism, liver damage has not been conclusively evident from exposure to this chemical. Narcosis (likely to occur at exposure levels in excess of 5,000 ppm) is the major health concern associated with exposure to 1,1,1-trichloroethane (ATSDR, 1990a).

The oral RfD for 1,1,1-trichloroethane has been withdrawn from IRIS and HEAST. An inhalation RfC is pending (EPA, 1993a,b). The weight-of-evidence carcinogenicity classification for this compound is Group D.

Table F6-1

Toxicity Constants for Chemicals of Potential Concern  
(for chronic noncarcinogenic effects)

Chemical	Oral RfD (mg/kg/day)	Inhalation RfC (mg/m <sup>3</sup> )	Inhalation RfD (mg/kg/day)	Uncertainty Factor	Overall Confidence in RfD	Target Organ/ Critical Effect	Ref <sup>a</sup>
1,1-Dichloroethene	0.009 <sup>1</sup>	Pending	Pending	1000	Medium	Liver/Heptatic Lesions	IRIS-01/20/92
Carbon Tetrachloride	0.0007	No Data	No Data	1000 -	Medium -	Liver/Heptatic Lesions -	IRIS-10/07/92 [Smith, 1993]
Tetrachloroethene	0.01 <sup>2</sup>	No Data	No Data	1000	Medium	Liver/Heptatic Lesions	IRIS-04/06/92
1,1,1-Trichloroethane	Withdrawn 0.09	Pending 0.93 <sup>7</sup>	Pending 0.266	- -	- -	- CNS	IRIS-04/01/93 [Smith, 1993]
Selenium	0.005	No Data	No Data	3	High	CNS, Skin	IRIS-07/01/93
Aroclor-1254	No data	No Data	No Data	-	-	-	IRIS-01/22/92
Toluene	0.2	0.4	0.11	Oral 1000 Inh 300	Medium Medium	Liver, Kidney Neurological Effects	IRIS-08/13/92 IRIS-08/13/92
<b>PAHS</b>							
-Acenaphthene	0.06	No Data	No Data	3000	Low	Liver/Hepatotoxicity	IRIS-05/03/93
-Benzo(a)anthracene	No Data	No Data	No Data	IRIS-01/22/92			
-Benzo(a)pyrene	No Data	No Data	No Data	IRIS-07/06/92			
-Benzo(b)flouranthene	No Data	No Data	No Data	IRIS-01/22/92			
-Benzo(k)flouranthene	No Data	No Data	No Data	IRIS-11/16/90			
-Dibenzo(a,h)anthracene	No Data	No Data	No Data	IRIS-01/22/92			
-Flouranthene	0.046	No Data	No Data	3000	Low	Kidney, Liver, Blood	IRIS-01/22/92
-Flourene	0.046	No Data	No Data	3000	Low	Blood	IRIS-01/22/92
-Pyrene	0.036	No Data	No Data	3000	Low	Kidney	IRIS-07/01/93

1 subchronic RfD is 0.009 (mg/kg/day), HEAST 3/93

2 subchronic RfD is 0.1 (mg/kg/day), HEAST 3/93

3 subchronic RfD is 0.005 (mg/kg/day), HEAST 3/93

4 subchronic RfD is 2 (mg/kg/day) IRIS 8/13/92

5 subchronic RfD is 0.11 (mg/kg/day), IRIS 8/13/92

6 Subchronic values are the same as chronic, IRIS

7 Calculated using 20 m<sup>3</sup>/day and 70 kg, without absorption adjustment

Table F6-2

**Toxicity Constants for Chemicals of Potential Concern  
(for carcinogenic effects)**

Chemical/Element	SF oral (mg/kg/day)-1	SF inh. ( $\mu\text{g}/\text{m}^3$ )-1	SF inh. (mg/kg/day)-1	Weight of Evidence	Ref <sup>a</sup>	Notes
<b>A. Non-Radionuclides</b>						
1,1-Dichloroethene	0.6	5.00E-05	0.175	C	IRIS-01/20/92	[1]
Carbon Tetrachloride	0.13	0.000015	0.052	B2	IRIS-10/07/92	[2]
Tetrachloroethene	Pending 0.052	Pending	Pending 0.00203	—	IRIS-04/06/92 Smith, Roy	[3,6] [3]
1,1,1-Trichloroethane	—	—	—	D	IRIS-04/01/93	[8]
Selenium	—	—	—	D	IRIS-07/01/93	[4,8]
Aroclor-1254	7.7	—	—	B2	IRIS-01/22/92	[5,9]
Toluene	—	—	—	D	IRIS-08/13/92	[8]
<b>PAHS</b>						
-Acenaphthene	Pending	—	—	—	IRIS-05/03/93	[6,7]
-Benzo(a)anthracene	0.73	—	—	B2	IRIS-01/22/92	[7,9]
-Benzo(a)pyrene	7.3	—	—	B2	IRIS-07/06/92	[7,9]
-Benzo(b)fluoranthene	0.73	—	—	B2	IRIS-01/22/92	[7,9]
-Benzo(k)fluoranthene	0.73	—	—	B2	IRIS-11/16/90	[7,9]
-Dibenzo(a,h)anthracene	7.3	—	—	B2	IRIS-01/22/92	[7,9]
-Flouranthene	—	—	—	D	IRIS-01/22/92	[7,8]
-Flourene	—	—	—	D	IRIS-01/22/92	[7,8]
-Pyrene	—	—	—	D	IRIS-07/01/93	[7,8]
<b>B. Radionuclides</b>						
	<b>Oral SF Risk/pCi</b>	<b>Inhalation SF Risk/pCi</b>		<b>Weight of Evidence</b>	<b>Ref.</b>	<b>Notes</b>
Americium-241	2.40E-10	3.20E-08		A	HEAST (3/93)	
Plutonium-239,240	2.30E-10	3.80E-08		A	HEAST (3/93)	
Uranium-233,234	1.60E-11	2.70E-08		A	HEAST (3/93)	
Uranium-238	2.80E-11	5.20E-08		A	HEAST (3/93)	

[<sup>a</sup>] Refers to last update date reported in IRIS or HEAST  
All searches on IRIS database performed in July 1993.

[1] Unit risk should not be used if DCE in water > 600  $\mu\text{g}/\ell$   
Unit risk-inh should not be used if DCE in air exceeds

200  $\mu\text{g}/\text{m}^3$  SF-inh (mg/kg/day) derived based on animal administered dose and pharmacokinetics for mice to human dose conversion.

[2] Unit risk for carbon tet. should not be used if concentration in water exceeds 3000  $\mu\text{g}/\ell$ . Unit risk-inh/should not be used if concentration in air exceeds 700  $\mu\text{g}/\text{m}^3$ . SF-inh (mg/kg/day) or SF-inh ( $\mu\text{g}/\text{m}^3$ ) based on SF-oral and assumes 40% absorption rate in humans.

[3] SFs are pending and not available on IRIS or HEAST.

Values given are from ECAO, as reported by EPA-RIII [Roy Smith]. Oral SF, and weight of evidence class reported.

## SECTION F7

### RISK CHARACTERIZATION

Risk characterization involves estimating the magnitude of the potential adverse effects under study and presents summaries of the nature of the threats to public health as well as considering the nature and weight of evidence supporting these risk estimates and the magnitude of uncertainty surrounding those estimates. Specifically, it involves combining the results of the exposure and toxicity assessments to provide numerical estimates of health risk. These estimates are comparisons of exposure levels with appropriate RfDs or estimates of the lifetime cancer risk with a given intake.

#### **F7.1 GENERALIZED APPROACH**

To quantify the health risks, the intakes are first calculated for each COC (as identified in Section F3) for each applicable scenario (as identified in Section F4). The intakes are calculated based on measured concentrations at the site and used the methodology documented in the EPA's RAGS (1989a). The specific intakes, calculated in Section F5, are then compared to the applicable chemical-specific toxicological data (presented in Section F6) to determine the health risk.

The health risks from each potential contaminant are calculated in two parts: first to determine potential carcinogenic effects and second to determine noncarcinogenic effects.

##### **F7.1.1 Carcinogenic Effects**

The following calculations are used to obtain numerical estimates, (i.e., unitless probability) of lifetime cancer risks:

$$\text{RISK} = \text{INTAKE} \times \text{SF} \quad (1)$$

where:

Risk	=	Potential lifetime excess cancer risk (unitless)
SF	=	Slope factor, for chemicals (mg/kg/day) <sup>-1</sup> , or radionuclides (pCi) <sup>-1</sup>
Intake	=	Chemical intake (mg/kg/day), or radionuclide intake (pCi)

Section F5 presents the estimated intakes for receptors in tabular form. Table F6-2 presents SFs that are extracted from IRIS and HEAST. Inhalation and oral ingestion SFs were used with respective inhalation and ingestion intakes to estimate risks. It should be noted that chemical SFs are extrapolated from animal experiments and based on the 95th percentile value, while radionuclide slope factors are best estimates derived from human epidemiological studies. Additional toxicity information is contained in Section F6.

Cancer risks are summed separately across all potential chemical carcinogens and across all radionuclides considered in the risk assessment using the following equation:

$$\text{RISK}_T = \sum \text{RISK}_i \quad (2)$$

where:

RISK <sub>T</sub>	=	Total cancer risk, expressed as a unitless probability
RISK <sub>i</sub>	=	Risk estimate for the i <sup>th</sup> contaminant

This equation is an approximation of the precise equation for combining risks to account for the probability of the same individual developing cancer as a consequence of exposure to two or more carcinogens. As stated in RAGS (EPA, 1989a), the difference between the precise equation and this approximation is negligible for total cancer risks less than 0.1. This risk summation assumes independence of action by the compounds involved. Some limitations are posed by using this approach, and they are discussed in RAGS (EPA, 1989a). For example, limitations apply when adding potential carcinogenic risk across the pertinent weight-of-evidence cancer classes.

For carcinogens, EPA assumes a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and tumor induction. This mechanism for carcinogenesis is referred to as stochastic, which means that there is theoretically no level of exposure to a given chemical that does not pose a small, but finite, probability of generating a carcinogenic response. Since risk at low exposure levels cannot be measured directly either in laboratory animals or human epidemiology studies, mathematical models have been developed to extrapolate from high to low exposure levels. Various models have been proposed to extrapolate from high to low doses (i.e., to estimate the dose-response relationship at low doses). The three most frequently used models are the one-hit model, the log-probit model, and the multistage model (Armitage and Doll, 1961). The one-hit model is based on the premise that a single molecule of a contaminant can be the single event that precipitates tumor induction (Cornfield, 1977). In other words, there is some finite response associated with any exposure. The log-probit model assumes that a response is normally distributed with the logarithm of the dose (Mantel et al., 1971). This theory seems to have little scientific basis, although some physiological parameters are lognormally distributed. This model usually yields much lower potency estimates due to the implied threshold at lower doses.

Currently, regulatory decisions are based on the output of the linearized multistage model (EPA, 1986). The basis of the linearized multistage model is that multiple events (versus the single-event paradigm of the one-hit model) may be needed to yield tumor induction (Crump et al., 1977). The linearized multistage model reflects the biological variability in tumor frequencies observed in animals or human studies. The dose-response relationship predicted by this model at low doses is essentially linear. Use of this model provides dose-response estimates intermediate between the one-hit and the log-probit models.

Most models produce quantitatively similar results in the range of observable data, but yield estimates that can vary by three or four orders of magnitude at lower doses. Animal bioassay data are simply not adequate to determine whether any of the competing models are better than the others. Moreover, there is no evidence to indicate that the precision of low-dose risk estimates increases through the use of more sophisticated models. Thus, if a carcinogenic response occurs at the exposure level studied, it is assumed that a similar response will occur at all lower doses, unless evidence to the contrary exists.

### F7.1.2 Noncarcinogenic Effects

Health risks associated with exposure to individual noncarcinogenic compounds are evaluated by calculating hazard quotients. The noncancer hazard quotient is the ratio of the intake rate to the RfD, as follows:

$$HQ = \text{INTAKE}/\text{RfD} \quad (3)$$

where:

HQ = Noncancer hazard quotient  
Intake = Chemical intake (mg/kg/day)  
RfD = Reference dose (mg/kg/day)

Chronic RfDs are extracted from IRIS and HEAST (Table F6-1). Similar to SFs, RfDs for inhalation and oral ingestion are used for inhalation and oral intakes, respectively.

Hazard indices are the summed hazard quotients for each chemical across the nine exposure pathways. If the hazard index for any chemical exceeds unity there may be concern for potential health effects. The hazard index is calculated using the following equation:

$$HI = \sum \frac{E_i}{\text{RfD}_i} \quad (4)$$

where:

HI = Hazard index  
 $E_i$  = Exposure level (intake) for the  $i^{\text{th}}$  toxicant  
 $\text{RfD}_i$  = Reference dose for the  $i^{\text{th}}$  toxicant

E and RfD are expressed in the same units and represent the same exposure period.

Limitations on the application of this procedure are discussed in RAGS (EPA, 1989a). The HI values for each chemical grouped by target organ are totaled to obtain a summed HI value applicable to a specific target organ.

## **F7.2 POINT ESTIMATES OF RISK**

After reasonable exposure pathway combinations are identified, the likelihood that the same individuals would consistently be exposed by more than one pathway is evaluated. In most situations a receptor could be exposed by several scenario pathways in combination. This section presents the RME point estimates of risk for carcinogenic and noncarcinogenic impacts for two current scenarios, three standard future hypothetical scenarios, three variations of data aggregation on the future residential scenario, and a future residential scenario with the major source removed.

Sections F7.2.1 through F7.2.4 present the carcinogenic and noncarcinogenic risks by scenario.

As recommended by EPA in RAGS (EPA, 1989a), carcinogenic risks are summed separately for each weight-of-evidence classification. A total carcinogenic risk has been calculated for Class A, B, and C carcinogens. As an additional point of reference, these risks have also been summed across weight-of-evidence classifications.

Noncarcinogenic risks are expressed as HI values. Hazard quotients have been summed according to target organ to calculate the total hazard index by target organ. These HI values should not be interpreted as statistical probabilities of an effect occurring. Again, as an additional point of reference, the total hazard index has been calculated by summing hazard quotients from all COCs without regard for the target organ affected. Impacts to both adult and child receptors are calculated for residential scenarios.

Sections F7.2.1 through F7.2.4 discuss the highest risk that are presented in Tables F7-1 through F7-26. In accordance with EPA guidance, only one significant digit is retained when summarizing calculated risks (EPA, 1989a). In some instances, this rounding results in what appear to be math errors, but are simply artifacts of the rounding process.

In many cases, inhalation of plutonium-239, 240, and americium-241 are calculated to present the highest risks. This is due to a source-term for modeling that is greatly elevated by the presence of surface soil hot spots several orders of magnitude above ambient concentrations.

To be consistent with the treatment of source and OU-wide groundwater data, the hot spot data were included with the OU-wide data using a simple average. This greatly biases the concentration and results in over estimates of risk to radionuclides. The effect of using a more realistic area-weighted average are discussed in Section 7.3.1.

### **F7.2.1 Current Land Use Scenarios**

This section presents the RME results for the two current exposure scenarios: (1) on-site commercial/industrial and (2) off-site residential land uses.

#### **F7.2.1.1 Current On-Site Commercial/Industrial Land Use Scenario**

Carcinogenic risks calculated for the current on-site worker, a security specialist, are shown on Table F7-1. The greatest contributor to the total risk ( $1E-04$ ) is from Class A carcinogens ( $1E-04$ ). Inhalation of dust from plutonium-239,-240 ( $9E-05$ ) and americium-241 ( $2E-05$ ) presents the highest risks. All other risks are calculated to be approximately two orders of magnitude lower. Noncarcinogenic hazard indices calculated for the current on-site worker are shown on Table F7-2. The total hazard index is calculated to be  $8E-05$ , dominated by dermal contact with surface soil and sediment containing fluoranthene, pyrene, fluorene, and acenaphthene.

Worker exposure is regulated by occupational standards; consequently, a comparison to exposure limits and dose limits is presented in Table F7-3 for the highest exposure/dose pathway, inhalation. Worker exposure/dose is typically two orders of magnitude lower than occupational limits.

#### **F7.2.1.2 Current Off-Site Residential Land Use Scenario**

Carcinogenic risks calculated for the current off-site resident are shown on Table F7-4. The greatest contributor to the total risk ( $2E-06$ ) is from Class A carcinogens ( $2E-06$ ). Inhalation of dust from plutonium-239,-240 ( $2E-06$ ) presents the highest risk. Other risks are approximately one order of magnitude lower.

Noncarcinogenic hazard indices calculated for the current off-site resident are shown on Tables F7-5 and F7-6, for adult and child receptors, respectively. The total hazard index for adult and child exposure is calculated to be  $6E-08$  and  $1E-07$ , respectively, dominated by ingestion of garden grown produce raised in soil contaminated by windblown PAHs from OU1, and dermal contact with that soil.

### **F7.2.2      Standard Future Hypothetical Scenarios**

This section presents the RME results for impacts to receptors under the three standard future on-site land use scenarios: (1) commercial/industrial, (2) ecological reserve, and (3) residential.

#### **F7.2.2.1      Future On-Site Commercial/Industrial Land Use Scenario**

Carcinogenic risks calculated for the future on-site worker are shown on Table F7-7a and Table F7-7b. The greatest contributors to the total risk for the future on-site office worker ( $2E-03$ ) is from Class A carcinogens ( $2E-03$ ) and Class C carcinogens ( $2E-04$ ). Inhalation of dust containing plutonium-239,-240 and americium-241 presents the highest risk ( $1E-03$  and  $3E-04$  respectively), followed by inhalation of 1,1-dichloroethene as it volatilizes through the foundation of the hypothetical commercial/industrial building ( $2E-04$ ). Several other calculated carcinogenic risks exceed  $1E-06$ . The contaminants and pathways involved are shown on Table F7-7a. Similarly, the greatest contributors to the total risk for the future on-site construction worker ( $4E-07$ ) is from Class C carcinogens ( $4E-07$ ). The highest calculated risk for the construction worker is from inhalation of 1,1-dichloroethene volatilized during excavation ( $4E-07$ ). Other risks are approximately two orders of magnitude lower.

Noncarcinogenic hazard quotients and indices calculated for the future on-site commercial/industrial worker are shown on Table F7-8a and F7-8b for the office and construction workers, respectively. The total hazard index for the office worker is  $3E-03$ , which arises primarily from inhalation of 1,1,1-trichloroethane volatilized through the foundation of the office building. The total hazard index for the construction worker is  $1E-04$ , which arises primarily from inhalation of 1,1,1-trichloroethane volatilized during excavation.

Worker exposure is regulated by occupational standards. Consequently, a comparison to exposure limits and dose limits is presented in Table F7-9 for the highest exposure/dose pathway, inhalation. Worker exposure/dose, in this case, exceeds dose limits.

#### **F7.2.2.2 Future On-Site Ecological Reserve Land Use Scenario**

Carcinogenic risks calculated for the future on-site ecological researcher are shown on Table F7-10. The greatest contributor to the total risk ( $2E-03$ ) is from Class A carcinogens ( $2E-03$ ). Inhalation of dust from plutonium-239,-240 ( $1E-03$ ) and americium-241 ( $3E-04$ ) presents the highest risks. All other risks were calculated to be approximately two orders of magnitude lower. Noncarcinogenic hazard indices calculated for the future on-site ecological researcher are shown on Table F7-11. The total hazard index is calculated to be  $2E-03$ , dominated by dermal contact with surface soil and sediment containing fluoranthene, pyrene, fluorene, and acenaphthene.

#### **F7.2.2.3 Future On-Site Residential Land Use Scenario**

Carcinogenic risks calculated for the future on-site resident are shown on Table F7-12. The greatest contributors to the total risk ( $3E-03$ ) are Class A carcinogens ( $3E-03$ ) and Class C carcinogens ( $2E-04$ ). Inhalation of plutonium-239,-240 and americium-241 dust ( $2E-03$  and  $4E-04$ , respectively) presents the highest risk, followed by inhalation of 1,1-dichloroethene as it volatilizes and enters the foundation of the hypothetical residence ( $2E-04$ ). Several other calculated carcinogenic risks exceed  $1E-06$ . The contaminants and pathways involved are shown on Table F7-12.

Noncarcinogenic hazard quotients and indices calculated for the hypothetical future on-site resident are shown on Tables F7-13 and F7-14, for adult and child receptors, respectively. The total hazard indices are  $5E-03$  for the adult and  $2E-02$  for the child. In both cases, impacts are dominated by the inhalation of 1,1,1-trichloroethane; these hazard quotients are  $2E-03$  and  $1E-02$ , respectively, for adult and child receptors.

### **F7.2.3      Other Future Scenarios**

This section presents the RME results for three variations of the future residential exposure scenario. The first scenario assumes that the on-site resident consumes groundwater from a residential well and is thus exposed through direct ingestion, dermal absorption, and inhalation of volatiles introduced to the house from indoor water use.

The second scenario makes the same assumptions with the additional constraint that risk is calculated using only the data gathered at the source (groundwater in IHSS 119.1 and radionuclides in soil), with the exception of media not located in OU1 proper (surface water and sediment). The data is aggregated in this manner because it is assumed that the house is built directly over the source.

The third scenario also assumes exposure at the source, but since not enough groundwater exists at IHSS 119.1 to support a family of four, it is assumed that well water (22.4 gallons/day, see Attachment F1) is augmented with public water (217.6 gallons/day) to meet typical needs (240 gallons/day).

#### **F7.2.3.1      Future On-Site Residential Land Use (Sitewide With Groundwater)**

Carcinogenic risks calculated for the future on-site resident who also uses groundwater are shown on Table F7-15. The total risk ( $6E-03$ ) consists of Class C carcinogens ( $3E-03$ ), Class A carcinogens ( $3E-03$ ), and Class B2 carcinogens ( $3E-04$ ). Ingestion of groundwater containing 1,1-dichloroethene presents the highest risk ( $3E-03$ ), followed by inhalation of plutonium-239, -240 dust ( $2E-03$ ), and inhalation of 1,1-dichloroethene volatilized through the foundation ( $2E-04$ ). Several other calculated carcinogenic risks exceed  $1E-06$ . The contaminants and pathways involved are shown on Table F7-15.

Noncarcinogenic hazard quotients and indices are shown on Tables F7-16 and F7-17, for adult and child receptors, respectively. The total hazard indices are calculated to be  $9E+00$  for an adult and  $2E+01$  for a child. Hazard quotients exceeding unity for the adult are: ingestion of carbon tetrachloride in groundwater ( $5E+00$ ); ingestion of selenium in groundwater ( $2E+00$ );

and ingestion of 1,1-dichloroethene in groundwater ( $1E+00$ ). Hazard quotients exceeding unity for the child are: ingestion of carbon tetrachloride in groundwater ( $1E+01$ ); ingestion of selenium in groundwater ( $4E+00$ ); and ingestion of 1,1-dichloroethene in groundwater ( $3E+00$ ). No other hazard quotients exceed unity.

#### **F7.2.3.2 Future On-Site Residential Land Use (Assuming Adequate Groundwater At Source)**

Carcinogenic risks calculated for the future on-site resident who uses groundwater for drinking and washing and resides at the IHSS 119.1 source area are shown on Table F7-18. The total risk ( $7E-02$ ) consists of Class C carcinogens ( $4E-02$ ), Class A carcinogens ( $3E-02$ ), and Class B2 carcinogens ( $4E-03$ ). Ingestion of groundwater containing 1,1-dichloroethene presents the highest risk ( $3E-02$ ), followed by inhalation of plutonium-239,-240 dust ( $2E-02$ ), and inhalation of 1,1-dichloroethene volatilized through the foundation ( $3E-03$ ). Several other calculated carcinogenic risks exceed  $1E-06$ . The contaminants and pathways involved are shown on Table F7-18.

Noncarcinogenic hazard quotients and indices are shown on Tables F7-19 and F7-20 for adult and child receptors, respectively. The total hazard indices are calculated to be  $1E+02$  for an adult and  $2E+02$  for a child. Hazard quotients exceeding unity for the adult are: ingestion of carbon tetrachloride in groundwater ( $7E+01$ ); ingestion of 1,1-dichloroethene in groundwater ( $2E+01$ ); ingestion of tetrachloroethene in groundwater ( $6E+00$ ); dermal contact with carbon tetrachloride in groundwater ( $4E+00$ ); ingestion of 1,1,1-trichloroethane in groundwater ( $2E+00$ ); and ingestion of selenium in groundwater ( $5E+00$ ). Hazard quotients exceeding unity for the child are: ingestion of carbon tetrachloride in groundwater ( $2E+02$ ); ingestion of 1,1-dichloroethene in groundwater ( $4E+01$ ); ingestion of tetrachloroethene in groundwater ( $1E+01$ ); dermal contact with carbon tetrachloride in groundwater ( $7E+00$ ); ingestion of 1,1,1-trichloroethane in groundwater ( $5E+00$ ); ingestion of selenium in groundwater ( $1.2E+01$ ); dermal contact with 1,1-dichloroethene in groundwater ( $1E+00$ ); and dermal contact with tetrachloroethene in groundwater ( $1E+00$ ). No other hazard quotients exceed unity.

### **F7.2.3.3 Future On-Site Residential Land Use (At Source With Public Water)**

Carcinogenic risks calculated for the future on-site resident who uses groundwater augmented by a public water supply and resides at the IHSS 119.1 source are shown on Table F7-21. The total risk ( $4E-02$ ) consists of Class A carcinogens ( $3E-02$ ), Class C carcinogens ( $6E-03$ ), and Class B2 carcinogens ( $5E-04$ ). Inhalation of plutonium-239,-240 dust presents the highest risk ( $2E-02$ ), followed by inhalation of americium-241 dust ( $4E-03$ ), inhalation of 1,1-dichloroethene volatilized through the foundation ( $3E-03$ ), and ingestion of groundwater containing 1,1-dichloroethene ( $4E-03$ ). Several other calculated carcinogenic risks exceed  $1E-06$ . The contaminants and pathways involved are shown on Table F7-21.

Noncarcinogenic hazard quotients and indices are shown on Tables F7-22 and F7-23 for adult and child receptors, respectively. The total hazard indices are calculated to be  $1E+01$  for an adult and  $3E+01$  for a child. Hazard quotients exceeding unity for the adult are: ingestion of carbon tetrachloride in groundwater ( $7E+00$ ); and ingestion of 1,1-dichloroethene in groundwater ( $2E+00$ ). Hazard quotients exceeding unity for the child are: ingestion of carbon tetrachloride in groundwater ( $2E+01$ ); ingestion of 1,1-dichloroethene in groundwater ( $4E+00$ ); ingestion of tetrachloroethene in groundwater ( $1E+00$ ); and ingestion of selenium in groundwater ( $1E+00$ ). No other hazard quotients exceed unity.

### **F7.2.4 Future On-Site Residential Use (Without Groundwater/Without Source)**

As a point of interest or additional perspective, the risk has been calculated for a hypothetical on-site resident with the source (IHSS 119.1) removed. This was calculated by using a subset of the sitewide data set excluding the data used to calculate the residential risk at the source (i.e., without including data from wells in IHSS 119.1 or the elevated radionuclide soil samples collected from the IHSS early in 1993).

Carcinogenic risks calculated for future residential use with the source removed are shown on Table F7-24. The total risk ( $5E-05$ ) consists of Class B2 carcinogens ( $3E-05$ ), Class A carcinogens ( $2E-05$ ), and Class C carcinogens ( $8E-07$ ). Ingestion of vegetables containing dibenzo(a,h)anthracene presents the highest risk ( $1E-05$ ), followed by ingestion of vegetables

containing arochlor-1254 (6E-06). Several other calculated carcinogenic risks exceed 1E-06. The contaminants and pathways involved are shown on Table F7-24.

Noncarcinogenic hazard quotients and indices are shown on Tables F7-25 and F7-26, for adult and child receptors, respectively. The total hazard indices are calculated to be 3E-03 for an adult and 8E-03 for a child. Individual hazard quotients or indices do not exceed unity for adult or child receptors.

### **F7.3 UNCERTAINTY ANALYSIS**

The quantification of uncertainty is an important component of the risk assessment process. According to the EPA *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, point estimates of risk "do not fully convey the range of information considered and used in developing the assessment" (EPA, 1992d). Furthermore, the guidance states that the Monte Carlo simulation may be used to estimate descriptive risk percentiles. To provide information about the uncertainties associated with the RME estimate and the relation of the RME estimate relative to other percentiles of the risk distribution, uncertainties were identified during the PHE process and are presented in qualitative and quantitative terms.

#### **F7.3.1 Sources of Uncertainty**

There are four stages of analysis applied in the risk assessment process that can introduce uncertainties:

- 1) Data Collection and Evaluation
- 2) Exposure Assessment
- 3) Toxicity Assessment
- 4) Risk Characterization

The uncertainty analysis characterizes the propagated uncertainty in public health risk assessments. These uncertainties are driven by uncertainty in the chemical monitoring data, the transport models used to estimate concentrations at receptor locations, receptor intake parameters, and the toxicity values used to characterize risk. Additionally, uncertainties are

introduced in the risk assessment when exposures to several substances across multiple pathways are summed.

Uncertainties in this risk assessment are due to uncertainties in the risk assessment process in general, specific uncertainties in characterizing the site, and the uncertainties associated with accurately describing exposures. Table F7-27 summarizes the uncertainties and limitations in this assessment.

Two sources of uncertainty presented in Table F7-27 were examined in more detail. These include:

- Contaminant Identification
- Air Modeling Assumptions

The use of professional judgement to analyze the data and identify contaminants introduces uncertainty. Some of the analytes had positive detections but were not identified as site contaminants due to lack of a spatial or temporal pattern that distinguishes them from background (e.g., antimony and manganese). At the request of the EPA, the ingestion of antimony and manganese in groundwater are evaluated quantitatively for the future on-site resident. The calculations were performed in the same manner as for the groundwater COC selenium (Table F5-27) using ingestion RfDs of  $4E-04$  and  $5E-03$  for antimony and manganese, respectively (EPA, 1993a). Using OU-wide 95% UCL concentrations of  $3.68E+01$  and  $416E+02$  ug/l for antimony and manganese, adult lifetime intakes of  $1E-03$  and  $1E-02$  mg/kg/dy and hazard quotients of  $2.5E+00$  and  $2.3E+00$  were calculated respectively. Similarly, hazard quotients of  $5.9E+00$  and  $5.3E+00$  were calculated for the child for antimony and manganese, respectively. These are similar in magnitude to the OU-wide hazard quotients calculated for selenium,  $1.6E+00$  and  $3.8E+00$  for the adult and child, respectively.

Two additional sources of uncertainty in contaminant identification result from the effect of toxicity values on the concentration-toxicity screen. Toxicity values in IRIS are subject to change and do not exist for some chemicals. Changing IRIS toxicity values can shift risk factors across the 1 percent screening criteria and change the outcome of the concentration-toxicity

screen. The chemicals that had risk factors near one percent and could potentially be affected by changing toxicity values are vanadium, 1,1,1-trichloroethane, uranium-238, anthracene, and indeno(1,2,3-cd)pyrene. Similarly, chemicals that were within 10 percent of the 1000xRBC criteria are 1,1,2-trichloroethane, 1,2-dichloroethane, carbon disulfide, and 1,2 dichloroethene. For the OU1 concentration-toxicity screens, no toxicity values were available for trichloroethylene, cis-1,2 dichloroethene, phenanthrene, and benzo(ghi)perlyene and consequently, these were not identified as COCs. For these contaminants without toxicity values, ingestion intakes were calculated for the OU-wide on-site resident. Using mean concentrations of 371.6 ug/l, 0.56 ug/l, 420 ug/kg, and 188ug/kg, adult intakes are 1.5E-02, 1.2E-05, 2.7E-07, and 1.4E-07 for trichloroethylene, cis-1,2 dichloroethene, phenanthrene, and benzo(ghi)perlyene, respectively. As toxicity values become available, these intakes can be used to calculate risks.

As presented in this report, one of the principal risk-driving pathways is the inhalation of radionuclides. Concentration values for this pathway were not measured but were modeled using the MILDOS-AREA computer code. The source term, concentration in soil, used in the model can greatly affect the model output. For OU1, the radionuclide hot spot data were included in the OU-wide data using a simple average. This was done to be consistent with the method that the groundwater source (IHSS 119.1) was included with the OU-wide groundwater data. However, this method overestimates the impact of the small surface area of the hot spots on the model output. Although the exact areal extent of the hot spots is not defined, the field report (Appendix A5 of the RI Report) indicates that the four hot spots have a combined area less than 2 m<sup>2</sup>. When this area is compared to the area of OU1, approximately 80,000 m<sup>2</sup>, it can be seen that use of an area-weighted average would reduce the source term (and the model output) by approximately three orders of magnitude. The effects of this overestimation are reflected in the inhalation pathway risks for plutonium-239,240, americium-214, uranium-233,234, and uranium-238 for all scenarios except the future on-site resident scenario where the hot spot data were removed from the data set (Section F7.2.4 and Table F7-24). This is illustrated by comparing the risks from the scenario assuming a future on-site resident at the source and hot spots (Section F7.2.3.2), approximately 3E-02, with the risk for the future on-site resident scenario where the hot spot data were removed, 2E-05.

One approach to address the uncertainties discussed here and presented in Table F7-27 is to use health-protective assumptions. Health-protective assumptions are those that systematically overstate the magnitude of health risks such that even with errors due to uncertainty in the methodology, actual health risks are expected less than those calculated. This process bounds the plausible upper limits of risk and facilitates an informed risk management decision.

### **F7.3.2      Quantitative Uncertainty Analysis**

The goal of the uncertainty analysis is to quantify the uncertainty in the final risk characterization estimates. Initially, the key site-related variables and assumptions that contribute most to the uncertainty are identified and, where possible, quantitative techniques to estimate uncertainty were applied. Assumptions and uncertainties inherent in the risk assessment are specified below to place the risk estimates in the proper perspective. Site data is used in such a way that the results can be presented as estimated probability distributions. The overall uncertainty for the risk assessment is estimated by Monte Carlo simulation for the pathway dominating the risk.

The Monte Carlo simulation is a technique that can be used to provide a probability function of estimated risk using random values of exposure factors and toxicity values in an exposure scenario. A Monte Carlo simulation involves assigning a joint probability distribution to the input variables (i.e., exposure factors) of an exposure scenario. Next, a large number of independent samples from the assigned joint distribution are taken and the corresponding outputs calculated. This is accomplished by repeated computer iterations using random numbers to assign values to the exposure factors. The simulated output represents a sample from the true output distribution. Methods of statistical inference are used to estimate, from the output sample, key parameters of the output distribution (e.g., percentiles).

Pathways from the RME sitewide residential scenario with groundwater ingestion were modeled with Monte Carlo simulations. In many cases, inhalation of plutonium-239, 240, and americium-241 are calculated to present the highest risks. This is due to a source-term for modeling that is greatly elevated by the presence of a surface soil hot spot several orders of magnitude above ambient concentrations. This overestimates the risk to those surface soil

radionuclides because area-weighted averaging was not used. Because they are more representative of current risks, pathways involving 1,1-dichloroethene and carbon tetrachloride were used for Monte Carlo simulations.

The review and selection of appropriate uncertainty analysis methods focused on providing an overall approach that would provide a quantitative result. To assess the uncertainty introduced into the risk assessment by each of the categories described above, methodologies for determining the uncertainty for each category were selected. The following sections discuss these methodologies.

#### **F7.3.2.1 Data Collection and Evaluation**

Variability in observed concentrations is due to sampling design and implementation, laboratory analysis, seasonality, contaminant level variation, and natural variation. The key issue in optimizing the usability of the data is to quantify these uncertainties in the risk assessment. Uncertainty introduced from sample collection and analysis was quantified by calculating the variance in the analytical results within OUI. After identifying the contaminants that dominated the risk for each credible pathway, a concentration distribution, mean concentration, and variance were calculated. The resulting variance accounts for the uncertainty introduced by sampling, analysis, seasonality, and natural variation.

#### **F7.3.2.2 Exposure Assessment**

The largest measure of uncertainty in the exposure assessment is associated with characterizing transport, dispersion, and transformation of COCs in the environment; establishing exposure settings; and deriving estimates of chronic intake. The ultimate effect of this process is the generation of a range or distribution of estimates for intake at a given exposure point.

The initial characterization that defines the risk assessment for a site involves many professional judgments and assumptions. Definition of the physical setting, population characteristics, and selection of the chemicals included in the risk assessment are examples of areas for which a quantitative estimate of uncertainty cannot be achieved because of the inherent reliance on

professional judgement. Assumptions and supporting rationale regarding these types of parameters, along with the potential impact on the uncertainty (i.e., over- or underestimation of uncertainty), are described qualitatively above as part of the qualitative exposure assessment uncertainty analysis.

Modeling data and parameter uncertainties are typically characterized by a range or distribution of values. A numerical uncertainty analysis propagates the uncertainty in the input parameters through a model to produce a distribution of resulting concentration estimates. This analysis provided the estimated concentration probability distribution at the receptor location. The uncertainty analysis in this exposure assessment used the range of observed values, the measure of central tendency and the distribution shape parameters for chemicals in the environment, and the factors used for developing intake estimates. As discussed below, a quantitative estimation of uncertainty associated with the other input parameters was also conducted.

#### Uncertainty in Soil Gas and Groundwater Concentrations

Uncertainty associated with soil gas (i.e., originating from groundwater) modeling is assessed by accomplishing the following four steps: (1) evaluate sensitivity of model input parameters; (2) sample distributions of sensitive parameters using LHS; (3) perform 100 simulations of on-site building concentrations based on model input from sampling techniques; and (4) produce probability distributions of building concentrations for each volatile COC. The concentration distribution for 1,1-dichloroethene, applicable to the inhalation pathway, is presented in Figure F7-1.

The concentration for groundwater is derived from the summary statistics presented in Section F3, Table F3-3. Assuming a normal distribution, the mean and standard deviation is used to simulate the concentration distribution for the data set. Concentration distributions for 1,1-dichloroethene and carbon tetrachloride, applicable to the ingestion pathway, are presented in Figures F7-2 and F7-3.

Porosity, moisture content, bulk density, and fraction of organic content are the most sensitive parameters. Attachment F-2 contains a data summary used for soil gas modeling and a

description of LHS technique used in the soil gas modeling. Section F5 and Attachment F-2 summarize the model and approach used to estimate building concentrations.

### Uncertainty in Human Intake Parameters

Inherent in the evaluation of modeled contaminant intake is the uncertainty in the values used to assign intakes. Uncertainty parameters of intake (such as breathing rate) as well as parameters of demographics (residence time, length of work day, etc.) are evaluated quantitatively to the extent possible so that the uncertainty about the mean for those important variables is propagated through the analysis along with modeled concentrations and toxicity constants. The evaluation of uncertainty in human intake parameters comprised the final set of uncertainty evaluations to be performed as the exposure assessment uncertainty analysis.

The selection of probability distributions as inputs to exposure and risk models is conducted according to guidance set forth in the *Exposure Factors Handbook* (EFH) (EPA, 1989d):

"In general, the selection of a probability distribution to represent an input factor in the exposure models should be based upon any gathered information about that factor, theoretical arguments, and/or expert opinions. A probability distribution can be ascertained for such information as the following: general shape of the distribution, minimum, maximum, mode, mean, median, midrange, and other percentiles. Available data on the probability distributions for each of the exposure factors discussed in this handbook have been presented in previous sections. When distribution data are not available, distributions can be assigned using professional judgement.

Although the exact shape of many of the distributions is not known, the estimated distributions approximate the current state of knowledge about these variables much better than a single point estimate. From the data presented in EFH, it may be seen that for each variable, a range of values exists. In many cases, additional information such as central tendency values (e.g., mean, median) and/or percentiles is provided. Selection of a single point estimate from such data is a significant loss of information. In effect, a point estimate is a distribution in which a single value has a 100 percent chance of occurring, and all other values have no chance of occurring. The data presented in EFH is capable of providing much more information than a single point estimate, particularly for the purpose of risk assessment.

One commonly voiced concern with Monte Carlo simulation is that if the exact distributions of the parameters are not known, the mechanics of the simulation may introduce an artificial uncertainty into the result (i.e., in addition to the true uncertainty). This can occur if distributions are used which are not representative of the available data, especially if the range of the estimated distribution greatly exceeds the range of the data. In that case, the simulation will occasionally sample these extreme values, resulting in exaggerated extremes in the resultant distribution.

To reduce the chance of introducing artificial extremes, the estimated distributions have been truncated at the minimum and maximum values presented in the data. In some cases it is possible to have real world extremes beyond these data values; however, EPA data were used to provide a consistent approach. This truncation at or within minimum and maximum data values may yield results that do not reflect the full range of variability, rather the results will provide information on a large proportion of that variability.

A further consideration is that exposure parameters may not be independent. For example, there is typically a positive correlation between inhalation rate and body weight. A range of values may be identified in the literature for this correlation. These correlations range from moderate to moderately high. Single values representative of particular correlations were not identified in EPA literature, so correlation between parameters was not included in the simulations. Since distributions were truncated to reduce combinations of extreme values, the effect of exaggerating extremes (by not including correlation of the parameters) is reduced.

The human exposure parameters associated with predominant risk pathways at OU1 are body weights, inhalation rates, ingestion rates, exposure duration, exposure frequency, and averaging times. To illustrate the uncertainty characteristic of the five scenarios presented, the hypothetical future on-site resident adult has been selected. The following is a discussion of the sources and professional judgement used to estimate each parameter distribution.

### Body Weight

Percentile values for adult male and female body weight are presented in EFH page 5-42 (EPA, 1989d). The average values for ages 18 to 75 are entered directly into a cumulative distribution. The minimum and maximum average values presented in the table are used to define the extremes of the cumulative distribution. Although the percentile data are used directly, it is worth noting that body weight approximates a normal distribution (EPA, 1989d). The body weight distribution is presented in Figure F7-4.

### Inhalation Rate

The *Supplemental Guidance to Risk Assessment Guidance for Superfund* (EPA, 1991b) states a highest weekly average inhalation rate for residents of 18.3 m<sup>3</sup>/day. The minimum value is identified on page 3-4 in EFH as 0.3 m<sup>3</sup>/hr for adult resting females, or 7.2 m<sup>3</sup>/day. Since breathing rate may be estimated as a linear function of body weight (EPA, 1985), it also approximates a normal distribution. With the total indoor and outdoor rate of 30 m<sup>3</sup>/day assumed to represent the 99 percentile, the standard deviation may be derived as 4.5 m<sup>3</sup>/day ( $[(30 - 18.3)/2.58]$ ). The distribution is truncated at 7.2 m<sup>3</sup>/day and 20 m<sup>3</sup>/day. The inhalation rate distribution is presented in Figure F7-5.

### Exposure Duration

Percentile values for exposure duration are presented in EFH page 5-33. The cumulative percentile values are summed from the information provided for each time period and entered directly into a cumulative distribution. The lowest value presented in the table is used to define a minimum of zero, and professional judgement is used to assign a maximum of 70 years for the cumulative distribution. The exposure duration distribution is presented in Figure F7-6.

### Exposure Frequency

Exposure frequency may range from zero up to 365 days per year. No information about the central tendency or percentile is identified. According to EFH, it is appropriate to assume a uniform distribution if only the range is known. Professional judgement is used to identify a minimum that appears more reasonable than zero days per year, because it would seem pointless to live somewhere if one were never there. A reasonable minimum of 124 days/year is identified based on a person that might travel extensively for work but be home on weekends, holidays, and vacation days. The exposure frequency distribution is presented in Figure F7-7.

### Averaging Time

Although EP (1991b) suggests a point estimate of 70 years for averaging time, EFH states a mean life expectancy of approximately 75 years in Part II, Section 1. Professional judgment is used to estimate minimum and maximum values. Humans sometimes die at birth and rarely live past the age of 110 years, however, the likelihood of occurrence is known to drop quite rapidly as these extremes are approached. On this basis, a truncated normal distribution is selected. The standard deviation is estimated to be 13.6 years ( $(110 - 75)/2.58$ ). The distribution is truncated at the maximum value of 110 years, but the minimum value is truncated within the range at the five standard deviation value recommended by the computer software. The averaging time distribution is presented in Figure F7-8.

### Ingestion Rate

The EFH, page 2-3, initiates the discussion of water ingestion rates and the resulting distributions. Upper bound consumption rates and the associated cumulative frequencies are entered directly into a cumulative distribution. The minimum and maximum values identified on page 2-3 of the EFH are also used to define the distributions. The ingestion distribution is presented in Figure F7-9.

## Results

Contaminant intake distributions are estimated for exposure to 1,1-dichloroethene by the inhalation of soil-gas pathway and for ingestion of groundwater contaminated with 1,1-dichloroethene and carbon tetrachloride by using a Monte Carlo simulation involving the equations (see Section F5) for inhalation and ingestion. The intake distributions are presented in Figures F7-10, F7-11, and F7-12.

### **F7.3.2.3 Toxicity Assessment**

Several important measures of toxicity are needed in conducting an assessment of risk to human health. RfDs are applied to the oral and inhalation exposure to evaluate noncarcinogenic and developmental effects, and SFs are applied to the oral and inhalation exposures to carcinogens. RfDs are derived from NOAELs or LOAELs and the application of UFs and MFs. UFs are used to account for the variation in sensitivity of human subpopulations and the uncertainty inherent in extrapolation of the results of animal studies to humans. MFs account for additional uncertainties in the studies used to derive the NOAEL or LOAEL. Uncertainty associated with the SFs is accounted for by an assigned weight-of-evidence rating that reflects the likelihood that the toxicant is a human carcinogen.

In presenting the results of the toxicity assessment portion of the risk assessment, it is important to provide an indication of the degree of confidence associated with these values. Weight-of-evidence classifications are tabulated and included in the discussion of SFs (see Section F6). Similarly, UFs and MFs used to derive RfDs from NOAELs or LOAELs are presented in Section F6.

Distributions for toxicity constants are derived from EPA animal data using a nonparametric bootstrap procedure (see Attachment F-3). These distributions reflect the uncertainty involved in estimating a toxicity constant from animal study data. The histogram of the inhalation toxicity distribution for 1,1-dichloroethene is presented in Figure F7-13. The histograms of ingestion toxicity for 1,1-dichloroethene and carbon tetrachloride are presented in Figures F7-14 and F7-15.

#### **F7.3.2.4 Risk Characterization**

The last step in the risk assessment is risk characterization. This is the process of integrating the results of the exposure and toxicity assessments (i.e., comparing the estimates of intake with appropriate toxicological measures to determine the likelihood of adverse effects in potentially exposed populations). Similarly, the propagated uncertainties defined throughout the uncertainty analysis process are combined and presented as part of the risk characterization to provide an overall uncertainty in the estimate of risk.

#### **F7.3.2.5 Propagation of Quantitative Uncertainty**

The Monte Carlo simulation is used again as the intake distributions are multiplied times the toxicity distributions to estimate the risk distributions. The risk distributions are annotated to show the approximate relation of the RME point estimates in relation to various percentiles. The risk distribution for the inhalation of 1,1-dichloroethene from the soil gas pathway is presented in Figure F7-16. Risk distributions for ingestion of 1,1-dichloroethene and carbon tetrachloride are presented in Figures F7-17 and F7-18.

The locations of the RME values on the respective distributions, and the degree of conservatism in the RME is unknown unless a quantitative uncertainty analysis is conducted. As several risk assessment experts have noted about the EPA RME method, "by selecting a combination of moderate, conservative, and worst-case assumptions, risk assessors and risk managers have no way of knowing the degree of conservatism in an assessment" (Thompson et al., 1992). In characterizing these unknowns, the Monte Carlo simulation reflects the following uncertainties in the input distributions:

- The input concentration is influenced by the presence of non-detects and the bias of the substitution method.
- The exposure parameters have been truncated to avoid exaggerating extreme values and to reduce possible extreme values from potentially correlated variables.

- The toxicity distribution is derived from EPA data using a non-parametric bootstrap method.

The resulting risk distribution, with associated uncertainties regarding extreme values, presents significantly more information than do point estimates. Consequently, quantitative uncertainty assessment is an approved and accepted method of characterizing these unknowns (EPA, 1992d).

#### **F7.4 OTHER RISK PERSPECTIVES**

Perspective may be provided for risk estimates for environmental contaminants by addressing questions regarding typical background environmental risks the expected impact on the community, the applicability of existing epidemiological information to environmental exposures, and the types of models used to estimate human health risks from laboratory animal studies. Section F7.4.1 through F7.4.4 address these issues.

##### **F7.4.1 Comparison to Background**

To place the NCP risk range of  $10^{-4}$  to  $10^{-6}$  (EPA, 1990d) in context, the incremental latent excess cancer risks due to contaminants at the site should be compared to several naturally occurring substances present both on and off site. Several naturally occurring substances present both on- and off-site present typical risks in the  $10^{-4}$  to  $10^{-5}$  range. Arsenic, radon progeny, and PAHs are some notable examples.

Arsenic is a naturally occurring trace element found in soils worldwide. Values averaging 7.2 ppm (range of less than 0.1 to 97 ppm) have been reported for United States soils (Adriano, 1986). At these natural levels, inhalation of resuspended particulates and inadvertent ingestion of surface soils typically results in an incremental cancer risks of approximately  $10^{-5}$ .

Naturally occurring radon gas occurs in the United States at an approximate average indoor concentration of 1 pCi/l. The estimated loss of life expectancy associated with this level of exposure is approximately 29 days, with a resulting life-time risk of approximately  $3 \times 10^{-5}$  (Cohen, 1991). EPA's recommended action guideline for homeowners of 4 pCi/l is four times

higher than this, and yields in an estimated loss of life expectancy of 110 days and an approximate lifetime excess cancer risk of  $10^{-4}$  (Cohen, 1991).

PAHs are introduced into the environment through both natural (e.g., forest and prairie fires) and anthropogenic (e.g., automobiles, charcoal broilers) incomplete combustion processes. Since PAHs are ubiquitous, humans are exposed to these chemicals throughout their lifetime. The predominant intake pathway for PAHs is through dietary ingestion, with primary sources being charcoal broiled meats and leafy vegetables (i.e., surface deposition of PAHs). Median daily intake has been estimated to be  $2.2 \mu\text{g}/\text{day}$  (Hattemer-Frey and Travis, 1991) and  $3.12 \mu\text{g}/\text{day}$  (Menzie, 1992), which results in a lifetime excess risk of approximately  $4\text{E-}04$  (Hattemer-Frey and Travis, 1991).

#### **F7.4.2      Expected Impact on the Community**

Although a risk assessment can estimate hypothetical numerical risks with regard to carcinogenic contaminants, there is no epidemiological (i.e., empirical) basis for expecting to observe any increases in incidence or fatality from the low risks typical of environmental levels.

This section describes the approach to determining collective risk for off-site and hypothetical on-site residential individuals. The collective risk to the population within 80 km of OU1, relative to the maximally exposed off-site individual risk, is assessed for the airborne contaminant dispersion pathway. The MILDOS-AREA code is used to model the dispersion of windblown contaminants from OU1 by using uranium-238 as a reference contaminant.

The 1989 population within 80 km of OU1 was obtained from DOE (1990a). The number of people in each of 16 compass directions and 10 radial distances (0-1, 1-2, 2-3, 3-4, 4-5, 5-10, 10-20, 20-30, 30-40, 40-50 miles) were entered in a spreadsheet. Since MILDOS-AREA does not allow the user to change the default radial distances used by the code, the population array had to be transformed accordingly. The population numbers in the original data were adjusted, using area-weighted scaling factors, to fit into the 12 radial distances required by the code (0-2, 2-3, 3-4, 4-5, 5-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80 km).

Six MILDOS-AREA simulations were performed, each assuming a unit concentration of uranium-238 in soil at OU1. Each simulation was performed over a separate radial population band: 0-5, 5-10, 10-20, 20-40, 40-60, and 60-80 km from the site. Figure F7-19 shows the number of people in each population band. The resulting collective dose for each population band, calculated by the code in person-rem, was converted to person-mrem and ratioed to the dose in mrem for the maximally exposed off-site individual. Assuming that the relationship between radiation dose and risk is linear, this ratio also represents the collective risk relative to the risk to the maximally exposed off-site individual, resulting in a set of population risk factors normalized to unit maximum individual risk. These normalized risk factors (NRF) were summed over the six radial population bands to obtain a total NRF for the population within 80 km of the site.

The collective NRF for each of the six population bands was divided by the population within each band to obtain a per-capita NRF in each population band. The total collective NRF was then divided by the total population to obtain a per-capita average NRF for the entire assessment area. It should be noted that these NRFs are valid for one year of exposure only (1989). They do not account for increases or decreases in population over the 30 years during which the individual is assumed to be exposed. If population changes are anticipated over a 30-year period, and such changes occur uniformly over the assessment region, the collective NRFs should be adjusted by the mean population during the 30-year assessment period. It should be noted that if population changes are uniform throughout the assessment region, the per-capita NRFs will not be affected; however, per-capita NRFs should be adjusted by the ratio of mean individual residence time to the 30-year residence time assumed for the maximally exposed off-site individual.

Figure F7-20 shows the collective NRFs for each population band and the total population, and Figure F7-21 shows the per-capita NRFs for each population band and the total population. As expected, per-capita risks shown in Figure F7-21 decrease as a function of distance due to atmospheric dispersion. Figure F7-20 is obtained by multiplying the population in each band

(Figure F7-19) by the per-capita risk (Figure F7-21). Table F7-28 shows the estimated collective and per-capita risks based on the calculated risk to the maximally exposed off-site individual.

Risk factors for radionuclides are based on fatalities while slope factors for nonradiological carcinogens are based on incidence. There are limitations to adding these risks, but an approximate method of summation is generally used in collective risk estimates. To calculate the estimated risk to the maximally exposed off-site individual, the sum of the radiological risks is added to one-half the sum of the nonradiological carcinogenic risks.

The estimated collective risks and per-capita risks based on the RME exposed off site individual are presented by radial distances and are shown in Table F7-30. The total collective off-site risk is  $7E-02$ .

Many epidemiologic studies have attempted to discern increased cancer rates in populations near nuclear facilities. A recent review of more than 40 radiological studies indicates that most papers reported at least one elevated disease rate in an area considered exposed to the nuclear facility, but clearly states that most of the studies have little chance of establishing causal relations between radiation exposure and elevations in cancer rates. This failure is due to the lack of strength in positive findings, usually borderline statistical significance, and a consistent disregard for the effect of low statistical power and substantial Type II (i.e., false negative) error probability. The difficulty in determining accurate individual radiation exposure, the fact that only a small portion of total radiation exposure comes from that source (i.e., the majority is received from natural background), and the relatively small number of cancer fatalities available in the population of interest compared to that required for adequate statistical analysis, prevent such studies from defining cause and effect relationships. The National Academy of Sciences (1990) cites an unquantifiable effect of selective reporting that increases the tendency of authors and editors to publish studies with positive findings. Thus, a clear picture of cancer risk from toxic agent exposures at low levels does not clearly emerge, and definitely does not result in easily noticeable increases in public health impacts (NAS, 1990).

### **F7.4.3      Epidemiological Evidence at Environmental Levels**

Increased human cancer mortality from uranium intake has been studied primarily in workers engaged in the uranium extraction industry. These studies focused on cancer types expected from inhalation of bone-seeking alpha emitters. The studies primarily relied on years of employment in the industry to determine intake and did not rely on measured uranium intake. These studies all have confounding factors such as simultaneous intake of radon daughter products, thorium isotopes, and other materials such as arsenic, silica, and vanadium. BEIR IV (NAS, 1980, p. 297) concludes as follows:

... these investigations have provided suggestive but not convincing evidence of deleterious human effects of chronic exposure to uranium dust.... Caution is required in the interpretation of these results as an indication of the absence of any effect. The surveys generally included a large number of workers who were exposed for only a short time, and environmental estimates were poor.

Risk estimates developed for uranium: (BEIR IV, p. 298)

...cannot be determined from published epidemiological studies because of confounding factors and because of the limited power of the surveys to detect increased rates of tumor incidence or mortality. For this reason, estimates have been based, by analogy, on the effects of other alpha-emitting elements in human populations and from experiments using uranium in animals.

As to the health effects of exposure to natural uranium (primarily low-specific-activity uranium-238); BEIR IV (p. 298) concludes that exposure to natural uranium is unlikely to be a significant health risk in the population and may well have no measurable effect.

Similarly, plutonium cancer rate increases have been examined through study of individuals occupationally exposed in the nuclear weapons production industry. Environmental level exposure does occur but occupational exposure is more likely to produce detectable health effects. BEIR IV (pp. 329 and 337) in summarizing this risk estimate determination, concludes that:

In the absence of adequate human epidemiological data, cancer risk for transuranic elements is usually estimated on the basis of human studies of other alpha-emitting radionuclides (e.g., uranium miners exposed to radon and its progeny, radium-dial painters, patients undergoing treatment with radium, or thorotrast-exposed patients) and of low linear energy transfer (LET) radiation exposures.... estimates of risk for transuranic elements cannot be derived from human epidemiological studies. Although risk estimates have been derived from experimental animals studies, they cannot readily be extrapolated to humans. Until problems associated with this extrapolation are resolved, the only acceptable alternative is to apply risk estimates derived from studies of human populations exposed to other alpha-emitting radionuclides.

#### **F7.4.4      Quantification of Human Carcinogenicity**

Since risk at low exposure levels cannot be measured directly either in laboratory animals or human epidemiology studies, mathematical models have been developed to extrapolate from high to low exposure levels. Various models have been proposed to extrapolate from high to low doses (i.e., to estimate the dose-response relationship at low doses). The three most frequently used models are (1) the one-hit model, (2) the log-probit model, and (3) the multistage model (Armitage and Doll, 1961). The one-hit model is based on the premise that a single molecule of a contaminant can be the single event that precipitates tumor induction (Cornfield, 1977). In other words, it is assumed that there is some finite response associated with any exposure. The log-probit model assumes that a response is normally distributed with the logarithm of the dose (Mantel et al., 1971). This theory seems to have little scientific basis, although some physiological parameters are lognormally distributed. This model usually yields much lower potency estimates due to the implied threshold at lower doses.

Regulatory decisions are based on the output of the linearized multistage model (EPA, 1986). The basis of the linearized multistage model is that multiple events (versus the single-event paradigm of the one-hit model) may be needed to yield tumor induction (Crump et al., 1977). The linearized multistage model reflects the biological variability in tumor frequencies observed in animals or human studies. The dose-response relationship predicted by this model at low doses is essentially linear.

Most models produce quantitatively similar results in the range of observable data, but yield estimates that can vary by three or four orders of magnitude at lower doses. Animal bioassay data are simply not adequate to determine whether any of the competing models are better than the others. Moreover, there is no evidence to indicate that the precision of low-dose risk estimates increases through the use of more sophisticated models. Thus, if a carcinogenic response occurs at the exposure level studied, it is assumed that a similar response will occur at all lower doses, unless evidence to the contrary exists.

## **F7.5 SUMMARY OF RISK CHARACTERIZATION**

Tables F7-29 and F7-30 summarize the major contributions for potential carcinogenic risks and noncarcinogenic HI values for each of the subject scenarios, respectively. Phase I, II, and III data analyses which were completed as of August 1993 are reflected in these evaluations.

As presented in this report, one of the principal risk-driving pathways is the inhalation of radionuclides. Concentration values for this pathway were not measured but were modeled using the MILDOS-AREA computer code. The source term, concentration in soil, used in the model can greatly affect the model output. For OU1, the radionuclide hot spot data were included in the OU-wide data using a simple average. This was done to be consistent with the method that the groundwater source (IHSS 119.1) was included with the OU-wide groundwater data. However, this method overestimates the impact of the small surface area of the hot spots on the model output. Although the exact areal extent of the hot spots is not defined, the field report (Appendix A5 of the RI Report) indicates that the four hot spots have a combined area less than 2 m<sup>2</sup>. When this area is compared to the area for OU1, approximately 80,000 m<sup>2</sup>, it can be seen that use of an area-weighted average would reduce the source term (and the model output) by approximately three orders of magnitude. The effects of this overestimation are reflected in the inhalation pathway risks for plutonium-239,240, americium-214, uranium-233,234, and uranium-238 for all scenarios except the future on-site resident scenario where the hot spot data were removed from the data set (Section F7.2.4 and Table F7-24). This is illustrated by comparing the risks from the scenario assuming a future on-site resident at the source and hot spots (Section F7.2.3.2), approximately 3E-02, with the risk for the future on-site resident scenario where the hot spot data were removed, 2E-05.

For the two current exposure scenarios evaluated, carcinogenic risks for Class A carcinogens are calculated to be within the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) target risk range of 1E-06 to 1E-04. All hazard indices are less than unity for both scenarios.

The risk calculated for exposure to Class A carcinogens for the current on-site worker is 1E-04, dominated by the inhalation of plutonium-239, 240 in windblown dust. The risk from exposure to Class B2 carcinogenic exposures is 6E-07, dominated by dermal contact with benzo(a)pyrene in surface soil. The hazard index of 8E-05 is dominated by dermal contact with fluoranthene in soil.

The risk calculated for Class A carcinogenic exposures to the current off-site resident is 2E-06, dominated by the inhalation of plutonium-239, 240 in windblown dust. The risk calculated from exposure to Class B2 carcinogens is 7E-10, primarily due to ingestion of PAHs on vegetables. The child hazard index of 1E-07 is dominated by the ingestion of garden grown vegetables contaminated by fluorene.

For the three standard exposure future scenarios evaluated, carcinogenic risk is calculated to be above the NCP target risk range. The noncarcinogenic impacts are calculated to be below the NCP target of unity for all three scenarios.

The risk calculated for Class A carcinogenic exposures to the future on-site office worker is 2E-03, dominated by the inhalation of plutonium-239, 240 in windblown dust. The risk calculated for Class C carcinogenic exposure is 2E-04, dominated by the inhalation of 1,1-dichloroethene volatilized through the foundation. Risk from exposure to B2 carcinogens is 2E-05. The hazard index of 3E-03 is dominated by the inhalation of 1,1,1-trichloroethane volatilized through the foundation.

The risk calculated for Class C carcinogenic exposures to the future on-site construction worker is 4E-07, dominated by the inhalation of 1,1-dichloroethene volatilized during excavation. The risk calculated for Class B2 carcinogenic exposure is 2E-08, dominated by the inhalation of carbon tetrachloride volatilized during excavation. Risk from exposure to A carcinogens is

5E-09. The hazard index of 1E-04 is dominated by the inhalation of 1,1,1-trichloroethane volatilized during excavation.

The risk calculated for Class A carcinogenic exposure to the future on-site ecological researcher is 2E-03, dominated by inhalation of plutonium-239, 240. The risk calculated for exposure to Class B2 carcinogens is 9E-06, dominated by dermal contact with benzo(a)pyrene in surface soil. The hazard index of 2E-03 is dominated by dermal contact with pyrene in surface soil.

The risk calculated for Class A carcinogenic exposure to the future on-site resident is 3E-03, dominated by the inhalation of plutonium-239,-240 dust. Risk from exposure to Class C carcinogens is 2E-04, dominated by the inhalation of 1,1-dichloroethene volatilized through the foundation. Risk from exposures to Class B2 carcinogens is 4E-05. The child hazard index of 2E-02 is dominated by the inhalation of 1,1,1-trichloroethane volatilized through the foundation.

For three of the four additional cases of the future on-site resident scenarios evaluated, carcinogenic risk is calculated to be above the NCP target risk range for three scenarios. The noncarcinogenic impacts are calculated to be below the NCP target of unity for one of the four scenarios.

The risk calculated for Class C carcinogenic exposure to the future on-site resident with groundwater ingestion is 3E-03, dominated by the ingestion of 1,1-dichloroethene in groundwater. Risk from exposure to Class A carcinogens is 3E-03, dominated by inhalation of plutonium-239,-240 dust. The risk from B2 carcinogens is 3E-04. The hazard indices of 9E+00 for the adult and 2E+01 for the child are dominated by the ingestion of carbon tetrachloride in the groundwater.

The risk calculated for Class C carcinogenic exposure to the future on-site resident assuming adequate supply of groundwater for use at the source (IHSS 119.1) is 4E-02, dominated by the ingestion of 1,1-dichloroethene in groundwater. Risk from exposure to Class A carcinogens is 3E-02, dominated by inhalation of plutonium-239,-240 dust. The risk from B2 carcinogens is 4E-03. The hazard indices of 1E+02 for the adult and 3E+02 for the child are dominated by the ingestion of carbon tetrachloride in the groundwater.

The risk calculated for Class A carcinogenic exposure to the future on-site resident with groundwater use at the source (IHSS 119.1) augmented with public water is  $3E-02$ , dominated by inhalation of plutonium-239,-240 dust. The risk from C carcinogens is  $4E-02$ , dominated by the inhalation of 1,1-dichloroethene volatilized through the foundation. The risk from exposure to Class B2 carcinogens is  $5E-04$ . The hazard indices of  $1E+01$  for the adult and  $3E+01$  for the child are dominated by the ingestion of carbon tetrachloride in the groundwater.

The risk calculated for Class B2 carcinogenic exposure to the future on-site resident without the source (IHSS 119.1) is  $3E-05$ , dominated by the ingestion of home grown produce containing dibenzo(a,h)anthracene. The risk for Class A carcinogens is  $2E-05$ , dominated by the inhalation of plutonium-239,-240 dust. The risk for Class C carcinogens is  $8E-07$ . The hazard indices of  $3E-03$  for the adult and  $7E-03$  for the child is dominated by the ingestion of fluorene in vegetables.

The quantification of uncertainty is an important component of the risk assessment process. According to the EPA *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, point estimates of risk "do not fully convey the range of information considered and used in developing the assessment" (EPA, 1992d). Furthermore, the guidance states that the Monte Carlo simulation may be used to estimate descriptive risk percentiles. To provide information about the uncertainties associated with the RME estimate and the relation of the RME estimate relative to other percentiles of the risk distribution, uncertainties were identified during the PHE process and are presented in both qualitative and quantitative terms.

Uncertainties in this risk assessment are due to uncertainties in the risk assessment process in general, specific uncertainties in characterizing the site, and the uncertainties associated with accurately describing exposures. Table F7-27 summarizes the uncertainties and limitations in this assessment. One approach to address this uncertainty is to use health-protective assumptions.

Health-protective assumptions are those that systematically overstate the magnitude of health risks such that even with errors due to uncertainty in the methodology, actual health risks are expected less than those calculated. This process bounds the plausible upper limits of risk and facilitates an informed risk management decision.

The quantitative uncertainty analysis characterizes the propagated uncertainty in public health risk through the pathway and contaminant that dominates the risk in the future on-site resident scenario. These uncertainties are driven by uncertainty in the chemical monitoring data, the transport models used to estimate concentrations at receptor locations, receptor intake parameters, and the toxicity values used to characterize risk. Additionally, uncertainties are introduced in the risk assessment when exposures to several substances across multiple pathways are summed.

Quantitative evaluations of 1,1-dichloroethene and carbon tetrachloride were performed for the hypothetical future on-site residential scenario and are provided in Table F7-31. For example, the range of the total risk for 1,1-dichloroethene inhalation pathway, spans almost six orders of magnitude, from the 5th percentile of  $9E-11$  to the 95th percentile of  $7E-05$ , while the central tendency is indicated by the 50th percentile of  $6E-08$ . The Monte Carlo simulations indicate that the calculated sitewide RME value is higher than the 95th percentile value for 1,1-dichloroethene, but lower for carbon tetrachloride.

The special cases of risk under residential use at the source (IHSS 119.1) and risk without the source (the site excluding IHSS 119.1) are provided to indicate the impact of the localized contaminants in IHSS 119.1. The site without the source refers to the absence of IHSS 119.1 ground-water volatiles and the elevated surface soil radionuclides collected early in 1993. The risk directly over IHSS 119.1 from these three pathways is estimated to be  $4E-02$ , which is greater than the 95th percentile of the sitewide residential risk. The risk associated with the site without the source for these three pathways is estimated to be  $8E-07$ , which is less than the 95th percentile of the sitewide residential risk.

To place the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) risk range of  $10^{-4}$  to  $10^{-6}$  (EPA, 1990c) in context, the incremental latent excess cancer risks due to

contaminants at the site should be compared to several naturally occurring substances present both on and off site. Several naturally occurring substances present both on- and off-site present typical risks in the  $10^{-4}$  to  $10^{-5}$  range. Arsenic, radon progeny, and PAHs (from natural and anthropogenic combustion) are some notable examples.

Cancer incidence in the Denver metropolitan area not associated with the site is 0.33 (CDH, 1991). In other words, one person in three living in the Denver metropolitan area will get cancer before the age of 75. The potential lifetime cancer risk to hypothetical on-site residential receptors directly attributable to the source at the site under "reasonable maximum exposure" conditions at some time in the future has many unquantified uncertainties, including the degree of confidence that residential use of the site would ever be permitted. Therefore, the impacts calculated under the on-site residential land use scenario are extremely conservative; actual exposure, even under plausible future use scenarios, is expected to be lower.

Information regarding the uncertainty in quantifying intakes, toxicological and carcinogenic response, credibility of future exposure scenarios, and the magnitude of "background" risks, will be used by the risk manager for regulatory decision making.

Table F7-1. RME Carcinogenic Risk - Current On-Site Worker (Security Specialist)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	----
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	----
Acenaphthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(a)anthracene	-	2.6E-09	NA	NA	1.5E-08	NA	NA	-	NA	1.8E-08
Benzo(a)pyrene	-	2.5E-08	NA	NA	1.4E-07	NA	NA	-	NA	1.7E-07
Benzo(b)fluoranthene	-	2.5E-09	9.9E-10	NA	1.4E-08	5.7E-09	NA	-	NA	2.4E-08
Benzo(k)fluoranthene	-	2.4E-09	9.8E-10	NA	1.4E-08	5.7E-09	NA	-	NA	2.3E-08
Aroclor-1254	-	1.9E-08	1.4E-08	NA	1.1E-07	7.9E-08	NA	-	NA	2.2E-07
Fluorene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Dibenzo(a,h)anthracene	-	1.5E-08	NA	NA	8.9E-08	NA	NA	-	NA	1.0E-07
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	----
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Uranium-233,234	-	1.0E-09	1.8E-13	1.3E-13	NA	NA	NA	-	2.5E-07	2.5E-07
Uranium-238	-	8.8E-10	2.9E-13	4.4E-13	NA	NA	NA	-	2.3E-07	2.4E-07
Americium-241	-	1.1E-06	7.6E-14	2.2E-14	NA	NA	NA	-	2.0E-05	2.1E-05
Plutonium-239,-240	-	3.6E-06	6.0E-12	6.3E-15	NA	NA	NA	-	8.5E-05	8.9E-05

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS	
CLASS A CARCINOGENS	1.1E-04
CLASS B2 CARCINOGENS	5.6E-07
CLASS C CARCINOGENS	0.0E+00
<b>Total Risk:</b>	<b>1.1E-04</b>

Table F7-2. RME Noncarcinogenic Hazard Indices - Current On-Site Worker (Security Specialist)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	----
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	----
Acenaphthene	-	1.0E-07	NA	NA	4.7E-06	NA	NA	-	NA	4.8E-06
Fluoranthene	-	5.7E-07	8.9E-08	NA	2.6E-05	4.1E-06	NA	-	NA	3.1E-05
Benzo(a)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(a)pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(b)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(k)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Aroclor-1254	-	NA	NA	NA	NA	NA	NA	-	NA	----
Fluorene	-	1.5E-07	NA	NA	7.0E-06	NA	NA	-	NA	7.1E-06
Pyrene	-	6.9E-07	1.2E-07	NA	3.2E-05	5.5E-06	NA	-	NA	3.8E-05
Dibenzo(a,b)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	----
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Uranium-233,234	-	NA	NA	NA	NA	NA	NA	-	NA	----
Uranium-238	-	NA	NA	NA	NA	NA	NA	-	NA	----
Americium-241	-	NA	NA	NA	NA	NA	NA	-	NA	----
Plutonium-239,-240	-	NA	NA	NA	NA	NA	NA	-	NA	----

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	3.8E-05
HEPATIC	4.8E-06
KIDNEY	3.8E-05
LUNG	0.0E+00
CNS	0.0E+00
<b>Total HI:</b>	<b>8.1E-05</b>

Table F7-3. Comparison to Occupational Guidelines - Current On-Site Worker (Security Specialist)  
(Sitewide)

Chemical	Concentrations in On-site Air (Outdoor) ( $\mu\text{g}/\text{m}^3$ ) <sup>1</sup>	TWA ( $\text{mg}/\text{m}^3$ ) <sup>2</sup>	TLVs ( $\text{mg}/\text{m}^3$ ) <sup>3</sup>	Annual Intake (pCi/yr) <sup>4</sup>	Dose Conversion Factor (mrem/pCi) <sup>5</sup>	Committed Effective Dose Equivalent (mrem)	Dose Limit (mrem/year) <sup>6</sup>
1,1-Dichloroethene	-	-	2.00E+01	-	-	-	-
Carbon Tetrachloride	-	-	3.10E+01	-	-	-	-
Tetrachloroethene	-	-	3.39E+02	-	-	-	-
1,1,1-Trichloroethane	-	-	1.91E+03	-	-	-	-
Acenaphthene	6.96E-08	4.35E-09	-	-	-	-	-
Fluoranthene	2.61E-07	1.63E-08	-	-	-	-	-
Benzo(a)anthracene	1.14E-07	7.13E-09	-	-	-	-	-
Benzo(a)pyrene	1.09E-07	6.81E-09	-	-	-	-	-
Benzo(b)fluoranthene	1.09E-07	6.81E-09	-	-	-	-	-
Benzo(k)fluoranthene	1.04E-07	6.50E-09	-	-	-	-	-
Dibenzo(a,h)anthracene	6.76E-08	4.23E-09	-	-	-	-	-
AROCLOR-1254	9.90E-08	6.19E-09	5.00E-01	-	-	-	-
Fluorene	6.89E-08	4.31E-09	-	-	-	-	-
Pyrene	1.25E-07	7.81E-09	-	-	-	-	-
Americium-241	7.95E-02	4.97E-03	-	2.56E+01	5.20E-01	1.33E+01	5.00E+03
Plutonium-239,-240	2.80E-01	1.75E-02	-	8.80E+01	5.20E-01	4.58E+01	5.00E+03
Uranium-233,-234	1.17E-03	7.31E-05	-	3.76E-01	1.30E-01	4.89E-02	5.00E+03
Uranium-238	5.64E-04	3.53E-05	-	1.80E-01	1.20E-01	2.16E-02	5.00E+03

<sup>0</sup> = chemical units in mg, radionuclide units in pCi

<sup>2</sup> Time Weighted Average - 0.5 hours per 8 hour workday

<sup>3</sup> Threshold Limit Values 1991-1992, American Conference of Governmental Industrial Hygienists

<sup>4</sup> estimated in Table 5-16

<sup>5</sup> DOE EH-0071

<sup>6</sup> Dose limits for non-radiation workers, DOE 5400.5

- = not available or applicable

Table F7-4. RME Carcinogenic Risk - Current Off-Site Resident (Adult)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	-	-	NA	-	-	-	NA	----
Carbon Tetrachloride	NA	NA	-	-	NA	-	-	-	NA	----
Tetrachloroethene	NA	NA	-	-	NA	-	-	-	NA	----
1,1,1-Trichloroethane	NA	NA	-	-	NA	-	-	-	NA	----
Acenaphthene	NA	NA	-	-	NA	-	-	-	NA	----
Fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(a)anthracene	3.9E-11	2.3E-12	-	-	6.6E-12	-	-	-	NA	4.8E-11
Benzo(a)pyrene	4.1E-11	2.2E-11	-	-	6.3E-11	-	-	-	NA	1.3E-10
Benzo(b)fluoranthene	4.4E-12	2.2E-12	-	-	6.3E-12	-	-	-	NA	1.3E-11
Benzo(k)fluoranthene	3.1E-12	2.1E-12	-	-	6.0E-12	-	-	-	NA	1.1E-11
Aroclor-1254	1.2E-10	2.1E-11	-	-	6.0E-11	-	-	-	NA	2.0E-10
Fluorene	NA	NA	-	-	NA	-	-	-	NA	----
Pyrene	NA	NA	-	-	NA	-	-	-	NA	----
Dibenzo(a,h)anthracene	2.3E-10	1.4E-11	-	-	3.9E-11	-	-	-	NA	2.9E-10
Selenium	NA	NA	-	-	NA	-	-	-	NA	----
Toluene	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-233,234	1.4E-11	9.2E-13	-	-	NA	-	-	-	5.0E-09	5.1E-09
Uranium-238	1.2E-11	7.7E-13	-	-	NA	-	-	-	4.7E-09	4.7E-09
Americium-241	1.3E-08	9.3E-10	-	-	NA	-	-	-	4.0E-07	4.2E-07
Plutonium-239,-240	4.9E-08	3.1E-09	-	-	NA	-	-	-	1.7E-06	1.7E-06

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS	
CLASS A CARCINOGENS	2.2E-06
CLASS B2 CARCINOGENS	6.8E-10
CLASS C CARCINOGENS	0.0E+00
<b>Total Risk:</b>	<b>2.2E-06</b>

Table F7-5. RMB Noncarcinogenic Hazard Indices - Current Off-Site Resident (Adult)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	-	-	NA	-	-	-	NA	----
Carbon Tetrachloride	NA	NA	-	-	NA	-	-	-	NA	----
Tetrachloroethene	NA	NA	-	-	NA	-	-	-	NA	----
1,1,1-Trichloroethane	NA	NA	-	-	NA	-	-	-	NA	----
Acenaphthene	1.2E-08	9.2E-11	-	-	2.1E-09	-	-	-	NA	1.5E-08
Fluoranthene	5.1E-09	5.2E-10	-	-	1.2E-08	-	-	-	NA	1.8E-08
Benzo(a)anthracene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(a)pyrene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(b)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(k)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Aroclor-1254	NA	NA	-	-	NA	-	-	-	NA	----
Fluorene	1.6E-08	1.4E-10	-	-	3.2E-09	-	-	-	NA	1.9E-08
Pyrene	4.3E-09	3.3E-10	-	-	7.7E-09	-	-	-	NA	1.2E-08
Dibenzo(a,h)anthracene	NA	NA	-	-	NA	-	-	-	NA	----
Selenium	NA	NA	-	-	NA	-	-	-	NA	----
Toluene	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-233,234	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-238	NA	NA	-	-	NA	-	-	-	NA	----
Americium-241	NA	NA	-	-	NA	-	-	-	NA	----
Plutonium-239,-240	NA	NA	-	-	NA	-	-	-	NA	----

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:

BLOOD 3.7E-08  
 HEPATIC 1.5E-08  
 KIDNEY 1.2E-08  
 LUNG 0.0E+00  
 CNS 0.0E+00

Total HI: 6.4E-08

Table F7-6. RME Noncarcinogenic Hazard Indices - Current Off-Site Resident (Child)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	-	-	NA	-	-	-	NA	----
Carbon Tetrachloride	NA	NA	-	-	NA	-	-	-	NA	----
Tetrachloroethene	NA	NA	-	-	NA	-	-	-	NA	----
1,1,1-Trichloroethane	NA	NA	-	-	NA	-	-	-	NA	----
Acenaphthene	2.9E-08	8.6E-10	-	-	4.0E-09	-	-	-	NA	3.4E-08
Fluoranthene	1.2E-08	4.9E-09	-	-	2.2E-08	-	-	-	NA	3.9E-08
Benzo(a)anthracene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(a)pyrene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(b)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Benzo(k)fluoranthene	NA	NA	-	-	NA	-	-	-	NA	----
Aroclor-1254	NA	NA	-	-	NA	-	-	-	NA	----
Fluorene	3.7E-08	1.3E-09	-	-	5.9E-09	-	-	-	NA	4.4E-08
Pyrene	1.0E-08	3.1E-09	-	-	1.4E-08	-	-	-	NA	2.7E-08
Dibenzo(a,h)anthracene	NA	NA	-	-	NA	-	-	-	NA	----
Selenium	NA	NA	-	-	NA	-	-	-	NA	----
Toluene	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-233,234	NA	NA	-	-	NA	-	-	-	NA	----
Uranium-238	NA	NA	-	-	NA	-	-	-	NA	----
Americium-241	NA	NA	-	-	NA	-	-	-	NA	----
Plutonium-239,-240	NA	NA	-	-	NA	-	-	-	NA	----

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	8.3E-08
HEPATIC	3.4E-08
KIDNEY	2.7E-08
LUNG	0.0E+00
CNS	0.0E+00
<b>Total HI:</b>	<b>1.4E-07</b>

Table F7-7a. RMB Carcinogenic Risk - Future On-Site Worker (Office)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Inhalation of Const Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	2.3E-04	NA	-	2.3E-04
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	1.0E-05	NA	-	1.0E-05
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	2.3E-07	NA	-	2.3E-07
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Acenaphthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Fluoranthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Benzo(a)anthracene	-	4.0E-08	NA	NA	2.3E-07	NA	NA	NA	NA	-	2.8E-07
Benzo(a)pyrene	-	3.9E-07	NA	NA	2.2E-06	NA	NA	NA	NA	-	2.6E-06
Benzo(b)fluoranthene	-	3.9E-08	9.9E-10	NA	2.3E-07	5.7E-09	NA	NA	NA	-	2.7E-07
Benzo(k)fluoranthene	-	3.7E-08	9.8E-10	NA	2.1E-07	5.7E-09	NA	NA	NA	-	2.6E-07
Aroclor-1254	-	2.9E-07	2.1E-07	NA	1.7E-06	1.2E-06	NA	NA	NA	-	3.4E-06
Fluorene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Pyrene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Dibenzo(a,h)anthracene	-	2.4E-07	NA	NA	1.4E-06	NA	NA	NA	NA	-	1.6E-06
Selenium	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Toluene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Uranium-233,234	-	1.6E-08	1.8E-13	1.3E-13	NA	NA	NA	NA	3.9E-06	-	4.0E-06
Uranium-238	-	1.4E-08	2.9E-13	4.4E-13	NA	NA	NA	NA	3.7E-06	-	3.7E-06
Americium-241	-	1.7E-05	7.6E-14	2.2E-14	NA	NA	NA	NA	3.2E-04	-	3.3E-04
Plutonium-239,-240	-	5.6E-05	6.0E-12	6.3E-15	NA	NA	NA	NA	1.3E-03	-	1.4E-03

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS:	
CLASS A CARCINOGENS	1.7E-03
CLASS B2 CARCINOGENS	1.9E-05
CLASS C CARCINOGENS	2.3E-04
<b>Total Risk:</b>	<b>2.0E-03</b>

Table F7-7b. RME Carcinogenic Risk - Future On-Site Worker (Construction)

Chemical	Ingestion of Vegetables	Ingestion of SubSoil	Ingestion of Surf. Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact SubSoil	Dermal Contact Surf. Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Inhalation of Const Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	-	-	NA	NA	-	-	3.6E-07	-	NA	3.6E-07
Carbon Tetrachloride	-	NA	NA	-	-	NA	NA	-	-	1.6E-08	-	NA	1.6E-08
Tetrachloroethene	-	NA	NA	-	-	NA	NA	-	-	3.7E-10	-	NA	3.7E-10
1,1,1-Trichloroethane	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Acenaphthene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Fluoranthene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Benzo(a)anthracene	-	NA	2.7E-12	-	-	NA	1.6E-11	-	-	NA	-	NA	1.8E-11
Benzo(a)pyrene	-	NA	2.6E-11	-	-	NA	1.5E-10	-	-	NA	-	NA	1.8E-10
Benzo(b)fluoranthene	-	NA	2.6E-12	-	-	NA	1.5E-11	-	-	NA	-	NA	1.8E-11
Benzo(k)fluoranthene	-	NA	2.5E-12	-	-	NA	1.4E-11	-	-	NA	-	NA	1.7E-11
Aroclor-1254	-	NA	1.9E-11	-	-	NA	1.1E-10	-	-	NA	-	NA	1.3E-10
Fluorene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Pyrene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Dibenzo(a,h)anthracene	-	NA	1.6E-11	-	-	NA	9.4E-11	-	-	NA	-	NA	1.1E-10
Selenium	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Toluene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Uranium-233,234	-	1.5E-12	1.1E-12	-	-	NA	NA	-	-	NA	-	2.0E-12	4.6E-12
Uranium-238	-	8.7E-13	9.2E-13	-	-	NA	NA	-	-	NA	-	1.3E-12	3.1E-12
Americium-241	-	1.5E-10	1.1E-09	-	-	NA	NA	-	-	NA	-	1.6E-11	1.3E-09
Plutonium-239,-240	-	4.2E-10	3.8E-09	-	-	NA	NA	-	-	NA	-	5.5E-11	4.2E-09

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS:	
CLASS A CARCINOGENS	5.5E-09
CLASS B2 CARCINOGENS	1.7E-08
CLASS C CARCINOGENS	3.6E-07
<b>Total Risk:</b>	<b>3.8E-07</b>

Table F7-8a. RMB Noncarcinogenic Hazard Indices - Future On-Site Worker (Office)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Inhalation of Const Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	1.9E-03	NA	-	1.9E-03
Acenaphthene	-	1.6E-06	NA	NA	7.3E-05	NA	NA	NA	NA	-	7.5E-05
Fluoranthene	-	8.9E-06	8.9E-08	NA	4.1E-04	4.1E-06	NA	NA	NA	-	4.3E-04
Benzo(a)anthracene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Benzo(a)pyrene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Benzo(b)fluoranthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Benzo(k)fluoranthene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Aroclor-1254	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Fluorene	-	2.3E-06	NA	NA	1.1E-04	NA	NA	NA	NA	-	1.1E-04
Pyrene	-	1.1E-05	1.2E-07	NA	5.0E-04	5.5E-06	NA	NA	NA	-	5.2E-04
Dibenzo(a,h)anthracene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Selenium	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Toluene	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Uranium-233,234	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Uranium-238	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Americium-241	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---
Plutonium-239,-240	-	NA	NA	NA	NA	NA	NA	NA	NA	-	---

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	5.4E-04
HEPATIC	7.5E-05
KIDNEY	5.2E-04
LUNG	0.0E+00
CNS	1.9E-03
<b>Total HI:</b>	<b>3.0E-03</b>

Table P7-8b. RMB Noncarcinogenic Hazard Indices - Future On-Site Worker (Construction)

Chemical	Ingestion of Vegetables	Ingestion of SubSoil	Ingestion of Surf. Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact SubSoil	Dermal Contact Surf. Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Inhalation of Const Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Carbon Tetrachloride	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Tetrachloroethene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
1,1,1-Trichloroethane	-	NA	NA	-	-	NA	NA	-	-	7.4E-05	-	NA	7.4E-05
Acenaphthene	-	NA	6.6E-08	-	-	NA	3.1E-06	-	-	NA	-	NA	3.1E-06
Fluoranthene	-	1.8E-07	3.7E-07	-	-	8.3E-06	1.7E-05	-	-	NA	-	NA	2.6E-05
Benzo(a)anthracene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Benzo(a)pyrene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Benzo(b)fluoranthene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Benzo(k)fluoranthene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Aroclor-1254	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Fluorene	-	NA	9.8E-08	-	-	NA	4.5E-06	-	-	NA	-	NA	4.6E-06
Pyrene	-	2.3E-07	4.5E-07	-	-	1.1E-05	2.1E-05	-	-	NA	-	NA	3.2E-05
Dibenzo(a,h)anthracene	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Selenium	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Toluene	-	1.2E-08	NA	-	-	5.8E-07	NA	-	-	NA	-	5.5E-10	5.9E-07
Uranium-233,234	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Uranium-238	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Americium-241	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---
Plutonium-239,-240	-	NA	NA	-	-	NA	NA	-	-	NA	-	NA	---

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	3.1E-05
HEPATIC	3.7E-06
KIDNEY	3.2E-05
LUNG	0.0E+00
CNS	7.4E-05
<b>Total HI: 1.4E-04</b>	

Table F7-9. Comparison to Occupational Guidelines - Future On-Site Worker (Office)  
(Sitewide)

Chemical	Concentrations in On-site Air (Indoor) (mg/m <sup>3</sup> ) <sup>1</sup>	Concentrations in On-site Air (Outdoor) ( <sup>μ</sup> m <sup>3</sup> ) <sup>1</sup>	TLVs (mg/m <sup>3</sup> ) <sup>2</sup>	Annual Intake (pCi/yr) <sup>3</sup>	Dose Conversion Factor (mrem/pCi) <sup>4</sup>	Committed Effective Dose Equivalent (mrem)	Dose Limit (mrem/year) <sup>5</sup>
1,1-Dichloroethene	1.84E-02	-	2.00E+01	-	-	-	-
Carbon Tetrachloride	2.79E-03	-	3.10E+01	-	-	-	-
Tetrachloroethene	1.61E-03	-	3.39E+02	-	-	-	-
1,1,1-Trichloroethane	2.84E-02	-	1.91E+03	-	-	-	-
Acenaphthene	-	6.96E-08	-	-	-	-	-
Fluoranthene	-	2.61E-07	-	-	-	-	-
Benzo(a)anthracene	-	1.14E-07	-	-	-	-	-
Benzo(a)pyrene	-	1.09E-07	-	-	-	-	-
Benzo(b)fluoranthene	-	1.09E-07	-	-	-	-	-
Benzo(k)fluoranthene	-	1.04E-07	-	-	-	-	-
Dibenzo(a,h)anthracene	-	6.76E-08	-	-	-	-	-
AROCOR-1254	-	9.90E-08	5.00E-01	-	-	-	-
Fluorene	-	6.89E-08	-	-	-	-	-
Pyrene	-	1.25E-07	-	-	-	-	-
Americium-241	-	7.95E-02	-	3.96E+02	5.20E-01	2.06E+02	1.00E+02
Plutonium-239,-240	-	2.80E-01	-	1.40E+03	5.20E-01	7.28E+02	1.00E+02
Uranium-233,-234	-	1.17E-03	-	6.00E+00	1.30E-01	7.80E-01	1.00E+02
Uranium-238	-	5.64E-04	-	2.84E+00	1.20E-01	3.41E-01	1.00E+02

<sup>0</sup> = chemical units in mg, radionuclide units in pCi

<sup>1</sup> Threshold Limit Values 1991-1992, American Conference of Governmental Industrial Hygienists

<sup>2</sup> estimated in Table 5-16

<sup>4</sup> DOE EH-0071

<sup>5</sup> Dose limits for non-radiation workers, DOE 5400.5

- = not available or applicable

Table F7-10. RME Carcinogenic Risk – Future On-Site Ecological Researcher

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	----
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	----
Acenaphthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(a)anthracene	-	4.0E-08	NA	NA	2.3E-07	NA	NA	-	NA	2.8E-07
Benzo(a)pyrene	-	3.9E-07	NA	NA	2.2E-06	NA	NA	-	NA	2.6E-06
Benzo(b)fluoranthene	-	3.9E-08	3.5E-08	NA	2.3E-07	2.0E-07	NA	-	NA	5.0E-07
Benzo(k)fluoranthene	-	3.7E-08	3.5E-08	NA	2.1E-07	2.0E-07	NA	-	NA	4.9E-07
Aroclor-1254	-	2.9E-07	2.1E-07	NA	1.7E-06	1.2E-06	NA	-	NA	3.4E-06
Fluorene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Dibenzo(a,h)anthracene	-	2.4E-07	NA	NA	1.4E-06	NA	NA	-	NA	1.6E-06
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	----
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Uranium-233,234	-	1.6E-08	6.5E-12	4.7E-12	NA	NA	NA	-	3.9E-06	4.0E-06
Uranium-238	-	1.4E-08	1.0E-11	1.6E-11	NA	NA	NA	-	3.7E-06	3.7E-06
Americium-241	-	1.7E-05	2.7E-12	7.7E-13	NA	NA	NA	-	3.2E-04	3.3E-04
Plutonium-239,-240	-	5.6E-05	2.1E-10	2.2E-13	NA	NA	NA	-	1.3E-03	1.4E-03

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS	
CLASS A CARCINOGENS	1.7E-03
CLASS B2 CARCINOGENS	8.9E-06
CLASS C CARCINOGENS	0.0E+00
<b>Total Risk:</b>	<b>1.7E-03</b>

Table F7-11. RME Noncarcinogenic Hazard Indices - Future On-Site Ecological Researcher

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Carbon Tetrachloride	-	NA	NA	NA	NA	NA	NA	-	NA	----
Tetrachloroethene	-	NA	NA	NA	NA	NA	NA	-	NA	----
1,1,1-Trichloroethane	-	NA	NA	NA	NA	NA	NA	-	NA	----
Acenaphthene	-	1.6E-06	NA	NA	7.3E-05	NA	NA	-	NA	7.5E-05
Fluoranthene	-	8.9E-06	3.2E-06	NA	4.1E-04	1.5E-04	NA	-	NA	5.7E-04
Benzo(a)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(a)pyrene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(b)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Benzo(k)fluoranthene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Aroclor-1254	-	NA	NA	NA	NA	NA	NA	-	NA	----
Fluorene	-	2.3E-06	NA	NA	1.1E-04	NA	NA	-	NA	1.1E-04
Pyrene	-	1.1E-05	4.2E-06	NA	5.0E-04	2.0E-04	NA	-	NA	7.1E-04
Dibenzo(a,h)anthracene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Selenium	-	NA	NA	NA	NA	NA	NA	-	NA	----
Toluene	-	NA	NA	NA	NA	NA	NA	-	NA	----
Uranium-233,234	-	NA	NA	NA	NA	NA	NA	-	NA	----
Uranium-238	-	NA	NA	NA	NA	NA	NA	-	NA	----
Americium-241	-	NA	NA	NA	NA	NA	NA	-	NA	----
Plutonium-239,-240	-	NA	NA	NA	NA	NA	NA	-	NA	----

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	6.8E-04
HEPATIC	7.5E-05
KIDNEY	7.1E-04
LUNG	0.0E+00
CNS	0.0E+00
<b>Total HI:</b>	<b>1.5E-03</b>

Table F7-12. RME Carcinogenic Risk – Future On-Site Resident (Adult)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	2.3E-04	NA	2.3E-04
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	1.0E-05	NA	1.0E-05
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	2.3E-07	NA	2.3E-07
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	1.9E-06	1.1E-07	NA	NA	3.2E-07	NA	NA	NA	NA	2.3E-06
Benzo(a)pyrene	1.9E-06	1.0E-06	NA	NA	3.0E-06	NA	NA	NA	NA	6.0E-06
Benzo(b)fluoranthene	2.1E-07	1.0E-07	1.9E-09	NA	3.0E-07	5.5E-09	NA	NA	NA	6.2E-07
Benzo(k)fluoranthene	1.5E-07	9.9E-08	1.9E-09	NA	2.9E-07	5.4E-09	NA	NA	NA	5.4E-07
Aroclor-1254	5.5E-06	7.8E-07	1.2E-08	NA	2.3E-06	3.3E-08	NA	NA	NA	8.6E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.1E-05	6.5E-07	NA	NA	1.9E-06	NA	NA	NA	NA	1.4E-05
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	8.6E-08	4.4E-08	3.5E-13	3.2E-10	NA	NA	NA	NA	5.3E-06	5.4E-06
Uranium-238	7.2E-08	3.7E-08	5.5E-13	1.1E-09	NA	NA	NA	NA	4.9E-06	5.0E-06
Americium-241	2.9E-05	4.5E-05	1.5E-13	5.2E-11	NA	NA	NA	NA	4.3E-04	5.0E-04
Plutonium-239,-240	2.6E-04	1.5E-04	1.1E-11	1.5E-11	NA	NA	NA	NA	1.8E-03	2.2E-03

NA = not a COC for this medium or no toxicity factor is available

-- = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS	
CLASS A CARCINOGENS	2.7E-03
CLASS B2 CARCINOGENS	4.2E-05
CLASS C CARCINOGENS	2.3E-04
<b>Total Risk:</b>	<b>3.0E-03</b>

Table F7-13. RME Noncarcinogenic Hazard Indices -- Future On-Site Resident (Adult)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.9E-03	NA	1.9E-03
Acenaphthene	5.9E-04	4.4E-06	NA	NA	1.0E-04	NA	NA	NA	NA	7.0E-04
Fluoranthene	2.4E-04	2.5E-05	1.8E-07	NA	5.8E-04	4.1E-06	NA	NA	NA	8.5E-04
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	7.6E-04	6.6E-06	NA	NA	1.5E-04	NA	NA	NA	NA	9.2E-04
Pyrene	2.0E-04	3.0E-05	2.4E-07	NA	7.0E-04	5.5E-06	NA	NA	NA	9.4E-04
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium or no toxicity factor is available  
 -- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	1.8E-03
HEPATIC	7.0E-04
KIDNEY	9.4E-04
LUNG	0.0E+00
CNS	1.9E-03
<b>Total HI:</b>	<b>5.4E-03</b>

Table F7-14. RME Noncarcinogenic Hazard Indices - Future On-Site Resident (Child)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.2E-02	NA	1.2E-02
Acenaphthene	1.4E-03	4.1E-05	NA	NA	1.9E-04	NA	NA	NA	NA	1.6E-03
Fluoranthene	5.6E-04	2.3E-04	1.7E-06	NA	1.1E-03	7.6E-06	NA	NA	NA	1.9E-03
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	1.8E-03	6.1E-05	NA	NA	2.8E-04	NA	NA	NA	NA	2.1E-03
Pyrene	4.8E-04	2.8E-04	2.2E-06	NA	1.3E-03	1.0E-05	NA	NA	NA	2.1E-03
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium or no toxicity factor is available

- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	4.0E-03
HEPATIC	1.6E-03
KIDNEY	2.1E-03
LUNG	0.0E+00
CNS	1.2E-02
<b>Total HI:</b>	<b>2.0E-02</b>

Table F7-15. RME Carcinogenic Risk - Future On-Site Resident (Adult)  
(Sitewide With Groundwater)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Grndwater	Dermal Contact Grndwater	Inhalation Volatiles Grndwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	2.3E-04	NA	2.5E-03	9.4E-05	3.0E-06	2.8E-03
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	1.0E-05	NA	1.7E-04	8.6E-06	2.7E-07	1.9E-04
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	2.3E-07	NA	7.5E-05	8.4E-06	1.2E-08	8.4E-05
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	1.9E-06	1.1E-07	NA	NA	3.2E-07	NA	NA	NA	NA	NA	NA	NA	2.3E-06
Benzo(a)pyrene	1.9E-06	1.0E-06	NA	NA	3.0E-06	NA	NA	NA	NA	NA	NA	NA	6.0E-06
Benzo(b)fluoranthene	2.1E-07	1.0E-07	1.9E-09	NA	3.0E-07	5.5E-09	NA	NA	NA	NA	NA	NA	6.2E-07
Benzo(k)fluoranthene	1.5E-07	9.9E-08	1.9E-09	NA	2.9E-07	5.4E-09	NA	NA	NA	NA	NA	NA	5.4E-07
Aroclor-1254	5.5E-06	7.8E-07	1.2E-08	NA	2.3E-06	3.3E-08	NA	NA	NA	NA	NA	NA	8.6E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.1E-05	6.5E-07	NA	NA	1.9E-06	NA	NA	NA	NA	NA	NA	NA	1.4E-05
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	8.6E-08	4.4E-08	3.5E-13	3.2E-10	NA	NA	NA	NA	5.3E-06	NA	NA	NA	5.4E-06
Uranium-238	7.2E-08	3.7E-08	4.4E-13	1.1E-09	NA	NA	NA	NA	4.9E-06	NA	NA	NA	5.0E-06
Americium-241	2.9E-05	4.5E-05	1.5E-13	5.2E-11	NA	NA	NA	NA	4.3E-04	NA	NA	NA	5.0E-04
Plutonium-239,-240	2.6E-04	1.5E-04	1.1E-11	1.5E-11	NA	NA	NA	NA	1.8E-03	NA	NA	NA	2.2E-03

NA = not a COC for this medium, or toxicity factor not available  
 - = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS:	
CLASS A CARCINOGENS	2.7E-03
CLASS B2 CARCINOGENS	3.0E-04
CLASS C CARCINOGENS	2.8E-03
<b>Total Risk:</b>	<b>5.9E-03</b>

Table P7-16. RMB Noncarcinogenic Hazard Indices - Future On-Site Resident (Adult)  
(Sitewide With Groundwater)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Grndwater	Dermal Contact Grndwater	Inhalation Volatiles Grndwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.4E+00	5.1E-02	NA	1.4E+00
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.4E+00	2.8E-01	NA	5.7E+00
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.3E-01	4.8E-02	NA	4.8E-01
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.9E-03	NA	1.7E-01	6.7E-03	2.1E-05	1.8E-01
Acenaphthene	5.9E-04	4.4E-06	NA	NA	1.0E-04	NA	NA	NA	NA	NA	NA	NA	7.0E-04
Fluoranthene	2.4E-04	2.5E-05	1.8E-07	NA	5.8E-04	4.1E-06	NA	NA	NA	NA	NA	NA	8.5E-04
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	7.6E-04	6.6E-06	NA	NA	1.5E-04	NA	NA	NA	NA	NA	NA	NA	9.2E-04
Pyrene	2.0E-04	3.0E-05	2.4E-07	NA	7.0E-04	5.5E-06	NA	NA	NA	NA	NA	NA	9.4E-04
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6E+00	3.8E-03	NA	1.6E+00
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium, or toxicity factor not available  
- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	1.8E-03
HEPATIC	7.6E+00
KIDNEY	9.4E-04
LUNG	0.0E+00
CNS	1.6E+00
<b>Total HI:</b>	<b>9.2E+00</b>

Table F7-17. RMB Noncarcinogenic Hazard Indices - Future On-Site Resident (Child)  
(Sitewide With Groundwater)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Grndwater	Dermal Contact Grndwater	Inhalation Volatiles Grndwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.2E+00	9.3E-02	NA	3.3E+00
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3E+01	5.1E-01	NA	1.3E+01
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E+00	8.8E-02	NA	1.1E+00
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.2E-02	NA	4.0E-01	1.2E-02	1.3E-04	4.2E-01
Acenaphthene	1.4E-03	4.1E-05	NA	NA	1.9E-04	NA	NA	NA	NA	NA	NA	NA	1.6E-03
Fluoranthene	5.6E-04	2.3E-04	1.7E-06	NA	1.1E-03	7.6E-06	NA	NA	NA	NA	NA	NA	1.9E-03
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	1.8E-03	6.1E-05	NA	NA	2.8E-04	NA	NA	NA	NA	NA	NA	NA	2.1E-03
Pyrene	4.8E-04	2.8E-04	2.2E-06	NA	1.3E-03	1.0E-05	NA	NA	NA	NA	NA	NA	2.1E-03
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.8E+00	6.9E-03	NA	3.8E+00
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium, or toxicity factor not available  
- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	4.0E-03
HEPATIC	1.7E+01
KIDNEY	2.1E-03
LUNG	0.0E+00
CNS	3.8E+00
<b>Total HI:</b>	<b>2.1E+01</b>

Table F7-18. RME Carcinogenic Risk - Future On-Site Resident (Adult)  
(Assuming Adequate Groundwater At Source)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Grndwater	Dermal Contact Grndwater	Inhalation Volatiles Grndwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	2.7E-03	NA	3.4E-02	1.2E-03	4.0E-05	3.8E-02
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	1.3E-04	NA	2.2E-03	1.1E-04	3.7E-06	2.5E-03
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	2.8E-06	NA	9.7E-04	1.1E-04	1.6E-07	1.1E-03
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	1.9E-06	1.1E-07	NA	NA	3.2E-07	NA	NA	NA	NA	NA	NA	NA	2.3E-06
Benzo(a)pyrene	1.9E-06	1.0E-06	NA	NA	3.0E-06	NA	NA	NA	NA	NA	NA	NA	6.0E-06
Benzo(b)fluoranthene	2.1E-07	1.0E-07	1.9E-09	NA	3.0E-07	5.5E-09	NA	NA	NA	NA	NA	NA	6.2E-07
Benzo(k)fluoranthene	1.5E-07	9.9E-08	1.9E-09	NA	2.9E-07	5.4E-09	NA	NA	NA	NA	NA	NA	5.4E-07
Aroclor-1254	5.5E-06	7.8E-07	1.2E-08	NA	2.3E-06	3.3E-08	NA	NA	NA	NA	NA	NA	8.5E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.1E-05	6.5E-07	NA	NA	1.9E-06	NA	NA	NA	NA	NA	NA	NA	1.4E-05
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	6.0E-07	3.1E-07	3.5E-13	3.2E-10	NA	NA	NA	NA	3.7E-05	NA	NA	NA	3.8E-05
Uranium-238	2.1E-07	1.1E-07	5.5E-13	1.1E-09	NA	NA	NA	NA	1.5E-05	NA	NA	NA	1.5E-05
Americium-241	2.9E-04	4.5E-04	1.5E-13	5.2E-11	NA	NA	NA	NA	4.3E-03	NA	NA	NA	5.0E-03
Plutonium-239,-240	3.1E-03	1.8E-03	1.1E-11	1.5E-11	NA	NA	NA	NA	2.1E-02	NA	NA	NA	2.6E-02

NA = not a COC for this medium, or toxicity factor not available  
 - = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS:	
CLASS A CARCINOGENS	3.1E-02
CLASS B2 CARCINOGENS	3.6E-03
CLASS C CARCINOGENS	3.8E-02
<b>Total Risk:</b>	<b>7.3E-02</b>

Table F7-19. RME Noncarcinogenic Hazard Indices - Future On-Site Resident (Adult)  
(Assuming Adequate Groundwater At Source)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Grndwater	Dermal Contact Grndwater	Inhalation Volatiles Grndwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.8E+01	6.7E-01	NA	1.9E+01
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.2E+01	3.7E+00	NA	7.6E+01
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.6E+00	6.2E-01	NA	6.2E+00
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	2.3E-02	NA	2.2E+00	8.7E-02	2.7E-04	2.3E+00
Acenaphthene	5.9E-04	4.4E-06	NA	NA	1.0E-04	NA	NA	NA	NA	NA	NA	NA	7.0E-04
Fluoranthene	2.4E-04	2.5E-05	1.8E-07	NA	5.8E-04	4.1E-06	NA	NA	NA	NA	NA	NA	8.5E-04
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	7.6E-04	6.6E-06	NA	NA	1.5E-04	NA	NA	NA	NA	NA	NA	NA	9.2E-04
Pyrene	2.0E-04	3.0E-05	2.4E-07	NA	7.0E-04	5.5E-06	NA	NA	NA	NA	NA	NA	9.4E-04
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.0E+00	1.2E-02	NA	5.0E+00
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium, or toxicity factor not available  
- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	1.8E-03
HEPATIC	1.0E+02
KIDNEY	9.4E-04
LUNG	0.0E+00
CNS	7.3E+00
<b>Total HI:</b>	<b>1.1E+02</b>

Table F7-20. RME Noncarcinogenic Hazard Indices - Future On-Site Resident (Child)  
(Assuming Adequate Groundwater At Source)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Groundwater	Dermal Contact Groundwater	Inhalation Volatiles Groundwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.2E+01	1.2E+00	NA	4.4E+01
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.7E+02	6.8E+00	NA	1.7E+02
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3E+01	1.1E+00	NA	1.4E+01
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.4E-01	NA	5.2E+00	1.6E-01	1.7E-03	5.5E+00
Acenaphthene	1.4E-03	4.1E-05	NA	NA	1.9E-04	NA	NA	NA	NA	NA	NA	NA	1.6E-03
Fluoranthene	5.6E-04	2.3E-04	1.7E-06	NA	1.1E-03	7.6E-06	NA	NA	NA	NA	NA	NA	1.9E-03
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	1.8E-03	6.1E-05	NA	NA	2.8E-04	NA	NA	NA	NA	NA	NA	NA	2.1E-03
Pyrene	4.8E-04	2.8E-04	2.2E-06	NA	1.3E-03	1.0E-05	NA	NA	NA	NA	NA	NA	2.1E-03
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2E+01	2.1E-02	NA	1.2E+01
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium, or toxicity factor not available  
 -- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	4.0E-03
HEPATIC	2.3E+02
KIDNEY	2.1E-03
LUNG	0.0E+00
CNS	1.7E+01
<b>Total HI:</b>	<b>2.5E+02</b>

Table F7-21. RME Carcinogenic Risk - Future On-Site Resident (Adult)  
(Groundwater At Source With Public Water)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Groundwater	Dermal Contact Groundwater	Inhalation Volatiles Groundwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	2.7E-03	NA	3.5E-03	1.3E-04	4.1E-06	6.3E-03
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	1.3E-04	NA	2.3E-04	1.2E-05	3.8E-07	3.7E-04
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	2.8E-06	NA	1.0E-04	1.1E-05	1.6E-08	1.1E-04
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	1.9E-06	1.1E-07	NA	NA	3.2E-07	NA	NA	NA	NA	NA	NA	NA	2.3E-06
Benzo(a)pyrene	1.9E-06	1.0E-06	NA	NA	3.0E-06	NA	NA	NA	NA	NA	NA	NA	6.0E-06
Benzo(b)fluoranthene	2.1E-07	1.0E-07	1.9E-09	NA	3.0E-07	5.5E-09	NA	NA	NA	NA	NA	NA	6.2E-07
Benzo(k)fluoranthene	1.5E-07	9.9E-08	1.9E-09	NA	2.9E-07	5.4E-09	NA	NA	NA	NA	NA	NA	5.4E-07
Aroclor-1254	5.5E-06	7.8E-07	1.2E-08	NA	2.3E-06	3.3E-08	NA	NA	NA	NA	NA	NA	8.5E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.1E-05	6.5E-07	NA	NA	1.9E-06	NA	NA	NA	NA	NA	NA	NA	1.4E-05
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	6.0E-07	3.1E-07	3.5E-13	3.2E-10	NA	NA	NA	NA	3.7E-05	NA	NA	NA	3.8E-05
Uranium-238	2.1E-07	1.1E-07	5.5E-13	1.1E-09	NA	NA	NA	NA	1.5E-05	NA	NA	NA	1.5E-05
Americium-241	2.9E-04	4.5E-04	1.5E-13	5.2E-11	NA	NA	NA	NA	4.3E-03	NA	NA	NA	5.0E-03
Plutonium-239,-240	3.1E-03	1.8E-03	1.1E-11	1.5E-11	NA	NA	NA	NA	2.1E-02	NA	NA	NA	2.6E-02

NA = not a COC for this medium, or toxicity factor not available  
- = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS:	
CLASS A CARCINOGENS	3.1E-02
CLASS B2 CARCINOGENS	5.2E-04
CLASS C CARCINOGENS	6.3E-03
<b>Total Risk:</b>	<b>3.8E-02</b>

Table F7-22. RMB Noncarcinogenic Hazard Indices - Future On-Site Resident (Adult)  
(Groundwater At Source With Public Water)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Grndwater	Dermal Contact Grndwater	Inhalation Volatiles Grndwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.9E+00	7.0E-02	NA	2.0E+00
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.4E+00	3.8E-01	NA	7.8E+00
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.8E-01	6.4E-02	NA	6.4E-01
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	2.3E-02	NA	2.3E-01	9.0E-03	2.8E-05	2.6E-01
Acenaphthene	5.9E-04	4.4E-06	NA	NA	1.0E-04	NA	NA	NA	NA	NA	NA	NA	7.0E-04
Fluoranthene	2.4E-04	2.5E-05	1.8E-07	NA	5.8E-04	4.1E-06	NA	NA	NA	NA	NA	NA	8.5E-04
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	7.6E-04	6.6E-06	NA	NA	1.5E-04	NA	NA	NA	NA	NA	NA	NA	9.2E-04
Pyrene	2.0E-04	3.0E-05	2.4E-07	NA	7.0E-04	5.5E-06	NA	NA	NA	NA	NA	NA	9.4E-04
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.2E-01	1.2E-03	NA	5.2E-01
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium, or toxicity factor not available  
- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	1.8E-03
HEPATIC	1.0E+01
KIDNEY	9.4E-04
LUNG	0.0E+00
CNS	7.8E-01
<b>Total HI:</b>	<b>1.1E+01</b>

Table F7-23. RMB Noncarcinogenic Hazard Indices - Future On-Site Resident (Child)  
(Groundwater At Source With Public Water)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	Ingestion of Grndwater	Dermal Contact Grndwater	Inhalation Volatiles Grndwater	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.4E+00	1.3E-01	NA	4.5E+00
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.7E+01	7.0E-01	NA	1.8E+01
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3E+00	1.2E-01	NA	1.5E+00
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	1.4E-01	NA	5.3E-01	1.7E-02	1.7E-04	6.9E-01
Acenaphthene	1.4E-03	4.1E-05	NA	NA	1.9E-04	NA	NA	NA	NA	NA	NA	NA	1.6E-03
Fluoranthene	5.6E-04	2.3E-04	1.7E-06	NA	1.1E-03	7.6E-06	NA	NA	NA	NA	NA	NA	1.9E-03
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	1.8E-03	6.1E-05	NA	NA	2.8E-04	NA	NA	NA	NA	NA	NA	NA	2.1E-03
Pyrene	4.8E-04	2.8E-04	2.2E-06	NA	1.3E-03	1.0E-05	NA	NA	NA	NA	NA	NA	2.1E-03
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2E+00	2.2E-03	NA	1.2E+00
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium, or toxicity factor not available  
- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	4.0E-03
HEPATIC	2.4E+01
KIDNEY	2.1E-03
LUNG	0.0E+00
CNS	1.9E+00
<b>Total HI:</b>	<b>2.6E+01</b>

Table F7-24. Carcinogenic Risk – Future On-site Resident (Adult)  
(Without Groundwater / Without Source)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	8.1E-07	NA	8.1E-07
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	5.9E-07	NA	5.9E-07
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	4.5E-09	NA	4.5E-09
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Acenaphthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)anthracene	1.9E-06	1.1E-07	NA	NA	3.2E-07	NA	NA	NA	NA	2.3E-06
Benzo(a)pyrene	1.9E-06	1.0E-06	NA	NA	3.0E-06	NA	NA	NA	NA	6.0E-06
Benzo(b)fluoranthene	2.1E-07	1.0E-07	1.9E-09	NA	3.0E-07	5.5E-09	NA	NA	NA	6.2E-07
Benzo(k)fluoranthene	1.5E-07	9.9E-08	1.9E-09	NA	2.9E-07	5.4E-09	NA	NA	NA	5.4E-07
Aroclor-1254	5.6E-06	7.8E-07	1.2E-08	NA	2.3E-06	3.3E-08	NA	NA	NA	8.7E-06
Fluorene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Dibenzo(a,h)anthracene	1.1E-05	6.5E-07	NA	NA	1.9E-06	NA	NA	NA	NA	1.4E-05
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	3.4E-08	1.7E-08	3.5E-13	3.2E-10	NA	NA	NA	NA	2.1E-06	2.2E-06
Uranium-238	5.9E-08	3.0E-08	5.5E-13	1.1E-09	NA	NA	NA	NA	4.0E-06	4.1E-06
Americium-241	7.4E-08	1.2E-07	1.5E-13	5.2E-11	NA	NA	NA	NA	1.1E-06	1.3E-06
Plutonium-239,-240	1.2E-06	6.6E-07	1.1E-11	1.5E-11	NA	NA	NA	NA	7.9E-06	9.7E-06

NA = not a COC for this medium or no toxicity factor is available  
-- = not a complete pathway for this receptor

SUMMED CARCINOGENIC RISKS BY CANCER CLASS:	
CLASS A CARCINOGENS	1.7E-05
CLASS B2 CARCINOGENS	3.2E-05
CLASS C CARCINOGENS	8.1E-07
<b>Total Risk:</b>	<b>5.0E-05</b>

Table F7-25. Noncarcinogenic Hazard Indices - Future On-site Resident (Adult)  
(Without Groundwater / Without Source)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	5.6E-06	NA	5.6E-06
Acenaphthene	5.9E-04	4.4E-06	NA	NA	1.0E-04	NA	NA	NA	NA	7.0E-04
Fluoranthene	2.4E-04	2.5E-05	1.8E-07	NA	5.8E-04	4.1E-06	NA	NA	NA	8.5E-04
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Fluorene	7.6E-04	6.6E-06	NA	NA	1.5E-04	NA	NA	NA	NA	9.2E-04
Pyrene	2.0E-04	3.0E-05	2.4E-07	NA	7.0E-04	5.5E-06	NA	NA	NA	9.4E-04
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	----
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	----

NA = not a COC for this medium or no toxicity factor is available

-- = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:

BLOOD 1.8E-03  
 HEPATIC 7.0E-04  
 KIDNEY 9.4E-04  
 LUNG 0.0E+00  
 CNS 5.6E-06

Total HI: 3.4E-03

Table F7-26. Noncarcinogenic Hazard Indices - Future On-site Resident (Child)  
(Without Groundwater / Without Source)

Chemical	Ingestion of Vegetables	Ingestion of Soil	Ingestion of Sediment	Ingestion of Surf. Water	Dermal Contact Soil	Dermal Contact Sediment	Dermal Contact Surf. Water	Inhalation of Volatiles	Inhalation of Dust	TOTAL
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	3.5E-05	NA	3.5E-05
Acenaphthene	1.4E-03	4.1E-05	NA	NA	1.9E-04	NA	NA	NA	NA	1.6E-03
Fluoranthene	5.6E-04	2.3E-04	1.7E-06	NA	1.1E-03	7.6E-06	NA	NA	NA	1.9E-03
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Aroclor-1254	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Fluorene	1.8E-03	6.1E-05	NA	NA	2.8E-04	NA	NA	NA	NA	2.1E-03
Pyrene	4.8E-04	2.8E-04	2.2E-06	NA	1.3E-03	1.0E-05	NA	NA	NA	2.1E-03
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-233,234	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	NA	---
Plutonium-239,-240	NA	NA	NA	NA	NA	NA	NA	NA	NA	---

NA = not a COC for this medium or no toxicity factor is available  
 - = not a complete pathway for this receptor

SUMMED NONCARCINOGENIC HAZARD INDICES BY TARGET ORGAN:	
BLOOD	4.0E-03
HEPATIC	1.6E-03
KIDNEY	2.1E-03
LUNG	0.0E+00
CNS	3.5E-05
<b>Total HI:</b>	<b>7.7E-03</b>

Table F7-27

Public Health Evaluation Uncertainty Factors at OU1  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Sampling and Analysis</b>		
Use of unvalidated data	May slightly underestimate risk	The percent of radionuclide data validated is 43%, with a rejection rate of 41%. However, the unvalidated data used are consistent with previous measurements and should affect risk estimates only slightly.
Identification of OU1 contaminants	May slightly over- or underestimate risk	The use of professional judgement to analyze the data and identify contaminants introduces uncertainty. Some of the detected analytes (e.g., antimony and manganese) can result in risks similar to those calculated for COCs, but are not identified as site contaminants.
Detection limits/COC screening	May slightly over- or underestimate risk	Measurements used in COC screening had multiple detection limits from the laboratory analysis. However, since maximum concentrations are used in screening, the effect is expected to be small.
Concentration-toxicity screen	May slightly over- or underestimate risk	EPA toxicity constants are subject to change and can effect the outcome of the COC screening process.
Identification of OU1 COCs in surface water and sediments	May slightly over- or underestimate risk	Surface soil COCs were used to identify possible OU1 contaminants in surface water and sediments. Surface water and sediments will be further evaluated in the OU5 risk assessment.
Data set completeness	May slightly over- or underestimate risk	The completeness goals were not achieved in all cases, however, critical samples in IHSS were complete.
<b>Fate and Transport Estimation</b>		
Assumed house volume and ventilation rate	May slightly over- or underestimate risk	The indoor concentration of soil gas penetrating the foundation depends on indoor ventilation.
Soil-gas source term assumptions	May over- or underestimate risk	The heterogeneous sources were assumed to be homogeneous.
Natural infiltration rate	May overestimate risk	A conservative value was used for this parameter.
Moisture content	May over- or underestimate risk	This varies seasonally in the upper vadose zone and may be subject to measurement error.
Water table fluctuations	May slightly over- or underestimate risk	The average value used is expected to be representative of the depth over the 25-year exposure period.

Table F7-27 (Continued)

Public Health Evaluation Uncertainty Factors at OU1  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Fate and Transport Estimation (continued)</b>		
Modeling of VOCs from soil gas through the foundation	May under or over estimate risk	There may be DNAPLs in the vadose zone, however, conservative assumptions were used in the modeling from the saturated zone.
Use of hot spot data in source term	May greatly overestimate risk	The radionuclide hot spot data were combined in the OU-wide data using a simple average. An area-weighted average indicates the source term is likely to be overestimated by approximately four orders of magnitude.
Volume of theoretical mixing space in near-field air dispersion model	May overestimate risk	The near-field model assumes a conservative volumetric flow rate.
Effect of micrometeorology on air dispersion	May slightly over or under estimate risk	While lower winds reduce the amount of dispersion (thus increasing the potential concentration of airborne contaminants), higher-velocity winds result in significantly higher emission rates of contaminated soils than do lower velocity winds, since resuspension is a non-linear function of wind speed. For example, a unit increase in wind speed will result in more than a unit increase in emission rate.
Variability in annual meteorological data	May slightly over or under estimate risk	Although a rigorous statistical analysis on annual variability was not conducted, the annual variability is less than approximately 1% in each category, resulting in less than approximately 5% from year to year.
Plant uptake estimation	May slightly under or over estimate risk	When specific values were not available, the uptake model used default uptake constants.
COC concentration on plants	May slightly over- or underestimate risk	Exterior plant concentrations depend on assumptions regarding deposition velocity, intercept fraction, and weathering removal rate.

Table F7-27 (Continued)

Public Health Evaluation Uncertainty Factors at OU1  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Exposure Estimation</b>		
Exposure scenario assumptions	May overestimate risk	<p>The likelihood of future scenarios has been qualitatively evaluated as follows: on-site resident - improbable on-site commercial/industrial - credible on-site ecological reserve - credible</p> <p>The likelihood of future onsite residential development is small. If future residential use of this site does not occur, then the risk estimates calculated for future onsite residents are likely to overestimate the true risk associated with future use of this site.</p>
Exposure parameter assumptions	May overestimate risk	Assumptions regarding media intake, population characteristics, and exposure patterns may not characterize actual exposures.
Receptor locations	May overestimate risk	In addition to sitewide risk, risk at the source was also evaluated. Evaluation of risk at the source assumes that a receptor builds directly over the source.
Exposure duration	May over- or underestimate risk	The assumption that an individual will work or reside at OU1 for 25 or 30 years in conservative. Short-term exposures involve comparison to sub-chronic toxicity values, which are generally less restrictive than chronic values.
Non chemical-specific constants (not dependent on chemical properties)	May overestimate risk	Conservative or upper bound values were used for all parameters incorporated into intake calculations.
Exclusion of some hypothetical pathways from the exposure scenarios	May underestimate risk	Exposure pathways were rigorously evaluated for each scenario and eliminated only if it was determined that they were either incomplete or negligible compared to other evaluated pathways.
External radiation	May slightly underestimate risk	The radionuclide COCs are alpha emitters and emit little penetrating radiation. The screening calculation presented in Section F4.5.1 indicates that this pathway has little effect on overall risk.
Permeability coefficients	May slightly over- or underestimate risk	EPA permeability coefficients were algorithmically predicted and have an uncertainty of approximately one order of magnitude.

Table F7-27 (Continued)

Public Health Evaluation Uncertainty Factors at OUI  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Exposure Estimation (continued)</b>		
Inclusion of groundwater ingestion in the future on-site residential scenario	May overestimate risk	The existence of the French Drain and the lack of available water to support residential development make this a very health-conservative evaluation.
NAPL in subsurface soil	May slightly underestimate risk	The nature and extent evaluation concludes that NAPL in subsurface soil is possible, although it was not sampled directly and a source term cannot be estimated.
Inclusion of hot spot data for radionuclides in surface soil in the sitewide scenarios	May substantially overestimate risk	The hot spots are highly localized. The sitewide without source scenario is more representative of the risk at the site from radionuclides.
Plant ingestion rate	May slightly over- or underestimate risk	The average plant ingestion rate was used with the assumption that homegrown plants would be consumed year-round.
Model does not consider biotic decay	May overestimate risk	Biotic decay would tend to reduce contamination over time. However, the modeling effort did not account for this process.
Exclusion of transformation products	May underestimate risk	Not all transformation products of the identified organic or radioactive compounds were evaluated.
<b>Toxicological data</b>		
Use of cancer slope factors	May overestimate risk	Potencies are upper 95th percentile confidence limits. Considered unlikely to underestimate true risk.
Critical toxicity values derived primarily from animal studies	May over- or underestimate risk	Extrapolation from animal to humans may induce error due to differences in absorption, pharmacokinetics, target organs, enzymes, and population variability.
Critical toxicity values derived primarily from high doses, most exposures are at low doses	May over- or underestimate risk	Assumes linear at low doses. Tend to have conservative exposure assumptions.
Critical toxicity values and classification of carcinogens	May over- or underestimate risk	Not all values represent the same degree of certainty. All are subject to change as new evidence becomes available. Of 16 animal studies with 1,1-dichloroethene, only one produced evidence of carcinogenicity, and it did not present a dose-response relationship.

Table F7-27 (Continued)

Public Health Evaluation Uncertainty Factors at OUI  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
Toxicological data (continued)		
Lack of inhalation slope factors	May underestimate risk	Carcinogenic COCs without inhalation slope factors, may or may not be carcinogenic through the inhalation pathway.
Use of oral slope factors to evaluate dermal absorption	May over- or underestimate risk	Assumes that introduction to the blood stream through the skin acts similarly to absorption through the gut.
Addition of risks across weight-of-evidence classifications	May overestimate risk	Addition of risks across weight-of-evidence classifications is extremely health conservative and potentially inappropriate.
Lack of RfDs or RfCs	May underestimate risk	Inhalation RfDs or RfCs are not available from IRIS for trichloroethylene, 1,1-dichloroethene, carbon tetrachloride, tetrachloroethene, selenium, Aroclor-1254, or PAHs.
Effect of absorption	May over- or underestimate risk	The assumption that absorption is equivalent across species is implicit in the derivation of the critical toxicity values. Absorption may actually vary with chemical.
Lack dermal absorption or direct action toxicity values	May slightly underestimate risk	The unavailability of consensus absorption values does not facilitate comparison of absorbed dose to toxicity constants based on administered dose. Dermal absorption of metals is expected to be insignificant compared to ingestion.

Table F7-28

**Collective and Per-Capita Population Risks  
Based on an Estimated Risk to Maximally Exposed  
Off-Site Individual of 2E-06**

Distance	Collective Risk	Population	Per-Capita Risk
0-5 km	5E-05	1.21E+02	4E-07
5-10 km	1E-02	6.67E+04	2E-07
10-20 km	3E-02	4.18E+05	7E-08
20-40 km	2E-02	1.02E+06	2E-08
40-60 km	6E-03	4.42E+05	1E-08
60-80 km	2E-03	2.58E+05	8E-09
0-80 km	7E-02	2.21E+06	3E-08

Table F7-29

## Summary of OU1 Point Estimates of Carcinogenic Risk

Scenario	Total Risk (classes)				Dominant COC	Dominant Pathway
	A	B2	C	Total		
<b>Current</b>						
On-Site Worker (Security Specialist)	1E-04	6E-07	N/A	1E-04	Plutonium-239, 240	Inhalation of dust
Off-Site Resident (Adult)	2E-06	7E-10	N/A	2E-06	Plutonium-239, 240	Inhalation of dust
<b>Standard Future</b>						
Future On-Site Worker (Office)	2E-03	2E-05	2E-04	2E-03	Plutonium-239, 240	Inhalation of dust
Future On-Site Worker (Construction)	5E-09	2E-08	4E-07	4E-07	1,1-Dichloroethene	Inhalation of volatiles
On-Site Ecological Researcher	2E-03	9E-06	N/A	2E-03	Plutonium-239, 240	Inhalation of dust
On-Site Resident (Adult)	3E-03	4E-05	2E-04	3E-03	Plutonium-239, 240	Inhalation of dust
<b>Other Future</b>						
On-Site Resident (Adult) (Sitewide With Groundwater)	3E-03	3E-04	3E-03	6E-03	1,1-Dichloroethene	Ingestion of groundwater
On-Site Resident (Adult) (Assuming Adequate Groundwater At Source)	3E-02	4E-03	4E-02	7E-02	1,1-Dichloroethene	Ingestion of groundwater
On-Site Resident (Adult) (Groundwater At Source With Public Water)	3E-02	5E-04	6E-03	4E-02	Plutonium-239, 240	Inhalation of dust
On-Site Resident (Adult) (Without Source / Without Groundwater)	2E-05	3E-05	8E-07	5E-05	Dibenzo(a,h)anthracene	Ingestion of vegetables

Table F7-30

## Summary of OU1 Point Estimates of Noncarcinogenic Risk

Scenario	Total Hazard Index		Dominant COC	Target Organ	Dominant Pathway
	Child	Adult			
<b>Current</b>					
On-Site Worker (Security Specialist)	N/A	8E-05	Pyrene	Blood	Dermal contact with soil
Off-Site Resident	1E-07	6E-08	Fluorene	Blood	Ingestion of vegetables
<b>Standard Future</b>					
Future On-Site Worker (Office)	N/A	3E-03	1,1,1-Trichloroethane	CNS	Inhalation of volatiles through foundation
Future On-Site Worker (Construction)	N/A	1E-04	1,1,1-Trichloroethane	CNS	Inhalation of volatiles during excavation
On-Site Ecological Researcher	N/A	2E-03	Pyrene	Blood	Dermal contact with soil
On-Site Resident	2E-02	5E-03	1,1,1-Trichloroethane	CNS	Inhalation of volatiles through foundation
<b>Other Future</b>					
On-Site Resident (Sitewide With Groundwater)	2E+01	9E+00	Carbon Tetrachloride	Liver	Ingestion of groundwater
On-Site Resident (Assuming Adequate Groundwater At Source)	3E+02	1E+02	Carbon Tetrachloride	Liver	Ingestion of groundwater
On-Site Resident (Groundwater At Source With Public Water)	3E+01	1E+01	Carbon Tetrachloride	Liver	Ingestion of groundwater
On-Site Resident (Without Source / Without Groundwater)	7E-03	3E-03	Fluorene	Blood	Ingestion of vegetables

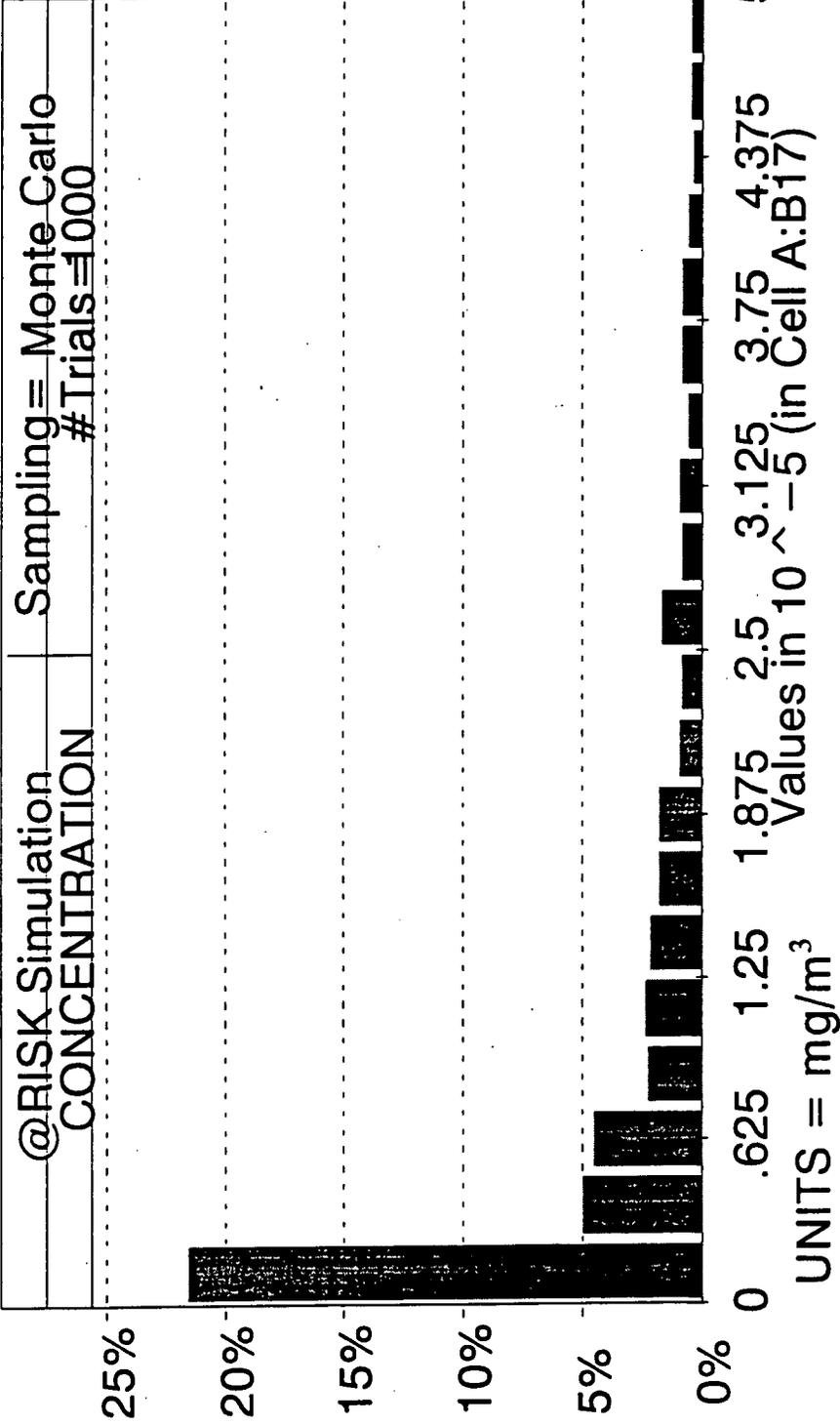
Table F7-31

Summary of Key Contaminants and Risks for the Hypothetical Future On-Site Resident

Contaminant	Exposure Route	Sitewide RME <sup>(a)</sup>	Risk at the Source	Sitewide With the Source Removed	Percentiles From Sitewide Monte Carlo Simulation						
					5	10	25	50	75	90	95
1,1-dichloroethene <sup>(b)</sup>	Inhalation	2E-04	3E-03	8E-07	9E-11	3E-10	4E-09	6E-08	8E-07	1E-05	7E-05
1,1-dichloroethene <sup>(b)</sup>	Ingestion	3E-03	3E-02	NA	1E-07	3E-07	2E-06	1E-05	8E-05	6E-04	1E-03
carbon tetrachloride	Ingestion	2E-04	2E-03	NA	1E-07	4E-07	3E-06	4E-05	2E-04	8E-04	2E-03

<sup>a</sup> Point estimate using EPA's reasonable maximum exposure (RME) method.

<sup>b</sup> It should be noted that risk values are driven by a Class C carcinogen.



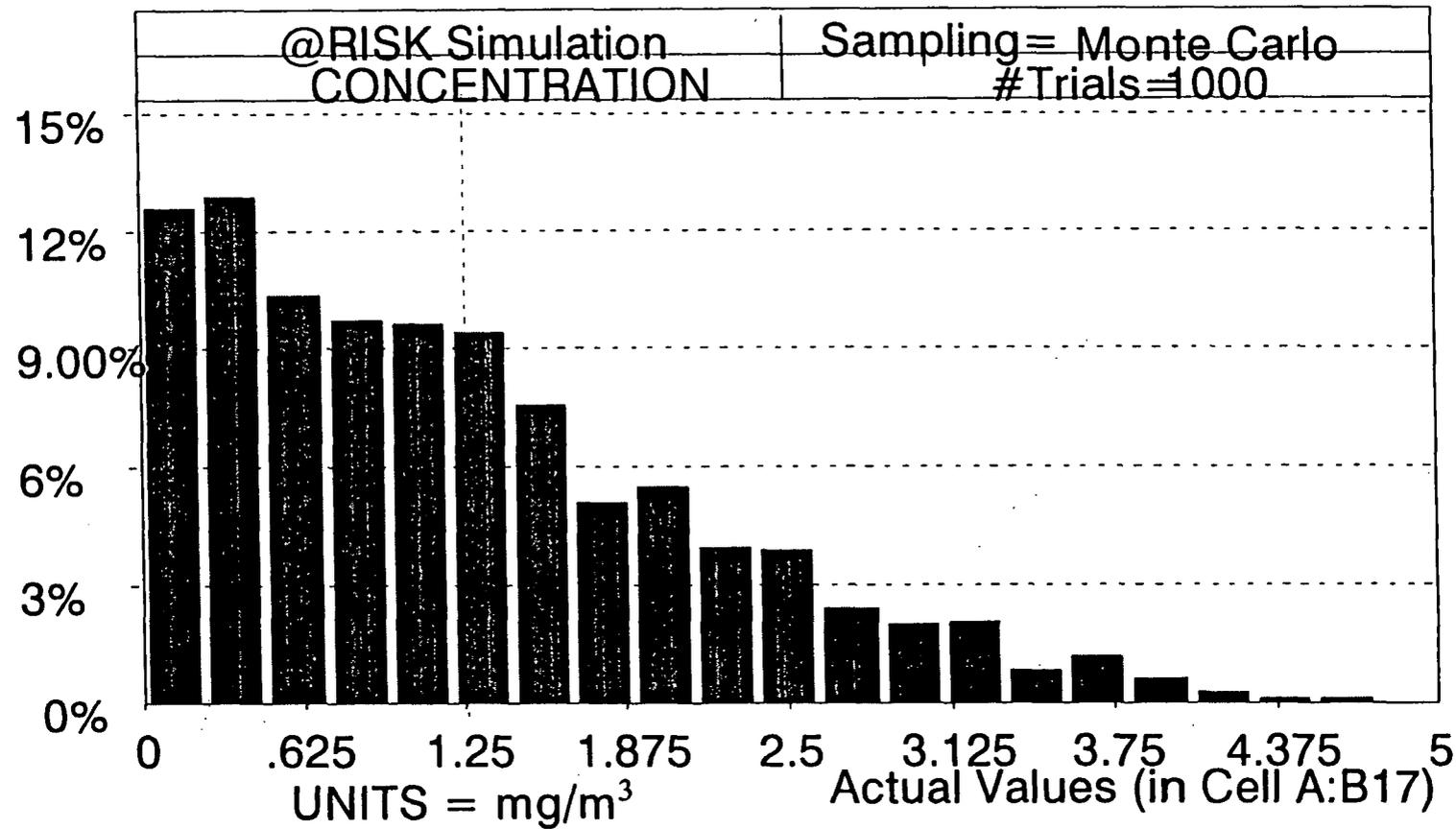
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1,1-Dichloroethene - Carcinogenic Risk  
Concentration (Inhalation)

Figure F7 - 1

September 1993



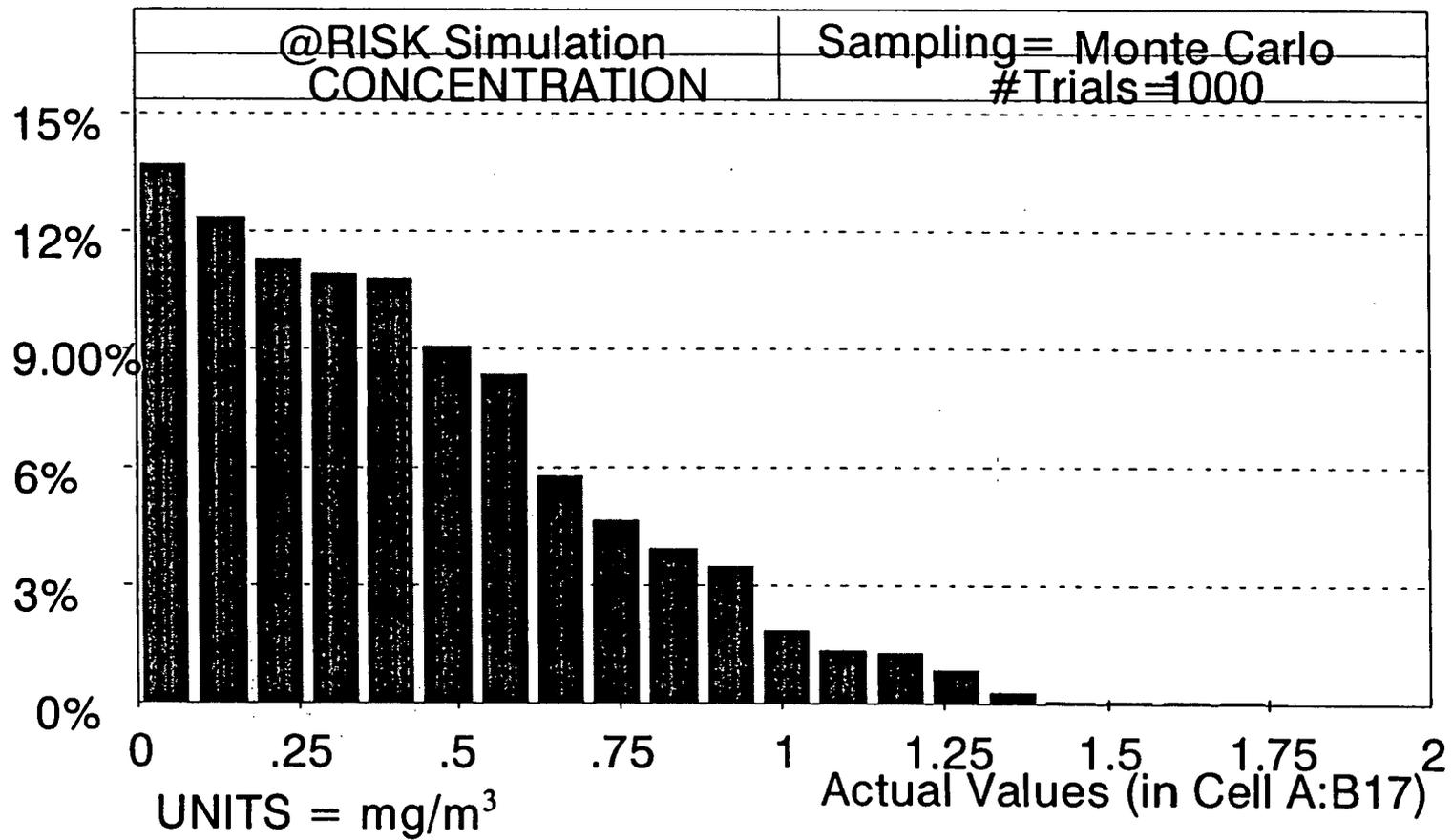
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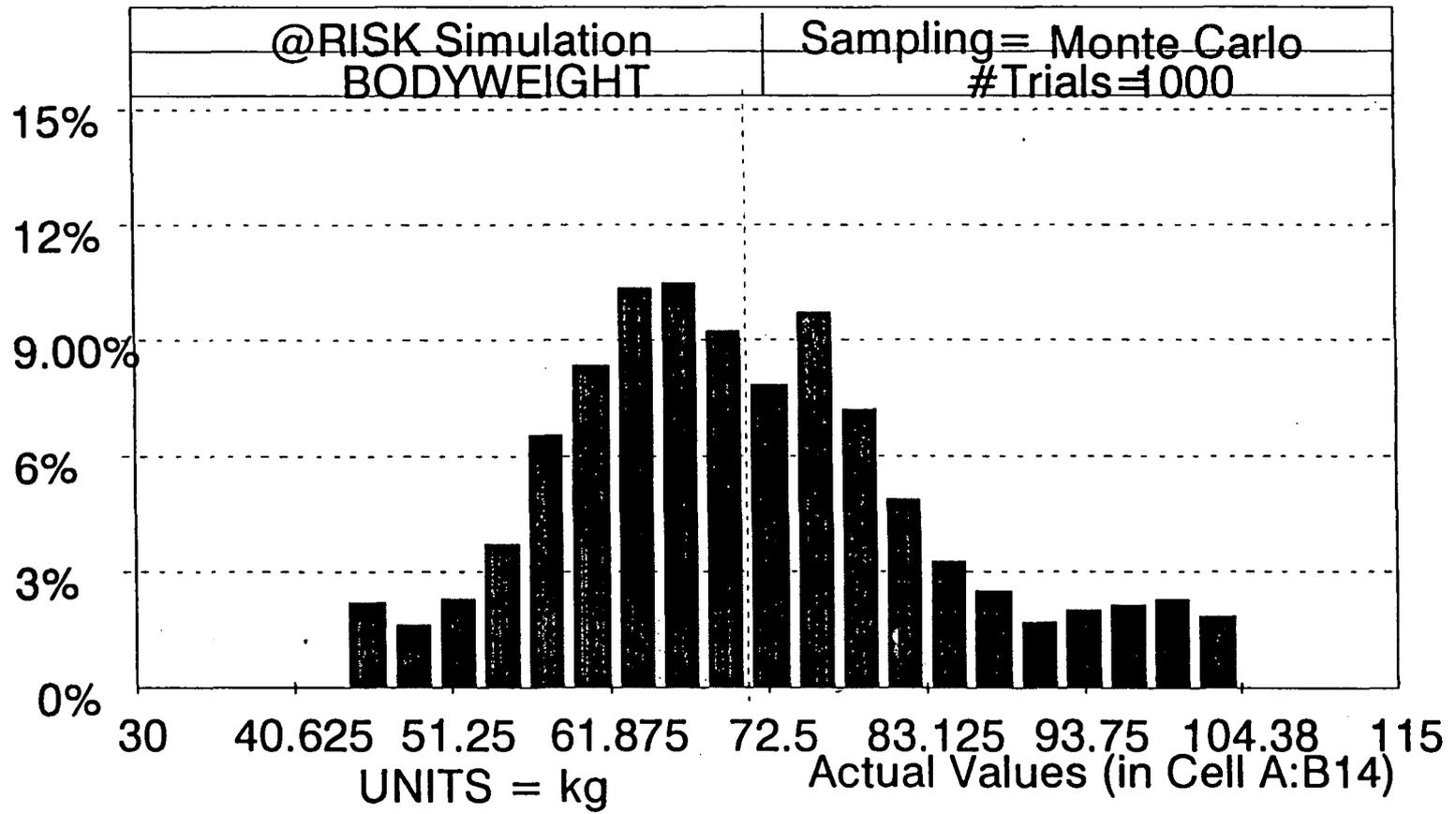
1,1-Dichloroethene - Carcinogenic Risk  
Concentration (Ingestion)

Figure F7-2

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Carbon Tetrachloride - Carcinogenic Risk Concentration (Ingestion)
Figure F7-3

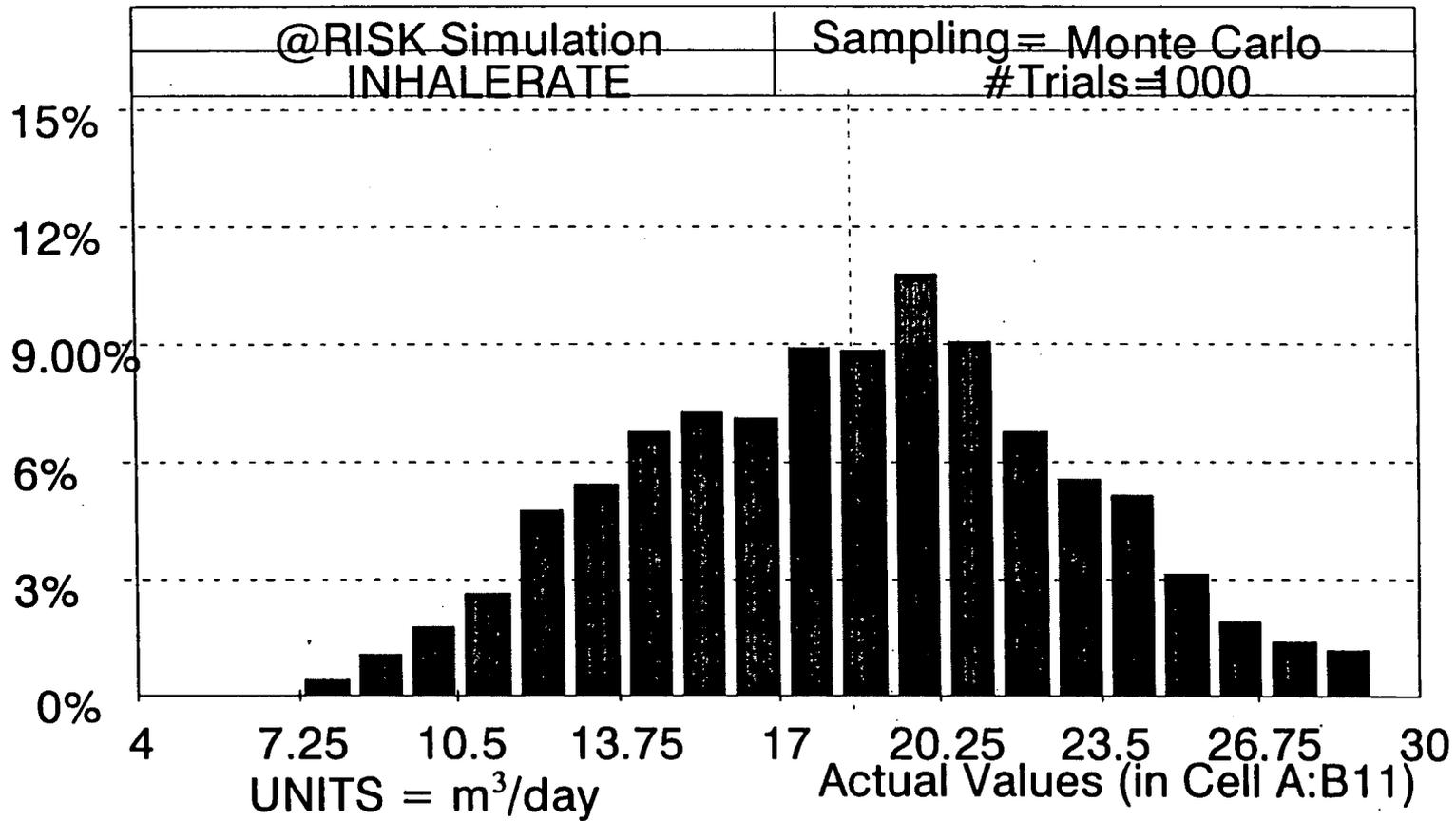


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1,1-Dichloroethene - Carcinogenic Risk  
 Body Weight

Figure F7-4



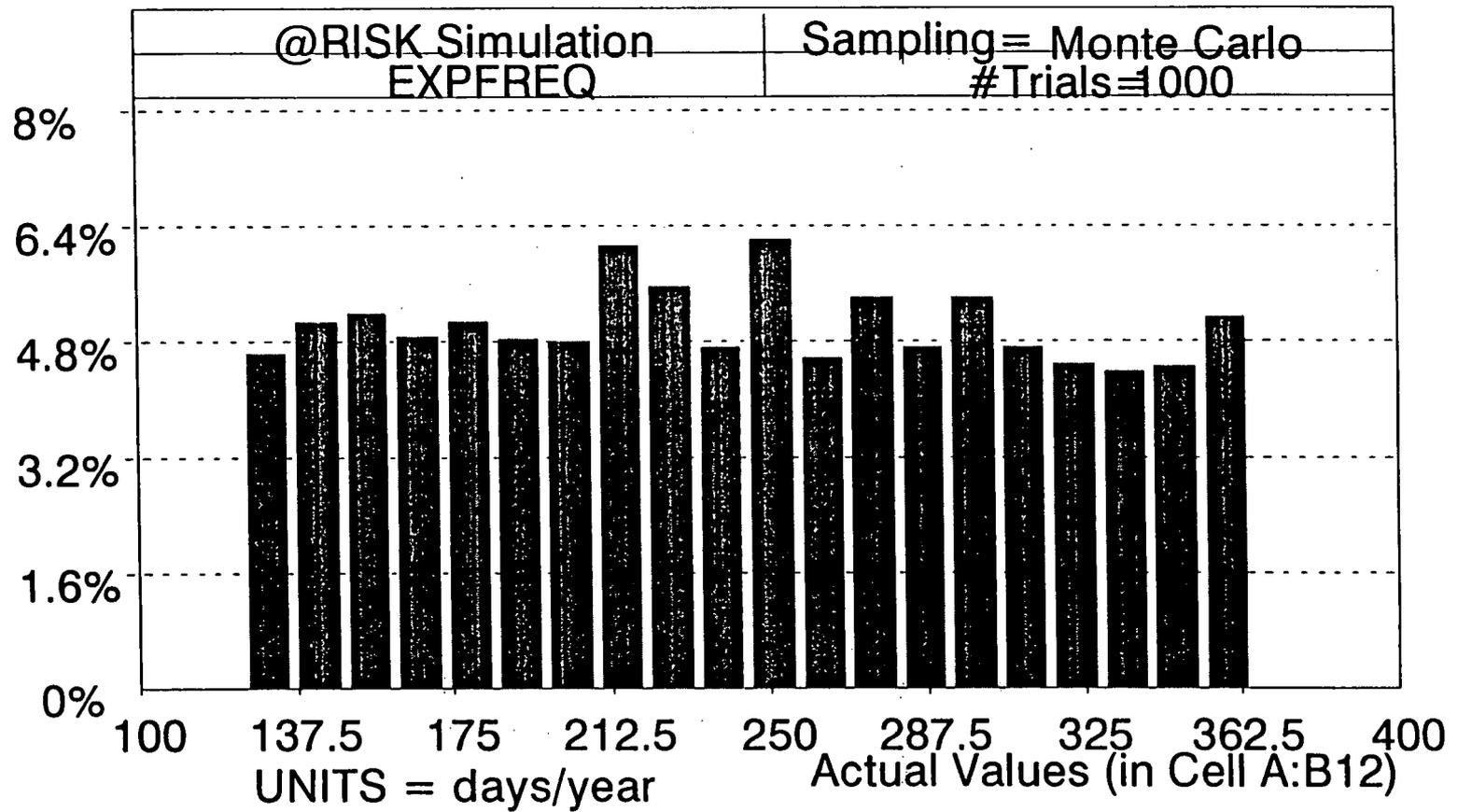
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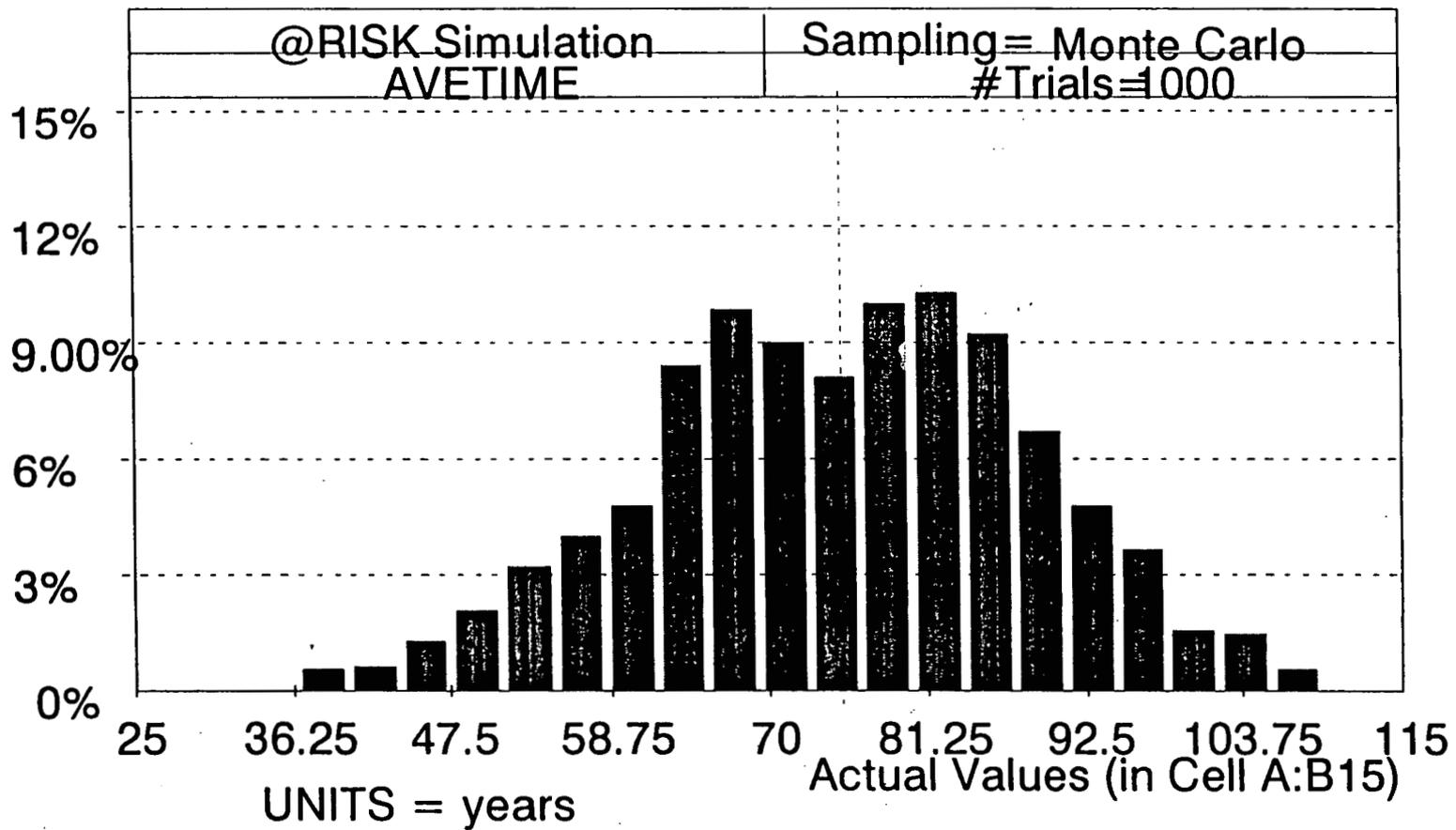
1,1-Dichloroethene - Carcinogenic Risk  
Inhalation Rate

Figure F7-5





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 1,1-Dichloroethene - Carcinogenic Risk  
 Exposure Frequency  
  
 Figure F7-7

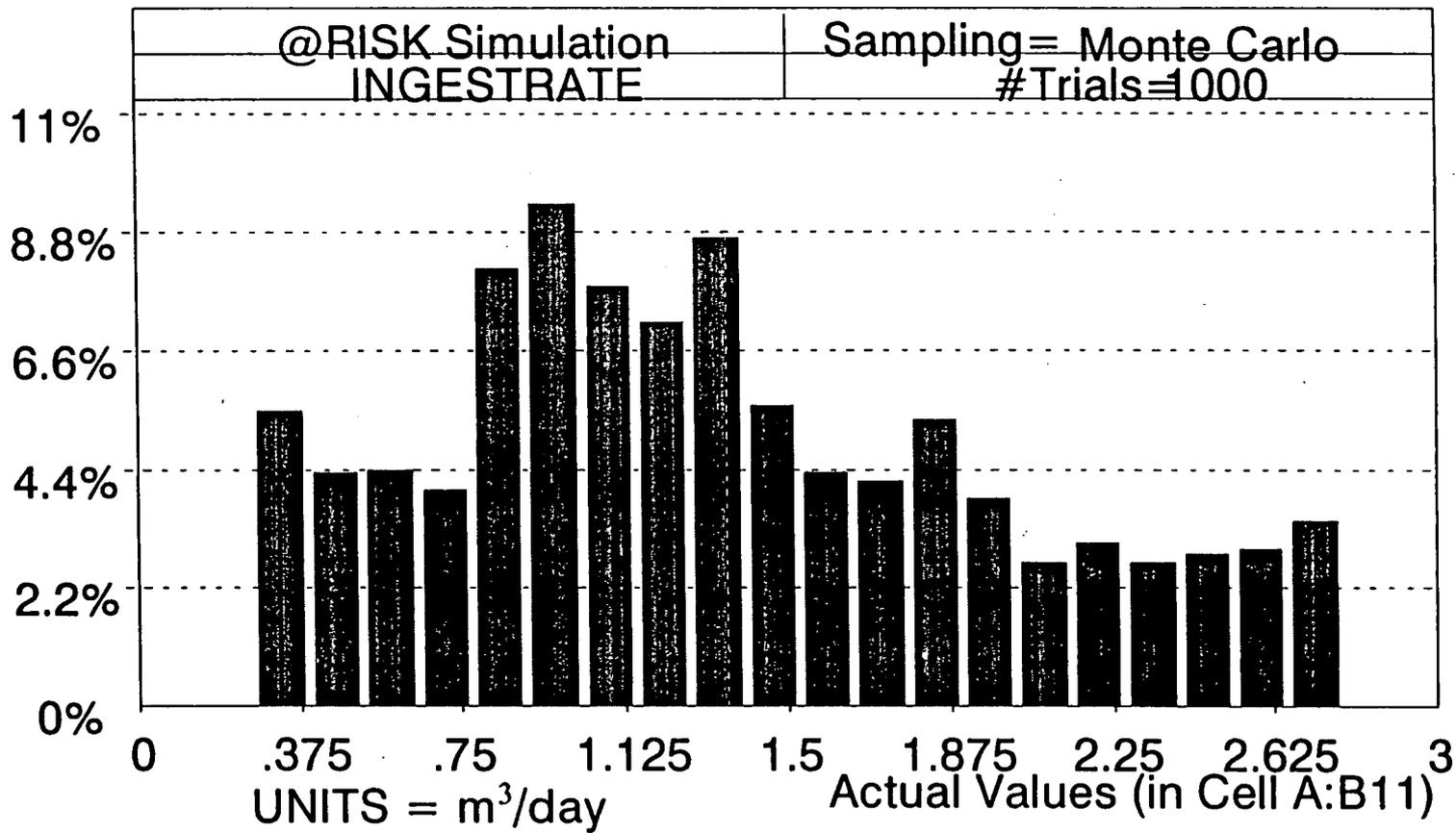


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1,1-Dichloroethene - Carcinogenic Risk  
Averaging Time

Figure F7-8

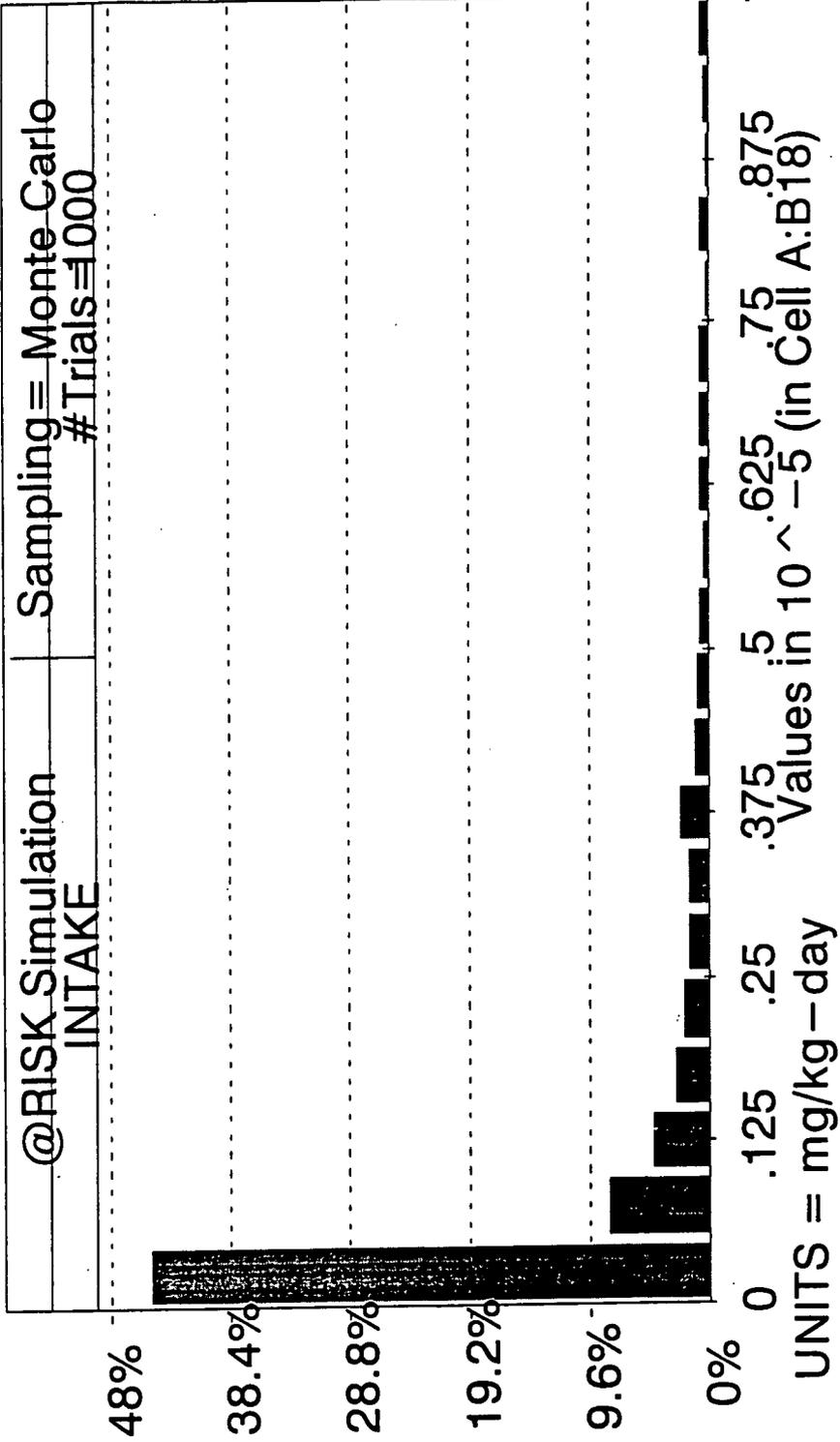


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1,1-Dichloroethene - Carcinogenic Risk  
Ingestion Rate

Figure F7-9



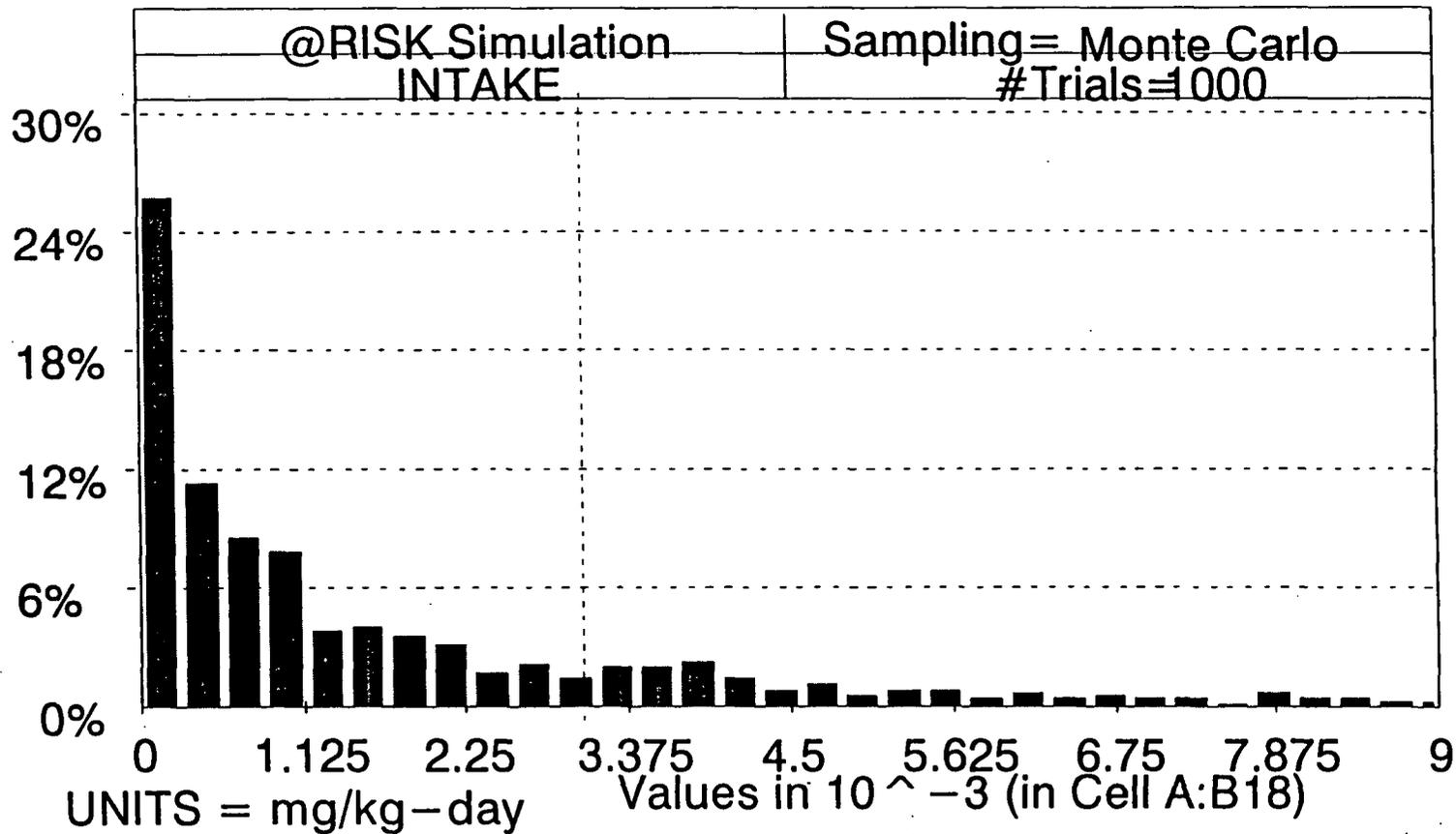
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1,1-Dichloroethene - Carcinogenic Risk  
Intake (Inhalation)

Figure F7 - 10

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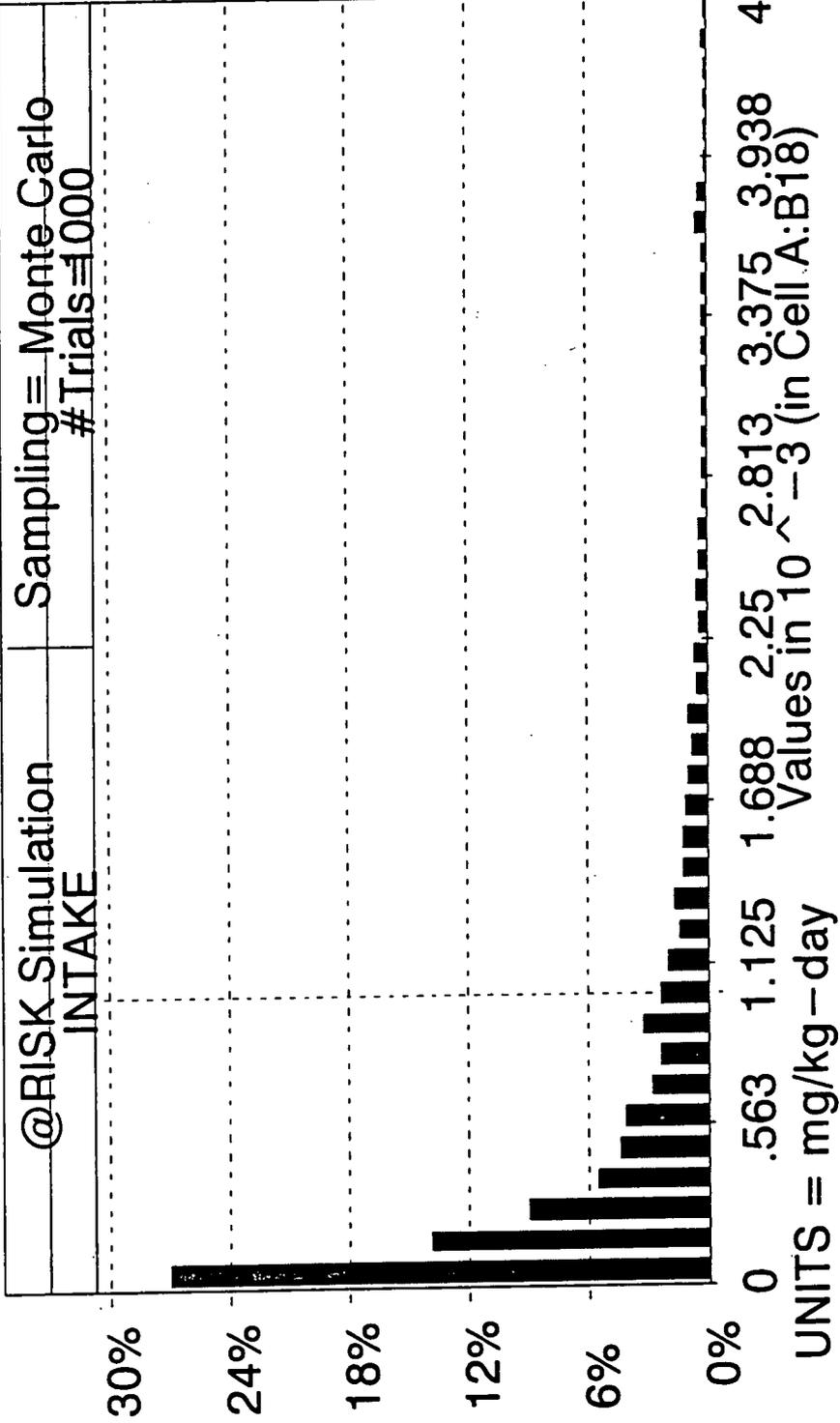


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1,1-Dichloroethene - Carcinogenic Risk  
Intake (Ingestion)

Figure F7-11



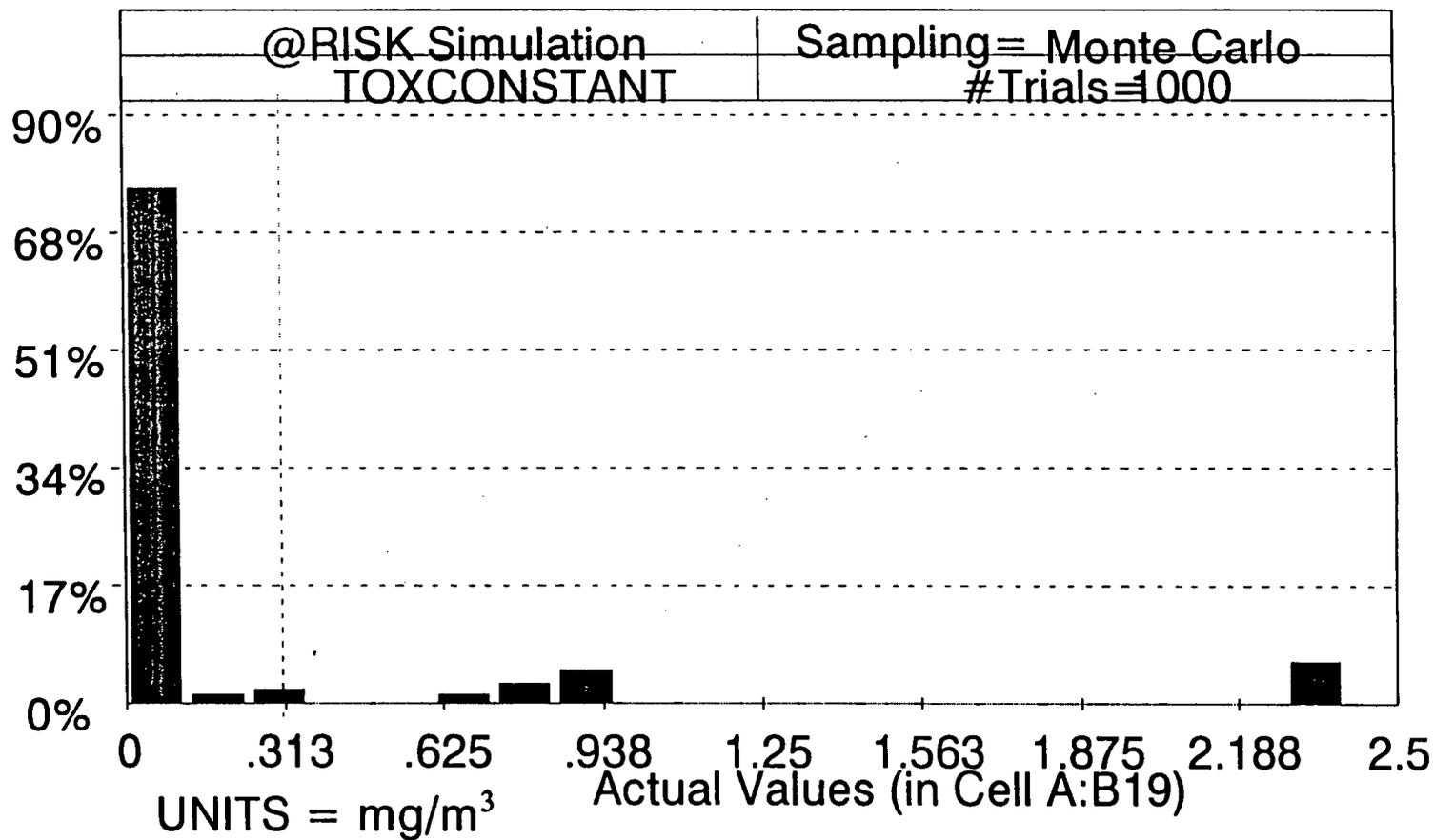
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Carbon Tetrachloride - Carcinogenic Risk  
Intake (Ingestion)

Figure F7 - 12

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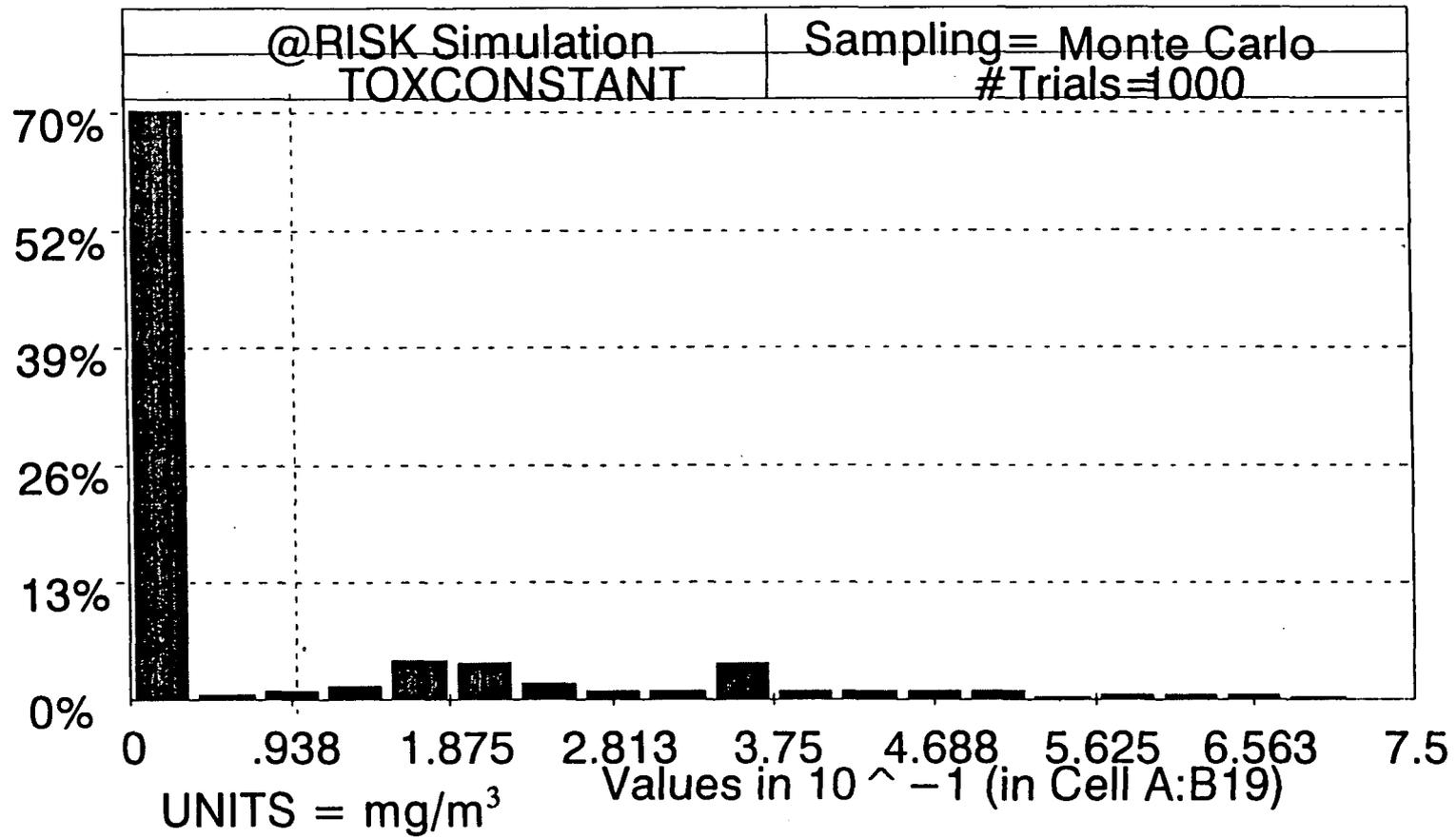
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1,1-Dichloroethene - Carcinogenic Risk  
Toxicity Constant Distribution (Inhalation)

Figure F7-13

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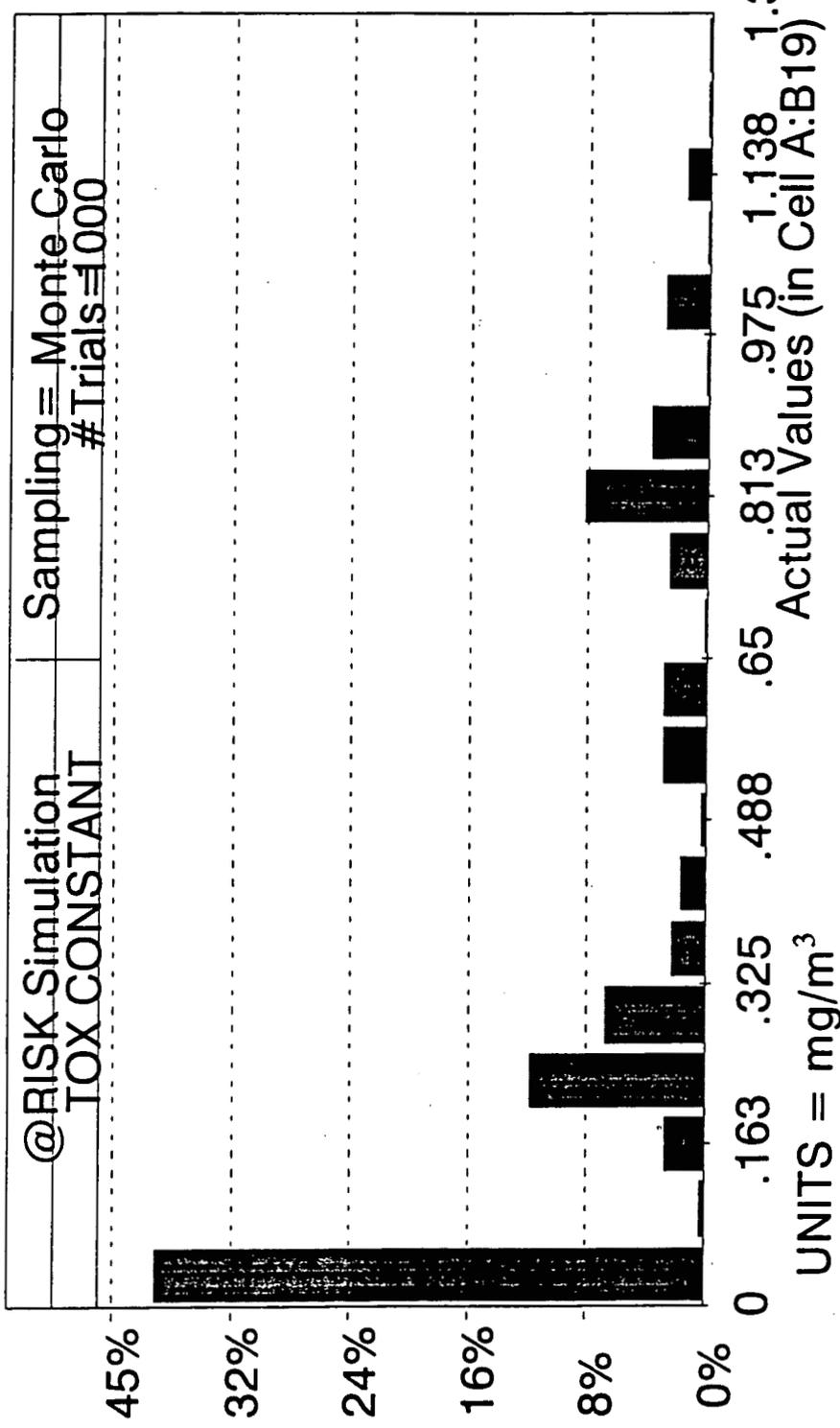


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1,1-Dichloroethene - Carcinogenic Risk  
Toxicity Constant Distribution (Ingestion)

Figure F7-14

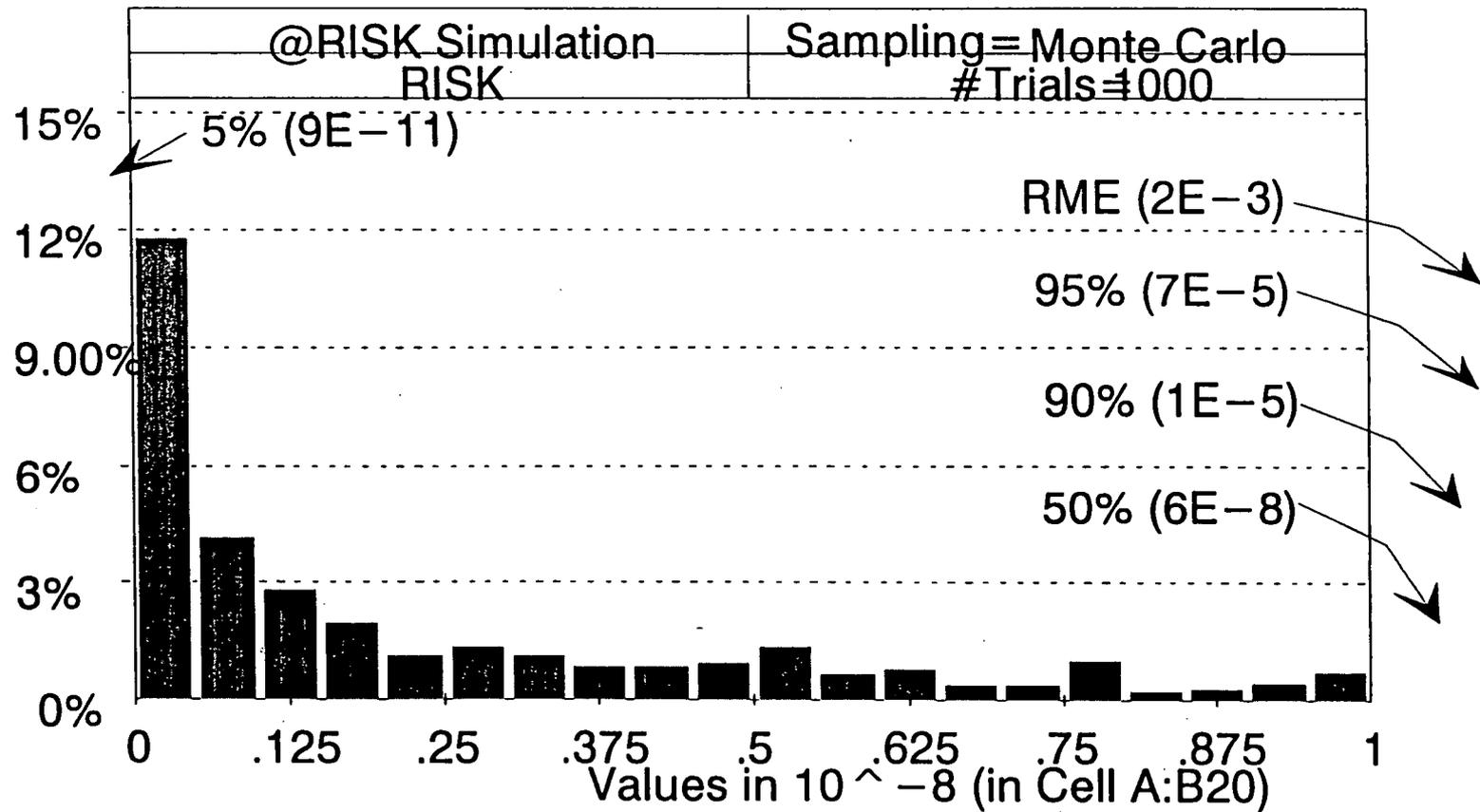


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Carbon Tetrachloride - Carcinogenic Risk  
Toxicity Constant Distribution (Ingestion)

Figure F7 - 15

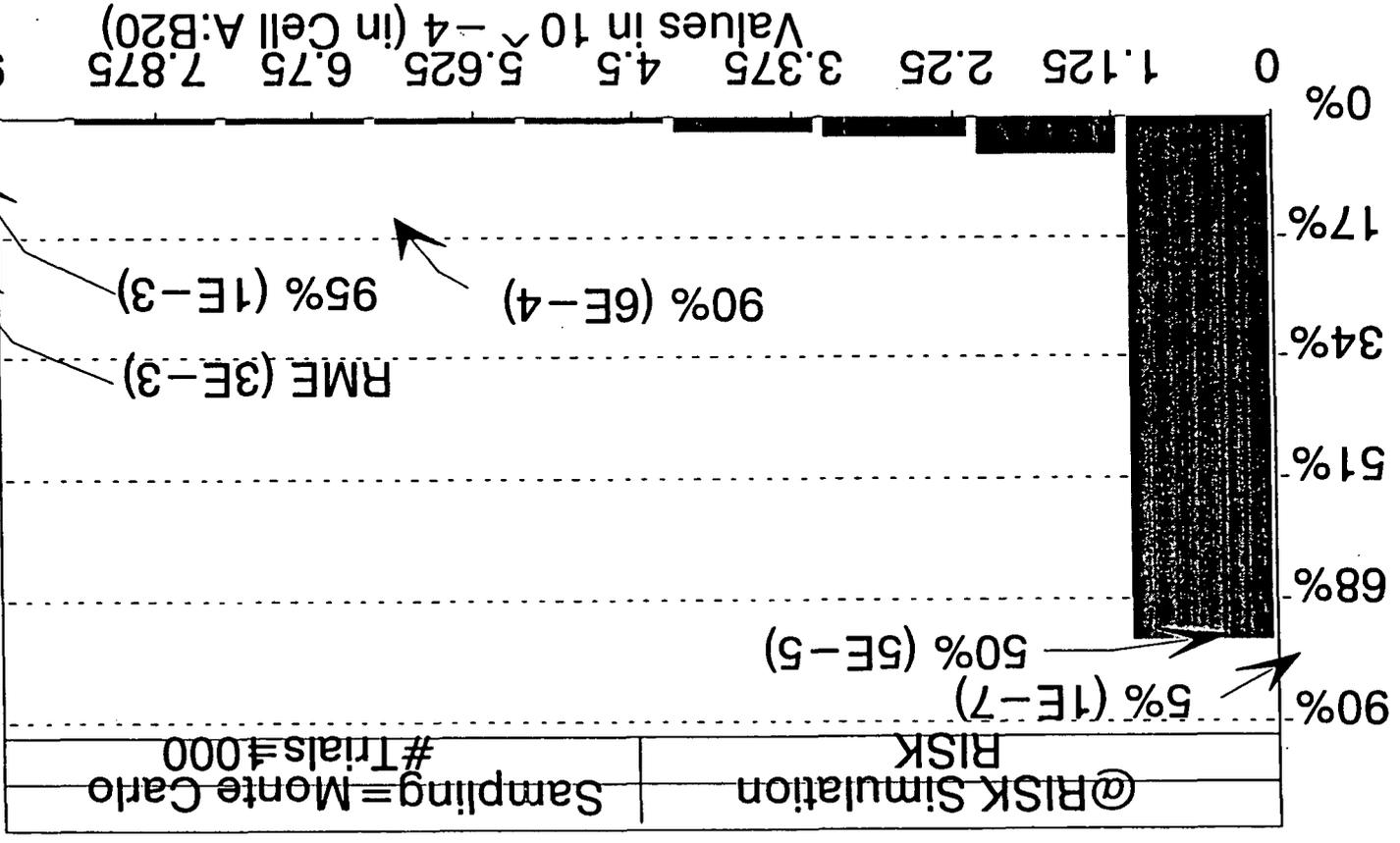


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1,1-Dichloroethene - Carcinogenic Risk  
Inhalation Risk - Future On Site Resident (Adult)

Figure F7 - 16



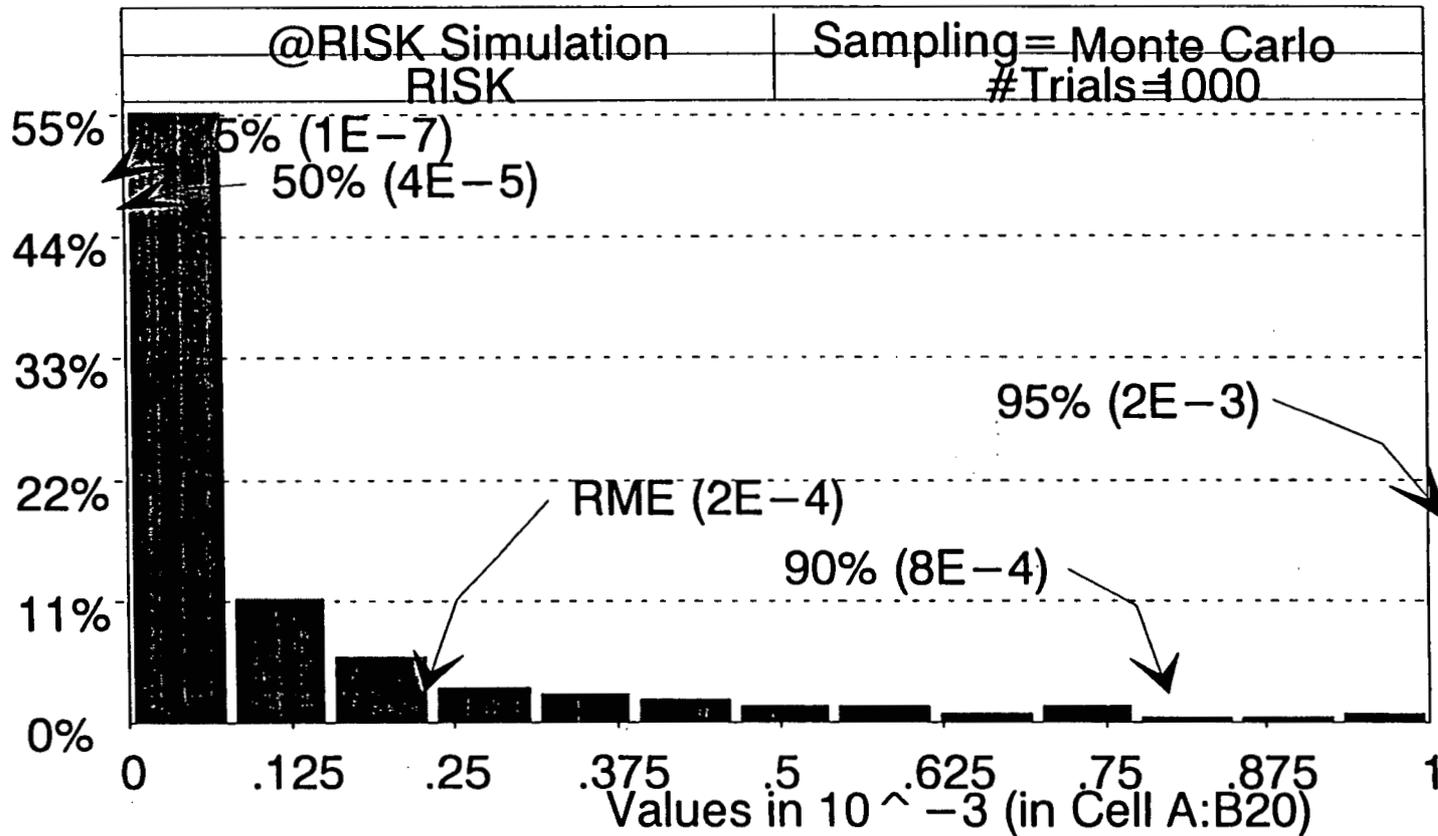
Values in  $10^{-4}$  (in Cell A:B20)

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1,1-Dichloroethene - Carcinogenic Risk  
 Ingestion Risk - Future On Site Resident (Adult)

Figure F7-17

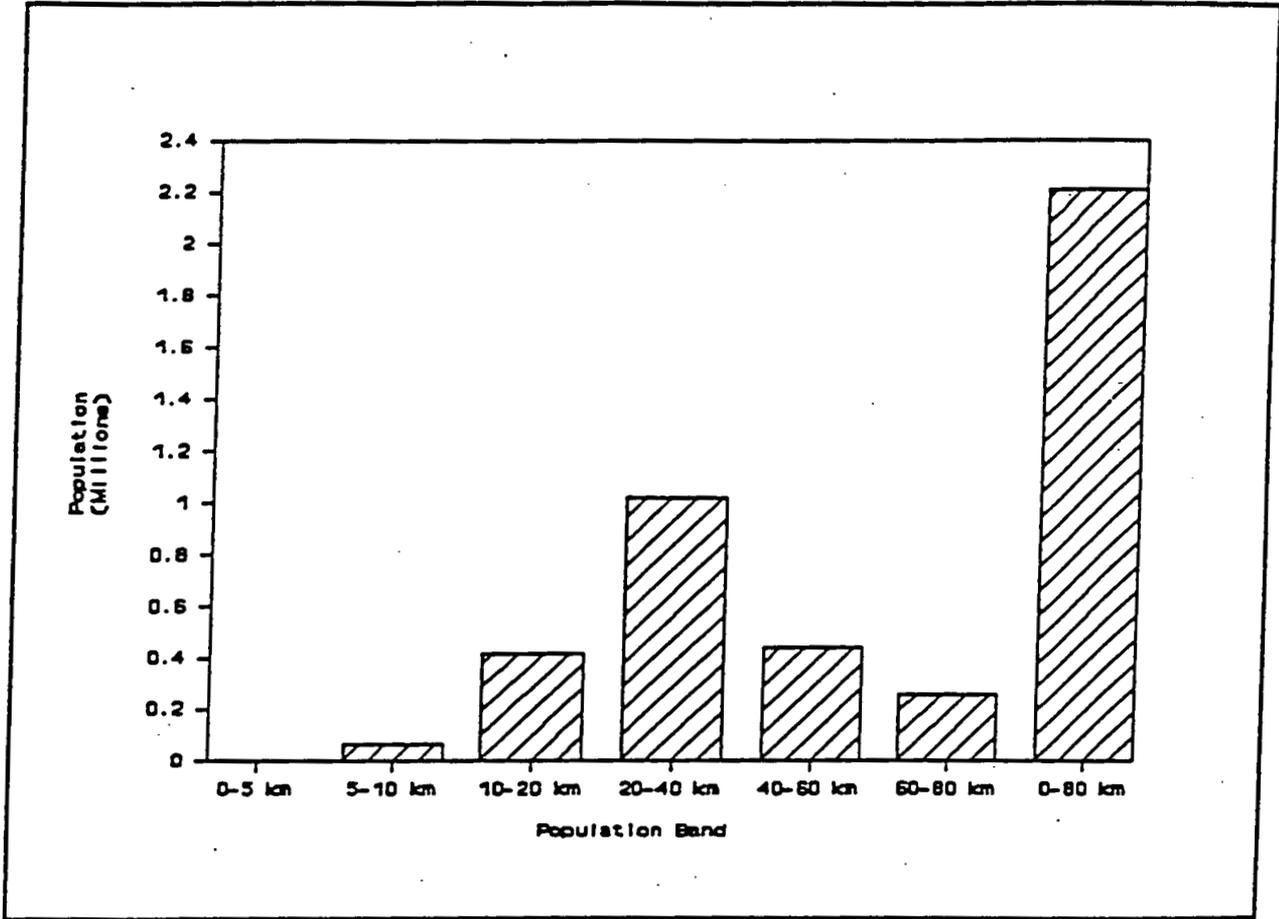


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Carbon Tetrachloride - Carcinogenic Risk  
Ingestion Risk - Future On Site Resident (Adult)

Figure F7-18



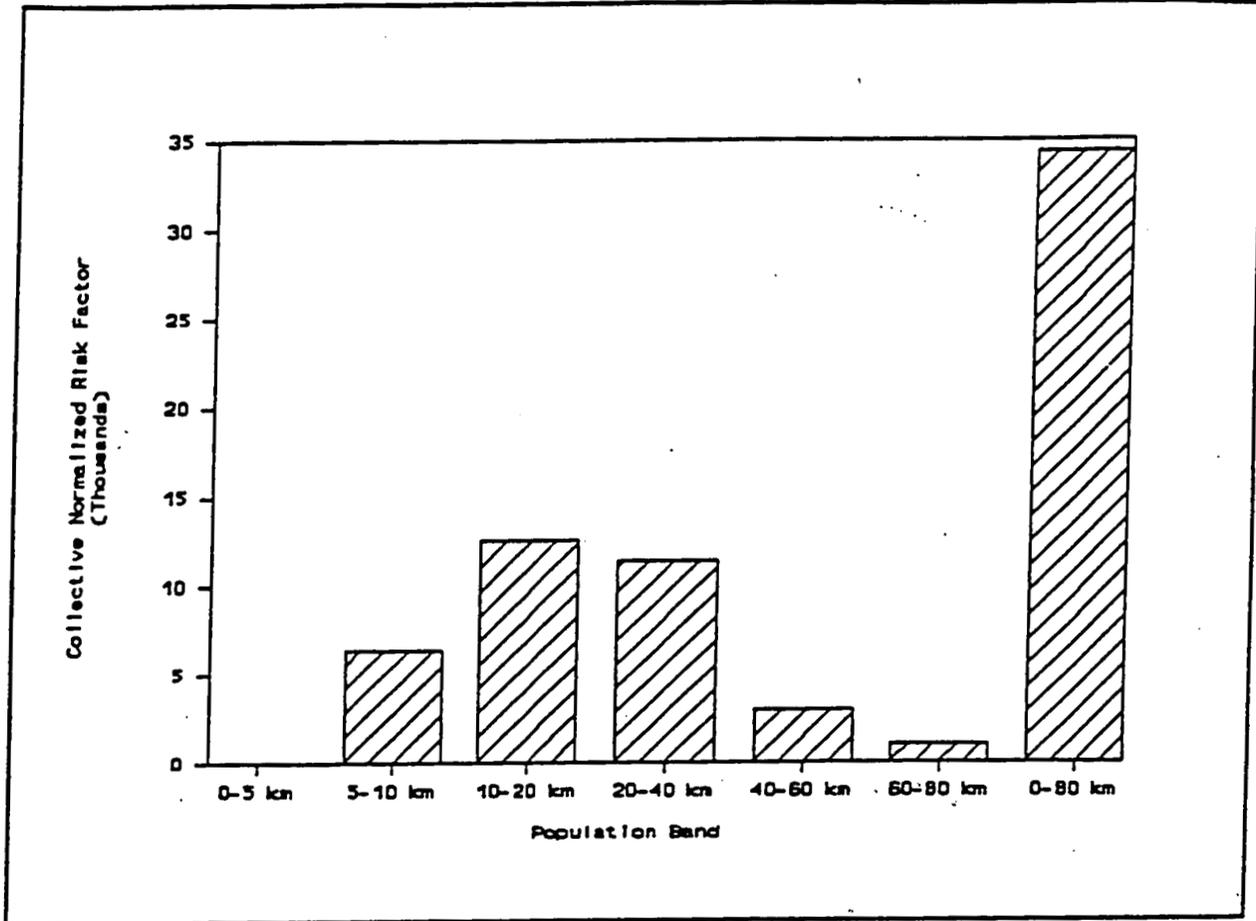
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1989 Population Distribution in Radial  
 Bands up to 80 km from OU1

Figure F7-19

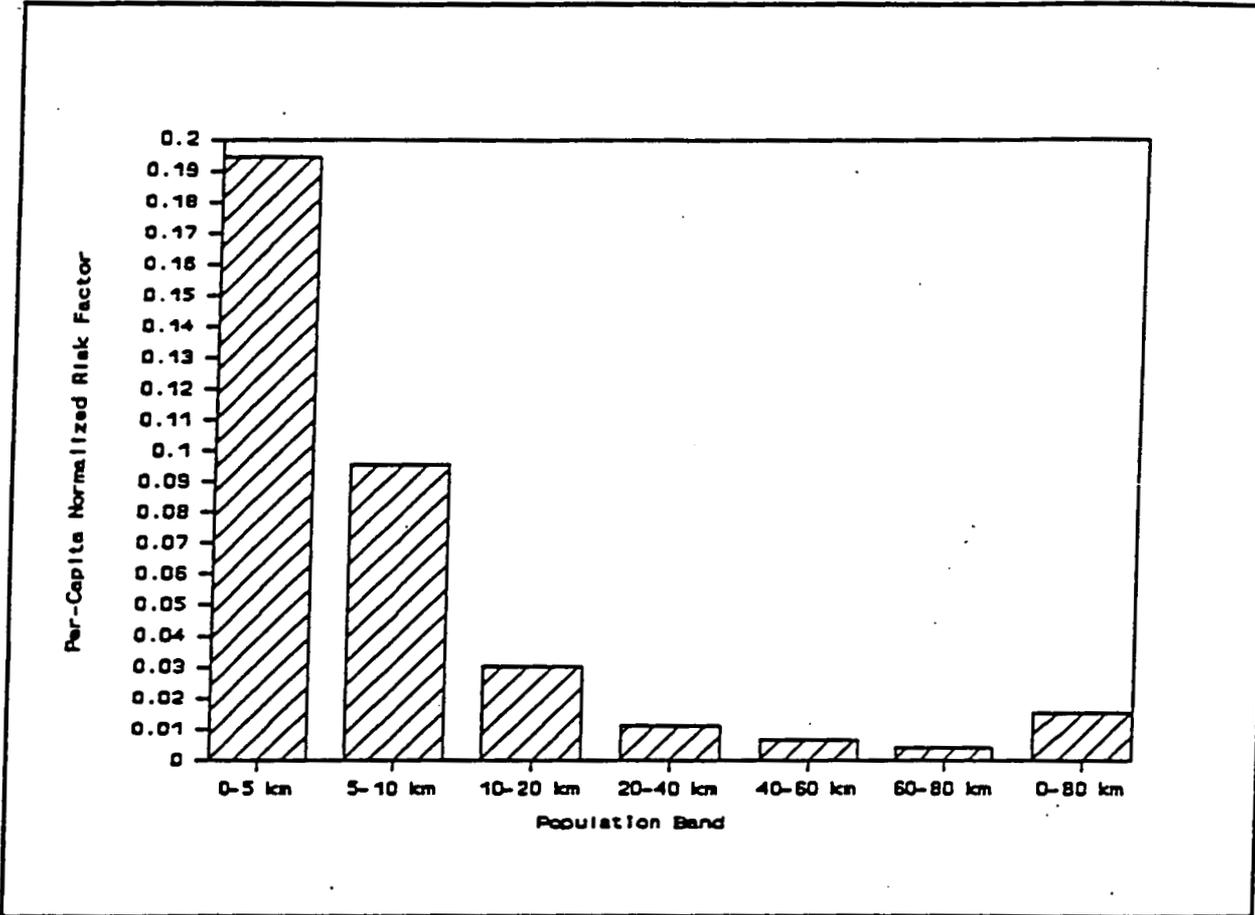
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 Collective Normalized Risk Factors

Figure F7-20



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Per-Capita Normalized Risk Factors

Figure F7-21

## SECTION F8

### SUMMARY OF PUBLIC HEALTH EVALUATION

This study developed a quantitative description and assessment of the risk to the public health posed by the COCs at OU1. Potential COCs are identified along with applicable scenarios that link the COCs to potentially exposed populations. Estimated incremental risks presented by the COCs to which the populations are exposed are then compared to EPA guidance. Finally, the uncertainty analysis formalizes and quantifies the conclusions drawn regarding the risk of the identified COCs.

The purpose of the OU1 PHE is to develop a quantitative description and assessment of the risk to the public posed by the COCs at OU1. This PHE is incorporated in its entirety as part of the Baseline Risk Assessment for OU1. The resulting analysis of the human health risks posed by OU1 responds to and fulfills Attachment 2, Section VII.D Interagency Agreement requiring an analysis acceptable to both EPA and CDH. Pursuant to this requirement, the method of evaluation is taken from the EPA RAGS (EPA, 1989a).

The OU1 area is located on the south side of the RFP security area, is south-facing, and slopes toward Woman Creek from Building 881. IHSSs within the OU1 study area were designated as high priority because it is possible that COCs have been released at these sites based on historical accounts of use or accidental releases (Rockwell, 1987). The following sites are designed as IHSSs at OU1:

- Oil Sludge Pit Site (IHSS 102)
- Chemical Burial Site (IHSS 103)
- Liquid Dumping Site (IHSS 104)
- Out-of-Service Fuel Tank Sites (IHSSs 105.1 and 105.2)
- Outfall Site (IHSS 106)
- Hillside Oil Leak Site (IHSS 107)
- Multiple Solvent Spill Sites (IHSSs 119.1 and 119.2)
- Radioactive Site - 800 Area Site No. 1 (IHSS 130)
- Sanitary Waste Line Leak Site (IHSS 145)

Identification of COCs involves identifying those contaminants that potentially represent the most toxic contaminants at the site based on environmental fate characteristics, toxicity, and the concentration of contaminants present at a site. Figure F8-1 illustrates the contaminant identification process applied for the Phase III RFI/RI through PHE COC identification. The goal is to identify those OU1 contaminants that present the most significant risk to current and future populations given the OU1 exposure scenarios and pathways.

Generally, each step in the COC identification process represents a screening criterion which, after evaluation, retains or eliminates a specific contaminant for consideration in the PHE. For the OU1 contaminants, the process is initiated using the environmental data aggregated for use in the Phase III RFI/RI for groundwater, subsurface soils, and surface soils within the OU boundaries. The PHE COC identification focuses on these media because each is observed within the OU1 IHSS areas, representing the actual physical characteristics of the contaminated portions of the site. As a result, the contaminants identified in these media are considered to be representative of the primary contaminant sources at OU1.

As illustrated in Figure F8-1, after consultation with the EPA and CDH a specific contaminant brought into the PHE COC identification process is either a site contaminant identified via the RFI/RI process or a potential anomaly. The process is applied on a medium-specific basis (i.e., groundwater, subsurface soil, surface soil) and accommodates the contaminants as follows:

- Contaminants identified by the RFI/RI process are evaluated using medium-specific concentration-toxicity screens. The screens are conducted independently for carcinogens and noncarcinogens. The results of the independent concentration-toxicity screens are then combined for each medium to form the COC list for that medium.
- Contaminants with a low frequency of detection are evaluated using an RBC screen. This screen ensures that anomalous contaminants eliminated by the RI process because of infrequent or unexplained detection in OU1 media are not overlooked if they are measured at concentrations that could pose a significant risk.

Application of the screening process shown on Figure F8-1 yields 20 OU1 COCs; these COCs are shown on Table F8-1.

The OU1 physical environment, including the French Drain and treatment system, was used with information about the potentially exposed population, land use scenarios, and exposure pathways to form the conceptual site model shown in Figure F8-2. This is evaluated to identify complete pathways for credible and plausible exposure scenarios. The following describe the specific land use scenarios and pathways selected with the conceptual site model for quantitative assessment:

- Current Off-Site Resident
  - Inhalation of airborne particulates
  - Soil ingestion (following deposition of particulates on residential soil)
  - Dermal contact with soil (following airborne deposition of particulates)
  - Ingestion of homegrown vegetables/fruit (following surface deposition and uptake of particulates)
  
- Current On-Site Worker
  - Inhalation of airborne particulates
  - Soil ingestion
  - Dermal contact with soil
  - Sediment ingestion
  - Dermal contact with sediment
  - Surface water ingestion
  - Dermal contact with surface water
  
- Future On-Site Worker
  - Inhalation of VOCs in indoor air (office worker only) and outdoor air (construction worker only)
  - Inhalation of airborne particulates
  - Soil ingestion
  - Dermal contact with soil
  - Sediment ingestion (office worker only)
  - Dermal contact with sediment (office worker only)
  - Surface water ingestion (office worker only)
  - Dermal contact with surface water (office worker only)
  
- Future On-Site Ecological Researcher
  - Inhalation of airborne particulates
  - Soil ingestion
  - Dermal contact with soil
  - Sediment ingestion
  - Dermal contact with sediment

- Surface water ingestion  
Dermal contact with surface water
- Future On-Site Resident
  - Inhalation of indoor VOCs from basement vapor
  - Inhalation of particulates
  - Soil ingestion
  - Dermal contact with soil
  - Sediment ingestion
  - Dermal contact with sediment
  - Surface water ingestion
  - Dermal contact with surface water
  - Ingestion of homegrown vegetables/fruit (following surface deposition of particulates and uptake)

In addition, four special cases of the on-site residential scenario have been included to show the impact of the use of groundwater and to evaluate risk at the source. The first case includes use of groundwater for an OU1-wide area. The second and third cases include the use of groundwater at the source and exposure to elevated concentrations of radionuclides in surface soil at the source (i.e., hot spots). As indicated by Attachment F-1, OU1 Domestic Water Supply Simulations, the yield of contaminated groundwater in IHSS 119.1 is inadequate to support a household of four people. However, to meet the direct ingestion requirements of RCRA, the second case residential scenario assumes that adequate well water supply exists. For comparison, the third case assumes that the inadequate well water capacity is used and supplemented with water from a public supply. A fourth use was also included to show the risk with the source(s) (groundwater VOCs and surface soil radionuclide hot spots) removed. In summary, the special case scenarios are:

- Future On-Site Resident (Sitewide with Groundwater)
- Future On-Site Resident (Assuming Adequate Groundwater at Source)
- Future On-Site Resident (Groundwater at Source with Public Water)
- Future On-site Resident Scenario without Source (without Groundwater/ without Source).

The special case scenarios involving residential groundwater use involve the same pathways as the on-site residential scenario with the addition of:

- Groundwater Ingestion
- Dermal Contact with Groundwater

- Inhalation of VOCs from Indoor Water Use

A summary of potentially complete exposure pathways that are quantitatively evaluated for all receptors in the baseline human health risk assessment is provided in Table F8-2.

Exposure point concentrations for each receptor are estimated through the use of fate and transport models or from summary statistics of the data. Modeling is used to study the migration of VOCs from groundwater through soil into a hypothetical future structure, and to simulate air dispersion, deposition, and plant uptake of contaminants.

Receptor intakes are estimated with methods consistent with RAGS (EPA, 1989a). The exposure parameter values used are identified in various EPA documents or published literature. Intake estimates are presented for each receptor by contaminant for each applicable pathway.

Toxicity constants for all contaminants, except for PAHs, were taken directly from the IRIS and HEAST (EPA, 1993a,b). PAH toxicity constants are based on relative potency factors using the slope factor of benzo(a)pyrene.

The results of the exposure and toxicity assessments are combined to provide RME risk estimates and to facilitate uncertainty analysis. A Monte Carlo simulation, used with exposure parameter distributions derived from EPA documents, illustrates the magnitude of uncertainty for the risk-predominant pathway. Specifically, the Monte Carlo simulations have been run for inhalation of 1,1-dichloroethene volatilizing through the foundation of a hypothetical on-site residence, and ingestion of groundwater contaminated with 1,1-dichloroethene and carbon tetrachloride.

## Risk Characterization Results and Conclusions

Tables F8-3 and F8-4 summarize the major contributions for RME point estimates of potential carcinogenic risks and noncarcinogenic hazard indices values for each of the subject scenarios, respectively. Phase I, II, and III data analyses which were completed as of August 1993 are reflected in these evaluations.

As presented in this report, one of the principal risk-driving pathways is the inhalation of radionuclides. Concentration values for this pathway were not measured but were modeled using the MILDOS-AREA computer code. The source term, concentration in soil, used in the model can greatly affect the model output. For OU1, the radionuclide hot spot data were included in the OU-wide data using a simple average. This was done to be consistent with the method that the groundwater source (IHSS 119.1) was included with the OU-wide groundwater data. However, this method overestimates the impact of the small surface area of the hot spots on the model output. Although the exact areal extent of the hot spots is not defined, the field report (Appendix A5 of the RI Report) indicates that the four hot spots have a combined area less than 2 m<sup>2</sup>. When this area is compared to the area of OU1, approximately 80,000 m<sup>2</sup>, it can be seen that use of an area-weighted average would reduce the source term (and the model output) by approximately three orders of magnitude. The effects of this overestimation are reflected in the inhalation pathway risks for plutonium-239,240, americium-214, uranium-233,234, and uranium-238 for all scenarios except the future on-site resident scenario where the hot spot data were removed from the data set (Section F7.2.4 and Table F7-24). This is illustrated by comparing the risks from the scenario assuming a future on-site resident at the source and hot spots (Section F7.2.3.2), approximately 3E-02, with the risk for the future on-site resident scenario where the hot spot data were removed, 2E-05.

For the two current exposure scenarios evaluated, carcinogenic risks for Class A carcinogens are calculated to be within the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) target risk range of 1E-06 to 1E-04. All hazard indices are less than unity for both scenarios.

The risk calculated for exposure to Class A carcinogens for the current on-site worker is  $1E-04$ , dominated by the inhalation of plutonium-239, 240 in windblown dust. The risk from exposure to Class B2 carcinogenic exposures is  $6E-07$ , dominated by dermal contact with benzo(a)pyrene in surface soil. The hazard index of  $8E-05$  is dominated by dermal contact with fluoranthene in soil.

The risk calculated for Class A carcinogenic exposures to the current off-site resident is  $2E-06$ , dominated by the inhalation of plutonium-239, 240 in windblown dust. The risk calculated from exposure to Class B2 carcinogens is  $7E-10$ , primarily due to ingestion of PAHs on vegetables. The child hazard index of  $1E-07$  is dominated by the ingestion of garden grown vegetables contaminated by fluorene.

For the three standard exposure future scenarios evaluated, carcinogenic risk is calculated to be above the NCP target risk range. The noncarcinogenic impacts are calculated to be below the NCP target of unity for all three scenarios.

The risk calculated for Class A carcinogenic exposures to the future on-site office worker is  $2E-03$ , dominated by the inhalation of plutonium-239, 240 in windblown dust. The risk calculated for Class C carcinogenic exposure is  $2E-04$ , dominated by the inhalation of 1,1-dichloroethene volatilized through the foundation. Risk from exposure to B2 carcinogens is  $2E-05$ . The hazard index of  $3E-03$  is dominated by the inhalation of 1,1,1-trichloroethane volatilized through the foundation.

The risk calculated for Class C carcinogenic exposures to the future on-site construction worker is  $4E-07$ , dominated by the inhalation of 1,1-dichloroethene volatilized during excavation. The risk calculated for Class B2 carcinogenic exposure is  $2E-08$ , dominated by the inhalation of carbon tetrachloride volatilized during excavation. Risk from exposure to A carcinogens is  $5E-09$ . The hazard index of  $1E-04$  is dominated by the inhalation of 1,1,1-trichloroethene volatilized during excavation.

The risk calculated for Class A carcinogenic exposure to the future on-site ecological researcher is  $2E-03$ , dominated by inhalation of plutonium-239, 240. The risk calculated for exposure to

Class B2 carcinogens is  $9E-06$ , dominated by dermal contact with benzo(a)pyrene in surface soil. The hazard index of  $2E-03$  is dominated by dermal contact with pyrene in surface soil.

The risk calculated for Class A carcinogenic exposure to the future on-site resident is  $3E-03$ , dominated by the inhalation of plutonium-239,-240 dust. Risk from exposure to Class C carcinogens is  $2E-04$ , dominated by the inhalation of 1,1-dichloroethene volatilized through the foundation. Risk from exposures to Class B2 carcinogens is  $4E-05$ . The child hazard index of  $2E-02$  is dominated by the inhalation of 1,1,1-trichloroethane volatilized through the foundation.

For three of the four additional cases of the future on-site resident scenarios evaluated, carcinogenic risk is calculated to be above the NCP target risk range for three scenarios. The noncarcinogenic impacts are calculated to be below the NCP target of unity for one of the four scenarios.

The risk calculated for Class C carcinogenic exposure to the future on-site resident with groundwater ingestion is  $3E-03$ , dominated by the ingestion of 1,1-dichloroethene in groundwater. Risk from exposure to Class A carcinogens is  $3E-03$ , dominated by inhalation of plutonium-239,-240 dust. The risk from B2 carcinogens is  $3E-04$ . The hazard indices of  $9E+00$  for the adult and  $2E+01$  for the child are dominated by the ingestion of carbon tetrachloride in the groundwater.

The risk calculated for Class C carcinogenic exposure to the future on-site resident assuming adequate supply of groundwater for use at the source (IHSS 119.1) is  $4E-02$ , dominated by the ingestion of 1,1-dichloroethene in groundwater. Risk from exposure to Class A carcinogens is  $3E-02$ , dominated by inhalation of plutonium-239,-240 dust. The risk from B2 carcinogens is  $4E-03$ . The hazard indices of  $1E+02$  for the adult and  $3E+02$  for the child are dominated by the ingestion of carbon tetrachloride in the groundwater.

The risk calculated for Class A carcinogenic exposure to the future on-site resident with groundwater use at the source (IHSS 119.1) augmented with public water is  $3E-02$ , dominated by inhalation of plutonium-239,-240 dust. The risk from Class C carcinogens is  $4E-02$ , dominated by the inhalation of 1,1-dichloroethene volatilized through the foundation. The risk from exposure to Class B2 carcinogens is  $5E-04$ . The hazard indices of  $1E+01$  for the adult and  $3E+01$  for the child are dominated by the ingestion of carbon tetrachloride in the groundwater.

The risk calculated for Class B2 carcinogenic exposure to the future on-site resident without the source (IHSS 119.1) is  $3E-05$ , dominated by the ingestion of home grown produce containing dibenzo(a,h)anthracene. The risk for Class A carcinogens is  $2E-05$ , dominated by the inhalation of plutonium-239,-240 dust. The risk for Class C carcinogens is  $8E-07$ . The hazard indices of  $3E-03$  for the adult and  $7E-03$  for the child is dominated by the ingestion of fluorene in vegetables.

The quantification of uncertainty is an important component of the risk assessment process. According to the EPA *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, point estimates of risk "do not fully convey the range of information considered and used in developing the assessment" (EPA, 1992d). Furthermore, the guidance states that the Monte Carlo simulation may be used to estimate descriptive risk percentiles. To provide information about the uncertainties associated with the RME estimate and the relation of the RME estimate relative to other percentiles of the risk distribution, uncertainties were identified during the PHE process and are presented in both qualitative and quantitative terms.

Uncertainties in this risk assessment are due to uncertainties in the risk assessment process in general, specific uncertainties in characterizing the site, and the uncertainties associated with accurately describing exposures. Table F8-5 summarizes the uncertainties and limitations in this assessment. One approach to address this uncertainty is to use health-protective assumptions.

Health-protective assumptions are those that systematically overstate the magnitude of health risks such that even with errors due to uncertainty in the methodology, actual health risks are expected less than those calculated. This process bounds the plausible upper limits of risk and facilitates an informed risk management decision.

The quantitative uncertainty analysis characterizes the propagated uncertainty in public health risk through the pathway and contaminant that dominates the risk in the future on-site resident scenario. These uncertainties are driven by uncertainty in the chemical monitoring data, the transport models used to estimate concentrations at receptor locations, receptor intake parameters, and the toxicity values used to characterize risk. Additionally, uncertainties are introduced in the risk assessment when exposures to several substances across multiple pathways are summed.

Quantitative evaluations of 1,1-dichloroethene and carbon tetrachloride were performed for the hypothetical future on-site residential scenario and are provided in Table F8-6. For example, the range of the total risk for 1,1-dichloroethene inhalation pathway, spans almost six orders of magnitude, from the 5th percentile of  $9E-11$  to the 95th percentile of  $7E-05$ , while the central tendency is indicated by the 50th percentile of  $6E-08$ . The Monte Carlo simulations indicate that the calculated sitewide RME value is higher than the 95th percentile value for 1,1-dichloroethene, but lower for carbon tetrachloride.

The special cases of risk under residential use at the source (IHSS 119.1) and risk without the source (the site excluding IHSS 119.1) are provided to indicate the impact of the localized contaminants in IHSS 119.1. The site without the source refers to the absence of IHSS 119.1 groundwater volatiles and the elevated surface soil radionuclides collected early in 1993. The risk directly over IHSS 119.1 from these three pathways is estimated to be  $4E-02$ , which is greater than the 95th percentile of the sitewide residential risk. The risk associated with the site without the source for these three pathways is estimated to be  $8E-07$ , which is less than the 95th percentile of the sitewide residential risk.

To place the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) risk range of  $10^{-4}$  to  $10^{-6}$  (EPA, 1990c) in context, the incremental latent excess cancer risks due to

contaminants at the site should be compared to several naturally occurring substances present both on and off site. Several naturally occurring substances present both on- and off-site present typical risks in the  $10^{-4}$  to  $10^{-5}$  range. Arsenic, radon progeny, and PAHs (from natural and anthropogenic combustion) are some notable examples.

Cancer incidence in the Denver metropolitan area not associated with the site is 0.33 (CDH, 1991). In other words, one person in three living in the Denver metropolitan area will get cancer before the age of 75. The potential lifetime cancer risk to hypothetical on-site residential receptors directly attributable to the source at the site under "reasonable maximum exposure" conditions at some time in the future has many unquantified uncertainties, including the degree of confidence that residential use of the site would ever be permitted. Therefore, the impacts calculated under the on-site residential land use scenario are extremely conservative; actual exposure, even under plausible future use scenarios, is expected to be lower.

Information regarding the uncertainty in quantifying intakes, toxicological and carcinogenic response, credibility of future exposure scenarios, and the magnitude of "background" risks, will be used by the risk manager for regulatory decision making.

**Table F8-1**  
**OU1 Contaminants of Concern 95 Percent Upper Concentration Limits (UCLs)**  
**Sitewide Data including Source**

Contaminant	Arithmetic Mean (x)	Standard Deviation (sd)	Number of Observations (n)	t Statistic (t)	UCL
<b>Groundwater</b> (ug/L)					
1,1-Dichloroethene	283	1449	211	1.645	447
Carbon Tetrachloride	81.2	500	211	1.645	138
Tetrachloroethene	103	481	211	1.645	157
1,1,1-Trichloroethane	363	1722	211	1.645	558
Selenium	132	172.3	5 *	2.132	296
<b>Surface Soils</b> (ug/kg) or (pCi/g)					
Americium-241	83.2807	460.997	32	1.697	221.6
Plutonium-239,240	294.6888	1776.33	38	1.684	779.9
Benzo (a) anthracene	266.6	156.8	28	1.703	317.1
Benzo (a) pyrene	258.4	136.5	28	1.703	302.3
Benzo (b) fluoranthene	259.8	139.2	28	1.703	304.6
Benzo (k) fluoranthene	246.1	133.5	28	1.703	289.1
Dibenzo (a,h) anthracene	171.6	50.8	27	1.706	188.3
Aroclor-1254	145	230	29	1.701	217.6
Pyrene	525	422	28	1.703	680.8
Fluoranthene	579.6	455	28	1.703	726.0
Fluorene	178.1	42.6	28	1.703	191.8
Acenaphthene	178.6	47.3	28	1.703	193.8
Uranium-233,234	2.1422	4.135	38	1.684	3.272
Uranium-238	1.3758	0.7157	38	1.684	1.571
<b>Subsurface Soils</b> (ug/kg) or (pCi/g)					
Americium-241	10.247	17.654	3 *	2.92	40.01
Plutonium-239,240	29.170	50.218	3 *	2.92	113.8
Pyrene	308	302	187	1.645	344.3
Fluoranthene	313	329	187	1.645	352.6
Toluene	107.9	181.8	432	1.645	122.3
Uranium-233,234	2.204	1.989	3 *	2.92	5.557
Uranium-238	1.186	0.178	3 *	2.92	1.486
<b>Surface Water</b> (pCi/L)					
Americium-241	0.0208	0.0381	173	1.645	0.0256
Plutonium-239,240	0.0071	0.0052	143	1.645	0.0078
Uranium-233,234	2.1047	1.5672	106	1.658	2.357
Uranium-238	3.5319	5.984	106	1.658	4.496
<b>Sediments</b> (ug/kg) or (pCi/g)					
Americium-241	0.027	0.0167	11	1.812	0.0361
Plutonium-239,240	1.305	3.2178	12	1.796	2.973
Benzo (b) fluoranthene	260	32	13	1.782	275.8
Benzo (k) fluoranthene	254.9	38	13	1.782	273.7
Aroclor-1254	132	47	10	1.833	159.2
Pyrene	224.6	69.7	13	1.782	259.0
Fluoranthene	222.7	74.2	13	1.782	259.4
Uranium-233,234	0.9753	0.624	12	1.796	1.299
Uranium-238	0.9394	0.4463	12	1.796	1.171

$UCL = x + t(sd/(n)^{.5})$

\* = Calculated from arithmetic means for each lithologic unit



Table F8-3

## Summary of OU1 Point Estimates of Carcinogenic Risk

Scenario	Total Risk (classes)				Dominant COC	Dominant Pathway
	A	B2	C	Total		
<b>Current</b>						
On-Site Worker (Security Specialist)	1E-04	6E-07	N/A	1E-04	Plutonium-239, 240	Inhalation of dust
Off-Site Resident (Adult)	2E-06	7E-10	N/A	2E-06	Plutonium-239, 240	Inhalation of dust
<b>Standard Future</b>						
Future On-Site Worker (Office)	2E-03	2E-05	2E-04	2E-03	Plutonium-239, 240	Inhalation of dust
Future On-Site Worker (Construction)	5E-09	2E-08	4E-07	4E-07	1,1-Dichloroethene	Inhalation of volatiles
On-Site Ecological Researcher	2E-03	9E-06	N/A	2E-03	Plutonium-239, 240	Inhalation of dust
On-Site Resident (Adult)	3E-03	4E-05	2E-04	3E-03	Plutonium-239, 240	Inhalation of dust
<b>Other Future</b>						
On-Site Resident (Adult) (Sitewide With Groundwater)	3E-03	3E-04	3E-03	6E-03	1,1-Dichloroethene	Ingestion of groundwater
On-Site Resident (Adult) (Assuming Adequate Groundwater At Source)	3E-02	4E-03	4E-02	7E-02	1,1-Dichloroethene	Ingestion of groundwater
On-Site Resident (Adult) (Groundwater At Source With Public Water)	3E-02	5E-04	6E-03	4E-02	Plutonium-239, 240	Inhalation of dust
On-Site Resident (Adult) (Without Source / Without Groundwater)	2E-05	3E-05	8E-07	5E-05	Dibenzo(a,h)anthracene	Ingestion of vegetables

Table F8-4

## Summary of OU1 Point Estimates of Noncarcinogenic Risk

Scenario	Total Hazard Index		Dominant COC	Target Organ	Dominant Pathway
	Child	Adult			
<b>Current</b>					
On-Site Worker (Security Specialist)	N/A	8E-05	Pyrene	Blood	Dermal contact with soil
Off-Site Resident	1E-07	6E-08	Fluorene	Blood	Ingestion of vegetables
<b>Standard Future</b>					
Future On-Site Worker (Office)	N/A	3E-03	1,1,1-Trichloroethane	CNS	Inhalation of volatiles through foundation
Future On-Site Worker (Construction)	N/A	1E-04	1,1,1-Trichloroethane	CNS	Inhalation of volatiles during excavation
On-Site Ecological Researcher	N/A	2E-03	Pyrene	Blood	Dermal contact with soil
On-Site Resident	2E-02	5E-03	1,1,1-Trichloroethane	CNS	Inhalation of volatiles through foundation
<b>Other Future</b>					
On-Site Resident (Sitewide With Groundwater)	2E+01	9E+00	Carbon Tetrachloride	Liver	Ingestion of groundwater
On-Site Resident (Assuming Adequate Groundwater At Source)	3E+02	1E+02	Carbon Tetrachloride	Liver	Ingestion of groundwater
On-Site Resident (Groundwater At Source With Public Water)	3E+01	1E+01	Carbon Tetrachloride	Liver	Ingestion of groundwater
On-Site Resident (Without Source / Without Groundwater)	7E-03	3E-03	Fluorene	Blood	Ingestion of vegetables

Table F8-5

**Public Health Evaluation Uncertainty Factors at OU1  
Rocky Flats Plant**

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Sampling and Analysis</b>		
Use of unvalidated data	May slightly underestimate risk	The percent of radionuclide data validated is 43 %, with a rejection rate of 41 %. However, the unvalidated data used are consistent with previous measurements and should affect risk estimates only slightly.
Identification of OU1 contaminants	May slightly over- or underestimate risk	The use of professional judgement to analyze the data and identify contaminants introduces uncertainty. Some of the detected analytes (e.g., antimony and manganese) can result in risks similar to those calculated for COCs, but are not identified as site contaminants.
Detection limits/COC screening	May slightly over- or underestimate risk	Measurements used in COC screening had multiple detection limits from the laboratory analysis. However, since maximum concentrations are used in screening, the effect is expected to be small.
Concentration-toxicity screen	May slightly over- or underestimate risk	EPA toxicity constants are subject to change and can effect the outcome of the COC screening process.
Identification of OU1 COCs in surface water and sediments	May slightly over- or underestimate risk	Surface soil COCs were used to identify possible OU1 contaminants in surface water and sediments. Surface water and sediments will be further evaluated in the OU5 risk assessment.
Data set completeness	May slightly over- or underestimate risk	The completeness goals were not achieved in all cases, however, critical samples in IHSS were complete.
<b>Fate and Transport Estimation</b>		
Assumed house volume and ventilation rate	May slightly over- or underestimate risk	The indoor concentration of soil gas penetrating the foundation depends on indoor ventilation.
Soil-gas source term assumptions	May over- or underestimate risk	The heterogeneous sources were assumed to be homogeneous.
Natural infiltration rate	May overestimate risk	A conservative value was used for this parameter.
Moisture content	May over- or underestimate risk	This varies seasonally in the upper vadose zone and may be subject to measurement error.
Water table fluctuations	May slightly over- or underestimate risk	The average value used is expected to be representative of the depth over the 25-year exposure period.

Table F8-5 (Continued)

Public Health Evaluation Uncertainty Factors at OU1  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Fate and Transport Estimation (continued)</b>		
Modeling of VOCs from soil gas through the foundation	May under or over estimate risk	There may be DNAPLs in the vadose zone, however, conservative assumptions were used in the modeling from the saturated zone
Use of hot spot data in source term	May greatly overestimate risk	The radionuclide hot spot data were combined in the OU-wide data using a simple average. An area-weighted average indicates the source term is likely to be overestimated by approximately four orders of magnitude.
Volume of theoretical mixing space in near-field air dispersion model	May overestimate risk	The near-field model assumes a conservative volumetric flow rate.
Effect of micrometeorology on air dispersion	May slightly over or under estimate risk	While lower winds reduce the amount of dispersion (thus increasing the potential concentration of airborne contaminants), higher-velocity winds result in significantly higher emission rates of contaminated soils than do lower velocity winds, since resuspension is a non-linear function of wind speed. For example, a unit increase in wind speed will result in more than a unit increase in emission rate.
Variability in annual meteorological data	May slightly over or under estimate risk	Although a rigorous statistical analysis on annual variability was not conducted, the annual variability is less than approximately 1% in each category, resulting in less than approximately 5% from year to year.
Plant uptake estimation	May slightly under or over estimate risk	When specific values were not available, the uptake model used default uptake constants.
COC concentration on plants	May slightly over- or underestimate risk	Exterior plant concentrations depend on assumptions regarding deposition velocity, intercept fraction, and weathering removal rate.

Table F8-5 (Continued)

Public Health Evaluation Uncertainty Factors at OUI  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Exposure Estimation</b>		
Exposure scenario assumptions	May overestimate risk	<p>The likelihood of future scenarios has been qualitatively evaluated as follows:                      on-site residential - improbable                      on-site commercial/industrial - credible                      on-site ecological reserve - credible</p> <p>The likelihood of future onsite residential development is small. If future residential use of this site does not occur, then the risk estimates calculated for future onsite residents are likely to overestimate the true risk associated with future use of this site.</p>
Exposure parameter assumptions	May overestimate risk	Assumptions regarding media intake, population characteristics, and exposure patterns may not characterize actual exposures.
Receptor locations	May overestimate risk	In addition to sitewide risk, risk at the source was also evaluated. Evaluation of risk at the source assumes that a receptor builds directly over the source.
Exposure duration	May over- or underestimate risk	The assumption that an individual will work or reside at OU1 for 25 or 30 years is conservative. Short-term exposures involve comparison to sub-chronic toxicity values, which are generally less restrictive than chronic values.
Non chemical-specific constants (not dependent on chemical properties)	May overestimate risk	Conservative or upper bound values were used for all parameters incorporated into intake calculations.
Exclusion of some hypothetical pathways from the exposure scenarios	May underestimate risk	Exposure pathways were rigorously evaluated for each scenario and eliminated only if it was determined that they were either incomplete or negligible compared to other evaluated pathways.
External radiation	May slightly underestimate risk	The radionuclide COCs are alpha emitters and emit little penetrating radiation. The screening calculation presented in Section F4.5.1 indicates that this pathway has little effect on overall risk.
Permeability coefficients	May slightly over- or underestimate risk	EPA permeability coefficients were algorithmically predicted and have an uncertainty of approximately one order of magnitude.

Table F8-5 (Continued)

Public Health Evaluation Uncertainty Factors at OUI  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
<b>Exposure Estimation (continued)</b>		
Inclusion of groundwater ingestion in the future on-site residential scenario	May overestimate risk	The existence of the French Drain and the lack of available water to support residential development make this a very health-conservative evaluation.
NAPL in subsurface soil	May slightly underestimate risk	The nature and extent evaluation concludes that NAPL in subsurface soil is possible, although it was not sampled directly and a source term cannot be estimated.
Inclusion of hot spot data for radionuclides in surface soil in the sitewide scenarios	May substantially overestimate risk	The hot spots are highly localized. The sitewide without source scenario is more representative of the risk at the site from radionuclides.
Plant ingestion rate	May slightly over- or underestimate risk	The average plant ingestion rate was used with the assumption that homegrown plants would be consumed year-round.
Model does not consider biotic decay	May overestimate risk	Biotic decay would tend to reduce contamination over time. However, the modeling effort did not account for this process.
Exclusion of transformation products	May underestimate risk	Not all transformation products of the identified organic or radioactive compounds were evaluated.
<b>Toxicological data</b>		
Use of cancer slope factors	May overestimate risk	Potencies are upper 95th percentile confidence limits. Considered unlikely to underestimate true risk.
Critical toxicity values derived primarily from animal studies	May over- or underestimate risk	Extrapolation from animal to humans may induce error due to differences in absorption, pharmacokinetics, target organs, enzymes, and population variability.
Critical toxicity values derived primarily from high doses, most exposures are at low doses	May over- or underestimate risk	Assumes linear at low doses. Tend to have conservative exposure assumptions.
Critical toxicity values and classification of carcinogens	May over- or underestimate risk	Not all values represent the same degree of certainty. All are subject to change as new evidence becomes available. Of 16 animal studies with 1,1-dichloroethene, only one produced evidence of carcinogenicity, and it did not present a dose-response relationship.

Table F8-5 (Continued)

Public Health Evaluation Uncertainty Factors at OUI  
Rocky Flats Plant

Uncertainty Factor	Effect of Uncertainty	Comment
Toxicological data (continued)		
Lack of inhalation slope factors	May underestimate risk	Carcinogenic COCs without inhalation slope factors, may or may not be carcinogenic through the inhalation pathway.
Use of oral slope factors to evaluate dermal absorption	May over- or underestimate risk	Assumes that introduction to the blood stream through the skin acts similarly to absorption through the gut.
Addition of risks across weight-of-evidence classifications	May overestimate risk	Addition of risks across weight-of-evidence classifications is extremely health conservative and potentially inappropriate.
Lack of RfDs or RfCs	May underestimate risk	Inhalation RfDs or RfCs are not available from IRIS for trichloroethylene, 1,1-dichloroethene, carbon tetrachloride, tetrachloroethene, selenium, Aroclor-1254, or PAHs.
Effect of absorption	May over- or underestimate risk	The assumption that absorption is equivalent across species is implicit in the derivation of the critical toxicity values. Absorption may actually vary with chemical.
Lack dermal absorption or direct action toxicity values	May slightly underestimate risk	The unavailability of consensus absorption values does not facilitate comparison of absorbed dose to toxicity constants based on administered dose. Dermal absorption of metals is expected to be insignificant compared to ingestion.

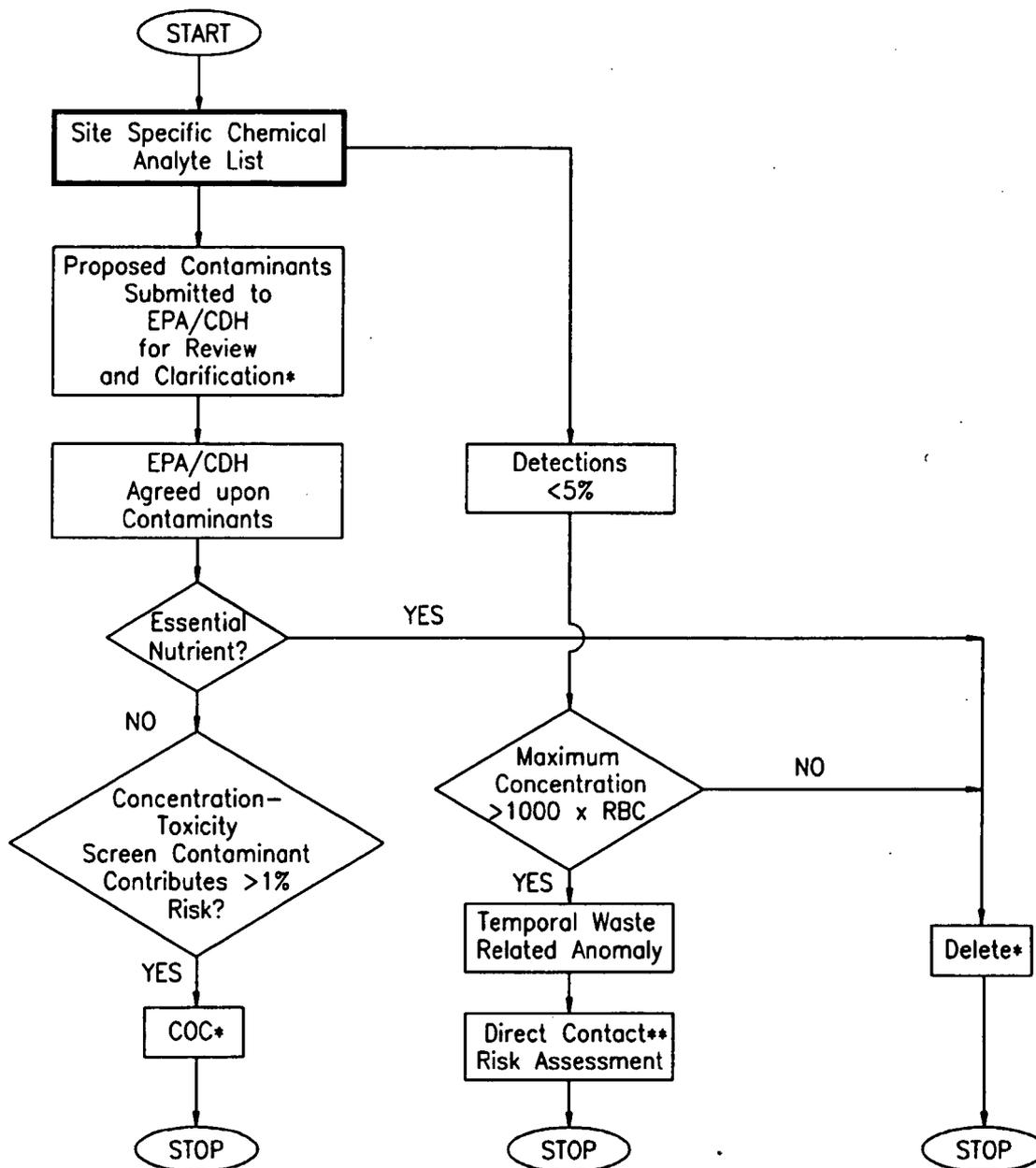
Table F8-6

Summary of Key Contaminants and Risks for the Hypothetical Future On-Site Resident

Contaminant	Exposure Route	Sitewide RME <sup>(a)</sup>	Risk at the Source	Sitewide With the Source Removed	Percentiles From Sitewide Monte Carlo Simulation						
					5	10	25	50	75	90	95
1,1-dichloroethene <sup>(b)</sup>	Inhalation	2E-04	3E-03	8E-07	9E-11	3E-10	4E-09	6E-08	8E-07	1E-05	7E-05
1,1-dichloroethene <sup>(b)</sup>	Ingestion	3E-03	3E-02	NA	1E-07	3E-07	2E-06	1E-05	8E-05	6E-04	1E-03
carbon tetrachloride	Ingestion	2E-04	2E-03	NA	1E-07	4E-07	3E-06	4E-05	2E-04	8E-04	2E-03

<sup>a</sup> Point estimate using EPA's reasonable maximum exposure (RME) method.

<sup>b</sup> It should be noted that risk values are driven by a Class C carcinogen.



• PROFESSIONAL JUDGEMENT MAY BE USED TO RETAIN OR DELETE A CHEMICAL.

\*\* DIRECT EXPOSURE THROUGH INGESTION, INHALATION OR DERMAL EXPOSURE AS APPLICABLE.

UTL = Upper Tolerance Limit  
ANOVA = Analysis of Variance  
RBC = Risk Based Concentration

U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

Contaminants of Concern  
Screening Flow Chart

Figure F8-1

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## SECTION F9

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**Attachment F-1**

**OUI Domestic Water Supply Simulations**

**OU-1 DOMESTIC WATER SUPPLY SIMULATIONS**

**The results of computer simulations of domestic  
water production capabilities from subsurface units beneath  
OU-1 at the Rocky Flats Plant, Golden, Colorado**

**This work was performed by the Geosciences Division  
in support of risk analysis studies.**

**December 14, 1992**

## INTRODUCTION

To investigate the water production capabilities of the colluvial materials beneath Operable-unit 1 at the Rocky Flats Plant several transient pumping computer simulations were performed. These simulations were designed to determine whether these saturated materials could produce sufficient water to supply a hypothetical four-member household. A daily pumping requirement of 240 gallons per day (gpd) was assumed based on a daily water requirement of 60 gallons per person.

## METHOD

Simulations were performed using the USGS MODFLOW groundwater flow simulation package (McDonald and Harbaugh, 1988). Input parameters common to all simulations are listed in Table 1. Simulations were run using a daily time-frame until the pumping-well grid cell went dry or the end of the simulation (365 days) was reached.

The pumping well was located at the center of the 19 by 19 grid cell array. A variable grid spacing ranging from 5 feet at the well to 50 feet at the boundaries was used to provide realistic drawdown conditions near the well. The grid spacing for each scenario are given in Table 1 and shown in Figure 1. The specific yield came from lab analyses of core samples and example values from the literature for fine-grained materials (Fetter, 1980, pg. 68). Boundary conditions were constant head equal to the initial head.

Table 1

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	1E-4 to 1E-5 cm/sec	Table 3-6 of OU1 Phase III Report
Specific Yield	0.10	Lab analyses/literature
Grid Spacing (variable)	from 5 to 50 ft	Assumed
Hydrogeologic Unit Character	Unconfined	On-site observation
Initial Saturated Thickness	10 ft	Figure 3-36 of OU1 Phase III Report
Boundary Conditions	Constant head	Assumed

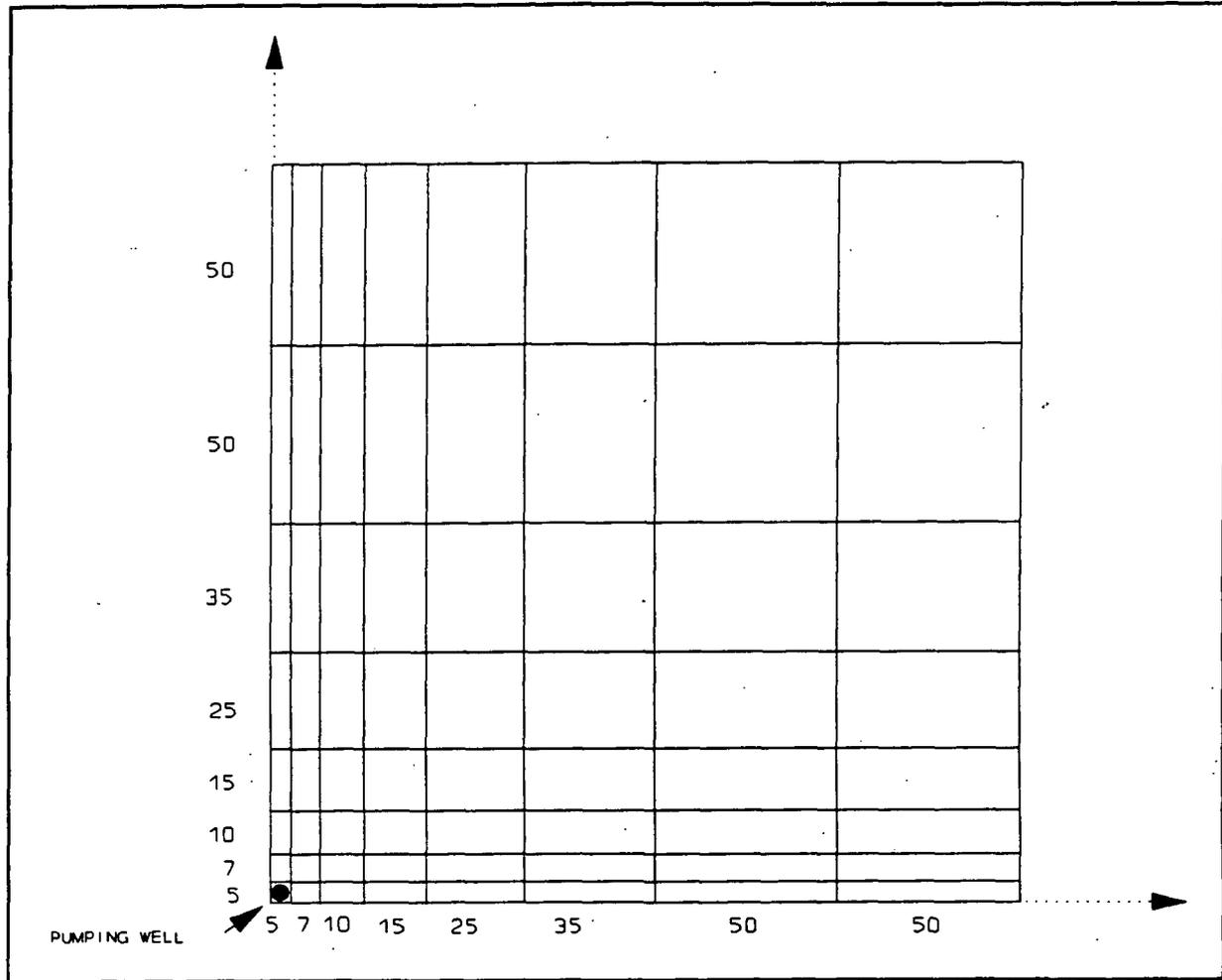


Figure 1. Figure shows 1/4 (upper right-hand quadrant) of an example model grid. In model well is at center of grid. Grid spacings in feet. The number of grid nodes for each model may differ, but grid spacings are similar. Not to scale.

1.5 GPM SCENARIO

For this scenario a pumping rate of 1.5 gpm was used. This rate is below the 3-5 gpm rate commonly used for domestic wells and as such is conservative. Each day of the transient simulation was divided into two stress periods and each period was divided into two timesteps. The first 2.7 hours of each day was used as a pumping period. It was assumed that the household maintained water storage capabilities and that this pumping period was used to replenish the water storage system. The pumping period was based on the total daily water requirement (240 gal.) and the pumping rate (1.5 gpm)

$$240 \text{ gal}/(1.5 \text{ gal/min} \cdot 60 \text{ min/hr}) = 2.7 \text{ hrs}$$

The remaining 21.3 hours of each day allowed water level recovery to take place.

To determine the effect of uncertainty in hydraulic conductivity, two simulations with different conductivity parameters were run. The results from these simulations are shown in the following table.

Summary of simulation results for 1.5 gpm scenario

HYDRAULIC CONDUCTIVITY (CM/SEC)	WATER PRODUCTION DAYS
1E-5	<1
1E-4	<1

**Results**

For the 1.5 gpm scenario the pumping-well grid cell went dry within the first day of the simulation regardless of which hydraulic conductivity was used. This is consistent with the low hydraulic conductivity and small saturated thickness observed for 881 Hillside colluvial materials.

**MAXIMUM POTENTIAL WATER PRODUCTION**

To further investigate the potential for water production from the colluvial materials on the 881 Hillside several simulations with differing pumping rates were performed. These simulations were not designed to produce 240 gallons of water per day, but instead were intended to determine a potential maximum water production. For this reason each day of the transient simulation was divided into two stress periods with each period divided into two timesteps. The first 12 hour stress period was a pumping period and second 12 hour segment was a recovery phase. Again, two different hydraulic conductivities were examined. All other simulation parameters are as listed in Table 1 and shown in Figure 1.

Results from simulations with a hydraulic conductivity of  $1e-4$  cm/sec are shown in the following table. Each row represents a different pumping rate (given both in cubic feet per day and gallons per minute). The "Daily Water Production" column gives the equivalent daily water production rate in gallons. This is the rate at which water was being produced prior to any desaturation of the well cell within the model and assumes a 12 hour pumping period. The "Water Production Days" column gives the number of simulated days before the well cell was desaturated (dried up). Values for "Water Production Days" greater than 365 indicate the well cell did not desaturate during the simulation.

Simulation Results with  $K = 1e-4$  cm/sec

PUMPING RATE FT <sup>3</sup> /DAY	PUMPING RATE GPM	DAILY WATER PRODUCTION (GAL.)	WATER PRODUCTION DAYS
100	0.52	374	< 1
50	0.26	187	3.5
35	0.18	130	43.5
30	0.16	115	221.5
27	0.14	101	> 365

Results from simulations with a hydraulic conductivity of  $1e-5$  cm/sec are shown in the following table. Column and row descriptions are as listed for the previous table. Note that pumping rates are lower than those in the previous simulation.

Simulation Results with  $K = 1e-5$  cm/sec

PUMPING RATE FT <sup>3</sup> /DAY	PUMPING RATE GPM	DAILY WATER PRODUCTION (GAL.)	WATER PRODUCTION DAYS
27	0.14	101	2.25
10	0.052	37	9.25
5	0.026	19	70.5
2.5	0.013	9	> 365

An additional simulation was run using a hydraulic conductivity based on OU-1 field measurements. The geometric mean of single well tests in colluvial materials was  $1.75E-05$  cm/sec. Using this  $K$  and the same values presented for other parameters, gives a maximum pumping rate of 6.0 ft<sup>3</sup>/day (or 22.4 gallons per day) for a 12-hour pump period without desaturating the well.

## Results

The results from these simulations to investigate the maximum potential water production capabilities from the 881 Hillside colluvium indicate maximum expected production capabilities that are less than 10% of that required to supply a family of four (240 gallons). In reality long term production rates would be lower because of the constant head boundary conditions assumed in the model. This type of boundary condition would represent an infinite water source to the well given a sufficiently low pumping rate. Actual field conditions on the 881 Hillside consist of saturated regions often surrounded by desaturated zones which would limit long term water production capabilities. The simulation also assumed a constant saturated thickness across the model domain. Field data from the 881 Hillside indicate that the thickness of saturated colluvium varies, often thinning below the 10 foot saturated thickness assumed in the modeling. The combination of these factors suggest that the model determined pumping rates would be higher than would be expected from an actual water production well on the 881 Hillside.

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**Attachment F-2**

**Transport Model Descriptions and Applications**

## ATTACHMENT F-2

### TRANSPORT MODEL DESCRIPTIONS AND APPLICATIONS

This attachment contains a description of the soil gas model and atmospheric models. The methods used in applying these models are also discussed.

#### **F-2.1 SOIL GAS MODEL**

Soil gas modeling was used to predict the transport and resulting concentrations of volatile contaminants through the soil gas exposure pathway. The migration of volatile contaminants into a residential/commercial structure was identified as a potential exposure pathway (Figure F-2-1). The residential/commercial structure associated with the future on-site receptor was hypothetical and did not consider the specific geotechnical feasibility of such construction on the hillside, which is discussed in Section F4. Figure F-2-2 illustrates the conceptual model for the future on-site receptor at OU1.

Two cases of soil gas transport were considered for characterizing contaminant concentrations in structures associated with a future on-site commercial/industrial receptor and a future on-site resident. Case 1 considers a uniform distribution of volatile organics in the unsaturated zone, and Case 2 considers a source of volatile organics at the water table (Figure F-2-3). Models that are designed to simulate Cases 1 and 2 are based on the work of Jury et al. (1983) and Johnson and Ettinger (1991), respectively. Phase III data indicate that contamination is predominately in the groundwater. Therefore, the Johnson and Ettinger model was used to predict indoor air concentrations. The Johnson and Ettinger model is referred as the Johnson model hereafter.

##### **F-2.1.1 Johnson Model**

The Johnson model, which simulates the volatilization of organic compounds from contaminated water in the saturated zone, employs the following equation:

$$E = \frac{A_B(C_v - C_{soil})D_T^{eff}}{L_T} \quad (1)$$

where:

- E = contaminant transport rate (M/T) across some cross-sectional area
- A<sub>B</sub> = cross-sectional area of building floor (L<sup>2</sup>)
- C<sub>v</sub> = vapor concentration of the contaminate source (M/l<sup>3</sup>)
- C<sub>soil</sub> = contaminant concentration in soil near the point at which E is to be estimated (M/l<sup>3</sup>)
- D<sub>T</sub><sup>eff</sup> = effective porous-media diffusion coefficient of a contaminant in soil gas (L<sup>2</sup>/T)
- L<sub>T</sub> = vertical distance between contaminate source and the point at which E is to be estimated (L)

This equation is a one-dimensional expression of Fick's first law. In Equation 1, C<sub>v</sub> is related to the concentration of contaminant in groundwater by Henry's law:

$$C_v = C_w K_H \quad (2)$$

where:

- C<sub>w</sub> = contaminant concentration in groundwater (M/l<sup>3</sup>)
- K<sub>H</sub> = Henry's constant

Equation 1 describes the diffusion of contaminants from the source to a location near the base of a structure (basement floor or floor slab). To estimate the flow rate (Q<sub>soil</sub>) of gas (air + contaminant) through the floor of the structure, Darcy's law, modified for gas flow across a permeable structure wall, can be used:

$$Q_{soil} = -\frac{k_v A_B \Delta P}{\mu_v \Delta Z} \quad (3)$$

where:

- Q<sub>soil</sub> = volumetric flow of soil gas into the structure (L<sup>3</sup>/T)
- k<sub>v</sub> = intrinsic permeability of soil (L<sup>2</sup>)
- μ<sub>v</sub> = viscosity of the gas (M/lT)
- ΔP = pressure differential across wall of structure (L)
- ΔZ = thickness of wall (L)

The intrinsic permeability ( $k_v$ ) is related to the hydraulic conductivity by:

$$k_v = \frac{K\mu_v}{\gamma_w} \quad (4)$$

where:

$$\begin{aligned} K &= \text{Hydraulic conductivity (L/T)} \\ \gamma_w &= \text{Specific weight of water (M/T}^2\text{/}\ell^2\text{)} \end{aligned}$$

When considering the flow properties of the foundation and assuming that gas flow occurs through permeable below-grade walls, rather than through cracks and openings, Equation 1 becomes:

$$C_{\text{building}} = \frac{\left\{ C_B^* \exp \left[ \frac{Q_{\text{soil}} L_T}{D_T^{\text{eff}} A_B} \right] \right\}}{\exp \left[ \frac{Q_{\text{soil}} L_T}{D_T^{\text{eff}} A_B} \right] + \left[ \frac{D_T^{\text{eff}} A_B}{Q_B L_T} \right] + \left[ \frac{D_T^{\text{eff}} A_B}{Q_{\text{soil}} L_T} \right] \left\{ \exp \left[ \frac{Q_{\text{soil}} L_T}{D_T^{\text{eff}} A_B} \right] - 1 \right\}} \quad (5)$$

and,

$$C_B^* = \left[ \frac{D_T^{\text{eff}} A_B C_v}{Q_B L_T} \right] \quad (6)$$

where:

$$C_{\text{building}} = \text{contaminant gas concentration in the building (M/}\ell^3\text{)}$$

Without a temporal component in this model (a nondepleting source), building concentration results are assumed constant through time (steady state). Therefore, results from Johnson and Ettinger (1991) produce conservative building concentrations for the future on-site receptors (commercial and residential), with groundwater as the contaminant source. Equations 1 through 6 are hereafter referred to as the Johnson model.

The assumptions and limitations inherent in the Johnson model include the following:

- Transport of gas in the unsaturated zone is only by diffusion -- The model does not account for advection of contaminants in the unsaturated zone. Pressure differentials associated with air (or gas) in the unsaturated zone are typically zero because air pressures are usually equivalent to ambient atmospheric pressures; therefore, there is no driving force for advective gas transport in the unsaturated zone.
- Source of contaminant gas is uniform and infinite -- The Johnson model assumes that the source of contaminant gas is large, non-depleting source. The model also assumes that the source is located directly below the floor of the structure and that all gases that diffuse upward beneath the structure eventually enter the structure.
- Structure has permeable walls -- It is assumed that the structure has uniformly permeable walls without cracks or holes. This assumption is conservative in that fractures form the primary permeability of most concrete structures.
- Advection occurs through structure walls -- It is assumed that gases are transported through walls into a structure by advection. The model does not account for diffusion through structure walls. Pressure differentials through the walls of a structure resulting from temperature differences and ventilation drive advective transport near the foundation of a structure.
- Homogeneous porous media -- Transport distances in the unsaturated zone beneath OU1 are likely to be short, and changes in the properties of subsurface soils probably do not vary significantly over short distances; therefore, the impact of heterogeneity on soil gas transport is not likely to be significant.
- Linear equilibrium sorption -- Adsorption and desorption are assumed to be linear, rapid, and reversible. For the purposes of risk assessment, this is a conservative assumption.
- Linear equilibrium liquid-gas partitioning -- The model assumes that Henry's law applies to partitioning (volatilization) between the liquid and gas phases. Henry's law applies to situations in which contaminant concentrations in water are relatively small. This is the case at OU1, according to Phase II data. Henry's law does not apply to concentrated solutions or to volatilization from a pure phase of contaminant.
- Uniform distribution of contaminant in groundwater -- The model does not apply to discontinuous or heterogeneously contaminated zones. For OU1, contamination in the saturated zone is probably fairly uniform.

### **F-2.1.2      Data Summary for Soil Gas Modeling**

A data summary of soil-gas modeling parameters is listed in Table F-2-1. The ranges of data values presented in Table F-2-1 are not intended to be fixed upper and lower limits on the values to be used in the model. The ranges presented convey what is known of the estimated average values and the variability around the average.

#### **F-2.1.2.1      Ventilation Rates for Hypothetical Buildings**

One air-exchange per hour was used as the ventilation rate for the on-site residential structure. This ventilation rate was selected based on typical ventilation rates per volume of structures presented in United Nations (1988). Defining the characteristics of a commercial structure is more complex. Chapter 7 of the Uniform Building Code (UBC, 1988) describes ventilation requirements of commercial structures (Group B Occupancy Buildings) in terms of air flow volumes per occupant. For example, Section 705 states "The mechanically operated ventilation system shall be capable of supplying a minimum of 5 cubic feet per minute of outside air per occupant with a total circulation of not less than 15 cubic feet per minute per occupant in all occupied portions of the building." Buildings where Class I, II, and III-A (flammable and combustible) liquids are used must provide a ventilation rate of six air exchanges per hour.

In this analysis, an area of 930 m<sup>2</sup> (10,000 ft<sup>2</sup>) and a volume of 2,550 m<sup>3</sup> (89,983 ft<sup>3</sup>) were assumed for the dimensions of the commercial structure. To comply with the UBC guidelines and remain conservative in the estimation of building concentrations, the guideline of 15 cubic feet per minute (cfm) per occupant was applied. To calculate the air exchange rate, 100 persons are assumed to occupy the building. These assumptions produced an air exchange rate of 2,550 m<sup>3</sup>/hour(hr) for the commercial structure. Therefore, estimated commercial and residential building concentrations from the Johnson model will be equivalent because one volume of air is exchanged per hour for each structure.

### F-2.1.2.2 Chemical and Material Property Parameters

Several chemical and material property parameters necessary for soil-gas modeling were estimated, using published equations. These parameters and their estimation method are discussed below.

Molecular diffusion is the net transport of a molecule in a liquid or gas medium as a result of intermolecular collision. This process is driven by advection, temperature gradients, and concentration gradients. Diffusion rates are dependent on the chemical constituent and the medium the chemical is moving through (Lyman et al., 1990). For unsaturated soils, liquid-phase and gas-phase diffusion, as well as diffusion along the water-air and water-solid interfaces, contribute to the spread of gases. To account for such spreading, an effective diffusion coefficient ( $D_i^{eff}$ ) is used. Diffusion coefficients in air and water,  $D_G^{Air}$  and  $D_L^{H2O}$  are required to estimate effective diffusion coefficients.

$D_G^{Air}$  for each COC was calculated by the Fuller, Schettler, and Giddings (FSG) method (Lyman et al., 1990). The method of FSG is recommended for estimating  $D_G^{Air}$  because of its ability to minimize error associated with aromatics. The Hayduk and Laudie method is recommended for estimating  $D_L^{H2O}$  of organic compounds in water. This method is recommended because its computation is easier than other techniques and because it has been validated (Lyman et al., 1990). Table F-2-2 lists the estimated values of  $D_G^{Air}$  and  $D_L^{H2O}$  for each COC.

Another parameter necessary for the estimation of soil-gas concentrations and subsequent building concentration is the effective porous medium diffusion coefficient. The effective diffusion coefficient is related to pure component molecular diffusivities in water and air,  $D_L^{H2O}$  and  $D_G^{Air}$ , total porosity,  $\phi$ , vapor filled porosity,  $a$ , and moisture filled porosity,  $\theta$ , by the Millington-Quirk Expression (Jury et al., 1984):

$$D_G = \frac{a^{10/3} D_G^{Air}}{\phi^2} \quad (7)$$

$$D_L = \frac{\theta^{10/3} D_L^{H_2O}}{\phi^2} \quad (8)$$

Assuming that diffusion transport is significant only in the vapor and soil moisture phases, Johnson and Ettinger (1991) define the effective diffusion coefficient as

$$D_i^{eff} = D_G + \frac{D_L}{K_H} \quad (9)$$

This expression does not consider the effects of soil adsorption. Jury et al. (1984a) provides an expression for an effective diffusion coefficient for a uniform soil layer that considers soil adsorption:

$$D_i^{eff} = \frac{K_H D_G + D_L}{\rho_b K_D + \theta + a K_H} \quad (10)$$

where:

- $\rho_b$  = soil bulk density ( $M/\ell^3$ )
- $K_D$  = distribution coefficient ( $L^3/M$ ).

Biodegradation is one of the most important environmental processes that causes organic compounds to break down. The processes contributing to biodegradation are complex and their dependence on soil and environmental parameters, such as water content, temperature, organic carbon, and soil pH are not well understood (Jury et al., 1983). Most research has focused on specific substances and the identification of organisms capable of degrading them. Experimental methods for measuring biodegradation have not been standardized. Thus, results only apply to specific conditions. Therefore, little generalized quantitative data is available (Lyman et al., 1990). For these reasons, a biodegradation factor is not considered in this analysis. This approach results in conservative predictions because building concentrations are overestimated since the source persists longer.

Most soil parameters were obtained from literature or taken from site specific studies (Table F-2-3). Porosities, however, were estimated with standard soil phase relationships, using data presented in the French Drain Geotechnical Report (EG&G, 1991c). Porosities were calculated for samples that had specific gravities and densities using:

$$e = \frac{G_s \rho_w}{\rho_d} - 1 \quad (12)$$

and

$$\phi = \frac{e}{e+1} \quad (13)$$

where:

$e$	=	void ratio (%)
$G_s$	=	specific gravity of sample (M/M)
$\rho_d$	=	dry density of soil sample (M/l <sup>3</sup> )
$\rho_w$	=	density of water (M/l <sup>3</sup> ).

Table F-2-4 lists the calculated porosity values for the upper hydrostratigraphic unit.

### F-2.1.3 Application of the Soil Gas Model

Section F-2.1.2 summarizes the chemical, material property, environmental, and building characteristic data available for conducting the soil gas modeling. The following assumptions apply to the soil gas model:

- 1) Contaminants are uniformly distributed in aerial extent beneath the structures
- 2) Contamination encompasses the entire plan view area of the structures
- 3) The 95% UCL (Section 3) are assumed the source concentration for all COCs
- 4) Contamination is limited to the upper hydrostratigraphic unit (Upper HSU)
- 5) Depth to water table (contaminant source) is 2.5 m from the ground surface and the building foundation has a 1-m crawl space with a permeable floor.

Assumptions 1 and 2 are conservative because building concentrations should be overestimated. Assumption 3 is used to satisfy the RME. Assumption 4 is based on Phase III data, which does not indicate significant contamination in bedrock. Assumption 5 reflects typical colluvial thickness in IHSS 119.1 (where consistently large values of volatile organic concentrations are detected) and complies with model framework assumptions. Figure F-2-4 is a schematic of the Johnson model.

Three source concentration scenarios are simulated. These scenarios are defined as follows:

- Sitewide, includes all wells in OU1
- IHSS 119.1, includes only wells in IHSS 119.1
- Sitewide without IHSS 119.1, includes all wells in OU1 except wells in IHSS 119.1.

Coupling the uncertainty analysis with the Johnson soil gas model required several steps for producing building concentrations. These steps are as follows:

- 1) evaluate the sensitivity of input parameters to the resulting building concentrations
- 2) construct cumulative distribution function (CDF) from the sensitive input distributions
- 3) randomly sample from CDFs using Latin hypercube and simple random sampling
- 4) produce probability distribution functions of steady-state COC building concentrations based on 100 samples or simulations.

In applying the soil gas model to conditions at OU1, two statistical sampling techniques were used as part of the uncertainty analysis of model inputs to building concentration results. A discussion of these sampling techniques is necessary to understand the procedures employed in this analysis. Following the discussion of statistical sampling techniques, the sensitivity and uncertainty analyses of soil gas modeling are addressed.

### F-2.1.3.1 Statistical Sampling Techniques

McKay et al. (1979) discuss different methods of selecting the values of input variables. They chose to discuss simple random sampling (SRS), stratified sampling, and Latin hypercube sampling (LHS) because each has a "considerable intuitive appeal." SRS is the most common technique; but it often requires an extensive number of simulations to adequately represent the content of the probability distribution function of the output. In stratified sampling, the random variable is divided into intervals (strata) and each interval is randomly sampled. The advantage of stratified sampling over SRS is that the model input values are representative of a more even coverage of the sample space. LHS utilizes techniques from both SRS and stratified sampling to ensure that each input variable has all parts of its distribution represented by the input variable (McKay et al., 1979).

To complete the tasks necessary for a soil-gas modeling uncertainty analysis, SRS and LHS techniques are used to select model input values from parameter distributions. A brief discussion and a list of steps for generating input values from random sampling and LHS follow.

SRS is the fundamental sampling plan in statistics (McKay, 1988). Random sampling simply generates samples from a parameter distribution with the use of a random number generator. McKay (1988) estimated that SRS results in characterization of 75% of the output distribution at least 95% for a sample size of 20. To generate randomly sampled input values, the following steps are performed:

1. Select input parameters important for analysis.
2. Estimate the range of variation for each input parameter.
3. Compute a probability density function (PDF) for each input,  $f(x)$ .
4. Assess dependence/independence of variables. A discussion of variable dependency and the sampling technique used to address this condition is provided below.
5. Choose sampling size,  $N$  (i.e., the number of simulations).

6. Generate  $N$  random samples from each PDF. Let  $\{x_{k1}, x_{k2}, \dots, x_{kN}\}$  denote the sample of  $N$  parameter values for input number  $k$ . These values become the  $k^{\text{th}}$  component of the  $N$  input vectors  $x_1, \dots, x_N$ . Random samples are chosen with the aid of a random number generator.
7. For each randomly selected input vector compute an output variable  $h(x)$ .

McKay et al. (1979) has shown that selecting an input variable with LHS produces an unbiased estimate of the mean and PDF of the output. When the function  $h(x)$  is monotonic for each  $x_k$ , the variances of the estimators are usually less than the variances of the input of a simple random sample. Unbiasedness is a desirable property of an estimator because the value of the estimator approaches, on average, the value of the quantity being estimated. The variance reduction of LHS is also a desirable property because it results in fewer computer runs necessary to obtain the same degree of precision as would be obtained using SRS and more simulations (McKay, 1988).

To generate a sample distribution by LHS, the following steps are performed:

1. Select input parameters important for analysis.
2. Estimate range of variation for each input.
3. Assign a PDF for each input,  $f(x)$ .
4. Assess dependence/independence of variables. A discussion of variable dependency and the sampling technique used to address this condition is provided below.
5. Choose sampling size,  $N$  (i.e., the number of simulations).
6. Divide range into  $N$ , equal-probable, intervals ( $N$ -distinct input values are chosen).
  - Let range of input number  $k$  be  $(L_k, U_k)$  and let  $L_k = a_{k0} < a_{k1} < a_{k2} < \dots < a_{ki} < \dots < a_{kn} = U_k$  partition the interval  $(L_k, U_k)$ . Therefore, the probability content of each interval  $(a_{k, i-1}, a_{ki})$  is  $1/N$ .
7. Solve for the end points of the intervals with  $F_k(a_{ki}) = i/N$ ,  $i = 0, 1, 2, \dots, N$

8. From each interval  $(a_{k, i-1}, a_{k,i})$ , a random sample  $x_{ki}$  is obtained from the PDF.
9. For each randomly selected input value, an output variable is produced by the computer code.

Random samples from a PDF are typically obtained via a CDF-inverse method. Let  $F(\cdot)$  be the CDF for the model parameter PDF and let  $U$  have a uniform distribution between 0 and 1. Then  $X = F^{-1}(U)$  has the distribution  $F(\cdot)$ . The procedure is shown in Figure F-2-5. As an example, consider generating 4 random values for  $F(\cdot)$ . The values of  $\frac{1}{4}$ ,  $\frac{2}{4}$ , and  $\frac{3}{4}$  divide the range of  $X$  into four equal-probability intervals through  $F(\cdot)$  as illustrated in Figure F-2-6. Let  $u_1, u_2, u_3,$  and  $u_4$  represent four random numbers on the interval  $(0, 1/N)$ . The four sampled values of  $X$  are sampled values of  $X$  are

$$x_i = F^{-1} \left[ \frac{i-1}{4} + u_i \right], \quad i = 1, 2, 3, 4. \quad (15)$$

The values  $(i-1)/4 + u_i$  represent a stratified sample of size four.

The LHS technique differs from stratified sampling in that it randomizes the order in which sampled values are grouped with sampled values from other parameter distributions (i.e., each model input value sampled are randomly matched with other parameters sampled from their distributions, assuming all parameters are independent). Therefore, each input is represented in the  $N$  sample vectors by  $N$  distinct values which span its range. Then the set of input vectors  $(x_1, x_2, \dots, x_N)$  are the LHS of input values (McKay, 1988).

The LHS method assumes the model input parameters are stochastically independent. When dependencies exist, the joint PDFs cannot be described by the marginal distribution of each input parameter. The LHS must be modified to produce sample distributions that reflect the true joint probability distribution of the inputs (McKay, 1988). McKay (1988) discusses several procedures for handling dependent variables:

- the iterative procedure
- the approximating method
- the exact sampling method.

The exact sampling method, as described by McKay, can always be used. This procedure, for two dependent inputs, stratifies one marginal distribution and is sampled as in LHS. The paired values of the other input is then randomly sampled from its conditional distribution using the values of the first input. The pairs remain together in the random assignment to the model runs. For several dependent inputs, the conditional distributions can be extended and each combination sampled from the conditional distribution remains together in the random assignment of model inputs.

#### F-2.1.3.2 Sensitivity of Soil Gas Model

Figure F-2-7 shows the sensitivity of building concentrations of carbon tetrachloride with respect to the variation of input parameters (building under-pressurization, fraction of organic carbon, intrinsic permeability, moisture content, porosity, and bulk density). The estimated building concentrations were estimated while varying each parameter independently according to its PDF. This was the procedure used for all parameters except porosity. Porosity and moisture content are dependent variables and cannot be varied over their entire range. To account for this condition in the sensitivity analysis, the moisture content was set to its minimum value, and porosity varied over its entire range. Then, porosity was set to its maximum value, and the moisture content was varied over its entire range. This was done so there would be no overlap in the assigned values of the two parameters; the moisture content cannot be larger than porosity. Each COC exhibited similar responses to the variation in input. It is apparent the resulting building concentrations are most sensitive to fraction of organic carbon, moisture content, porosity, and dry density.

The sensitivity of the model to these parameters can be attributed to the effective diffusion coefficient (see Section F-2.1.2.2). The effective diffusion coefficient  $D_T^{\text{eff}}$  is the property

principally responsible for volatilization of an organic compound. For example, for volatile organics residing predominantly in the gas phase,  $D_T^{eff}$  is proportional to the 10/3 power of volumetric air content. Therefore, an increase in the water content decreases the volatilization flux.

### F-2.1.3.3 Uncertainty Analysis

LHS was used to estimate the uncertainty (mean and variance) of COC concentrations in the hypothetical structures. In Section F-2.1.3.2 organic carbon fraction, moisture content, porosity, and dry density were identified as being the most important parameters in the model and were subsequently included in the uncertainty analysis. Table F-2-5 lists the input parameter statistics and sampling methods for the sensitive material properties for the models. Table F-2-6 lists the source concentration (95% UCL) for each COC.

To assess the uncertainties associated with soil gas modeling, LHS was used for sampling independent input variables. For dependent variables (bulk density/porosity and porosity/moisture content), the Exact Sampling Method (Section F-2.1.3.1.5) was used. Because porosity had the smallest number of available data (six data points), bulk density was first sampled and porosity was calculated using the sampled bulk density value and an average specific gravity value of 2.65. The sampling of moisture content was then constrained to the calculated value of porosity. The relationship of porosity to moisture content is as follows:

$$\phi = \theta + a \quad (16)$$

As discussed in Section F-2.1.3.2, the PDF of moisture content is conditional to the fixed porosity value. This means that maximum moisture content is less than or equal to porosity. LHS was used to select input values of porosity and SRS was used to select input values of moisture content from its conditional distribution. Because the SRS technique was used, a larger number of simulations were necessary to adequately represent the distribution of building concentrations (Section F-2.1.3.1). Therefore, 100 simulations were used to estimate the uncertainty.

In using either LHS or SRS, the CDF-inverse technique was employed. By using this technique, no assumptions with regard to statistical distributions were made. The actual measured variability for each COC was represented in the model. The CDFs were used in the sampling process to obtain a set of input values for each simulation. For each set of values, the model was executed, for a total of 100 simulations. The 100 output values approximate the PDF of COC concentrations in the hypothetical structure. The results of the soil gas modeling are listed in Table F-2-7.

## **F-2.2 ATMOSPHERIC MODELS**

### **F-2.2.1 Far-Field Model**

The MILDOS-AREA code (Yuan et al., 1989) was used to model OU1 particulate emissions from the source, transport in air, and deposition at the receptor locations. This code has been used extensively by the U.S. Nuclear Regulatory Commission to assess impacts to the public of aeolian (wind) erosion of particulates and radon gas from uranium mill tailings piles. The results of the code compare favorably to the results obtained in similar cases using AIRDOS-EPA. The assumptions and limitations inherent in MILDOS-AREA include the following:

- Homogeneous surface soil contaminant concentrations - While MILDOS-AREA is capable of modeling a number of sub-areas with different soil concentrations, such divisions require significantly more time to implement. At distances greater than 10 times the largest dimensions of the site, use of a weighted average concentration will result in the same concentrations at the receptor locations as would the use of subareas with different concentrations.
- Gaussian Dispersion - Limitations inherent in a Gaussian model of dispersion apply to MILDOS-AREA. Studies have shown that, for relatively simple terrains, Gaussian dispersion predicts concentrations within a factor of two of the actual concentrations, particularly over long time periods. Topographic maps of OU1 do not indicate drastic changes in slopes such as large valleys or hills between source and receptor, which tend to cause non-Gaussian dispersion.
- Discrete Particle Sizes - MILDOS-AREA assumes that suspendible particles, which in nature are distributed in a continuous spectrum of sizes, can be grouped into one or more discrete groups represented by the Aerosol Mean Aerodynamic

Diameter (AMAD) for each group. This assumption affects the how particles are resuspended and deposited in the model. While the number of groups that can be used is limited to four, the field data will typically include only two discrete particle size distributions total suspended particulates (TSP and PM-10). Therefore, the model will adequately represent the available field data.

- **Vegetated Cover Fraction - MILDOS-AREA** assumes that the entire contaminated surface is bare. To correct for vegetation, resulting concentrations are multiplied by the ratio of bare surface to total surface (that is,  $[1-VF]$  where  $VF$  is the vegetated cover fraction). This may still lead to an overestimate of predicted concentrations depending on the height of the vegetation. However, since mostly grasses and shrubs cover parts of the site, rather than tall trees, predicted concentrations are not overly conservative.
- **Soil Moisture - MILDOS-AREA** assumes that the contaminated soil is dry. This assumption is conservative since contaminated dust will be generated in greater amounts from dry soils, rather than wet soils. Since the code was developed for Western mill tailings sites near Colorado with similar climates, this assumption is appropriate.

MILDOS-AREA was used to estimate the amount of contaminants released and contaminant concentrations at the receptor location, not actual doses. Once concentrations at the receptor locations were calculated, near-field models were applied. A 15-centimeter (cm) root zone/plow model was used to convert the output of the MILDOS-AREA code from surface concentrations (due to deposition) to soil concentrations in the root zone. The following paragraphs describe the use of the dispersion and root-zone models in more detail.

Most emissions from OU1 will result from wind erosion of contaminated soils, which take the form of airborne particulates of various sizes. Most wind-erosion, particulate-emission models are non-linear polynomial functions of average wind speed that consider vegetated cover fractions, threshold wind speeds, and surface roughness. MILDOS-AREA incorporates a dusting algorithm that couples particulate emissions with the joint frequency distributions of wind speed, direction, and stability. The algorithm in MILDOS-AREA was developed for emissions from uranium mill tailings and allows the user to input the anticipated particle size distribution. Due to the original purpose of the code to assess the impacts of uncovered mill tailings piles, MILDOS-AREA assumes unvegetated surfaces; therefore, a correction factor to account for the vegetated fraction of land surface (Cowherd et. al, 1984) was applied to the results  $(1-VF)$ , where

VF is the fraction of soil covered by vegetation), providing a more realistic estimate of actual emissions.

Emissions from OU1 will occur over a relatively long time scale. MILDOS-AREA is a long-term atmospheric dispersion model that uses annual average meteorological data similar to the data required to run AIRDOS-EPA. The transport section of MILDOS-AREA consists of the standard Gaussian model (as found in most airborne dispersion codes, including ISC, FDM and AIRDOS-EPA), which can adequately describe long-term dispersion from OU1. In addition, the algorithm coupling wind-dependent particulate emissions with particulate dispersion is particularly advantageous since it reduces the amount of input required and provides a more realistic description of an actual physical phenomenon.

MILDOS-AREA is capable of modeling the long-term emissions from OU1 that may occur over several years by integrating the deposition/depletion of contaminants at the receptor location, and accounting for resuspension of previously deposited contamination. The model is also capable of calculating the different deposition (and plume depletion) rates for each particle size class. Different time frames were input to MILDOS-AREA, which was used to compute the long-term accumulation and resuspension of contaminants at the receptor location over a 30-year residence period. In addition, MILDOS-AREA calculated the deposition rates of each particle-size class individually, so that respirable PM-10 and TSP concentrations and deposition are computed separately.

MILDOS-AREA was used to compute relative concentration at the receptor location based on unit concentration in soil at the source.

#### **F-2.2.2 Near-Field Model**

The concentrations of respirable contaminants in air over OU1 were calculated to assess the potential health impacts to current or future users of the site. MILDOS-AREA was used to estimate the total relative annual emission from the site based on a unit source concentration of

uranium-238 in soil. This annual emission rate was coupled with a simple box model and source concentration for each COC to estimate concentrations of COCs in air above the source:

$$C_{air} \left( \frac{*}{m^3} \right) = C_{soil} \left( \frac{*}{g} \right) \times C_{dust} \left( \frac{g}{m^3} \right)$$

$$C_{dust} \left( \frac{g}{m^3} \right) = \frac{Q \left( \frac{pCi/yr}{pCi/g} \right) \times (1-VF) \times RF}{3.15 \times 10^7 \left( \frac{sec}{yr} \right) \times VR \left( \frac{m^3}{sec} \right)} \quad (17)$$

$$VR \left( \frac{m^3}{sec} \right) = W (m) \times H (m) \times u \left( \frac{m}{sec} \right)$$

where:

$C_{air}$	=	respirable concentration of contaminant in air
$C_{soil}$	=	concentration of contaminant in soil
$C_{dust}$	=	respirable concentration of dust
H	=	mixing height
Q	=	annual emission rate from OU1 per unit concentration of uranium-238 in soil (calculated using MILDOS-AREA)
RF	=	respirable fraction of dust (<10 microns [ $\mu m$ ])
u	=	mean annual wind-speed
VF	=	fraction of soil covered by vegetation
VR	=	ventilation rate in air mixing volume above OU1
W	=	crosswind width of OU1
*	=	contaminant unit: pCi for radionuclides, milligram (mg) for nonradionuclides.

### F-2.2.3 Data Summary for Atmospheric Models

Specific data requirements for airborne transport models may be grouped into the following general categories:

- Soil/contaminant characteristics (soil concentration, particle size, distribution)
- Source characteristics (vegetated fraction, size, shape)
- Topography (elevation from ground level of receptor relative to source)
- Meteorological data (wind speed/direction, stability, mixing heights)

- Receptor characteristics (distance from source)
- Duration of emission and exposure.

Table F-2-8 provides a summary of the atmospheric model data used for each of these categories. The distance between the source and receptor were obtained by inspection of a topographic map of the area. The distance to the nearest residence in the prevailing downwind direction was selected since this location will receive the highest contaminant concentrations.

The ~~most current~~ (1990) annual meteorologic data set ~~available~~ for the RFP was used as input to the code. ~~The code input and output is provided in~~ (Table F-2-9). Since the releases will occur at ground level, only measurements taken at a height of ten meters or less ~~will be~~ ~~were~~ used. Only limited wind data specific to OU1 have been collected, but the data collected from the on-site RFP meteorological tower are considered to be representative of conditions encountered at OU1. Since no site-specific data exist for average mixing heights at RFP, annual-average mixing heights recorded for the Denver area were used ~~as~~ input. Because the model is relatively insensitive to these parameters and because they exhibit small spatial variability, the values used are appropriate and are representative of conditions at OU1.

#### **F-2.2.4      Application of Air Emission and Transport Models**

This section describes the application of the atmospheric transport models described in Section F-2.2, applying the data described in Section F-2.2.1.

##### **F-2.2.4.1      Far-Field Model**

For radionuclides, a 1 pCi/g concentration of uranium-238 in soil (distributed over the entire area covered by OU1) was input to the MILDOS-AREA. The resulting output concentrations at the receptor location were obtained in units of pCi/m<sup>3</sup> in air (for each particle size) and pCi/m<sup>2</sup> deposited on soil. This was repeated for each time frame, and 30-year average concentrations were computed. These average concentrations can be considered scaling factors, with units of pCi/m<sup>3</sup> in air or pCi/m<sup>2</sup> in soil at the receptor per pCi/g in soil at the source. Soil

contamination at the source, expressed as  $\mu\text{g/g}$  or  $\text{mg/g}$  for nonradionuclides, were converted to output concentrations in units of  $\mu\text{g}$  or  $\text{mg}$  per  $\text{m}^3$  (in air) or per  $\text{m}^2$  (on surface) at the receptor location using the same scaling factors used for radionuclides. In modeling root-zone uptake by vegetation, the surface concentrations in pCi, mg, or  $\mu\text{g}$  per  $\text{m}^2$  were distributed uniformly in the top 15 cm of the soil layer by assuming the soil is plowed annually (Gilbert et al. 1989). Volume-based concentrations in soil were then divided by a soil density of  $1.6 \text{ g/cm}^3$  to obtain mass-based concentrations (e.g.,  $1 \text{ pCi/m}^2 = 6.7 \text{ E-06 pCi/cm}^3$  in top 15 cm =  $4.2 \text{ E-06 pCi/g}$ ).

Table F-2-10 presents the relative concentrations computed by MILDOS-AREA based on a 1 pCi/g uranium-238 concentration in soil at OU1. These results were used to convert contaminant soil concentrations at OU1 into contaminant concentrations at the receptor locations. The MILDOS-AREA model was also used to estimate the total annual emission of contaminants per unit contaminant concentration in soil at OU1. An annual emission rate of  $1.46 \text{ E-04}$  Curies/year (Ci/yr) per pCi/g was computed by MILDOS-AREA and used as input to the near-field model.

#### **F-2.2.4.2 Near-Field (On-Site) Model**

The on-site concentration of contaminants in air was calculated using the equations presented in Section F-2.2.2. Assuming a down-wind width (W) of 200 m, a mixing height (H) of 3 meters, and a mean wind speed (u) of 4.0 meters per second (m/sec), the ventilation rate (VR) over OU1 is calculated at  $2,400 \text{ m}^3/\text{sec}$ . Using this ventilation rate, an emission rate of  $1.46 \text{ E+08 pCi/yr}$  per pCi/g, a vegetated fraction of 0.57, and a respirable particulate fraction of 0.44 results in a respirable dust concentration of  $3.6 \text{ E-04 g/m}^3$ . For comparison, this is within a factor of two of the default respirable dust concentration used in the RESRAD code (Gilbert et al., 1989).

#### **F-2.2.4.3 Sensitivity Analysis of Air Emission and Transport Models**

Particle size fractions were varied plus or minus 25 % to estimate sensitivity of the air emission and transport models. There is a direct linear correspondence of respirable airborne mass with

particle size fraction. Particle deposition, however, has a non-linear inverse relationship to particle size fraction. An increase of 25 % of the respirable fraction results in an approximately 10 % decrease in deposition.

Sensitivity analysis was not conducted on the other standard parameters of the Gaussian plume equation. Gaussian models are firmly rooted in available experimental data and are also the most extensively validated class of dispersion models (NCRP, 1984). In general, predictions over long periods of time are within a factor of two of actual concentrations (EPA, 1992).

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Table F-2-1

## Data Summary for Soil-Gas Modeling

Parameter	Units	Range <sup>a</sup>	Source
<b>Properties of Upper Hydrostratigraphic Unit</b>			
Total Porosity <sup>b</sup>	%	44 - 30	FD Report <sup>c</sup>
Bulk Density	kg/m <sup>3</sup>	1,925 - 1,452	FD Report <sup>c</sup>
Fraction of Organic Carbon	%	0.001 - 2.3	Phase III Draft (RFI/RI Report <sup>d</sup> )
Water Content	% dry weight	28.3 - 6.8	FD Report <sup>c</sup>
Hydraulic Conductivity	cm/sec	$1.0 \times 10^{-4}$ - $9.0 \times 10^{-7}$	Phase III Draft (RFI/RI Report <sup>e</sup> )
Intrinsic Permeability	cm <sup>2</sup>	$9.14 \times 10^{-9}$ - $8.23 \times 10^{-8}$	Phase III Draft (RFI/RI Report <sup>e</sup> )
<b>Environmental Properties</b>			
Relative Humidity	%	50 - 36	Koffer <sup>f</sup>
Evapotranspiration Rate	m/day	$5.59 \times 10^{-3}$ - $6.71 \times 10^{-4}$	Koffer <sup>f</sup>
<b>On-Site Building Characteristics</b>			
Building Under- Pressurization	g·m <sup>2</sup> /s <sup>2</sup>	1 - 300	Johnson <sup>g</sup>
Ventilation Rate	cm <sup>3</sup> /s	2800	United Nations <sup>g</sup>
<b>Properties for Carbon Tetrachloride</b>			
Groundwater Concentration	µg/l	0.2U - 4,500	Phase III Draft (RFI/RI Report <sup>d</sup> )
Mass of Contaminant in Soil or Groundwater	g/m <sup>3</sup>	—	Phase III RI/FS (unavailable)
Area of Contamination (within IHSS)	m <sup>2</sup>	—	Phase III RI/FS (unavailable)
Saturated Vapor Density	g/m <sup>3</sup>	6,290 - 5,500	Montgomery and Welkom <sup>j</sup> Verschueren <sup>k</sup>
Solubility	g/m <sup>3</sup>	1,160 - 757	Montgomery and Welkom <sup>j</sup> Verschueren <sup>k</sup>

Table F-2-1

## Data Summary for Soil-Gas Modeling

Parameter	Units	Range <sup>a</sup>	Source
Henry's Law Constant	—	0.94	Montgomery and Welkom <sup>1</sup> Peterson et al. <sup>2</sup>
Organic Carbon Partition Coefficient	log (ml/g)	2.35 - 2.62	Montgomery and Welkom <sup>1</sup> Kanega and Goring <sup>3</sup>
Absorption Distribution Coefficient (Saturated Zone)	ml/g	$1.1 \times 10^{-6}$ - $1.0 \times 10^{-2}$	Typical Range <sup>d</sup>
Molecular Diffusion Coefficient in Air	cm <sup>2</sup> /sec	$8.18 \times 10^{-2}$	Lyman <sup>1</sup>
Molecular Diffusion Coefficient in Water	cm <sup>2</sup> /sec	$9.34 \times 10^{-6}$	Lyman <sup>1</sup>
<b>Properties for Tetrachloroethene</b>			
Groundwater Concentration	µg/l	0.04U - 6,000	Phase III Draft (RFI/RI Report <sup>d</sup> )
Mass of Contaminant in Soil or Groundwater	g/m <sup>3</sup>	—	Phase III RI/FS (unavailable)
Area of Contamination (within IHSS)	m <sup>2</sup>	—	Phase III RI/FS (unavailable)
Saturated Vapor Density	g/m <sup>3</sup>	6,780	Montgomery and Welkom <sup>1</sup>
Solubility	g/m <sup>3</sup>	400 - 150	Montgomery and Welkom <sup>1</sup> Verschueren <sup>t</sup>
Henry's Law Constant	—	0.625 - 0.536	Montgomery and Welkom <sup>1</sup>
Organic Carbon Partition Coefficient	log (ml/g)	2.56 - 2.322	Montgomery and Welkom <sup>1</sup>
Absorption Distribution Coefficient (Saturated Zone)	ml/g	$2.10 \times 10^{-6}$ - $8.35 \times 10^{-3}$	Typical Range <sup>d</sup>
Molecular Diffusion Coefficient in Air	cm <sup>2</sup> /sec	$7.60 \times 10^{-2}$	Lyman <sup>1</sup>
Molecular Diffusion Coefficient in Water	cm <sup>2</sup> /sec	$8.69 \times 10^{-6}$	Lyman <sup>1</sup>
<b>Properties for 1,1,1 Trichloroethane</b>			

Table F-2-1

Data Summary for Soil-Gas Modeling

Parameter	Units	Range <sup>a</sup>	Source
Groundwater Concentration	$\mu\text{g}/\ell$	0.1U - 2,000	Phase III Draft (RFI/RI Report <sup>d</sup> )
Mass of Contaminant in Soil or Groundwater	$\text{g}/\text{m}^3$	—	Phase III RI/FS (unavailable)
Area of Contamination (within IHSS)	$\text{m}^2$	—	Phase III RI/FS (unavailable)
Saturated Vapor Density	$\text{g}/\text{m}^3$	5,450	Montgomery and Welkom <sup>j</sup>
Solubility	$\text{g}/\text{m}^3$	1,334 - 300	Montgomery and Welkom <sup>j</sup> Verschueren <sup>k</sup>
Henry's Law Constant	—	0.74 - 0.53	Montgomery and Welkom <sup>j</sup>
Organic Carbon Partition Coefficient	$\log (\text{m}\ell/\text{g})$	2.18 - 2.017	Montgomery and Welkom <sup>j</sup>
Absorption Distribution Coefficient (Saturated Zone)	$\text{m}\ell/\text{g}$	$1.04 \times 10^{-6}$ - $3.47 \times 10^{-3}$	Typical Range <sup>d</sup>
Molecular Diffusion Coefficient in Air	$\text{cm}^2/\text{sec}$	$8.18 \times 10^{-2}$	Lyman <sup>l</sup>
Molecular Diffusion Coefficient in Water	$\text{cm}^2/\text{sec}$	$9.28 \times 10^{-6}$	Lyman <sup>l</sup>

Table F-2-1

## Data Summary for Soil-Gas Modeling

Parameter	Units	Range <sup>a</sup>	Source
<b>Properties for 1,1 Dichloroethene</b>			
Groundwater Concentration	µg/l	0.2U - 18,000	Phase III Draft (RFI/RI Report <sup>d</sup> )
Mass of Contaminant in Soil or Groundwater	g/m <sup>3</sup>	—	Phase III RI/FS (unavailable)
Area of Contamination (within IHSS)	m <sup>2</sup>	—	Phase III RI/FS (unavailable)
Saturated Vapor Density	g/m <sup>3</sup>	3,960	Montgomery and Welkom <sup>1</sup>
Solubility	g/m <sup>3</sup>	5,000 - 273	Montgomery and Welkom <sup>1</sup>
Henry's Law Constant	—	0.859 - 0.614	Montgomery and Welkom <sup>1</sup>
Organic Carbon Partition Coefficient	log (ml/g)	1.81	Montgomery and Welkom <sup>1</sup>
Absorption Distribution Coefficient (Saturated Zone)	ml/g	$6.5 \times 10^{-7} - 1.5 \times 10^{-3}$	Typical Range <sup>d</sup>
Molecular Diffusion Coefficient in Air	cm <sup>2</sup> /sec	$9.36 \times 10^{-2}$	Lyman <sup>1</sup>
Molecular Diffusion Coefficient in Water	cm <sup>2</sup> /sec	$1.10 \times 10^{-5}$	Lyman <sup>1</sup>

- <sup>a</sup> Range of observed values, typically from Phase I and II reports (footnote 8) or reports to OUI investigations.
- <sup>b</sup> Total porosity calculated from the formula  $e/(1+e)$  where  $e = (g_r/r_w) - 1$  and  $g$  is the specific gravity of a soil/rock sample,  $r_w$  is the density of water, and  $r_s$  is the dry density of the sample. Data was obtained from the geotechnical report (EG&G 1991c).
- <sup>c</sup> EG&G (1991c).
- <sup>d</sup> Typical estimates:
  - Values of organic carbon content from Table 5-3 (soils and alluvium/colluvium) of the Phase III Draft RFI/RI Report.
  - Adsorption distribution coefficient ranges were estimated using maximums and minimums for percent organic carbon ( $P_o$ ) and organic carbon partition coefficient ( $K_{oc}$ ), and using the equation  $K_d = K_{oc}P_o/100$  (Lyman et al. 1990).
- <sup>e</sup> Hydraulic conductivity ranges taken from B1.4-3 of the Phase III Draft RFI/FS Report (EG&G 1992b).
- <sup>f</sup> Koffer (1989).
- <sup>g</sup> —: unitless, not detected, no data or no information source.
- <sup>h</sup> Rockwell International (1988).
- <sup>i</sup> Only one value obtained from Montgomery and Welkom (1990).
- <sup>j</sup> Montgomery and Welkom (1990).
- <sup>k</sup> Verschuuren (1983).
- <sup>l</sup> Lyman et al. (1990); calculated using the PSG method (Lyman et al. 1990). Note that the diffusion coefficients depend on both material and fluid properties.
- <sup>m</sup> Johnson and Btinger (1991).
- <sup>n</sup> Interpreted from hydraulic conductivities presented in the Phase III Draft RFI/FS Report (EG&G 1992b) and known properties of pure water.
- <sup>o</sup> Interpreted from typical dimensions of a house given by the United Nations (1988).
- <sup>p</sup> Peterson et al. (1978)
- <sup>q</sup> Kanega and Goring (1980)

**Table F-2-2  
Mean Chemical Input Parameters**

COC	CONSTANTS		CALCULATED			
	Henry's Constant	Organic Carbon Partition Coefficient (cm <sup>3</sup> /g)	Distribution Coefficient* (ml/g)	Molecular Diffusion Coefficient in Air (cm <sup>2</sup> /s)	Molecular Diffusion Coefficient in Water (cm <sup>2</sup> /s)	Effective Diffusion Coefficient (cm <sup>2</sup> /s)
Carbon tetrachloride	0.94	354.8	2.210	8.18x10 <sup>-2</sup>	9.34x10 <sup>-6</sup>	5.83x10 <sup>-4</sup>
1,1 Dichloroethene	0.74	64.60	0.403	9.36x10 <sup>-2</sup>	1.10x10 <sup>-5</sup>	2.15x10 <sup>-3</sup>
Tetrachloroethene	0.58	271.6	1.693	7.60x10 <sup>-2</sup>	8.69x10 <sup>-6</sup>	4.35x10 <sup>-4</sup>
1,1,1-trichloroethane	0.64	8.150	0.051	8.18x10 <sup>-2</sup>	9.28x10 <sup>-6</sup>	4.20x10 <sup>-3</sup>

\* Based on average (0.0062) fraction organic carbon content.

μg/l = micrograms per liter.  
 cm<sup>3</sup>/s = cubic centimeters per second.  
 ml/g = micrograms per liter.  
 cm<sup>2</sup>/s = centimeters squared per second.

Table F-2-3

Environmental, Material Property, and Building  
Characteristic Parameters

Parameter	Units	Value
<b>ASSUMED ENVIRONMENTAL PARAMETERS</b>		
Evaporation <sup>a</sup>	m/day	6.71x10 <sup>-4</sup>
Relative Humidity <sup>a</sup>	-	0.50
Temperature <sup>a</sup>	°C	25
<b>MATERIAL PROPERTIES (MEAN VALUES FOR UPPER HSU)</b>		
Bulk Density <sup>b</sup>	kg/m <sup>3</sup>	1,665
Moisture Content <sup>b</sup>	% Mass	18.86
Hydraulic Conductivity <sup>b,c</sup>	cm/sec	2.74x10 <sup>-4</sup>
Organic Carbon Fraction <sup>f</sup>	%	0.60
Intrinsic Permeability <sup>g</sup>	cm <sup>2</sup>	2.5x10 <sup>-9</sup>
Porosity <sup>b</sup>	% Volume	38.1
<b>RESIDENTIAL BUILDING CHARACTERISTICS</b>		
Area <sup>f</sup>	m <sup>2</sup>	100
Volume <sup>f</sup>	m <sup>3</sup>	250
Air Exchange <sup>d,e</sup>	m <sup>3</sup> /hr	250
<b>COMMERCIAL BUILDING CHARACTERISTICS</b>		
Area <sup>f</sup>	m <sup>2</sup>	930
Volume <sup>f</sup>	m <sup>3</sup>	2550
Air Exchange <sup>d,e</sup>	m <sup>3</sup> /hr	2550

- a Koffer (1989)
- b French Drain Geotechnical Report (EG&G 1991)
- c Phase III Work Plan (EG&G 1991b)
- d United Nations (1988)
- e Uniform Building Code (1988)
- f EG&G (1992)
- g Calculated value (Section F-2.1.2.2)
- h Calculated value (Section F-2.1.2.2)

**Table F-2-4**

**Soil Phase Relationship Data for Porosity Calculations**

<b>Borehole Number</b>	<b>Sample Interval (feet)</b>	<b>Specific Gravity</b>	<b>Dry Density (lbs/ft<sup>3</sup>)</b>	<b>Porosity</b>
<b>UPPER HYDROSTRATIGRAPHIC UNIT</b>				
B300790	6.0-6.3	2.72	119.3	0.30
B303790	5.3-6.3	2.71	94.7	0.44
B303990	3.7-5.2	2.80	109.8	0.37
B304090	4.5-5.5	2.73	106.5	0.37
B304190	4.0-4.5	2.74	108.8	0.36
B304290	8.8-9.5	2.73	95.5	0.44

Table F-2-5

Material Property Statistics and Sampling Method  
for Johnson Model

Parameter	Number of Samples/ Simulations	Maximum	Mean <sup>a</sup>	Standard Deviation	Minimum	Sampling Method <sup>b</sup>
Porosity (% volume)	100	0.440	0.381	0.0029	0.297	Calculated <sup>c</sup>
Water Content (% volume)	100	0.439	0.337	0.058	0.217	LHS/ESM
Fraction Organic Carbon (%)	100	0.023	0.006	0.0072	0.00001	LHS
Bulk Density (g/cm <sup>3</sup> )	100	1.93	1.66	0.119	1.45	LHS

<sup>a</sup> Arithmetic mean.

<sup>b</sup> LHS (Latin hypercube sampling). ESM (Exact sampling method).

<sup>c</sup> Porosity calculated from the sampled bulk density value and assuming a average specific gravity of 2.65.

Table F-2-6

Groundwater COC Concentrations  
for Johnson Model Input

COC	Sitewide <sup>a</sup> ( $\mu\text{g}/\ell$ )	Source <sup>a</sup> ( $\mu\text{g}/\ell$ )	Sitewide-Source <sup>a</sup> ( $\mu\text{g}/\ell$ )
Carbon Tetrachloride	138	1841	8.0
1,1-Dichloroethene	447	5961	1.6
Tetrachloroethene	157	2032	3.1
1,1,1-Trichloroethane	558	7273	1.6

<sup>a</sup> Concentrations are the 95% UCL.

$\mu\text{g}/\ell$  = micrograms per liter.

Table F-2-7

Residential/Commercial Building Concentrations  
Estimated from Johnson Model

COC	OU1 without IHSS 119.1	OU1	IHSS 119.1
	Residential/Commercial	Residential/Commercial	Residential/Commercial
	Mean* (mg/m <sup>3</sup> )	Mean* (mg/m <sup>3</sup> )	Mean* (mg/m <sup>3</sup> )
Carbon Tetrachloride	$1.61 \times 10^{-4}$	$2.79 \times 10^{-3}$	$3.56 \times 10^{-2}$
1,1-Dichloroethene	$6.59 \times 10^{-5}$	$1.84 \times 10^{-2}$	$2.18 \times 10^{-1}$
Tetrachloroethene	$3.18 \times 10^{-5}$	$6.61 \times 10^{-3}$	$1.96 \times 10^{-2}$
1,1,1-Trichloroethane	$8.13 \times 10^{-5}$	$2.84 \times 10^{-2}$	$3.3 \times 10^{-1}$

\* Geometric mean of resulting PDFs. Source concentrations based on 95% UCL.

(mg/m<sup>3</sup>) milligrams per cubic meter.

Table F-2-8

## Data Summary for Airborne Emission and Transport Modeling

PARAMETER	UNITS	VALUE	SOURCE
Joint frequency distribution of atmospheric stability class (A, B, C, D, E, F), wind speed (1-3, 4-6, 7-10, 11-16, 17-21, >21 knots), and wind direction (16 sectors)	— <sup>a</sup>	576 values	RFP Site Environmental Report for 1990, RFP-ENV-90, Table F-2-9 <sup>b</sup>
Mean wind speed	m/s	4.0 m/s	RFP Site Environmental Report for 1990, RFP-ENV-90
Mean annual morning and afternoon mixing heights	m	268 m (morning) 2543 m (afternoon)	Data for Denver, CO, from Holzworth (1972) <sup>c</sup>
Mean particle size	$\mu\text{m}$	5.5 $\mu\text{m}$ , particles < 10 $\mu\text{m}$ 35 $\mu\text{m}$ , particles > 10 $\mu\text{m}$	MILDOS-AREA defaults used for mill tailings piles
Particle size distribution	—	0.44, particles < 10 $\mu\text{m}$ 0.56, particles > 10 $\mu\text{m}$	Average values from Phase III RI
Contaminant distribution ratio (contaminant concentration in particles < 10 $\mu\text{m}$ to total contaminant concentration)	—	2.5	MILDOS-AREA default used for mill tailings piles
Soil concentration	pCi/g <sup>d</sup>	Phase II data	Phase II RI
Contaminated area (dimensions and surface area)	m, m <sup>2</sup>	400 m, E-W) x 200 m, N-S) = 80,000m <sup>2e</sup>	Conversion to rectangular area based on area of OU-1 covering ~19 acres
Fraction of source area covered by vegetation	—	0.57	Phase III RI

Table F-2-8

Data Summary for Airborne Emission and Transport Modeling

PARAMETER	UNITS	VALUE	SOURCE
Receptor location, elevation above source, distance from source	x coord. (E-W), km y coord. (N-S), km z coord. (Elev), m	3.2 km E, 1.7 km S, 1.5 m elevation, 3.6 km distance	Distance from OU-1 to nearest resident in prevailing wind directions; height of breathing zone
Near-field model mixing height	m	3 m	RESRAD <sup>f</sup>
Emission and exposure time steps and durations used to calculate average concentrations	yr	6 time steps, Starting at current year 5 years each 30 years total	Assumed residence time of off-site individual

<sup>a</sup> — = Unitless.

<sup>b</sup> EG&G (1991).

<sup>c</sup> Holzworth (1972).

<sup>d</sup> Soil contamination input as pCi/g is converted to µg/g or mg/g for nonradionuclides by interpreting output concentrations in units of µg or mg, respectively, per m<sup>3</sup> (in air) or per m<sup>2</sup> (on surface) at the receptor location.

<sup>e</sup> Approximate dimensions of OU1 boundary and surface area.

<sup>f</sup> Gilbert et. al. (1988).



Table F-2-9

REGION: ROCKY FLATS PLANT (OU1)		CODE: MILDOS-AREA (03/89)		PAGE 2													
METSET: 10 METER TOWER - 1990		DATA: ou1.dat		02/11/94													
JOINT FREQUENCY IN PERCENT, DIRECTION INDICATES WHERE WIND IS FROM																FREQS=0.12895,0.34479,0.30555,0.13694,0.04295,0.03696	
MPH	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOT
-----																	
STABILITY CLASS 1																	
1.5	0.1269	0.1781	0.2123	0.1708	0.3465	0.1854	0.1806	0.0903	0.0708	0.0415	0.0098	0.0220	0.0146	0.0220	0.0390	0.0561	1.7667
5.5	0.0512	0.0903	0.0927	0.0927	0.1415	0.0805	0.0512	0.0146	0.0146	0.0000	0.0098	0.0000	0.0024	0.0024	0.0098	0.0122	0.6659
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	0.1781	0.2684	0.3050	0.2635	0.4880	0.2659	0.2318	0.1049	0.0854	0.0415	0.0196	0.0220	0.0170	0.0244	0.0488	0.0683	2.4326
-----																	
STABILITY CLASS 2																	
1.5	0.0198	0.0370	0.0422	0.0502	0.0528	0.0568	0.0383	0.0066	0.0224	0.0132	0.0066	0.0092	0.0092	0.0092	0.0066	0.0092	0.3893
5.5	0.0515	0.0752	0.1584	0.1228	0.2099	0.1439	0.0475	0.0304	0.0092	0.0145	0.0026	0.0000	0.0000	0.0026	0.0092	0.0145	0.8922
10.0	0.0026	0.0066	0.0000	0.0000	0.0000	0.0026	0.0026	0.0000	0.0026	0.0000	0.0026	0.0000	0.0026	0.0066	0.0000	0.0066	0.0354
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	0.0739	0.1188	0.2006	0.1730	0.2627	0.2033	0.0884	0.0370	0.0342	0.0277	0.0118	0.0092	0.0118	0.0184	0.0158	0.0303	1.3169
-----																	
STABILITY CLASS 3																	
1.5	0.0277	0.0554	0.0484	0.0727	0.0727	0.0588	0.0727	0.0415	0.0208	0.0208	0.0035	0.0138	0.0069	0.0208	0.0311	0.0311	0.5987
5.5	0.1384	0.3114	0.3598	0.3149	0.4602	0.3564	0.3010	0.1038	0.0727	0.0311	0.0208	0.0104	0.0208	0.0173	0.0586	0.0692	2.6470
10.0	0.0208	0.0242	0.0242	0.0104	0.0104	0.0138	0.0138	0.0069	0.0069	0.0104	0.0104	0.0104	0.0104	0.0035	0.0242	0.0104	0.2111
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0035	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0000	0.0000	0.0105
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	0.1869	0.3910	0.4324	0.3980	0.5433	0.4325	0.3910	0.1522	0.1004	0.0623	0.0347	0.0346	0.0381	0.0451	0.1141	0.1107	3.4673
-----																	
STABILITY CLASS 4																	
1.5	0.3496	0.3995	0.3496	0.2996	0.2996	0.2497	0.2497	0.2996	0.2497	0.1998	0.1998	0.1498	0.2996	0.2497	0.2996	0.2497	4.3946
5.5	1.0487	1.1486	0.9489	0.5993	0.7990	0.8989	1.2485	0.9988	0.6492	0.4495	0.2996	0.2996	0.2497	0.3496	0.4994	0.5993	11.0866
10.0	1.5481	1.2984	0.7491	0.3995	0.3496	0.9489	1.7978	1.2485	0.5493	0.3496	0.3496	0.2996	0.3995	0.5993	0.7990	1.0487	12.7345
15.5	1.3484	0.6992	0.1998	0.0499	0.0000	0.0499	0.3995	0.3995	0.4994	0.3995	0.5493	1.2984	1.5981	2.9465	2.1474	1.0987	13.6835
21.5	0.1998	0.0499	0.0000	0.0000	0.0000	0.0000	0.0000	0.0499	0.0499	0.0499	0.0999	0.3496	0.9489	1.7479	0.5993	0.1498	4.2948
28.0	0.1498	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1998	1.3484	1.7978	0.1998	0.0000	3.6956
ALL	4.6444	3.5956	2.2474	1.3483	1.4482	2.1474	3.6955	2.9963	1.9975	1.4483	1.4982	2.5968	4.8442	7.6908	4.5445	3.1462	49.8896
-----																	
STABILITY CLASS 5																	
1.5	0.2399	0.2399	0.2099	0.2099	0.2099	0.0900	0.1500	0.2099	0.2699	0.2399	0.2099	0.2699	0.2699	0.3299	0.3299	0.3299	3.8086
5.5	0.6598	0.6598	0.5698	0.3599	0.2399	0.2999	0.4499	0.4199	0.5398	0.5098	0.4798	0.5098	0.7198	0.7198	0.7797	0.7198	8.6372
10.0	0.9597	0.7198	0.3599	0.1200	0.0900	0.2399	0.4199	0.5698	1.3196	1.3496	2.1293	2.5192	1.5595	1.6495	2.0393	1.5295	17.5745
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	1.8594	1.6195	1.1396	0.6898	0.5398	0.6298	1.0198	1.1996	2.1293	2.0993	2.8190	3.2989	2.5492	2.6992	3.1489	2.5792	30.0203
-----																	
STABILITY CLASS 6																	
1.5	0.0875	0.0500	0.0250	0.0250	0.0250	0.0125	0.0375	0.1375	0.1750	0.1875	0.2000	0.2375	0.2500	0.2250	0.1750	0.0875	1.9375
5.5	0.4500	0.2250	0.1000	0.0750	0.0750	0.0750	0.2500	0.5375	0.8750	0.9750	0.9875	1.2875	1.6375	1.4125	0.9875	0.6000	10.5500
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	0.5375	0.2750	0.1250	0.1000	0.1000	0.0875	0.2875	0.6750	1.0500	1.1625	1.1875	1.5250	1.8875	1.6375	1.1625	0.6875	12.4875
-----																	
ALL	7.4802	6.2683	4.4500	2.9726	3.3820	3.7664	5.7140	5.1650	5.3968	4.8416	5.5708	7.4865	9.3478	12.1154	9.0346	6.6222	99.6142



Table F-2-9

70.0-80.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0-80.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TOTAL 1-80 KM POPULATION IS 0 PERSONS

1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 5  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94

FINITE ELEMENT DATA FOR SOURCE NO. 1: IPX= 3 ID= 5001

VERTEX (M) = 0.0000E+00 -2.0000E+02 4.0000E+02 -2.0000E+02 0.0000E+00 0.0000E+00 4.0000E+02 0.0000E+00

AREA SOURCE ELEMENT NO. = 1 NODES= 1 3 2 4  
 AREA SOURCE ELEMENT NO. = 2 NODES= 3 5 4 6

0 NODAL COORDINATES (M):

NODE NO. = 1 XS= 0.0000E+00 YS= -2.0000E+02  
 NODE NO. = 2 XS= 0.0000E+00 YS= 0.0000E+00  
 NODE NO. = 3 XS= 2.0000E+02 YS= -2.0000E+02  
 NODE NO. = 4 XS= 2.0000E+02 YS= 0.0000E+00  
 NODE NO. = 5 XS= 4.0000E+02 YS= -2.0000E+02  
 NODE NO. = 6 XS= 4.0000E+02 YS= 0.0000E+00

1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 6  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94

NUMBER OF SOURCES= 1

NO.	KM X	KM Y	M Z	KM2 AREA	U-238	Th-230	CI/YEAR Ra-226	Pb-210	Rn-222	ID	PSIZE SET	M/SEC EXIT VEL	SOURCE NAME
1	0.00	0.00	0.00	0.0800	1.46E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5001	3	0.00E+00	881 HILLSIDE PHE

INPUT TAILS ACTIVITIES, PCI/G

SET	URANIUM	THORIUM	RADIUM	LEAD
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	1.00E+00	0.00E+00	0.00E+00	0.00E+00

AMAD AND FRACTIONAL DISTRIBUTION

SET	1.5	3.0	7.7	54.0
1	0.000	1.000	0.000	0.000
2	1.000	0.000	0.000	0.000
3	0.000	0.000	0.440	0.560

PARTICULATE SOURCE STRENGTH MULTIPLIERS BY TIME STEP, 6 TIME STEP(S) USED FOR THIS RUN

SOURCE NUMBER	TSTEP 1 5.00YRS	TSTEP 2 5.00YRS	TSTEP 3 5.00YRS	TSTEP 4 5.00YRS	TSTEP 5 5.00YRS	TSTEP 6 5.00YRS	TSTEP 7 0.00YRS	TSTEP 8 0.00YRS	TSTEP 9 0.00YRS	TSTEP10 0.00YRS
1	1.000E+00									

RADON SOURCE STRENGTH MULTIPLIERS BY TIME STEP, 6 TIME STEP(S) USED FOR THIS RUN

SOURCE NUMBER	TSTEP 1 5.00YRS	TSTEP 2 5.00YRS	TSTEP 3 5.00YRS	TSTEP 4 5.00YRS	TSTEP 5 5.00YRS	TSTEP 6 5.00YRS	TSTEP 7 0.00YRS	TSTEP 8 0.00YRS	TSTEP 9 0.00YRS	TSTEP10 0.00YRS
1	1.000E+00									

1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 7  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94

TIME STEP NUMBER 1, YEAR 0-5 DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR PARTICULATE CONCENTRATIONS

NO.	NAME	PTSZ	AIRBORNE CONCENTRATIONS, PCI/M3				GROUND CONCENTRATIONS, PCI/M2			
			U-238	Th-230	Ra-226	Pb-210	U-238	Th-230	Ra-226	Pb-210
-----										

Table F-2-9

1 Downwind Resident	1	0.000E+00										
1 Downwind Resident	2	0.000E+00										
1 Downwind Resident	3	7.888E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.412E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1 Downwind Resident	4	3.622E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.977E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CONCENTRATION TOTALS		1.151E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.719E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

REGION: ROCKY FLATS PLANT (OU1)      CODE: MILDOS-AREA (03/89)      PAGE 8  
 METSET: 10 METER TOWER - 1990      DATA: ou1.dat      02/11/94  
 TIME STEP NUMBER 1, YEAR 0-5      DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR RADON AND RADON DAUGHTER CONCENTRATIONS

NO.	AIRBORNE CONCENTRATIONS, PCI/M3						GROUND CONCENTRATIONS, PCI/M2					
	Rn-222	Po-218	Pb-214	Bi-214	Pb-210	Bi-210	Po-210	WL	Po-218	Pb-214	Bi-214	Pb-210
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

REGION: ROCKY FLATS PLANT (OU1)      CODE: MILDOS-AREA (03/89)      PAGE 9  
 METSET: 10 METER TOWER - 1990      DATA: ou1.dat      02/11/94  
 TIME STEP NUMBER 2, YEAR 5-10      DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR PARTICULATE CONCENTRATIONS

NO.	NAME	PTSZ	AIRBORNE CONCENTRATIONS, PCI/M3				GROUND CONCENTRATIONS, PCI/M2					
			U-238	Th-230	Ra-226	Pb-210	U-238	Th-230	Ra-226	Pb-210		
1	Downwind Resident	1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	3	7.895E-07	0.000E+00	0.000E+00	0.000E+00	1.433E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	4	3.650E-07	0.000E+00	0.000E+00	0.000E+00	5.755E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CONCENTRATION TOTALS			1.155E-06	0.000E+00	0.000E+00	0.000E+00	7.188E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

REGION: ROCKY FLATS PLANT (OU1)      CODE: MILDOS-AREA (03/89)      PAGE 10  
 METSET: 10 METER TOWER - 1990      DATA: ou1.dat      02/11/94  
 TIME STEP NUMBER 2, YEAR 5-10      DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR RADON AND RADON DAUGHTER CONCENTRATIONS

NO.	AIRBORNE CONCENTRATIONS, PCI/M3						GROUND CONCENTRATIONS, PCI/M2					
	Rn-222	Po-218	Pb-214	Bi-214	Pb-210	Bi-210	Po-210	WL	Po-218	Pb-214	Bi-214	Pb-210
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

REGION: ROCKY FLATS PLANT (OU1)      CODE: MILDOS-AREA (03/89)      PAGE 11  
 METSET: 10 METER TOWER - 1990      DATA: ou1.dat      02/11/94  
 TIME STEP NUMBER 3, YEAR 10-15      DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR PARTICULATE CONCENTRATIONS

NO.	NAME	PTSZ	AIRBORNE CONCENTRATIONS, PCI/M3				GROUND CONCENTRATIONS, PCI/M2					
			U-238	Th-230	Ra-226	Pb-210	U-238	Th-230	Ra-226	Pb-210		
1	Downwind Resident	1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	3	7.902E-07	0.000E+00	0.000E+00	0.000E+00	2.078E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	4	3.676E-07	0.000E+00	0.000E+00	0.000E+00	8.347E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CONCENTRATION TOTALS			1.158E-06	0.000E+00	0.000E+00	0.000E+00	1.043E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

REGION: ROCKY FLATS PLANT (OU1)      CODE: MILDOS-AREA (03/89)      PAGE 12  
 METSET: 10 METER TOWER - 1990      DATA: ou1.dat      02/11/94  
 TIME STEP NUMBER 3, YEAR 10-15      DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR RADON AND RADON DAUGHTER CONCENTRATIONS

NO.	AIRBORNE CONCENTRATIONS, PCI/M3						GROUND CONCENTRATIONS, PCI/M2					
	Rn-222	Po-218	Pb-214	Bi-214	Pb-210	Bi-210	Po-210	WL	Po-218	Pb-214	Bi-214	Pb-210

Table F-2-9

1 0.000E+00  
 1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 13  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94  
 TIME STEP NUMBER 4, YEAR 15-20 DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR PARTICULATE CONCENTRATIONS

NO.	NAME	PTSZ	AIRBORNE CONCENTRATIONS, PCI/M3				GROUND CONCENTRATIONS, PCI/M2				
			U-238	Th-230	Ra-226	Pb-210	U-238	Th-230	Ra-226	Pb-210	
1	Downwind Resident	1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	3	7.908E-07	0.000E+00	0.000E+00	0.000E+00	2.680E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	4	3.700E-07	0.000E+00	0.000E+00	0.000E+00	1.077E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CONCENTRATION TOTALS			1.161E-06	0.000E+00	0.000E+00	0.000E+00	1.345E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00

1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 14  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94  
 TIME STEP NUMBER 4, YEAR 15-20 DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR RADON AND RADON DAUGHTER CONCENTRATIONS

NO.	AIRBORNE CONCENTRATIONS, PCI/M3							GROUND CONCENTRATIONS, PCI/M2				
	Rn-222	Po-218	Pb-214	Bi-214	Pb-210	Bi-210	Po-210	WL	Po-218	Pb-214	Bi-214	Pb-210
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 15  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94  
 TIME STEP NUMBER 5, YEAR 20-25 DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR PARTICULATE CONCENTRATIONS

NO.	NAME	PTSZ	AIRBORNE CONCENTRATIONS, PCI/M3				GROUND CONCENTRATIONS, PCI/M2				
			U-238	Th-230	Ra-226	Pb-210	U-238	Th-230	Ra-226	Pb-210	
1	Downwind Resident	1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	3	7.913E-07	0.000E+00	0.000E+00	0.000E+00	3.242E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	4	3.723E-07	0.000E+00	0.000E+00	0.000E+00	1.302E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CONCENTRATION TOTALS			1.164E-06	0.000E+00	0.000E+00	0.000E+00	1.626E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00

1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 16  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94  
 TIME STEP NUMBER 5, YEAR 20-25 DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR RADON AND RADON DAUGHTER CONCENTRATIONS

NO.	AIRBORNE CONCENTRATIONS, PCI/M3							GROUND CONCENTRATIONS, PCI/M2				
	Rn-222	Po-218	Pb-214	Bi-214	Pb-210	Bi-210	Po-210	WL	Po-218	Pb-214	Bi-214	Pb-210
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

1REGION: ROCKY FLATS PLANT (OU1) CODE: MILDOS-AREA (03/89) PAGE 17  
 METSET: 10 METER TOWER - 1990 DATA: ou1.dat 02/11/94  
 TIME STEP NUMBER 6, YEAR 25-30 DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR PARTICULATE CONCENTRATIONS

NO.	NAME	PTSZ	AIRBORNE CONCENTRATIONS, PCI/M3				GROUND CONCENTRATIONS, PCI/M2				
			U-238	Th-230	Ra-226	Pb-210	U-238	Th-230	Ra-226	Pb-210	
1	Downwind Resident	1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	3	7.919E-07	0.000E+00	0.000E+00	0.000E+00	3.766E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1	Downwind Resident	4	3.744E-07	0.000E+00	0.000E+00	0.000E+00	1.513E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CONCENTRATION TOTALS			1.166E-06	0.000E+00	0.000E+00	0.000E+00	1.889E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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 1REGION: ROCKY FLATS PLANT (OU1)      CODE: MILDOS-AREA (03/89)      PAGE 18  
 METSET: 10 METER TOWER - 1990      DATA: ou1.dat      02/11/94  
 TIME STEP NUMBER 6, YEAR 25-30      DURATION IN YRS IS... 5.0

INDIVIDUAL RECEPTOR RADON AND RADON DAUGHTER CONCENTRATIONS

NO.	AIRBORNE CONCENTRATIONS, PCI/M3							GROUND CONCENTRATIONS, PCI/M2				
	Rn-222	Po-218	Pb-214	Bi-214	Pb-210	Bi-210	Po-210	WL	Po-218	Pb-214	Bi-214	Pb-210
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

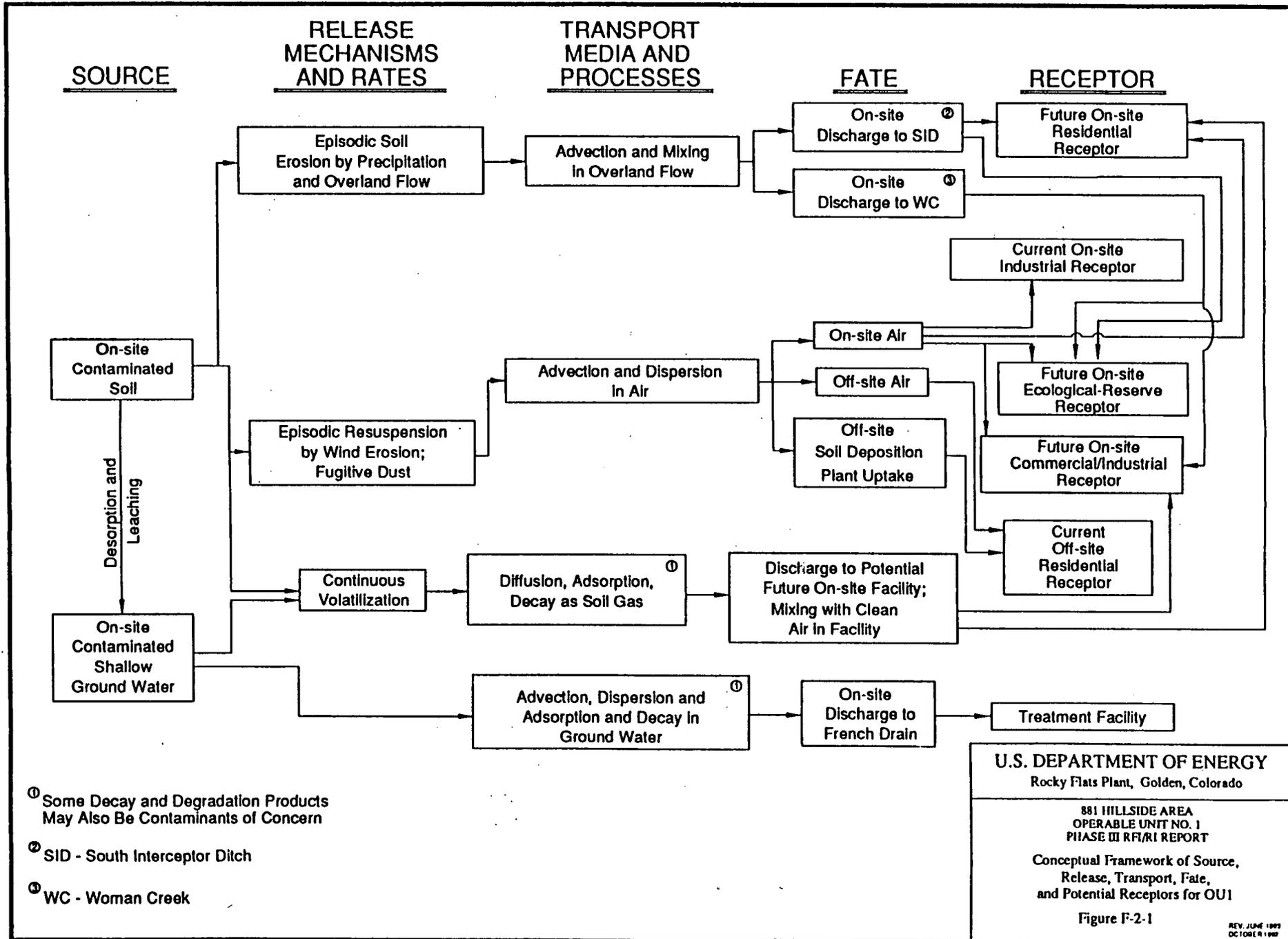
Program execution time = 5.21 seconds

Table F-2-10

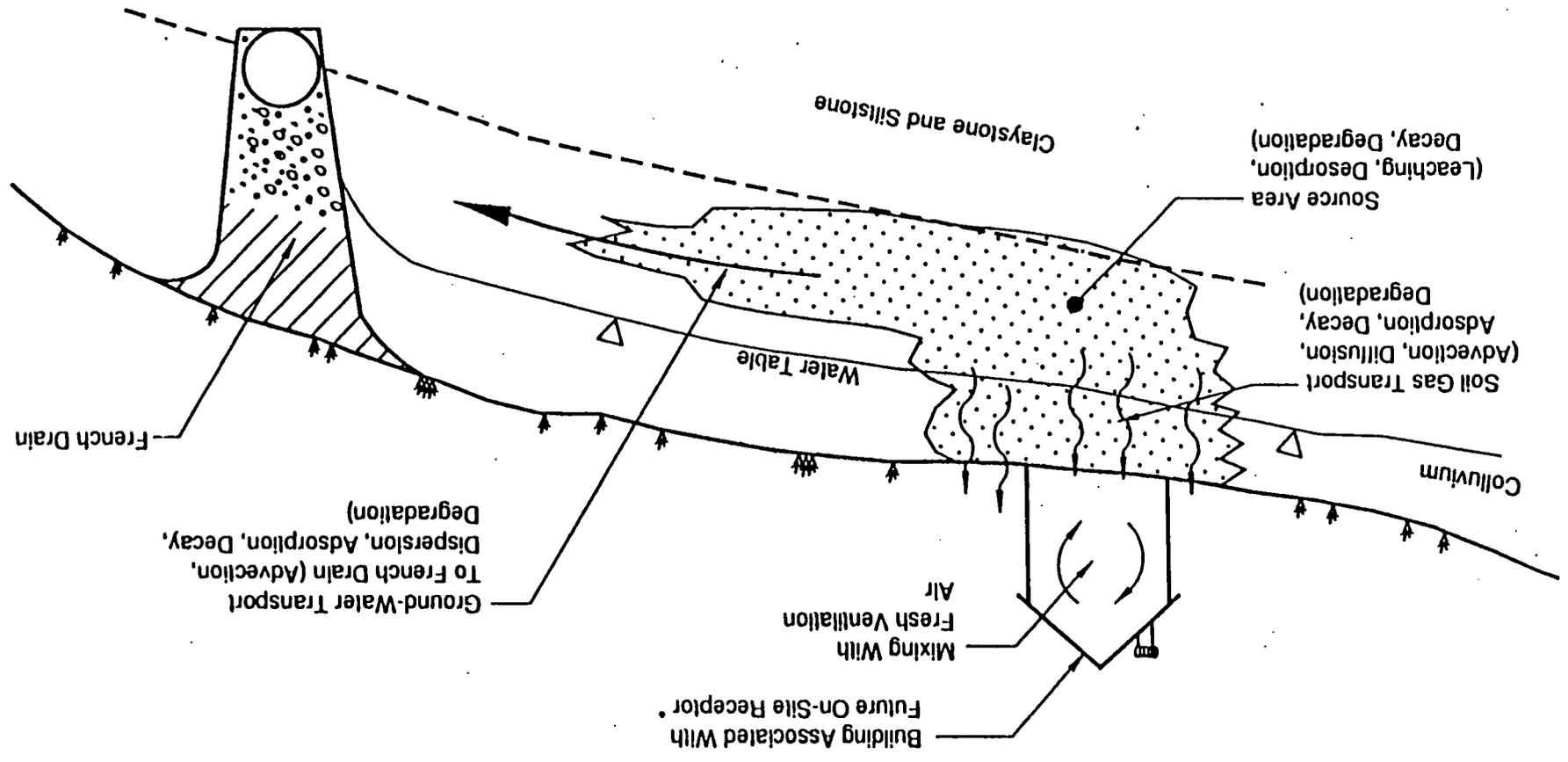
Results of Far-Field Model

Time Step	Concentration in Air */m <sup>3</sup> per */g		Soil Surface Concentration	Concentration in 15 cm of Soil
	Particles < 10 μm	Particles > 10 μm	*/m <sup>3</sup> per */g	*/g per */g
Year 0-5	3.39E-07	1.56E-07	1.60E+00	6.66E-06
Year 5-10	3.39E-07	1.57E-07	3.09E+00	1.29E-05
Year 10-15	3.40E-07	1.58E-07	4.48E+00	1.87E-05
Year 15-20	3.40E-07	1.59E-07	5.78E+00	2.41E-05
Year 20-25	3.40E-07	1.60E-07	6.99E+00	2.91E-05
Year 25-30	3.41E-07	1.61E-07	8.12E+00	3.38E-05
30-Year average	3.40E-07	1.58E-07	5.01E+00	2.09E-05

\* pCi for radioactive contaminants, mg for chemical contaminants



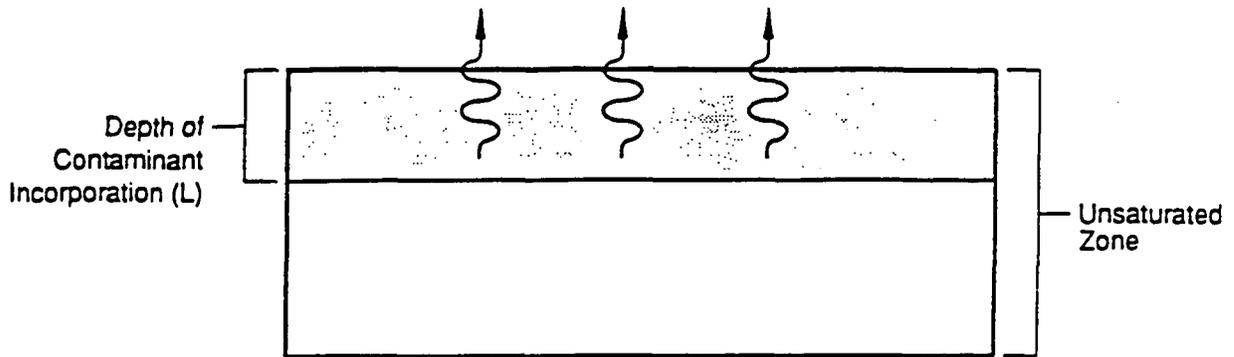
The geotechnical feasibility of on-site construction is unfavorable (Section 3.5.2.1).



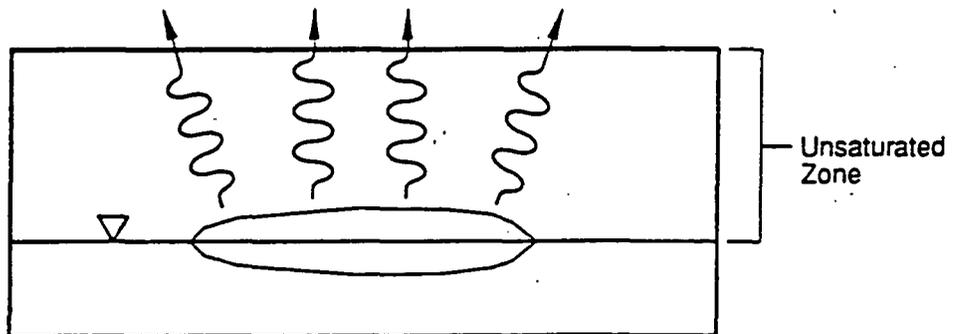
U.S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden, Colorado  
 881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE B RI/RM/R1 REPORT  
 Future OUI Soil Gas Receptor  
 Model with On-Site Receptor  
 Figure F-2-2

REV A 10/11/81  
OCTOBER 1981

**CASE 1  
UNIFORM DISTRIBUTION OF VOLATILE  
ORGANICS IN UNSTAURATED ZONE**

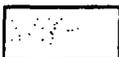


**CASE 2  
VOLATILE ORGANIC SOURCE AT WATER TABLE**



**EXPLANATION**

▽ - Water Table

 - Uniform Distribution of VOCs

 - Volatilization of Compound

**U.S. DEPARTMENT OF ENERGY**  
Rocky Flats Plant, Golden, Colorado

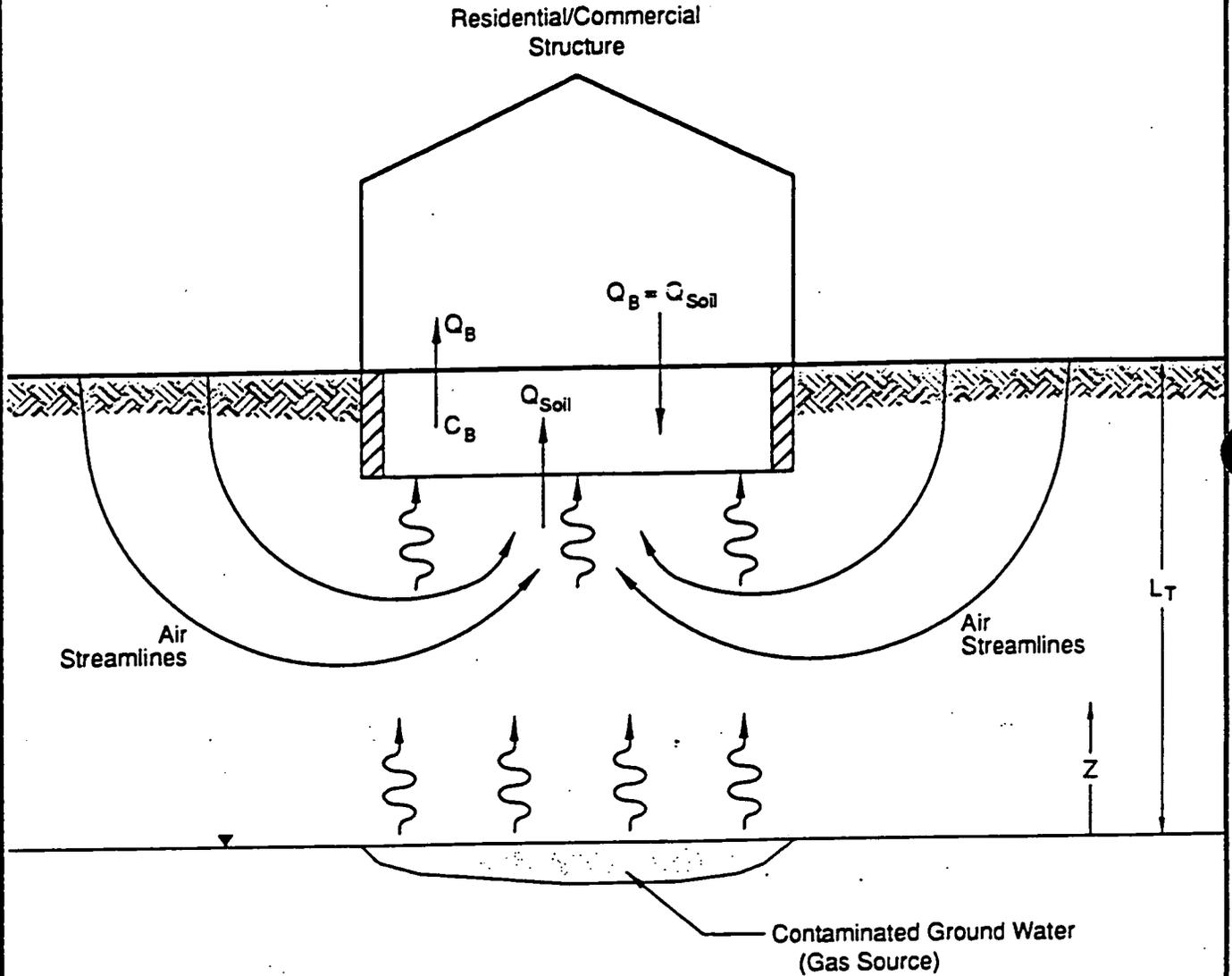
881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

VOC Distribution and Volatilization  
for Soil Gas Modeling

Figure F-2-3

REV. JUNE 1989  
OCTOBER 1982

JOHNSON and ETTINGER (1991)



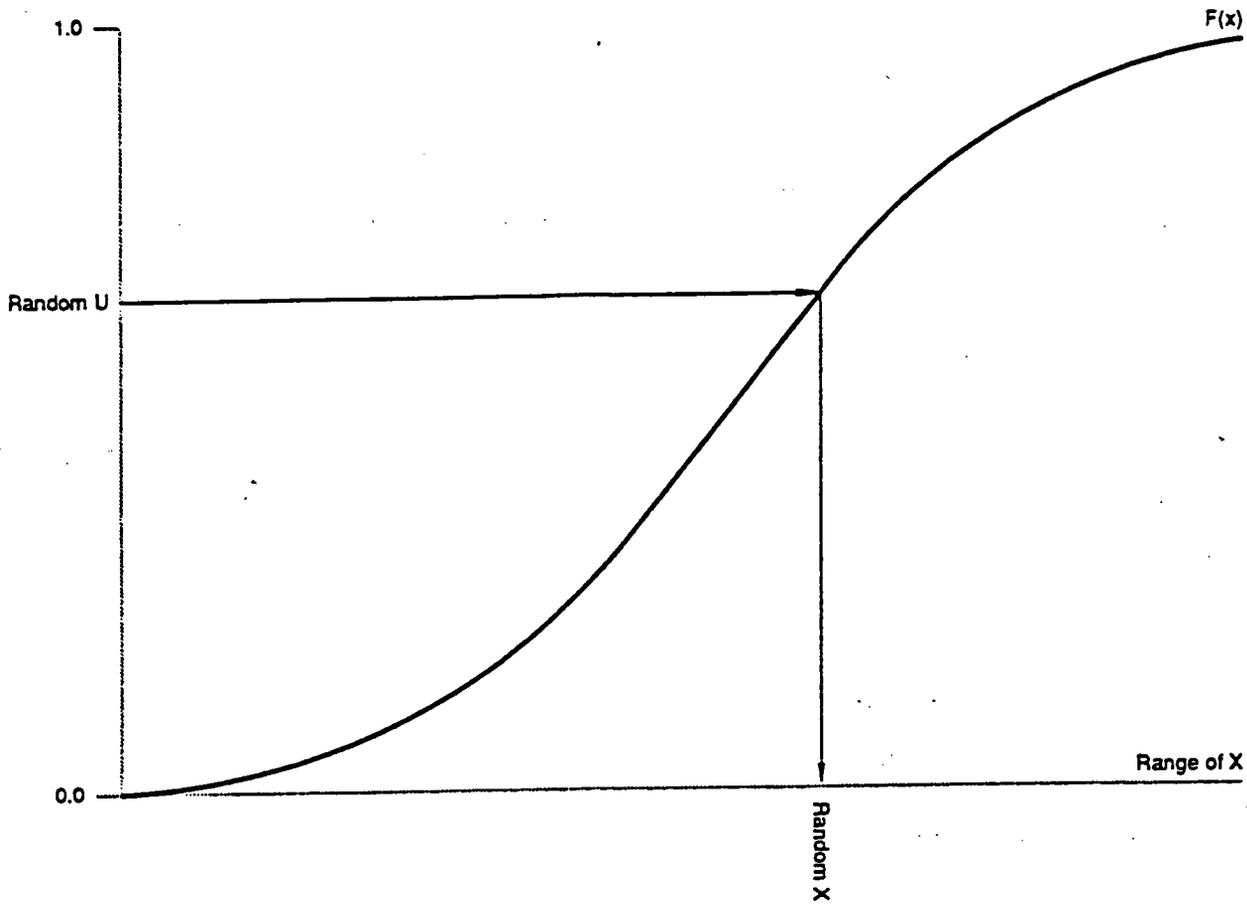
U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFR/RJ REPORT

Schematic of OU1 Soil Gas Simulation  
for Johnson Model

Figure F-2-4

REV. APR 1993  
OCTOBER 1992



CDF.DWG

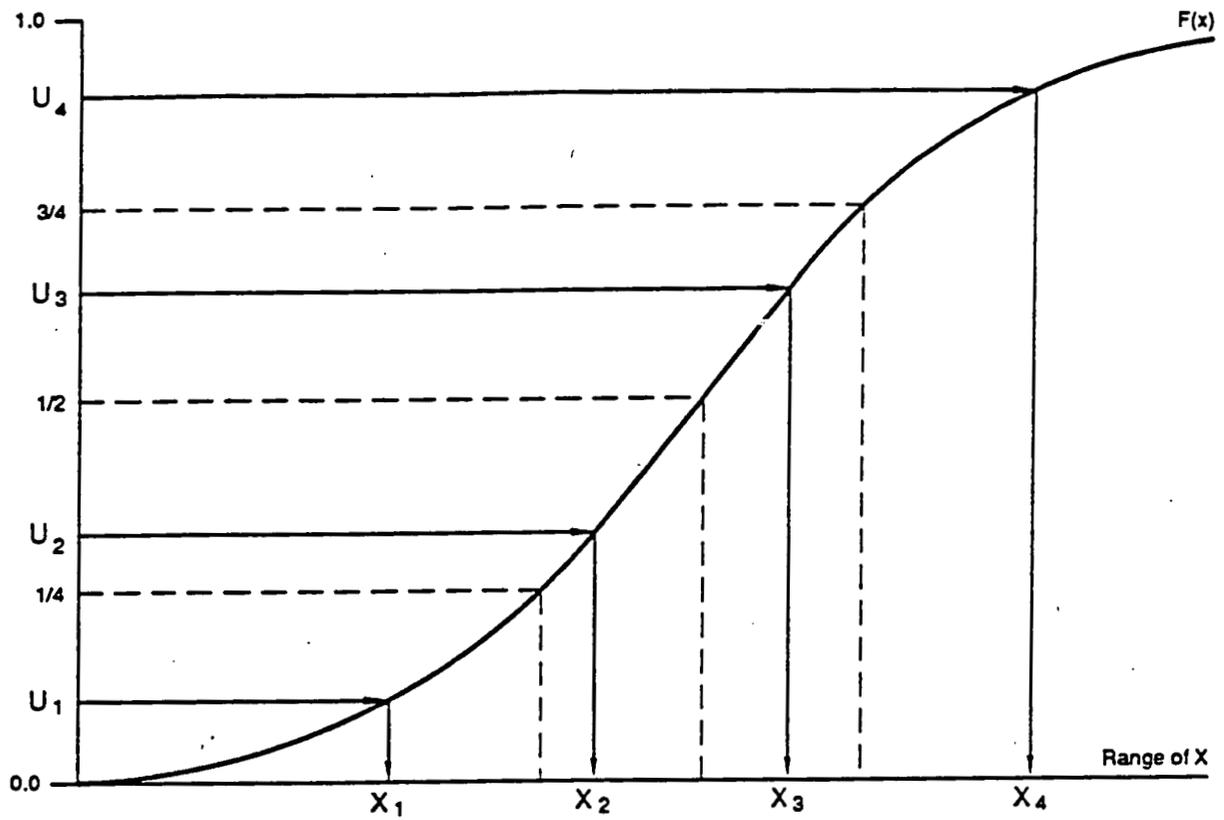
U.S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RF/RI REPORT

Inverting the CDF at  
 a Random Value, U

Figure F-2-5

REV. APR 1989  
 OCT 28 1982



U.S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden, Colorado

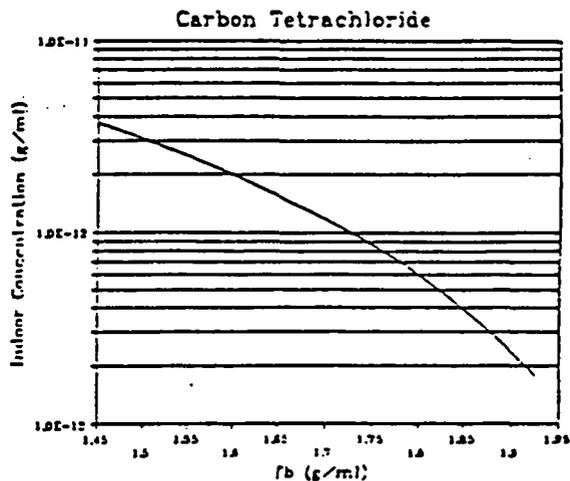
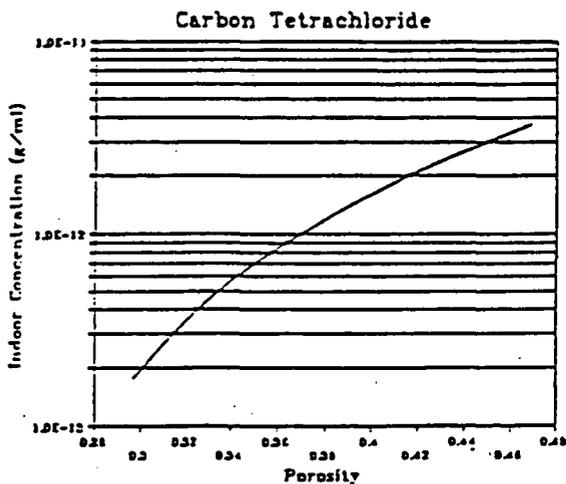
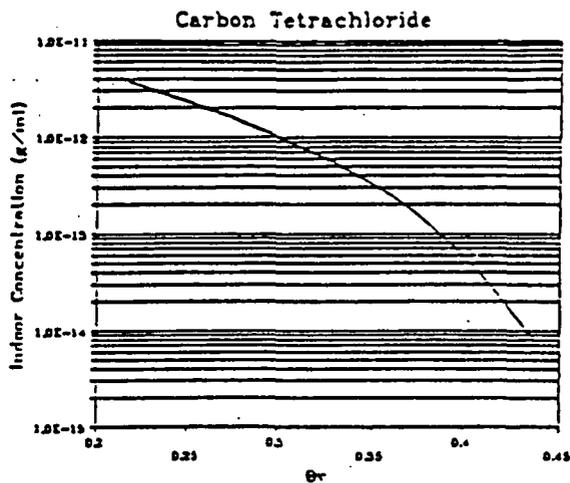
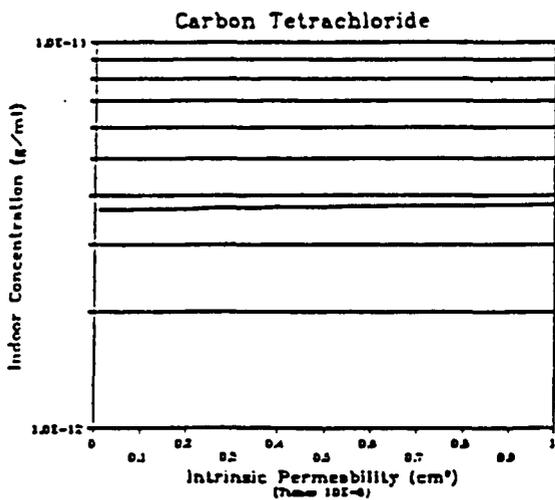
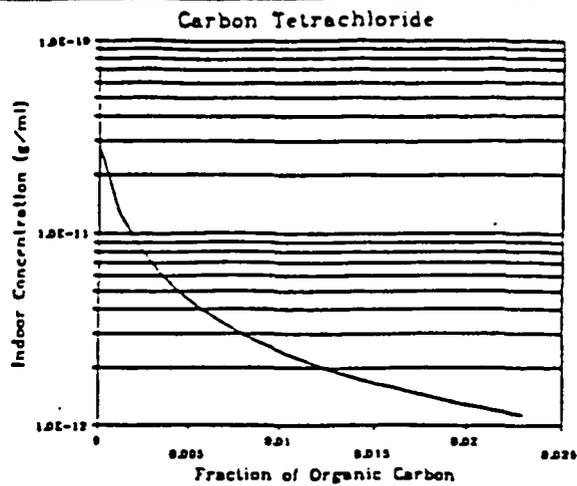
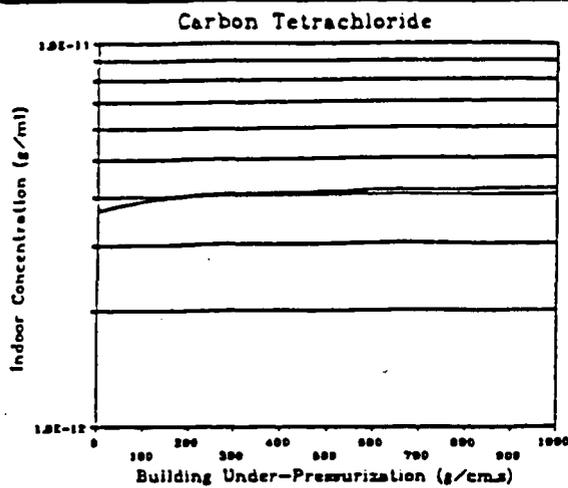
881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
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Sampling in Four  
 Equal-Probability Intervals

Figure F-2-6

REV. APRIL 1982  
 OCTOBER 1982

4INT.DWG



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Sensitivity of Building Concentrations  
to Model Input Values

Figure F-2-7

REV. JUNE 1982  
OCT. 1981

**Attachment F-3**

**Oak Ridge National Laboratory Toxicity Distributions**

### 3. APPROACH

EPA CPF point estimates involve many sources of uncertainty that are inherent in the process of low-dose extrapolation. These include:

- Extrapolation from high administered doses to low exposure doses;
- Inter-species extrapolation from non-human to human;
- Exposure route extrapolation;
- Lack of consideration for variability in human susceptibility;
- Experimental design limitations imposed by typical bioassays;
- Exclusive use of the LMS dose-response modeling procedure;
- Statistical estimation error in model parameters;
- Use of a most sensitive species/strain with positive results; and
- Combination of results from heterogeneous bioassay data sets (different species, strain, sex, tumor types).

Several of these steps have been the subject of considerable attention and debate. In this paper, a procedure is examined which characterizes the uncertainty associated with CPFs and which can be utilized as an extension of current EPA methodology. The study focuses solely on parameter uncertainty in the CPF as a function of random variations in bioassay outcomes. The procedure utilizes a non-parametric bootstrap process (Sielken 1988) to generate hypothetical experiments which are based on original experimental results. The results of the simulated bioassays can then be used to generate a probability distribution function (PDF) for CPF uncertainty. This PDF not only characterizes the range of CPF values but also their relative likelihood of occurrence. In addition, four techniques will be examined which combine multiple PDFs into a single grand PDF.

The preliminary analysis was applied to a limited database of chemical carcinogens. Since this technique was specifically designed to supplement the current regulatory approach, experimental design was based on the EPA quantitative risk assessment format (extrapolation model, dose scale, inter-species scaling factors, etc.) as presented in EPA source documentation (the Integrated Risk Information System [IRIS] (EPA 1987) or the Health Effects Assessment Summary Tables [HEAST] (EPA 1991)). In addition, all cancer risk computations were derived

from the same animal bioassays that EPA utilized to calculate toxicity values for use in their quantitative risk assessment, with no additional screening or quality criteria imposed on the input data set(s). None of the assumptions, data biases or default values which were utilized by EPA were modified in the computation process. Note that the only relaxation of regulatory policy was the use of MLE values rather than upper-bound values, both to supplement upper-bound values and to provide a "more central estimate" of risk. The software program GENT (Sielken Inc. 1991) was utilized to fit the LMS model (extra risk) to the animal dose-response data.

### **3.1 Bootstrap Procedure**

Because performing a single bioassay on a small number of animals is a random event, a possible source of error in the estimation of the fitted CPF value may be introduced by random variations in the observed experimental results. Therefore, small shifts in experimental results (which can occur with appreciable probability) would change the estimated CPF value. Monte Carlo simulation is frequently used as a means of quantitatively estimating parameter uncertainty. These simulation techniques can be utilized to statistically characterize the sensitivity of the MLE CPF to random variations in the observed experimental outcomes.

Several authors have utilized "bootstrap" techniques to estimate parameter variability or to construct percentile intervals as approximate confidence intervals (Crump et. al 1977; Sielken 1988). These techniques may be either "parametric" or "non-parametric." Parametric bootstrap techniques use the fitted MLE dose-response model to simulate experimental results. In addition, they assume that the fitted model portrays the dose-response relationship as it exists in nature (i.e., the fitted model and the true underlying model are equivalent). In practice, the true underlying model is rarely known without error.

GEN.T performs a non-parametric bootstrap procedure that utilizes the observed original data in conjunction with binomial simulation techniques to generate any number of independent

replicates of the original experiment. This technique assumes that the uncertainty in the number of tumor responses is binomially distributed about the observed value. An advantage of this technique is that it does not presume that the estimated model is the correct function underlying the true dose-response relationship. In addition, each experimental replicate has the same dose levels and the same number of tested animals (per dose level) as the original experiment. The procedure is summarized below:

- The observed data determines a binomial distribution for the number of tumor responding animals in each dose group.
- The computer then randomly samples from the tumor response distribution at each dose level.
- The LMS model is re-fit to the "simulated" bioassay dose-response data, and new MLE potencies are computed for each of the simulated groups.
- A PDF is "fit" to the sample distribution of CPF values.

Typical animal bioassays for dose-response modelling consist of 2 or 3 test groups of animals, where each group is assumed to receive a fixed average daily dose over a specified time period. At each dose level, the number of tumor responding animals,  $r$ , can then be modeled as a random binomial variable, after the following conditions are satisfied:

- The experiment includes  $n$  trials ( $n$  animals tested);
- The trials are identical, and each trial results in one of two outcomes (success [tumor response] or failure [no tumor response]);
- The trials are independent (The outcome of one trial does not influence the outcome of any other); and
- The probability of success ( $p = k/n$  ;  $k = \#$  observed tumors) for each individual trial is constant from trial-to-trial.

As a result, the probability of  $r$  tumors is given by the following formula for the binomial distribution:

$$P(X=r) = \binom{n}{r} * p^r * (1-p)^{n-r}, \text{ where}$$

$$0 \leq r \leq n, \text{ and } \binom{n}{r} = (n!) / r!(n-r)!$$

Simulated animal bioassay results can be generated by assuming a binomial tumor response distribution determined by the observed results from the original experiment. As an example, consider the dose-response data for hepatocellular carcinoma in female mice from a 1982 National Toxicology Program (NTP) study of trichloroethene (TCE). This bioassay consisted of two dose groups: control and high dose. The control dose incidence rate was  $k=2$  out of  $n=49$ , while the high dose incidence rate was  $k=13$  out of  $n=49$ . On the basis of the observed proportions, the MLEs of a tumor response,  $p$ , are  $2/49 \approx 0.041$  and  $13/49 \approx 0.265$ , for each dose level.

The binomial distribution weights the observed response rates with the greatest probability as compared to other possible outcomes. If each value on the probability axis is equally likely, then the height of each response in the cumulative distribution function (CDF) plot represents the probability of that outcome. A uniform random number generator is used to sample replicated experiments from the binomial CDF.

This method does have several weaknesses, however. The assumption of trial independence is not completely valid, because it is possible that the genetic homogeneity of test animals may introduce some correlation among the animals. In addition, binomial sampling will not yield any variability if there is either a 0% or 100% observed response rate (i.e.,  $r$  will always be zero or  $n$ ). This lack of variability may be undesirable and certainly does not

intuitively allow for the possibility of either measurement error (eg. misdiagnosis of tumor responses [i.e., Type I/II error rate) or random error (fluctuation).

Although the zero response rate is an extreme case, it did occur in several of the bioassays utilized for this analysis. The impact of no binomial variability was informally assessed for two types of dose-response data: linear and non-linear (i.e., strong MLE with 95% UCL correspondence or no correspondence, respectively). Several possible alternatives to the purely binomial bootstrap method include replacing the observed 0% incidence rate with an upper bound rate, a pathology error rate, or a generic control dose response rate, etc. However, for this study, rather than modifying the observed experimental incidence rate, the method of simulation was modified to incorporate a Bayesian updating technique (Finkel 1988). This method uses a Bayesian technique to generate a posterior distribution for the number of hypothetical tumor responding animals,  $r$ . By assuming a uniform distribution for the prior tumor response rate and a binomial likelihood distribution based on the observed results, the conditional probability of  $r$  tumors (given  $k$ ) is:

$$P(X=r | k) = \frac{(n+1)! n! (k+r)! (2n-k-r)!}{k! (n-k)! (n-r)! r! (2n+1)!}$$

Whereas, the classical binomial variability yields a conditional probability distribution given by:

$$P(X=r | k) = \frac{n!}{r! (n-r)!} * \left(\frac{k}{n}\right)^r * \left(1 - \frac{k}{n}\right)^{n-r}$$

Although the Bayesian approach allows for variability given a 0% response rate, the observed rate is still the most probable (similar to binomial variability).

### 3.2 Parameterized Distributions

In addition to the original results, 999 simulations were generated for each bioassay included in this analysis. The 1000 sample data points constitute a bioassay dataset for a discrete distribution for the variability in CPF values. Several statistical measures and

distributional tests were applied to the bioassay dataset. For this preliminary analysis, a continuous distribution was assumed to approximate the discrete distribution. In practice, however, the discrete empirical distribution may be used if desired. Several types of common distributions were "fit" to the sample data points: normal, lognormal and mixture. It was assumed that the fitted distribution of the sample MLE CPFs approximates the true, but unknown, probability distribution of uncertainty in MLE values for the LMS model.

CPF uncertainty with a normal distribution is denoted as  $CPF \sim N(\mu_x, \sigma_x)$ , where  $\mu_x$  and  $\sigma_x$  represent the population arithmetic mean and standard deviation, respectively. Population parameters for the fitted distribution were estimated directly from the corresponding 1000 sample data points. Since CPF values must be non-negative (zero or positive), the fitted normal PDF is truncated with a minimum value of 0 (denoted as  $CPF \sim TN(\mu_x, \sigma_x)$ ).

CPF uncertainty with a log-normal distribution is denoted as  $CPF \sim LN(GM, GSD)$ , where GM and GSD represent the population geometric mean and geometric standard deviation, respectively. These values are derived from the underlying normal parameters  $\mu_x$  and  $\sigma_x$ . Parameters for the underlying normal distribution are directly estimated by taking the natural logarithm of the 1000 sample data points.

The last type of distribution for CPF uncertainty is based on a "mixture" method. This method relies on a combination of distributions rather than a single distribution. It was utilized whenever a normal or lognormal distribution failed to adequately fit the empirical variability. Some of the simulation results displayed a bi-modal distribution with two modal values: "zero" and "non-zero". This split between CPF values is the result of random combinations of the simulated experimental dose-response data such that the MLE LMS fit results in either a "zero" linear term or a "non-zero" linear term. In other words, the fitted dose-response curve (and hence the CPF) from the simulated data is essentially either a linear function of dose or a quadratic function of dose (and/or higher order terms).

Two types of weighted mixture combinations were utilized: uniform/normal and uniform/log-normal. A uniform component was forced to fit the "zero" CPF values, and the normal or log-normal component was fit to the "non-zero" CPF values. Hence, the resulting aggregate distribution is described by a weighted sum. The normalized weights were determined on the basis of the amount of mutually exclusive data utilized in each of the source components. A threshold of  $1 \times 10^{-6}$  was used to stratify the "zero" CPF values (uniform) and the non-zero CPF values (normal or log-normal). The value of  $1 \times 10^{-6}$  as a "zero" threshold was arbitrary and, in actuality, most "zero" CPF values were several orders of magnitude less than the threshold. Therefore, as a default, the "zero" CPF component was fixed as uniform distribution on the interval  $[0, 1 \times 10^{-6}]$ , (i.e.,  $CPF \sim U(5 \times 10^{-7}, 2.89 \times 10^{-7})$ ). The normal or log-normal component was estimated from the corresponding sub-set of "non-zero" CPF values.

It is important to note that the distributions of CPF uncertainty are based primarily on hypothetical experiments simulated from observed experimental data; hence, they only describe LMS parameter uncertainty as a function of MLE sensitivity to varying dose-response data. Although the fitted mixture distributions appear to provide a reasonable graphical fit, statistical tests for distributional assumptions often rejected those fits in most cases. As a result, the fitted probability distributions should not be considered rigorous PDFs for the true CPF variability. In fact the empirical distribution should be utilized rather than fitted distributions.

### 3.3 Grand Distribution

The majority of chemicals analyzed for this study had associated EPA slope estimates which were based on the results of a single animal bioassay. However, some chemicals which are evaluated in quantitative risk assessments have associated slope estimates which are based on data from several animal bioassays. For illustrative purposes, suppose that the EPA has utilized  $m$  animal bioassays for its cancer risk assessment. These  $m$  animal bioassays could differ substantially in experimental design/conduct (eg., different animal species, sexes, strains,

dose scales, routes of exposure, number of dose groups and/or number of animals per dose group). Despite these differences, EPA will typically utilize one of two methods to combine 95% UCL potency values from multiple data sources:

$$CPF = \begin{cases} \text{arithmetic average} = \frac{\sum_{i=1}^{i=m} CPF_i}{m} \\ \text{geometric average} = \left( \prod_{i=1}^{i=m} CPF_i \right)^{\frac{1}{m}} \end{cases}$$

For this analysis, four meta-analysis approaches were taken to combine multiple PDFs:

- Overlay average of the empirical uncertainty distributions,
- Pooled weighted average of the fitted mixture distributions,
- Variance weighted average of the fitted mixture distributions, and
- Two stage variance weighted average of the fitted mixture distributions.

The first approach is based directly on the empirical results from the bootstrap simulation. The three remaining methods utilize the parameters from the fitted mixture distributions. Both the pooled and variance weighted average approaches are based on a "fixed effects" (FE) model for combining evidence. The FE model assumes that the results from each of the bioassays are homogeneous, i.e. samples from a single normal population. Under the assumption of homogeneity, each of the bioassays provides an estimate of the "true" CPF (=  $CPF_1 = CPF_2 = \dots = CPF_m$ ). With the RE model, differences in bioassay results are accounted for only by experimental error (intra-study variability). The experimental error is modeled as independent and normally distributed. On the other hand, the two stage variance weighted average, is based on a "random effects" (RE) model. The RE model assumes that each of the bioassay datasets is a random sample from a spectrum of true CPF values in a larger

superpopulation (Eddy et al. 1992). The RE model assumes that the superpopulation is a normal distribution and that each of the bioassay datasets are exchangeable draws from the superpopulation. The RE model accounts for two types of random variability: intra-study and inter-study.

The FE model assumes that each of the bioassay results are equally predictive. As a result, this method is most appropriate for combining uncertainty distributions derived from individual bioassays based on the same animal species. In this case, there is no issue concerning which animal species best extrapolates to man. However, this approach may not be appropriate when different species of animals are tested. The RE model is better suited since it yields greater uncertainty than the FE model.

The first method, overlay average, generates a composite distribution by overlaying individual distributions (empirical or fitted). This method "superimposes" the uncertainty results from each of the bioassays, regardless of the species tested. It is equivalent to randomly and uniformly selecting a CPF value from any of the  $m$  distributions, rather than combining any of the distributions. Given  $m$  empirical PDFs for CPF uncertainty, where each PDF consists of a histogram of  $n$  identically spaced histogram bins, the grand histogram is determined as follows:

The remaining methods utilize several weighted pooling techniques to combine information. Similar components from the individual fitted mixture PDFs, each of which is characterized by the parameters,  $w_i$ ,  $n_i$ ,  $\bar{x}_i$ ,  $s_i^2$ , (the PDF mixture weight, sample size, sample mean and variance, respectively) are combined to yield a single composite mixture distribution.

The pooled average method assumes that each bioassay uncertainty PDF is a sample from a single population with a common mean ( $H_0: \mu_1 = \mu_2 = \dots = \mu_m$ ) and a common (but unknown) variance ( $H_0: \sigma_1^2 = \sigma_2^2 = \dots = \sigma_m^2$ ). The best estimate of the common, underlying

$$[ \text{bin}_1 , \text{prob}_{11} ] + [ \text{bin}_2 , \text{prob}_{12} ] + \dots + [ \text{bin}_n , \text{prob}_{1n} ] \quad \text{PDF \# 1}$$

$$[ \text{bin}_1 , \text{prob}_{21} ] + [ \text{bin}_2 , \text{prob}_{22} ] + \dots + [ \text{bin}_n , \text{prob}_{2n} ] \quad \text{PDF \# 2}$$

...

$$[ \text{bin}_1 , \text{prob}_{m1} ] + [ \text{bin}_2 , \text{prob}_{m2} ] + \dots + [ \text{bin}_n , \text{prob}_{mn} ] \quad \text{PDF \# m}$$

$$\left[ \text{bin}_1 , \frac{\sum_{i=1}^{i=m} \text{prob}_{1i}}{m} \right] + \left[ \text{bin}_2 , \frac{\sum_{i=1}^{i=m} \text{prob}_{2i}}{m} \right] + \dots + \left[ \text{bin}_n , \frac{\sum_{i=1}^{i=m} \text{prob}_{in}}{m} \right] \quad \text{grand PDF}$$

$$\left[ \text{bin}_j , \frac{\sum_{i=1}^{i=m} \text{prob}_{ij}}{m} \right]$$

mean and variance is given by the familiar pooled estimates:

*Pooled Average Grand CPF PDF* -  $(\mu_p, \sigma_p^2)$  with

$$\hat{\mu}_p = \sum_{i=1}^{i=m} w_i \bar{x}_i \quad \text{where } w_i = \frac{n_i}{\sum_{i=1}^{i=m} n_i}$$

$$\hat{\sigma}_p^2 = \frac{\sum_{i=1}^{i=m} v_i s_i^2}{\sum_{i=1}^{i=m} v_i} \quad \text{where } v_i = n_i - 1 = \text{degrees of freedom}$$

The variance weighted average method generates a composite value using weights that are proportional to information or precision (i.e. the inverse of variance). The best estimate of

the composite mean and variance is given by the following rule based on weighted least squares (Finney 1978):

*Variance Weighted Average Grand CPF PDF -  $(\mu_p, \sigma_p^2)$  with*

$$\hat{\mu}_p = \frac{\sum_{i=1}^{i=m} w_i \bar{x}_i}{\sum_{i=1}^{i=m} w_i} \quad \text{where } w_i = \frac{n_i}{s_i^2}$$

$$\hat{\sigma}_p^2 = \frac{1}{\sum_{i=1}^{i=m} v_i} \quad \text{where } v_i = \left[ \frac{n_i}{\sum n_i} \frac{1}{s_i^2} \right]$$

Since the weights for each distribution are inversely proportional to the variance, a distribution with small experimental variability (high precision) has greater influence than a distribution with large variability (low precision). Hence, each bioassay is NOT equally predictive of the true CPF, and the resulting grand PDF is biased to favor those individual bioassay PDFs with the least variance (greatest certainty). It is interesting to note that this method is equivalent to the exact closed-form Bayesian solution for a posterior normal distribution when both the prior and the likelihood distributions are normal (Eddy et. al. 1992).

The two-stage variance weighted average method generates a composite value using weights that attempt to account for the heterogeneity of the bioassay datasets. Real differences between the datasets are accounted for by a between study variance,  $\tau^2$ . A non-iterative approach based on the method of moments is used to roughly estimate  $\tau^2$ :

$$\hat{\tau}^2 = \max \left[ 0, \frac{Q_w - (m-1)}{\sum w_i - \frac{\sum w_i^2}{\sum w_i}} \right] \quad \text{where } w_i = \frac{1}{s_i^2}$$

The value  $Q_w$  is a FE model test statistic that measures the degree of homogeneity between each dataset's mean CPF (relative to its own variability) and the common pooled CPF. Since the number of bioassay datasets to combine is usually small (2-6),  $Q_w$  will often fail to reject homogeneity because of limited statistical power. It is defined as follows (Cochran 1937):

$$Q_w = \sum_{i=1}^{i=m} w_i * (\bar{x}_i - \hat{\mu}_p)^2 \quad \text{where } w_i = \frac{1}{s_i^2}$$

Note that the FE and RE models differ only in the choice of their weights. In fact, if  $\tau^2 = 0$ , then the RE and FE models are equivalent. The best estimate of the composite mean and variance is given by the following rule:

*Two-Stage Variance Weighted Average Grand CPF PDF ~ (  $\mu_p$  ,  $\sigma_p^2$  ) with*

$$\hat{\mu}_p = \frac{\sum_{i=1}^{i=m} w_i^* * \bar{x}_i}{\sum_{i=1}^{i=m} w_i^*} \quad \text{where } w_i^* = \left[ \frac{1}{\frac{s_i^2}{n_i} + \tau^2} \right]$$

$$\hat{\sigma}_p^2 = \frac{1}{\sum_{i=1}^{i=m} v_i^*} \quad \text{where } v_i^* = \left[ \frac{n_i}{\sum n_i} \left( \frac{1}{s_i^2 + \tau^2} \right) \right]$$

The estimates for the common mean ( $\hat{\mu}_p$ ) for the FE (variance-weighted) and the RE models are often similar. However, estimates for the common variance ( $\hat{\sigma}_p^2$ ) are more sensitive to the effect of  $\tau^2$ . In general, the RE model will generate greater variability than the FE model.

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Table 1 - Summary of Oral CPF Results \*

Chemical	ORAL CPF (mg/kg/day) <sup>-1</sup>		
	EPA 95% UCL	MLE	Ratio of EPA 95% UCL to MLE
Single Bioassays			
<i>Tetrachloroethene</i> (PCE)	0.051	0.039	1.31
Bis(2-ethylhexyl)phthalate (BEHP)	0.014	0.0091	1.54
<i>1,2-Dichloroethane</i>	0.091	0.042	2.17
<i>1,1,2,2-Tetrachloroethane</i>	0.2	0.1	2.00
Chloroform (CHCL <sub>3</sub> )	0.0061	0.0030	2.03
Beryllium	4.3	1.68	2.56
Bromodichloromethane	0.13	0.075	1.73
1,2-Dichloropropane (EDC)	0.068	0.036	1.89
1,1,2-Trichloroethane (VTC)	0.057	0.0058	9.83
Vinyl Chloride (VCM)	1.9	1.6	1.19
Polychlorinated Biphenyls (PCBs)	7.7	5.3	1.45
Chloromethane	0.013	0.0037	3.51
1,1-Dichloroethene (VDC)	0.6	3.70E-14	1.62E+13
<i>1,1-Dichloroethane</i>	None	2.73E-24	-
<i>N-nitrosodiphenylamine</i> (NDPA)	0.0049	3.34E-22	1.47E+19
Multiple Bioassays			
<i>Trichloroethene</i> (TCE)	0.011	0.0059	1.86
<i>Carbon Tetrachloride</i> (CCL <sub>4</sub> )	0.13	0.087	1.49
<i>Methylene Chloride</i> (DCM)	0.0075	0.0035	2.14
Chlordane	1.3	2.97E-5	4.38E+4
Benzo(a)pyrene (BaP)	7.3	1.13E-4	6.46E+4

\* Italicized chemicals have at least one dose group with a 0 % response rate.

Table 2 - Oral CPF Uncertainty Probability Distributions  
Single Bioassays

Chemical	ORAL CPF (mg/kg/day)		MLE CPF Uncertainty Fitted Mixture PDF			
	EPA 95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	TN ( $\mu$ , $\sigma$ ) or LN (GM, GSD)
Tetrachloroethene	0.051	0.039	0.025	U(5.00E-7, 2.89E-7)	0.975	TN(3.64E-2, 9.91E-3)
Bis(2-ethylhexyl)phthalate	0.014	0.0091	0.041	U(5.00E-7, 2.89E-7)	0.959	TN(8.61E-3, 3.43E-3)
1,2-Dichloroethane	0.091	0.042	0.059	U(5.00E-7, 2.89E-7)	0.941	TN(3.75E-2, 1.36E-2)
1,1,2,2-Tetrachloroethane	0.2	0.1	0.076	U(5.00E-7, 2.89E-7)	0.924	TN(1.08E-1, 5.11E-2)
Chloroform	0.0061	0.0030	0.118	U(5.00E-7, 2.89E-7)	0.882	TN(3.15E-3, 1.69E-3)
Beryllium	4.3	1.68	0.143	U(5.00E-7, 2.89E-7)	0.857	TN(1.78E+0, 1.38E+0)
Bromodichloromethane	0.13	0.075	0.164	U(5.00E-7, 2.89E-7)	0.836	TN(7.42E-2, 3.60E-2)
1,2-Dichloropropane	0.068	0.036	0.244	U(5.00E-7, 2.89E-7)	0.756	TN(3.53E-2, 1.74E-2)
1,1,2-Trichloroethane	0.057	0.0058	0.432	U(5.00E-7, 2.89E-7)	0.568	TN(2.48E-2, 1.73E-2)
Vinyl Chloride	1.9	1.6	0.000	—	1.000	LN(1.52E+0, 1.16E+0)
Polychlorinated Biphenyls *	7.7	5.3	0.000	—	1.000	LN(5.25E+0, 1.20E+0)
Chloromethane	0.013	0.0037	0.326	U(5.00E-7, 2.89E-7)	0.674	LN(4.43E-3, 3.05E+0)
1,1-Dichloroethene	0.6	3.7E-14	0.658	U(5.00E-7, 2.89E-7)	0.342	TN(2.93E-1, 1.76E-1)
1,1-Dichloroethane	None	2.73E-24	1.000	U(5.00E-7, 2.89E-7)	—	—
N-nitrosodiphenylamine	0.0049	3.34E-22	1.000	U(5.00E-7, 2.89E-7)	—	—

Modified data set, sample size reduced from 1000 to 891 data points because of 100 % simulation response rate in the high dose group.

Table 3 - Oral CPF Uncertainty Probability Distributions  
Multiple Bioassays

Chemical	ORAL CPF (mg/kg/day) <sup>1</sup>		MLE CPF Uncertainty Fitted Mixture PDF			
	95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	TN( $\mu$ , $\sigma$ ) or LN(GM, GSD)
<b>Trichloroethene (TCE)</b>						
NTP, 1982 (B6C3F1 Male Mice)	0.019	0.013	0.000	—	1.000	TN(1.34E-2, 3.44E-3)
NTP, 1982 (B6C3F1 Female Mice)	0.008	0.005	0.000	—	1.000	TN(4.94E-3, 1.71E-3)
NCI, 1976 (B6C3F1 Male Mice)	0.021	0.016	0.004	U(5.00E-7, 2.89E-7)	0.996	TN(1.57E-2, 3.52E-3)
NCI, 1976 (B6C3F1 Female Mice)	0.0067	0.0012	0.431	U(5.00E-7, 2.89E-7)	0.569	TN(3.03E-3, 1.70E-3)
<i>Geometric Mean</i>	0.012	0.0059	Grand PDF			
Pooled Average			0.109	U(5.00E-7, 2.89E-7)	0.891	TN(1.00E-2, 2.84E-3)
Variance Weighted Average						TN(6.66E-3, 2.25E-3)
Two-Stage Variance Weighted Average						TN(9.25E-3, 5.54E-3)
<b>Carbon Tetrachloride (CCL<sub>4</sub>)</b>						
Della et al., 1961 (Syrian Golden Hamsters)	1.19	0.735	0.000	—	1.000	TN(7.74E-1, 2.59E-1)
Edwards et al., 1942 (Inbred L Mice)	0.329	0.249	0.000	—	1.000	TN(2.48E-1, 4.94E-2)
NCI, 1976 (B6C3F1 Mice) *	0.063	0.049	0.040	U(5.00E-7, 2.89E-7)	0.960	TN(4.75E-2, 7.73E-3)
NCI, 1976 (Osborne-Mendel Rats)	0.011	0.0066	0.150	U(5.00E-7, 2.89E-7)	0.850	TN(5.92E-3, 2.57E-3)
<i>Geometric Mean</i>	0.13	0.087				
Pooled Average			0.095	U(5.00E-7, 2.89E-7)	0.905	TN(3.06E-1, 1.42E-1)
Variance Weighted Average						TN(9.71E-3, 4.98E-3)
Two-Stage Variance Weighted Average						TN(8.37E-2, 5.72E-2)

\* Modified data set, sample size reduced from 1000 to 626 data points because of 100% simulation response rate in the mid dose group.

Table 3 - Oral CPF Uncertainty Probability Distributions  
Multiple Bioassays (Continued)

Chemical	ORAL CPF (mg/kg/day) <sup>1</sup>		MLE CPF Uncertainty Fitted Mixture PDF			
	95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	TN( $\mu$ , $\sigma$ ) or LN(GM, GSD)
<b>Methylene Chloride (DCM)</b>						
NTP, 1986 (B6C3F1 Female Mice)	0.0026	1.17E-27	0.781	U(5.00E-7, 2.89E-7)	0.219	TN(1.37E-1, 1.14E-3)
NCA, 1983 (B6C3F1 Male Mice)	0.012	0.0070	0.049	U(5.00E-7, 2.89E-7)	0.951	TN(7.22E-3, 3.49E-3)
<i>Arithmetic Mean</i>	0.0075	0.0035	Grand PDF			
Pooled Average			0.415	U(5.00E-7, 2.89E-7)	0.585	TN(6.14E-3, 3.20E-3)
Variance Weighted Average						TN(3.23E-5, 2.19E-3)
Two-Stage Variance Weighted Average						TN(5.72E-3, 5.42E-3)
<b>Chlordane</b>						
Velsicol, 1973 (CD-1 Female Mice)	2.98	1.42	0.148	U(5.00E-7, 2.89E-7)	0.852	TN(1.51E+0, 7.88E-1)
Velsicol, 1973 (CD-1 Male Mice)	4.74	3.84	0.067	U(5.00E-7, 2.89E-7)	0.933	TN(3.25E+0, 1.01E+0)
NCI, 1977 (B6C3F1 Male Mice)	0.76	8.79E-10	0.966	U(5.00E-7, 2.89E-7)	0.034	TN(5.15E-1, 4.84E-1)
NCI, 1977 (B6C3F1 Male Mice)	0.25	1.62E-10	1.000	U(5.00E-7, 2.89E-7)	0.000	-
<i>Geometric Mean</i>	1.3	2.97E-5	Grand PDF			
Pooled Average			0.545	U(5.00E-7, 2.89E-7)	0.455	TN(2.38E+0, 9.06E-1)
Variance Weighted Average						TN(2.10E+0, 8.65E-1)
Two-Stage Variance Weighted Average						TN(2.33E+0, 1.92E+0)

Table 3 - Oral CPF Uncertainty Probability Distributions  
Multiple Bioassays (Continued)

Chemical	ORAL CPF (mg/kg/day) <sup>1</sup>		MLE CPF Uncertainty Fitted Mixture PDF			
	95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	TN( $\mu$ , $\sigma$ ) or LN(GM, GSD)
<b>Benzo(a)pyrene (BaP)</b>						
Neal & Rigdon, 1967 <sup>b</sup> (CFW Male/Female Mice)	12.44	2.90	0.379	U(5.00E-7, 2.89E-7)	0.621	LN(4.06E+0, 1.72E+0)
Brune et. al, 1981 (Sprague-Dawley Male/Female Rats)	11.73	4.41E-9	0.627	U(5.00E-7, 2.89E-7)	0.373	LN(5.87E+0, 1.65E+0)
<i>Geometric Mean</i>	12.08	1.13E-4	Grand PDF			
Pooled Average						LN(4.70E+0, 1.65E+0)
Variance Weighted Average			0.503	U(5.00E-7, 2.89E-7)	0.497	LN(4.97E+0, 1.62E+0)
Two-Stage Variance Weighted Average						LN(4.97E+0, 1.62E+0)

<sup>b</sup> Low-dose extrapolation via LMS model does not conform with models as reported in IRIS

Table 4 - Summary of Inhalation CPF Results \*

Chemical	INHALATION CPF (mg/kg/day) <sup>1</sup>		
	EPA 95% UCL	MLE	Ratio of EPA 95% UCL to MLE
Single Bioassays			
<i>1,1-Dichloroethene</i> (VDC)	1.16	2.3E-9	5.04E+8
Multiple Bioassays			
Trichloroethene (TCE)	0.017	5.4E-6	3.15E+3
Tetrachloroethene (PCE)	0.074	3.5E-5	2.11E+3
Methylene Chloride (DCM)	0.0051	5.6E-12	9.11E+8
<i>Chloroform</i> (CHCL <sub>3</sub> )	0.0081	3.1E-10	2.61E+7

\* Italicized chemicals have at least one dose group with a 0 % response rate.

Table 5 - Inhalation CPF Uncertainty Probability Distributions  
Single Bioassays

Chemical	INHALATION CPF (mg/kg/day) <sup>1</sup>		MLE CPF Uncertainty Fitted Mixture PDF			
	EPA 95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	TN( $\mu$ , $\sigma$ ) or LN(GM, GSD)
1,1-Dichloroethene (VDC)	0.175	2.38E-9	1.000	U(5.00E-7, 2.89E-7)	0.000	-

Table 6 - Inhalation CPF Uncertainty Probability Distributions  
Multiple Bioassays

Chemical	INHALATION CPF (mg/kg/day) <sup>1</sup>		MLE CPF Uncertainty Fitted Mixture PDF			
	EPA 95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	TN( $\mu$ , $\sigma$ ) or LN(GM, GSD)
<b>Trichloroethene (TCE)</b>						
Maltoni, 1986 (Swiss Male Mice)	0.024	0.017	0.079	U(5.00E-7, 2.89E-7)	0.921	TN(1.45E-2, 5.81E-3)
Maltoni, 1986 (Swiss Female Mice)	0.009	5.3E-16	0.775	U(5.00E-7, 2.89E-7)	0.225	TN(4.20E-3, 3.07E-3)
Maltoni, 1986 (B6C3F1 Female Mice)	0.013	0.0078	0.147	U(5.00E-7, 2.89E-7)	0.853	TN(7.14E-3, 3.51E-3)
Fukuda et al., 1986 (ICR Female Mice)	0.024	0.012	0.096	U(5.00E-7, 2.89E-7)	0.904	TN(1.15E-2, 6.48E-3)
<i>Geometric Mean</i>	0.017	5.3E-6	Grand PDF			
Pooled Average						TN(1.06E-2, 5.31E-3)
Variance Weighted Average			0.274	U(5.00E-7, 2.89E-7)	0.726	TN(8.73E-3, 4.52E-3)
Two-Stage Variance Weighted Average						TN(9.03E-3, 5.01E-3)

Table 6 - Inhalation CPF Uncertainty Probability Distributions  
Multiple Bioassays (Continued)

Chemical	INHALATION CPF (mg/kg/day) <sup>-1</sup>		MLE CPF Uncertainty Fitted Mixture PDF			
	EPA 95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	TN( $\mu$ , $\sigma$ ) or LN(GM, GSD)
<b>Tetrachloroethene (PCE)</b>						
NTP, 1985 (Fischer 344 Male Rats)	0.121	0.069	0.209	U(5.00E-7, 2.89E-7)	0.791	TN(6.62E-2, 3.37E-2)
NTP, 1985 (Fischer 344 Female Rats)	0.101	0.063	0.117	U(5.00E-7, 2.89E-7)	0.883	TN(5.99E-2, 2.50E-2)
NTP, 1985 (B6C3F1 Male Mice) (carcinoma)	0.0667	0.0490	0.018	U(5.00E-7, 2.89E-7)	0.982	TN(4.66E-2, 1.27E-2)
NTP, 1985 (B6C3F1 Female Mice) (carcinoma)	0.0364	9.6E-12	0.957	U(5.00E-7, 2.89E-7)	0.043	TN(2.26E-2, 1.84E-2)
NTP, 1985 (B6C3F1 Male Mice) (carcinoma/adenoma)	0.108	0.048	0.250	U(5.00E-7, 2.89E-7)	0.750	TN(5.79E-2, 2.98E-2)
NTP, 1985 (B6C3F1 Female Mice) (carcinoma/adenoma)	0.0505	1.8E-11	0.923	U(5.00E-7, 2.89E-7)	0.077	TN(2.49E-2, 2.41E-2)
<i>Geometric Mean</i>	0.0738	3.5E-5	Grand PDF			
Pooled Average			0.412	U(5.00E-7, 2.89E-7)	0.588	TN(5.60E-2, 2.57E-2)
Variance Weighted Average						TN(5.05E-2, 1.95E-2)
Two-Stage Variance Weighted Average						TN(5.05E-2, 1.95E-2)

Table 6 - Inhalation CPF Uncertainty Probability Distributions  
Multiple Bioassays (Continued)

Chemical	INHALATION CPF (mg/kg/day) <sup>-1</sup>		MLE CPF Uncertainty Fitted Mixture PDF			
	EPA 95% UCL	MLE	Wt1	U( $\mu$ , $\sigma$ )	Wt2	N( $\mu$ , $\sigma$ ) or LN(GM, GSD)
<b>Methylene Chloride (DCM)</b>						
NTP, 1986 (B6C3F1 Female Mice)	0.00252	4.20E-21	0.839	U(5.00E-7, 2.89E-7)	0.161	TN(1.27E-3, 1.02E-3)
NTP, 1986 (B6C3F1 Female Mice)	0.0106	0.00739	0.025	U(5.00E-7, 2.89E-7)	0.975	TN(6.60E-3, 2.63E-3)
<i>Sum</i>	0.0131	0.00739	Grand PDF			
Pooled Average						TN(5.84E-3, 2.47E-3)
Variance Weighted Average			0.432	U(5.00E-7, 2.89E-7)	0.568	TN(3.82E-3, 1.96E-3)
Two-Stage Variance Weighted Average						TN(5.71E-3, 5.58E-3)
<b>Chloroform (CHCL<sub>3</sub>)</b>						
Velsicol, 1973 (CD-1 Female Mice)	0.20	0.1584	0.116	U(5.00E-7, 2.89E-7)	0.884	TN(1.44E-1, 3.70E-2)
Velsicol, 1973 (Cd-1 Male Mice)	0.033	6.3E-19	1.000	U(5.00E-7, 2.89E-7)	0.000	—
<i>Geometric Mean</i>	0.0812	3.12E-10	Grand PDF			
Pooled Average						TN(1.44E-1, 3.70E-2)
Variance Weighted Average			0.558	U(5.00E-7, 2.89E-7)	0.442	TN(1.44E-1, 3.70E-2)
Two-Stage Variance Weighted Average						TN(1.44E-1, 3.70E-2)

**Attachment F-4**

**OU1 Contaminants of Concern 95 Percent Upper Confidence Limits**

**Table F-4-1**  
**OU1 Contaminants of Concern 95 Percent Upper Concentration Limits (UCLs)**  
**Sitewide Data including Source**

Contaminant	Arithmetic Mean (x)	Standard Deviation (sd)	Number of Observations (n)	t Statistic (t)	UCL
<b>Groundwater (ug/L)</b>					
1,1-Dichloroethene	283	1449	211	1.645	447
Carbon Tetrachloride	81.2	500	211	1.645	138
Tetrachloroethene	103	481	211	1.645	157
1,1,1-Trichloroethane	363	1722	211	1.645	558
Selenium	132	172.3	5 *	2.132	298
<b>Surface Soils (ug/kg) or (pCi/g)</b>					
Americium-241	83.2807	460.997	28	1.697	231.1
Plutonium-239,240	294.6888	1776.33	34	1.684	807.7
Benzo (a) anthracene	266.6	156.8	28	1.703	317.1
Benzo (a) pyrene	258.4	136.5	28	1.703	302.3
Benzo (b) fluoranthene	259.8	139.2	28	1.703	304.6
Benzo (k) fluoranthene	246.1	133.5	28	1.703	289.1
Dibenzo (a,h) anthracene	171.6	50.8	27	1.706	188.3
Aroclor-1254	145	230	29	1.701	217.6
Pyrene	525	422	28	1.703	660.8
Fluoranthene	579.6	455	28	1.703	726.0
Fluorene	178.1	42.6	28	1.703	191.8
Acenaphthene	178.6	47.3	28	1.703	193.8
Uranium-233,234	2.1422	4.135	34	1.684	3.336
Uranium-238	1.3758	0.7157	34	1.684	1.582
<b>Subsurface Soils (ug/kg) or (pCi/g)</b>					
Americium-241	10.247	17.654	3 *	2.92	40.01
Plutonium-239,240	29.170	50.218	3 *	2.92	113.8
Pyrene	308	302	187	1.645	344.3
Fluoranthene	313	329	187	1.645	352.6
Toluene	107.9	181.8	432	1.645	122.3
Uranium-233,234	2.204	1.989	3 *	2.92	5.557
Uranium-238	1.186	0.178	3 *	2.92	1.486
<b>Surface Water (pCi/L)</b>					
Americium-241	0.0208	0.0381	173	1.645	0.0256
Plutonium-239,240	0.0071	0.0052	143	1.645	0.0078
Uranium-233,234	2.1047	1.5672	106	1.658	2.357
Uranium-238	3.5319	5.984	106	1.658	4.496
<b>Sediments (ug/kg) or (pCi/g)</b>					
Americium-241	0.027	0.0167	11	1.812	0.0361
Plutonium-239,240	1.305	3.2178	12	1.796	2.973
Benzo (b) fluoranthene	260	32	13	1.782	275.8
Benzo (k) fluoranthene	254.9	38	13	1.782	273.7
Aroclor-1254	132	47	10	1.833	159.2
Pyrene	224.6	69.7	13	1.782	259.0
Fluoranthene	222.7	74.2	13	1.782	259.4
Uranium-233,234	0.9753	0.624	12	1.796	1.299
Uranium-238	0.9394	0.4463	12	1.796	1.171

UCL =  $x + t(sd/(n)^{.5})$

\* = Calculated from arithmetic means for each lithologic unit

**Table F-4-2**  
**OU1 Contaminants of Concern 95 Percent Upper Concentration Limits (UCLs)**  
**Sitewide Data without Source**

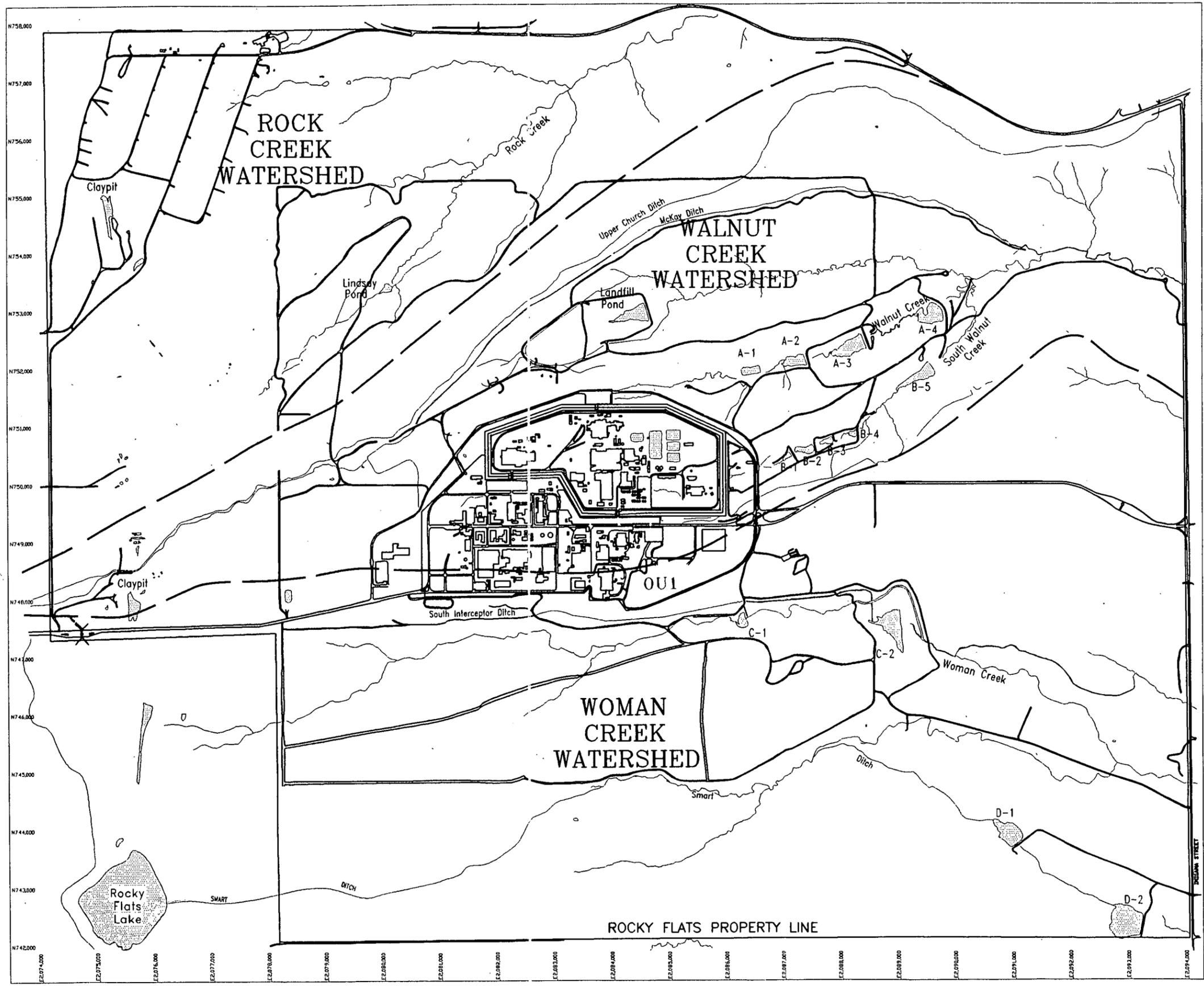
Contaminant	Arithmetic Mean (x)	Standard Deviation (sd)	Number of Observations (n)	t Statistic (t)	UCL
<b>Groundwater</b> (ug/L)					
1,1-Dichloroethene	1.467	1.325	181	1.645	1.629
Carbon Tetrachloride	1.462	1.308	182	1.645	1.621
Tetrachloroethene	5.094	23.7	182	1.645	7.984
1,1,1-Trichloroethane	2.486	5.063	182	1.645	3.103
Selenium	103	245	195	1.645	131.9
<b>Surface Soils</b> (ug/kg) or (pCi/g)					
Americium-241	0.4078	0.5142	28	1.703	0.5733
Plutonium-239,240	2.4084	3.4885	34	1.697	3.424
Benzo (a) anthracene	266.6	156.8	28	1.703	317.1
Benzo (a) pyrene	258.4	136.5	28	1.703	302.3
Benzo (b) fluoranthene	259.8	139.2	28	1.703	304.6
Benzo (k) fluoranthene	246.1	133.5	28	1.703	289.1
Dibenzo (a,h) anthracene	171.6	50.8	27	1.706	188.3
Aroclor-1254	145	230	29	1.701	217.6
Pyrene	525	422	28	1.703	660.8
Fluoranthene	579.6	455	28	1.703	726.0
Fluorene	178.1	42.6	28	1.703	191.8
Acenaphthene	178.6	47.3	28	1.703	193.8
Uranium-233,234	1.2109	0.3144	34	1.697	1.302
Uranium-238	1.1725	0.3753	34	1.697	1.282

UCL =  $x + t(sd/(n)^{.5})$

**Table F-4-3**  
**OU1 Contaminants of Concern 95 Percent Upper Concentration Limits (UCLs)**  
**Source Only Data**

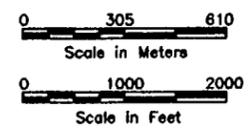
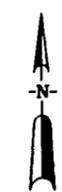
Contaminant	Arithmetic Mean (x)	Standard Deviation (sd)	Number of Observations (n)	t Statistic (t)	UCL
<b>Groundwater</b> (ug/L)					
1,1-Dichloroethene	4228	3394	21	1.725	5506
Carbon Tetrachloride	1080	694	17	1.746	1374
Tetrachloroethene	1517	1065	21	1.725	1918
1,1,1-Trichloroethane	5429	4046	21	1.725	6952
Selenium	792	410	32	1.697	915.0
<b>Surface Soils</b> (ug/kg) or (pCi/g)					
Americium-241	664	1325	4	2.353	2223
Plutonium-239,240	2781	5546	4	2.353	9306
Uranium-233,234	10.665	10.3795	4	2.353	22.88
Uranium-238	2.5875	1.7667	4	2.353	4.666

$UCL = x + t(sd/(n)^{.5})$



**LEGEND**

-  Watershed Boundary
-  Open Water

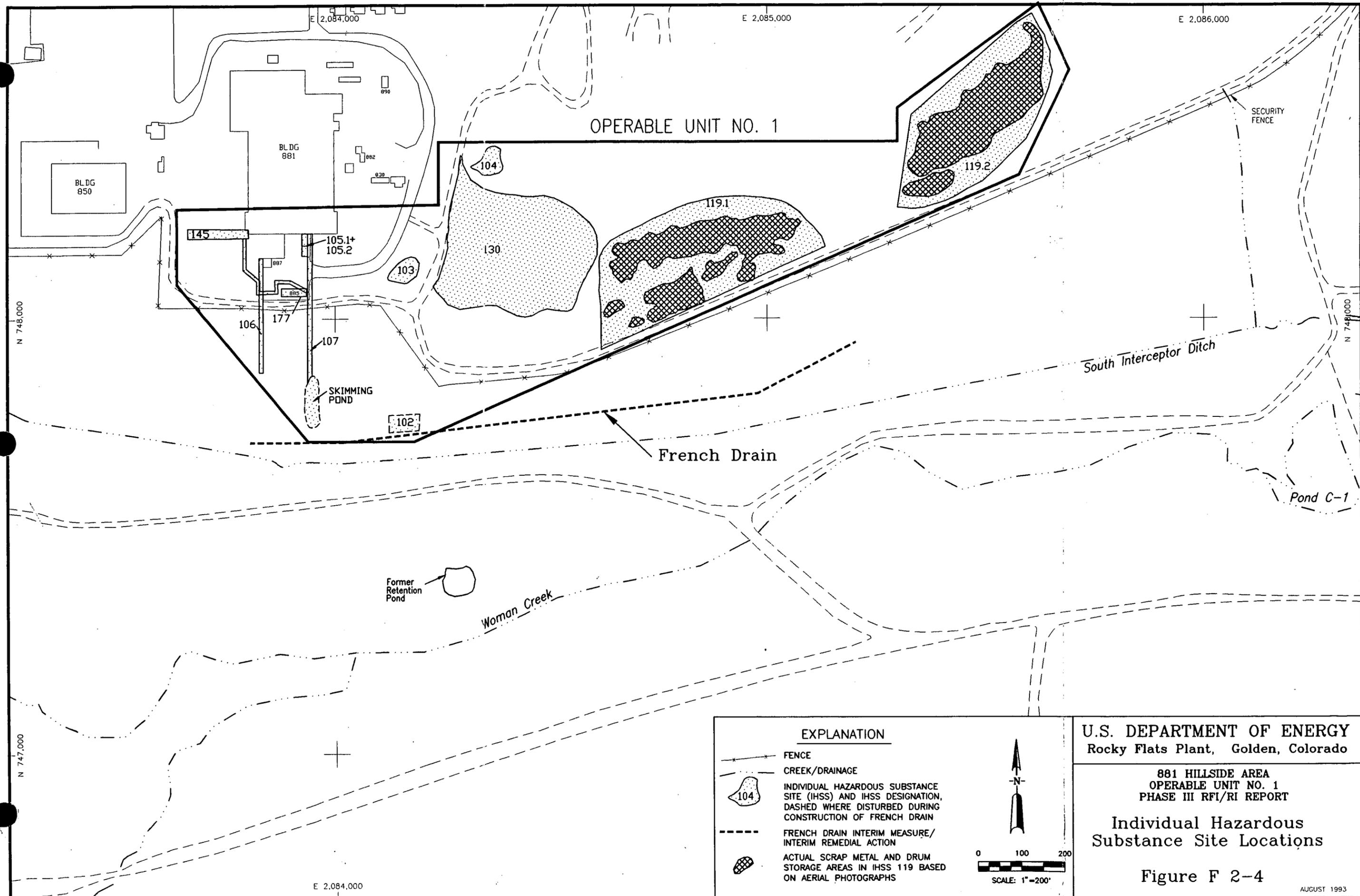


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881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFI/RI REPORT

Location of OU1

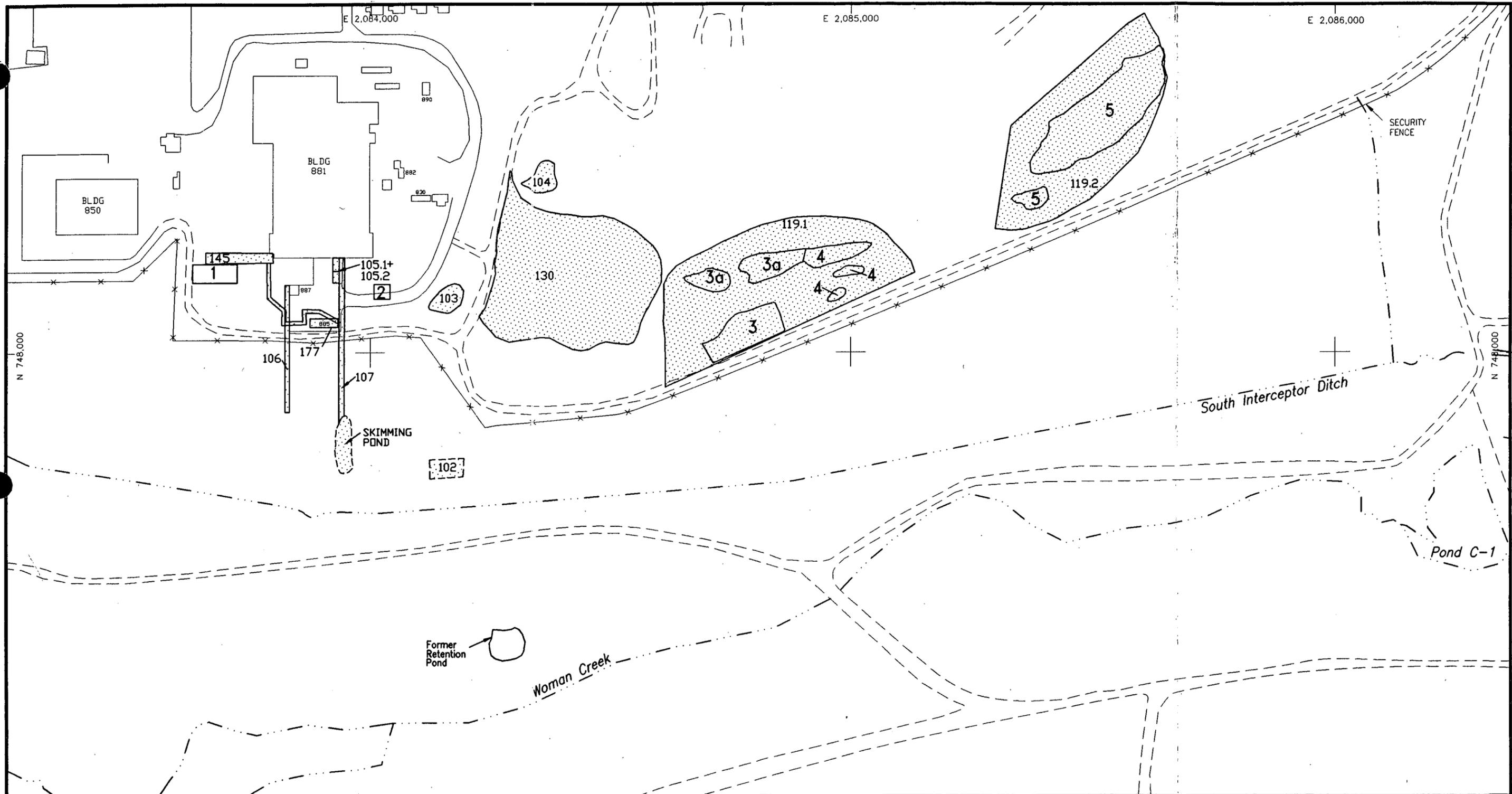
Figure F 2-3



EXPLANATION	
	FENCE
	CREEK/DRAINAGE
	INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION, DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
	FRENCH DRAIN INTERIM MEASURE/ INTERIM REMEDIAL ACTION
	ACTUAL SCRAP METAL AND DRUM STORAGE AREAS IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS

SCALE: 1"=200'

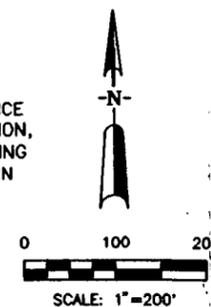
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**881 HILLSIDE AREA**  
**OPERABLE UNIT NO. 1**  
**PHASE III RFI/RI REPORT**  
  
**Individual Hazardous**  
**Substance Site Locations**  
  
**Figure F 2-4**  
 AUGUST 1993



- 1** SUSPECTED SOURCE AREA FOR DIFFUSE VOC GROUNDWATER PLUME IN BUILDING 881 AREA. SUSPECTED SOURCE IS A SANITARY SEWER DISCHARGING AQUEOUS VOC SOLUTION. EXACT LOCATION UNKNOWN.
- 2** SUSPECTED SOURCE AREA FOR DIFFUSE VOC GROUNDWATER PLUME IN BUILDING 881 AREA. SUSPECTED SOURCE IS SURFACE RELEASE OF PCE BASED ON SOIL GAS SURVEY DETECTION OF 68,576 RELATIVE RESPONSE UNITS (SEE FIGURE 4-36).
- 3** KNOWN SOURCE FOR DISCRETE VOC GROUNDWATER PLUME IN AND DOWN-GRADIENT OF IHSS 119.1. LOCATION OF SOURCE BASED ON HISTORICAL AERIAL PHOTOGRAPHS DEPICTING DRUM STORAGE.
- 3a** OTHER SUSPECTED VOC SOURCE AREAS BASED ON HISTORICAL WASTE STORAGE DEPICTED ON AERIAL PHOTOGRAPHS.
- 4** SUSPECTED SOURCE FOR SMALL VOC GROUNDWATER PLUME, DOWNGRADIENT OF THE EAST END OF IHSS 119.1. EXACT LOCATION UNKNOWN.
- 5** SUSPECTED SOURCE FOR DIFFUSE VOC GROUNDWATER PLUME DOWNGRADIENT OF IHSS 119.2. EXACT LOCATION IS UNKNOWN. PRESENCE OF A SOURCE WITHIN IHSS 119.2 IS UNCERTAIN AS GROUNDWATER CONTAMINATION IN THIS AREA MAY BE DUE TO RELEASES AT THE 903 PAD.

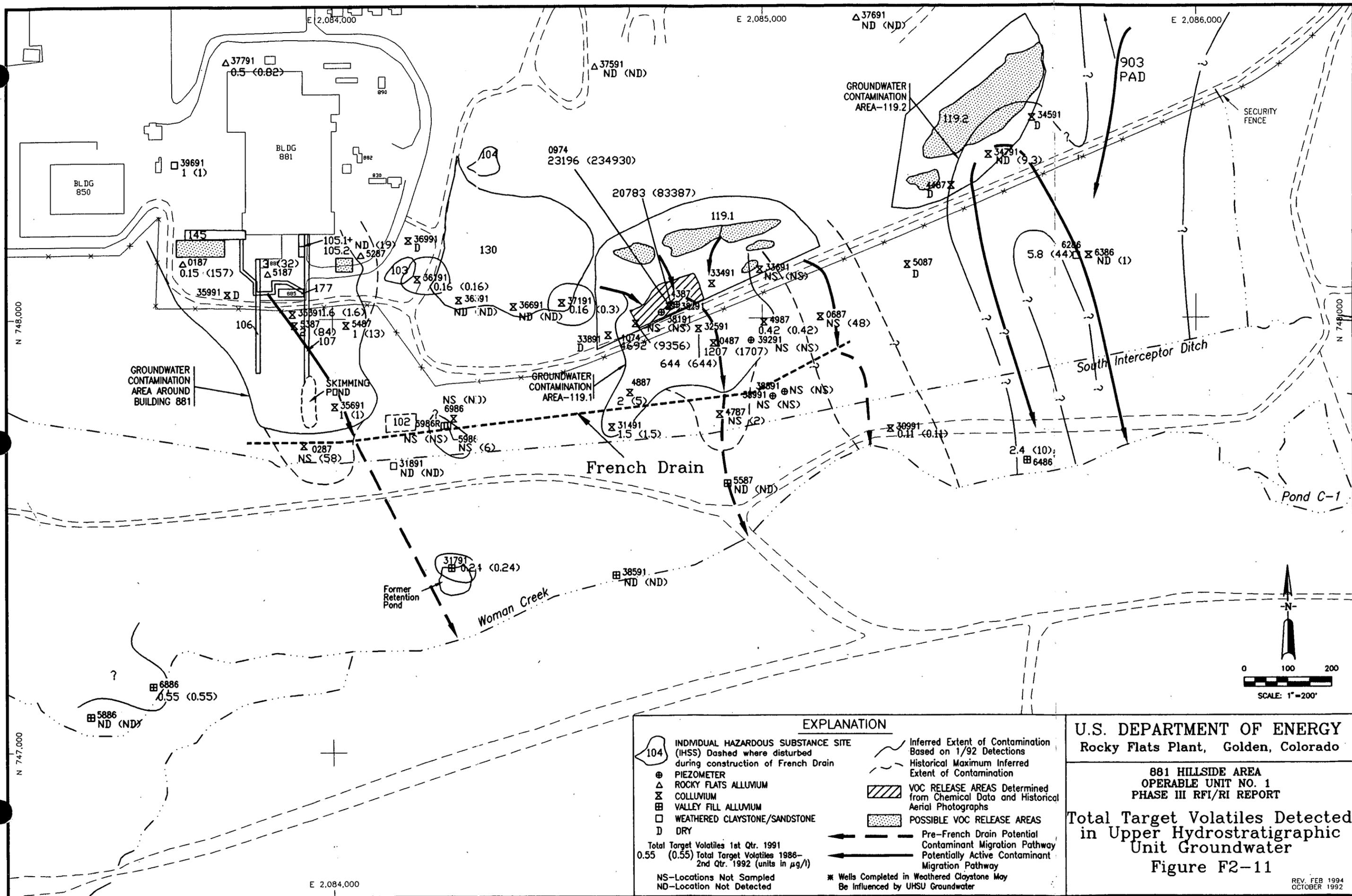
**EXPLANATION**

- FENCE
- CREEK/DRAINAGE
- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION, DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN



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**881 HILLSIDE AREA**  
**OPERABLE UNIT NO. 1**  
**PHASE III RFI/RI REPORT**  
**Suspected Source**  
**Areas for VOC-Contaminated**  
**Groundwater**  
**Figure F2-9**



**EXPLANATION**

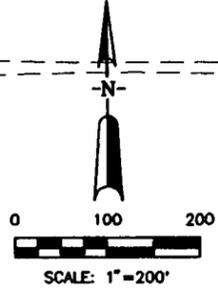
- 104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) Dashed where disturbed during construction of French Drain
- ⊕ PIEZOMETER
- △ ROCKY FLATS ALLUVIUM
- ⊗ COLLUVIUM
- ⊞ VALLEY FILL ALLUVIUM
- WEATHERED CLAYSTONE/SANDSTONE
- D DRY
- ▨ VOC RELEASE AREAS Determined from Chemical Data and Historical Aerial Photographs
- ▤ POSSIBLE VOC RELEASE AREAS
- Inferred Extent of Contamination Based on 1/92 Detections
- - - Historical Maximum Inferred Extent of Contamination
- ← Pre-French Drain Potential Contaminant Migration Pathway
- Potentially Active Contaminant Migration Pathway
- \* Wells Completed in Weathered Claystone May Be Influenced by UHSU Groundwater
- NS—Locations Not Sampled
- ND—Location Not Detected

Total Target Volatiles 1st Qtr. 1991  
0.55 (0.55) Total Target Volatiles 1986-2nd Qtr. 1992 (units in µg/l)

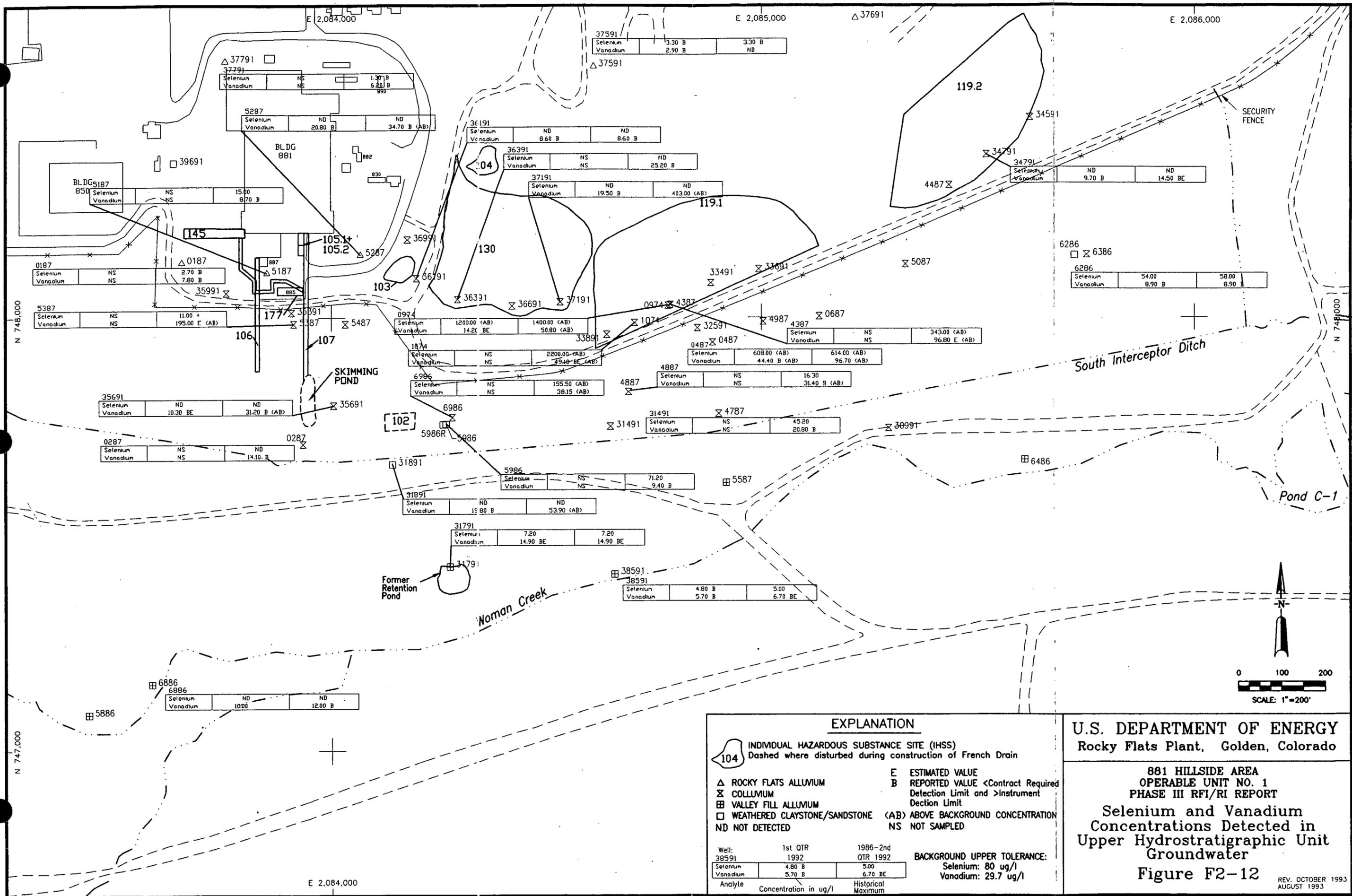
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**881 HILLSIDE AREA**  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

**Total Target Volatiles Detected**  
in Upper Hydrostratigraphic  
Unit Groundwater  
Figure F2-11



REV. FEB 1994  
OCTOBER 1992



EXPLANATION		
104	INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) Dashed where disturbed during construction of French Drain	
△	ROCKY FLATS ALLUVIUM	E ESTIMATED VALUE
×	COLLUVIUM	B REPORTED VALUE <Contract Required Detection Limit and >Instrument Detection Limit
⊞	VALLEY FILL ALLUVIUM	(AB) ABOVE BACKGROUND CONCENTRATION
□	WEATHERED CLAYSTONE/SANDSTONE	NS NOT SAMPLED
ND	NOT DETECTED	
Well:	1st QTR	1986-2nd
38591	1992	QTR 1992
Selenium	4.80 B	5.00
Vanadium	5.70 B	6.70 BE
Analyte	Concentration in ug/l	Historical Maximum
BACKGROUND UPPER TOLERANCE: Selenium: 80 ug/l Vanadium: 29.7 ug/l		

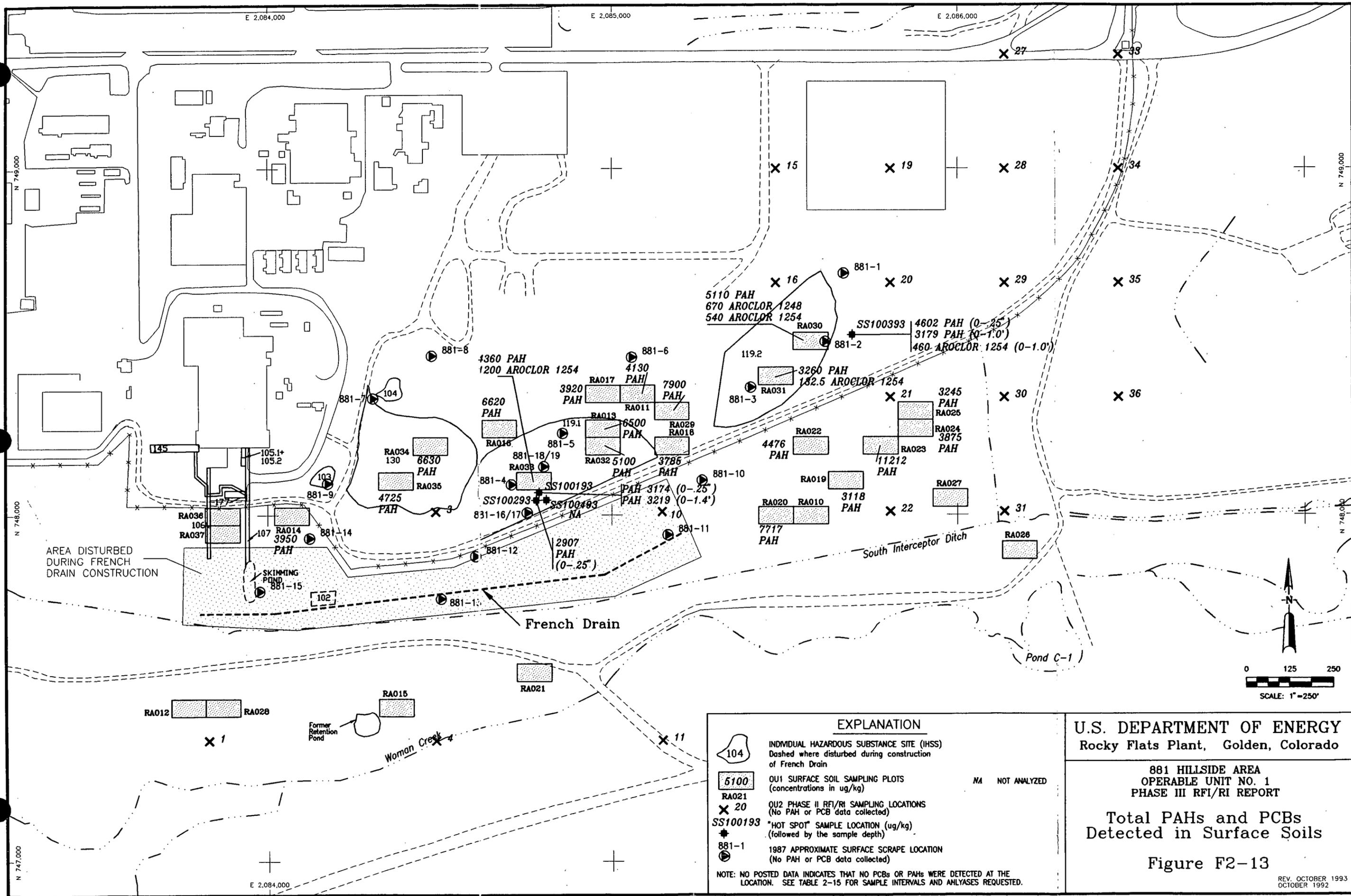
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881 HILLSIDE AREA  
OPERABLE UNIT NO. 1  
PHASE III RFI/RI REPORT

Selenium and Vanadium  
Concentrations Detected in  
Upper Hydrostratigraphic Unit  
Groundwater

Figure F2-12

REV. OCTOBER 1993  
AUGUST 1993



5110 PAH  
670 AROCLOR 1248  
540 AROCLOR 1254

3260 PAH  
182.5 AROCLOR 1254

4602 PAH (0-25")  
3179 PAH (0-1.0")  
460 AROCLOR 1254 (0-1.0")

4360 PAH  
1200 AROCLOR 1254

6620 PAH

4130 PAH

6500 PAH

3785 PAH

PAH 3174 (0-25")  
PAH 3219 (0-1.4")

2907 PAH (0-25")

4476 PAH

3245 PAH  
RA025

3875 PAH  
RA024

11212 PAH  
RA023

3118 PAH  
RA019

7717 PAH  
RA020

7717 PAH  
RA010

3118 PAH  
RA027

7717 PAH  
RA026

6630 PAH  
RA034

4725 PAH  
RA035

3950 PAH  
RA014

3950 PAH  
RA037

3950 PAH  
RA015

3950 PAH  
RA012

3950 PAH  
RA028

3950 PAH  
RA021

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RA016

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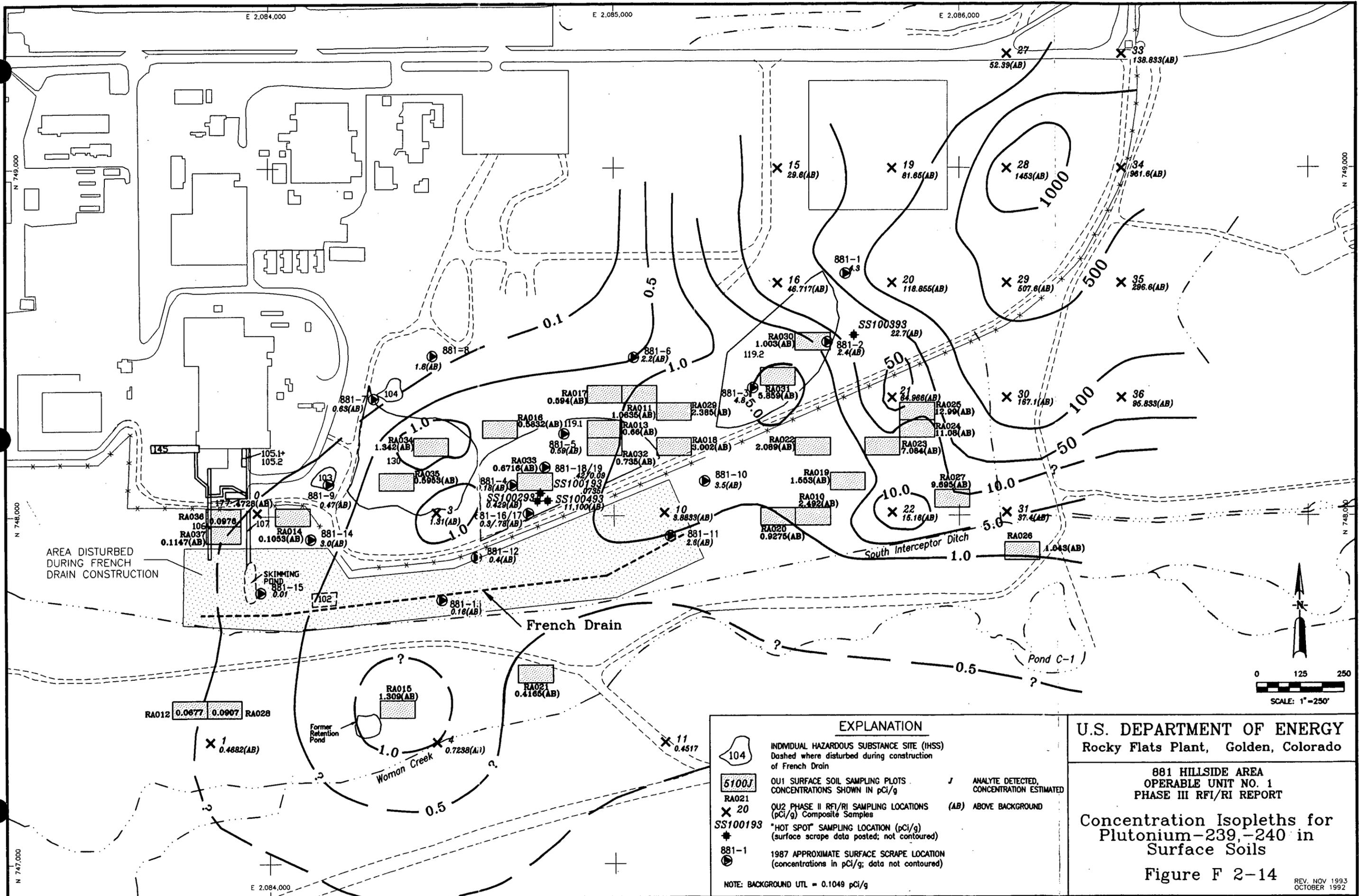
3950 PAH  
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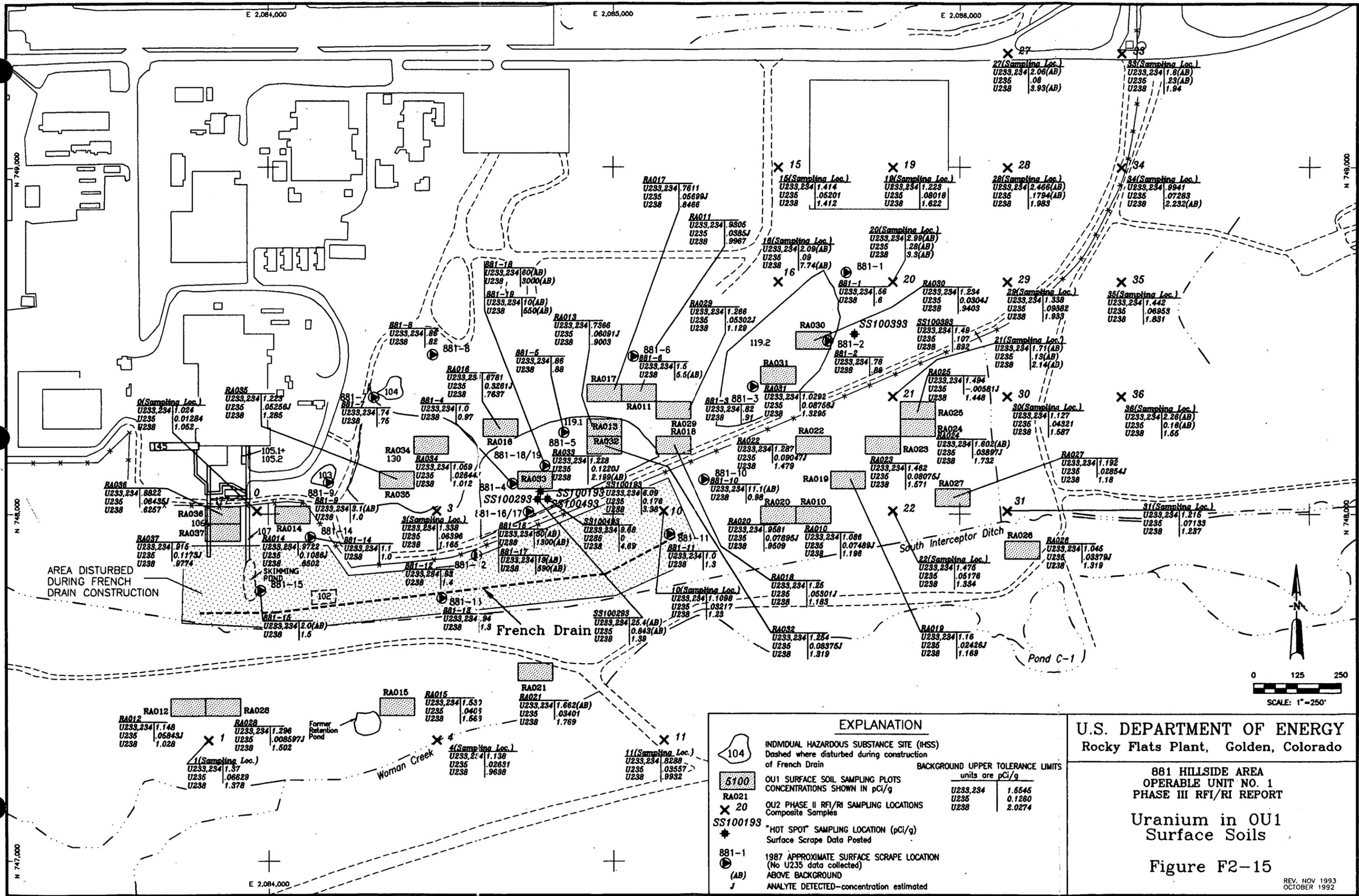
**EXPLANATION**

104	INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) Dashed where disturbed during construction of French Drain	/	ANALYTE DETECTED, CONCENTRATION ESTIMATED
5100J	OU1 SURFACE SOIL SAMPLING PLOTS CONCENTRATIONS SHOWN IN pCi/g	(AB)	ABOVE BACKGROUND
RA021	OU2 PHASE II RFI/RI SAMPLING LOCATIONS (pCi/g) Composite Samples		
SS100193	"HOT SPOT" SAMPLING LOCATION (pCi/g) (surface scrape data posted; not contoured)		
881-1	1987 APPROXIMATE SURFACE SCRAPE LOCATION (concentrations in pCi/g; data not contoured)		

NOTE: BACKGROUND UTL = 0.1049 pCi/g

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**881 HILLSIDE AREA**  
**OPERABLE UNIT NO. 1**  
**PHASE III RFI/RI REPORT**  
  
**Concentration Isopleths for**  
**Plutonium-239, -240 in**  
**Surface Soils**  
  
**Figure F 2-14**

REV. NOV 1993  
 OCTOBER 1992



**EXPLANATION**

- 104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS)
- Dashed where disturbed during construction of French Drain
- 6100 OU1 SURFACE SOIL SAMPLING PLOTS CONCENTRATIONS SHOWN IN pCi/g
- RA021 OU2 PHASE II RFI/RI SAMPLING LOCATIONS Composite Samples
- SS100193 "HOT SPOT" SAMPLING LOCATION (pCi/g) Surface Scrape Data Posted
- 881-1 1987 APPROXIMATE SURFACE SCRAPE LOCATION (No U235 data collected)
- (AB) ABOVE BACKGROUND
- J ANALYTE DETECTED—concentration estimated

BACKGROUND UPPER TOLERANCE LIMITS	
units are pCi/g	
U233,234	1.5545
U235	0.1280
U238	2.0274

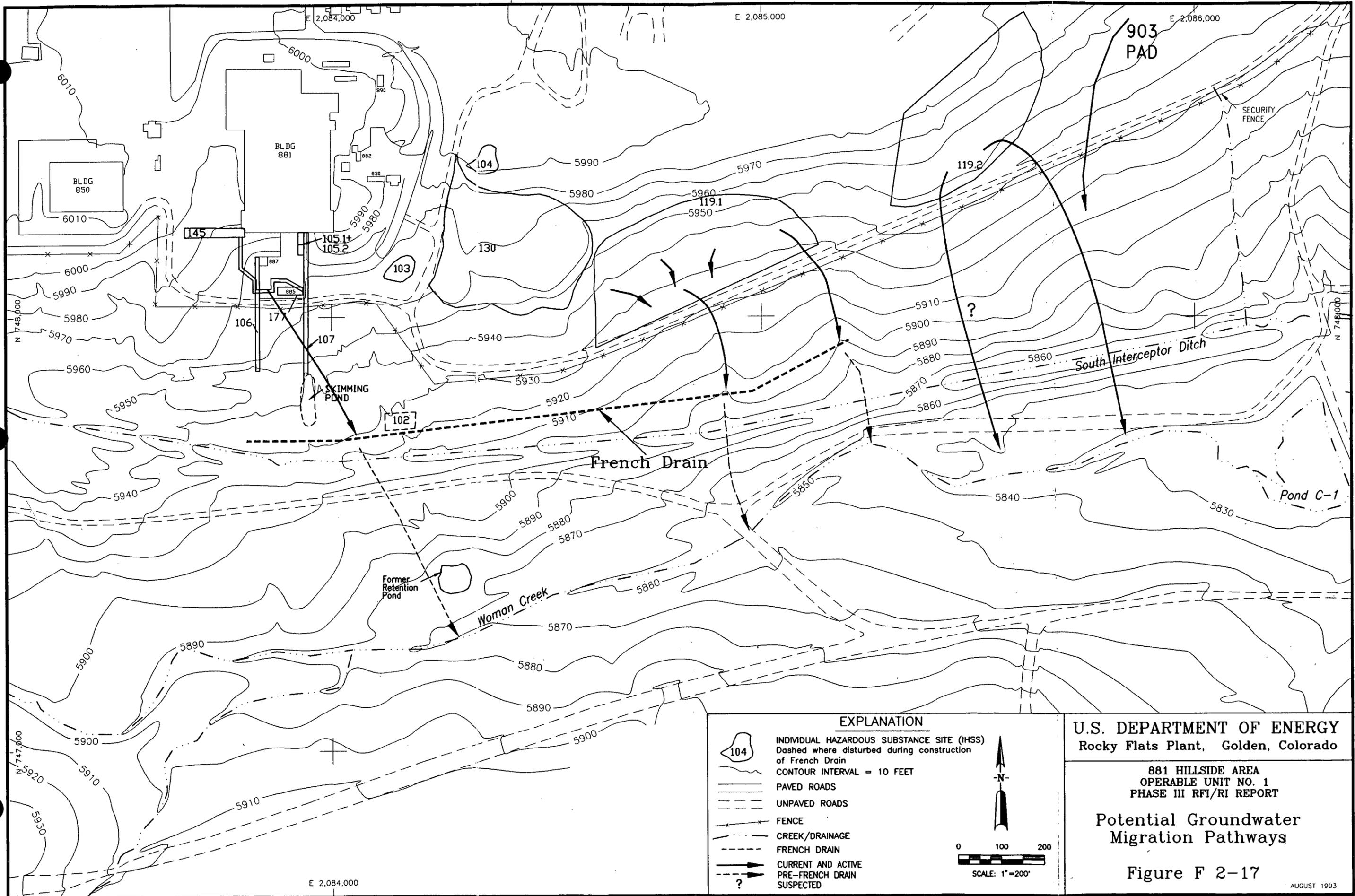
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 OPERABLE UNIT NO. 1  
 PHASE III RFI/RI REPORT

**Uranium in OU1**  
 Surface Soils

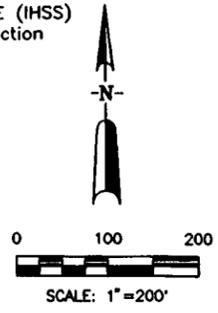
**Figure F2-15**

REV. NOV 1993  
 OCTOBER 1992



**EXPLANATION**

-  INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS)  
Dashed where disturbed during construction of French Drain
-  CONTOUR INTERVAL = 10 FEET
-  PAVED ROADS
-  UNPAVED ROADS
-  FENCE
-  CREEK/DRAINAGE
-  FRENCH DRAIN
-  CURRENT AND ACTIVE PRE-FRENCH DRAIN
-  SUSPECTED



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881 HILLSIDE AREA  
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PHASE III RFI/RI REPORT

Potential Groundwater  
Migration Pathways

Figure F 2-17

AUGUST 1993

Table F3-25  
Contaminant and COC Screening Process  
Groundwater Total Metals

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance	Significant Difference by ANOVA	Spatial/Temporal Considerations?	OU1 Contaminant?(a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections > 5%)	Results		Include? (Detections < 5%)	Max. Concentration > 1000xRBC?	
								Non-carcinogenic %	Carcinogenic %			
ALUMINUM	81/81	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
ANTIMONY	38/77	49.35	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
ARSENIC	51/81	62.96	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
BARIUM	81/81	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
BERYLLIUM	25/80	31.25	NO	NA	NA	NO	NO	--	--	NO	--	NO
CADMIUM	42/79	53.16	NO	NA	NA	NO	NO	--	--	NO	--	NO
CALCIUM	81/81	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
CESIUM	16/74	21.62	NO	NA	NA	NO	NO	--	--	NO	--	NO
CHROMIUM	70/81	86.42	YES	NO	NA	NO	NO	--	--	NO	--	NO
COBALT	51/81	62.96	NO	NA	NA	NO	NO	--	--	NO	--	NO
COPPER	76/80	95.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
IRON	81/81	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
LEAD	69/81	85.19	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
LITHIUM	78/81	96.30	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
MAGNESIUM	81/81	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
MANGANESE	80/81	98.77	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
MERCURY	6/81	7.41	YES	NO	NA	NO	YES	--	--	NO	--	NO
MOLYBDENUM	71/81	87.65	NO	NA	NA	NO	NO	--	--	NO	--	NO
NICKEL	68/81	83.95	NO	NA	NA	NO	NO	--	--	NO	--	NO
POTASSIUM	79/81	97.53	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
SELENIUM	47/80	58.75	YES	YES	RETAINED	YES	YES	34	NO TOX	NO	--	YES
SILICON	31/31	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
SILVER	26/78	33.33	NO	NA	NA	NO	NO	--	--	NO	--	NO
SODIUM	81/81	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
STRONTIUM	76/76	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
THALLIUM	4/81	4.94	NO	NA	NA	NO	NO	--	--	NO	--	NO
TIN	22/81	27.16	NO	NA	NA	NO	NO	--	--	NO	--	NO
VANADIUM	80/81	98.77	YES	YES	RETAINED	YES	YES	< 1	NO TOX	NO	--	NO
ZINC	79/81	97.53	YES	NO	NA	NO	NO	--	--	NO	--	NO

-- not included in this screen.

No RBC Risk based concentration not available.

(a) Contaminants are subjected to either the Conc/Tox or 1000xRBC screen depending on detection frequency.

NA Not applicable

NO TOX Toxicity values not available in IRIS or HEAST

**Table F3-26  
Contaminant and COC Screening Process  
Groundwater Quality Parameters**

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant? (a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections > 5%)	Results		Include? (Detections <5%)	Max Concentration >1000xRBC	
								Non- carcinogenic %	Carcinogenic %			
BICARBONATE AS CaCO3	97/97	100.00	YES	NP	ELIMINATED	NO	NO	--	--	NO	--	NO
CARBONATE AS CaCO3	26/75	34.67	NO	NA	NA	NO	NO	--	--	NO	--	NO
CHLORIDE	102/104	98.08	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
CYANIDE	1/5	20.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
FLUORIDE	109/114	95.61	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
NITRATE/NITRITE	93/115	80.87	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
ORTHOPHOSPHATE	34/56	60.71	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
SILICA, DISSOLVED	53/54	98.15	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
SULFATE	107/111	96.40	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
TOTAL DISSOLVED SOLIDS	113/115	98.26	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
pH	21/21	100.00	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO

NP Not Performed

- not included in this screen.

No RBC Risk based concentration not available.

(a) Contaminants are subjected to either the Conc/Tox or 1000xRBC screen depending on detection frequency.

NA Not applicable

**Table F3-27  
Contaminant and COC Screening Process  
Groundwater Total Radiochemistry**

Isotope	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contam- inant? (a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections > 5%)	Results		Include? (Detections <5%)	Max. Concentration > 1000xRBC	
								Non-carcinogenic %	Carcinogenic %			
AMERICIUM-241	117/118	99.15	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
CESIUM-137	100/103	97.09	YES	NO	ELIMINATED	NO	NO	--	--	NO	--	NO
GROSS ALPHA	13/13	100.00	NA	NA	NA	NA	NO	--	--	NO	--	NO
GROSS BETA	10/10	100.00	NA	NA	NA	NA	NO	--	--	NO	--	NO
PLUTONIUM-239,-240	131/133	98.50	NO	NA	NA	NO	NO	--	--	NO	--	NO
RADIUM-226	4/4	100.00	YES	ID	ELIMINATED	NO	NO	--	--	NO	--	NO
STRONTIUM-89,-90	8/8	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
TRITIUM	160/166	96.39	NO	NA	NA	NO	NO	--	--	NO	--	NO
URANIUM-233,-234	15/15	100.00	YES	ID	ELIMINATED	NO	NO	--	--	NO	--	NO
URANIUM-235	15/15	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
URANIUM-238	18/18	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO

-- not included in this screen.  
 No RBC Risk based concentration not available.  
 (a) Contaminants are subjected to either the Conc/Tox or 1000xRBC screen depending on detection frequency.  
 NA Not applicable  
 ID Insufficient data

Table F3-28  
Contaminant and COC Screening Process  
Groundwater Organics

Compound	Detections/ Observations	Percent Detected	Known Waste?	Known Degradation Product?	Spatial/Temporal Considerations?	Laboratory Artifact Considerations?	OU1 Contaminant? (a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
								Include? (Contaminant detections > 5%)	Results		Include? (Detections < 5%)	Max. Concentration > 1000xRBC?	
									Non- carcinogenic %	Carcinogenic %			
1,1,1-TRICHLOROETHANE	30/211	14.22	YES	NA	NA	NA	YES	YES	1	NO TOX	NO	--	YES
1,1,2-TRICHLOROETHANE	6/211	2.84	NO	NO	RETAINED	RETAINED	YES	NO	--	--	YES	NO	NO
1,1-DICHLOROETHANE	10/211	4.74	NO	YES	NA	RETAINED	YES	NO	--	--	YES	NO	NO
1,1-DICHLOROETHENE	27/211	12.80	NO	YES	NA	RETAINED	YES	YES	12	92	NO	--	YES
1,2-DICHLOROETHANE	6/211	2.37	NO	NO	RETAINED	RETAINED	YES	NO	--	--	YES	NO	NO
1,2-DICHLOROETHENE	6/148	4.11	NO	YES	NA	RETAINED	YES	NO	--	--	YES	NO	NO
1,2-DICHLOROPROPANE	1/211	0.47	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
2,6-DINITROTOLUENE	1/26	3.85	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
2-BUTANONE	4/123	3.25	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	YES	NO RBC	NO
2-HEXANONE	1/138	0.72	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO RBC	NO
4-METHYL-2-PENTANONE	1/148	0.68	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO RBC	NO
ACETONE	47/142	33.10	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
BENZENE	1/211	0.47	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
BENZENE, 1,2,4-TRIMETHYL	1/56	1.79	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO RBC	NO
BENZOIC ACID	1/19	5.26	NO	NO	ELIMINATED	NA	NO	NO	--	--	NO	--	NO
BIS(2-ETHYLHEXYL)PHTHALATE	2/26	7.69	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
CARBON DISULFIDE	1/156	0.64	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
CARBON TETRACHLORIDE	34/211	16.11	YES	NA	NA	NA	YES	YES	48	5	NO	--	YES
CHLOROFORM	40/211	18.96	NO	YES	RETAINED	RETAINED	YES	YES	<1	<1	NO	--	NO
Di-n-BUTYL PHTHALATE	4/26	15.38	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
DIBROMOCHLOROMETHANE	1/211	0.47	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
DICHLORODIFLUOROMETHANE	3/56	5.36	NO	NO	ELIMINATED	NA	NO	NO	--	--	NO	--	NO
DIETHYL PHTHALATE	5/26	19.23	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
ETHYLBENZENE	1/211	0.47	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
METHYLENE CHLORIDE	96/212	45.28	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
NAPHTHALENE	2/56	3.57	YES	NA	ELIMINATED	NA	NO	NO	--	--	YES	NO RBC	NO
STYRENE	3/211	1.42	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
TETRACHLOROETHENE	60/211	28.44	YES	NA	NA	NA	YES	YES	4	3	NO	--	YES
TOLUENE	21/211	9.95	NO	NO	RETAINED	RETAINED	YES	YES	<1	NA	NO	--	NO
TOTAL XYLENES	5/180	2.13	NO	NO	RETAINED	RETAINED	YES	NO	--	--	YES	NO	NO
TRICHLOROETHENE	72/211	34.12	YES	NA	NA	NA	YES	YES	NO TOX	NO TOX	NO	--	NO
TRICHLOROFUOROMETHANE	3/56	5.36	NO	NO	ELIMINATED	NA	NO	NO	--	--	NO	--	NO
VINYL ACETATE	1/142	0.70	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
VINYL CHLORIDE	1/211	0.47	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
beta-BHC	1/15	6.67	NO	NO	ELIMINATED	NA	NO	NO	--	--	NO	--	NO
cis-1,2-DICHLOROETHENE	3/56	5.36	NO	YES	RETAINED	RETAINED	YES	YES	<1	NO TOX	NO	--	NO
m-XYLENE	1/51	1.96	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
p-CHLOROTOLUENE	1/56	1.79	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO RBC	NO
p-CYMENE	1/56	1.79	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO RBC	NO
sec-BUTYLBENZENE	5/56	8.93	NO	NO	ELIMINATED	NA	NO	NO	--	--	NO	--	NO

tert-BUTYLBENZENE	1/56	1.79	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	YES	NO RBC	NO
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-- not included in this screen.

No RBC Risk based concentration not available.

(a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection frequency.

NA Not applicable

NO TOX Toxicity values not available in IRIS or HEAST

Table F3-29  
Contaminant and COC Screening Process  
Geologic Materials Total Metals

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant?	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern? (a)
							Include? (Contaminant detections >5%)	Results		Include? (Detections <5%)	Max. Concentration >1000xRBC?	
								Non-carcinogenic %	Carcinogenic %			
ALUMINUM	227/227	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
ANTIMONY	161/228	70.61	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
ARSENIC	212/229	92.58	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
BARIIUM	228/229	99.56	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
BERYLLIUM	179/229	78.17	NO	NA	NA	NO	NO	--	--	NO	--	NO
CADMIUM	28/223	12.56	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
CALCIUM	229/229	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
CESIUM	47/213	22.07	NO	NA	NA	NO	NO	--	--	NO	--	NO
CHROMIUM	229/229	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
COBALT	167/229	72.93	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
COPPER	228/229	99.56	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
IRON	228/228	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
LEAD	229/229	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
LITHIUM	147/229	64.19	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
MAGNESIUM	229/229	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
MANGANESE	229/229	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
MERCURY	38/228	16.67	NO	NA	NA	NO	NO	--	--	NO	--	NO
MOLYBENDUM	89/227	39.21	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
NICKEL	222/229	96.94	NO	NA	NA	NO	NO	--	--	NO	--	NO
POTASSIUM	186/228	81.58	NO	NA	NA	NO	NO	--	--	NO	--	NO
SELENIUM	41/227	18.06	NO	NA	NA	NO	NO	--	--	NO	--	NO
SILICON	21/21	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
SILVER	27/224	12.05	NO	NA	NA	NO	NO	--	--	NO	--	NO
SODIUM	156/229	68.12	YES	NO	NA	NO	NO	--	--	NO	--	NO
STRONTIUM	155/229	67.69	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
THALLIUM	83/227	36.56	NO	NA	NA	NO	NO	--	--	NO	--	NO
TIN	18/223	8.07	YES	ID	NA	NO	NO	--	--	NO	--	NO
VANADIUM	228/229	99.56	NO	NA	NA	NO	NO	--	--	NO	--	NO
ZINC	229/229	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO

-- not included in this screen.  
No RBC Risk based concentration not available.  
(a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection frequency.  
NA Not applicable  
ID Insufficient data  
NO TOX Toxicity values not available in IRIS or HEAST

**Table F3-30  
Contaminant and COC Screening Process  
Geologic Materials Water Quality Parameters**

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant? (a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections > 5%)	Results		Include? (Detections <5%)	Max. Concentration > 1000xRBC?	
								Non-carcinogenic %	Carcinogenic %			
NITRATE/NITRITE	31/66	46.97	YES	NA	ELIMINATED	NO	NO	--	--	NO	--	NO
SULFIDE	29/83	34.94	NO	NA	NA	NO	NO	--	--	NO	--	NO
pH	83/83	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO

-- not included in this screen

NA Not applicable

No RBC Risk based concentration not available

(a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection.

NO TOX No toxicity data available in IRIS or HEAST

**Table F3-31  
Contaminant and COC Screening Process  
Geologic Materials Total Radiochemistry**

Isotope	Detections/ Observations	Percent Detected	UTL Exceedance ?	Significant Difference by ANOVA	Spatial/Temporal Considerations?	OU1 Contaminant?(a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections >5%)	Results		Include? (Detections <5%)	Max. Concentration > 1000xRBC?	
								Non-carcinogenic %	Carcinogenic %			
AMERICIUM-241	194/200	97.00	YES	YES	RETAINED	YES	YES	NO TOX	31	NO	--	YES
CESIUM-137	152/152	100.00	YES	NO	ELIMINATED	NO	NO	--	--	NO	--	NO
PLUTONIUM-239,-240	154/156	98.72	YES	ID	RETAINED	YES	YES	NO TOX	85	NO	--	YES
RADIUM-226	138/138	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
RADIUM-228	158/158	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
STRONTIUM-89,-90	169/174	97.13	YES	ID	ELIMINATED	NO	NO	--	--	NO	--	NO
TRITIUM	186/192	96.88	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
URANIUM-233,-234	189/189	100.00	YES	NO	RETAINED	YES	YES	NO TOX	3	NO	--	YES
URANIUM-235	189/189	100.00	YES	ID	RETAINED	YES	YES	NO TOX	< 1	NO	--	NO
URANIUM-238	189/189	100.00	YES	YES	RETAINED	YES	YES	NO TOX	1	NO	--	YES

-- not included in this screen

NA Not applicable

No RBC Risk based concentration not available

ID Insufficient data

(a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection.

NO TOX No toxicity data available in IRIS or HEAST

Table F3-32  
Contaminant and COC Screening Process  
Geologic Materials Organics

Compound	Detections/ Observations	Percent Detected	Known Waste?	Known Degradation Product?	Spatial/Temporal Considerations?	Laboratory Artifact Considerations?	OU1 Contaminant?(a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
								Include? (Contaminant detections >5%)	Results		Include? (Detections <5%)	Max. Concentration > 1000xRBC?	
									Non- carcinogenic %	Carcinogenic %			
1,1,1-TRICHLOROETHANE	2/432	0.46	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
1,1-DICHLOROETHENE	2/432	0.46	NO	YES	NA	RETAINED	YES	NO	--	--	YES	NO	NO
1,2-DICHLOROETHANE	1/422	0.24	NO	NO	YES	RETAINED	YES	NO	--	--	YES	NO	NO
1,4-DICHLOROBENZENE	4/187	2.14	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
2-BUTANONE	21/330	6.36	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
2-HEXANONE	3/373	0.80	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
2-METHYLNAPHTHALENE	1/187	0.53	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
4-METHYL-2-PENTANONE	8/387	2.07	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
4-NITROPHENOL	2/185	1.08	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
ACENAPHTHENE	4/187	2.14	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
ACETONE	170/365	46.58	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
ANTHRACENE	5/187	2.67	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
BENZO(a)ANTHRACENE	4/187	2.14	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
BENZO(a)PYRENE	3/187	1.60	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
BENZO(b)FLUORANTHENE	3/184	1.63	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
BENZO(ghi)PERYLENE	2/187	1.07	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
BENZO(k)FLUORANTHENE	2/184	1.08	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
BENZOIC ACID	2/182	1.10	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
BIS(2-ETHYLHEXYL)PHTHALATE	30/184	16.30	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
BUTYL BENZYL PHTHALATE	1/187	0.53	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	YES	NO	NO
CARBON DISULFIDE	7/424	1.65	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
CARBON TETRACHLORIDE	2/432	0.46	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
CHLOROBENZENE	1/432	0.23	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
CHLOROFORM	1/432	0.23	NO	YES	RETAINED	RETAINED	YES	NO	--	--	YES	NO	NO
CHRYSENE	4/187	2.14	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
DI-n-BUTYL PHTHALATE	41/187	21.93	NO	NO	RETAINED	ELIMINATED	NO	NO	--	--	NO	--	NO
DI-n-OCTYL PHTHALATE	2/187	1.07	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	YES	NO	NO
DIBENZOFURAN	1/185	0.54	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
DIETHYL PHTHALATE	1/187	0.53	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	YES	NO	NO
ETHYLBENZENE	1/432	0.23	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
FLUORANTHENE	11/187	5.88	YES	NA	NA	NA	YES	YES	43	NO TOX	NO	--	YES
FLUORENE	2/187	1.07	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
INDENO(1,2,3-cd)PYRENE	2/187	1.07	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
METHYLENE CHLORIDE	211/424	49.76	NO	YES	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
N-NITROSODIPHENYLAMINE	2/187	1.07	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
NAPHTHALENE	3/187	1.60	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
PENTACHLOROPHENOL	2/187	1.07	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
PHENANTHRENE	9/187	4.81	YES	NA	NA	NA	YES	YES	NO TOX	NO TOX	NO	--	NO

PYRENE	13/187	6.95	YES	NA	NA	NA	YES	YES	53	NO TOX	NO	--	YES
STYRENE	3/432	0.69	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO
TETRACHLOROETHENE	7/431	1.62	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
TOLUENE	419/432	86.99	NO	NO	RETAINED	RETAINED	YES	YES	4	NO TOX	NO	--	YES
TOTAL XYLENES	1/432	0.23	NO	NO	RETAINED	RETAINED	YES	NO	--	--	YES	NO	NO
TRICHLOROETHENE	8/432	2.08	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
trans-1,3-DICHLOROPROPENE	1/413	0.24	NO	NO	ELIMINATED	NA	NO	NO	--	--	YES	NO	NO

-- not included in this screen.

No RBC Risk based concentration not available.

(a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection frequency.

NA Not applicable

ID Insufficient data

NO TOX Toxicity values not available in IRIS or HEAST

**Table F3-33  
Contaminant and COC Screening Process  
Surface Soil Total Metals**

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/Temporal Considerations?	OU1 Contaminant?(a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections >5%)	Results		Include? (Detections <5%)	Max. Concentration >1000xRBC?	
								Non-carcinogenic %	Carcinogenic %			
ALUMINUM	34/34	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
ANTIMONY	1/34	2.94	NO	NA	NA	NO	NO	--	--	NO	--	NO
ARSENIC	33/34	97.06	NO	NA	NA	NO	NO	--	--	NO	--	NO
BARIUM	34/34	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
BERYLLIUM	34/34	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
CADMIUM	6/28	21.43	YES	NO	NA	NO	NO	--	--	NO	--	NO
CALCIUM	34/34	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
CESIUM	34/34	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
CHROMIUM	34/34	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
COBALT	34/34	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
COPPER	34/34	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
IRON	34/34	100.00	YES	NO	NA	NO	NO	--	--	NO	--	NO
LEAD	33/34	97.06	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
LITHIUM	34/34	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
MAGNESIUM	34/34	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
MANGANESE	34/34	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
MERCURY	5/34	14.71	NO	NA	NA	NO	NO	--	--	NO	--	NO
MOLYBDENUM	26/32	81.25	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
NICKEL	34/34	100.00	YES	NC	NA	NO	NO	--	--	NO	--	NO
POTASSIUM	34/34	100.00	YES	NC	NA	NO	NO	--	--	NO	--	NO
SELENIUM	17/33	51.52	NO	NA	NA	NO	NO	--	--	NO	--	NO
SILICON	34/34	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
SODIUM	34/34	100.00	YES	NC	NA	NO	NO	--	--	NO	--	NO
STRONTIUM	34/34	100.00	YES	YES	ELIMINATED	NO	NO	--	--	NO	--	NO
THALLIUM	22/34	64.71	NO	NA	NA	NO	NO	--	--	NO	--	NO
TIN	24/34	70.59	YES	NC	NA	NO	NO	--	--	NO	--	NO
VANADIUM	34/34	100.00	YES	NC	NA	NO	NO	--	--	NO	--	NO
ZINC	34/34	100.00	YES	NC	NA	NO	NO	--	--	NO	--	NO

-- not included in this screen.  
 No RBC Risk based concentration not available.  
 (a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection frequency.  
 NA Not applicable  
 ID Insufficient data

**Table F3-34  
Contaminant and COC Screening Process  
Surface Soil Water Quality Parameters**

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant?	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections >5%)	Results		Include? (Detections <5%)	Max. Concentration >1000xRBC	
								Non-carcinogenic %	Carcinogenic %			
NITRATE/NITRITE	26/29	89.66	NO	NA	NA	NO	NO	--	--	NO	NO	

NA Not applicable

**Table F3-35  
Contaminant and COC Screening Process  
Surface Soil Total Radiochemistry**

Isotope	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/Temporal Considerations?	OU1 Contaminant?(a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
							Include? (Contaminant detections >5%)	Results		Include? (Detections <5%)	Max. Concentration > 1000xRBC?	
								Non-carcinogenic %	Carcinogenic %			
AMERICIUM-241	28/28	100.00	YES	YES	NA	YES	YES	NO TOX	17	NO	--	YES
PLUTONIUM-239,-240	34/34	100.00	YES	YES	NA	YES	YES	NO TOX	83	NO	--	YES
RADIUM-226	21/21	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
RADIUM-228	21/21	100.00	NO	NA	NA	NO	NO	--	--	NO	--	NO
URANIUM-233,-234	34/34	100.00	YES	YES	NA	YES	YES	NO TOX	< 1	NO	--	YES (b)
URANIUM-235	34/34	100.00	NO	NA	RETAINED	YES	YES	NO TOX	< 1	NO	--	NO
URANIUM-238	34/34	100.00	YES	YES	NA	YES	YES	NO TOX	< 1	NO	--	YES (b)

-- not included in this screen.

No RBC Risk based concentration not available.

(a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection frequency

(b) The "hot spot" concentrations for Am-241 and Pu-239/ -240 have biased the concentrations toxicity screen. The contaminants have been included as COCs based on professional judgement and results from previous concentration - toxicity screens

NA Not applicable

ID Insufficient data

NO TOX No toxicity data available in IRIS or HEAST

Table F3-36  
Contaminant and COC Screening Process  
Surface Soil Organics

Compound	Detections/ Observations	Percent Detected	Known Waste	Known Degradation Product	Spatial/Temporal Considerations?	Laboratory Artifact Consideration	OU1 Contaminant?(a)	Concentration/Toxicity Screen			1000xRBC Screen		OU1 Contaminant of Concern?
								Include? (Contaminant detections >5%)	Results		Include? (Detections <5%)	Max. Concentration > 1000xRBC?	
									Non-carcinogenic %	Carcinogenic %			
ACENAPHTHENE	6/28	21.43	YES	NA	NA	NA	YES	YES	3	NO TOX	NO	--	YES
ACENAPHTHYLENE	1/28	3.57	YES	NA	NA	NA	YES	NO	--	--	YES	NO RBC	NO
ANTHRACENE	6/28	21.43	YES	NA	NA	NA	YES	YES	< 1	NO TOX	NO	--	NO
AROCLOR-1248	1/29	3.45	NO	NO	RETAINED	RETAINED	YES	NO	--	--	YES	NO	NO
AROCLOR-1254	3/29	10.34	NO	NO	RETAINED	RETAINED	YES	YES	NO TOX	53	NO	--	YES
BENZO(a)ANTHRACENE	13/28	46.43	YES	NA	NA	NA	YES	YES	NO TOX	4	NO	--	YES
BENZO(a)PYRENE	14/28	50.00	YES	NA	NA	NA	YES	YES	NO TOX	32	NO	--	YES
BENZO(b)FLUORANTHENE	13/28	46.43	YES	NA	NA	NA	YES	YES	NO TOX	3	NO	--	YES
BENZO(ghi)PERYLENE	8/28	28.57	YES	NA	NA	NA	YES	YES	NO TOX	NO TOX	NO	--	NO
BENZO(k)FLUORANTHENE	12/28	42.86	YES	NA	NA	NA	YES	YES	NO TOX	3	NO	--	YES
BIS(2-ETHYLHEXYL)PHTHALATE	5/28	17.86	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
CHRYSENE	16/28	57.14	YES	NA	NA	NA	YES	YES	NO TOX	< 1	NO	--	NO
DI-n-BUTYL PHTHALATE	5/28	17.86	NO	NO	ELIMINATED	ELIMINATED	NO	NO	--	--	NO	--	NO
DIBENZO(a,h)ANTHRACENE	4/27	14.81	YES	NA	NA	NA	YES	YES	NO TOX	4	NO	--	YES
DIBENZOFURAN	2/28	7.14	NO	NO	ELIMINATED	NA	NO	NO	--	--	NO	--	NO
FLUORANTHENE	19/28	67.86	YES	NA	NA	NA	YES	YES	40	NO TOX	NO	--	YES
FLUORENE	5/28	17.86	YES	NA	NA	NA	YES	YES	5	NO TOX	NO	--	YES
INDENO(1,2,3-cd)PYRENE	11/28	39.29	YES	NA	NA	NA	YES	YES	NO TOX	< 1	NO	--	NO
NAPHTHALENE	1/28	3.57	YES	NA	NA	NA	YES	NO	--	--	YES	NO	NO
PHENANTHRENE	16/28	57.14	YES	NA	NA	NA	YES	YES	NO TOX	NO TOX	NO	--	NO
PYRENE	18/28	64.29	YES	NA	NA	NA	YES	YES	51	NO TOX	NO	--	YES

-- not included in this screen.  
 No RBC Risk based concentration not available.  
 (a) Contaminants are subjected to either the conc/tox or 1000 RBC screen depending on detection frequency.  
 NA Not applicable  
 ID Insufficient data

**Table F3-37  
Contaminant and COC Screening Process  
Surface Water Total Metals**

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant?	OU1 Contaminant of Concern? (a)
ALUMINUM	233/271	85.98	YES	NO	NA	NO	NO
ANTIMONY	33/270	12.22	YES	YES	ELIMINATED	NO	NO
ARSENIC	28/259	10.81	YES	YES	ELIMINATED	NO	NO
BARIUM	231/273	84.62	YES	YES	ELIMINATED	NO	NO
BERYLLIUM	17/257	6.61	NO	NA	NA	NO	NO
CADMIUM	23/253	9.09	NO	NA	NA	NO	NO
CALCIUM	272/273	99.63	YES	YES	ELIMINATED	NO	NO
CESIUM	30/271	11.07	NO	NA	NA	NO	NO
CHROMIUM	50/272	18.38	YES	YES	ELIMINATED	NO	NO
COBALT	28/273	10.26	NO	NA	NA	NO	NO
COPPER	113/271	41.70	YES	YES	ELIMINATED	NO	NO
IRON	253/273	92.67	YES	NO	NA	NO	NO
LEAD	133/271	49.08	YES	YES	ELIMINATED	NO	NO
LITHIUM	152/270	56.30	YES	YES	ELIMINATED	NO	NO
MAGNESIUM	269/273	98.53	YES	YES	ELIMINATED	NO	NO
MANGANESE	244/273	89.38	NO	NA	NA	NO	NO
MERCURY	12/252	4.76	NO	NA	NA	NO	NO
MOLYBDENUM	42/270	15.56	NO	NA	NA	NO	NO
NICKEL	37/236	13.91	YES	YES	ELIMINATED	NO	NO
POTASSIUM	206/272	75.74	YES	YES	ELIMINATED	NO	NO
SELENIUM	54/252	20.61	YES	YES	ELIMINATED	NO	NO
SILICON	131/131	100.00	YES	NO	NA	NO	NO
SILVER	41/271	15.13	YES	YES	ELIMINATED	NO	NO
SODIUM	271/273	99.27	YES	YES	ELIMINATED	NO	NO
STRONTIUM	212/268	79.10	YES	YES	ELIMINATED	NO	NO
THALLIUM	3/260	1.15	NO	NA	NA	NO	NO
TIN	47/251	18.73	NO	NA	NA	NO	NO
VANADIUM	115/273	42.12	YES	YES	ELIMINATED	NO	NO
ZINC	225/272	82.72	YES	NO	NA	NO	NO

(a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect  
 NA Not applicable

**Table F3-38  
Contaminant and COC Screening Process  
Surface Water Quality Parameters**

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant?	OU1 Contaminant of Concern (a)?
BICARBONATE AS CaCO <sub>3</sub>	92/93	98.92	YES	NA	ELIMINATED	NO	NO
CARBONATE AS CaCO <sub>3</sub>	44/77	57.14	NO	NA	NA	NO	NO
CHLORIDE	163/163	100.00	YES	NA	ELIMINATED	NO	NO
CYANIDE	4/94	4.26	YES	NA	ELIMINATED	NO	NO
FLUORIDE	80/89	89.89	YES	NA	ELIMINATED	NO	NO
NITRATE/NITRITE	127/158	80.38	YES	NA	ELIMINATED	NO	NO
ORTHOPHOSPHATE	9/69	13.04	NO	NA	NA	NO	NO
SILICA, DISSOLVED	52/53	98.11	YES	NA	ELIMINATED	NO	NO
SULFATE	156/158	98.73	YES	NA	ELIMINATED	NO	NO
SULFIDE	9/52	17.31	YES	NA	ELIMINATED	NO	NO
TOTAL DISSOLVED SOLIDS	168/170	98.82	YES	NA	ELIMINATED	NO	NO
pH	73/73	100.00	NO	NA	NA	NO	NO

(a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect  
 NA Not applicable

# NORTH PLAINS COMMUNITY PLAN STUDY AREA SUMMARY MAP

Nonresidential: Retail, or Office, or Industrial
Open Space & Rural Residential 1 du/2 to 35 acres
Residential up to 4 du/2 ac
Enclaves
Secondary Landfills
Zoned for Mining

- |  |  |   |  |   |
|--|--|---|--|---|
| <p>1 Cemetery</p> <p>2 Existing Parks and Recreation Areas, Schools</p> <p>5 Open Space, Parks and Recreation Areas, Agriculture, Ranching, and Residential up to 1 du/10 ac</p> <p>6 Residential up to 4 du/2 ac</p> <p>7 Light Industrial</p> <p>8 Retail and Office</p> <p>9 Residential up to 4 du/2 ac</p> <p>10 Business Park, i.e., Office, Light Industrial</p> <p>11 Aviation Use, Jefferson County Airport, Business Park, i.e., Office, Light Industrial</p> <p>12 Business Park, i.e., Office, Light Industrial</p> <p>13 Residential up to 2 du/2 ac</p> <p>14 Business Park, i.e., Office, Light Industrial</p> <p>15 Business Park, i.e., Office, Light Industrial</p> <p>16 Residential up to 2.5 du/2 ac</p> <p>17 Residential up to 10 du/2 ac</p> | <p>18 Infill Area, Retail, Office, Light Industrial</p> <p>19 Infill Area, Retail, Office and Light Industrial, Residential up to 15 du/2 ac</p> <p>20 Infill Area, Recreational Vehicle Parks, Retail, Office, Light Industrial, Residential up to 15 du/2 ac</p> <p>21 Mixed Use Area. A balance of Office, Light Industrial, Retail, Community Facilities, Residential</p> <p>22 Office</p> <p>23 Residential up to 2.5 du/2 ac outside existing Retail, Office and Industrial areas</p> <p>24 Residential up to 3 du/2 ac</p> <p>25 Residential up to 3.5 du/2 ac</p> <p>26 Residential up to 2.5 du/2 ac</p> <p>27 Residential up to 2 du/2 ac adjacent to Van Bibber loop/drain</p> <p>28 Residential up to 2.2 du/2 ac</p> <p>29 West 64th Avenue and McIntyre Street Activity Center, Residential up to 15 du/2 ac, Retail</p> <p>30</p> | <p>31 Office, Light Industrial</p> <p>32 Golf Course, Open Space and Residential up to 4 du/2 ac, neighborhood-scale Retail and Office development of approximately 100,000 square foot north of West 64th Avenue</p> <p>33 Residential up to 1.5 du/2 ac</p> <p>34 Open Space, Conservation because Geologic Hazard Area exists</p> <p>35 Retail, Research and Development, Open Space and Trails</p> <p>36 Residential up to 4 du/2 ac, Neighborhood-scale Retail and Office development up to 150,000 square foot in one quadrant of the West 56th Avenue and Colorado State Highway 93 Intersection</p> <p>37 Activity Center, Residential up to 10 du/2 ac, Light Industrial, Office, Retail, and Tourist Services</p> <p>38 Residential up to 2.5 du/2 ac</p> | <p>39 Residential 1 du/5 to 35 ac</p> <p>40 Residential up to 4 du/2 ac, Retail and Office up to a 1500 foot radius of West 64th Avenue and W-470 Interchange, west of Colorado State Highway 93</p> <p>41 Office, Industrial</p> <p>42 Special Use Area, Office and Industrial II hazards can be mitigated</p> <p>43 Residential up to 1 du/2 ac</p> <p>44 Mixed Use, Office, Light Industrial, Residential up to 4 du/2 ac</p> <p>45 Office, Industrial</p> <p>46 Special Use Area, Office, Industrial II hazards can be mitigated</p> <p>47 Office, Light Industrial, Golf Course, and limited Residential up to 4 du/2 ac</p> <p>48 Office, Industrial, Retail approximately 1500 feet around the W-470 and Indiana Street and W-470 and West 104th Avenue Interchanges</p> <p>49 Retail, Office</p> | <p>50 Equestrian center, Residential 1 du/2 ac</p> <p>51 Mixed Use Area, Residential up to 1 du/2 ac, Office, Light Industrial</p> <p>52 Special Use Area, Rocky Flats Nuclear Facility and buffer zone</p> |
|--|--|---|--|---|

Enclaves: Residential up to 4 du/2 ac or existing zoning, whichever is greater. If adjacent land use is non-residential, then a similar land use could be considered provided adverse impacts are mitigated.

NOTES: du/2 ac: Dwelling units per acre

Ranching and Agriculture land uses, if consistent with current zoning, are permitted anywhere in the North Plains.

Ancillary retail is allowed in all office/industrial areas unless explicitly prohibited.

Refer to specific Subarea policies for conditions affecting development in areas shown on the Summary Map and legend. In addition, the General Policies Section of this plan applies.

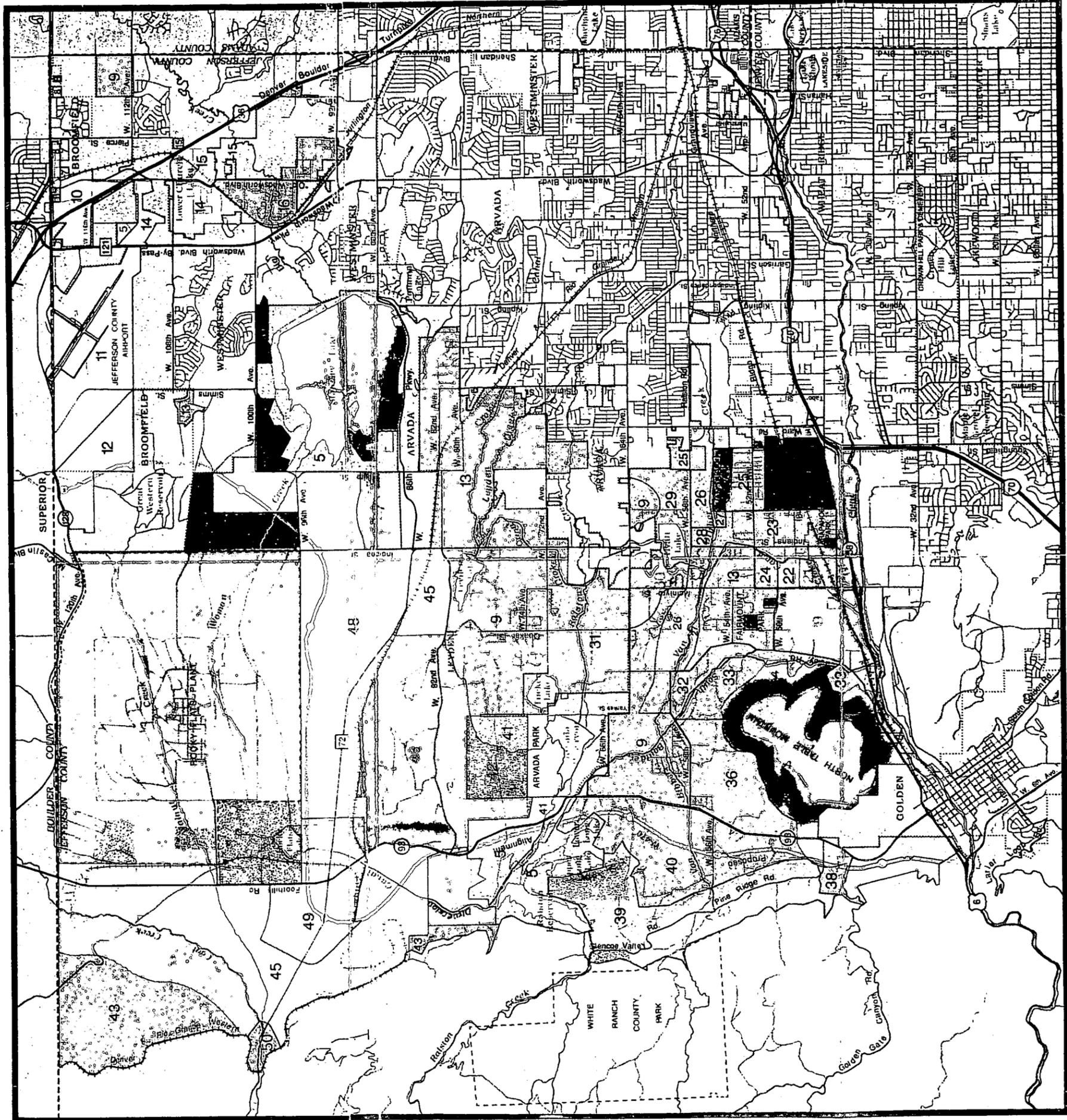
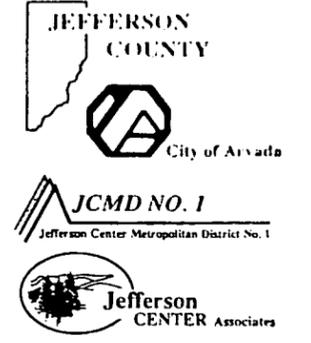
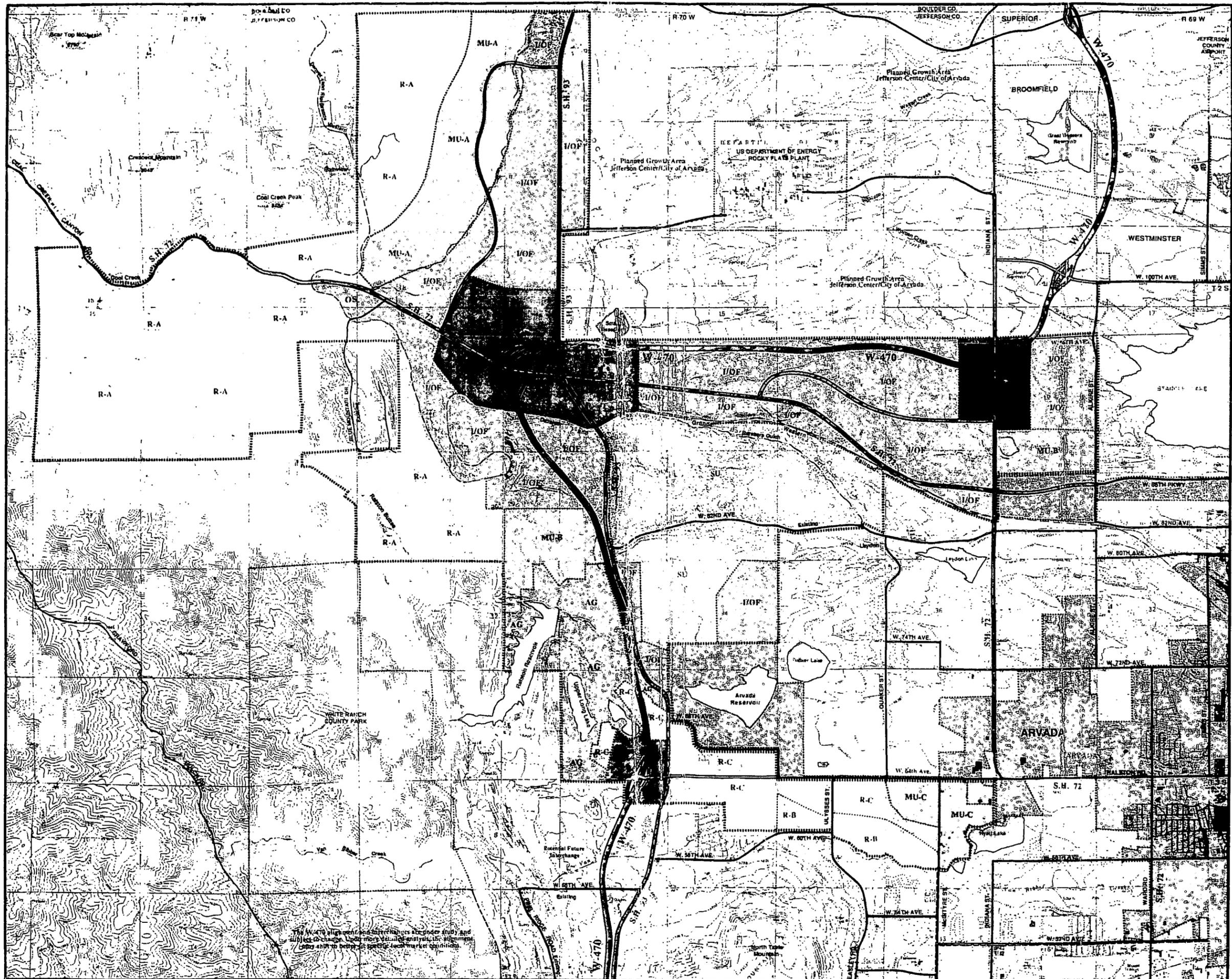


Figure F4-2



**Jefferson Center  
Comprehensive Development  
Plan  
Figure F4-3**

**Legend**

	Commercial and Office
	Industrial and Office
	Mixed-Use: A B or C
	Residential (A, B or C)
	Agricultural
	Open Space
	Special Use
	W-470
	Arterial Roadways
	Collector Roadways
	Existing Roadways
	Jefferson Center Development Area

**Approval**

Jefferson County  
 By: *[Signature]* Date: 9/15/89  
 Title: Chairman of the Board of the County Commissioners

ATTEST:  
 By: *[Signature]* Date: 8-15-89  
 Title: County Clerk and Recorder

City of Arvada  
 By: *[Signature]* Date: 8-14-89  
 Title: Mayor

ATTEST:  
 By: *[Signature]* Date: 8-14-89  
 Title: City Clerk

Jefferson Center Metropolitan District No. 1  
 By: *[Signature]* Date: 11/7/89  
 Title: President

ATTEST:  
 By: *[Signature]* Date: 11-7-89  
 Title: Secretary

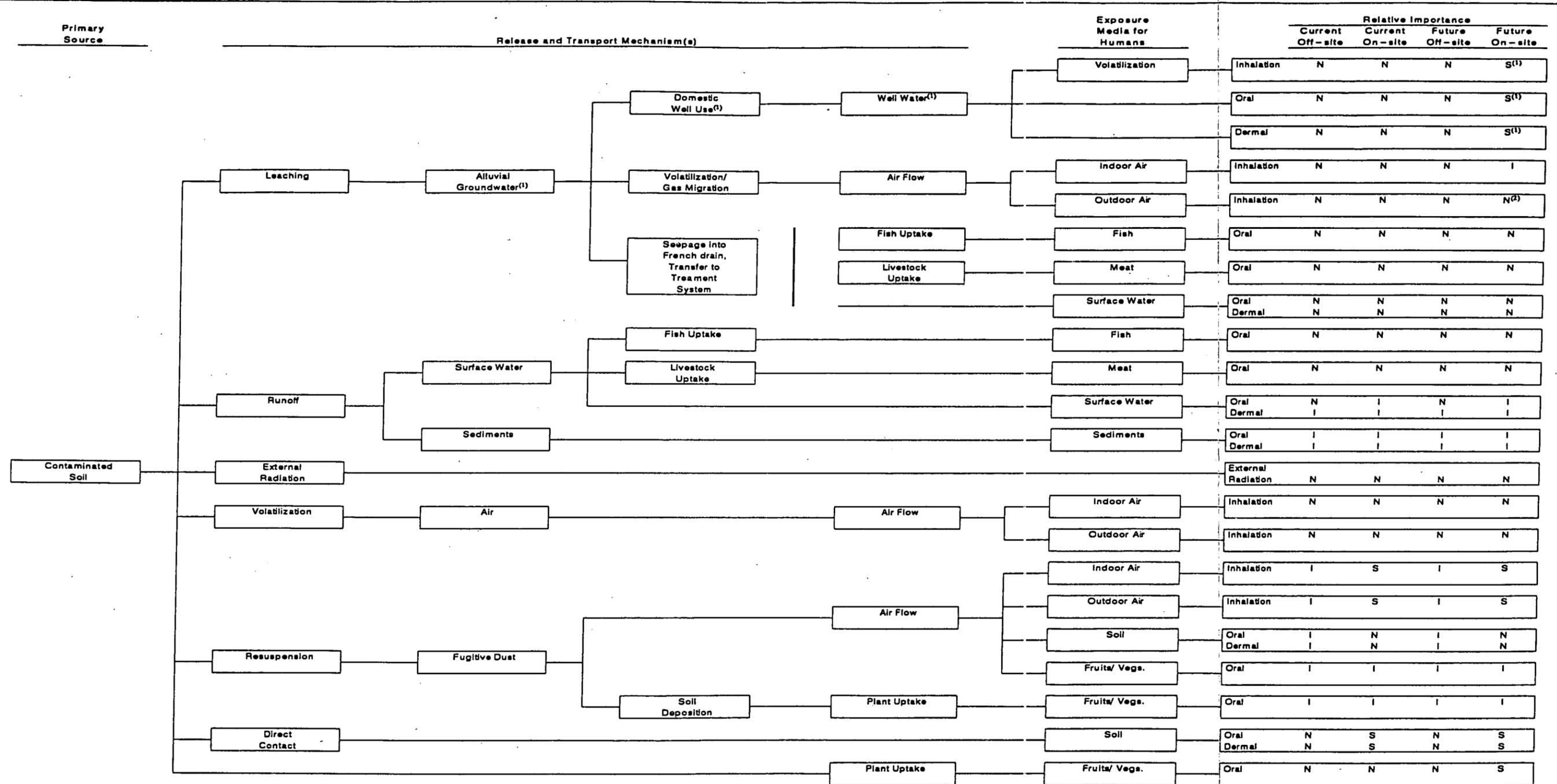
Jefferson Center Associates  
 By: *[Signature]* Date: 8/11/89  
 Title: President

ATTEST:  
 By: *[Signature]* Date: 8/11/89  
 Title: Vice President

**Table F3-41  
Contaminant and COC Screening Process  
Sediment Total Metals**

Analyte	Detections/ Observations	Percent Detected	UTL Exceedance?	Significant Difference by ANOVA?	Spatial/ Temporal Considerations?	OU1 Contaminant?	OU1 Contaminant of Concern? (a)
ALUMINUM	11/11	100.00	NO	NA	NA	NO	NO
ARSENIC	12/12	100.00	NO	NA	NA	NO	NO
BARIUM	12/12	100.00	YES	YES	ELIMINATED	NO	NO
BERYLLIUM	9/12	75.00	NO	NA	NA	NO	NO
CADMIUM	4/12	33.33	NO	NA	NA	NO	NO
CALCIUM	12/12	100.00	YES	YES	ELIMINATED	NO	NO
CESIUM	3/12	25.00	NO	NA	NA	NO	NO
CHROMIUM	12/12	100.00	NO	NA	NA	NO	NO
COBALT	12/12	100.00	YES	YES	ELIMINATED	NO	NO
COPPER	12/12	100.00	NO	NA	NA	NO	NO
IRON	12/12	100.00	NO	NA	NA	NO	NO
LEAD	12/12	100.00	YES	YES	ELIMINATED	NO	NO
LITHIUM	12/12	100.00	NO	NA	NA	NO	NO
MAGNESIUM	12/12	100.00	NO	NA	NA	NO	NO
MANGANESE	12/12	100.00	NO	NA	NA	NO	NO
MOLYBDENUM	6/12	50.00	NO	NA	NA	NO	NO
NICKEL	11/12	91.67	NO	NA	NA	NO	NO
POTASSIUM	11/12	91.67	NO	NA	NA	NO	NO
SELENIUM	7/12	58.33	NO	NA	NA	NO	NO
SILICON	11/11	100.00	NO	NA	NA	NO	NO
SILVER	3/12	25.00	YES	YES	ELIMINATED	NO	NO
SODIUM	12/12	100.00	YES	YES	ELIMINATED	NO	NO
STRONTIUM	12/12	100.00	YES	YES	ELIMINATED	NO	NO
THALLIUM	2/12	16.67	YES	YES	ELIMINATED	NO	NO
TIN	4/12	33.33	NO	NA	NA	NO	NO
VANADIUM	12/12	100.00	NO	NA	NA	NO	NO
ZINC	12/12	100.00	YES	YES	ELIMINATED	NO	NO

(a) Risk assessment contaminants in surface water were assessed using surface soil COCs. Surface soil COCs were not detect  
 NA Not applicable  
 ID Insufficient data



(1) - The on-site alluvial groundwater system does not yield sufficient quantity of water to support residential use. To meet RCRA requirements, water supply well is assumed adequate for a special case scenario.

(2) - An exception may be inhalation of VOCs during excavation.

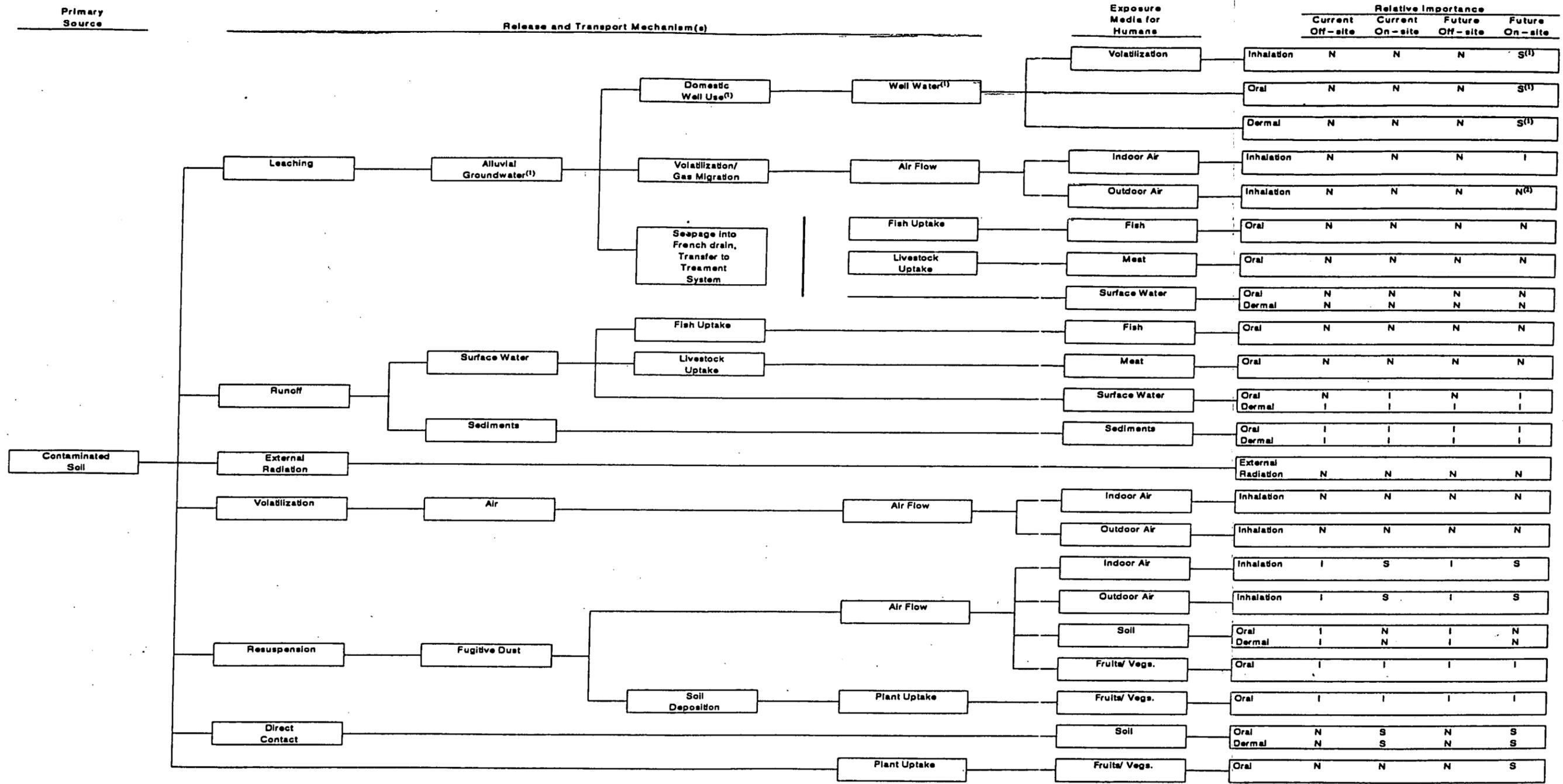
S Significant  
 I Insignificant  
 N Negligible or Incomplete

U.S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFVRI REPORT

Conceptual Site Model

Figure F4-4



(1) - The on-site alluvial groundwater system does not yield sufficient quantity of water to support residential use. To meet RCRA requirements, water supply well is assumed adequate for a special case scenario.

(2) - An exception may be inhalation of VOCs during excavation.

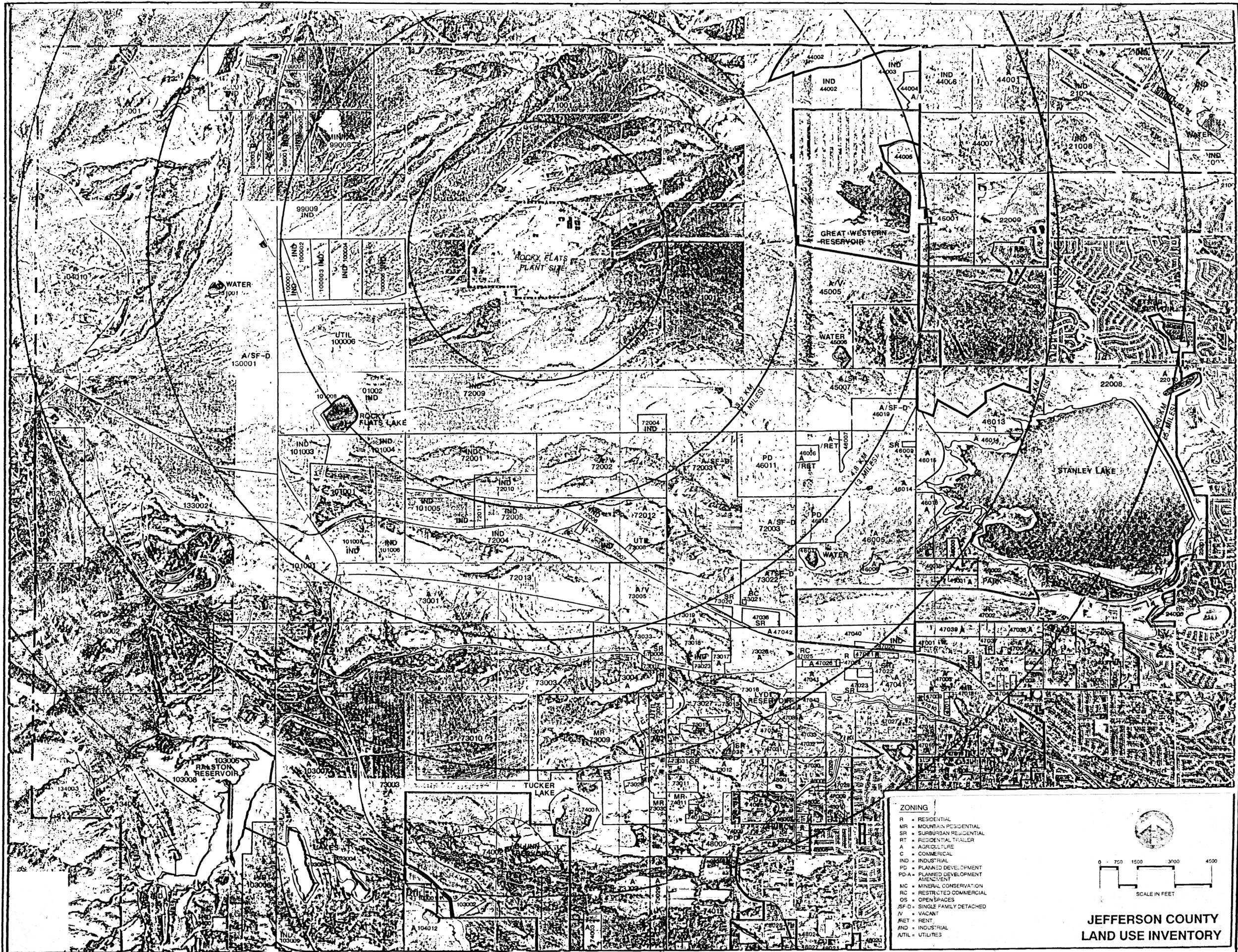
S Significant  
 I Insignificant  
 N Negligible or Incomplete

**U.S. DEPARTMENT OF ENERGY**  
 Rocky Flats Plant, Golden, Colorado

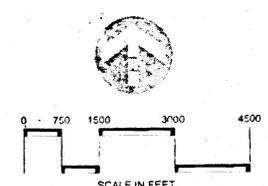
861 HILLSIDE AREA  
 OPERABLE UNIT NO. 1  
 PHASE III RFA/RN REPORT

Conceptual Site Model

**Figure 8-2**



- ZONING**
- R - RESIDENTIAL
  - MR - MOUNTAIN RESIDENTIAL
  - SR - SUBURBAN RESIDENTIAL
  - RT - RESIDENTIAL TRAILER
  - A - AGRICULTURE
  - C - COMMERCIAL
  - IND - INDUSTRIAL
  - PD - PLANNED DEVELOPMENT
  - PD-A - PLANNED DEVELOPMENT AMENDMENT
  - MC - MINERAL CONSERVATION
  - RC - RESTRICTED COMMERCIAL
  - OS - OPEN SPACES
  - SF-D - SINGLE FAMILY DETACHED
  - V - VACANT
  - RET - RENT
  - IND - INDUSTRIAL
  - UTIL - UTILITIES



**JEFFERSON COUNTY  
LAND USE INVENTORY**

0001-A-000653

FIGURE F-1