APPENDIX J TO THE
PHASE I RFI/RI WORK PLAN FOR OPERABLE UNIT 6

HUMAN HEALTH RISK ASSESSMENT
TECHNICAL MEMORANDUM NO. 2
EXPOSURE ASSESSMENT

FINAL

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM
JUNE 1995

TITLE: TECHNICAL MEMORANDUM NO. 2, EXPOSURE ASSESSMENT

Approved By:

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Director, Date
EG&G Environmental Restoration Program Department

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Quality Assurance Program Manager, Date
Data Management and Reporting Services

Effective Date: ______________

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ACRONYMS

AC	Areal Activity Concentration
AEC	Atomic Energy Commission
AOC	Area of Concern
C	Mass Activity Concentration
CDPHE	Colorado Department of Public Health and Environment
CSM	Conceptual Site Model
CT	Central Tendency
D	Soil Depth
EATM	Exposure Assessment Technical Memorandum
ED	Exposure Duration
EF	Exposure Frequency
EG&G	EG&G Rocky Flats, Inc.
ER	External Irradiation Exposure
HHRA	Human Health Risk Assessment
IAG	Interagency Agreement
IF	Intake Factor
IHSSs	Individual Hazardous Substances Sites
IR	Intake Rate
MSL	Mean Sea Level
NPDES	National Pollutant Discharge Elimination System
No.	Number
OU6	Operable Unit Number 6
RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFLII	Rocky Flats Local Impacts Initiative
RME	Reasonable Maximum Exposure
SD	Soil Density
Se	Gamma Shielding Factor
Te	Gamma Exposure Time Factor
TM	Technical Memorandum
UCL	Upper Confidence Limit
UHSU	Upper Hydrostratigraphic Unit
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Services
VOCs	Volatile Organic Compounds

UNITS OF MEASURE

g	gram
hr	hour
kg	kilogram
l	liter
m	meter
m^2	square meters
m^3	cubic meters
mg	milligram
mg/kg-day	milligrams per kilogram-day
mrem	millirem
pCi	picocuries
pCi-yr/g	picocurie per gram per year
yr	years

EXECUTIVE SUMMARY

Technical Memorandum No. 2, Exposure Assessment, is presented in support of the human health risk assessment (HHRA) for Operable Unit Number 6 (OU6), which includes the Walnut Creek Priority Drainage located at Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado. This Technical Memorandum (TM) identifies potentially complete exposure pathways and receptors at OU6 and presents quantitative values for exposure parameters and equations for estimating central tendency (CT) and reasonable maximum exposure (RME) to be used in the HHRA. This TM does not quantify chemical intake, which is dependent on the chemical concentration at exposure points.

The following subjects are covered in this TM:

- Identification of current onsite and offsite land uses and characterization of future land use scenarios as credible or improbable, depending on likelihood of occurrence.

- Identification of potential human receptors (people potentially exposed to contaminants in OU6) based on current and future land use scenarios.

- Development of a conceptual site model (CSM), which is a schematic representation that summarizes information regarding chemical sources, chemical release mechanisms, environmental transport media, and human intake routes. The CSM also identifies pathways as potentially complete and significant, potentially complete but relatively insignificant, negligible, or incomplete.

- Identification of quantitative values for exposure parameters and equations to be used in estimating CT and RME chemical intake for each exposure pathway and receptor evaluated in the HHRA.

Current onsite land use at OU6 includes security surveillance and environmental restoration activities. Offsite land uses are mixed, consisting of open space, agricultural, commercial/industrial, and residential areas. Future onsite land uses that could occur at

RFETS include commercial or industrial development or preservation as an ecological reserve or open space. Onsite residential development is not consistent with expected future use and is considered to be improbable. Future offsite land use is expected to continue to include open space, agricultural, commercial/industrial, and residential land uses.

Potential receptors identified for evaluation in the HHRA are:

- Current onsite worker
- Future onsite office worker
- Future onsite construction worker
- Future onsite ecological researcher
- Future onsite open space user

Current and future onsite exposure scenarios will be evaluated in the HHRA for each area of concern (AOC) identified in a letter report prepared for the Colorado Department of Public Health and Environment (CDPHE) and the United States Environmental Protection Agency (USEPA) (USDOE 1994a). AOCs are identified as one or several individual hazardous substance sites (IHSSs) that are in close proximity and can be evaluated as a unit in the HHRA. Four AOCs have been identified in OU6 (Figure 3-2): AOC No. 1 (North Spray Field); AOC No. 2 (Triangle, Sludge Dispersal and Soil Dump areas); AOC No. 3 (Ponds A-1, A-2, and A-3); and AOC No. 4 (Ponds B-1, B-2, B-3, and B-4). Seven other IHSSs that were investigated in OU6 were eliminated from further evaluation based on minimal contamination or transfer to other OUs (USDOE 1994a).

Chemical sources in OU6 include potentially contaminated soil and sediment. Potential chemical release mechanisms identified in the CSM include storm water runoff, volatilization, wind suspension, infiltration and percolation to groundwater, direct oral and dermal contact with soil or sediment, root uptake from surface soil, and radioactive decay. Transport media include groundwater, surface water, and air. Based on evaluation of migration pathways, current and future land use, exposure points, and human intake routes, OU6 pathways were characterized as either potentially complete and significant, potentially complete and relatively insignificant, negligible, or incomplete. Negligible and incomplete pathways are discussed but were eliminated from further consideration in the quantitative HHRA. A summary of potentially complete exposure pathways to be quantitatively evaluated in the HHRA is provided in Table ES-1.

Exposure factors to be used for estimating chemical intake were identified for each of the exposure pathways and receptors to be evaluated in the risk assessment (Attachment 1). Both CT and RME values are provided, as recommended by USEPA (USEPA 1992). Exposure factors are reasonable estimates of numerous variables, including body weight, daily inhalation volume, daily ingestion rates, body surface area, soil matrix effects, and frequency and duration of exposure. Exposure point concentrations (determined by chemical analytical results and fate and transport modeling) will be used with these exposure factors to obtain pathway-specific chemical intakes for each receptor for use in the HHRA.

TABLE ES-1
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite worker	Current	Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil External irradiation from surface soil
Onsite worker (industrial/office)	Future	Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil External irradiation from surface soil Inhalation of indoor VOCs (from migration through foundation)
Onsite construction worker	Future	Inhalation of airborne particulates from subsurface soil Ingestion of subsurface soil Dermal contact with subsurface soil External irradiation from subsurface soil
Onsite open space recreational user	Future	Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil External irradiation from surface soil Inhalation of airborne particulates from stream or dry sediment Ingestion of sediment Dermal contact with sediment External irradiation from stream or dry sediment Ingestion of surface water Dermal contact with surface water

TABLE ES-1
(Continued)

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite ecological researcher	Future	Ingestion of surface water Dermal contact with surface water Ingestion of sediment Dermal contact with sediment Inhalation of airborne particulates from stream or dry sediment External irradiation from stream or dry sediment Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil . External irradiation from surface soil

1.0 INTRODUCTION

This Exposure Assessment Technical Memorandum (EATM) is presented to support the development of the baseline human health risk assessment (HHRA) for the Walnut Creek Priority Drainage, otherwise known as Operable Unit Number 6 (OU6), located at the Rocky Flats Environmental Technology Site (RFETS). The HHRA will evaluate human health risks for onsite receptors under current land-use conditions and under potential future land-use conditions, assuming no remedial action takes place at OU6. The HHRA for OU6 will be submitted as part of the Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) Report for OU6. The RFI/RI is conducted pursuant to the U.S. Department of Energy (USDOE) Environmental Restoration Program; a Compliance Agreement between USDOE, the U.S. Environmental Protection Agency (USEPA), and the Colorado Department of Public Health and Environment (CDPHE), dated July 31, 1986; and the Federal Facility Agreement and Consent Order known as the Interagency Agreement (IAG 1991).

The objectives of this EATM are to: (1) identify human receptor populations that may be exposed to chemicals released from OU6 under current and potential future use exposure scenarios, (2) describe exposure pathways by which chemicals could be transported from sources to human exposure points, (3) identify the principal routes of chemical intake (e.g., inhalation or ingestion), and (4) present central tendency (CT) and reasonable maximum exposure (RME) factors to estimate chemical intake for each exposure pathway and receptor. This EATM does not quantify chemical intake, which is dependent on the chemical concentration at the exposure points. Exposure point concentrations were estimated based on the analytical results of the remedial investigation and fate and transport modeling, as appropriate.

This EATM is organized as follows:

- Section 2.0, Site Description, briefly describes site history and site characteristics such as meteorology, geology, surface water, and groundwater that affect exposure pathways.

- Section 3.0, Potential Receptors and Exposure Areas, identifies current and future human receptors that could be exposed to chemicals released from sources in OU6 based on current and potential future land use scenarios. This section also describes the exposure areas and receptor locations that will be evaluated in the HHRA.

- Section 4.0, Exposure Pathways, discusses potential chemical release and transport mechanisms and identifies potentially complete exposure pathways for which chemical intake will be quantitatively evaluated in the HHRA.

- Section 5.0, Estimating Chemical Intakes, describes the methodology used to estimate the intake of chemicals from various media (e.g., soil or groundwater).

- Section 6.0 contains references cited in the EATM.

- Attachment 1 contains tables identifying CT and RME factors for each of the potentially complete exposure pathways and receptors to be evaluated in the HHRA for OU6.

2.0 SITE DESCRIPTION

A detailed description of the site location and general site conditions for the RFETS is included in Sections 1.0 and 2.0 of the Phase I RFI/RI Work Plan for OU6 (EG&G 1992a). Information provided in this section is new or has been revised from the OU6 Work Plan.

2.1 HISTORIC AND FUTURE USE

RFETS history prior to its change in mission in 1989 is well documented in the OU6 Work Plan and elsewhere. The current mission of RFETS is to manage waste and materials, to clean up contamination, and to convert the site to beneficial use in a manner that is safe, environmentally and socially responsible, physically secure, and cost-effective. In pursuing the mission, RFETS is performing environmental restoration activities and planning for decontamination and decommissioning, economic development, and waste management.

A group of local businesses and government representatives, known as the Rocky Flats Local Impacts Initiative (RFLII), has been formed to help guide the economic transition at RFETS. One of the group's goals is to encourage businesses to occupy existing buildings, once cleaned and renovated (RFLII 1992). Therefore, continued beneficial commercial and industrial use of the facility is anticipated. The Rocky Flats Future Site Uses Working Group has also been established to make recommendations on future use of the RFETS property.

2.2 DESCRIPTION OF OU6

OU6 includes the Walnut Creek Priority Drainage, as well as a large portion of the buffer zone extending east to Indiana Street. OU6 is comprised of 20 individual hazardous substances sites (IHSSs) where waste materials were historically stored or disposed. Figure 2-1 shows the locations of the following IHSSs within OU6:

- A-Series Ponds (IHSSs 142.1, 142.2, 142.3, 142.4)
- B-series ponds (IHSSs 142.5, 142.6, 142.7, 142.8, and 142.9)
- Walnut and Indiana (W&I) Pond (IHSS 142.12)
- North Spray Field Area (IHSS 167.1)
- Former South Spray Field Area (old IHSS 167.3)
- Trenches A, B, and C (IHSSs 166.1, 166.2, and 166.3)
- Old Outfall Area (IHSS 143)
- Sludge Dispersal Area (IHSS 141)
- Triangle Area (IHSS 165)
- Soil Dump Area (IHSS 156.2)
- East Spray Field Area (IHSS 216.1)

The above list differs slightly from the IHSS list presented in the OU6 Work Plan. IHSS 167.2, Pond Spray Field Area, was transferred to OU7, Present Landfill, and a new IHSS

167.3, South Spray Field Area, was established for OU7. The old IHSS 167.3 was retained in OU6. A more detailed description of each IHSS and the types of associated contamination can be found in the Phase I RFI/RI Work Plan for OU6 (EG&G 1992a).

2.3 PHYSICAL SETTING

Topographic and other physical features of RFETS are described in the OU6 Work Plan. However, summary descriptions of the meteorology, geology, hydrogeology, surface water hydrology, and ecology in the area of RFETS are presented in this section to provide updated or more concise information pertinent to exposure assessment.

2.3.1 Meteorology

In general, winds blow from northerly through westerly directions approximately 64 percent of the year. Southerly winds occur with less frequency (approximately 20 percent of the year), while easterly winds are infrequent (only 11 percent of the year). Wind patterns are heavily influenced by large-scale meteorological patterns, convective storms, and mountain/valley flows.

The wind speeds are greatest from the northwesterly direction. Wind speeds in excess of 34 miles per hour are regularly observed. Winds are calm approximately 5 percent of the year. Figure 2-2 presents a wind rose illustrating wind patterns in the region for the year 1990. This wind rose is generated from wind speed and direction data recorded at an onsite meteorological tower at a monitoring height of approximately 20 feet.

Atmospheric stability at the site is generally neutral (Class D) to slightly stable (Class E). Periods of very stable (Class F) and unstable (Classes A through C) atmospheric stability occur less than 20 percent of the year (USDOE 1992). Neutral to slightly stable conditions generally allow for uniform dispersion of contaminants. Very stable atmospheric conditions inhibit dispersion. Unstable atmospheric conditions aid in dispersing contaminants.

Precipitation at RFETS averages 15 inches per year. A majority of the precipitation is in the form of snowfall and occurs during the winter and spring seasons. Average annual total snowfall is 2160 millimeters (85 inches). The summers are generally dry with isolated thunderstorms contributing up to 30 percent of the annual precipitation. Autumn is the driest period of the year. Annual potential free-water evaporation is approximately 45 inches, which is significantly greater than the annual precipitation (USDOE 1992).

2.3.2 Geology

The surficial deposits at OU6 consist of pediment alluvium (Rocky Flats Alluvium), colluvium, valley-fill alluvium, and artificial fill that overlie bedrock. The near-surface bedrock (Arapahoe and Laramie formations), as well as the Rocky Flats Alluvium, are shown on Figure 2-3 and are discussed below. The regional dip of the bedrock in the vicinity of OU6 is approximately two degrees to the east (EG&G 1992b).

The Rocky Flats Alluvium is a gravel deposit that overlies the bedrock. The deposit consists of poorly to moderately sorted, poorly stratified clays, silts, sands, gravels, and cobbles. Creeks to the south and within OU6 have cut through the alluvium into the underlying bedrock, leaving the alluvium exposed along the valley walls. The Rocky Flats Alluvium is the surficial deposit in the vicinity of the western portion of the North and South Spray Fields, the East Spray Field and Soil Dump Area, Trenches A, B, and C, the Sludge Dispersal Area, and the Triangle Area.

Colluvial materials in OU6 were derived from slope wash and creep of the Rocky Flats Alluvium and from the Arapahoe and Laramie Formations. The colluvium consists of clays, sands, and gravels. Colluvium derived from the Rocky Flats Alluvium characteristically covers the alluvial/bedrock contact along the hillsides, especially near the A- and B-series ponds (EG&G 1992b). Artificial fill and disturbed ground occur in localized areas of OU6, especially in the Old Outfall and Soil Dump area. Recent valley-fill alluvium occurs in the active stream channels of Walnut Creek and near the Old Outfall. This material is derived from reworked older alluvial and bedrock deposits.

The Arapahoe Formation underlies much of the western part of OU6. The Arapahoe Formation is composed of claystones, siltstones, sandstones, and occasional lignitic coal seams and ironstones. A medium-grained to conglomeritic sandstone marker bed, locally known as the No. 1 Sandstone, is often present at the base of the Arapahoe Formation and defines the contact between the Arapahoe Formation and the underlying Laramie Formation.

The Laramie Formation is composed of claystone, siltstone, and sandstone deposited in a shallow marine or brackish water environment.

Within the OU6 area, the No. 1 Sandstone (Arapahoe Formation) was encountered in IHSS 165 (Triangle Area) from 5946 feet to 5937 feet mean sea level (MSL). The Arapahoe Formation thickness in this central portion of RFETS ranges from 8 to 22 feet. Additionally, the No. 1 Sandstone outcrops in the road cut between IHSSs 165 and 156.2 (Soil Dump Area) and on the northern and southern hillsides beneath IHSS 216.1 (East Spray Field Area), where it is truncated along this narrow ridge. Other sandstones observed in the OU6 area were an outcrop on the north side of Pond A-2 at 5820 feet MSL and approximately 4 feet thick; beneath Pond A-4 in the sediment samples at 5735 feet MSL, approximately 1 inch thick; and outcrops southwest of IHSS 142.12 (W&I Pond) near the OU6 boundary from 5720 feet to 5715 feet MSL. These sandstone outcrops are classified as Laramie sandstones.

A potential fault is believed to extend northeast from Woman Creek to just east of the Walnut Creek confluence. According to the Appendix C Addendum of the HAP's Briefing Book No. 12 (May 1993), the fault trace lies between RFETS and downgradient receptor wells. This fault is believed to be a normal fault with the downthrown side on the southeast. The medium-grained to conglomeritic sandstone marker bed at the base of the Arapahoe Formation has been vertically displaced just east of the inner east gate to RFETS (EG&G 1992b). No evidence of this fault could be verified by the OU6 Phase I field investigation.

The geology at depth in OU6 is largely unconfirmed. A sitewide Bedrock Characterization Program has been conducted to better define the subsurface geology and reinterpret information from previous studies. Aside from the subsurface investigation conducted during the Phase I RFI/RI for OU6, there has been limited subsurface investigation in much of OU6.

2.3.3 Groundwater

The upper hydrostratigraphic unit (UHSU) at OU6 is the water-bearing unit of primary concern for potential transport of contaminants in groundwater. The UHSU of OU6 consists of Rocky Flats Alluvium, valley fill alluvium, colluvium, and weathered claystones of the Arapahoe and Laramie Formations that are hydraulically connected with the saturated surficial materials. In addition, Arapahoe No. 1 Sandstone and Laramie sandstones, where they appear to be hydraulically connected with saturated surficial materials, are considered part of the UHSU. The UHSU in OU6 is believed to exist predominantly under unconfined conditions; however, partially confining conditions may exist in bedrock sandstones that are part of the UHSU. Lower hydrostatigraphic units, consisting of unweathered claystone and sandstone of the Arapahoe and Laramie Formations, are not considered part of the uppermost aquifer because (1) they are not in direct hydraulic connection with the UHSU and (2) these unweathered units have relatively low hydraulic conductivities (EG&G 1991b).

Groundwater in OU6 is likely to occur under unconfined conditions in saturated surficial deposits (Rocky Flats Alluvium, colluvium, and valley fill) and in the Arapahoe and Laramie Formation sandstones that are in direct contact with the saturated surficial materials. In addition, limited areas of subcropping claystone may be saturated, particularly where the claystone is fractured and weathered (EG&G 1991b).

Groundwater flow across the area is generally west to east, but local variations occur. Groundwater in the Rocky Flats Alluvium follows the scoured lows in the underlying claystone bedrock. Water in the colluvium mantling the valley slopes flows towards Walnut Creek and its tributaries.

Recharge to the UHSU beneath OU6 is primarily due to precipitation, snowmelt, and water loss from ditches, streams, and ponds. Groundwater levels in the aquifer reflect seasonal changes; groundwater levels reach their highest in the spring and early summer and decline the remainder of the year, with periodic higher flows due to precipitation or irrigation.

Groundwater discharge from the UHSU occurs at seeps and springs at the contact between the Rocky Flats Alluvium and the claystone bedrock. Seep or spring water is consumed by evapotranspiration or flows downslope through the colluvial deposits where it discharges to Walnut Creek or into the valley fill alluvium.

2.3.4 Surface Water

Walnut Creek and its tributaries are intermittent streams located in OU6; they flow generally west to east. Walnut Creek and its tributaries are ephemeral because of the seasonal response to freezing, spring runoff, and storms. Onsite, Walnut Creek flows through a series of detention ponds (A and B series). Offsite, Walnut Creek is diverted east of Great Western Reservoir through the Broomfield Diversion Ditch.

Figure 2-1 illustrates the current surface water bodies in the Walnut Creek drainage. Detention Ponds B-1 through B-5 are located on South Walnut Creek and receive storm runoff from the East Spray Field, Soil Dump Area, Triangle Area, and Sludge Dispersal Area. Detention Ponds A-1 through A-4 are located on North Walnut Creek and receive storm runoff from the East Spray Field, Soil Dump Area, Triangle Area, Old Outfall, and South Spray Field. Detention Pond IHSS 142.12 at Indiana Street receives storm runoff from the easternmost portion of the Walnut Creek drainage at RFETS. Surface water held in Ponds A-1, A-2, B-1 and B-2 is generally not discharged to the lower ponds; instead the water is spray evaporated or naturally evaporates from the ponds so that a relatively constant water level is maintained. Pond B-3 receives effluent from the Sewage Treatment Plant and periodically discharges to B-4. Pond B-4 continuously discharges to Pond B-5; water from B-5 is pumped to Pond A-4 where it is treated by granular activated carbon (GAC) prior to discharge downstream. An underground pipeline (A-1 Bypass) carries water from North Walnut Creek, west of the A-series ponds, to Pond A-3. Ponds A-3, A-4, B-3, and B-5 are all sampled for National Pollutant Discharge Elimination System (NPDES) compliance.

All surface water discharges from RFETS are monitored in compliance with the NPDES permit and with the USEPA-approved RFETS surface water management program (EG&G 1991a).

2.3.5 Offsite Domestic Wells Along the Walnut Creek Drainage

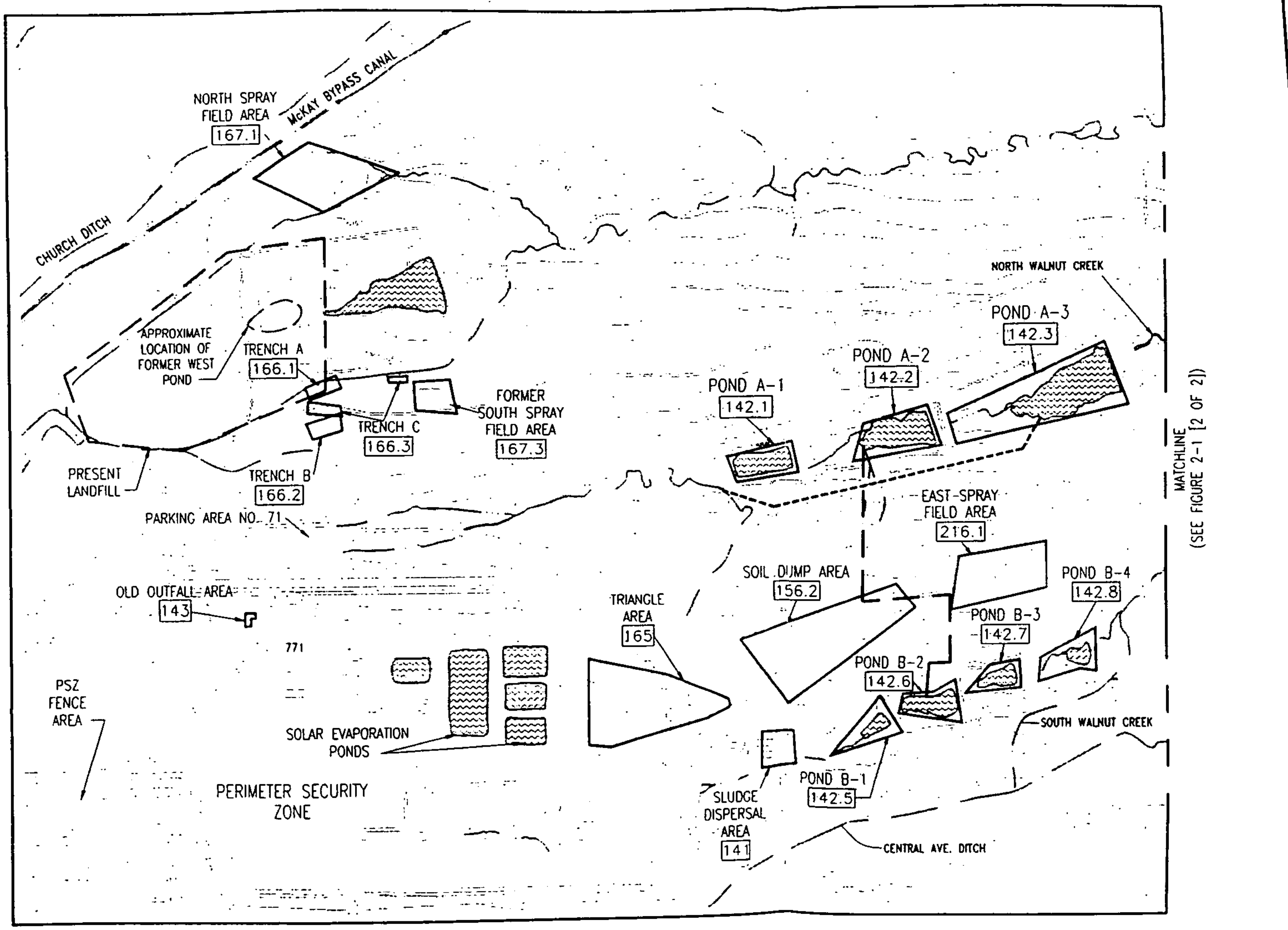
The groundwater in the UHSU is discharged via seeps and springs into the Walnut Creek drainage in OU6. Beyond the RFETS boundary, land surrounding the Walnut Creek drainage and Great Western Reservoir is used as open space and does not contain residential or commercial developments. No water wells are registered at the Colorado State Engineer's office for this area.

2.4 ECOLOGY

This section presents a brief summary of biological resources at RFETS. Plants representative of tall-grass prairie, short-grass plains, lower mountain, and foothill ravine regions can be found within the boundaries of RFETS. Grasses predominantly cover the steep sides of the hillsides along the Walnut Creek drainage. The Walnut Creek drainage also hosts grasses, cattails, rushes, and cottonwood trees. Since the acquisition of the property, vegetative recovery from former grazing has occurred, as evidenced by the presence of disturbance-sensitive grass species such as big bluestem and side oats grama. No vegetative stresses attributable to hazardous waste contamination have been identified (EG&G 1991c).

The animal life inhabiting RFETS consists of species associated with western prairie regions. The most common large mammal is the mule deer. A number of small carnivores such as coyote, red fox, striped skunk, and long-tailed weasel are present. The bird population includes the western meadowlark, mourning doves, vesper sparrows, great horned owl, and ferruginous and American rough-legged hawks. Many varieties of ducks, killdeer, and redwing blackbirds have been observed near the ponds on Walnut Creek. Minnows have been observed in Walnut Creek, and it is possible that other fish may appear in the creeks, but this would most likely occur only during high-flow periods. Bull snakes and rattlesnakes can be seen on the hillsides of OU6. The western painted turtle and western plains garter snake inhabit the greens near the ponds. The Prebles meadow jumping mouse inhabits creek drainages and is a candidate for listing as an endangered species (USDOE 1994b).

Ecological surveys performed in compliance with the Threatened and Endangered Species Act indicate the presence of habitat that is potentially suitable to four plant species and several wildlife species of concern. The plant species include the forktip threeawn, Colorado butterfly plant, toothcup, and Diluvium lady's tresses (EG&G 1991c). The wildlife species include the bald eagle, peregrine falcon, whooping crane, Prebles meadow jumping mouse, and the black-footed ferret (USDOE 1991; USFWS 1990; USDOE 1994b). Because of the unique and undisturbed nature of the buffer zone, it is possible that it may be designated as an ecological reserve.



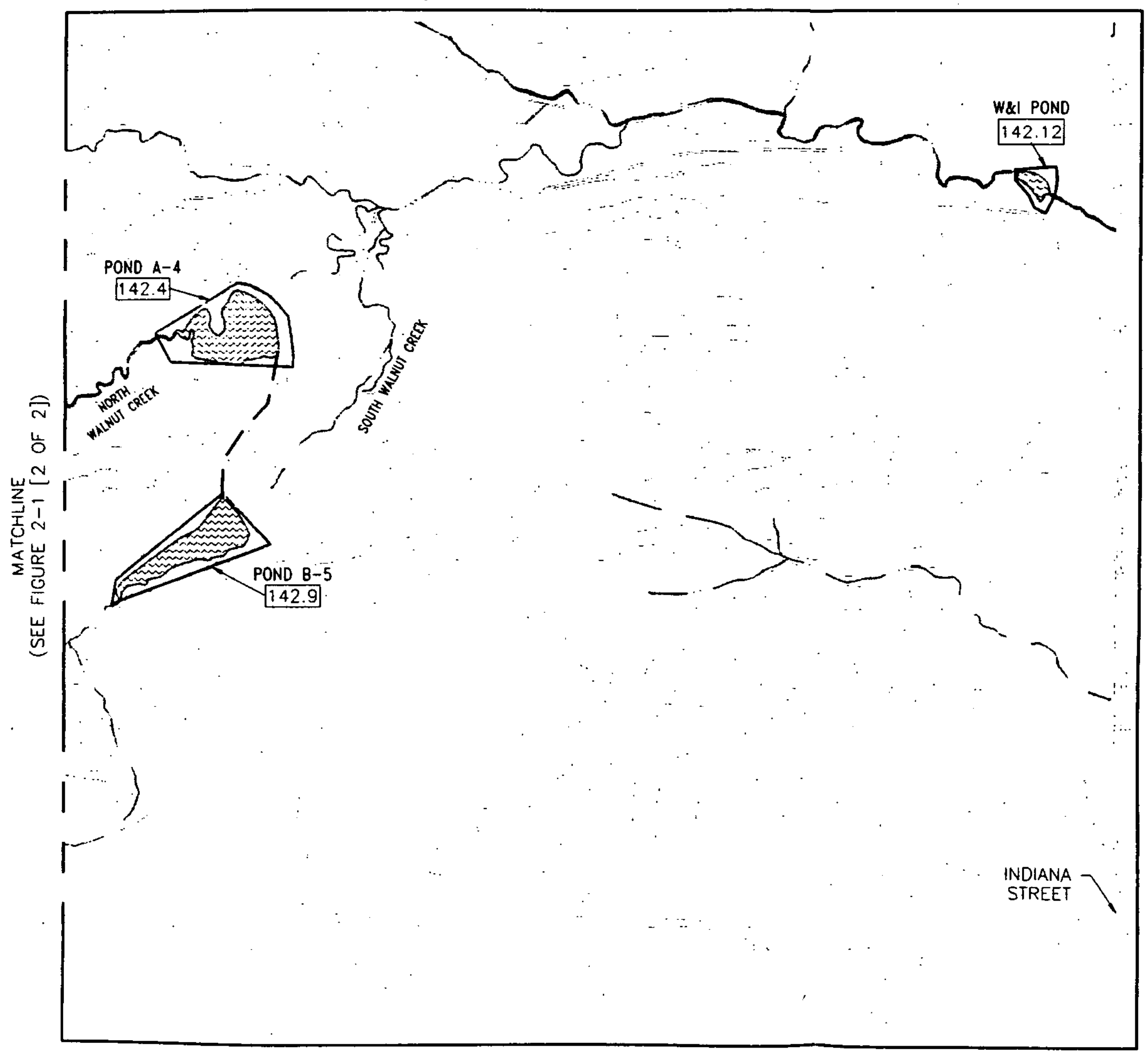
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

OPERABLE UNIT NO. 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

LOCATION MAP OF INDIVIDUAL HAZARDOUS SUBSTANCE SITES AND DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS

FIGURE 2-1 (1 OF 2) JUNE 1995

OU6RI252 1=600



EXPLANATION

-N-

0 300 600
SCALE IN FEET

INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) IN OPERABLE UNIT 6

115 IHSS REFERENCE NUMBER

DIRT ROAD

INTERMITTENT STREAM

TRANSFER LINE FROM POND B-5 TO POND A-4

U.S. DEPARTMENT OF ENERGY
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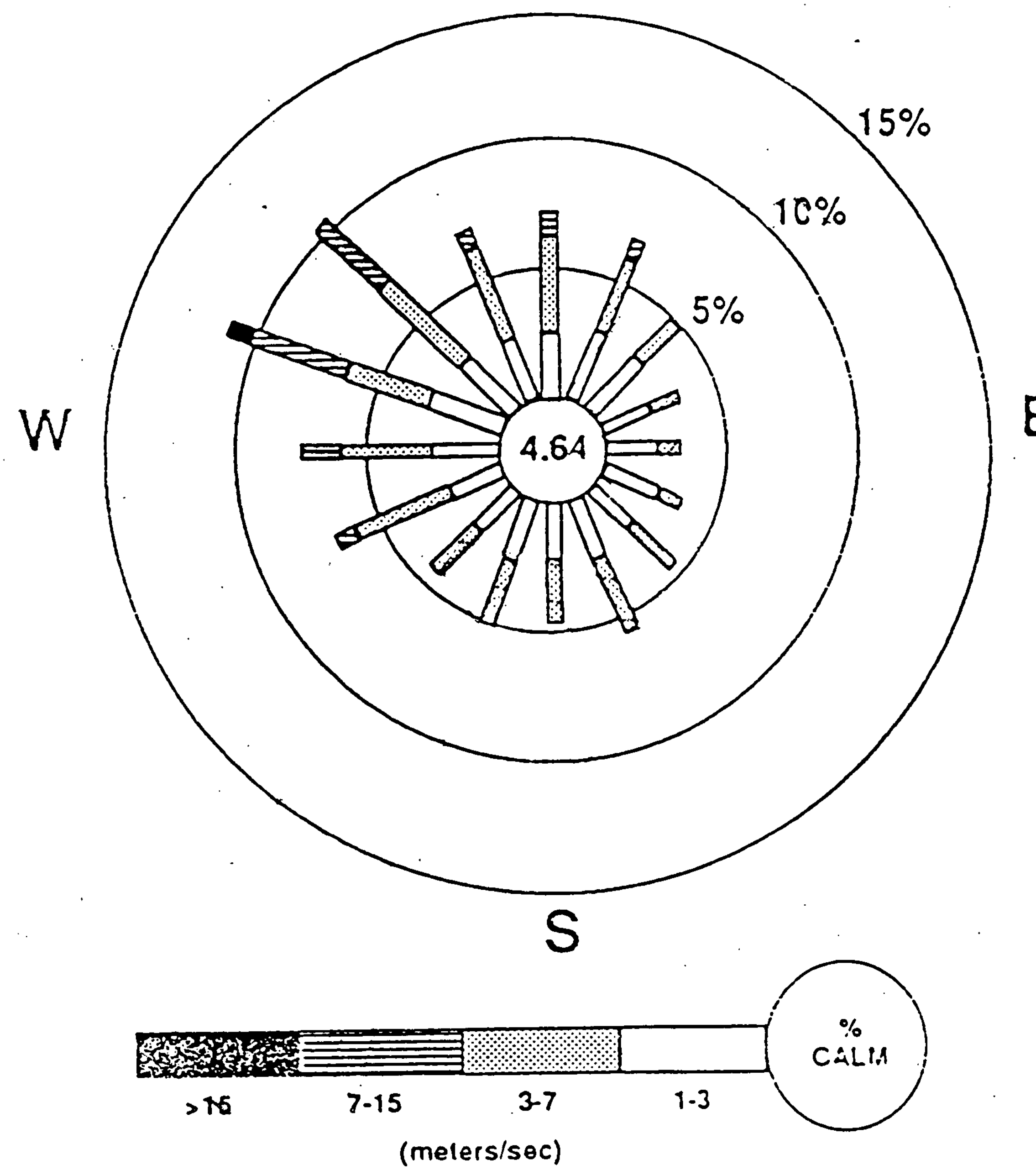
LOCATION MAP OF INDIVIDUAL HAZARDOUS SUBSTANCE SITES AND DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS

FIGURE 2-1 (2 OF 2) JUNE 1995

OU6RI263 1=600



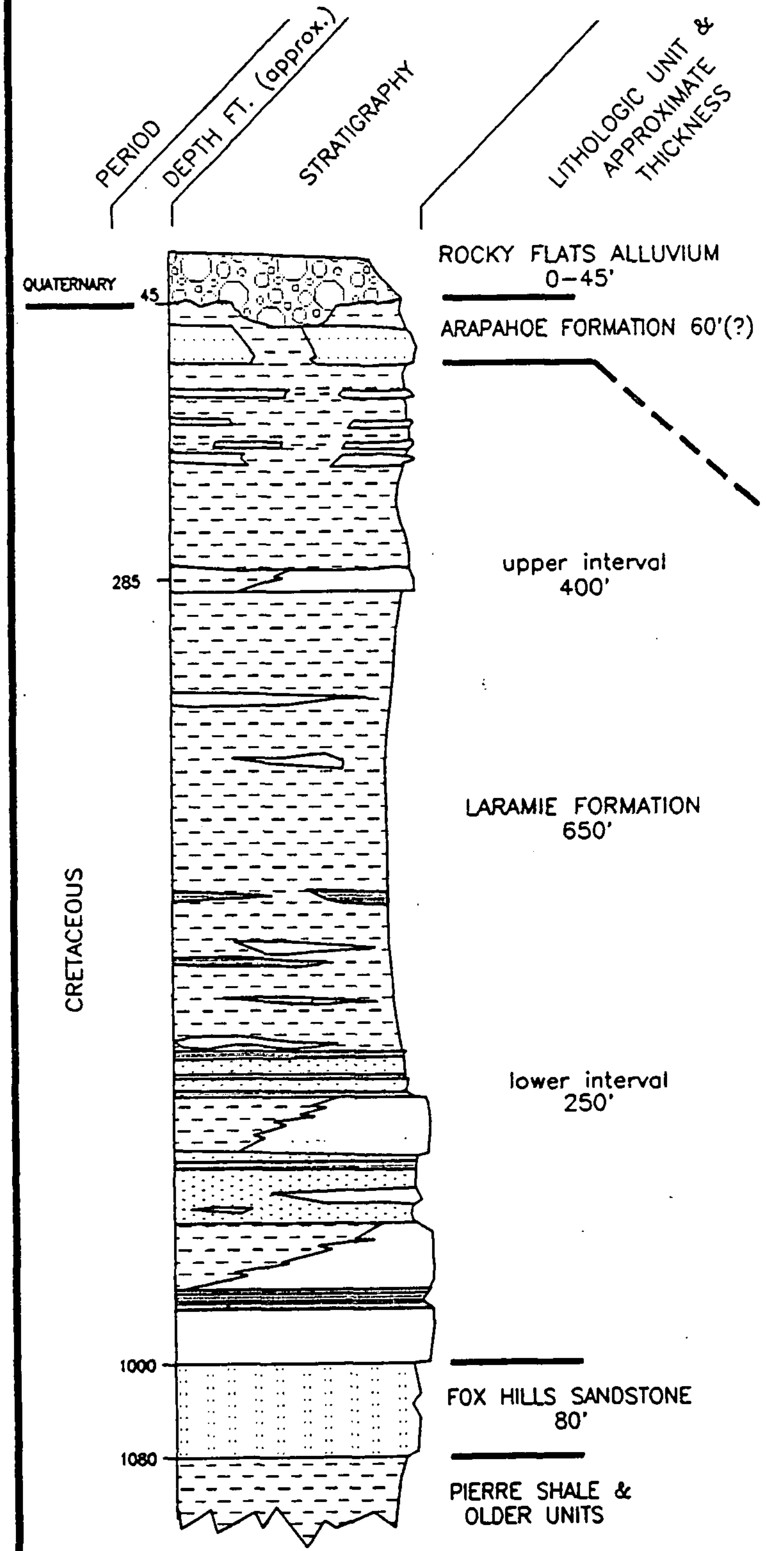
SOURCE: EG&G 1990.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

OPERABLE UNIT NO. 6
EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

WIND ROSE FOR ROCKY FLATS
1990 ANNUAL

FIGURE 2-2 JUNE 1995



DESCRIPTION

CLAYEY SANDY GRAVELS– light brown to yellowish–orange, grayish–orange to dark gray, poorly sorted, angular to subrounded, cobbles, coarse gravels coarse sands and gravelly clays: varying amounts of caliche

CLAYSTONE SILTSTONES, CLAYEY SANDSTONES, SANDSTONE– light to medium olive–gray with some dark olive–black claystone and silty claystone. Weathered intervals may be yellowed, and basal sand is often conglomeratic

CLAYSTONES, SILTSTONES, AND COAL– kaolinitic, light to medium gray claystone and siltstone and some dark gray to black carbonaceous claystone, thin (2') coals and thin discontinuous very fine–to–medium grained, moderately sorted sandstone intervals

SANDSTONES light to medium gray, fine–to coarse–grained, poorly–to moderately–sorted, silty, immature quartzitic sandstone with numerous lenticular, sub–bituminous coal beds and seams that range from 2' thick in the upper lower interval to 8' thick at the base of the lower interval

SANDSTONES– grayish–orange to light gray, calcareous, fine–grained, subrounded, glauconitic, feldspathic, friable sandstone

EXPLANATION

ALLUVIUM
SILTSTONE & CLAYSTONE
FINE–GRAINED & COARSER SANDSTONE
COAL
FINE GRAINED SANDSTONE
SILTY SANDSTONE

MODIFIED FROM LEROY AND WEIMER, 1971 AND WEIMER 1973

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NEAR SURFACE STRATIGRAPHIC SECTION

FIGURE 2–3 JUNE 1995

6/2/95 OU6RI264 1=1

3.0 POTENTIAL RECEPTORS AND EXPOSURE AREAS

RFETS is located in a rural area of unincorporated Jefferson County, approximately 16 miles northwest of Denver and approximately 10 miles south of Boulder. The area to the west of RFETS is mountainous, sparsely populated, and primarily government-owned. The area east of RFETS is an arid plain, densely populated in some areas, and privately owned. Most of the development in the plains east of RFETS has occurred since the plant was built, and development is expected to continue in the future.

The most significant commercial and residential development within a 10-mile radius of the center of RFETS is located 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, are also present within this 10-mile radius.

3.1 CURRENT AND FUTURE LAND USE

Table 3-1 summarizes the current patterns of land use on and near RFETS and categorizes future land use scenarios as (1) improbable (unlikely to occur) or (2) credible (could reasonably occur or is expected to occur). Current and future land use is discussed in more detail in the following sections.

3.1.1 Current Offsite Land Use

Land adjacent to RFETS is used for open space (recreational), agricultural, residential, and commercial/industrial purposes. Predominant land uses in the area immediately southeast of RFETS include open space, single-family detached dwellings, and horse-boarding operations. The nearest residence is located across Indiana Street at the southeast corner of the RFETS property line (Figure 3-1). Another nearby residence in the predominant wind direction (southeast) is located about 0.8 miles east of Indiana Street, also near the southeast boundary of RFETS. Small cattle herds (approximately 10 to 60 cattle in each herd) graze seasonally in fields east and southeast of the site. Industrial facilities to the south include the TOSCO laboratory, Great Western Inorganics Plant, and Frontier Forest Products (USDOE 1990).

3.1.2 Future Offsite Land Use

The northeastern Jefferson County area near RFETS is among the most active areas of industrial development in the Denver metropolitan area. The "Northeast Community Profile" (Jefferson County 1989) contains a baseline profile of growth and land use in the area and describes compatible future development scenarios. As a result of this study, Jefferson County expects that industrial land use will dominate the northeastern portion of the county. Industrial and commercial development of the area is attractive to businesses and developers because of the lower cost and lower taxes associated with locating on undeveloped land in an unincorporated portion of the county. With the increase in industrial development, household and population growth is expected to increase only moderately because of the reduced availability of land for residential development.

Future land use in the area is also the topic of "The North Plains Community Plan" (Jefferson County 1990). The plan is intended to serve 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 developed by representatives of Jefferson County, five cities (Arvada, Broomfield, Golden, Superior, and Westminster), and participants from a variety of interest groups including homeowners, businesses, builders/developers, environmentalists, and special districts. The plan identifies Rocky Flats and the Jefferson County Airport as potential constraints to future residential development in the area and recommends office and light industrial development. The plan further identifies the acquisition of land 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).

Under the plan, the predominant future land uses to the south and southeast of Rocky Flats will consist of commercial, industrial, and office space. Directly to the east, the zoning and usage are expected to remain open space and agricultural or vacant. The areas closest to Rocky Flats are planned for industrial, commercial, or office space, with the areas further from Rocky Flats designated for residential development.

To the north of Rocky Flats, in Boulder County, two areas adjacent to Rocky Flats 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; City of Broomfield 1990; Boulder County 1991).

The above information indicates that land adjacent to RFETS is lightly populated, with current use being primarily open space and agricultural. These uses, as well as commercial/industrial development, are likely to continue in the future. Residential development in the area northeast of the site may be impeded by the growth of business and industry that is expected to occur. However, land use in the area immediately east and southeast of the site is likely to continue to be open space, residential, agricultural, and commercial/industrial. Thus, future offsite use of land for commercial/industrial development, residential communities, agriculture, and recreational activities were all considered credible scenarios.

Current and future offsite receptors were not evaluated in the HHRA for OU6 because estimating effects from individual OUs would not address potential cumulative impacts to offsite receptors from other sources at RFETS. However, exposure of offsite receptors is expected to be evaluated in a future site-wide risk assessment and is also addressed in the RFI/RI Report for OU3, Offsite Areas (in preparation).

3.1.3 Current Onsite Land Use

RFETS operations and maintenance activities do not occur in OU6. Most of OU6 is located in the buffer zone, beyond the security fence and developed portion of the facility. Current activities in OU6 consist of environmental investigations, monitoring, cleanup, and routine security surveillance.

Elsewhere in the RFETS buffer zone, along the western edge of the RFETS property, gravel mining operations have been conducted since the early 1900s. Since 1990, Western Aggregates, Inc. has operated a mine and processing plant there.

3.1.4 Future Onsite Land Use

RFETS is currently performing environmental restoration activities and planning for decontamination and decommissioning, waste management, transition, and economic development.

Commercial and industrial uses of developed portions of the site are considered to be beneficial. The Rocky Flats Local Impacts Initiative (RFLII) is working with the USDOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the RFETS (RFLII 1992). Private industry could occupy existing buildings and use existing equipment after decontamination is complete. The RFLII is working to achieve this objective and promote the socioeconomic and environmental transformation of Rocky Flats.

The Rocky Flats Future Site Uses Working Group is also developing recommendations regarding future onsite land use at RFETS. The Future Site Uses Working Group has indicated that residential development is considered outside the range of what is reasonable for future land use at Rocky Flats (USEPA 1995). Therefore, residential development in OU6 is considered to be an improbable future land use scenario and was not evaluated in the HHRA. Onsite agricultural development is considered to be improbable because of the decline of agriculture in the Northeast Jefferson County area.

Large portions of the buffer zone surrounding the developed portions of the plant, including portions encompassed by OU6, could remain open space. When the U.S. Atomic Energy Commission (AEC) acquired the undeveloped land surrounding the production area, it established plans to preserve the land as open space (AEC 1972). Because open space is located adjacent to the RFETS property, it is possible that the buffer zone and OU6 area will be preserved as open space or as an ecological reserve.

Ecological surveys of the buffer zone, performed in compliance with the Threatened and Endangered Species Act, have identified the presence of several listed species at Rocky Flats. 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. Because the buffer zone has not been affected by commercial development for many years, thus allowing progressive re-establishment of quality native habitats, the future use of this area as open space or an ecological reserve is reasonable. This usage is consistent with USDOE policy and plans (USDOE 1992) and with the Jefferson County Planning Department's recommendations for the provision of large amounts of undeveloped land in the area (Jefferson County 1990). The Jefferson County Board of Commissions has also adopted a resolution stating its support of maintaining, in perpetuity, the undeveloped buffer zone of open space around Rocky Flats for environmental, safety, and health reasons (Jefferson County Board of Commissioners 1994).

Extensive development of the buffer zone is unlikely due to the potential for preservation of the buffer zone as open space or an ecological reserve and the steep topography in parts of the drainages. The steep slopes associated with some of the drainages in the area, particularly the Walnut Creek drainage, are not conducive to extensive residential or commercial development. 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). Approximately 25 percent of the land in the eastern portion of RFETS is at or approaching this grade.

Gravel mining is considered an improbable future land use scenario, because minable quantities of Rocky Flats Alluvium are not present in OU6. Therefore, this scenario will not be evaluated in the HHRA.

In summary, future onsite residential development is inconsistent with expected land use for the area. Future onsite land use would more likely involve industrial or office complexes at the developed portions of the plant and open-space uses in the buffer zone. Thus, onsite commercial/industrial uses of facilities and designation of the buffer zone as open space or an ecological reserve were considered to be credible future land use scenarios, whereas onsite use of land for residential, mining, or agricultural purposes was considered to be improbable.

3.2 RECEPTORS SELECTED FOR QUANTITATIVE RISK ASSESSMENT

Receptor populations selected for quantitative evaluation in the HHRA at OU6 are summarized in Table 3-2. Current receptors are onsite workers. Hypothetical future receptors are onsite industrial/office workers, construction workers, ecological workers, and open space users. Each of these receptors is described in further detail below.

- Current Onsite Workers: Current onsite workers are RFETS plant security personnel who are assumed to spend a portion of their time in OU6 while conducting routine patrols in the buffer zone.

- Future Onsite Workers: Future onsite office workers, construction workers, and ecological researchers will be evaluated in the HHRA. The future office worker is assumed to work indoors. The future onsite construction worker is assumed to contact subsurface soil during excavation activities associated with the building construction. The future onsite ecological researcher is assumed to perform specific field projects of relatively limited duration involving contact with surface soil, pond surface water, and sediment. These research projects would involve a combination of periodic field work coupled with time in the library, office, or laboratory.

- Future Open Space Recreational User: The open space scenario was developed to estimate potential risks from recreational use of open space at RFETS. Future open space use by children and adults in OU6 is assumed to include activities such as hiking and wading in creeks and ponds and to involve contact with surface soil, pond surface water, and sediment in ponds and streambeds.

3.3 DELINEATION OF AREAS OF CONCERN FOR EXPOSURE ASSESSMENT

For HHRAs conducted at RFETS, onsite exposures will be evaluated in separate Areas Of Concern (AOCs) identified in the operable unit. AOCs are defined as one or several contaminant source areas that are in close proximity and can be evaluated as a unit in the HHRA. A baseline HHRA will be conducted for each AOC. To assess health risk under a future office worker scenario, an exposure area of 30 acres, comparable to an industrial park, was agreed upon by CDPHE, USEPA, and USDOE. Delineation of AOCs and receptor exposure areas was described in a separate report prepared for CDPHE and USEPA (USDOE 1994a). A summary is provided in the following paragraphs.

Eighteen contaminant source areas were identified in OU6. These are equivalent to IHSSs, except IHSSs 166.1, 166.2, and 166.3 (Trenches A, B, and C) were treated as one source area. Of these 18 source areas, 6 source areas were eliminated from further evaluation in an HHRA because they passed the CDPHE conservative risk-based screen for residential exposure to soil or sediment and they are not sources of groundwater contamination (USDOE 1994a). The six source areas eliminated were IHSS 166 (Trenches A, B, and C), former IHSS 167.3 (South Spray Field Area), IHSS 142.4 (Pond A-4), IHSS 142.9 (Pond B-5), IHSS 142.12 (W & I Pond), and IHSS 216.1 (East Spray Field Area). These IHSSs were not included in the delineation of AOCs for the HHRA. IHSS 143 (Old Outfall Area) was also excluded from further evaluation in the OU6 HHRA because it is proposed to be transferred to OU8 (Industrial Areas).

The remaining 11 source areas can be grouped into four AOCs based on close proximity and similarity of exposure media, as described below. The four AOCs are shown on Figure 3-2.

AOCs were designated in part from similarity of exposure media, including contaminated groundwater sources. However, direct groundwater ingestion is an incomplete pathway for all current and potential future receptors, because ingestion of groundwater will not occur onsite and groundwater does not discharge offsite. Instead, groundwater in the UHSU either discharges to surface water in Walnut Creek or is lost to evapotranspiration at seeps.

AOC No. 1 is IHSS 167.1 (North Spray Field Area). This source area is spatially separated from the other source areas that warrant further evaluation. The entire AOC is less than 10 acres (Figure 3-3).

AOC No. 2 includes IHSSs 165 (Triangle Area), 141 (Sludge Dispersal Area), and 156.2 (Soil Dump Area), as well as contaminated groundwater co-located within the Triangle Area and Sludge Dispersal Area. These three source areas are in close proximity and represent the largest volume of contaminated soil in OU6. Therefore IHSSs 165, 141, and 156.2 form a logical AOC for exposure and risk assessment and for evaluation for potential remedial alternatives. The three IHSSs comprise less than 50 acres (Figure 3-4).

AOC No. 3 includes IHSSs 142.1, 142.2, and 142.3 (Ponds A-1, A-2, and A-3). These ponds all have similar contamination in the pond sediments and are all in the North Walnut Creek drainage, so they are hydraulically connected; therefore, they form a logical AOC for exposure and risk assessment and evaluation of potential remedial alternatives for sediment and surface water (Figure 3-5). Groundwater in the North Walnut Creek drainage is also contaminated, although the ponds are not the likely source of contamination. Current and future industrial use is not considered an exposure scenario for the ponds, since construction would not occur in the drainages due to steep slopes and location within the flood plain. However, exposure of future ecological researchers or open space users may occur.

AOC No. 4 includes IHSSs 142.5, 142.6, 142.7, and 142.8 (Ponds B-1, B-2, B-3, and B-4). These ponds have similar contaminants in the sediment and are hydraulically connected since they are in the South Walnut Creek drainage (Figure 3-6). The groundwater in the South Walnut Creek drainage is also contaminated, although the ponds are not likely the source of the contamination. Therefore Ponds B-1 through B-4 form a logical area of concern for exposure and risk assessment and evaluation for potential remedial alternatives for sediment and surface water. No construction or industrial/office use will occur in these ponds; however, exposure of future ecological researchers or open space users is possible.

In addition, a 30-acre maximum exposure area representing maximum contaminant levels in AOC No. 2 was delineated for purposes of evaluating reasonable maximum risk to individuals in a future industrial or office park (Figure 3-4).

TABLE 3-1

ROCKY FLATS OU6
SUMMARY OF CURRENT AND FUTURE LAND USES

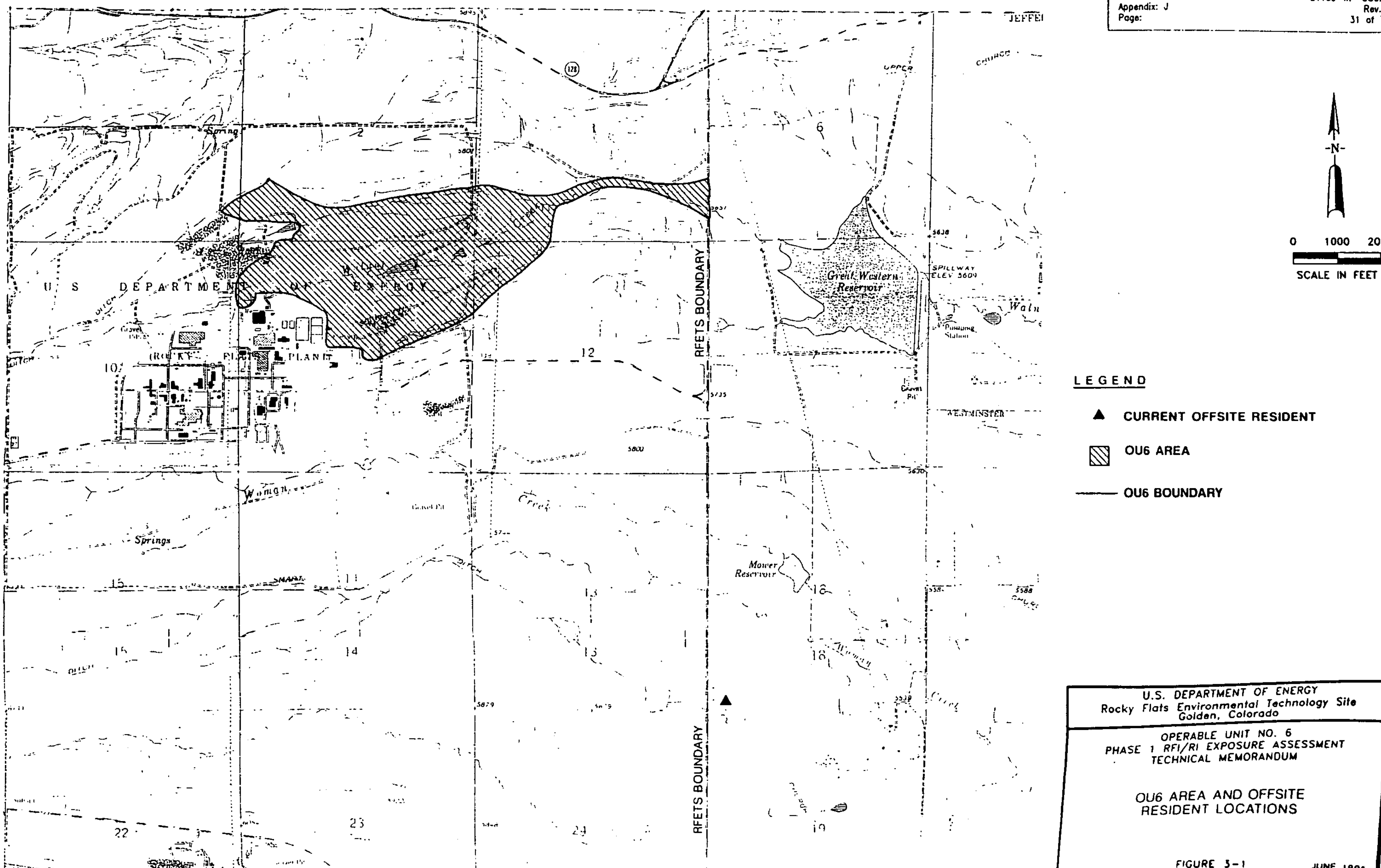
Land Use Category	Current		Future	
	Offsite	Onsite	Offsite	Onsite
Residential	Yes	No	Credible[a]	Improbable[b]
Commercial/Industrial	Yes	Yes	Credible	Credible[c]
Open Space/Recreational	Yes	No	Credible	Credible[d]
Ecological Reserve	No	No	Improbable	Credible[d]
Agricultural	Yes	No	Credible	Improbable
Gravel Mining	Yes	No	Credible	Improbable

[a] Credible is used to indicate scenarios that could reasonably occur.
[b] Improbable is used to indicate scenarios that are unlikely to occur.
[c] Expected in the currently developed area of the plant site.
[d] Expected in the buffer zone.

TABLE 3-2

ROCKY FLATS OU6
POTENTIALLY EXPOSED RECEPTORS

Current Scenario	Hypothetical Future Scenarios
Onsite worker	Onsite office worker Onsite construction worker Onsite ecological researcher Onsite open space user



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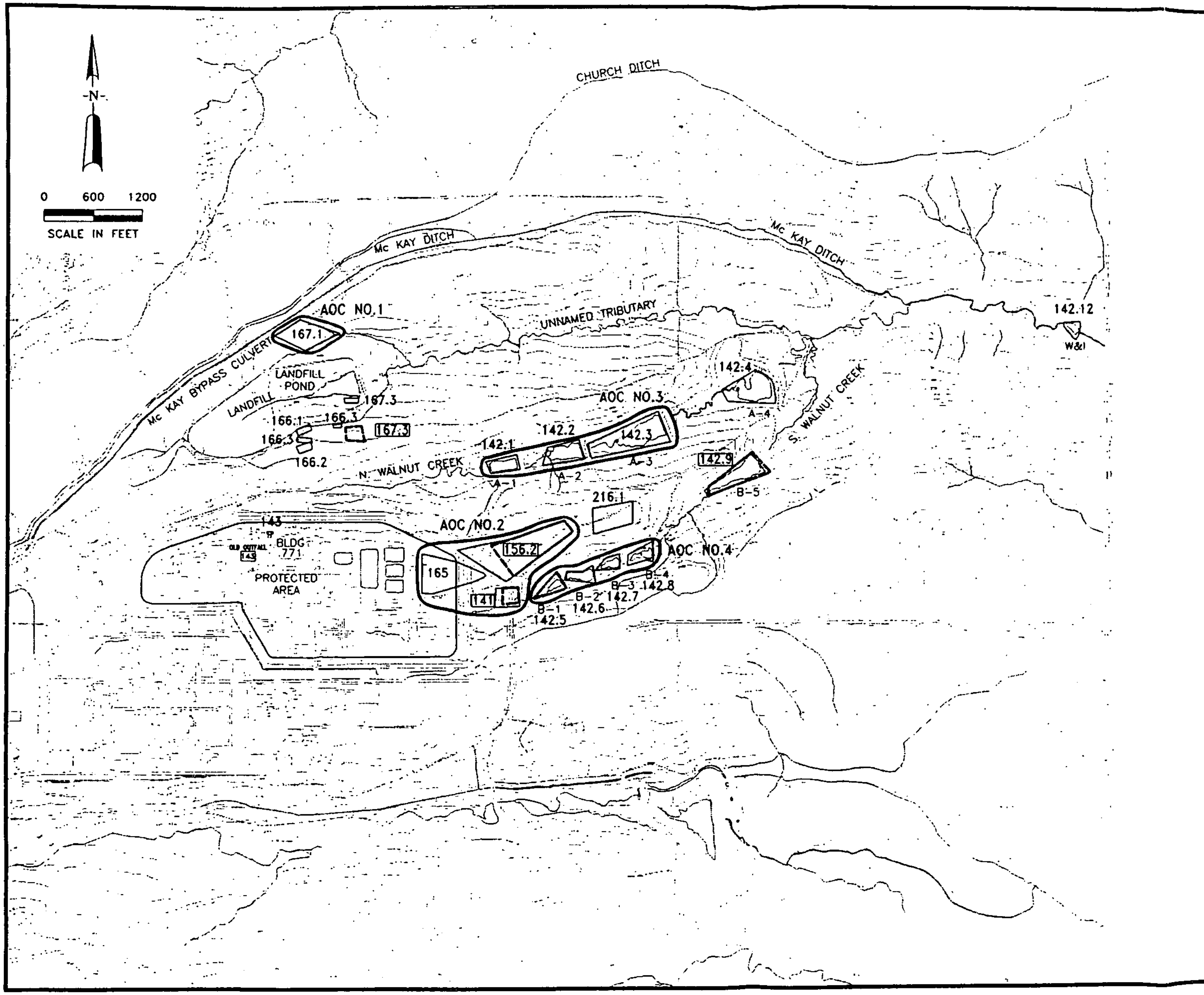
OU6 AREA AND OFFSITE RESIDENT LOCATIONS

FIGURE 3-1 JUNE 1995



EXPLANATION

PONDS/LAKES

142.12 OU6 IHSS BOUNDARY AND IHSS REFERENCE NUMBER

PROTECTED AREA BOUNDARY

167.3 OU6 HISTORICAL IHSS BOUNDARY AND IHSS REFERENCE NUMBER FOR: 141, 142.5, 142.9, 143, 156.2, AND 167.3

AOC BOUNDARY

IHSS	COMMON NAME
141	SLUDGE DISPERSAL AREA
142.1 - 142.4	A-SERIES PONDS
142.5 - 142.9	B-SERIES PONDS
142.12	WALNUT AND INDIANA (W&I) POND
143	OLD OUTFALL AREA
156.2	SOIL DUMP AREA
165	TRIANGLE AREA
166.1-166.3	TRENCHES A, B, C
167.1	NORTH SPRAY FIELD AREA
167.3	SOUTH SPRAY FIELD AREA
216.1	EAST SPRAY FIELD AREA

IHSS LOCATIONS SHOWN ARE BASED ON REVISED INTERPRETATIONS IN HISTORICAL HISTORICAL RELEASE REPORT DOE, JUNE 1992b.

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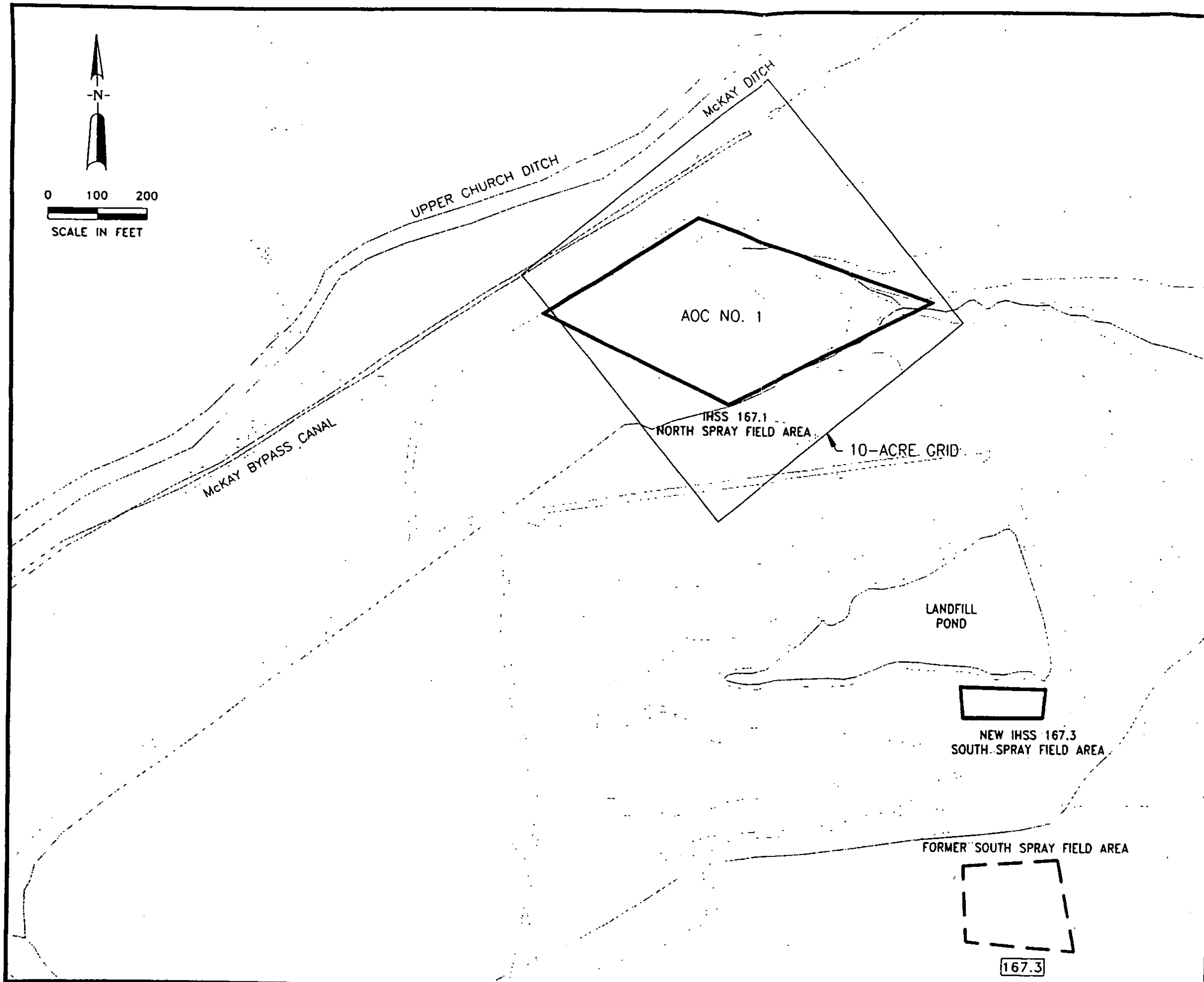
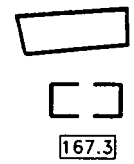
AREAS OF CONCERN
WITHIN OPERABLE UNIT NO. 6

FIGURE 3-2 JUNE 1995

OU6RI265 1=1200



EXPLANATION



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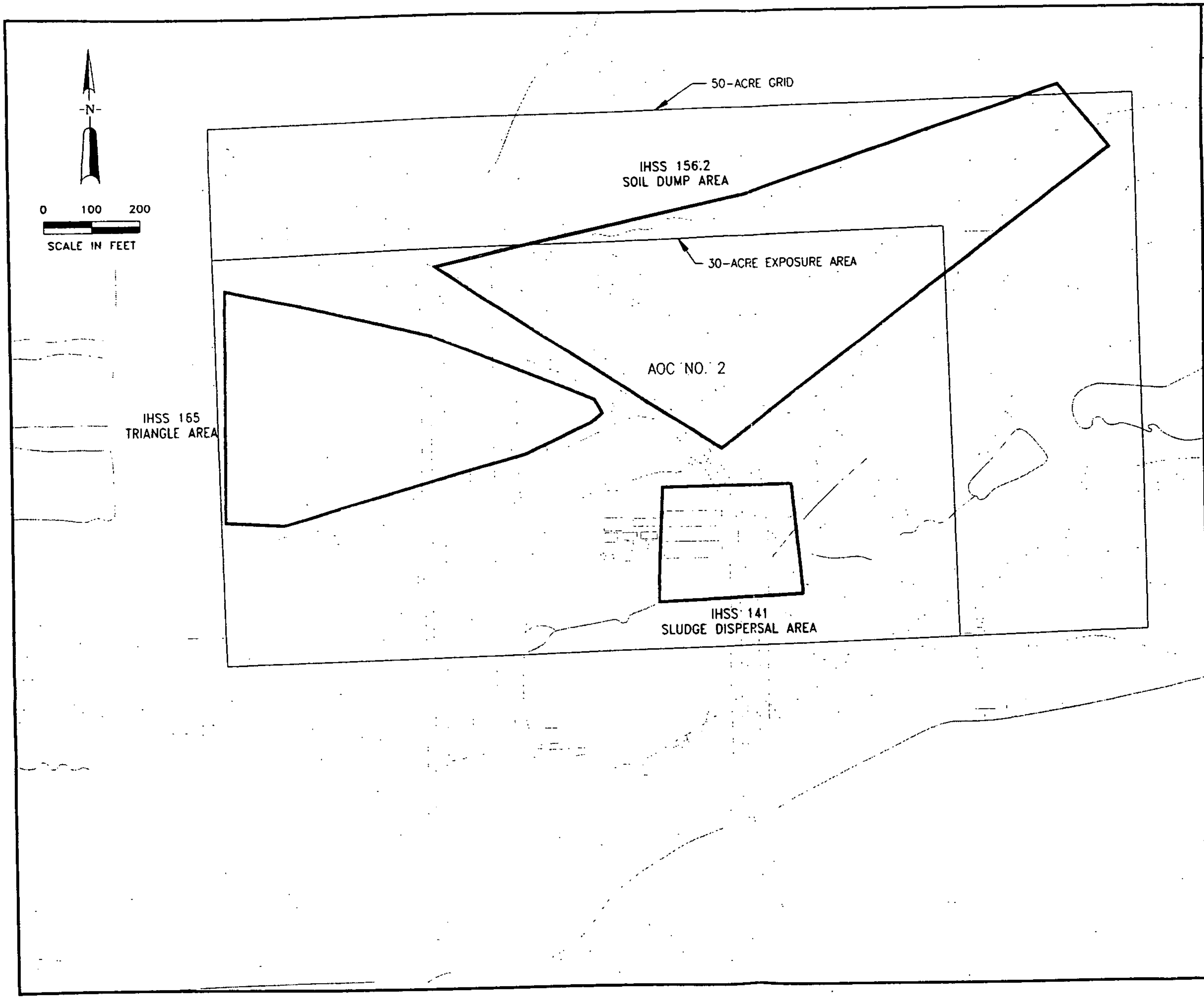
AREA OF CONCERN NO. 1

FIGURE 3-3 JUNE 1995

OU6RI266 1=200



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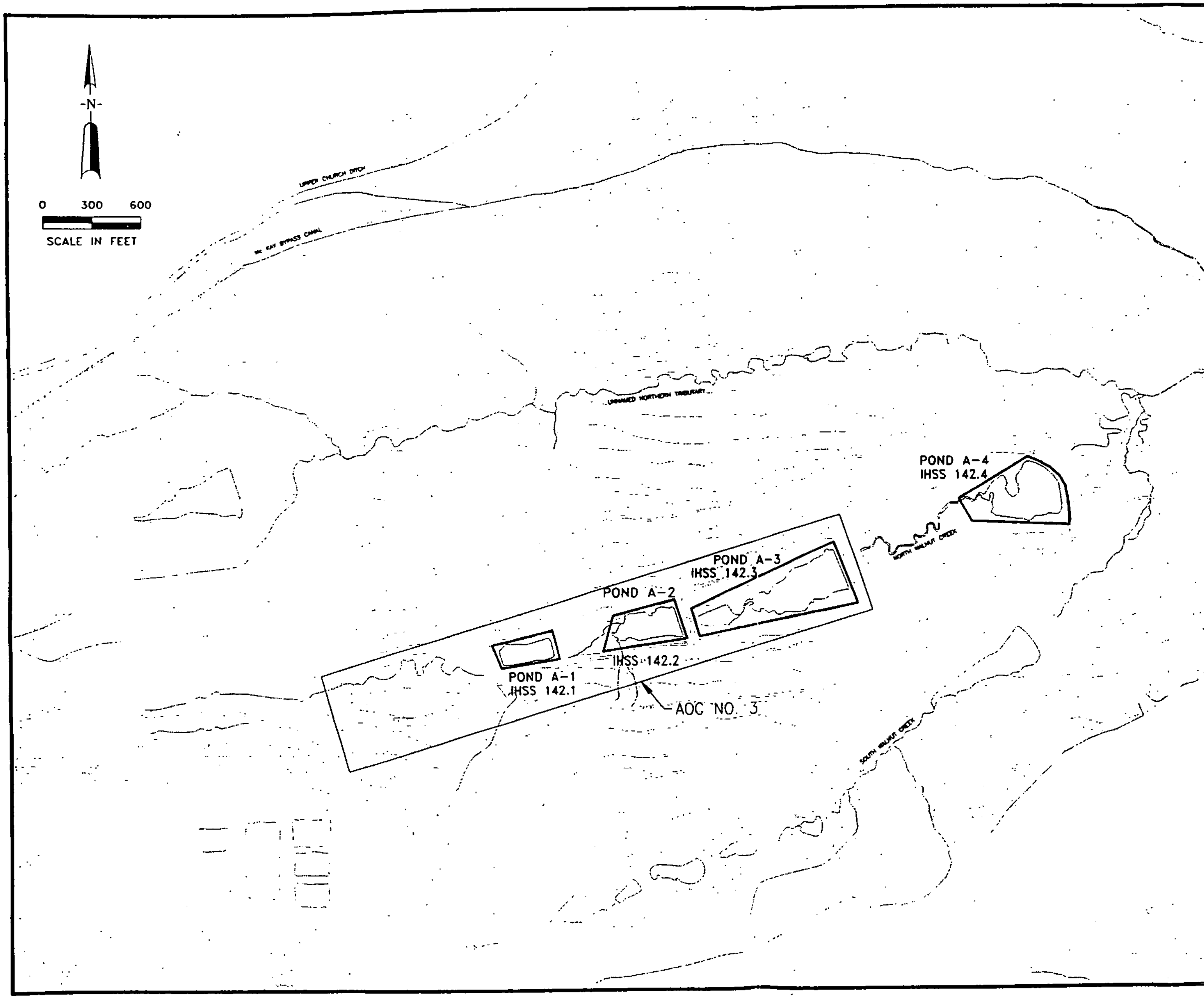
AREA OF CONCERN NO.2
AND 30-ACRE MAXIMUM
EXPOSURE AREA

FIGURE 3-4 JUNE 1995

OU6RI267 1=200



EXPLANATION

IHSS BOUNDARIES

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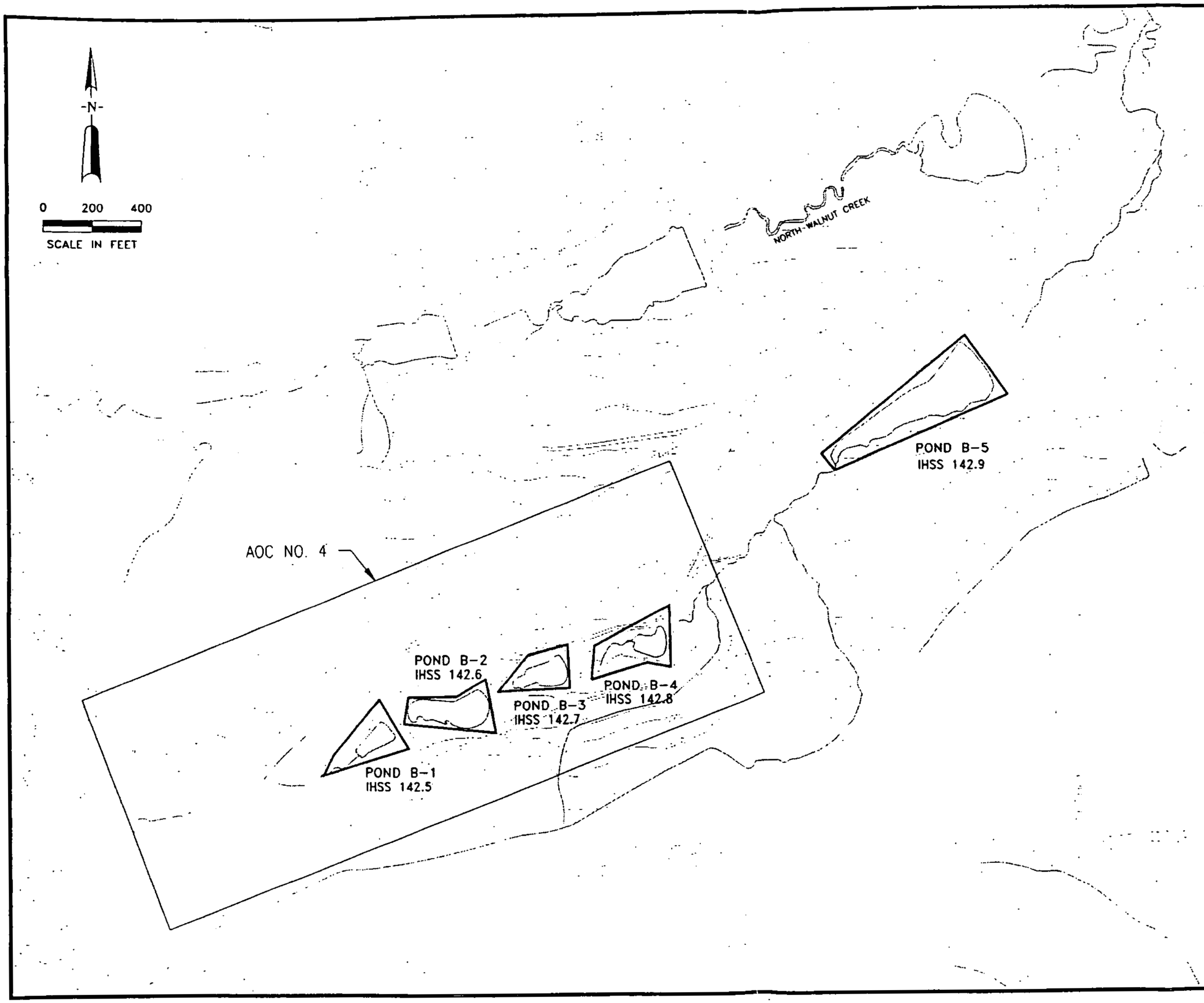
AREA OF CONCERN NO.3

FIGURE 3-5 JUNE 1995

OU6R1268 1=600



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

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AREA OF CONCERN NO.4

FIGURE 3-6 JUNE 1995

OU6RI269 1=400

4.0 EXPOSURE PATHWAYS

This section discusses the potential release and transport of chemicals from OU6 and identifies exposure pathways by which the receptor populations identified in Section 3.0 may be exposed to site chemicals.

An exposure pathway describes a specific environmental pathway by which chemicals may be transported to human exposure points. A complete exposure pathway requires each of the following five elements:

- Source of chemicals
- Mechanism of chemical release
- Environmental transport medium
- Exposure point
- Human intake route

If one of these elements is lacking, the pathway is incomplete and no human exposure can occur. Incomplete pathways, as well as negligible pathways that would not contribute to overall risk estimates, are identified in the EATM but will not be evaluated in the risk assessment.

4.1 CHEMICAL SOURCES AND RELEASE AND TRANSPORT MECHANISMS

The primary source of chemicals in OU6 is contaminated surface and subsurface soil and contaminated sediments. Potential release mechanisms include storm water runoff, sediment transport, volatilization, wind suspension, infiltration and percolation to groundwater, direct contact, root uptake from surface soil, and radioactive decay. Transport media include groundwater, surface water, and air. These release and transport mechanisms and affected media are illustrated in the Conceptual Site Model (CSM) presented in Figure 4-1.

4.2 EXPOSURE POINTS

An exposure point is a specific location where human receptors could come in contact with site-related chemicals. Exposure points are selected so that reasonable maximum exposures (RMEs) will be quantitatively evaluated. Evaluation of risks at these exposure points will bound the risks for receptors at other locations where chemical exposure is lower. Receptors and exposure areas were discussed in Sections 3.2 and 3.3 and are summarized below.

Current Use

- Onsite worker. AOC No. 1 and AOC No. 2.

Future Use

- Onsite industrial/office worker. AOC No. 1 and 30-acre maximum exposure area within AOC No. 2.
- Onsite construction worker. AOC No. 1 and AOC No. 2.
- Onsite ecological researcher. AOC Nos. 1 through 4.
- Onsite open space recreational user. AOC Nos. 1 through 4

4.3 HUMAN INTAKE ROUTES

A human intake route is the mechanism by which a chemical is taken into the body. There are four basic human intake routes: dermal absorption, inhalation, ingestion, and, for radionuclides, external irradiation. Quantifying chemical intake by these routes is described further in Section 5.0.

4.4 POTENTIAL EXPOSURE PATHWAYS

Figure 4-1 shows a CSM of potential human exposure pathways for OU6. The CSM is a schematic representation of the chemical sources, chemical release mechanisms, environmental transport media, human intake routes, and human receptors for OU6. The purpose of the CSM is to provide a framework for problem definition, to identify exposure pathways that may result in human health risks, to aid in identifying data gaps, and to aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

The CSM identifies three types of exposure scenarios: (1) potentially complete and significant exposure pathways, (2) potentially complete but relatively insignificant exposure pathways, and (3) incomplete or potentially complete but negligible exposure pathways. Potentially complete significant and relatively insignificant pathways will be quantitatively addressed in the risk assessment; central tendency (CT) and RME intake factors for these pathways and receptors are presented in Attachment 1. Incomplete and potentially complete but negligible exposure pathways are discussed in the EATM but are eliminated from further consideration in the quantitative HHRA.

The following subsections describe the exposure pathways shown in the CSM and the assumptions used in characterizing them. A summary of potentially complete exposure pathways that will be quantitatively evaluated in the HHRA is provided in Table 4-1.

4.4.1 Site-Wide Incomplete Exposure Pathways

The CSM indicates that the following exposure pathways are negligible or incomplete (indicated with an N) for all receptors. These pathways will not be addressed in the risk assessment.

- Ingestion of fish in Walnut Creek is an incomplete exposure pathway for all OU6 receptors because sports fishing is unlikely (due to intermittent flow in the creeks and absence of game fish) and because fishing is not a relevant activity under future occupational uses.

- Ingestion of livestock is an incomplete pathway for all OU6 receptors because livestock grazing is an improbable future use at OU6 and beef ingestion is not relevant to future occupational and open space uses.

- Inhalation of volatile organic chemicals (VOCs) released to outdoor air through volatilization from soil or groundwater is considered a negligible pathway for all receptors. Volatile chemicals in surface soils, if once present, will have already volatilized; VOCs released from groundwater will be significantly retarded through the subsurface soil and diluted in the ambient air; and VOCs released from subsurface soil upon excavation will also be diluted to negligible concentrations in the outdoors.

- Ingestion of groundwater is an incomplete pathway for current and future onsite receptors because drinking water is currently provided by a municipal water supply that does not tap aquifers at RFETS and future demands are also expected to be met by public water supplies.

- Dermal uptake of metals and radionuclides from soil and sediment is considered a negligible pathway for all receptors, because their permeability constants are low (USEPA 1989a) and binding to soil or sediment particles further reduces absorption potential.

- Exposure to airborne particulate matter that was eroded from and redeposited on surface soil is negligible via ingestion, dermal contact, and external irradiation routes because the exposures are accounted for through evaluating direct contact with and irradiation from surface soil.

- Ingestion of homegrown produce is an incomplete pathway for all receptors because gardening will not occur under occupational or open space use.

4.4.2 Current Onsite Worker

For the current onsite worker (security personnel), exposure pathways associated with wind suspension of particulates and exposure to surface soil (incidental ingestion, dermal contact, and external irradiation) are potentially complete.

Incomplete or negligible pathways for this receptor include those listed in Section 4.4.1 as well as the following. Incidental ingestion of and dermal contact with surface water, sediments, and subsurface soil are incomplete exposure pathways for current onsite workers because their work does not bring them into contact with Walnut Creek, the detention ponds, or with subsurface soil. Inhalation of VOCs migrating from subsurface soil or groundwater into buildings is an incomplete exposure pathway, because no offices or other permanent structures are currently located within OU6.

In summary, potentially complete human exposure pathways for current onsite workers are:

- Inhalation of airborne particulates
- Ingestion of surface soil
- Dermal contact with surface soil
- External irradiation from decay of radionuclides in surface soil

4.4.3 Future Onsite Office Workers

For the future onsite office worker, pathways associated with wind suspension of particulates and exposure to surface soil are potentially complete. In addition, migration of VOCs from groundwater or subsurface soil through foundations, with a resultant accumulation in indoor air, represents a potentially complete inhalation exposure pathway.

Incomplete or negligible pathways for this receptor include those listed in Section 4.4.1 as well as the following. Incidental ingestion of and dermal contact with surface water, sediments, and subsurface soil are considered incomplete exposure pathways for future onsite industrial/office workers because their work will not bring them into contact with the ponds or creek channels or with subsurface soil.

In summary, potentially complete human exposure pathways for the future onsite industrial/office workers are:

- Inhalation of airborne particulates from surface soil
- Ingestion of surface soil
- Dermal contact with surface soil
- External irradiation from decay of radionuclides in surface soil
- Inhalation of VOCs migrating from subsurface soil or groundwater through foundations to indoor air

4.4.4 Future Onsite Construction Worker

The onsite construction worker scenario is used to evaluate potential exposure to subsurface soil at OU6. Direct contact exposure to surface soil is evaluated for other onsite receptors and is not included in the construction worker exposure scenario. Therefore, for the future onsite construction worker, pathways associated with suspension of particulates and direct contact with subsurface soil are potentially complete. Contact with surface water and sediments is incomplete because construction is assumed not to occur in the creek beds. Since work occurs outdoors, inhalation of VOCs that may accumulate in buildings is also an incomplete pathway. Other incomplete or negligible pathways were listed in Section 4.4.1.

Complete exposure pathways to be evaluated for the construction worker scenario are:

- Inhalation of airborne particulates from surface and subsurface soil
- Subsurface soil ingestion
- Dermal contact with subsurface soil
- External irradiation from decay of radionuclides in subsurface soil

4.4.5 Future Onsite Ecological Researcher

For the future onsite ecological researcher, exposure pathways associated with surface water and sediment, wind suspension, and surface soil are potentially complete.

Chemicals may be transported from contaminated soils to surface water and sediments in Walnut Creek by storm water runoff. Contaminants may also be released to surface water via groundwater discharges at seeps. Incidental ingestion of and dermal contact with surface water and sediments are potentially complete exposure pathways for the ecological researcher who may be wading in Walnut Creek.

Inhalation, ingestion, dermal, and external irradiation exposure to contaminants in surface soil are each potentially complete pathways for future onsite ecological researchers.

Direct exposure to groundwater, ingestion of plants and animals, and indoor air exposure are incomplete pathways for future onsite ecological researchers.

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

- Surface water ingestion
- Dermal contact with surface water
- Sediment ingestion
- Dermal contact with sediment
- Inhalation of airborne particulates from stream or dry sediment
- External irradiation from decay of radionuclides in stream or dry sediment
- Inhalation of airborne particulates from surface soil
- Ingestion of surface soil
- Dermal contact with surface soil
- External irradiation from decay of radionuclides in surface soil

4.4.6 Future Open Space Recreational User

For the future onsite open space user, exposure pathways associated with surface water and sediment, wind suspension, and surface soil are potentially complete.

Incidental ingestion of and dermal contact with surface water and sediments are potentially complete pathways for the open space user who may be wading in creeks and ponds.

Inhalation, ingestion, dermal, and external irradiation exposure to contaminants in surface soil are each potentially complete pathways for open space users. Soil and sediment ingestion pathways were evaluated for both children and adults.

Direct exposure to groundwater, ingestion of plants and animals, and indoor air exposure are incomplete pathways for future open space users.

In summary, potentially complete exposure pathways for the future open space user are:

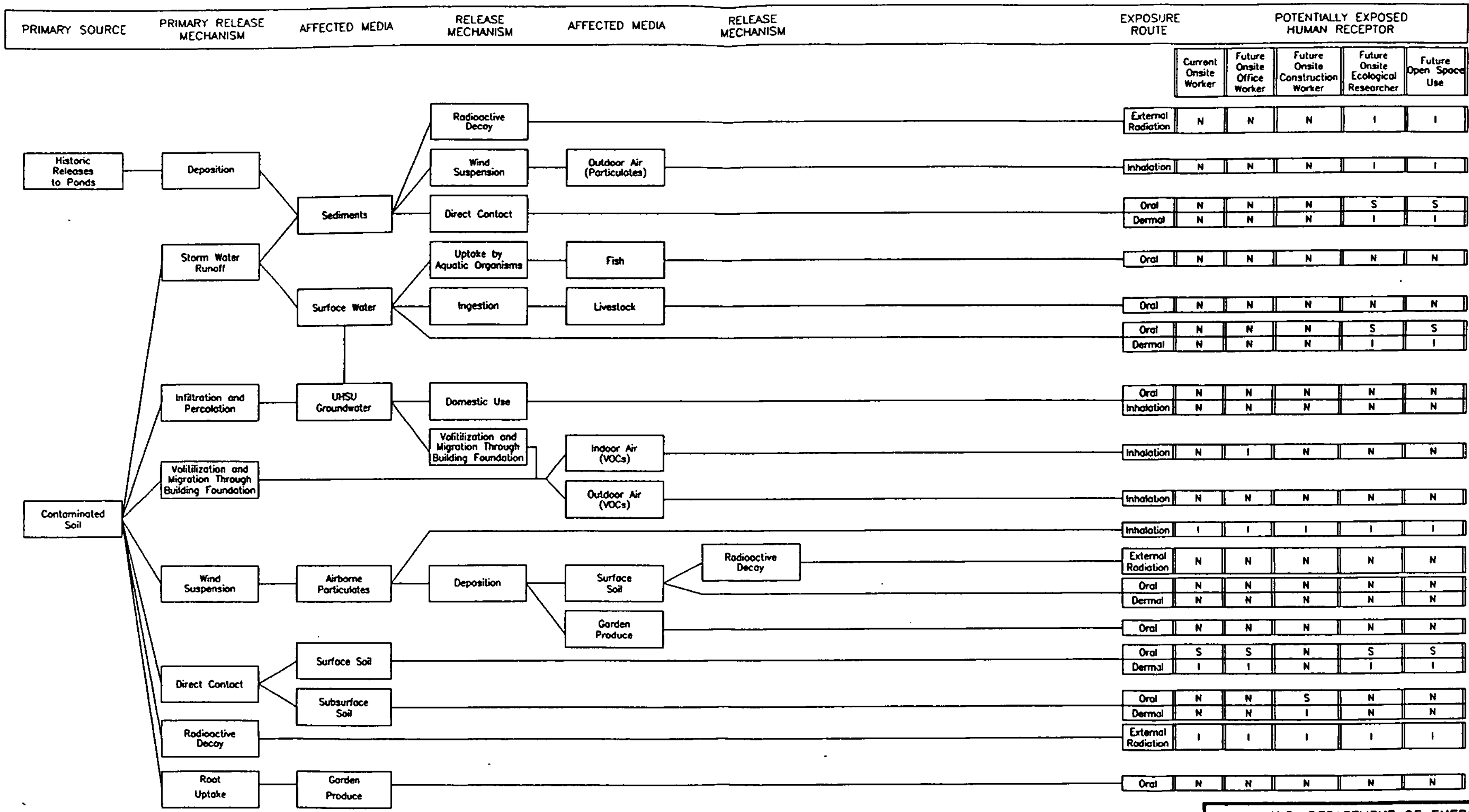
- Surface water ingestion
- Dermal contact with surface water
- Sediment ingestion
- Dermal contact with sediment
- Inhalation of airborne particulates from stream or dry sediment
- External irradiation from decay of radionuclides in stream or dry sediment
- Inhalation of airborne particulates from surface soil
- Ingestion of surface soil
- Dermal contact with surface soil
- External irradiation from decay of radionuclides in surface soil

TABLE 4-1
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite worker	Current	Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil External irradiation from surface soil
Onsite worker (industrial/office)	Future	Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil External irradiation from surface soil Inhalation of indoor VOCs (from migration through foundation)
Onsite construction worker	Future	Inhalation of airborne particulates from subsurface soil Ingestion of subsurface soil Dermal contact with subsurface soil External irradiation from subsurface soil
Onsite open space recreational user	Future	Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil External irradiation from surface soil Inhalation of airborne particulates from stream or dry sediment Ingestion of sediment Dermal contact with sediment External irradiation from stream or dry sediment Ingestion of surface water Dermal contact with surface water

TABLE 4-1
(Continued)

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite ecological researcher	Future	Ingestion of surface water Dermal contact with surface water Ingestion of sediment Dermal contact with sediment Inhalation of airborne particulates from stream or dry sediment External irradiation from stream or dry sediment Inhalation of airborne particulates from surface soil Ingestion of surface soil Dermal contact with surface soil External irradiation from surface soil



Primary Source	Primary Release Mechanism	Affected Media	Release Mechanism	Affected Media	Release Mechanism	Exposure Route	Current Onsite Worker	Future Onsite Office Worker	Future Onsite Construction Worker	Future Onsite Ecological Researcher	Future Open Space Use
Historic Releases to Ponds	Deposition	Sediments	Radioactive Decay			External Radiation	N	N	N	I	I
Historic Releases to Ponds	Deposition	Sediments	Wind Suspension	Outdoor Air (Particulates)		Inhalation	N	N	N	I	I
Historic Releases to Ponds	Deposition	Sediments	Direct Contact			Oral	N	N	N	S	S
						Dermal	N	N	N	I	I
Contaminated Soil	Storm Water Runoff	Surface Water	Uptake by Aquatic Organisms	Fish		Oral	N	N	N	N	N
Contaminated Soil	Storm Water Runoff	Surface Water	Ingestion	Livestock		Oral	N	N	N	N	N
Contaminated Soil	Storm Water Runoff	Surface Water				Oral	N	N	N	S	S
						Dermal	N	N	N	I	I
Contaminated Soil	Infiltration and Percolation	UHSU Groundwater	Domestic Use			Oral	N	N	N	N	N
						Inhalation	N	N	N	N	N
Contaminated Soil	Infiltration and Percolation	UHSU Groundwater	Volatilization and Migration Through Building Foundation	Indoor Air (VOCs)		Inhalation	N	I	N	N	N
Contaminated Soil	Volatilization and Migration Through Building Foundation			Outdoor Air (VOCs)		Inhalation	N	N	N	N	N
Contaminated Soil	Wind Suspension	Airborne Particulates				Inhalation	I	I	I	I	I
Contaminated Soil	Wind Suspension	Airborne Particulates	Deposition	Surface Soil	Radioactive Decay	External Radiation	N	N	N	N	N
Contaminated Soil	Wind Suspension	Airborne Particulates	Deposition	Surface Soil		Oral	N	N	N	N	N
						Dermal	N	N	N	N	N
Contaminated Soil	Wind Suspension	Airborne Particulates	Deposition	Garden Produce		Oral	N	N	N	N	N
Contaminated Soil	Direct Contact	Surface Soil				Oral	S	S	N	S	S
						Dermal	I	I	N	I	I
Contaminated Soil	Direct Contact	Subsurface Soil				Oral	N	N	S	N	N
						Dermal	N	N	I	N	N
Contaminated Soil	Radioactive Decay					External Radiation	I	I	I	I	I
Contaminated Soil	Root Uptake	Garden Produce				Oral	N	N	N	N	N

LEGEND

S Significant Potential Exposure Pathway
I Insignificant Potential Exposure Pathway
N Negligible or Incomplete Exposure Pathway
UHSU Upper Hydrostratigraphic Unit

Note: Significant and insignificant potential exposure pathways will be quantitatively evaluated.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

OPERABLE UNIT NO. 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

CONCEPTUAL SITE MODEL FOR HUMAN EXPOSURE PATHWAYS

FIGURE 4-1 JUNE 1995

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5.0 ESTIMATING CHEMICAL INTAKES

This section describes how intake is calculated for chemicals and radionuclides. CT and RME intake factors for each of the receptors and exposure pathways identified in Section 4.0 are presented in Attachment 1. Chemical intakes are not presented in this memorandum since they are dependent on exposure point concentrations determined from chemical data and from fate and transport modeling, as appropriate.

5.1 METHOD FOR CALCULATING INTAKE

Using exposure point concentrations of chemicals in soil, sediment, surface water, groundwater, and air, it is possible to estimate the potential human intake of those chemicals via each exposure pathway. Chemical intake is expressed in terms of milligram (mg) chemical ingested, inhaled, or dermally absorbed per kilogram body weight per day (mg/kg-day). Intakes are estimated using reasonable estimates of body weight, inhalation volume, ingestion rates, soil or food matrix effects, frequency and duration of exposure, and chemical concentration. Intake parameters are estimated following guidance in "Risk Assessment Guidance for Superfund" (USEPA 1989a), the "Exposure Factors Handbook" (USEPA 1989b), other USEPA guidance documents, relevant scientific literature, and professional judgment regarding probable site-specific exposure conditions.

Intakes are estimated for CT and for RME conditions, as recommended by USEPA (USEPA 1992). The RME is estimated by selecting values for exposure variables so that the combination of all variables results in the maximum exposure that can reasonably be expected to occur at the site. The CT is estimated by selecting average values for exposure variables.

The general equation for calculating chemical intake in terms of mg/kg-day is:

$$\text{Intake} = \frac{\text{chemical concentration} * \text{contact rate} * \text{exposure frequency} * \text{exposure duration}}{\text{body weight} * \text{averaging time}}$$

with corresponding units of:

$$\text{mg/kg-day} = \frac{\text{mg/volume or mass} * \text{volume or mass/day} * \text{day/year} * \text{year}}{\text{kg} * \text{day}}$$

The variable "averaging time" is expressed in days to calculate average daily intake. For noncarcinogenic chemicals, intakes are calculated by averaging over the period of exposure to yield an average daily intake. For carcinogens, intakes are calculated by averaging the total dose over a lifetime, yielding "lifetime average daily intake." Different averaging times are used for carcinogens and noncarcinogens because it is thought that their effects occur by different mechanisms. The approach for carcinogens is based on the scientific opinion and USEPA policy that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime, and that even very low doses of carcinogens have the potential to cause cancer. Therefore, the intake of a carcinogen is averaged over a 70-year lifetime (USEPA 1989a). Intake of noncarcinogens is averaged only over the period of exposure in order to compare an estimate of actual daily dose to a reference dose considered safe for a lifetime of exposure.

Omitting chemical concentrations from the intake equation yields an "intake factor" that is constant for each exposure pathway/receptor combination. The intake factor can then be multiplied by the concentration of each chemical to obtain the pathway/receptor-specific intake of that chemical. Intake factors will be calculated separately for each potentially exposed receptor and exposure pathway that was identified in Section 4.0. Contact rates, such as dermal contact, food intake, and inhalation (but not soil ingestion) are assumed to be approximately proportional to body weight. It is acknowledged that body weight is not exactly proportional to body surface area and that age-specific ratios of body weight to inhalation rate differ by factors of about two or less. However, these differences are assumed to be negligible. Therefore, child intakes are not estimated for any exposure route except sediment ingestion.

5.2 CALCULATING RADIATION EXPOSURES

5.2.1 Internal Exposure to Radionuclides

Internal exposure to radionuclides will be evaluated in two ways. First, the committed effective dose equivalent per year exposure based on the annual intake of radionuclides via ingestion or inhalation will be calculated and compared to annual radiation protection standards. The second method for evaluating internal radionuclide exposure is to calculate the lifetime intake of each radionuclide and multiply that intake by the respective USEPA-derived carcinogenic slope factor (USEPA 1989a). The result of this calculation is the lifetime incremental cancer risk associated with ingestion or inhalation of a given radionuclide.

Calculation of intake for radionuclides is conducted in a similar manner as for nonradioactive chemicals. Intake of radionuclides by either ingestion or inhalation is a function of radionuclide activity concentration, intake rate (or the amount of contaminated medium contacted per unit time or event), and exposure frequency and duration. The only difference between calculating intake for radionuclides and nonradioactive substances is that the averaging time and body weight are excluded from the intake equation.

The first step in calculating the annual committed effective dose equivalent for comparison to radiation protection standards is to estimate the annual intake of radionuclides through inhalation or ingestion using the following equation:

$$\text{Intake} = C * IR * EF$$

Where:

Intake	=	Annual internal radionuclide intake via inhalation or ingestion (pCi/yr)
C	=	Activity concentration of a radionuclide at the exposure point (pCi/m^3, pCi/l, or pCi/g)
IR	=	Intake rate (m^3/day, l/day, or kg/day)
EF	=	Exposure frequency (days/yr)

The result is an estimate of the annual intake of the radionuclide, expressed in units of activity per year (pCi/yr). This value is then multiplied by a dose conversion factor to estimate the committed effective dose equivalent. The dose conversion factor is expressed in units of millirem (mrem) per pCi. The committed effective dose equivalent can then be compared to a radiation protection standard expressed in mrem/yr.

To estimate lifetime incremental cancer risk, intake is calculated using the following equation:

$$Intake = C * IR * EF * ED$$

Where:

Intake	=	Lifetime internal radionuclide intake via inhalation or ingestion (pCi)
ED	=	Exposure duration (yr)

Other parameters are as previously defined. Lifetime incremental cancer risk is then estimated by multiplying the total intake in pCi by the cancer slope factor expressed in units of risk/pCi.

5.2.2 External Irradiation

To calculate an effective dose equivalent for external irradiation exposures, first an adjusted areal activity concentration is calculated:

$$AC = C * \frac{10^3 g}{kg} * SD * D * (1-Se)$$

Where:

AC = Areal activity concentration in soil, adjusted for a gamma shielding factor (pCi/m^2)

C = Mass activity concentration of a radionuclide at the exposure point (pCi/g soil)

SD = Soil density (kg/m^3)

D = Soil depth (m)

Se = Gamma shielding factor (unitless)

The adjusted areal activity concentration in pCi/m^2 is multiplied by the number of hours of exposure per year to obtain the annual external radiation exposure, as indicated in the following equation.

$$EI = AC * Te * EF * CF$$

Where:

EI = Annual external irradiation exposure ($pCi\text{-}hr/m^2\text{-}year$)

AC = Areal activity concentration (pCi/m^2)

Te = Gamma exposure time factor (fraction of day) (unitless)

EF = Exposure frequency (days/year)

CF = Conversion factor (24 hours/day)

The annual irradiation exposure is then multiplied by the effective dose coefficient for external irradiation (mrem/hr per pCi/m^2) to estimate the annual effect dose equivalent (mrem/year) for each radionuclide for one year of exposure.

To estimate lifetime incremental cancer risk, external irradiation exposure is estimated using the following equation:

$$ER = C * (1\text{-}Se) * Te * EF * ED$$

Where:

ER	=	External irradiation exposure (pCi/g soil/yr, or pCi-yr/g)
ED	=	Exposure duration (yr)

Other parameters are as previously defined. ER is then multiplied by the USEPA slope factor for external irradiation expressed in risk per pCi-yr/g to yield lifetime incremental cancer risk.

5.3 INTAKE FACTOR CALCULATIONS

Parameters to be used for calculations of intake factors are shown in the tables in Attachment 1. Exposure point concentrations will be used with these parameters to obtain pathway-specific intakes.

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ATTACHMENT 1
EXPOSURE FACTORS FOR HUMAN HEALTH RISK ASSESSMENT

TABLE AT2-1. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker
SOIL/DUST INGESTION					
Ingestion Rate	RME*	50[1]	50[1]	480[4]	106[6]
(mg/day)	CT*	10[2]	5[3]	95[5]	33[6]
Fraction Ingested from		1.0[7]	1.0[7]	1.0[7]	1.0[7]
Contaminated Source		0.9[7]	0.9[7]	0.9[7]	0.9[7]
Matrix Effect in GI Tract		CS[8]	CS	CS	CS
(Absorption Factor)		CS[8]	CS	CS	CS
Exposure Frequency		250[1]	250[1]	30[10]	65[10]
(days/yr)		219[9]	219[9]	30[10]	65[10]
Exposure Duration		25[1]	25[1]	1[10]	2.5[10]
(years)		4[11]	4[11]	1[10]	2.5[10]
Body Weight		70	70	70	70
(kg)[5]		70	70	70	70
Averaging Time-		9125	9125	365	915
Noncarcinogenic (days)[12]		1460	1460	365	915
Averaging Time:		25550	25550	25550	25550
Carcinogen (days)[13]		25550	25550	25550	25550

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NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(CS) Chemical-specific exposure parameter determined from quantitative analysis and toxicology literature.

(1) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a.

(2) Average of CT soil ingestion rates of 15 mg/day (outdoor industrial worker) and 5 mg/day (indoor industrial worker) based on inferences drawn from Finley and Paustenbach, 1994.

(3) One-half of industrial workers based on inferences drawn from Finley and Paustenbach, 1994; soil ingestion rates for workers indoors (e.g., office workers) are one-half the average of workers both indoors and outdoors (e.g., industrial workers).

(4) Hawley, 1985, and EPA Exposure Factors Handbook, 1989a. A more defensible HE default is 205 mg/day based on adjusting Hawley's soil adherence value from 3.5 mg/cm^2 to the correct upper bound of 1.5 mg/cm^2 (EPA, 1992a) (480 x 1.5/3.5).

(5) Estimated using HE ingestion rate ratio of construction worker to industrial worker (480/50 = 9.6; CT = 9.6 x 10 mg/day), but a more defensible CT default is 40 (see Note 8).

(6) Based on RME and CT exposure assessment work at Rocky Mountain Arsenal. (Integrated Endangerment Assessment/Risk Characterization) Rocky Mountain Arsenal, August 1993.

(7) The CT is based on average weekly time spent at work (0.9) using a base of 40 hours per week. EPA RAGS, HHEM Pt. a (1989b), recognizes the need for a soil "fraction ingested" (FI) from a contaminated source to reflect "population activity patterns."

(8) In the absence of a CS value, consult methods to estimate maximum oral bioavailability (absorption in the gastrointestinal tract) such as reported by EPA (1994) for lead in soil and by Finley and Paustenbach (1994) for TCDD in soil. Assuming chemical toxicity values are based on absorption from drinking water, absorption adjustments are indicated because toxic chemicals only partially desorb from soil particles (EPA RAGS, HHEM Pt. A, 1989b - Appendix A).

(9) Preliminary CT default value (EPA, 1993).

(10) Final Rocky Flats Programmatic Risk-Based

(11) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(12) Exposure duration (years) X 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(13) Lifetime exposure (70) years X 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE AT2-2. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker
SOIL/DUST INHALATION					
Inhalation Rate (m^3/hr)	RME*	0.83[1]	0.83[1]	1.4[3]	1.4[3]
	CT*	0.83[1]	0.63[2]	1.25[3]	0.83[1]
Respirable Fraction (PM_{10})[4]		0.36	0.36	0.36	0.36
		0.36	0.36	0.36	0.36
Respiratory Deposition Factor (unitless)[5]		0.85	0.85	0.85	0.85
		0.85	0.85	0.85	0.85
Exposure Time (hr/day)		8[1]	8[1]	8[1]	8[1]
		7.2[6]	7.2[6]	7.2[6]	7.2[6]
Exposure Frequency (days/yr)		250[1]	250[1]	30[3]	65[3]
		219[7]	219[7]	30[3]	65[3]
Exposure Duration (years)		25[1]	25[1]	1[3]	2.5[3]
		4[8]	4 [8]	1[3]	2.5[3]
Body Weight (kg) [1]		70	70	70	70
		70	70	70	70

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POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	**Current On-Site Industrial Worker**	**Future On-Site Office Worker**	**Future On-Site Construction Worker**	**Future On-Site Ecological Worker**
Averaging Time:	9125	9125	365	915
Noncarcinogen (days) (9)	1460	1460	365	915
Averaging Time:	25550	25550	25550	25550
Carcinogen (days)(10)	25550	25550	25550	25550

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) EPA RAGS, HHEM, Standard Default Exposure Factors 1991a.

(2) CT worker inhalation rate of 0.63 m^3/hr (adult indoors) based on EPA Exposure Factors Handbook (1989a).

(3) Outdoor inhalation rate from EPA Exposure Factors Handbook (1989a) and the CT from Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(4) Five-year (1988-1992) mean annual ratio of PM_{10} soil or dust particles to total suspended particulates (TSP) as reported in 1992 RFP Site Environmental Report; EPA Exposure Factors Handbook (1989a) recognizes the need for a "respirable fraction of particulates" (RF) to indicate the total respirable fraction assumed deposited in the lung (100% of PM_{10}).

(5) Based on Exposure Assessment work done at Rocky Mountain Arsenal (Integrated Endangerment Assessment/Risk Characterization, August 1993).

(6) Based on average time spent at work (36 hr/wk) (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(7) Preliminary CT default value (EPA, 1993).

(8) American Industrial Health Council, 1994, Gephart, Tell and Triemer, 1994.

(9) Exposure duration (years) x 365 days (EPA RAGS,HHEM Pt. A, 1989b).

(10) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE AT2-3. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES EXPOSURE		Current Onsite Industrial Worker	Future Onsite Office Worker	Future Onsite Construction Worker	Future Onsite Ecological Worker
SOIL/DUST DERMAL CONTACT					
Exposed Skin	RME*	3400[2]	2100[2]	4700[2]	4700[2]
Surface (cm^2/day)	CT*	3400[2]	2100[2]	4700[2]	4700[2]
Fraction Contacted from		1[3]	1[3]	1[3]	1[3]
Contaminated Source		0.9[4]	0.9[4]	0.9[4]	0.9[4]
Soil Adherence		1[1]	1[1]	1[1]	1[1]
(mg/cm^2)		0.2[1]	0.2[1]	0.2[1]	0.2[1]
Skin Absorption		CS[5]	CS	CS	CS
Factor		CS[5]	CS	CS	CS
Exposure Frequency		250[6]	250[6]	30[8]	65[8]
(days/yr)		219[7]	211[7]	30[8]	65[8]
Exposure Duration		25[6]	25[6]	1[8]	2.5[8]
(years)		4[9]	4[9]	1[8]	2.5[8]
Body Weight		70	70	70	70
(kg)[6]		70	70	70	70

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POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	**Current Onsite Industrial Worker**	**Future Onsite Office Worker**	**Future Onsite Construction Worker**	**Future Onsite Ecological Worker**
Averaging Time:	9125	9125	365	915
Noncarcinogen (days) (10)	1460	1460	365	915
Averaging Time:	25550	25550	25550	25550
Carcinogen (days)(11)	25550	25550	25550	25550

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1992a; EPA 1991a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(CS) Chemical-specific exposure parameter determined from quantitative analysis and toxicology literature.

(1) EPA Dermal Exposure Assessment: Principles and Applications, 1992a.

(2) Industrial worker HE value is an average between exposed skin surfaces of 4,700 cm^2 (outdoor construction or ecological worker) and 2,100 cm^2 (indoor office worker) based on EPA Exposure Factors Handbook, 1989a; indoor worker exposure assumes median surface area of adult head and hands (1,200 cm^2 + 900 cm^2), whereas outdoor worker assumes median surface area of adult head, hands, and arms (1,200 cm^2 + 900 cm^2 + 2,600 cm^2).

(3) RME based on EPA guidance. The CT is based on average weekly time spent at work (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(4) As in Note 3, based on average weekly time spent at work (0.9) using a base of 40 hours per week.

(5) In the absence of a CS value, consult EPA Region IV Interim Guidance dated 11 February 1992 (default values: 0.01 organics; 0.001 inorganics) (EPA, 1992c). However, alternative values of 0.06 (organic compounds) and 0.01 (metals) are based on maximum dermal bioavailability as reported in "Dermal Absorption Factors for Multiple Chemicals" (15 December 1992; EPA, 1992d).

(6) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a (for consistency with soil/dust ingestion and inhalation).

(7) Preliminary CT default value (EPA, 1993).

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(8) Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(9) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(10) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(11) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE AT2-4. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		Current Onsite Industrial Worker	Future Onsite Office Worker	Future Onsite Construction Worker	Future Onsite Ecological Worker
SURFACE WATER/SUSPENDED SEDIMENT INGESTION*					
Ingestion Rate	RME*	NA	NA	NA	0.05[1, 3]
(L/hr)	CT*	NA	NA	NA	0.01[2, 4]
Exposure Rate		NA	NA	NA	1[5]
(hr/day)		NA	NA	NA	1[5]
Exposure Frequency		NA	NA	NA	12[3]
(days/yr)		NA	NA	NA	7[3]
Exposure Duration		NA	NA	NA	2.5[3]
(years)		NA	NA	NA	2.5[3]
Body Weight		NA	NA	NA	70[3]
(kg)		NA	NA	NA	70[3]
Averaging Time:		NA	NA	NA	915
Noncarcinogen (days) [6]		NA	NA	NA	915
Averaging Time:		NA	NA	NA	25550
Carcinogen (days) [7]		NA	NA	NA	25550

* Direct ingestion of exposed *in situ* shoreline sediments will utilize *OU-specific* exposure factors.

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NOTES:

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the RME risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set at central tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on CT used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable worst case", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) The RME is based on EPA guidance. The CT is from the Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(4) On the premise that actual swimming rather that wading is unlikely, the CT ingestion rate while wading is assumed to be one-fifth as much as while swimming.

(5) An exposure "event" for the ecological worker (see Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995) is assumed to last 1 hour per day.

(6) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(7) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE AT2-5. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		**Current Onsite Industrial Worker**	**Future Onsite Office Worker**	**Future Onsite Construction Worker**	**Future Onsite Ecological Worker**
SURFACE WATER DERMAL CONTACT*					
Exposed Skin	RME*	NA	NA	NA	9275[1, 3]
Surface (cm^2)	CT*	NA	NA	NA	9275[2, 3]
Dermal Permeability		NA	NA	NA	CS[4]
(cm/hr)		NA	NA	NA	CS[4]
Exposure Time		NA	NA	NA	1[5]
(hr/day)		NA	NA	NA	1[5]
Exposure Frequency		NA	NA	NA	12[6]
(days/yr)		NA	NA	NA	7[6]
Exposure Duration		NA	NA	NA	2.5[6]
(years)		NA	NA	NA	2.5[6]
Body Weight		NA	NA	NA	70[6]
(kg)		NA	NA	NA	70[6]

• Direct dermal contact with exposed *in situ* shoreline sediment will utilize *OU-specific* exposure factors.

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POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	Current Onsite Industrial Worker	Future Onsite Office Worker	Future Onsite Construction Worker	Future Onsite Ecological Worker
Averaging Time: Non-Carcinogen (days) [7]	NA NA	NA NA	NA NA	915 915
Averaging Time: Carcinogen (days)[8]	NA NA	NA NA	NA NA	25550 25550

NOTES:

(NA) Not applicable because the exposure pathway is incomplete.

(CS) Chemical-specific exposure parameter determined from quantitative analysis and toxicology literature.

(1) Top entry is based on High-End (HE) exposure used to characterize the Reasonable Maximum Exposure (RME) risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) On the premise that actual swimming by the ecologist, rather than wading, is highly unlikely, the exposed adult skin surface while wading and reaching underwater is assumed to include the legs (5,950 cm^2), feet (1,250 cm^2), forearms (1,175 cm^2), and hands (900 cm^2) (EPA Exposure Factors Handbook, 1989a).

(4) In the absence of a CS value, consult methods to estimate maximum dermal bioavailability. Possible maxima are: HE value of 1.0 cm/hr determined experimentally for ethylbenzene and toluene among *organic* compounds; HE value of 0.001 cm/hr determined experimentally for cadmium chloride and mercuric chloride among *inorganic* compounds (EPA Dermal Exposure Assessment: Principles and Applications, 1992a).

(5) An exposure "event" for the ecological worker (see Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1994) is assumed to last 1 hour per day.

(6) RME is from EPA guidance. The CT is from the Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995 (for consistency with surface water ingestion).

(7) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(8) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE AT2-6. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	Current Onsite Industrial Worker	Future Onsite Office Worker	Future Onsite Construction Worker	Future Onsite Ecological Worker
GROUND WATER INGESTION				
Ingestion Rate RME*	NA	1	NA	NA
(L/day) CT*	NA	1	NA	NA
Fraction Ingested from	NA	1	NA	NA
Contaminated Source	NA	0.3	NA	NA
Exposure Frequency	NA	250	NA	NA
(days/yr)	NA	219	NA	NA
Exposure Duration	NA	25	NA	NA
(years)	NA	4	NA	NA
Body Weight	NA	70	NA	NA
(kg)	NA	70	NA	NA
Averaging Time:	NA	9125	NA	NA
Noncarcinogen (days) (1)	NA	1460	NA	NA
Averaging Time:	NA	25550	NA	NA
Carcinogen (days)(2)	NA	25550	NA	NA

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NOTES:

(NA) Not applicable because the exposure pathway is incomplete.

(1) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(2) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE AT2-7. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		Current Onsite Industrial Worker	Future Onsite Office Worker	Future Onsite Construction Worker	Future Onsite Ecological Worker
GROUNDWATER/SUBSOIL VOC INHALATION*					
Inhalation Rate	RME*	NA	0.83[1, 3]	1.4[5]	NA
(m^3/hr)	CT*	NA	0.63[2, 4]	1.25[5]	NA
Exposure Time		NA	8[3]	8[3]	NA
(hr/day)		NA	7.2[6]	7.2[6]	NA
Exposure Frequency		NA	250[3]	30[5]	NA
(days/yr)		NA	219[7]	30[5]	NA
Exposure Duration		NA	25[3]	1[5]	NA
(years)		NA	4[8]	1[5]	NA
Body Weight		NA	70	70	NA
(kg) [3]		NA	70	70	NA
Averaging Time:		NA	9125	365	NA
Noncarcinogen (days) [9]		NA	1460	365	NA
Averaging Time:		NA	25550	25550	NA
Carcinogen (days)[10]		NA	25550	25550	NA

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• Includes *indoor* VOC vapor from household use of groundwater supply and VOC vapor infiltration from subsoil into offices.

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a; EPA 1989a) used to calculate conservative risks based on *Reasonable Maximum Exposure* (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the Reasonable Maximum Exposure (RME) risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a.

(4) CT worker inhalation rate of 0.63 m^3/hr (adult indoors) based on EPA Exposure Factors Handbook, 1989a.

(5) RME is based on EPA guidance. The CT is from the Final Rocky Flats Programmatic Risk-Based preliminary Remediation Goals, 1995.

(6) Based on average time spent at work (36 hr/wk) (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(7) Preliminary CT default value (EPA 1993).

(8) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(9) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(10) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE AT2-8. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

POTENTIALLY EXPOSED RECEPTORS

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		**Current Onsite Industrial Worker**	**Future Onsite Office Worker**	**Future Onsite Construction Worker**	**Future Onsite Ecological Worker**
EXTERNAL IRRADIATION					
Gamma Exposure	RME*	**0.3**[1, 3]	**0.3**[3]	**0.3**[3]	**0.3**[3]
Time Factor (T_e)	CT*	0.3[2, 3]	0.3[3]	0.3[3]	0.3[3]
Gamma Shielding		**0.8**[5]	**0.8**[5]	1[7]	1[7]
Factor ($1\text{-}S_e$)		0.5[6]	0.5[6]	0.8[8]	0.8[8]
Exposure Frequency[12]		**0.7**[4]	**0.7**[4]	0.1[10]	0.2[10]
(unitless)		0.6[9]	0.6[9]	0.1[10]	0.2[10]
Exposure Duration		**25**[4]	**25**[4]	1[10]	2.5[10]
(years)		4[11]	4[11]	1[10]	2.5[10]

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a; EPA 1989a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize *the Reasonable Maximum Exposure (RME) risks in a baseline or* remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

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(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) Assuming the HE fraction of time exposed (8 out of 24 hours or 0.33) according to EPA RAGS, HHEM Pt. B- Revised (Dinan, 1992).

(4) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991b. Based on 250 days/year.

(5) Standard default screening value specified in EPA RAGS, HHEM Pt. B, 1991b (1 - 0.2 = 0.8), assuming substantial time shielded by structures.

(6) Estimated typical value for residents and indoor workers shielded by buildings (DOE documents for RFP, such as "Mining Exposure Scenario for Baseline Risk Assessments at the Rocky Flats Environmental Technology Site" (9 August 1994).

(7) Standard default screening value specified in EPA RAGS, HHEM Pt. B, 1991b, assuming limited time shielded by structures.

(8) Assumed typical value for outdoor workers with only limited shielding indoors.

(9) Preliminary CT default value (219 days/yr) (EPA, 1993).

(10) Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995. Based on 30 and 65 days/yr, respectively.

(11) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(12) **Calculated by dividing exposure frequency for each scenario for soil/dust exposure by days/year; ratio used to allow equation units to balance.**

TABLE 9-A
OPEN-SPACE EXPOSURE PARAMETERS
INCIDENTAL INGESTION

DUST, SURFACE SOIL, OR SEDIMENT

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

(1) Assumes standard default *residential* rates as specified for open-space recreational users at DOE's Fernald Site and Hanford Site (RME=200 mg/day for children and 100 mg/day for adults) and at Denver's Lowry Landfill Superfund Site (CT=100 mg/day for children and 50 mg/day for adults). Assumes that Exposure Time is 1.5 hours per day (CT); 5.0 hours per day (RME) (see Note 2, Table B) and that total soil ingestion occurs over 10 daylight hours (1.5/10 = 0.15; 5.0/10 = 0.5). Using the default daily ingestion rates, soil ingestion per visit for children is calculated as RME=0.5 x 200=100 mg/visit; CT=0/15 x 100=15 mg/visit. For adults the ingestion rates are RME=5 and CT=8. Actual open-space recreational intakes would vary, depending on the activity, possibly with dirt biking at one extreme and photographing wildlife at the other.

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

TABLE 9-B
OPEN-SPACE EXPOSURE PARAMETERS
PARTICULATE INHALATION

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

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

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

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

TABLE 9-C
OPEN-SPACE RECREATIONAL EXPOSURE PARAMETERS
DERMAL CONTACT

DUST, SURFACE SOIL, OR SEDIMENT

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

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

(2) The fraction contacted for the RME is very conservatively set at 1.0. This assumes that soil dermally contacted during a 5 hour visit to the open space contributes 100% of the dermal dose. The CT assumes that 50% of the dermal dose is site related. This is consistent with the ingestion parameters.

(3) See Table 9A, Note 2.

TABLE 9-D
OPEN-SPACE EXPOSURE PARAMETERS
INGESTION WHILE WADING

SHALLOW SURFACE WATER

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

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

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

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

TABLE 9-E
OPEN-SPACE EXPOSURE PARAMETERS
DERMAL CONTACT WHILE WADING

SHALLOW SURFACE WATER

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

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

(2) See Table D, Note 2.

(3) See Table D, Note 3.

TABLE 9-F
OPEN-SPACE EXPOSURE PARAMETERS

EXTERNAL IRRADIATION

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

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

(2) See Table A, Note 3.